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Classical swine fever and wild boar in Denmark: A risk analysis

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WILDRISK GROUP

Classical swine fever and wild boar in Denmark: A risk analysis

Project report

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Prologue

Classical swine fever (CSF) is endemic in certain wild boar populations in Europe. This poses a constant risk of transmitting CSF virus (CSFV) to domestic pigs in the affected and neighbouring areas. The economic consequences of an introduction of CSF could be devastating not only for the individual farmer, but also for national economies. Denmark, the world's largest net exporter of pork, exports around 84% of its pork production and would therefore be particularly vulnerable. In 2002, Denmark exported pork in the order of 26 bDKK. Therefore, a temporary ban on export, which would follow an introduction of CSFV, would be detrimental for the pig industry. Contact with infected wild boar is only one among several ways by which CSFV might be introduced into Denmark. Livestock trucks with contaminated material, swill feeding, and movement of infected animals are other ways CSF might enter Denmark.

In Denmark, there is no established population of free-range wild boar. Danish wildlife organisations have presented the idea that wild boar should be reintroduced into Denmark in order preserve nature and national biodiversity. This poses the question of the additional risk of introducing CSFV to Denmark compared with the present risks. To address this issue, a risk analysis was conducted at the Danish Institute for Food and Veterinary Research (DFVF) in cooperation with the Danish Bacon and Meat Council (DBMC), the Danish Veterinary and Food Administration (FVST) and the National Environmental Research Institute (DMU) with support from the UFZ - Centre for Environmental Research Leipzig-Halle (Germany) between January 2004 and December 2004.

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Summary

Introduction

Currently there is no established population of free-range wild boar in Denmark. In order to preserve nature and manage national biodiversity, Danish wildlife organisations have presented the idea that the wild boar should be reintroduced into Denmark. There is evidence that wild boar are involved in CSF outbreaks in pigs in Europe. For that reason Danish pig farmers are concerned about the risk associated with such an introduction. The economic consequences of an introduction of CSF would be devastating, not only for the individual farmer, but also for national economies. Denmark, which is the world's largest net exporter of pork and exports around 84% of its pork production, would be particularly vulnerable. In 2002, Denmark exported pork in the order of 26 bDKK. Therefore, a temporary ban on export, which would follow an introduction of CSFV, would be detrimental for the pig industry.

Materials and methods

Contact with infected wild boar is only one among several ways by which CSFV might be introduced into Denmark. Livestock trucks with contaminated material, illegal swill feed, and movement of infected animals are other ways of entry. The question is, which additional risk free-range wild boar might pose, in terms of introducing CSFV into Denmark. To answer this question, a risk analysis process was conducted following the guidelines specified by the World Organisation for Animal Health (OIE).

Estimate of the risk

In the following the results are summarized:
-   A free-range wild boar population in Denmark could get infected with CSFV through contact to infected wild boar that migrated up from Germany. As long as there is no CSF north of the Kieler-channel we consider, that this route of entry is associated with a negligible probability.
-   The wild boar habitat in Southern Jutland is of limited size, and this decreases the natural migration of wild boar sows to the most southeast part of Southern Jutland.
-   The risk of introducing CSFV through tourists accidentally depositing meat remnants was highest in Ribe, Ringkøbing, and Northern Jutland counties. North and East Zealand had the lowest risk.
-   The presence of free-range wild boar will result in problems between farmers and wild boar in area where both reside. Damages to crops will be the main problem. Only in case CSF is present among wild boar, will the concern for virus transmission be real.
-   If CSFV reaches free-range wild boar, then either the virus is self-limiting or an epidemic of several months duration will occur.
-   The spreading of disease between domestic pigs and wild boar will only occur if the domestic herd is located close to a wild boar area. If the index case (first infected case) is observed in a domestic herd, then one epidemic is expected. If the index case is observed among wild boar, then either no epidemic or up to two epidemics are expected.
-   The monetary consequences of an outbreak will vary very much depending on the assumed reactions of export markets and the duration of the epidemics. The total extra costs related to wild boar would increase with several hundred million DKK.

Risk is a product of probability and consequences. As can be noted, the probability of CSFV entering the country will increase slightly from the present low level if free-range wild

boar are reintroduced. The economic consequences will increase partly because of changed reactions of export markets and partly because of increased duration of the epidemic.

Hazard identification

Classical swine fever virus (CSFV) can infect both wild boar and domestic pigs. On several occasions, infected wild boar have been involved in the transmission of CSFV to domestic pigs, particularly in Germany, Slovakia, and Luxembourg. In countries that have been able to keep their wild boar populations free from CSFV, wild boar have not been a risk for domestic pig herds. Even when domestic pigs are infected, wild boar do not have to become infected, as all domestic pigs with CSFV are culled quickly after diagnosis. Awareness and early diagnosis are therefore very important factors. CSF has not been present in Denmark since 1933. If wild boar are reintroduced into Denmark, wild boar might get infected with CSFV and hence pose a risk to domestic pigs. As a result, CSFV is classified as a potential hazard.

Biology and ecology of the wild boar

The wild boar is a potential candidate for reintroduction into Denmark, but before a decision can be made, the possible consequences would have to be evaluated in a feasibility study. In general, Danish landscapes seem to meet the requirements of the wild boar. Provided wild boar are reintroduced or allowed to migrate from Germany there is no doubt that damages to crop will be one of the most important determinants of future distribution and population density of wild boar.

Wild boar prefer forests for reproduction and hiding-place whereas they forage on the surrounding fields up to a distance of around 1km from the forest. One family group needs around 4km^2 and at least 25% of this area should be covered with forest (suitable habitat) or natural vegetation (semi-suitable habitat). Based on this assumption, we calculated that suitable or semi-suitable habitats cover 9-10% of the total area of Denmark (Bornholm excl.). To display where wild boar will be observed we used a buffer of 1km around the suitable habitat and a buffer of 0.5km around the semi-suitable habitat. Areas with a high probability of having wild boar are found in many parts of the country. However, a large part of the Danish forests consists of smaller forests and forest patches. Certain landscapes like open fields and towns will form barriers slowing the spread of wild boar, whereas forests will form corridors that will enhance the spread of the animals.

Conflicting interests are expected between farmers and wild boar in the geographical areas where both reside. In Denmark, 24% of the pig herds are located close (within the buffer of 1km and 0.5km) to the suitable or semi-suitable wild boar areas. This will pose a problem since wild boar could get too close to the pig herds. Moreover, damage to crops is likely to occur.

Release assessment

The individual pathways by which CSFV could reach Danish domestic pigs - without wild boar - were associated with a low or even negligible probability. This is a result of the present trade patterns and actions in place – and if these are changed, the risk will change. The most risky pathways identified were livestock trucks passing the border, import of breeding stock, import of boar semen, hunters hunting abroad as well as legal/illegal imports of meat.

Unregulated migration of wild boar from Germany will only affect a limited part of Southern Jutland, because the wild boar habitat is limited in this area. The wild boar habitat in the western part of Southern Jutland is not connected with Germany, which limits the

probability of migration, whereas the habitat in the eastern part might favour migration. However, since this habitat is narrow, it will also enable control of migration. As long as the German area north of the Kieler Channel is free from CSF, the migration of wild boar in itself is not seen as a risk of introducing CSFV into Denmark.

Wild boar are likely to include easy accessible garbage in their diet, and meat remnants can contain CSFV for longer time periods. Tourists could bring in CSFV contaminated meat and leave leftovers accessible to wild boar. Tourists from countries that have had CSF during the most recent decade were used to illustrate who might bring in contaminated food. The likelihood of bringing in food also depends on the type of the stay. The types of stays that were considered to constitute the highest risk are stays at camping grounds and in summer cottages. We also incorporated the size of the wild boar habitat in a county by multiplying with the expected wild boar density (animals per km^2). The relative risk of exposure was greatest in the two counties that make up the western part of Jutland (Ribe and Ringkøbing). The risk in these counties was 9-10 times the risk in North and East Zealand that had the lowest risk. The northern part of Jutland (Northern Jutland) had the third highest risk (4 times the risk in North and East Zealand).

Exposure assessment

The forest around Silkeborg is a key habitat because it is the largest coherent wild boar habitat in Denmark. Furthermore, it is the area that is associated with the most severe potential for the spread of the disease. According to the simulations, the epidemics will last longer, the infected area will be larger, and there will be a higher intensity of disease spreading compared with other areas in Denmark. The remaining Denmark provides less optimal conditions both for wild boar and spread of disease, because all other wild boar habitats are fragmented and less coherent compared with Silkeborg.

The spread of CSFV between domestic pigs and wild boar was simulated by use of the software programme InterSpreadPlus. Seven scenarios were run to elucidate the effect of: 1) presence of wild boar (yes/no), 2) locations for the index case, i.e. the first outbreak (domestic pig herd/wild boar), 3) type of control strategy for wild boar (geographical separation and shooting/vaccination). The results show that the spread of infection from domestic pigs to wild boar will only occur if the herd is located in close proximity to an area with wild boar (e.g. 0.5 km). When the index case is a domestic herd, one epidemic can be expected (not more than 200 days between two successive outbreaks). When the index case is a wild boar, then either no domestic herd will be infected (no epidemic) or periodical outbreaks among domestic herds can be expected (≥1 epidemic). The number of infected domestic herds tended to be lower when the index case was a wild boar compared with a domestic herd.

Consequence assessment

The economic consequences of different scenarios with and without wild boar were calculated. The calculations showed that if free-range wild boar were infected with CSF, the economic consequences would be more severe than if not having wild boar. Both control costs and costs to the pig industry would increase if wild boar were infected, and the total costs would increase with several hundred million DKK. The main reason for the increased costs is the changed reaction of export markets if wild boar are present in Denmark. Another reason is the increased duration of the epidemic because the virus would circulate in the wild boar population and periodically spread to domestic herds.

Risk estimation

There is a low base-line probability that CSFV would enter the country because of the current trade patterns and actions in place to reduce the risk. This has ensured that CSF has not been present since 1933.

The probability of CSFV entering Denmark will increase slightly if free-range wild boar are reintroduced. A free-range population of wild boar inside Denmark can get infected through contact with infected wild boar migrating from Germany. As long as there is no CSF north of the Kieler Channel, we consider this way of CSF-entry associated with a negligible probability. Furthermore, the wild boar habitat is small in Southern Jutland, and this limits the possible migration to the very southeast part of Southern Jutland.

Another way of entry is through tourists that accidentally feed CSF-contaminated meat remnants to wild boar. It was not possible to estimate the probability of this happening, but the relative risk between counties was highest in Ribe, Ringkøbing, and Northern Jutland.

If free-range wild boar are present, conflicting interests will be expectable between farmers and wild boar in areas where both reside. Crop damages will constitute the main problem. Only in case CSFV has been introduced into the wild boar population, will the fear of a CSF introduction to domestic pigs be real.

If CSFV is introduced to wild boar, then either the infection will die out relatively soon or an epidemic will be seen (median length 112 days) – this depends among others on the wild boar habitat in which the virus is released. The larger the wild boar population is, the longer the epidemic will last. Spreading of infection between wild boar and domestic pigs will only occur if the pig herd is located close to the wild boar habitat. When the index case is a domestic herd, then one epidemic is to be expected, whereas if wild boar are the index case, then either no epidemic among domestic pigs – or more than one epidemic can be expected.

The economic calculations showed that – on average - the expenses related to a CSF outbreak would be 500-700 million DKK (or 36-53%) higher if free-range wild boar are present compared with the current situation (in a more pessimistic scenario regarding the reaction of the Japanese market these figures are 300-400 million DKK – corresponding to 10-17%). However, the probability of an outbreak increases if free-range wild boar are present. Furthermore, presence of wild boar might results in long-lasting epidemics or more than one epidemic because of periodic transfer of virus from groups of infected wild boar.

Outdoor productions cannot be compared with free-range wild boar because the probability is low of fenced animals transmitting CSFV to animals outside the fence (double fence is prescribed for outdoor productions). The reason is that CSFV is not airborne, and infection among the fence animals will be diagnosed within a short time after appearance.

Risk is a product of probability and consequences. As can be noted, the probability of CSFV entering the country will increase slightly from the present low level. The monetary consequences will vary from an average of 36-53% extra costs to a much higher level in case of long-lasting epidemics.

Risk management

The minimum measures, in the case of an outbreak of CSF in a EU member country, are described in Council Directive 2001/89/EC. The directive gives wide possibilities to interpret and choose control strategy. We analysed the effect of different control strategies – mainly varying with respect to the control strategy for wild boar. Our simulations showed that a vaccination strategy would not improve the course of an epidemic compared with the basic strategy for wild boar consisting of separation and shooting. Furthermore, a vaccination

strategy would be extremely costly for the industry because of strong reactions from third country export markets. Fencing of free-range domestic herds would not alter the course of the epidemic, whereas fencing all domestic herds within a radius of 16km from wild boar habitats would shorten the epidemic only limited in time. The costs of these scenarios were not much different from the basic scenario. Finally, the choice of not doing anything to control the virus in the wild boar population (not allowed according to the EU) would be the end of Danish pig production.

Risk communication

To ensure an active risk communication strategy, a contact group was established at the beginning of the project. The contact group consisted of representatives from different stakeholders: The National Environmental Research Institute, The Danish Society for the Conservation of Nature, The Danish Institute for Food and Veterinary Research, The Danish Forest & Nature Agency, The Danish Hunters' Association, the Danish Bacon & Meat Council as well as The Danish Veterinary & Food Administration. It has been planned to write several popular papers in order to communicate the results of the project to the public.

Fig 5.4. Map displaying location of Danish pig herds within the wild boar habitat – taken from the report.

Sammendrag

Introduktion

Der findes ikke fritlevende vildsvin i Danmark. De findes derimod under hegn f.eks. i Tofte Skov i Lille Vildmose. Naturbeskyttelsesorganisationer har fremsat forslag om genindførelse af vildsvin som led i den nationale forvaltning af biologisk mangfoldighed. I Europa har vildsvin spillet en rolle i forhold til udbrud af klassisk svinepest. Derfor er danske svineproducenter bekymrede for den risiko, der er forbundet med en eventuel genindførelse. De økonomiske konsekvenser, der er forbundet med udbrud af svinepest, er ødelæggende ikke kun for den landmand, der berøres, men i høj grad også for den nationale økonomi. Danmark er her særlig sårbar, da vi er verdens største eksportør af svinekød og eksporterer ca. 84% af svinekødsproduktionen. I 2002 var denne eksport 26 mia. DKK værd. Derfor vil selv et midlertidigt eksportstop være forbundet med betydelige omkostninger.

Materiale og metode

Kontakt til inficerede vildsvin er en af de adskillige smitteveje, ad hvilke svinepestsmitte kan komme ind i Danmark. Dyretransporter kontaminerede med smitsomt materiale, ulovlig fodring med madaffald, og flytning af smittede dyr er andre måder, hvorpå smitte kan komme ind. Spørgsmålet er, hvor stor den ekstra risiko er for at få svinepest i Danmark som følge af fritlevende vildsvin. For at besvare dette, blev der udført en risikoanalyse, der følger den internationale dyresundhedsorganisations guidelines.

Estimat af den samlede risiko

I det følgende opsummeres resultaterne:
- En fritlevende vildsvinebestand i Danmark kan blive smittet gennem kontakt til smittede vildsvin, der er migreret op fra Tyskland. Så længe der ikke er svinepest nord for Kieler-kanalen vurderer vi, at denne smittevej er forbundet med en ubetydelig sandsynlighed.
- Vildsvinehabitatet i Sønderjylland er af begrænset størrelse, og dette begrænser den naturlige indvandring af vildsvinesøer til den sydøstlige del af Sønderjylland.
- Risikoen for indslæbning af smitte gennem turisters deponering af kødaffald er højest i Ribe, Ringkøbing og Nordjyllands amter. Nord- og Østsjælland har den laveste risiko.
- Tilstedeværelse af fritlevende vildsvin vil medføre problemer mellem landmænd og vildsvin i områder, hvor begge har interesser. Markskader vil udgøre det største problem. Kun hvis der er svinepest blandt vildsvin, vil bekymringen for smitte til tamsvin være reel.
- Hvis svinepestsmitte når fritlevende vildsvin, vil smitten enten dø ud relativt hurtigt, eller der vil opstå en epidemi af flere måneders varighed.
- Spredning af smitte mellem tamsvin og vildsvin vil kun ske, såfremt tamsvinebesætningen er placeret meget tæt på et vildsvineområde. Når den første smitte optræder i en tamsvinebesætning forventes én epidemi. Optræder den derimod i en gruppe vildsvin, så forventes enten ingen epidemi blandt tamsvin eller op til flere epidemier.
- De økonomiske konsekvenser forbundet med et svinepestudbrud afhænger af eksport markedernes reaktioner og varigheden af epidemien. Ekstraomkostningerne som følge af vildsvin i Danmark vil beløbe sig til flere hundrede millioner kroner.

Risiko er et produkt af sandsynlighed og konsekvens. Sandsynligheden for introduktion af svinepest vil stige lidt fra det nuværende lave niveau, hvis fritlevende vildsvin genindføres. De økonomiske konsekvenser vil stige – dels som følge af ændrede reaktioner fra eksportmarkeder, og dels som følge af epidemiens længere varighed.

I det følgende gennemgås de enkelte dele af risikoanalysen kort.

Identifikation af fare

Svinepestvirus kan smitte både vildsvin og tamsvin. I adskillige tilfælde har smittede vildsvin været involveret i overførsel af smitte til tamsvin. Dette er særligt set i Tyskland, Slovakiet og Luxembourg. I lande, der har evnet at holde deres vildsvin fri for svinepest, har vildsvin ikke været en risiko for tamsvin. Selv hvis tamsvin har været inficeret med svinepest, er vildsvin ikke nødvendigvis blevet smittet. Dette skyldes, at smittede tamsvinebesætninger slås ned umiddelbart efter, at diagnosen er stillet. Dette gør derfor opmærksomhed og hurtig diagnose til centrale elementer i beredskabet mod svinepest. Der har ikke været svinepest i Danmark siden 1933. Hvis vildsvin genindføres, kan de blive smittede med svinepestvirus, hvorved de kan smitte tamsvin.

Vildsvins biologi og økologi

Danske landskaber ser generelt ud til at møde vildsvins behov. Hvis vildsvin genindføres eller tillades at indvandre naturligt fra Tyskland, vil problematikken om markskader uvægerligt blive en af de mest afgørende parametre for vildsvinets fremtidige fordeling og populationstæthed. Vildsvin foretrækker skov til reproduktion og skjul og marker op til 1km fra skoven som forageringsområde.

En familiegruppe har behov for ca. 4km^2, og i hvert fald 25% af dette område skal bestå af skov (velegnet habitat) eller naturlig vegetation (delvist egnet habitat). Cirka 9-10% af Danmark består af velegnede eller delvist egnede vildsvineområder. For at vise hvor vildsvin vil blive observeret, lagde vi en buffer på 1km omkring de velegnede områder og 0,5km omkring de delvist egnede områder. Der findes områder med en høj sandsynlighed for vildsvin i mange dele af landet. Dog er hovedparten af de danske skove små eller består af mindre, usammenhængende skovparter. Visse landskaber, såsom åbne marker og byer danner barrierer, der mindsker spredning af vildsvin, mens sammenhængende skov vil danne korridorer, der øger spredning.

Vildsvin er en potentiel kandidat for genindførelse til Danmark. Men før der kan træffes en beslutning om dette, bør de mulige konsekvenser også blive evalueret i et såkaldt feasibility studium.

Der vil sandsynligvis opstå konflikter mellem landmænd og vildsvin i de geografiske områder, hvor begge parter har interesser. Det viste sig, at 24% af samtlige danske svinebesætninger er placeret tæt på et vildsvineområde (indenfor en afstand af 1km til et velegnet habitat eller 0,5km fra et mindre egnet habitat). Dette vil udgøre et problem, fordi vildsvin vil kunne komme meget tæt på besætningen.

Release vurdering

Sandsynligheden for indslæbning af svinepestsmitte direkte til tamsvin – udenom vildsvin - blev vurderet som lav eller ubetydelig for hver af de undersøgte smitteveje. Dette er et resultat af de nuværende handelsmønstre og iværksatte tiltag – og hvis der sker forandringer her, vil risikoen også ændres. De smitteveje, der er forbundet med den højeste sandsynlighed for indslæbning af smitte til Danmark, er dyretransporter, der kører over grænsen, import af avlsdyr eller sæd, jægere der går på jagt i udlandet, samt lovlig/ulovlig import af kød.

I dag skydes fritlevende vildsvin, hvis de ses i Danmark. Hvad vil der ske, hvis vi lader vildsvin indvandre fra Tyskland? Vi valgte at fokusere på vildsvinesøer, da det er dem - og ikke ornerne - der formerer sig. Vores analyser viste, at den naturlige indvandring er af

begrænset omfang og kun vil påvirke en lille del af Sønderjylland. Som det ses af Figur 1 er vildsvinehabitatet i den vestlige del af Sønderjylland ikke forbundet med tilsvarende arealer i Tyskland. Dette mindsker sandsynligheden for indvandring. Derimod kan der ske indvandring igennem vildsvinehabitatet i den østlige del af Sønderjylland. Så længe Schleswig-Holstein er frit for svinepest, er indvandring af vildsvin fra Tyskland ikke i sig selv forbundet med risiko for introduktion af svinepest.

Bekymringen er, at turister uvidende medbringer kød med svinepestsmitte ind i Danmark, og at rester af dette kød efterlades i nærheden af vildsvin. Vildsvin æder gerne madaffald, og da kødaffald kan indeholde svinepestsmitte igennem længere tid, kan der ske smitte til vildsvin. For at illustrere hvem, der kan bringe smittet kød med ind i landet, valgte vi at se på turister, der kommer fra lande, der har haft svinepest indenfor de seneste 10 år. Desværre er informationer om turisme kun opgjort per amt, hvorved vi kun kunne opgøre den relative risiko amterne i mellem. Sandsynligheden for at medbringe kød afhænger også af typen af overnatning. Overnatning på campingplads eller i sommerhus blev vurderet som forbundet med højst sandsynlighed for at medbringe kød. Vi indregnede også størrelsen på vildsvinehabitatet i et amt i forhold til amtets størrelse. Den relative risiko for eksponering gennem turister var højst i de to amter, der udgør Vestjylland (Ribe og Ringkøbing). Her var risikoen 9-10 gange højere end i Nord- og Østsjælland, der havde den laveste risiko. I Nordjylland var der den tredje største risiko, der var fire gange større end i Nord- og Østsjælland.

Eksponeringsvurdering

Sygdomsspredning i fritlevende vildsvin blev vurderet ved hjælp af et computerprogram, der er udviklet til belysning af netop sådanne spørgsmål. Resultaterne viste, at en epidemi enten vil dø ud eller vare flere måneder (middelvarighed 112 dage). Dette afhænger bl.a. af vildsvinehabitatet, hvor smitten introduceres. Jo større og mere sammenhængende habitat, jo længere epidemi.

Skovene omkring Silkeborg er et nøglehabitat, fordi det er Danmarks største og sammenhængende vildsvinehabitat. Det er også det område, som vil være forbundet med den største mulighed for spredning af svinepest. Ifølge simuleringerne vil 1) en epidemi vare længere her, 2) det smittede område være større og 3) der være en større intensitet af sygdomsspredning i forhold til alle andre områder i Danmark. Dette skyldes, at den øvrige del af Danmark byder på mindre optimale forhold både for vildsvin og sygdomsspredning i sammenligning med Silkeborg.

Spredning af svinepestvirus mellem tamsvin og vildsvin blev simuleret ved hjælp af software programmet InterSpreadPlus. Vi belyste effekten af 1) tilstedeværelse af vildsvin (ja/nej), 2) placering af det første udbrud (tamsvinebesætning/vildsvin), og 3) type af kontrolstrategi for vildsvin (geografisk adskillelse og nedskydning/ vaccination). Resultaterne viste, at spredning af infektion fra tamsvin til vildsvin kun vil ske, hvis tamsvinebesætningen er placeret tæt på et vildsvinehabitat (f.eks. 0,5km afstand). Når det første udbrud optræder i en tamsvinebesætning, forventes kun én epidemi. Optræder det første udbrud derimod i en vildsvinegruppe, vil der enten ikke ske smitte til tamsvin (ingen epidemi) eller der vil forekomme periodiske udbrud blandt tamsvinebesætninger. Dette vil give mulighed for mere end en epidemi, hvilket vil sige mere end 200 dage mellem to på hinanden følgende udbrud i tamsvinebesætninger. Antallet af smittede tamsvinebesætninger tenderede til at være lavere, når det første udbrud optrådte blandt vildsvin i forhold til i en tamsvinebesætning.

Udendørsdrevne svineproduktioner kan ikke sammenlignes med fritlevende vildsvin, idet der er en lav sandsynlighed for smitteoverførsel fra indhegnede svin til svin udenfor hegnet.

Dette skyldes bl.a., at svinepest ikke er luftbåren, og direkte eller indirekte kontakt er nødvendig for at opnå overførsel af smitte, samt at en smitte blandt tamsvin opdages ret hurtigt.

Konsekvensvurdering

Vores beregninger viser, at de økonomiske konsekvenser forbundet med svinepestudbrud vil være mere alvorlige, hvis vildsvin blev involveret i en epidemi i forhold til, at der ikke var vildsvin. Både kontroludgifter og udgifter til svinesektoren ville blive forøgede, hvis vildsvin blev smittede med svinepest, og de totale omkostninger ville (i gennemsnit) stige med 500-700 mio. DKK. Hovedårsagen til dette er eksportmarkedernes reaktion i tilfælde af vildsvin i Danmark. En anden årsag er den længere varighed af en epidemi som vil være et resultat af, at virus cirkulerer i vildsvinepopulationen og periodisk spredes til tamsvin.

Vurdering af den samlede risiko

Der er som udgangspunkt en lav sandsynlighed for introduktion af svinepest til Danmark. Dette er et resultat af de eksisterende handelsmønstre og risikobegrænsende tiltag. Dette har sikret, at svinepest ikke har været i landet siden 1933.

Sandsynligheden for introduktion af svinepest vil stige lidt, hvis fritlevende vildsvin genindføres. En fritlevende vildsvinebestand i Danmark kan blive smittet gennem kontakt til smittede vildsvin, der er migreret fra Tyskland. Så længe der ikke er svinepest nord for Kieler-kanalen vurderer vi, at denne smittevej er forbundet med en ubetydelig sandsynlighed. Derudover er vildsvinehabitatet i Sønderjylland af begrænset størrelse, og dette mindsker den forventede migration til den sydøstlige del af Sønderjylland.

En anden smittevej er gennem turister, der tilfældigt kommer til at efterlade svinepest-kontaminerede kødrester i naturen. Det var ikke muligt at estimere sandsynligheden for, at dette sker, men den relative risiko mellem amter var højest i Ribe, Ringkøbing og Nordjylland.

Hvis fritlevende vildsvin er tilstede kan det forventes, at der vil opstå problemer mellem landmænd og vildsvin i områder, hvor begge har interesser. Markskader vil udgøre det største problem. Kun hvis der er svinepest blandt vildsvinene, vil bekymringen for smitte til tamsvin være reel.

Hvis svinepestvirus når vildsvin, vil smitten enten dø ud relativt hurtigt, eller der vil opstå en epidemi (median længde 112 dage). Dette afhænger bl.a. af vildsvinehabitatet, hvor smitten introduceres. Jo større habitat, jo længere epidemi. Spredning af smitte mellem tamsvin og vildsvin vil kun ske, såfremt tamsvinebesætningen er placeret i nærheden af et vildsvineområde. Når den første smitte optræder i en tamsvinebesætning, forventes en epidemi, mens hvis det er i gruppe vildsvin, så forventes enten ingen epidemi blandt tamsvin eller mere end en epidemi.

De økonomiske beregninger viste, at de gennemsnitlige udgifter forbundet med et svinepestudbrud vil være 500-700 mio. kr. (eller 36-53%) højere, hvis der er fritlevende vildsvin i forhold til i dag (i er mere pessimistisk scenario for Japans reaktion var de tilsvarende tal 300-400 mio. kr. – svarende til 10-17%). Men sandsynligheden for et udbrud stiger, hvis der er fritlevende vildsvin. Derudover vil tilstedeværelse af fritlevende vildsvin kunne medføre langvarige epidemier eller mere end en epidemi som følge af periodisk smitteoverførsel fra grupper af smittede vildsvin.

Udendørsdrevne svineproduktioner kan ikke sammenlignes med fritlevende vildsvin, idet der er en lav sandsynlighed for smitteoverførsel mellem indhegnede svin og svin uden for hegnet, inden infektion opdages. Dette skyldes bl.a. at svinepestvirus ikke er luftbåren, og direkte eller indirekte kontakt er nødvendig mellem to grise for at opnå overførsel af smitte.

Risiko er et produkt af sandsynlighed og konsekvens. Som det fremgår af det ovenstående, vil sandsynligheden for introduktion af svinepest stige lidt fra det nuværende lave niveau. De økonomiske konsekvenser vil variere fra 36-53% ekstra (gennemsnit) til et langt højere niveau i tilfælde af langvarige epidemier.

Risk management

Minimumskravene i tilfælde af udbrud af svinepest er beskrevet i et EU Rådsdirektiv, der giver vid mulighed for fortolkning og valg af kontrolstrategi. Vi analyserede effekten af forskellige kontrolstrategier hovedsageligt varierende med hensyn til vildsvin. Vores simuleringer viste, at vaccination af vildsvin ikke vil forkorte forløbet af en epidemi i forhold til den basale strategi, som består af geografisk adskillelse og nedskydning. Ydermere vil en vaccinationsstrategi være ekstrem kostbar for svinebranchen som følge af kraftige reaktioner fra tredjelandenes eksportmarkeder. Indhegning af udendørsdrevne besætninger vil ikke ændre forløbet af en epidemi. Indhegning af alle tamsvinebesætninger indenfor en radius af 16km fra vildsvinehabitater vil forkorte forløbet af en epidemi ganske lidt. De samlede udgifter forbundet med disse scenarier var ikke væsentligt forskellige fra det basale scenarie uden hegning. Hvis man valgte ikke at gøre noget for at håndtere smitten blandt vildsvin (ikke tilladt ifølge EU), ville den resulterende reaktion fra eksportmarkederne betyde enden for dansk svineproduktion.

Risikokommunikation

For at sikre en god kommunikation blev der etableret en kontaktgruppe fra begyndelsen af projektet. En kontaktgruppe blev etableret bestående af repræsentanter fra forskellige interessenter: Danmarks Miljøundersøgelser, Danmarks Naturfredningsforening, Danmarks Fødevareforskning, Danmarks Jægerforbund, Danske Slagterier og Fødevarestyrelsen. Det er planlagt, at der skal publiceres flere populærvidenskabelige artikler for at kommunikere resultaterne af projektet til befolkningen.
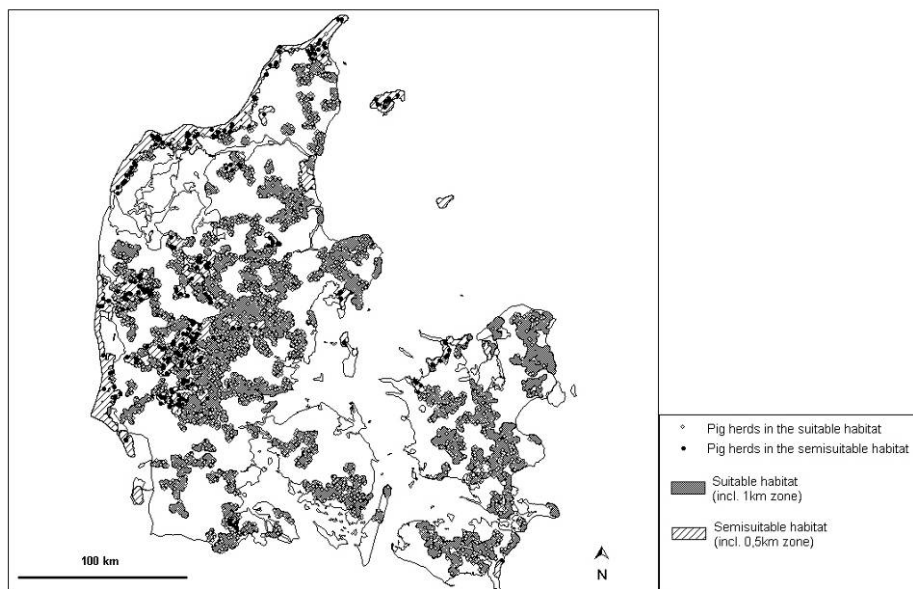

Fig 5.4. Kort, der viser placering af danske svinebesætninger i vildsvinehabitatet – taget fra rapporten.

1. Introduction

Currently there is no established population of free-range wild boar in Denmark. As a part of nature conservation and management of national biodiversity, Danish wildlife organisations have presented the idea that the wild boar should be reintroduced into Denmark. Historically, wild boar were present in Denmark until the beginning of the 19th century where they disappeared. At that time, only 2% of Denmark was covered with forest.

There is evidence that wild boar play a role for CSF outbreaks in pigs in Europe. Therefore, Danish pig farmers are concerned about the risk associated with such an introduction. In Europe, certain free-range wild boar populations are infected with classical swine fever virus (CSFV), and the presence of infected wild boar poses a constant risk of transmitting CSFV to domestic pigs (Artois et al., 2002). Examples of this have repeatedly been seen, particularly in Germany (see e.g. ftp://ftp.oie.int/SAM/2003/DEU_A.pdf, visited November 2, 2004).

The economic consequences of an outbreak of CSF would be devastating, not only for the individual farmer, but also for Denmark which is the world's largest net exporter of pork. More than 85% of the pork produced is exported. The main markets are other EU members, in particular Germany, Great Britain, France and Italy, as well as third countries like Japan, Russia and the USA. In 2003, this represented a value of 24 bDKK. Therefore, the temporary ban on export that would follow an introduction of CSFV would be detrimental for the pig industry.

To elucidate the additional risks the presence of wild boar might pose in terms of introducing CSFV into Denmark, a risk analysis was conducted with the following objectives:

1. To describe and characterize CSFV
2. To describe the biology and ecology of the free-range wild boar in Denmark
3. To estimate the suitable habitat and population density of wild boar
4. To estimate the general risk that CSFV would be introduced to domestic pigs – in the absence of wild boar in Denmark
5. To estimate the probability of introducing CSFV through infected garbage of foreign origin into a population of wild boar
6. To estimate disease spreading within a wild boar population after the introduction of CSFV
7. To estimate the probability of diseases spreading between wild boar and domestic pigs
8. To assess the financial consequences of having wild boar in Denmark in case of an outbreak of CSF
9. To integrate the results from the hazard identification, biology and ecology assessment, and the release assessment (1-4), exposure assessment (5-7) and consequence assessment (8) to produce an overall measure of the risk
10. To evaluate different risk mitigating means in terms of efficiency and expenses
11. To communicate the risks

The positive aspects related to the wild boar were not covered in this risk analysis. Damages to crops caused by wild boar as well as other possible sanitary hazards were only dealt with briefly. Population dynamic aspects related to wild boar were only studied with respect to disease spreading within wild boar populations.

2. Materials

The GIS programme MapInfo was used to estimate the suitable habitat and population density of wild boar. The GIS maps used were area usage maps and they are a part of the area information system, administrated by the National Environmental Research Institute, Denmark. The area usage maps consist of several different land use types, a road map (DAV 98) and vector maps (DDO_vector_04_plus) different from the Danish Bacon & Meat Council's (DBMC) own GIS. The pig farm coordinates used originated from the DBMC's own GIS database (All in the Danish coordinate system, UTM Zone 32, ED50). In order to estimate the suitable wild boar core habitat and density in Denmark, we used the AAK (Area Usage Map) that is a part of AIS (Area Information System, admin. by NERI). The raster map consists of different land use types such as forest, natural vegetation, pastures and extensive agriculture, intensive agriculture and urban areas and water bodies. For the tourism data, the GIS programme ArcGIS was used. A detailed description of the materials used for addressing the other questions is presented in sections 5 to 7. Published literature, expert opinion, and official statistics have been used wherever needed.

3. Methods

A disease risk assessment following the guidelines specified by the World Organisation for Animal Health (OIE) was conducted (OIE, 2004; Murray, 2002). Parts of the assessment are qualitative whereas others are quantitative. The latter was made where sufficient data of good quality existed. Because of data limitations, a substantial part of the results are presented as relative risks. This risk assessment contains the following elements:

Hazard identification
Biology and ecology assessment
Release assessment
Exposure assessment
Consequence assessment
Risk estimation

The risk assessment was followed by a risk management part, and risk communication was performed during the entire project. Hereby, the entire work constitutes a risk analysis (Murray, 2002).

As our aim was to assess the extra risk of CSFV entering the country, we estimated the risk both for the present situation without wild boar as well as the hypothetical situation where wild boar are present. Figure 3.1 presents the different pathways for introduction of CSFV into Denmark that were studied.

- Through release of CSFV directly to domestic pigs in Denmark by e.g. returning livestock trucks, import of infected animals, or swill feed of illegally imported meat (section 6.1)
- Through contact to an infected wild boar that has migrated from Northern Germany to Denmark (section 6.2)
- From ingestion of infected garbage left in nature or garbage bins e.g. by tourists from countries with CSF (section 6.3)
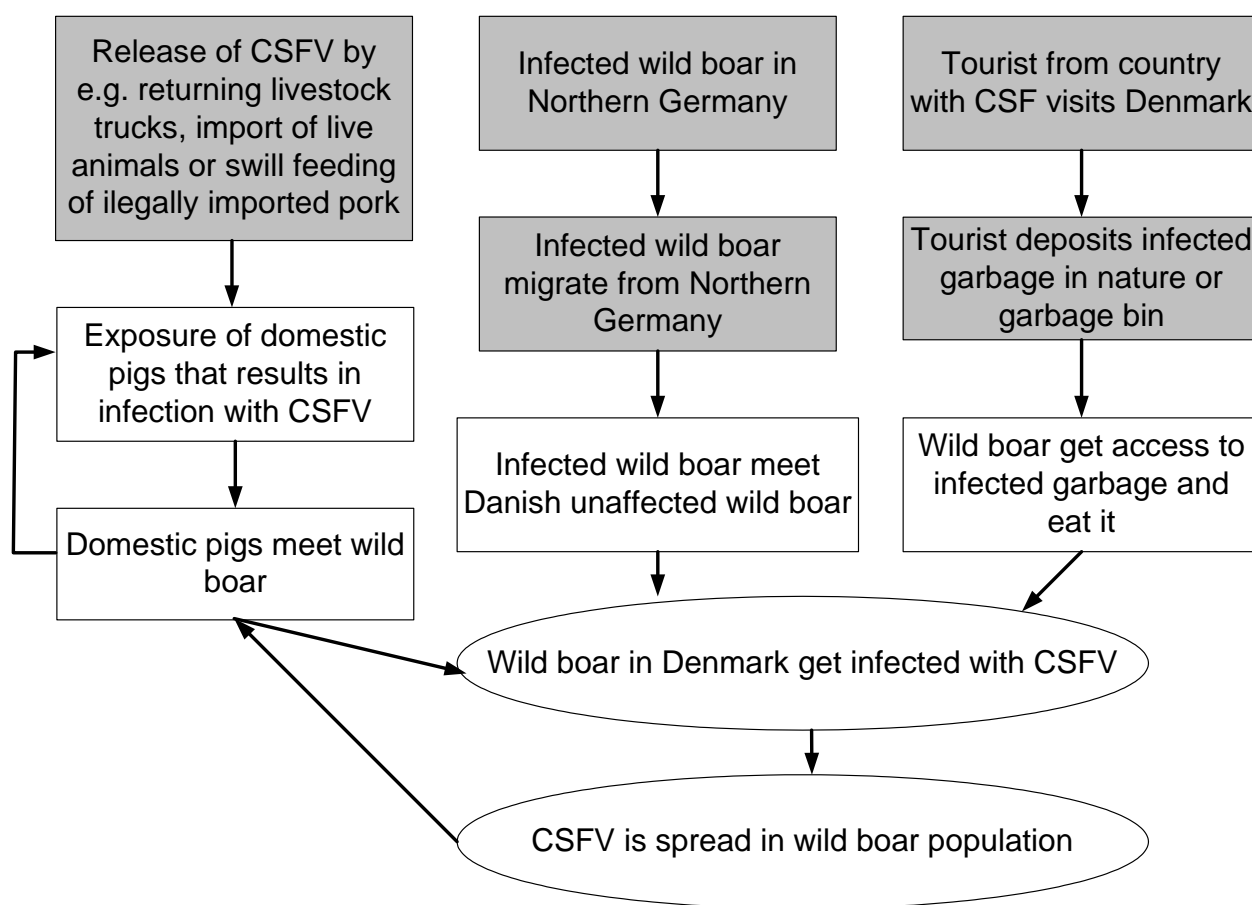
Figure 3.1. Disease introductory pathways for CSFV reaching a Danish population of wild boar. Events marked with grey are dealt with in the release assessment, the remaining event in the exposure assessment.

4. Hazard identification

The wild boar might host other serious pathogens that are not present in Danish domestic pigs. Examples are *Trichinella spiralis* and *Brucella suis*. Even though these pathogens might constitute a potential zoonotic problem, they were not considered in this risk analysis because it focused entirely on CSFV.

The hazard identification was based primarily on two literature reviews: Uttenthal (2004) (section 14.3) and Bronsvoort et al. (2004).

Aetiologic agent
Family *Flaviviridae*, Genus *Pestivirus*, Classical swine fever virus, Hog cholera virus.

OIE classification
Classical swine fever is on OIE's List A. This list contains transmissible diseases, which spread rapidly, irrespective of national borders, and have serious socio-economic or public health consequences and inflict heavy losses in the international trade in animals and animal products. Public health consequences are not relevant for this disease.

Denmark's status

Classical swine fever was most recently reported in Denmark in 1933. Denmark, as well as the other Nordic countries, has the status of "historically free" from CSF.

Epidemiology

Classical swine fever is an infectious contagious disease of swine. Pigs of all breeds, including wild boar, are susceptible to the infection. Several virus strains exist and they vary in virulence. Highly virulent strains produce lethal infections, whereas low-virulent strains give rise to mild disease or asymptomatic infections (Mittelholzer et al., 2000). CSF virus is widely distributed across the globe. There have mainly been outbreaks in Asia, South America and Europe. Table 4.1 lists year of the most recent outbreaks of CSF in Europe. As can be seen there is a continuing problem of CSF, including in countries close to Denmark. In particular Germany and Italy have ongoing problems partly due to infections in the wild boar populations.

The population of wild boar consists of around 1.5 or 2 million (Table 4.1). In Europe there seem to be a general increase in numbers of animals. The mere presence of wild boar is not a threat to the domestic pig populations. Accordingly, the increase in the wild boar population in Germany, just south of the Danish border has so far not been considered a problem according to the Danish Food and Veterinary Administration. If, however, CSFV is introduced in the domestic pig population the presence of a very effective reservoir host is a major problem.

Fig 4.1. Ear of a pig infected with Classical swine fever virus. Photo by Senior Research Officer Åse Uttenthal, DFVF, Lindholm.

Clinical course and pathology

Only few studies have been performed in wild boar, so the description of the disease course was based on observations in domestic pigs.

There are different clinical forms of CSF. Some pigs have the *acute form* whereas others have the *chronic form*. Following a short incubation period that lasts 7 to 10 days, pigs have increased body temperature for 1-3 weeks. During the hyperthermic period, CSFV is detected in the blood. This so-called viraemic period might be as short as 1 week. Usually, the viraemic period is 5-14 days for an acute infection (median 10.6 days). After the viraemic period, the

pigs may die from disease or survive and produce antibodies to CSFV. The pigs then have the acute form of CSF, where the clinical picture includes skin bleedings (Fig. 4.1) shows the ear of a pig with CSFV. The outcome of the infection depends on the age and the breed of the animal as well as the virulence of the virus strain. In some pigs, the virus is not cleared but the pigs survive for a longer period (from 5 to more than 40 days) displaying the chronic form of CSF, where the pig excretes large amounts of virus until succumbing to the infection several weeks after. The prolonged period where virus excretion is observed for more than 10 days has been seen in 40% of experimentally infected domestic pigs (Uttenthal et al., 2003).

Table 4.1. Year of most recent outbreak of CSF in Europe and the estimated numbers of wild boar present in each country

Country	Estimate of wild boar population	Month/Year of last report of CSFV in Domestic pig herd	Wild boar
Austria	30,000	3/1996	2001
Belgium	15,000	1997	2001
Bulgarien	45,000	5/2004	10/2004
Czech Republic	38,000	11/1999	11/1999
Denmark	250*	1933	Not reported
Estonia	15,000	01/1994	Not reported
Finland	45,000	1917	Not reported
France	750,000	4/2002	11/2003
Germany	418,667	2/2003	8/2004
Greece	500	7/1985	Not reported
Hungary	65,000	5/1993	Not reported
Ireland	0	1958	Not reported
Italy	No information	9/2003	1997
Lithuania	24,050	11/1992	Not reported
Latvia	30,347	4/1996	Not reported
Luxembourg	10,000	8/2003	8/2003
The Netherlands	3,000	3/1998	Not reported
Norway	500	1963	Not reported
Poland	160,000	9/1994	Not reported
Portugal	60,000	1985	Not reported
Slovakia	24,000	11/2004	8/2004
Slovenia	5,000	5/1996	Not reported
Spain	No information	5/2002	Not reported
Sweden	8,000	1944	Not reported
Switzerland	10,000	12/1993	9/1999
United Kingdom	600	10/2000	Not reported

* All fenced. Source: Information based on Handistatus OIE homepage and NSFL meeting reports

If pregnant sows are infected with CSFV, the offspring might have a *congenital persistent swine fever infection*. The persistently infected (PI) piglets appear clinically normal and have a normal humoral immunity to unrelated antigens, but they seem to be tolerant to CSFV. The PI-pigs may live up to 1 year, during which they are excreting virus. The role of PI-pigs in wild boar is not that well known, but it is suspected that PI-pigs exist in low numbers.

The virus is present in body fluids and muscle tissue. The stability of virus is dependant on both pH and on temperature. It is impossible to give definite guidelines for the survival time of CSFV in the environment (Edwards, 2000). Laboratory studies have shown CSFV to be stable in pH range 5-10, but inactivated at pH 3 or below and above pH 10. Therefore, no destruction of virus is expected as the pH decreases during rigor mortis in muscles. The virus is relatively stable in moist excretions and fresh meat products kept for long-time periods, like ham and dry-cured sausages. However, detergents, lipid solvents and common disinfectants can readily inactivate the virus. CSF virus is highly contagious to pigs via the oral route. One gram of fresh pork could contain 2.2×10^3 oral doses. This demonstrates why feeding untreated swill is so hazardous.

Outbreak and eradication

The main source of recent outbreaks of CSF in Europe 1997-2003 has been either wild boar, transport of infected animals, livestock trucks contaminated with infectious material, or swill feeding. In Germany in the period 1990-1998, 59% of the index cases (the first infected herd in a series of related outbreaks) were caused by CSFV-infected wild boar, and 23% by swill feeding. During outbreaks in Germany, France and Luxembourg in 2002-2003, contact with wild boar played a substantial role.

The experience from Central Europe is that the eradication process of CSFV in wild boar lasts several years. Large coherent areas densely populated with wild boar constitute the main problem. Pigs surviving a CSFV infection will remain antibody positive for the rest of their lives. Therefore, a detailed study of the age of the antibody positive animals is needed to be able to distinguish new infections from old ones.

Regarding epidemics in domestic pigs, the situation is very different. The eradication of even huge outbreaks like the 1997-epidemic in the Netherlands was successful within a year, but resulted in tremendous losses, because if one positive pig is detected, the entire herd will be eradicated as soon as possible upon diagnosis. This makes awareness and early diagnosis extremely important.

Vaccination

Vaccination of wild boar has been attempted by use of oral vaccine with live virus imbedded in cereal baits. The baits have been deposited at the usual feeding places. A substantial proportion of the older animals ate the baits, which led to 100% immunization of adult wild boar, whereas only 50% of animals less than 1 year became vaccinated. Because young animals are the most susceptible to CSFV, the effect of vaccination is limited. Furthermore, the antibody response from vaccinated animals cannot be distinguished from naturally infected animals, because the vaccine is not a marker vaccine. Therefore, trade problems may arise, in case a country wants to vaccinate its population of wild boar. In certain areas of Germany the eradication of CSFV in wild boar have been successful with combined use of vaccination and targeted hunting of young animals, which are the most susceptible individuals.

> **Conclusion of hazard identification**
> Classical swine fever virus (CSFV) can infect both wild boar and domestic pigs. On several occasions, infected wild boar have been involved in the transmission of CSFV to domestic pigs, particularly in Germany, Slovakia, and Luxembourg. In countries that have been able to keep their wild boar populations free from CSFV, wild boar have not been a risk for domestic pig herds. Even when domestic pigs are infected, wild boar do not have to become infected, as all domestic pigs with CSFV are culled quickly after diagnosis. Awareness and early diagnosis are therefore very important factors. CSF has not been present in Denmark since 1933. If wild boar are reintroduced into Denmark, wild boar might get infected with CSFV and hence pose a risk to domestic pigs. As a result, CSFV is classified as a potential hazard.

5. The biology and ecology of the wild boar

5.1 Literature review

Reintroduction of species that have become nationally extinct is increasingly seen as one of many tools to preserve nature and national biodiversity. The wild boar is a potential candidate for reintroduction into Denmark. The feasibility of reintroducing wild boar into Denmark has never been studied properly. Therefore, input to a classical swine fever risk assessment model has to be based on information from the literature most relevant to Danish conditions, e.g. information from a recently established population in South-east Sweden.

The wild boar immigrated to Denmark in the Preboreal era (ca. 9,000 BC), and it was a rather common and important game species until the beginning of the 19th century when it became extinct due to direct persecution and loss of habitat. Today, there are no established populations of free-range wild boar in Denmark. However, a number of wild boar are found in deer parks and a few farmers keep wild boar either for meat production or for cross-breeding with domestic pigs.

The wild boar is a social animal. Outside the rutting season, adult males live solitarily, but all other animals are organized in matrilinear groups, i.e. groups of 1-5 closely related females and their recent litters. During the rut (August-December) males join the groups to get access to females and, having achieved matings, they move to another group. Gestation lasts about 115 days, and 4 out of 5 sows give birth during February-April. Puberty is reached between 7 and 22 months of age. Females may breed as 1-year-old, dependent on population density and food availability. Fecundity rates and litter size are highly variable: first-time breeders (1-year-old) = 2.71 piglets, 2-year-old = 4.45 piglets and 3-years and older = 4.25 piglets (average values based on Swedish data). The sex and age specific survival pattern of the wild boar is to a large extent controlled by hunting regulations as hunting is the most important cause of death in healthy wild boar populations. Mortality is highest in the youngest age-classes. In a recently established population in Sweden 63.6% of the females in a cohort survived their first year of life, while 28.9% and 22.5% survived to their second and third year of life, respectively. Corresponding survival for males were 68.8%, 14.1% and 5.4%, respectively, reflecting a higher hunting pressure on males in general, especially on inexperienced, dispersing 1-2-year-old animals.

Fig. 5.1. Two young male wild boar

Young males leave their family groups, usually forced by older males, when they reach sexual maturity. However, young females seem to have a number of options dependent on the population size in the natal area in relation to carrying capacity. They may stay in the natal area, in which case they usually do not breed. They may disperse a short distance and start their own family group. Finally, they may disperse over longer distances. Mean dispersal distances are 4.5km for females and 16,6km for males.

Because of the social organization pattern, group home-ranges are more relevant indicators of space use in the wild boar than individual home-ranges. The home-range size differs between groups ($9-18km^2$), mainly depending on population density, landscape structure, cover, food distribution and food availability, including supplemental feeding. Data on population densities of free-living populations of wild boar are rather sparse in the literature, varying from 1 to 25 animals
perkm^2 but very much dependent on percentage of forest cover and extent of supplemental feeding. For modelling purposes, 1-5 animals per km^2, including 25% forest cover is recommended.

The wild boar is primarily nocturnal. Activity starts around sunset, lasting 6-8 hours. Mean distance covered is 7km per night, varying between 2 and 16km. Activity periods are mainly used for feeding. Animals may search for food, e.g. attractive agricultural crops, on open land up to a few hundred meters away from the forest edge.

The wild boar is an opportunistic omnivore. The diet is largely determined by the relative, local availability of different food types. Vegetable foods constitute the bulk of the food ingested and also occur more frequently than animal foods. The main vegetable foods are mast, roots, green plant matter and agricultural crops. Access to at least one energy-rich plant food source, e.g. cereal grain, potatoes or maize, is important. Animal foods include insects, earthworms, birds and mammals as well as a few amphibians, reptiles and gastropods.

Wild boar often cause substantial damage to agricultural crops, particularly when other energy-rich foods are scarce. Foraging activities may cause significant damage, not only because of consumption of the crops *per se* but also because of trampling. However, there are also examples of beneficial effects of wild boar activity as e.g. rooting may promote botanical diversity and natural regeneration of forests. There is no doubt that the crop damage aspect – provided wild boar is reintroduced or allowed to immigrate - will be one of the most important determinants of future distribution and population density of the wild boar in Denmark.

The aim of this review was to identify and present estimates of essential parameters of wild boar biology and ecology to be used as input to a classical swine fever risk assessment model. In general, Danish landscapes seem to meet the basic habitat requirements of the wild boar. Presumably, it would be possible for the wild boar to establish and maintain free-living, sustainable populations in most regions of Denmark. However, besides the life history characteristics and habitat requirements of the wild boar it will be necessary to consider several limiting factors; e.g. the small coverage of forest, the intensive land use including agriculture, the high density of the human population and the extended infrastructure.

Full text of the literature review (in Danish) and references are found in Appendix 14.2.

Conclusion on biology and ecology of wild boar
The wild boar is a potential candidate for reintroduction in Denmark, but before a decision can be made, possible consequences would have to be evaluated in a feasibility study. In general, Danish landscapes seem to meet the requirements of the wild boar. Provided wild boar are reintroduced or allowed to migrate from Germany there is no doubt that damages to crop will be one of the most important determinants of future distribution and population density of wild boar.
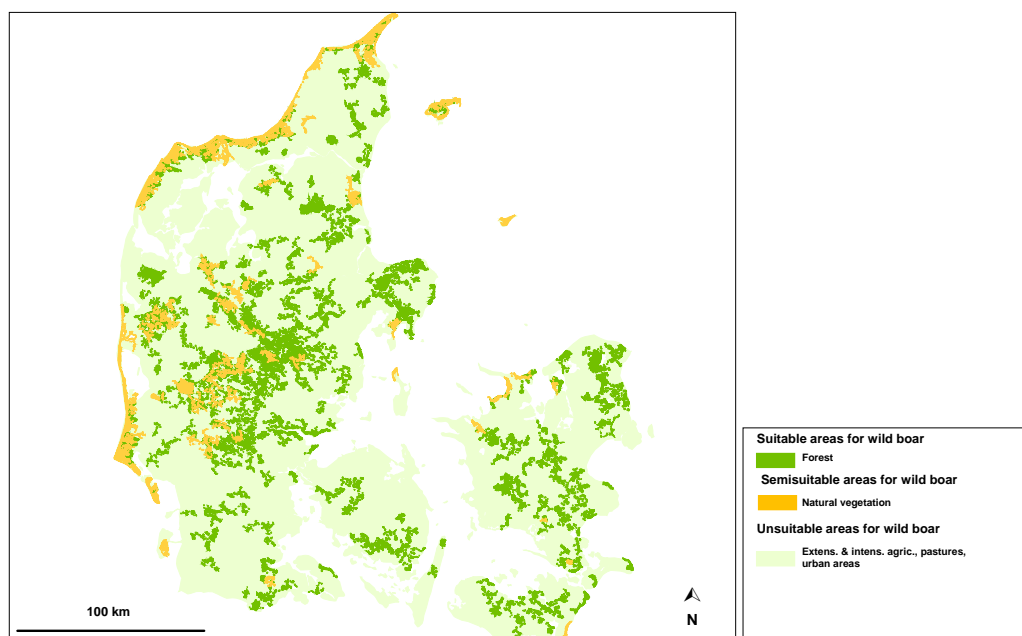
Fig. 5.1. Qualitative estimation of core habitat (allowing for reproduction) in Denmark based on land use types.

5.2 The suitable wild boar habitat in Denmark

Suitable areas for wild boar reproduction were identified as the following types of land use: Forest, deciduous forest, coniferous forest and mixed forest. Natural vegetation was considered a semi-suitable area, and it was identified as the following land use types: Natural grassland, heath-land and peat bog. Pasture and agriculture (intensive as well as extensive) were considered unsuited land use types for reproduction. Likewise, urban areas and water bodies were considered barriers. These assumptions are similar to those used in Germany (Kramer-Schadt, personal communication).

Based upon the literature review in section 5.1, we assumed that one family group of wild boar needs an area that at least covers 4km^2, and that 25% of this area should be covered with forest or natural vegetation. It could also consist of smaller patches of forest or natural vegetation that in total cover 4km^2 with a maximum of 1km between the patches. Finally, we defined the habitat that allows for reproduction a core habitat.

A map displaying the wild boar core habitat was created based upon the above-mentioned assumptions (Fig. 5.1). It is noted that there are suitable or semi-suitable habitats in several places in Denmark, despite that the majority of the country consists of pasture and agriculture. We considered that reproduction could take place in semi-suitable areas in particular if in the vicinity of forest patches. In total, suitable or semi-suitable habitats cover some 9-10% of the total area of Denmark (Bornholm excl.).
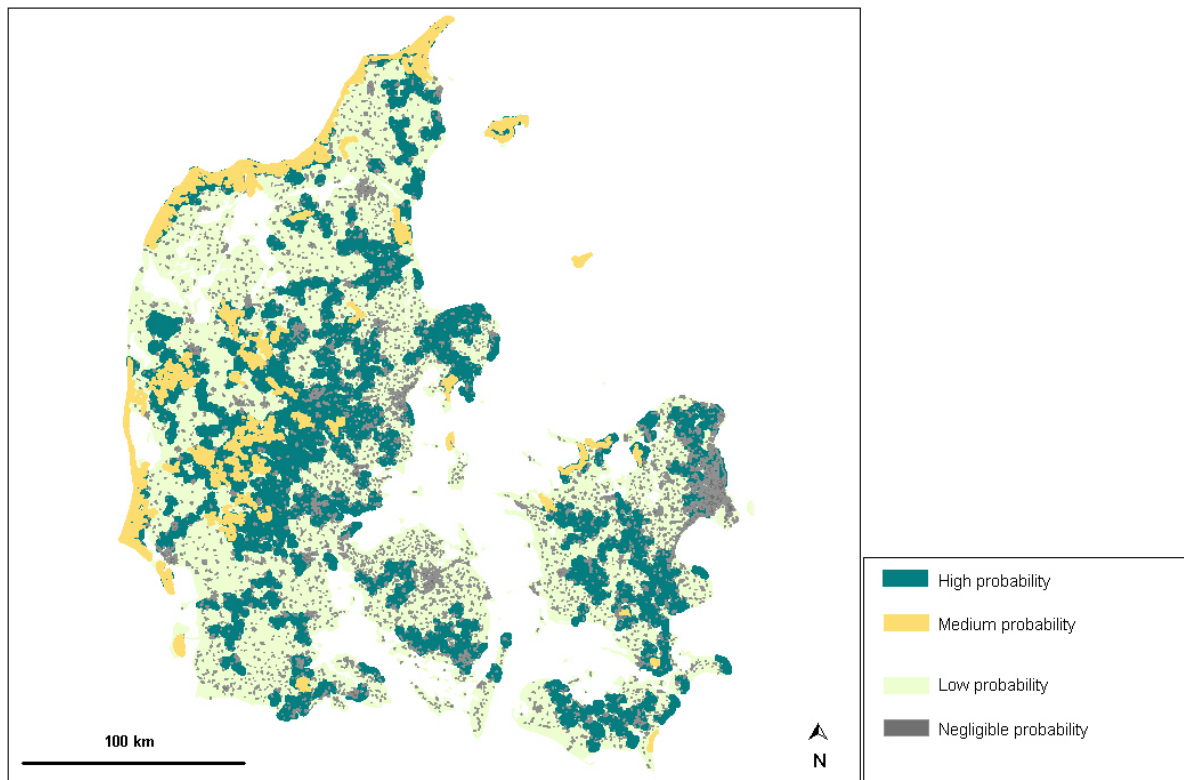
Fig. 5.2. Wild boar home range areas: semi-quantitative assessment of appearance of wild boar based on quality of reproduction and forage areas in Denmark.

The wild boar uses the forest for reproduction as well as a place to hide, and they forage on the surrounding fields (see section 5.1). We assumed that wild boar forage on fields up to a distance of 1km to the forest. To illustrate the geographical distribution of villages, towns and cities in Denmark a part of a vector maps was used as urban areas. Towns more than 0.04 km² in area are represented on this map. Based upon this, a map that displays the appearance of wild boar in Denmark can be made (Fig. 5.2).

1. High probability: Suitable reproduction habitats with a buffer of 1km
2. Medium probability: Natural vegetation patches with a buffer of 0.5km
3. Low probability: Pastures and extensive agriculture
4. Negligible probability/barriers: Intensive agriculture/ Urban areas.

It is noted that areas with a high probability of wild boar appearance are seen several places in Denmark. However, it is also noted, that a substantial part of the Danish forest consists of forest patches, which implies that many flocks would be separated.

The question is whether the females migrate between patches and between forests if the distance in between is too long. Certain landscapes like open fields and towns form barriers slowing the spreading of wild boar. In contrast, a forest will form a corridor, enhancing the spreading of wild boar. This aspect is not covered in this report, but will be a natural part of a feasibility study.

At present, about 11% of Denmark is covered with forest, and it is foreseen that within the coming 80 to 100 years the forested area should be doubled. The new forests will be planted both by privates and public authorities. A reforestation plan, which indicates areas in which new forests are wanted, has been made (Fig. 5.3). These areas have been identified based upon 1) protection of underground water supply, 2) low forest coverage in the parish. The majority of the areas are situated close to cities. Some areas will create corridors between existing forests. This will enable a potential wild boar population to spread more than at present.

Seven areas in Denmark have also been suggested as possible future national parks. These are: The island Læsø, Vadehavet, North Sealand, Thy, Lille Vildmose, Mols Bjerge and the island Møn http://www.skovognatur.dk/nationalparker. Currently, the possibilities and disadvantages associated with these possible locations as future national parks are being addressed by authorities, private organisations and local interests.

Conclusion of the suitable wild boar habitat
Wild boar prefer forests for reproduction and hiding-place whereas they forage on the surrounding fields up to a distance of around 1km from the forest. One family group needs around 4km² and at least 25% of this area should be covered with forest (suitable habitat) or natural vegetation (semi-suitable habitat). Based on this assumption, we calculated that suitable or semi-suitable habitats cover 9-10% of the total area of Denmark (Bornholm excl.). To display where wild boar will be observed we used a buffer of 1km around the suitable habitat and a buffer of 0.5km around the semi-suitable habitat. Areas with a high probability of having wild boar are found in many parts of the country. However, a large part of the Danish forests consists of smaller forests and forest patches. Certain landscapes like open fields and towns will form barriers slowing the spreading of wild boar, whereas forests will form corridors that will enhance the spreading of the animals.

Fig. 5.3. Map of Denmark displaying the areas officially identified for reforestation. Green circles indicate areas where the National Forestry Commission has initiated reforestation projects. Red triangles indicate possible future reforestation areas. Source: http://www.sns.dk/aktuelleemner/skovrejsning/kort.htm.

5.3 Conflicting interests between man and wild boar

Conflicts can be expected in areas where the wild boar habitat overlaps villages, towns, and cities as well as pig herds. Because the aim of this risk analysis deals with CSF, we only looked on conflicting interests between pig herds and wild boar. Apart from the concern for introduction of CSFV, damages to crops will be a conflicting issue.

Firstly, we made a map illustrating the location of pig herds within the areas where wild boar will be seen (0.5km buffer around semi-suitable and 1km buffer around the suitable wild boar habitat of Denmark) (Fig. 5.4). The green and yellow habitat areas in Fig. 5.4 are the same as in Fig. 5.2. The map shows that a total of 24% of all pig herds are located within the area where wild boar will be seen. These farms represent 23% of the pig population in Denmark. The out-door pig herds account for just under 2% of the herds in Denmark.

Fig 5.4. Map displaying location of Danish pig herds within the wild boar habitat.

Secondly, we made a map that displayed the location of all Danish pig herds. A 1km buffer was used around the individual herd (Fig. 5.5). It is noted that pig farming occurs in all parts of the country.
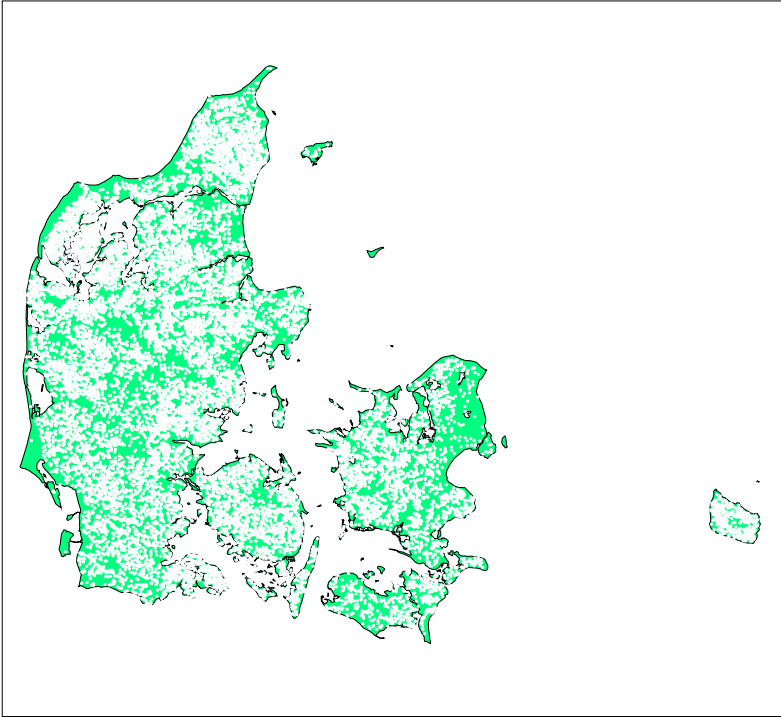
Fig. 5.5. Wild boar and pig herds: white areas consist of a 1km buffer zone around each Danish pig farm, whereas the green areas are the remaining parts of Denmark.

Conclusion regarding conflicting interests between man and wild boar
Conflicting interests are expected between farmers and wild boar in the geographical areas where both reside. In Denmark, 24% of the pig herds are located closely (within the buffer of 1km and 0.5 km) to the suitable or semi-suitable wild boar areas. This will pose a problem since wild boar could get too close to the pig herds. Moreover, damage to crops is likely to occur.

6. Release assessment

There is always a risk that CSFV would enter the country. In order to identify the extra risk associated specifically with free-range wild boar we tried to compare the different pathways that would enable CSFV to enter Denmark.

The release assessment in this study consists of an identification of the pathways leading to an introduction of CSFV to either Danish domestic pigs or wild boar, as well as an assessment of associated likelihoods. The pathways are graphically presented in Fig. 3.1.

6.1 Introduction of CSFV from a foreign source to domestic pigs

In 2003, a risk assessment regarding introduction of exotic swine diseases to Denmark was conducted (Bronsvoort et al., 2004ab). This work was used to address the risk of CSFV being introduced from a foreign source directly to domestic pigs. It was concluded that the main

pathways considered were associated with a low or even negligible likelihood. That is not to say that disease could never enter via these routes, rather that the flow of animals or products or people along these pathways is so small that the likelihood of introduction is low or negligible based on the information available at the time of the assessment.

The disease introductory pathways that were believed to be associated with the highest risk of introducing CSFV into Denmark was returning livestock trucks, imports of pork products (legally/illegally and including hunters) and boar semen. Risk mitigating initiatives are in place for all these pathways whereby the likelihood is reduced to low (Table 6.1).

A quantitative analysis was performed to estimate the expected number of years to pass before an outbreak would occur due to returning contaminated livestock trucks. The analysis was conducted for two scenarios: 1) no cleaning, disinfection and quarantine, or 2) 85% effective cleaning, disinfection and quarantine. The results showed that in the first scenario one outbreak would be seen within 20 years, whereas in the second scenario, one outbreak was to be expected within 134 years.

Table 6.1. Assessment of risks associated with different pathways for the introduction of CSF to Denmark

Pathways	Comments/Action taken	Risk*
Airborne	Not airborne	Irrelevant
Import of livestock	Voluntary quarantine, limited number	Low
Import of slaughteranimals	No pigs for slaughter imported	Negligible
Returning livestock trucks	Mandatory disinfection & quarantine	Low
Boar semen	Approval & quarantine	Low
Embryos	Not traded commercially	Irrelevant
Pet pigs	Information campaigns	Low
Exotic animals	Mostly species that do not carry CSFV	Irrelevant
Birds of prey	Could be involved in the spreading of CSFV but presumably not in introduction	Negligible
Wild boar in Denmark	At present, under fence. If free-range, serological monitoring crucial	Negligible
Hunters	Information campaigns needed	Low
Legal import of meat	Only from approved areas/countries	Low
Illegal import of meat	Custom control & information campaigns, apparently small amounts	Low
Movement of people	Investigation needed	Not assessed
Swill feed	Information campaigns needed	Low
Bioterrorism	General intelligence measures in place	Negligible

*: If the conditions regarding a pathway are changed, e.g. more livestock is imported, the risk should be reassessed. Modified after Alban et al. (2004).

According to Bronsvoort et al. (2004), illegal trade in pork was only considered associated with a negligible likelihood. This was based on available information that demonstrated that only small amounts of illegal meat was found during a field study at Danish border controls. It was assumed that the non-registered pork would presumably be for personal consumption. Because there is a ban on swill feed, it becomes less likely that these small amounts will reach pigs. However, in September 2004, the police, the customs and the veterinary authorities

discovered one case of organised smuggling of meat into Denmark. This was part of a campaign running during the autumn of 2004 in Southern Jutland. This reveals that organised illegal import of meat does take place. However, the extent is unknown. For more information on this campaign, please see http://www.foedevarestyrelsen.dk/GUID.asp?ID=2DDDF147-DAFA-4A93-9DC8-5DD0CB99F73E. To assess the risk associated with organised, illegally imported meat, it is necessary to identify the volume and type of meat (species of origin, treatment of meat), the country of origin, as well as the planned destination of the meat.

Moreover, the potential problem associated with migrant workers from Eastern Europe and the apparent relocation of Danish pig operations to the East need further investigations.

The low overall likelihood of introduction was a result of current trade patterns and ways of behaviour. If trade patterns or behaviour changes, the likelihood of introduction will change. For example, if the number of livestock imported to Denmark increases, and the compliance with the voluntary quarantine is lowered from the presently expected very high level, the likelihood of introduction will increase dramatically. Likewise, if there is no full compliance with the mandatory requirement for cleaning, disinfection and quarantine of returning livestock trucks, the likelihood of introduction increases.

Conclusion on the risk of introduction of CSF from other sources than wild boar
The individual pathways by which CSFV could reach Danish domestic pigs without wild boar - were associated with a low or even negligible probability. This is a result of the present trade patterns and actions in place – and if these are changed, the risk changes. The most risky pathways identified were livestock trucks passing the border, import of breeding stock, import of boar semen, hunters hunting abroad as well as legal/illegal imports of meat.

6.2 Migration of wild boar from Germany to Denmark

Introduction

Wild boar are present in Germany, south of Denmark. Of primary interest is the population of wild boar living north of the Kieler Channel in Germany as this population has the possibility of migrating to Denmark. The population was supposed to be low in 1995 (Clausen, 1995). According to the local German veterinary authorities, the population is on the increase because more animals are shot in the recent years. In the hunting year 2002-2003, 29 wild boars were shot in the Rendsburg-Eckernförde area, whereas in 2003-2004, 94 wild boars were shot in the same area. Furthermore in 2003-2004, 2 wild boars were also shot in the Schleswig-Flensburg area. All wild boars shot are tested for CSF, and so far none of the ones hunted in Schleswig-Holstein has tested positive for CSF.

CSFV is present in wild boar populations further south in Germany. The closest to Denmark has been in Lower-Saxony and in Mecklenbourg Western-Pommerania. In Lower Saxony, the most recently infected wild boar was found in June 2002, and in Mecklenbourg Western-Pommerania in July 2000 (Teuffert et al. 2003).

From 1993 to 1996, wild boar were present in Lindet forest in Southern Jutland, 28km from the border to Germany. These animals were not a result of migration from Germany because they originated from a pregnant sow that escaped an enclosure with wild boars. Within 2 years, the population grew to 23 wild boars. During the winter of 1996, the

population was hunted down as a result of political pressure from the agricultural organisations supported by the Danish Veterinary & Food Administration. According to the official data, 17 wild boars were shot, leaving maximum 6 wild boars. Rumours also said that some wild boars were shot on surrounding private areas. On February 27, 1995, one wild boar entered an outdoor pig production situated close to Gram town in Southern Jutland. The wild boar most likely originated from the wild boar population in Lindet forest, 7km away (http://www.faktalink.dk/publish.php?linknavn=vildhele).

In spite of the fact that there are no established wild boar populations in Denmark, wild boar has occasionally been witnessed. In the fall 2002 two incidents occured. One wild boar was killed by a car near Haderslev, tissues from the animal were analysed but CSFV could not be detected. One herd of outdoor domestic pigs in Åbenrå were put in quarantine as a 1-year-old male wild boar was shot inside the fence. This was not the first visit of wild boar to the herd, previously one of the sows have had a litter of hybrid piglets crossed in by wild boar. Tissue samples from the killed wild boar did not contain CSFV, and no pigs within the herd has clinical symptoms of CSFV. The origin of these two animals could not be traced. They could be escapées from fenced herds of wild boar or it could be speculated if these wild boars could have migrate from the nearby German border.

Experiment simulating the migration of wild boar sows from Germany to Denmark
Free-range wild boar populations migrating from northern Germany are as noted assumed to be a possible stepping-stone for the introduction of CSF virus to Denmark. Therefore, attempts have been in place to shoot any wild boar migrating from Germany to Denmark. Hereby, the natural establishment of wild boar in Southern Jutland has been avoided.

Fig. 6.1. Explanation of the model manipulation applied in the migration experiment. The red cells on the map depict an artificially rich boar habitat at the German side of the border.

The question is what would happen if wild boar were no longer shot when observed trespassing? To assess the size of a wild boar population that would be established based on migration, a simulation experiment was performed. For the "Migration-Experiment" (Rule Mig1) the spatial model (see Appendix) was run at the geographical scale with the following modifications:

On the German side of the border, a 20km-wide belt was assumed with perfect wild boar habitat allowing 5 sows to breed per $4km^2$ (a breeding patch) (Fig. 6.1). This would result in family sizes of 30-40 animals.

To study how far into Denmark the wild boar would manage to migrate we oriented towards the worst-case scenario i.e. a situation during which the migration of female wild boar from Germany would be certain. The females are of interest because they breed. Under natural conditions, the migration potential of the game animals will be much less because the habitat area on the German side of the border is less suitable than assumed in the modelling experiment.

Hunting was not included in the model, so the results are based upon the assumption of no hunting. In reality, hunting would take place and delimit the probability of wild boar being established in a specific cell.

The population dynamics were simulated for 25 years. For each possible breeding patch in Denmark, the probability to be reached was recorded from 100 repetitions.

Results

Figure 6.2 shows the resulting Danish boar population after 5 and 25 years, respectively. The probability of successfully established herds is very low in most forest patches because in southern Denmark the breeding habitat for wild boar is very sparse.

The corridor in the western part of this region of Denmark is not connected with Germany, which limits the probability of migration. The corridor in the eastern part of Southern Jutland might favour migration. However, since it is narrow, it will also enable control of migration. As long as the German area north of the Kieler Channel is free from CSF, the migration of wild boar in itself is not seen as a risk of introducing CSF into Denmark

Sensitivity analyses

The natural search radius of female wild boar is up to 6km (see also sections 5.1 and 14.2), To model how sensitive the conclusion of the modelling experiment was to changes in the parameter describing search radius, we repeated the experiment with two non-natural search radii for dispersing sub-adult females; 10km or 20km, respectively. Again, these values determine the maximum distance covered stochastically by some sub-adult group. When comparing the results of these scenarios, only minor differences were observed (Fig. 6.4). This underlines the conservative character of the results of the invasion experiment.

Conclusion

In conclusion, not managing natural wild boar migration in the border region to Germany will only lead to a minor degree of migration, and only in the most south-eastern parts of Southern Jutland. According to Fig. 6.3, the forestation plan will add two small projects in Southern Jutland, and thus, the effect for the migration analysis is negligible.
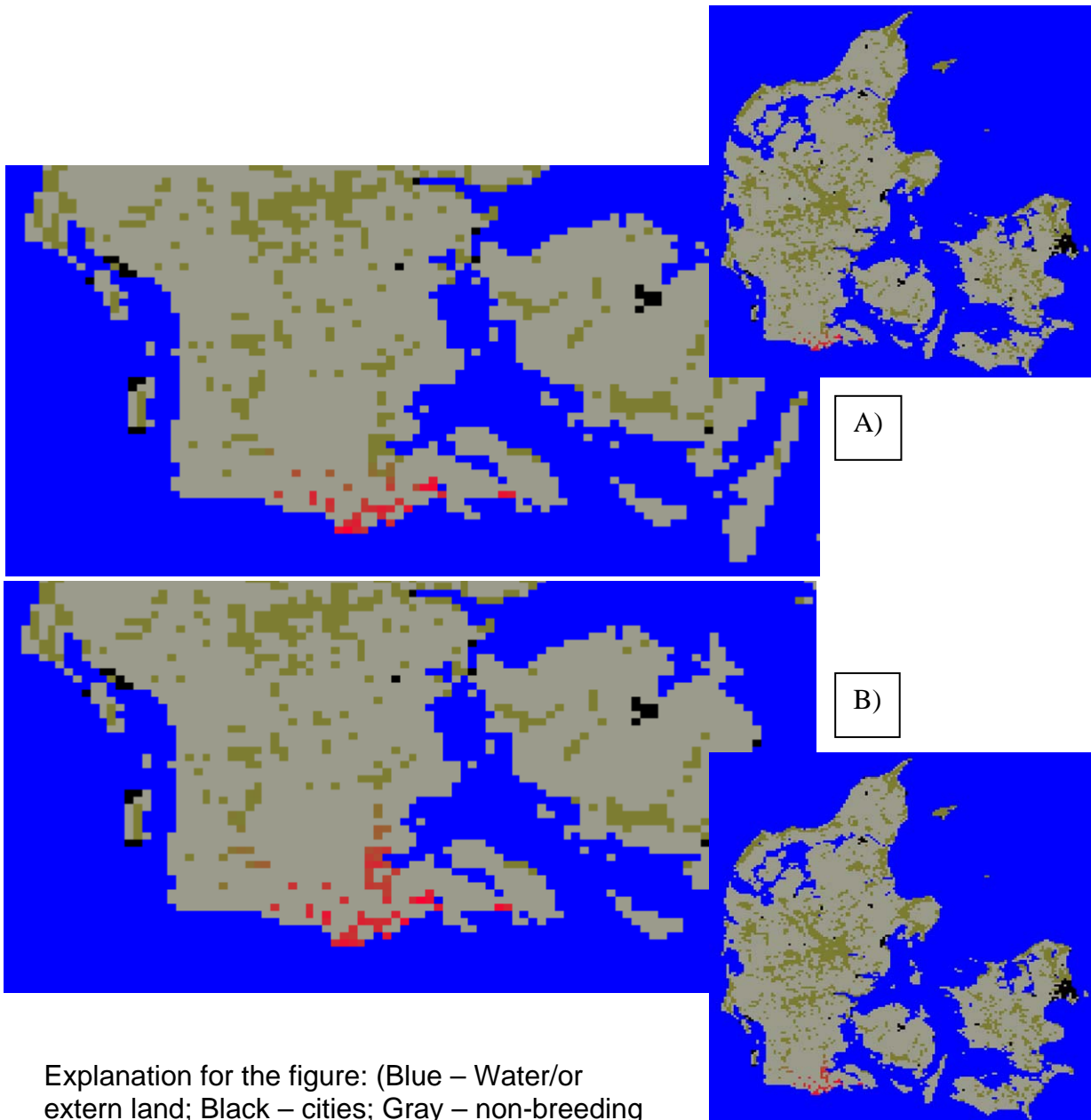
Explanation for the figure: (Blue – Water/or extern land; Black – cities; Gray – non-breeding habitat; Olive – zero probability. Red with increasing intensity reflects higher probability).

Fig. 6.2. Migration of wild boar from Germany: Probability surface of habitat in Denmark occupied by wild boar, either after (A) 5 years or (B) 25 years.
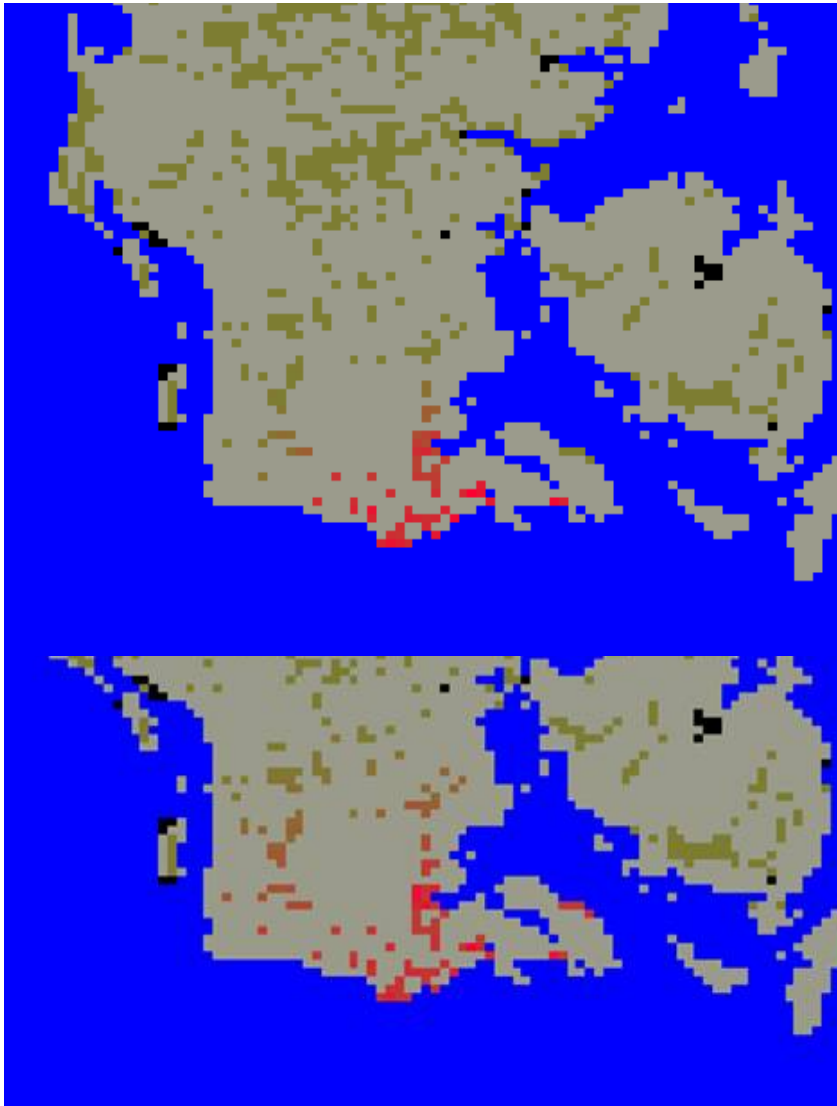
Fig. 6.3 Sensitivity analysis: effect of changing the parameter for female search radius from 6km (the natural – top figure) to 10km (artificially enlarged – bottom figure). For explanation of the colours and specification of the model, please see Fig. 6.2.

Conclusion of migration of wild boar from Germany
Unregulated migration of wild boar from Germany will only affect a limited part of Southern Jutland because the wild boar habitat is limited in this area. The wild boar habitat in the western part of Southern Jutland is not connected with Germany, which limits the probability of migration, whereas the habitat in the eastern part might favour migration. However, since this habitat is narrow, it will also enable control of migration. As long as the German area north of the Kieler Channel is free from CSF, the migration of wild boar in itself is not seen as a risk of introducing CSFV into Denmark.

6.3 Transmission of CSFV through garbage to wild boar

The infected garbage route
    One way of introducing CSF to a Danish wild boar population could be through contaminated meat products left accessible to wild boars. The meat could be brought here and left by e.g. foreign tourists, truck drivers or Danes returning from vacation abroad. It could also be illegally imported meat/meat products left in nature (e.g. if the importer suddenly had to get rid of it in a hurry).
    There is no information available on truck drivers and Danes returning from vacations abroad.
Increasing attention has been put on illegally imported meat over the border to Germany. In 2004, the Danish Veterinary and Food Administration carried out a campaign in cooperation with the customs, the tax authorities, and the police. The findings were larger than expected and approximately 12 tons of illegally imported meat where seized and destroyed. This was mainly meat from chicken, turkey, duck and lamb (Rosenørn, E, personal comment, 2005). These types of meat do not constitute a risk in relation to CSF, which only involves pigs and pork. Meat from pigs was only found in processed products. These could of course constitute a risk of bringing in CSF but due to limited knowledge of the findings these are not included in the further analysis. The foreign tourists are therefore used in the further analysis and the risk of transmission through garbage is then illustrated by the risk of transmission through tourists. In order to investigate this risk it is necessary to obtain information on tourist behaviour and on the habitats of the wild boar.

The proportional risk of infection PR in each county is determined by the following equation:

$$6.a \qquad PR = \frac{P(\text{infection occurs in county}_{i0})}{\sum P(\text{infection occurs in county}_i)} = \frac{E_i}{\sum_i E_i}$$

    That is the probability that infections occurs in county i_0 relative to the probability that exposure occurs at all. Full text is found in appendix 14.5.

Data about tourists in Denmark and legal background for registration
    It is compulsory for hotels, motels, inns, holiday centres, and pensions (with >40 beds) and camping grounds (with >75 camping units) to report bed nights spent to Statistics Denmark. A bed night equals one person for one night (Departmental order no. 595 of June 22, 2000).
    The data used in this section originate from Danish Statistics Office, which registers "bed nights spent" on the different types of stay, time period, county and nationality of tourists. There are some limitations in the data since length of stay is not directly registered. Furthermore, the travel routes for arriving in Denmark are unknown.
    The Danish Tourist Board has made an analysis on business and pleasure travels. The results are based on 28,858 interviews with travellers in Denmark (The Danish Tourist board, 1998), and to sum up:
    1. The tourists come to Denmark mainly because of the nature
    2. Most bed nights were spent at camping grounds or in summer cottages
    3. They come in small groups of 1-4 people
    4. They stay for 4-12 nights

Calculation of the risk associated with tourists

Tourists from countries that have reported CSFV to the OIE during the most recent decade is used as an illustration of who could bring in contaminated meat (see section 14.5). The risk of bringing in meat also depends on the type of stay. Some types of stays are believed to be associated with a higher probability of bringing in meat than other types of stays. For example, we only associated hotel stays with a very low probability (0.01). Likewise, we only associated visits at holiday centres with a low probability (0.2). However, we associated stays at camping grounds or summer cottages with a high probability (1 for each) of bringing in meat. The robustness of these somewhat arbitrarily set assignments was investigated through a sensitivity analysis, and it was found that variation within reasonable intervals did not change much in the result ranking. Based on these results, we consider the relative risk of the types of stay as appropriately assessed (see section 14.5). The proportional risk of exposure and subsequent infection is described in formula 6.b and shown in table 6.2.

$$6.b \qquad E_i = \sum_j \left(\frac{B_{ij}}{S_j} \right) \times F_j \times D_i$$

Where E_i is the exposure in county i,
B is the sum of bed nights spend in stay type j in county i,
S is the mean length of stay in stay type j,
F is the factor used to assess the risk of the type of stay, according to the probability of a tourist bringing in food from his/her native country or from a country that he/she travelled through on the way to Denmark and leaving it accessible to wild boars
And D is the estimated wild boar density in county i.

Table 6.2. The relative risk of infection with Classical swine fever virus associated with tourism - by county and type of stay in Denmark, 2003

County	Wild boar density (animals/km²)	Hotel	Holiday centre	Hostel	Camping	Summer Cottage	Proportional Risk	Relative Risk
Mean length of stay(nights)		3.8	4.7	5.6	11.9	10.9		
Relative risk factor		0.01	0.2	0.01	1.0	1.0		
København	0.28	2,475	575	105	10,199	13,028	0.03	1.0
Frederiksborg								
Roskilde								
Vestsjælland	0.19	54	6,198	17	10,449	58,716	0.06	2.0
Storstrøm								
Bornholm	*	225	1,595	6	7,844	36,514	*	*
Fyn	0.10	115	1,160	17	21,739	52,110	0.03	1.0
Sønderjylland	0.11	61	3,286	27	61,349	103,670	0.07	2.3
Ribe	0.21	170	4,947	16	48,431	272,477	0.27	9.0
Ringkøbing	0.23	60	2,985	7	23,180	283,578	0.29	9.7
Vejle	0.27	358	1,726	32	11,560	71,835	0.09	3.0
Århus								
Viborg	0.20	37	660	5	5,898	52,385	0.05	1.7
Nordjylland	0.16	155	4,078	16	29,472	150,826	0.12	4.0

*: The suitable wild boar habitat on Bornholm was not estimated

The parameter "bed nights spent" does not say anything about how many tourists are coming and for how long they stay. Therefore, the parameter "number of stays" was used. How this and the wild boar density are reached is described in the appendix (section 14.5). Regarding the carrying capacity section 5.1 recommends 1 to 5 animals pr. km^2 is for modelling purposes. In this section 2.5 animals pr. km^2 are used to calculate the density of wild boars.
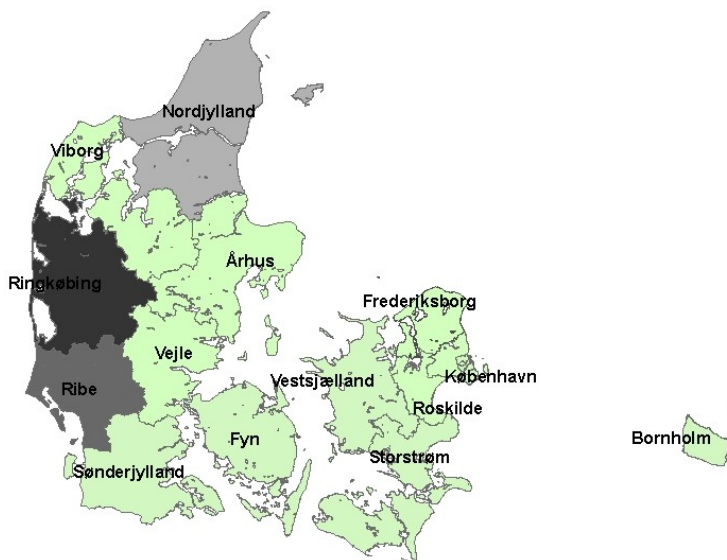
Figure 6.4. Geographical representation of the relative risk of tourists infecting wild boar with CSFV, by counties in Denmark. The darker the colour, the higher is the risk.

The relative risk of exposure was greatest in the two counties that make up the western part of Jutland (Ribe and Ringkøbing). The risk in these counties was 9-10 times the risk in North and East Zealand that had the lowest risk. The northern part of Jutland (Northern Jutland) had the third highest risk (4 times the risk in North and East Zealand).

Conclusion on the garbage route
Wild boar is likely to include easy accessible garbage in their diet, and meat remnants can contain CSFV for longer time periods. CSFV-contaminated meat can be brought in by e.g. tourists and leftovers left accessible to wild boar. Tourists from countries that have had CSF during the most recent decade were used to illustrate who might bring in contaminated food. The likelihood of bringing in food also depends on the type of the stay. The types of stays that were considered to constitute the highest risk are stays at camping grounds and in summer cottages. The wild boar habitat size in a county was also incorporated by multiplying with the expected wild boar density (animals per km^2). The relative risk of exposure was greatest in the two counties that make up the western part of Jutland (Ribe and Ringkøbing). The risk in these counties was 9-10 times the risk in North and East Zealand that had the lowest risk. The northern part of Jutland (Northern Jutland) had the third highest risk (4 times the risk in North and East Zealand).

7. Exposure assessment

The exposure assessment deals with pathways and associated likelihood of CSFV exposure of domestic pigs or wild boar in Denmark. The pathways are described in Fig. 6.1.

7.1 Disease transmission within an infected herd of wild boar

We applied a spatial simulation model developed for understanding the spread of CSF in the wild and support control efforts in European wild boar populations. The assumptions, rules and parameterisation of the model are detailed in Section 14.4.

The basis of the further analysis is the assumption that a free-range wild boar population has been established in some areas of Denmark. We limited our investigations to the general concept of "occurrence in some areas" to avoid *a priori* presumption as to where wild boar would be released because our study did not focus on the sustainability of different release options from the meta-population point of view.

For the following analysis, we assumed (i) wild boar populations would be present in all suitable areas, and (ii) that an infection might be introduced by any route. The first assumption does not include that wild boar would actually be released everywhere, but refers to the above argument that release areas should not be selected in advance. Therefore, the results will allow the analysis of potential epidemics *relative* to each other. After a selection of release places, it is possible to select the region from the map to achieve more quantitative measures. Further, we need not to differentiate between the routes and/or places of introductory infections because eventually any route will end in an infection of certain wild boar groups, and logically, it will happen only in the regions selected for the release.

On top of the infection risk introduced in Danish domestic pigs, free-range wild boar have two fates: (a) the animals are added to the total swine population that might be susceptible to an introduction into Denmark: the increased risk is elaborated in section 6, and (b) for how long the disease is present/persists within wild boar after the occurrence of the initial infection. Indeed, as long as CSF is spreading within the wild boar population, any infected individual poses a risk of transmitting the disease to domestic pigs in the respective regions.

The impact of potential wild boar occurrence on the risk structure after an introductory infection depends on (i) the region that would potentially be affected by the successive outbreak, (ii) the time horizon during which the infection will be present after an outbreak, (iii) resulting of this, the intensity of the outbreak measured as infected wild boar group-weeks and infected animal-weeks, and (iv) the chance of any established wild boar group to become infected by any outbreak anywhere in Denmark.

The aim of this risk evaluation was the identification of areas that have highest hazard ratio if wild boar would have been released and established within them.

From this point of view we have investigated 4 aspects of risk formalisation to describe the resulting epidemic after an introduction in a wild boar group (part 1-3) and the vulnerability of groups to transmission (part 4):

1. Spatial extent – number of infected wild boar groups
   We classified all potential wild boar groups according to the expected total number of infected groups after an outbreak started from that group.

2. Time at risk – duration of an outbreak

The risk put by an epidemic in wild boar would accumulate with the time that the infection persists within an area. Therefore, for each group we analysed the expected duration of an outbreak starting within that particular group.

3. Intensity of outbreak – total infected animal-weeks/total infected group-weeks

The risk put by an epidemic in wild boar would accumulate with the accumulated time any wild boar groups are infected. Therefore, for each (outbreak) group we analysed the expected total number of infected group-weeks throughout the epidemic starting within that particular group. The risk put by an epidemic in wild boar would accumulate with the time individual animals are infected. Therefore, for each (outbreak) group we analysed the expected total infected animal-weeks throughout the epidemic starting within that group of wild boar.

4. Risk areas – probability to be involved in an outbreak

For each group of wild boar, we estimated the expected number of outbreaks that would affect the group. The information discovers areas that would suffer more seriously from any introductory infection compared with others – given that wild boar will be released in the area.

5. Effect of virulence

Finally, we looked into the effect of the virulence of the virus.

Methodology

The spatio-temporal infection risk resulting from an introduction of CSF was simulated with the standard 'Classical Swine Fever – wild Boar Model (see Appendix) on the geographical scale of Denmark. The simulation regime successively initiated a primary infection within each group no matter how likely an introduction at this 'origin' would have been. The respective simulations started at an optimal population, i.e. each family group was initialised with a number that equates to the maximum allowed number of breeding sows (breeding capacity of the habitat * 2 for adult pigs * 3 for piglets – adults ~ 33% (1:1) + piglets 67%; the actual age and sex of each individual was selected randomly according to the age distribution in free-range wild boar herds – see Appendix). Before virus release in each simulation run, 5 years were passed by to balance the population dynamics. Virus was released in the sixth year at week 14, i.e. mid April, to get a comparable situation. Simulations were stopped when the virus went extinct. During the simulation any infected group, any week a group was infected and any week anyone animal was infected were recorded. Finally, the spatial extent of the epidemic was stored as a spatial output.

Analysis

The habitat map used in the simulation comprises 1,990 habitat cells. Each cell covers 4km², and by use of the land use map of Denmark (Weiers et al., 2002) the breeding capacity in the cell was determined according to field observations by Jedrzejewska et al. (1994).

After the simulation was completed for each of the 1,990 habitat cells, values for the three measures 'Spatial extend', 'Duration', and 'Intensity' (part 1-3) were scaled linearly between 0-255 to produce coloured spatial maps expressing low to high risk in the relative spatial context of each 'wild boar group of origin'. All the 1,990 spatial maps of wild boar groups

affected (part 4 – 'Risk areas') were superimposed to estimate the relative frequency a group was involved in all of the 1,990 epidemics.

1. Output: spatial extent – number of infected wild boar groups

We counted for each simulation run, i.e. each simulated epidemic, the wild boar groups affected by the epidemic. The number estimates the spatial extent of the affected area for each initial wild boar group. Larger values identify wild boar groups, which would initiate high-risk epidemics if they get infected – hence, releasing wild boar in that area would result in a likely higher risk compared with a release in areas were only lower numbers of secondary wild boar groups will be affected.
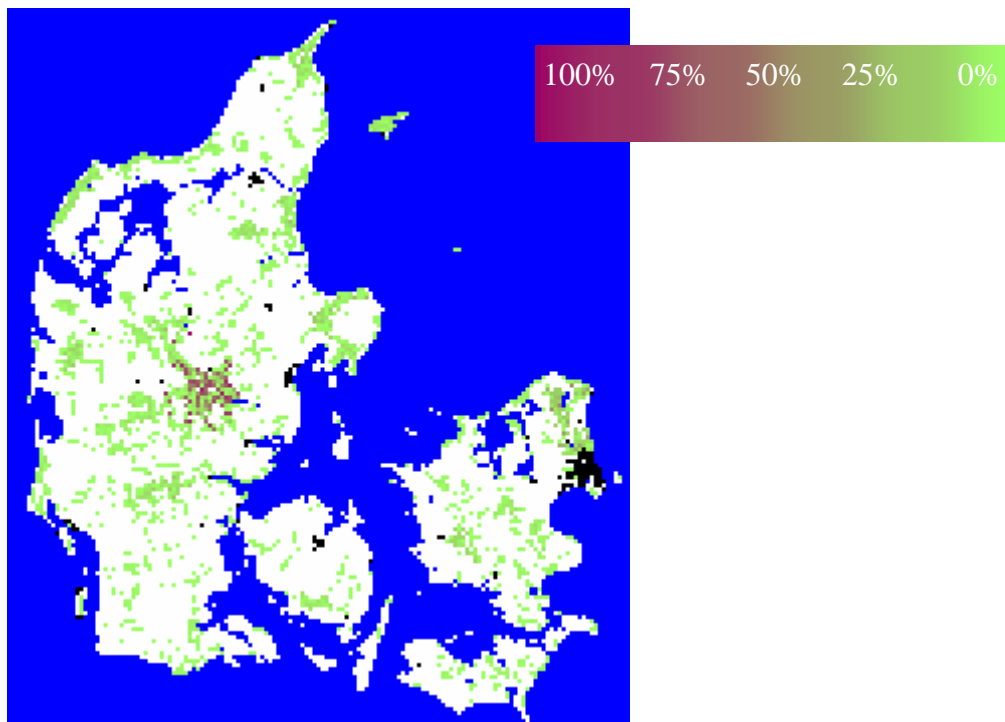
Fig. 7.1. Spatial extent of CSF epidemic in wild boar. Outcome aspect: Number of CSF-infected wild boar groups based on simulation results (Linear colour scheme relative to the maximum number of secondary infections an outbreak ever had; scaling 100% refers to the maximum value of 214 secondarily infected herds found for an epidemics in the simulations; see text for further explanation).

If a CSF epidemic starts in more violet-coloured wild boar groups in Fig. 7.1, the total number of eventually affected groups will be higher. Thus, clumped violet cells in the figure indicate regions where established wild boar populations would result in larger epidemics.

The simulated epidemics affected between 0 and 214 neighbouring wild boar groups. Scaling 100% refers to the maximum observed value of 214 neighbouring wild boar groups in the simulations. The mean number of affected wild boar groups was 13.7 whereas the median was 4, indicating that the maximum values were only observed occasionally.

It is noted that in the area around the Silkeborg forests several cells are violet (Fig. 7.1). This indicates that a large epidemic can occur in this area.

2. Output: Time at risk – duration of a CSF outbreak among wild boar

For each simulated epidemic, we recorded the duration of the epidemic. This was calculated as the time interval between first infection and last infected animal was removed. The number estimates the time a region is put under risk by the infection in certain initial wild boar group. Larger values identify wild boar groups which would initiate long-lasting epidemics – hence, releasing wild boar in that area would result in a likely higher hazard due to increased time under risk compared to a release in areas were epidemics last only shorter.
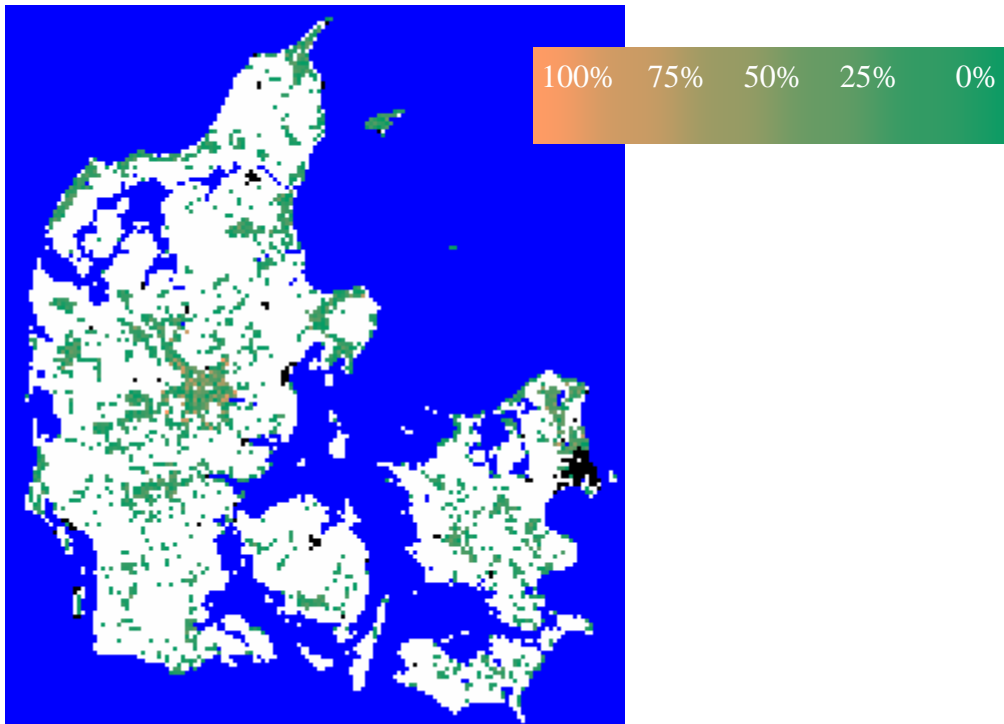
Fig. 7.2. Time at risk. Outcome aspect: Duration of CSF epidemics based on simulation results (Linear colour scheme relative to the maximum duration an outbreak ever had; scaling 100% refers to the maximum value of 123 weeks an epidemics persisted in the simulations; see text for further explanation).

More terracotta-coloured wild boar groups in Fig. 7.2 will result in longest epidemics - if the initial infection was in that group. The simulated epidemics lasted between 1 and 123 weeks (corresponding to 7- 861 days). They had a mean duration of 20.1 weeks (141 days) and a median duration of 16 weeks (112 days), indicating that only in a few cases the epidemic lasted extremely long.

3. Output: Intensity of a CSF-outbreak – infected animal- or group weeks

100%   75%   50%   25%   0%
Infected individual-weeks

100%   75%   50%   25%   0%
Infected wild boar group-weeks
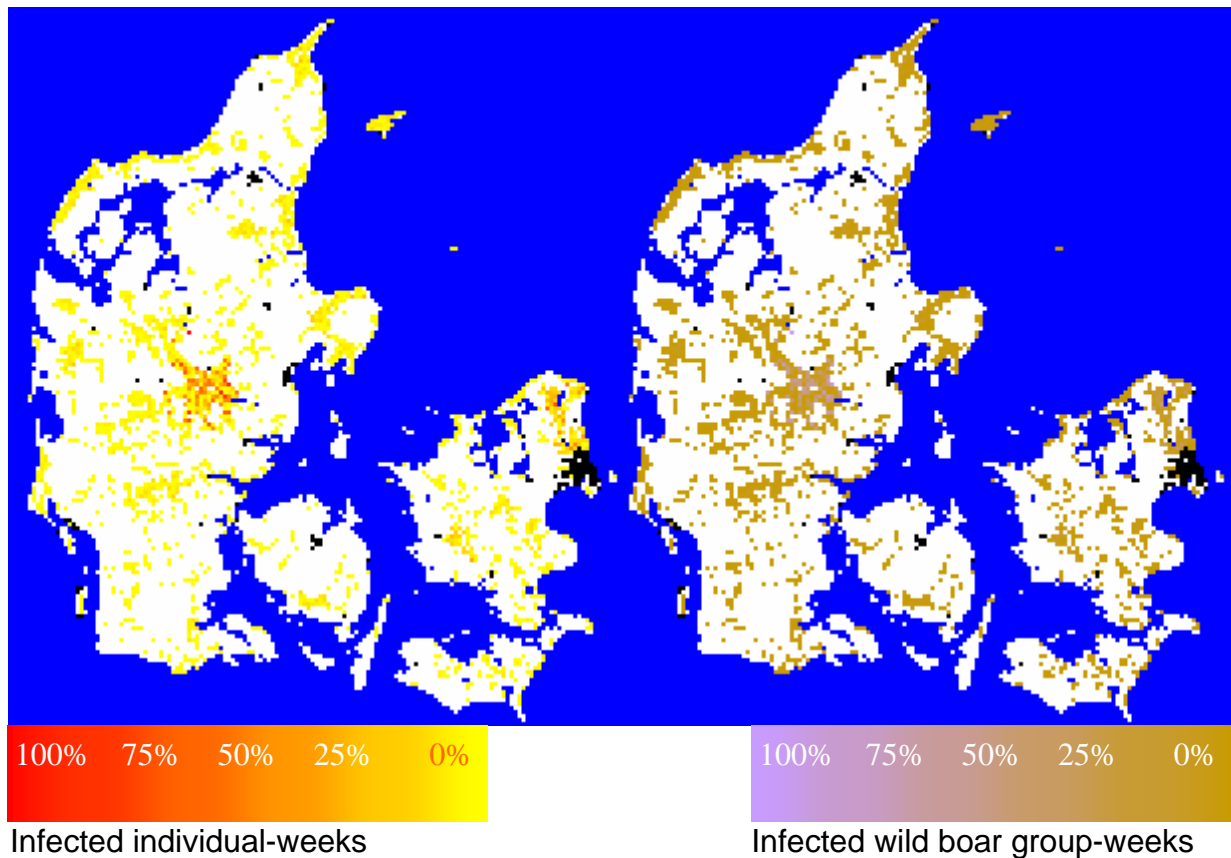
Fig. 7.3. Intensity of CSF epidemic. Outcome aspect: Infected animal-weeks and infected wild boar group-weeks based on simulation results (Linear colour scheme relative to the maximum duration an outbreak ever had; scaling 100% refers to the maximum value of 4,268 (2,157) infected animal- (wild boar group-) weeks in the simulations; see text for further explanation).

Cells coloured more reddish (lilac) indicate the presence of wild boar groups that produce more infected animal-weeks (infected group-weeks) if the initial infection was in that group of wild boar (Fig. 7.3). The simulated epidemics resulted in between 0 and 4,268 infected animal weeks (between 0 and 2,157 infected wild boar groups-weeks). The mean intensity was 210.2 infected animal-weeks (Median: 47 infected animal-weeks). Calculated as infected wild boar group-weeks, the mean was 110.8 (median 25.5). Again, it is the area around the Silkeborg forests that harbour most infected cells.

4. Output: Risk areas – probability of a wild boar group to be involved in an outbreak of CSF
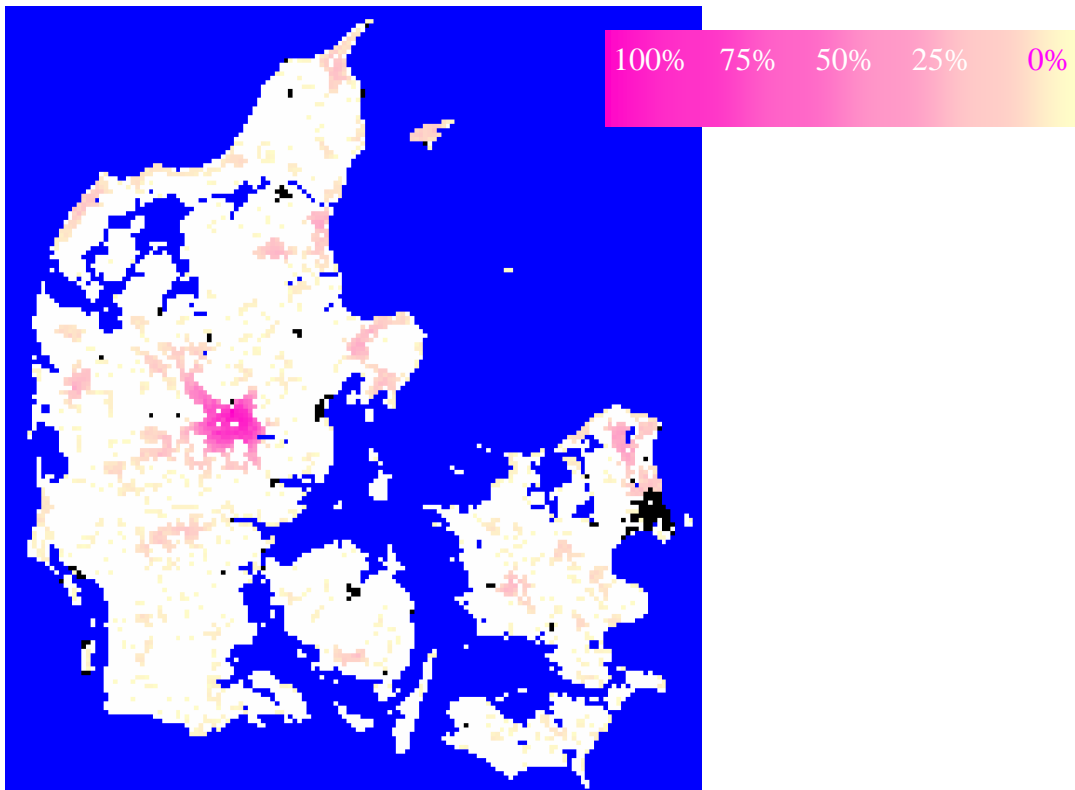
Fig. 7.4. Risk areas. Outcome aspect: Probability surface of being involved in any potential CSF-epidemic based on simulation results (Linear colour scheme relative to the maximum number of outbreaks a herd was ever involved; scaling 100% refers to the maximum value of 94 outbreaks a herd was involved in the simulations; see text for further explanation).

 More intensive pink-coloured cells in Fig. 7.4 indicate higher probabilities of the respective wild boar group to become involved in an epidemic if wild boar are established and an infection is introduced in the surrounding area.

 According to Fig. 7.4, the wild boar groups were involved in at most 94 epidemics out of all epidemics initiated in the 1,990 wild boar groups. Again, the wild boar groups at Silkeborg forests had a higher probability to become involved in an epidemic compared with wild boar groups elsewhere.

5. Virulence of Virus

It is known that the fate of an epidemic depends on factors related to the population dynamics of the affected species, but it also depends on the virulence of the virus (Kramer-Schadt et al. – in press, Proceedings SVEPM 2005). Therefore, we decided to analyse the effect of different virulence for Denmark. To do so, we changed the assumed characteristics describing CSFV (Table 7.1). This resulted in a different frequency distribution of the infection courses on the population level. At this stage of the risk evaluation, we performed indicatively three particular simulation scenarios assuming low, medium, or high virulent virus. E.g. we changed the parameter describing transient infection (probability of shedding for one week then surviving and immune after 4 weeks post infection). Likewise, we changed the parameter for acute infection (probability of dying within 3 weeks) and chronic infection (probability of being infectious up to 100 days but eventually dying).

'Virulence'

| Low | Medium | High |

Maximum number of epidemics some wild boar group was involved

| 164 | 94 | 30 |
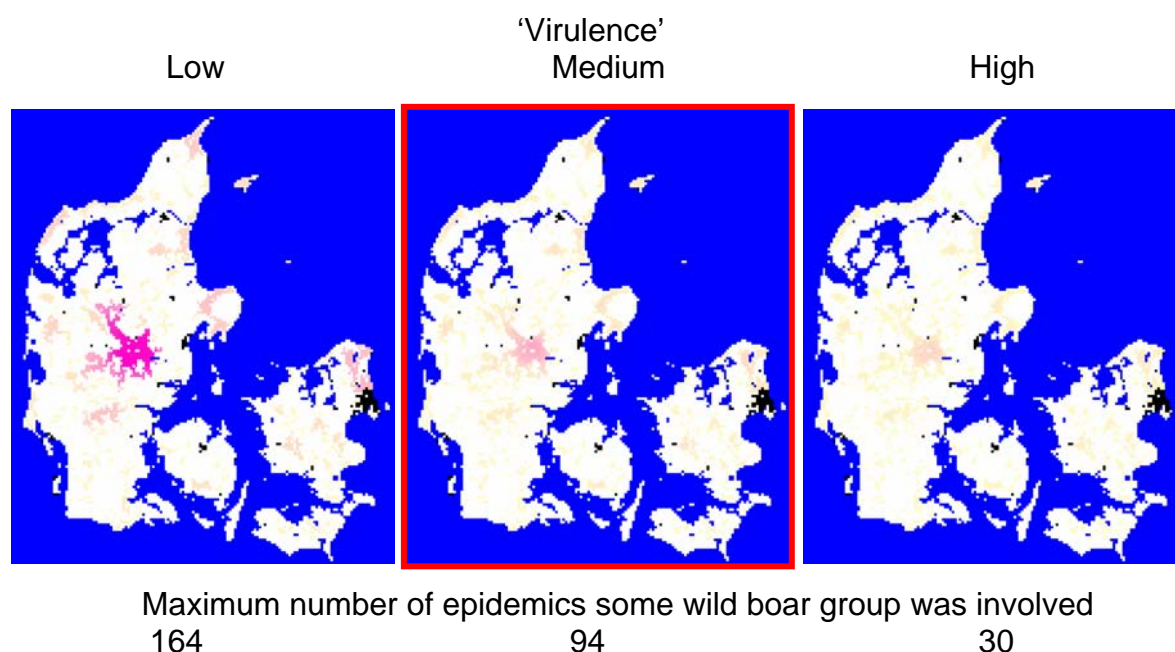
Fig. 7.5. Risk areas - Different virulence assumptions. Outcome aspect: Probability surface of being involved in any potential epidemic based on simulation results (Linear colour scheme relative to the maximum number of outbreaks a herd was ever involved; scaling 100% refers to the maximum value of 164 outbreaks one wild boar group was involved in the simulations; see text for further explanation).

The three outputs were scaled relatively to the maximum of 164 epidemics found in 'low virulence scenario'. The 'medium virulence' scenario is equal to Fig. 7.4 but for the scale of the colouring scheme (100% = 164 epidemics instead of 94 epidemics in Fig. 7.4).

More intensive pink-coloured cells in Fig. 7.5 indicate higher probabilities of the respective wild boar group to become involved in an epidemic if wild boar are established and an infection is introduced in the surrounding area.

Table 7.1. Three indicative virulence scenarios

Feature	High	Medium	Low
Percentage of infections transient (i.e. boar eventually immune)	Low (i.e. 40%)	Medium (i.e. 80%)	High (i.e. 90%)
Maximum duration of chronic infections	Short (i.e. 4 weeks)	Medium (i.e. 22 weeks)	Long (i.e. 30 weeks)
Survival probability of chronically infected between 0 and Maximum duration	Fast decline (i.e. Exponential with value 10)	Medium decline (i.e. Nearly linear with value 1)	Slow decline (i.e. less then linearly value 0.1)

Different virulence assumptions dramatically change the spatial dynamics of CSF epidemics (Fig. 7.5). The lower the assumed 'virulence', the larger is the risk of the individual wild boar group to be involved in an epidemic in its local region. In other words: the lower the virulence, the larger the areas that will be involved in an epidemic of CSF among wild boar. It is also noted that whatever 'virulence' was assumed, the wild boar groups at Silkeborg forests always had the highest probability to get involved in any epidemic. Hence, releasing wild boar anywhere at Silkeborg forest will put the highest risk of disease spread in the area compared to other large forests in Denmark.

Discussion of simulation results

The presented analysis tackles the question what an infection in any wild boar group would result in. In particular, we expected different risk figures depending on where an epidemic was initiated. Basically, there is no doubt that the more wild boar there would be within a region the more intense an associated epidemic would be. However, the issue is vague and ignores well-known effects of ecology on disease dynamics. Thus, we had to bother with the spatial fragmentation of potential Danish wild boar populations due to habitat variability. Non-homogeneous habitat quality within clusters of wild boar habitat will generate locally varying animal density on top of landscape fragmentation. Therefore, we expected quite different spatio-temporal characteristics of CSF outbreaks in wild boar depending on the location of primary infected groups.

It is generally known that the larger extended the wild boar population is, the larger an epidemic must be expected. But this is modified by the geography of real landscapes in such a way that spatial fragmentation of habitat for the host might either limited the spread of the of the virus or even enhance its persistence by a successive affection of consecutive habitat islands. To cover these aspects we investigated the simulated epidemics first according to their spatial extend describing connectivity of the Danish wild boar habitat from the "virus point of view". To the next we compare the analysis with the temporal characteristics to discover the spatio-temporal entities of jointly exposed boar habitat. Preparing the analysis we identified 4 *concepts that relate the spatio-temporal dynamics of an outbreak to the risk exposure for domestic pig industry* in the vicinity of the running epidemic.

It is obvious, that the **spatial extend** an outbreak finally will reach is directly associated with the risk exposure. Therefore, we analysed the total number of wild boar groups that will be affected after an outbreak had occurred (Fig. 7.1). The aim was to highlight wild boar group locations that would generate epidemics that affect relatively large numbers of secondary groups. Clumped locations of high values will indicate regions that inherit higher competence to distribute the infection in space. Astonishingly in 50% of all outbreaks the total epidemic spread only over up to 5 groups which highlight the importance of spatial size and structure of

the identified wild boar habitat. On the other hand, the region around Silkeborg forest contains nearly all locations that produced wide spread epidemics with maximum of 214 neighbouring wild boar groups affected by one simulated outbreak. It is reasonable that we found many exemplary group locations within the Silkeborg area because of the size of the forest area – but it noteworthy that other even large forest areas are not related to epidemics of comparable extent.

The varying outcome of the measure can be explained by the spatial structure of the different geographical regions. The characteristics of the Silkeborg area are long stretched annexes, which extend the affected area if eventually reached by the disease. Although the largest spatial extent will involve more than 200 groups, not all parts of the region have the same risk characteristics. But, unfortunately, without fencing it would not be possible to exploit the difference because wild boar released in the annexes will quickly establish also in the centre of the Silkeborg area.

Another criterion of increased risk exposure due to a CSF epidemic maintained in a wild boar population is the **time horizon** the disease will be present, and thus enables transmission to domestic pigs. The quality was measured in terms of duration of the simulated epidemic (Fig. 7.2). In general most epidemics out of Silkeborg forest were self limiting, potentially due to the insufficient size or spatial structure of the identified wild boar habitat, which results in 50% of all epidemics lasting less 16 weeks (4 months). Particularly, we expected to identify areas were small but long ensembles of wild boar habitat will allow a steady move forward and thus longer lasting epidemics, i.e. the stabilising competence of the area. Any region where locations with high values for the spatial extend are clumped could be qualified according to the duration measure as associated with heavy outbreaks in wild boar (i.e. rather short duration) or smoulder epidemic spread (i.e. high values for duration coincide with high value for spatial extent). The simulations did not discover such areas. Indeed the Silkeborg forest contains almost all locations that produced long-lasting epidemics. Moreover, as we see from Figure 7.2, locations at the outskirt of Silkeborg forest result in the longest lasting scenarios after infection. Unfortunately, exactly these wild boar groups might have the highest risk of introduction.

Following the area and the time at risk, another concept in risk evaluation addresses to total amount of risk exposure times the time it occurs. To adapt the idea we investigated the **intensity** of an epidemic according to the total number of infected animal-weeks or wild boar group-weeks respectively (Fig. 7.3). For the Danish habitat structure we found that locations causing the longest lasting epidemics also generate outbreaks of higher intensity. The reason for the observation was attributed to the compact and coherent assemblage of optimal habitat patches in one region – the Silkeborg forest.

Finally, we were interested in the receiver competence of wild boar habitat areas that is the integral **probability of an area to receive an infection**. Therefore we determined the chance of wild boar group locations to get involved in an epidemic (Fig. 7.4). Again, for the central Silkeborg forest we recognized a rather perfect probability for all locations to become affected by epidemics spreading within the area. That means any infection introduced in the centre of Silkeborg forest will result in a serious epidemic because all groups have equally high probability to suffer from the introduction.

For example, the peninsula of Djursland also includes more than 400km² wild boar habitats, but the patches are only loosely connected in the middle, which hardens the direct spread and thus lowers the probability of southern locations to become involved in an epidemic starting in the north. Such landscape characteristics influence the expected risk for

domestic pigs due to serious epidemics in wild boar – and the difference was highlighted by our geographical analysis.

To this point we restricted our investigation to the general analysis on the geographical scale of Denmark. A further and extended analysis will be useful and feasible if specific regions are selected for more detailed evaluation.

However, in conclusion we found the Silkeborg forests representing the largest coherent and best-quality wild boar area in Denmark. This area turns up as the area with highest risk no matter whether we measured the risk as spatial extent, duration of an epidemic, intensity of an outbreak, and probability of being involved in an outbreak. Thus, this region might appear as the best area from a nature conservation point of view, but the worse release area from a disease management point of view. The emerging questions orient the evaluation towards the trade-off decision and the identification of an optimised area under both restrictions:

1) population dynamics and 2) disease management.

Conclusion of disease spreading within a wild boar population
The forest around Silkeborg is a key habitat because it is the largest coherent wild boar habitat in Denmark. Furthermore, it is the area that is associated with the most severe potential for the spreading of disease. According to the simulations, the epidemics will last longer, the infected area will be larger, and there will be a higher intensity of disease spreading compared with other areas in Denmark. The remaining Denmark provides less optimal conditions both for wild boar and disease spreading, because all other wild boar habitats are fragmented and less coherent compared with Silkeborg.

7.2 Simulation of the spread of CSF between domestic pigs and wild boar

Introduction

If the CSF virus enters either a domestic pig herd or a population of wild boar, there is a high probability that the virus will spread either to other pig herds or through the wild boar population. In this case, an epidemic occurs. By far the most important economic consequence of a CSF outbreak is the resulting loss in exports. Two parameters are essential for this loss: the duration of the ban on exports and the size of the area restricted from exporting to the EU market.

To assess the extra risk related to the presence of wild boar in Denmark, we simulated the spread of CSF virus under different scenarios: 1) wild boar present or not, 2) different locations for the index case. Furthermore, we simulated the effect of different control strategies for wild boar. For each scenario, the simulated size and duration of the CSF epidemic were recorded and compared with the other scenarios (Table 7.2-7.3).

The simulations were carried out using the generic simulation programme InterSpreadPlus. This computer programme is designed to model the spread of farm-based disease in space and time. The programme was initially developed as a decision support system for the control of Foot-and-Mouth epidemics, and has later been adapted to CSF (Jalvingh et al., 1999).

For each scenario, we performed 100 repetitions, and therefore the results are probability distributions and are presented as summations (mean, median, min, max) in most cases.

To study the effect of the presence of wild boar, we assumed in some scenarios that free-range wild boar were present in two areas: the Rold forest and a forest near Silkeborg, both in Jutland.

For the scenarios starting in a domestic herd, we chose two different sow herds: one situated close to Rold forest (distance 0.5km) that sold piglets once a week, and another situated 5km from Rold forest that sold piglets once every second week.

Control strategy for domestic pigs and wild boar

In the case of an outbreak of CSF, the current Danish control strategy was used for domestic pigs. This control strategy is laid out in Council Directive 2001/89/EF of October 23, 2001, as follows:
- Culling of all detected herds.
- Culling of all herds within 0.5km of a detected herd to avoid local spread.
- Culling of all herds that have purchased pigs from the detected herd in the period between infection and detection.
- Movement standstill in the whole country for 72 hours after the first detection of CSF.
- Movement restrictions within the 10-km surveillance zone (40 days).
- Active surveillance within the 3-km protection zone (40 days).

For wild boar, one of the following mutually exclusive control strategies was applied:

- Separating and shooting of all wild boar
- Vaccination of wild boar
- No control of wild boar

List of simulated scenarios

A total of 16 scenarios were run, of which 9 served to estimate the effect of the different control strategies or to test model sensitivity towards changes in certain parameters. A full list of the scenarios can be found in Appendix 14.5. Both the Rold and the WildStart scenarios are also run with no control strategy for wild boar - although such a "non-strategy" is unthinkable in practice because of the consequences for exports.

The main scenarios are the following:

Scenarios 1-5: The index case is a domestic pig herd
1. Rold: The index case is situated close (0.5km) to a wild boar area in the Rold forest and the control strategy for wild boar is separation and shooting.
2. RoldNoWild: Like the Rold scenario, but with no free-range wild boar in Denmark.
3. Rold5km: The index case is situated 5km from the Rold forest.
4. Rold5kmNoWild: As the Rold5km scenario but with no free-range wild boar in Denmark.
5. RoldVacc: Like the Rold scenario, but with vaccination of wild boar instead of separation and shooting.

Scenario 6-7: The index case is a group of wild boar
6. WildStart: The index case is situated in the forests near Silkeborg and the control strategy for wild boar is separation and shooting.
7. WildStartVacc: As the WildStart scenario but with vaccination of wild boar instead of separation and shooting.

We defined "an outbreak" as the presence of CSF in a domestic herd, whereas we used the term "epidemic" to describe one or more correlated outbreaks. By correlated, we mean that

there is a connection between the outbreaks, e.g. by movements of animals, contact with infected wild boar or local spread of virus. In some of the simulated cases, the number of days between two successive outbreaks in domestic herds exceeded 200 days – and in a few cases there were several hundred days between two such outbreaks. When the number of days between two successively infected domestic herds exceeded 200 days, we defined such outbreaks as belonging to two different epidemics. This definition was made because we assumed that exports would have been back to normal between the two outbreaks.

Results of simulations: number of epidemics

In Table 7.2, the probability distribution of the number of epidemics in each of the main scenarios can be seen. It should be noted that when the index case is a domestic herd, only one epidemic is generally seen.

Table 7.2. The distribution of the simulated number of CSF-epidemics

	Scenario		Number of repetitions out of 100 that resulted in		
No.	Name	Index case	0 epidemic	1 epidemic	2 epidemics
1	Rold	Domestic herd		99	1
2	RoldNoWild	Domestic herd		100	
3	Rold5km	Domestic herd		100	
4	Rold5kmNoWild	Domestic herd		100	
5	RoldVacc	Domestic herd		99	1
6	WildStart	Wild boar	35	58	7
7	WildStartVacc	Wild boar	22	70	8

Rows marked in grey are scenarios without wild boar

In scenarios where the index case is a group of wild boar, the variation in the number of epidemics is greater. In several repetitions (35 and 22 out of 100 for WildStart and WildStartVacc, respectively), the CSF virus did not reach domestic herds at all, and therefore no epidemic was started. However, in few repetitions (out of the 100 run for each scenario), the CSF virus in the wild boar population periodically caused outbreaks in domestic herds and gave rise to separate epidemics.

From a biological viewpoint, the virus circulating in the wild boar population can explain this. Continued circulation is seen if the virus has a low virulence (Fig. 7.5) and if susceptible animals are present in the wild boar population continuously. The probability of the latter depends on the size and the density of the wild boar population, whereas the virulence depends entirely on the virus strain that might enter the wild boar population.

Results of simulations: number of herds infected and duration of epidemics

Table 7.3 presents the number of herds infected as well as the number of days of the epidemic(s) for each scenario. For WildStart and WildStartVacc, only repetitions with spread to domestic pigs are included as only in these cases does an epidemic actually occur. The important question is whether the presence of free-range wild boar will affect the size and duration of the epidemic. The present simulations suggest that when wild boar are present, there is a greater risk that the CSF virus will reappear at a later time giving cause to more than one outbreak (the Rold scenario). In RoldNoWild, the mean number of domestic herds

infected is 2 and the mean number of days in the epidemic is 2, whereas those figures rose to 6 and 15, respectively when wild boar are present (the Rold scenario) (Table 7.3). This, again, reflects the periodical transfer of virus from groups of infected wild boar to domestic pigs during the period considered.

Table 7.3. Duration and size of simulated CSF-epidemics: summation of 100* repetitions per scenario

Scenario			Number of herds infected		Number of days in epidemic	
No. Name		Index case	Mean	Median (min - max)	Mean	Median (min, max)
1	Rold	Domestic herd	6	5 (2 - 17)	15	14 (1 - 127)
2	RoldNoWild	Domestic herd	2	2 (2 - 6)	2	1 (1 – 19)
3	Rold5km	Domestic herd	5	5 (3 - 10)	13	14 (1 - 31)
4	Rold5kmNoWild	Domestic herd	5	5 (3 - 10)	13	14 (1 - 31)
5	RoldVacc	Domestic herd	6	6 (2 - 17)	17	15 (1 - 202)
6	WildStart	Wild boar	2	2 (1 -5)	13	1 (1 - 95)
7	WildStartVacc	Wild boar	3	2 (1 -10)	41	3 (1 - 270)

Rows marked in grey are scenarios without wild boar
* For WildStart and WildStartVacc only repetitions with outbreaks in pig herds are used (65 and 78 repetitions respectively)

If the index case is situated 5km from Rold forest (scenario Rold5km), the virus will not spread to the wild boar, and the course of the epidemic is the same as it would be without free-range wild boar (Rold5kmNoWild). This suggests that in case of an outbreak of CSF in a domestic pig herd, the importance of the presence of wild boar depends on whether the infected herd is situated in close proximity to a wild boar habitat or not.

The difference between the RoldNoWild scenario and Rold5kmNoWild scenario reflects differences in the movement of pigs: the greater the number of pigs sold/purchased in the period between the infection of the herd and the diagnosis, the larger the epidemic.

The results of the simulations indicate that the number of herds that will be infected is dependent on the index case being a domestic herd or a group of wild boar. The scenarios in which the index case is a group of wild boar generally result in fewer infected domestic herds (Table 7.2: WildStart compared with Rold and WildStartVacc compared with RoldVacc). However, when more than one domestic herd is infected, the period between successive outbreaks in domestic herds seems longer because the CSF virus is circulating in the wild boar population. This increases the mean number of days in the epidemic and, more notably, the maximum values observed in the repetitions (Table 7.3).

Results of simulations: effect of the different control strategies for wild boar
According to the results of the simulation, the control strategy for wild boar influences the course of the epidemic. When the index case is a domestic herd, the separation and shooting

strategy seems slightly more efficient than vaccination of wild boar, whereas if the epidemic starts among wild boar, the separation and shooting strategy seems to be much more efficient than vaccination. The economic considerations related to these different types of risk management are dealt with in Section 10.

Comparison of results with other simulations

The number of infected premises found in the present simulation is similar to the results of earlier simulations (Alban et al., 2004). However, the duration of the epidemic is shorter. This is probably a result of improved modelling, because the actual movement pattern of an individual herd can now be included in the simulation programme InterSpreadPlus. The previous version of the programme, which was used by Alban et al. (2004), used the average movement intensity for all herds. Because pigs from only around 4,000 of the 16,000 pig herds are sold to other farmers, the majority of the herds are so-called dead-ends for an infection like CSF.

Figure 7.6. Outdoor pig production located close to a wild boar habitat will be exposed to an increased risk of catching CSF if free-range wild boar get infected with CSFV.

The results of the modelling in this section were also compared with the results of the modelling in section 7.1, in which the duration of epidemics within an infected wild boar population is simulated. It is noted that the mean duration within an infected population of wild boar was 141 days (min: 7 days, max: 861 days). This corresponds well with the results presented in Table 7.2, which shows that if the infection starts in the wild boar population, more than one epidemic (defined as two successive outbreaks occurring with more than 200 days in between) will be seen occasionally.

Sensitivity tests and supplementary simulations

The results of the sensitivity tests (5 out of the 9 scenarios in Appendix 14.5) indicate that the results are robust towards small changes in the parameters that define the probability of contacts between wild boar and domestic pigs and between wild boar groups respectively. More specifically, the parameters that were subjected to sensitivity analyses were the lambda

(1/average time until event) in the Poisson distribution for the probability of contacts between wild boar and domestic pigs, and the lambda in the Poisson distribution for the probability of contacts between groups of wild boar.

In the sensitivity tests, it was also illustrated that a higher risk of transferring CSF (here, a doubling of the risk) would not alter the average duration of the epidemic or the number of infected herds.

Finally, the supplementary simulations indicate that fencing free-range domestic pigs will change neither the number of herds infected nor the duration of the epidemic. If *all* domestic herds in a distance of 16km were fenced, the duration of the epidemic would be slightly shorter (on average 14 days instead of 15), but the number of infected herds would remain as in the basic Rold scenario.

Conclusion regarding CSF-spreading between domestic pigs and wild boar
The spread of CSFV between domestic pigs and wild boar was simulated using the software programme InterSpreadPlus. The results show that the spread of infection from domestic pigs to wild boar will only occur if the herd is located in close proximity to an area with wild boar (e.g. 0.5 km). When the index case is a domestic herd, one epidemic can be expected (not more than 200 days between two successive outbreaks). When the index case is a wild boar, then either no domestic herd will be infected (no epidemic) or periodical outbreaks among domestic herds can be expected (≥1 epidemic). The number of infected domestic herds tended to be lower when the index case was a wild boar compared with a domestic herd.

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8. Consequence assessment

According to the World Organisation for Animal Health (OIE), outbreaks of CSF are associated with serious socio-economic consequences, and therefore, CSF ranks among the most important animal diseases (OIE's list A). The question is how severe the socio-economic consequences would be for Denmark, and whether the presence of wild boar would increase these consequences.

To address this issue, we estimated the economic consequences in case of an outbreak of CSF. We based our calculations on the assumption that the control strategies for domestic pigs and wild boar would be those of today. Four major cost elements were identified: control costs related to domestic pig herds and control costs related to wild boar – both covered by the national budget in some way – the control-related costs of the pig industry, and the loss in export of live pigs and pig products following an outbreak of CSF in Denmark. The costs of a general surveillance programme for wild boar in Denmark were not included.

Assumptions used in the calculations
The cost elements generally included in the control costs for domestic pig herds were:
- The lost value of depopulated pigs
- The costs of killing, destruction and cleaning
- 20% of the costs of empty stables (production loss)
- The costs of establishing and controlling surveillance and protection zones
- The costs of blood tests

The basic control strategy for wild boar was assumed to be separation and shooting. We did not assume that any costs were associated with the geographical separation of wild boar. Furthermore, no costs associated with shooting were assumed, as hunters would probably volunteer to carry out this task.

In case of an outbreak of CSF, there would be an immediate national standstill of pigs for 72 hours. This means that the slaughterhouses would be closed for three days. According to Alban et al. (2004), the costs of such a standstill would be between DKK 30 and 50m. Other control costs to the pig industry would be 80% of the production loss following depopulation (empty stables) as well as the lost value of pigs culled for welfare reasons and the associated destruction and cleaning costs.

By far the most significant cost relates to the loss in export – and this is also associated with the highest uncertainty as there is no definite answer to the question of how export markets would react in the case of an outbreak of CSF in Denmark.

All third countries (non-EU members) would discontinue their import of Danish pigs and pork. The duration of this ban on exports is uncertain and may differ between the export countries. In our analysis, we assumed that if wild boar were not present in Denmark, 100 days would pass after the most recent outbreak of CSF before export to third countries could be resumed (100 days must be considered the minimum reaction, Anne-Mette Olsen, personal communication). Furthermore, meat exported to third countries from 40 days before the first outbreak would be traced and withdrawn from the market. For each third country, bilateral negotiations would be needed – and these take time and usually include inspections by the veterinary authorities of the specific third country. If wild boar were present in Denmark, also the freedom from CSF in the wild boar population would need to be documented and accepted by the third markets before they would reopen. It was estimated that this would prolong the halt in export with two months to 160 days (again this should be considered the minimum reaction).

In case of an outbreak of CSF, zones around infected herds would be established, and within these the movement of meat and live pigs would be restricted. This means that export from such zones would come to a standstill, whereas the rest of the country would still be able to produce for the EU market. It was expected that the EU would accept such a regionalisation, and that it would last until approximately 40 days after the most recent outbreak. Exports to EU markets would then be resumed at their full level.

The closing of third markets would imply that all meat would be sold on the EU market instead. This would reduce the value of the export because 1) a considerably larger volume of meat would be sold on the EU market, and 2) the prices of certain cuts are higher in some third countries than on the EU market (e.g. ribs on the US market, or streaky bacon on the Japanese market). Seen as a whole (all export markets), the ex producer value would be reduced by an estimated 20% (Karsten Flemin, personal communication). Furthermore, it was assumed that the restricted zones would get market support from the EU, which would cover 50% of the loss in these zones (Alban et al., 2004).

The higher economic consequences of a CSF outbreak in scenarios with wild boar compared with no wild boar occur mainly because of a prolonged process of bilateral negotiations, but also because of longer duration of the epidemic. The estimates of the economic consequences of the basic scenarios with and without wild boar are summarised in Table 8.1.

Table 8.1. Economic consequences (x mio DKK) of a CSF outbreak - with and without wild boar

Description of costs	Rold	RoldNoWild	Scenarios Rold5km	Rold5kmNoWild	Wildstart
Control costs					
- Domestic pigs	6	4	5	5	3
- Wild boar	0	0	0	0	0
Control-related costs to pig industry	104	66	99	99	91
Loss in export	1912	1250	1875	1349	2033
Total	2021	1319	1979	1453	2127
Total in bDKK	2.0	1.3	2.0	1.5	2.1

Columns marked in grey are scenarios without wild boar

Following an outbreak of CSF in Spain in 2002, Japan suspended the import of Spanish pork for a period of eighteen months. Another example is the Japanese reaction towards CSF in Germany. The most recent case of CSF in a domestic herd in Germany was in February 2003, and the Japanese market has not yet been reopened – i.e. a period of nearly 2 years (and possibly longer). This is due to cases of CSF in the wild boar population in Germany. Similarly, when Belgium had CSF in the wild boar population in 2002, the Japanese market was closed for a period of 1 year (Anne-Mette Olsen, personal communication).

The estimated reaction of the export markets in the presence of wild boar in Denmark is associated with great uncertainty. Because of the enormous importance of the export to third countries, the Danish pig industry and authorities would work very hard to regain the confidence of third countries after an outbreak of CSF in Denmark, and it is expected that third countries would be closed for a shorter period (e.g. 160 days in the case of wild boar present). Even so, the estimated halt in export to third countries – especially Japan – might be optimistic, and therefore we performed an "uncertainty analysis" where we estimated the halt in export to Japan to 1 year after the most recent outbreak (irrespective of wild boar present or not). The results of this analysis are given in Table 8.2.

Table 8.2. Economic consequences (x mio DKK) of a CSF outbreak - with and without wild boar – uncertainty analysis with respect to Japan's reaction

Description of costs	Rold	RoldNoWild	Scenarios Rold5km	Rold5kmNoWild	Wildstart
Control costs					
- Domestic pigs	6	4	5	5	3
- Wild boar	0	0	0	0	0
Control-related costs to pig industry	104	66	99	99	91
Loss in export	2819	2411	2773	2510	2976
Total	2929	2481	2878	2615	3070
Total in bDKK	2.9	2.5	2.9	2.6	3.1

Columns marked in grey are scenarios without wild boar

The calculations were based on mean values from the 100 repetitions in each simulated scenario for the spread of CSF virus (however, for the WildStart scenario only repetitions with spread to domestic pigs were used for the economic consequences presented in the Tables). In

the economic calculations, it was not taken into account that it might be difficult to fully regain market shares after an outbreak of CSF in Denmark.

Results of economic calculations

The presence of wild boar will in itself lead to a prolonged period of documentation of freedom from CSF and therefore a greater loss in exports. Furthermore, the presence of wild boar in the Rold scenario – as opposed to the RoldNoWild without wild boar – leads to a longer duration of the epidemic (15 days versus 2 days – see section 7.2) and therefore a greater loss in exports.

As can be seen from Table 8.1, the results indicate that the presence of wild boar would increase the costs of a CSF outbreak considerably. In the scenario where wild boar were not infected (Rold5km) the increased costs would arise solely because of the prolonged documentation process. The increase in costs was estimated to be DKK 0.5b or approximately 36%.

If furthermore wild boar were infected – as in the Rold scenario – the duration of the epidemic would also increase and therefore a greater loss in exports would occur. The increase in costs was DKK 0.7b corresponding to 53%.

For the WildStart scenario, one of two things would happen: either the CSF virus would spread from wild boar to domestic pigs, and the average economic consequences associated with this would be as illustrated in Table 8.1, *or* the CSF virus would *not* spread from wild boar to domestic pigs, and the export loss would be more "moderate".

In the latter case, we assumed that the third markets would close for a period of 3-6 months if it could be made probable that the virus in wild boar was under control. As mentioned above, the Japanese market was closed to Belgian pork for a period of 1 year after an outbreak in the wild boar population, and has been closed to German pork for a period of nearly 2 years after the most recent outbreak in a domestic herd. This is because of CSF in the wild boar population (Anne-Mette Olsen, personal communication).

When there were epidemics of foot-and-mouth disease in Europe (but not in Denmark) the third markets reacted with a ban on the import of Danish pork for periods between 16 and 100 days. The uncertainty associated with the "safeness" of Danish pork during the foot-and-mouth disease epidemic can be compared with the situation when there have been cases of CSF in wild boar, but not in domestic pigs. Hence, the assumption that third markets will close for 3-6 months seems reasonable (Anne-Mette Olsen, personal communication).

The EU market would not close if only wild boar were infected. In cases where the virus would remain in the wild boar population, the lost payment to producers would thus be around DKK 1.4 b (assuming the same 160-day ban on exports to third countries as when CSF spreads to domestic pigs).

To address the uncertainty associated with the reaction of especially the Japanese market we calculated the economic consequences of a halt in export to Japan of one year after the last outbreak (instead of 160 days). The results of this uncertainty analysis are depicted in Table 8.2. Naturally, the overall picture is that the total costs increase in each scenario. At the same time the difference in costs between scenarios with or without wild boar decreases. This is because the bilateral negotiations with Japan would now be assumed to last one year irrespective of whether wild boar are present in Denmark or not. The difference in costs would now be in the range of 10-17%.

Conclusion of consequence assessment
The economic consequences of a CSF outbreak in different scenarios with and without wild boar were calculated. The calculations showed that if free-range wild boar were present in Denmark, the economic consequences to the pig sector would be more severe than if wild boar were not present. If wild boar were also infected both control costs and costs to the pig industry would increase. The total costs of a CSF outbreak would increase by approx. DKK 500-700 m – corresponding to 36-53% – in the presence of wild boar (all other things being equal). The calculations depend highly on the assumptions on the reactions of export markets. If less optimistic assumptions are used, the total costs will increase – however, the difference in costs between scenarios with and without wild boar will decrease.

9. Risk estimation

In this section, the results of the previous sections will be summarised to obtain a risk estimate. It was not possible to come up with exact probabilities because of limitations in the available data. Moreover, there is a non-negligible level of uncertainty related to several parts of the assessment. Therefore, we can only present a qualitative risk estimate.

There is a low base-line probability that CSFV might enter the country because of the current trade patterns and actions in place to reduce the risk. This has ensured that CSF has not been present since 1933.

The probability of CSFV entering Denmark will increase slightly if free-range wild boar are reintroduced. A free-range population of wild boar inside Denmark can get infected through contact with infected wild boar that migrate from Germany. As long as there is no CSF north of the Kieler Channel, we consider this way of CSF-entry associated with a negligible probability. Furthermore, the wild boar habitat is small in Southern Jutland, and this limits the possible migration to the very southeast part of Southern Jutland.

Another way of entry is through tourists that accidentally feed CSF-contaminated meat remnants to wild boar. It was not possible to estimate the probability of this happening, but the relative risk between counties was highest in Ribe, Ringkøbing, and Northern Jutland.

If free-range wild boar are present, then conflicting interests can be expected between farmers and wild boar in areas where both reside. Crop damages will constitute the main problem. Only in case CSFV has been introduced into the wild boar population, the fear of introducing CSF to domestic pigs will be real.

If CSFV is introduced to wild boar, then either the infection will die out relatively soon or an epidemic lasting from half a year to one year will be seen – this depends on the wild boar habitat in which the virus is released. The larger the wild boar population is, the longer the epidemic will last. Spreading of infection between wild boar and domestic pigs will only occur if the pig herd is located close to the wild boar habitat. When the index case is a domestic herd, one epidemic is expectable, whereas if wild boar are the index case, then either no epidemic among domestic pigs – or more than one epidemic can be expected.

The economic calculations showed that – on average - the expenses related to a CSF outbreak would only be 36-53% higher if free-range wild boar are present compared with the current situation. However, the probability of an outbreak increases if free-range wild boar are present. Furthermore, the presence of wild boar might result in long-lasting epidemics or more than one epidemic because of periodic transfer of virus between groups of infected wild boar.

Outdoor productions cannot be compared with free-range wild boar because the probability is low of fenced animals transmitting CSFV to animals outside the fence (double fence is prescribed for outdoor productions). The reason is that CSFV is not airborne, and direct or indirect contact between two pigs is needed for transmission to occur.

Conclusion of risk estimation
Risk is a product of probability and consequences. As can be noted, the probability of CSFV entering the country will increase slightly from the present low level. The monetary consequences will vary from 36-53% extra costs (average) to a much higher level in case of long epidemics.

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10. Risk Management

10.1 The legal basis

The Danish Veterinary and Food Administration, Division of Animal Diseases (competent authority) is responsible for controlling classical swine fever, CSF, and for applying the necessary measures in case of an outbreak to eradicate the disease. Reintroduction of wild boar to the Danish fauna would add a new aspect and complicate this control.

The legal basis used is Council Directive 2001/89/EC of 23 October 2001 on Community Measures for the Control of Classical Swine Fever. The directive describes the minimum Community measures and also takes into account the presence of feral pigs (def. in directive: pigs which are not kept or bred on a holding). It should be noted that all wild boar in Denmark at present are fenced and have a CHR number. In the case of CSF being registered in a wild boar herd, the outbreak will be handled as an outbreak in a domestic pig herd.

In case the presence of CSF is suspected in free-range wild boar, the competent authority must implement the appropriate measures. Most important is the investigation, sampling and laboratory testings to confirm or rule out the presence of CSFV.

If a primary outbreak of CSF in free-range wild boar is confirmed, the directive will give the competent authorities a list of actions to initiate in order to reduce the spread of disease and to eradicate the disease from the population. An expert group that includes veterinarians, hunters, wildlife biologists and epidemiologists must be formed to be able to assist the authorities in:

- Getting an overview of the epidemiological situation
- Defining the infected area
- Establishing the appropriate measures
- Drawing up the eradication plan and
- Carrying out audits (verify effectiveness of measures).

The pig holdings in the defined infected area must be placed under official surveillance. This must include:
- Official census
- Isolation from free-range wild boar
- Restrictions on movement

- Appropriate means of disinfectants
- Hygiene measures after contact with free-range wild boar
- Testing of all dead or diseased pigs with CSF symptoms and
- No intra-Community trade of pigs, their semen, embryos or ova.

All free-range wild boar shot or found dead in the defined infected area must be inspected and examined for CSF, and the CSF virus isolate must be sequenced and genotyped.

In all outbreaks of CSF, it will be essential to keep free-range wild boar and pig holdings separated. The measures applied on the holdings would be very similar in case of an outbreak in free-range wild boar or on a pig holding.

A written plan describing the measures for eradication of CSF from the feral pig population must be presented to the Commission within 90 days from the confirmation. This plan may be amended or supplemented by the Commission and will replace the initial measures. The plan must contain:
- Results of epidemiological investigations and the defined infected area
- Organisations in close cooperation
- Information for hunters and requirements to be complied with by hunters
- Specific efforts to determine number and location of feral pig meta-populations and to determine extent of infection in the populations
- Measures to reduce spread (movement, contact between meta-populations) and to reduce susceptible free-range wild boar (particular young piglets)
- Epidemiological inquiries and methods to remove free-range wild boars found dead or shot
- Surveillance programmes and prevention measures for holdings in the infected area
- Other criteria
- System established for the expert group to review the results of the eradication plan

If a Member State intends to introduce vaccination, it shall submit an emergency vaccination plan to the Commission – this is also the case if vaccination of free-range wild boar with baits is introduced.

The directive describes the minimum community measures and sets up guidelines and means for the surveillance, control and eradication of CSF. The Danish Veterinary and Food Administration, Division of Animal Diseases will use the directive, risk assessment, advice from the expert group and experiences from other countries to decide on appropriate measures in the given situation where free-range wild boar are involved. Zoning would be applied immediately. The use of vaccination among the free-range wild boar, geographical separation/fencing of the feral pig population, targeted hunting, shooting of all free-range wild boar in the infected area or a combination of the mentioned measures, would be considered to eradicate the disease.

10.2. Scientific and trade considerations

Culling is the tool most-frequently used to control wildlife, which has been infected with a serious, contagious disease (Artois et al., 2002). However, hunting pressure might be ineffective in attempts to control CSF. Side effects of hunting are (i) increased home-range size and (ii) frequent long-distance movement dispersal. This is a result of disturbance notably linked with the use of dogs when hunting.

According to Artois et al. (2002), the management of CSF among wild boar should initially consist of surveillance and monitoring of the infection, followed by control and eradication of the disease. In the following these two aspects are described based upon the results of Artois et al. (2002). Finally, risk management specifically for Denmark is discussed.

Surveillance and monitoring: Initially, the infected area needs to be identified and delineated, and the size of the affected wild boar population should be assessed. Next, a sample size should be calculated by use of ordinary sample size formulas (e.g. Martin el al., 1987). The aim is to have a sample size large enough to identify infection – if present at a prevalence of minimum 2.5%. For example, if the population has been assessed to consist of around 1,000 individuals, 112 wild boar should be examined and found negative to ensure that if infection is present, it will be present at a prevalence below 2.5%. Sampling should be designed to ensure that the individuals included in the sample are representative of the population of interest. When infection is low, sensitive tests are necessary – specificity can be checked afterwards. Special caution must be taken regarding the samples during transport and storage to ensure the value of the samples.

Control and eradication: A temporary hunting ban should be imposed immediately to reduce the spread of the infection within the wild boar population. Next, a hunting plan should be made that e.g. preserves the adults that are considered naturally immunised. The use of hunting dogs should be banned. According to Artois et al. (2002), vaccination can be considered if the previous attempts did not result in a decreased infection rate. There is limited knowledge about the effect of emergency vaccination for CSF. Such programmes might be used to target identified sub-populations that are maintaining infection. In this case, the aim is to reduce the number of susceptible individuals below the threshold of transmission.

Apart from emergency vaccination, vaccination has been used extensively in areas with wild boar populations that have been infected for a longer time. Germany has implemented vaccination of wild boar in areas with affected populations with a high degree of success. After 1-2 years, no CSF virus circulation seems to take place. Vaccination programmes have been applied in Lower Saxony, Saarland and Nord-Rhein-Westphalia resulting in lifting of all restrictions imposed by the EU, and a vaccination programme in Rhineland-Palatinate at a later stage than the above-mentioned also shows promising results. Luxembourg has vaccinated since 2003 and so far not detected circulating CSF-virus in the wild boar population. Based on these experiences, Slovakia is working out a programme for vaccination of wild boar in order to prevent CSF from spreading and eventually to eradicate CSF.

The situation in Denmark: The situation in Denmark varies from the rest of Europe on certain aspects; therefore, the optimal risk management strategy might be different for Denmark compared with other European countries. Danish forests are small and easily accessible (No mountain areas). Additionally, Denmark has a huge export of pork to third countries like the US, Japan and Russia, mainly due to the absence of CSF. Because the loss associated with export (assessed in Section 8) is significant and proportional to the duration of the epidemic, the agricultural industry would put pressure on the veterinary authorities to obtain an effective and swift eradication of CSF among wild boar. This implies that the industry would be reluctant to wait until the infection dies out naturally in the wild boar population, which according to our simulations would occur after 7-861 days (median: 112 days) (section 7.3). Moreover, in Italy the infection did not die out by itself during the 1997-2000 epidemic, but

spread to the neighbouring Swiss territory (Zanardi et al., 2003). In the subsequent section, the economic aspects related to different control strategies for wild boar have been evaluated.

10.3. Economic consequences of different control strategies

The economic consequences of different control strategies in case of an outbreak of CSF were estimated. Together with the direct costs of a control strategy, the costs to the pig industry were also estimated – to give a full picture of the socio-economic consequences.

The basic control strategy for domestic herds was as described in section 7.2. For wild boar, the basic control strategy was geographical separation and shooting.

The Rold and the WildStart scenarios included the basic strategies for both domestic herds and wild boar. The RoldVacc and the WildStartVacc scenarios included vaccination of wild boar instead of separation and shooting. NoWildControl and WildStartNWC both applied the strategy of not doing anything to control the spread of CSF in wild boar. Finally, the Fence scenario included fencing of all domestic herds within a distance of 16km to the wild boar habitats in Rold Forest and the forest area near Silkeborg, whereas the FenceFree scenario included extra fencing of only the domestic free-range herds in these areas. The distance of 16km was chosen as this was assumedto be the longest distance wild boar would migrate. All scenarios included the basic control strategy for domestic pig herds.

The duration and size of the simulated epidemic associated with the different control scenarios are given in Table 10.1.

On the basis of these simulations, the economic consequences of the different control scenarios were calculated. The underlying assumptions of the costs of the basic strategies are described in Section 8.

Assumed reactions on export markets: Export markets would react differently to the different control strategies mentioned above. The "basic" initial reaction from third country export markets was assumed to be a complete standstill for a period lasting an average of 160 days. However, the actual reaction will always depend on the specific situation, e.g. how swiftly the disease will be controlled and eradicated. Furthermore, it will also depend on how fast confidence in the Danish veterinary health status is regained.

Table 10.1 Duration and size of simulated CSF epidemics: summation of 100* repetitions per scenario

Scenario		No. of herds infected		No of days in epidemic	
Name	Index case	Mean	Median (min - max)	Mean	Median (min, max)
Rold	Domestic herd	6	5 (2 - 17)	15	14 (1 - 127)
RoldVacc	Domestic herd	6	6 (2 - 17)	17	15 (1 - 202)
Fence	Domestic herd	6	5 (2 - 17)	14	13 (1 - 124)
FenceFree	Domestic herd	6	5 (2 - 17)	15	14 (1 - 127)
WildStart	Wild boar	2	2 (1 - 5)	13	1 (1 - 95)
WildStartVacc	Wild boar	3	2 (1 - 10)	41	3 (1 - 270)

*For WildStart, WildStartVacc and WildStartNWC only repetitions with epidemics are used (65, 78 and 90 repetitions respectively)

With respect to the EU market, it was assumed that only export from restricted zones would come to a standstill for a period of 40 days after the most recent outbreak. This assumption was based on the restrictions formulated in Directive 89/2001. In case a vaccination strategy would be applied for the wild boar, it was assumed that most third markets and the EU would react in the same way as for the separation-and-shooting strategy (which is the basic strategy accepted by the EU). However, a few large markets would probably behave differently. Hence, in the case of a vaccination strategy it was assumed that the US would perform risk analyses before the US market would be reopened to Danish pigs and pork. The US acknowledgement of regionalisation of areas in the EU considering CSF was initiated in 1997 and finalized with an amended US law in 2003. The US approved regionalisation of the United Kingdom in 2001, a few months after the first outbreak. It was estimated that the process of the US performing a risk analysis and approving the vaccination strategy would take around 1-2 years (in the calculations, 1½ years was used). The US might approve regionalisation of Denmark, e.g. accept the import of pork from Funen and Zealand, depending on appropriate control and documentation (Anne-Mette Olsen, personal communication). This possibility was not included in the calculations.

It was also assumed that the Japanese market would be closed for a longer period of time if wild boar were vaccinated. We assumed that this market would reopen 1-2 years after the most recent outbreak (in the calculations, 1½ years was used). Japanese authorities have approved regionalisation for CSF in the EU, as import of fresh pig meat is approved from certain areas of Belgium and France. Nevertheless, no areas in Germany have yet been approved for export to Japan despite German requests for exports for at least a couple of years. (Anne-Mette Olsen, personal communication.)

In the unlikely event that not even the basic control strategy required by the EU would be applied to control the CSF virus in wild boar, all exports would probably be discontinued, since the other EU countries would not be obliged to accept trade with Denmark. Such a strategy would lead to the end of Danish pig production.

Table 10.2 Economic consequences of different control strategies associated with outbreaks of CSF - *where index case is a domestic pig herd* (x m DKK)

Description of costs	Scenarios			
	Rold	RoldVacc	Fence	FenceFree
Control costs				
- Domestic pigs	6	6	6	6
- Wild boar	0	0.3	0	0
Subtotal, total control costs	6	6	6	6
Control-related costs to pig sector	104	89	196	110
Loss in exports	1912	4340	1885	1912
Subtotal, total costs to pig sector	2016	4429	2082	2022
Total in bDKK	2.0	4.4	2.1	2.0

Column marked in grey is the scenario that the alternative scenarios were compared with.

Calculation of costs related to the control strategies: The cost of the basic control strategy for wild boar was assumed to be negligible as mentioned in Section 8. In case of vaccination, the cost was calculated as a unit cost of baits per boar (Åse Uttenthal, personal communication).

No costs other than the direct costs of baits were assumed in connection with vaccination as it was expected that forest workers and hunters would volunteer to distribute the baits (Åse Uttenthal, personal communication).

For the alternative scenarios Fence and FenceFree, the costs of fencing were added to the control-related costs to the pig industry. The fencing costs were based on an estimate of the average circumference of ordinary and free-range domestic herds respectively, and the costs included the costs of one grating in each herd.

The economic consequences of the different control strategies in case of an outbreak in a domestic herd and a group of wild boar respectively are given in Tables 10.2 and 10.3. In Table 10.2 the calculations were based on mean values from the 100 repetitions in each simulated scenario for the spread of CSF virus. However, for the WildStart scenarios in Table 10.3 the economic consequences are calculated as the average consequences *in case the virus spreads to domestic pigs*. The relative number of repetitions with spread to domestic pigs is also given in the Table. The alternative strategies are compared with the most likely scenario (Index case a domestic pig herd: Rold; index case a wild boar group: WildStart). In case the virus would not spread to domestic pigs, the loss in exports would be more moderate (see section 8).

The calculations show that the basic strategies for wild boar and domestic pigs appeared to result in the lowest total costs: the Rold scenario resulted in total costs of DKK 2.0 b (Table 10.2) whereas the WildStart scenario resulted in total costs of DKK 2.1 b (Table 10.3). Although the control costs associated with separating and shooting wild boar were marginally higher than the control costs of vaccination, the vaccination strategy is much more costly in relation to exports. This is mainly due to the assumed reactions of export markets but also because the duration of the epidemic is longer in case a vaccination strategy would be applied (Table 10.1 and 10.2). The vaccination strategy would more than double the total costs of an outbreak compared with the separating-and-shooting strategy (Table 10.2 and 10.3).

Table 10.3. Economic consequences of different control strategies associated with an outbreak of CSF - *where index case is a group of wild boar* (x m1000 DKK)

| | Scenarios | |
	WildStart	WildStartVacc
Percentage of repetitions with epidemic in domestic pigs	65%	78%
Control costs,		
- Domestic pigs	3	2
- Wild boar	0	0.3
Subtotal, total control costs	3	2
Control-related costs to pig industry	91	43
Loss in exports	2033	4739
Subtotal, total costs to pig industry	2124	4782
Total in bDKK	2.1	4.8

Column marked in grey is the scenario that the alternative strategies were compared with

Furthermore, the calculations indicate that fencing of domestic herds is costly and has little effect on the course of the epidemic (Table 10.1 and 10.2).

> **Conclusion of risk management**
> The minimum measures, in case of CSF in an EU member country, are described in Council Directive 2001/89/EC. The directive offers numerous possibilities for interpreting and choosing a control strategy. We analysed the effect of different control strategies – mainly varying with respect to the control strategy for wild boar. Our simulations showed that a vaccination strategy would not improve the course of an epidemic compared with the basic strategy for wild boar consisting of separation and shooting. Furthermore, a vaccination strategy would be extremely costly for the industry because of strong reactions from third country export markets. Fencing of free-range domestic herds would not alter the course of the epidemic, whereas fencing all domestic herds within a radius of 16km from wild boar habitats would slightly shorten the duration of the epidemic. The costs of these scenarios were not much different from those of the basic scenario.

11. Risk communication

In an increasingly sophisticated society there are great expectations from various stakeholders, whose interests may be affected by the findings, recommendations or decisions arising from a risk analysis. Therefore, it should be possible for the stakeholders to receive consultation before decisions are made (Murray, 2001). Therefore, it is essential to establish a communication strategy from the beginning of the project. Good risk communication is interactive and involves a two-way dialogue.

The communication strategy of this one-year project has been to publish results and findings in Danish popular journals as they arose. Moreover, a contact group consisting of representatives from different stakeholders was established. These are listed below:

Aksel Bo Madsen, National Environmental Research Institute
Bo Håkansson, The Danish Society for the Conservation of Nature
Hans Henrik Dietz, Danish Institute for Food and Veterinary Research
Lars Richter Nielsen, Danish Forest & Nature Agency
Niels Kanstrup, Danish Hunters' Association
Nina Blom, Danish Bacon & Meat Council
Poul Tolstrup Christensen, Danish Bacon & Meat Council
Sten Mortensen, Danish Veterinary & Food Administration

Three meetings were held between the project group and the contact group: at the beginning of the project, midway, and at the end. At each meeting, aims, findings and conclusion etc. were discussed.

The report was sent to external review to one international expert (risk assessment as a method) and one Danish expert (biology) on January 6, 2005. Hereafter, comments from stakeholders and the official reviewers were incorporated. The report was finalized on March 2, 2005.

On March 9, 2005, a public meeting was held at the Royal Veterinary & Agricultural School, Copenhagen where the results of the project was presented in a dialogue with the audience.

Furthermore, several papers in Danish were and will be published in Danish popular journals. Additionally, a research paper describing the entire risk analysis will be presented March 2005 at the Annual Meeting of the Society for Veterinary Epidemiology and Preventive Medicine in Scotland. Furthermore, two scientific papers for peer-reviewed journals are planned; one on the spread of disease within an infected wild boar population in Denmark, and another on the spread of disease between wild boar and domestic pigs in Denmark.

The references for the papers already published are listed in the appendix to the report (section 14.1).

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Niels Kanstrup, Danish Hunters' Association
Nina Blom, Danish Bacon & Meat Council
Karsten Flemin, Danish Bacon & Meat Council
Finn Udesen, Danish Bacon & Meat Council
Anne-Marie Mårtensson, Danish Bacon & Meat Council
Anne-Mette Olsen, Danish Bacon & Meat Council
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Uttenthal, Å., 2004. Classical swine fever virus and infection of wild boar. Literature review. Danish Institute for Food and Veterinary Research. Section 14.3 in this report. 15 pp.

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14. Appendix

14.1 List of published popular papers related to the project

Alban, L., 2004. Gi´r fritlevende vildsvin øget risiko for svinepest? DS-Nyt, No. 5, May 2004. p. 15.

Alban L., Boes, J., 2004. Vildsvin og svinepest – Hvad kan vi lære? DS-Nyt, No. 7, July 2004. 22-23.

Alban, L., Andersen, M.M., Asferg, T., Boklund, A., Fernández, N., Goldbach, S.G., Greiner, M., Højgaard, A., Kramer-Schadt, S., Stockmarr, A., Thulke, H.H., Uttenthal, Å., Ydesen, B., 2005. Assessment for reintroduction of wild boar (*Sus scrofa*) to Denmark. Proceeding of the Annual Meeting of Society for Veterinary Epidemiology and Preventive Medicine, Nairn, Scotland. March 30 to April 1, 2005. 12 pp.

Vildsvin *Sus scrofa* – biologi og økologi

Litteraturudredning med henblik på modellering af risikoen for spredning af svinepest under scenarier med fritlevende vildsvin i Danmark

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Indhold

Indledning

Reintroduktion af oprindeligt hjemmehørende arter er et af mange redskaber i den nationale forvaltning af biologisk mangfoldighed. Fx blev den europæiske bæver *Castor fiber* efter ca. 2.000 års fravær reintroduceret til Danmark ved udsætning af 18 individer på Klosterheden Statsskovdistrikt i 1998 (Elmeros *et al.* 2004).

Også vildsvinet *Sus scrofa* hører til de arter, der kunne komme på tale i forbindelse med reintroduktion, idet arten var en del af den vilde fauna i Danmark indtil begyndelsen af 1800-tallet. Synspunkter for og imod reintroduktion af vildsvin er i den seneste halve snes år oftest dukket op i forbindelse med de sporadiske tilløb til opbygning af små, lokale bestande, som er set i forbindelse med udslip af vildsvin fra dyrehaver eller svinehold. Senest har emnet været til diskussion i forbindelse med udryddelsen af en lokal bestand i 2000 i Lindet Skov i Sønderjylland og Danske Slagteriers udlovning af skydepræmier i 2002 til jægere, som i bestræbelser på at forhindre indvandring til Danmark ville nedlægge vildsvin i området mellem Kielerkanalen og den dansk-tyske grænse.

Den afgørende faktor for den officielle stillingtagen til spørgsmålet om reintroduktion af vildsvin til Danmark har været frygten for, at vildsvin skulle overføre sygdomme, bl.a. svinepest, til tamsvin og således udløse et eksportstop.

Eventuelle konsekvenser ved reintroduktion af vildsvin til Danmark er tidligere vurderet i en specialeafhandling fra Københavns Universitet (Andersen 1997). De fleste af afhandlingens generelle betragtninger vedrørende vildsvin og reintroduktioner gælder stadig, men afhandlingen kan ikke benyttes som grundlag for en risikovurdering i forhold til svinepest. Sygdoms- og smitteproblematikken er kun summarisk behandlet, og for at eliminere muligheden for direkte kontakt med tyske vildsvin vælger afhandlingen jyske og fynske lokaliteter fra og ender med at udpege to sjællandske skovområder som potentielle udsætningsområder for vildsvin i Danmark

Formålet med denne udredning er at give en kort beskrivelse af vildsvinets biologi og økologi med særlig vægt på parametre, som er centrale for opbygningen af en model, der kan bruges i en vurdering af risikoen for udbrud af svinepest under forskellige scenarier med og uden fritlevende vildsvin.

Rapporten indeholder ikke vurderinger, overvejelser eller konkrete forslag til, hvordan virkelige situationer svarende til de forskellige scenarier vil kunne opstå, dvs. der er ikke taget stilling til, hvordan, hvornår eller under hvilke betingelser en reintroduktion i givet fald skulle eller kunne foregå.

Udbredelse og forekomst

Vildsvinet indvandrede til Danmark i midten af Præboreal (ca. 9.000-8.000 f.Kr.), og det var et vigtigt jagtobjekt fra stenalderen og langt op i tiden. Det er vanskeligt at sige, hvornår de sidste rene bestande forsvandt, idet der skete en opblanding med fritgående tamsvin, men omkring 1500-1600-tallet var vildsvinet næsten udryddet i Danmark. Senere blev bestanden dog delvis fornyet gennem udsætning af tyske vildsvin. Fortsat hård jagt kombineret med en række meget kolde vintre i 1700-tallet bevirkede dog, at bestanden var helt udryddet i begyndelsen af 1800-tallet.

I dag findes der kun vildsvin i nogle få dyrehaver, hvorfra der undertiden bryder dyr ud. Vildsvin efterlader sig så tydelige spor i landskabet, at fritlevende individer – som eventuelt kunne grundlægge en bestand – ikke vil forblive uopdaget i en længere periode. I en kortlægning af udbredelsen af pattedyr i Danmark er der i perioden 1990-2003 registreret

vildsvin på 12 lokaliteter (felter á 10 x 10km^2) i Jylland og på Fyn, Sjælland og Bornholm (Dansk Pattedyratlas, upubl.). Udover vildsvin i dyrehaver findes der et ukendt antal vildsvin i mindre svinehold, ofte med henblik på at producere krydsninger mellem vildsvin og tamsvin. Der foreligger desværre ikke en oversigt over antal bestande eller antal vildsvin i dyrehaver og svinehold.

Social organisation

Vildsvinet er et socialt dyr. Uden for brunstperioden lever de gamle orner hver for sig, mens de øvrige dyr er delt op i såkaldt matrilineale grupper, dvs. familiegrupper som hver især ledes og domineres af en gammel so og nogle af dennes døtre fra tidligere kuld samt små-grisene fra det seneste kuld (Lemel 1999). Der vil således ofte være omkring fem voksne søer i en familiegruppe. Under brunsten, der kan indtræffe over en relativt lang periode fra august til december, slutter de gamle orner sig til familiegrupperne. Senest omkring fødselstidspunktet støder de gamle søer ungerne fra sidste år fra sig. Ungerne holder som regel sammen i mindre grupper, der i løbet af eftersommeren igen optages i familiegrupper med de gamle søer og deres nye kuld af smågrise. Også unge orner kan indgå i disse familiegrupper, men senest når de er mellem 18 og 24 måneder, drives de bort fra gruppen. De kan undertiden danne løsere grupperinger, men vil – undtagen i brunstperioden – i stigende grad leve solitært.

Home-range
Det gennemsnitlige home-range på individniveau er ved hjælp af mærkning med radio-halsbånd målt til 332 ha for voksne søer og 400 ha for voksne orner i en bestand i det sydøstlige Sverige (Lemel 1999).

Tabel 1. Home-range (mean og standard deviation; ha) for vildsvin i Sverige. AK = adaptiv kernel; MCP = minimum convex polygon (efter Lemel 1999)

	Mean ± SD 95% AK (ha)	Mean ± SD 95% MCP (ha)	Median 95% AK (ha)	Median 95% MCP (ha)	N
Søer	331,9 ± 196,1	724,6 ± 618,2	307,2	468,9	30
Orner	400,3 ± 346,4	822,1 ± 806,2	286,8	531,5	29
Alle	365,5 ± 279,9	772,5 ± 712,4	293,0	521,4	50

Der er dog en betydelig individuel variation (Tabel 1). Home-range for unge orner, dvs. op til 18 mdr., ligger på linie med home-range hos voksne søer.

På grund af det sociale organisationsmønster er det ved vurdering af pladsbehovet for en bestand af vildsvin mere relevant at se på home-range for grupper end for enkeltindivider. Det er karakteristisk, at visse dele af home-range udnyttes mere intensivt end andre. Det kan fx illustreres ved at sammenligne størrelsen af det totale home-range (beregnet som det areal der omfatter 95% af alle positioner i et datasæt baseret på radiotelemetri, dvs. alle positioner undtagen de 5% mest ekstremt beliggende) med størrelsen af det såkaldte kerneområde, der ofte defineres ved 75%-niveauet (Tabel 2). De store forskelle i gruppernes home-range skyldes især forskelle i områdets og landskabets karakter samt fordelingen af naturlig føde i området og sidst, men ikke mindst omfanget af eventuel fodring (Lemel 1999).

Tabel 2. Home-range (ha) for 6 grupper af vildsvin i Sverige

	Gruppe 1	Gruppe 2	Gruppe 3	Gruppe 4	Gruppe 5	Gruppe 6
95%	859,7	1.179,4	1.841,7	708,0	1.695,9	1.070,9
75%	199,4	378,2	519,9	276,7	407,7	579,2

Kilde: Lemel, 1999

Vildsvin er overvejende nataktive. Aktivitetsperioden påbegyndes omkring solnedgang og strækker sig over 6-8 timer. I tiden omkring midsommer er svinene også aktive i nogle af døgnets lyse timer. Observationer af radiomærkede vildsvin i det sydøstlige Sverige har vist, at dyrene i gennemsnit tilbagelægger 7km i løbet af en aktivitetsperiode, men med store, individuelle variationer fra 2 til 16km (Lemel 1999). Det meste af aktivitetsperioden bruges til fødesøgning. Afhængig af årstiden og fordelingen af føde i området, herunder forekomsten af attraktive landbrugsafgrøder, vil en del af aktiviteten ske på de åbne arealer uden for skov-grænsen, men sjældent længere væk end at de hurtigt kan søge dækning, dvs. højst nogle hundrede meter. Om dagen opholder dyrene sig i uforstyrrede områder med god dækning, oftest skovområder med tæt undervegetation.

Bestandstæthed

De foreliggende, detaljerede home-range data for fritlevende vildsvin lader det sig desværre ikke umiddelbart omsætte til konkrete bestandstætheder, dvs. præcise angivelser af antallet af vildsvin per arealenhed. Litteraturen er ligeledes sparsom med konkrete oplysninger om bestandstætheder i fritlevende bestande, men der findes dog enkelte eksemlper.

I et 47.030 ha stort område i Ungarn, hvor 25% af arealet er dækket af løvskov og 75% af landbrugsarealer, overvejende kornafgrøder, angiver Náhlik & Sándor (2003) fx en samlet vildsvinebestand på ca. 500 dyr, svarende til 1,06 vildsvin per km^2 for hele området og 4,21 vildsvin per km^2 skov. Det skal bemærkes, at der i det samme område er en bestand på 400 krondyr og 500 rådyr, og at der fodres dagligt året rundt med ca. 1 kg foder per dyr, i alt 1.400 kg per dag.

I den anden ende af tæthedsspektret ligger et eksempel fra en nationalpark i Polen, hvor bestanden i kraft af intensiv fodring nåede op på 10 vildsvin per km^2, men efterfølgende faldt til 1-2 dyr per km^2 som følge af stigende ungedødelighed, faldende fødselsrate og stigende udvandring (Andrzejewski & Jezierski 1978). Under særlig gunstige omstændigheder kan tætheden komme helt op i nærheden af 25 vildsvin per km^2, hvilket er observeret efter et godt oldenår i de bedste områder af en anden polsk nationalpark (Jedrzejewska *et al.* 1994). Normalt lå tætheden i disse områder omkring 6 vildsvin per km^2, mens den i andre, mindre optimale dele af samme nationalpark lå på 3-4 dyr per km^2.

Herre (1986) angiver 2 vildsvin per km^2 som forårstæthed for bestande på fri vildtbane, og anser i øvrigt ikke bestande med tætheder under 1 vildsvin per km^2 for levedygtige på længere sigt. I en skotsk forundersøgelse med henblik på reintroduktion af vildsvin anbefaler Leaper *et al.* (1999) at operere med maksimale tætheder på 3-5 vildsvin per km^2. I den efterfølgende modellering anbefales det at arbejde med tætheder på 1-5 vildsvin per km^2.

Spredning

Afhængig af bestandstæthed i forhold til områdets bæreevne vil der normalt ske en vis udvandring/spredning fra en vildsvinebestand. Alle de unge orner forlader familiegrupperne og vandrer ud, senest i 18-24 måneders alderen, men de kan udvandre allerede i deres første

efterår, dvs. i en alder af 4-10 måneder (Tabel 3). De unge søer udvandrer ikke i samme omfang som ornerne. De fleste bliver derimod i det område og i den familiegruppe, hvor de er født. Årsagen til denne forskel mellem kønnene skal sandsynligvis findes i "motivationen" bag udvandringen. De unge orner drives bort fra familiegruppen af de gamle orner i forbindelse med brunsten, hvorefter de udvandrer og prøver at etablere sig i et område, hvor der er adgang til parringsvillige søer og begrænset konkurrence fra gamle orner. De unge søers udvandrings-mønster styres tilsyneladende af bestandstætheden i moderens område. Hvis bestanden set over et større område er under bæreevnen, vil de unge søer komme i brunst og starte deres egne familiegrupper i umiddelbar nærhed af moderens område. Hvis der ikke er plads, kan de unge søer derimod vælge at blive i moderens område, men så vil de i reglen ikke blive drægtige. Hvis hele området er overbefolket, kan de unge søer endelig vælge at udvandre over længere afstande, men det sker kun undtagelsesvis.

Tabel 3. Grisenes alder når spredningen starter, kulminerer og slutter samt gennemsnitlig spredningsafstand for hhv. søer og orner i en SØ-svensk bestand

	Start	Maximum	Slut	Afstand
Søer	7 mdr	9 mdr	11 mdr	4,5km
Orner	10 mdr	13 mdr	16 mdr	16,6km

Kilde: Lemel, 1999

Genmeldinger af mærkede vildsvin i bestanden i det sydøstlige Sverige viste, at orner i gennemsnit spredes længere væk fra mærkningsstedet end søer, hhv. 16km og 4km (Tabel 3; Lemell 1999). Ingen af de mærkede søer vandrede længere end 20km, mens 4 orner blev genmeldt fra meget lange afstande: 60, 86, 86 og 105km. I øvrigt blev en stor del af dyrene genmeldt som døde (oftest skudte) inden for 2km fra mærkningsstedet: 55% af de mærkede søer og 39% af de mærkede orner (Lemel 1999).

Udvandringsmønster og spredningsafstande, som de ses i den svenske bestand, er formentlig karakteristisk for bestande med gode vækst- og spredningsmuligheder, og hvor den største del af dødeligheden – ud over ungedødeligheden – skyldes jagt.

Reproduktion

Tabel 4. Fødselsrater i forskellige lande

Land	Fødselsrate	Kilde
Polen	1,6-5,5	Andrzejewski & Jezierski 1978
Tyskland	6,0	Briedermann 1971
Frankrig	4,62	Mauget 1972
Frankrig	4,6	Aumaitre et al. 1984
Østrig	5,8	Martys 1982
Ungarn	3,5-6,7	Köhalmy 1979
Ungarn	6,6	Heltay et al. 1981
Ungarn	6,7	Nàhlik & Sandor 2003
Italien	4,9	Pedone et al. 1991
Spanien	4,3	Sáez-Royuela & Tellería 1987
Spanien	4,1	Abaigar 1992
Spanien	4,2	Garzon-Heydt 1992

Vildsvin bliver kønsmodne forholdsvis hurtigt, ornerne når de er 10 måneder gamle, og søerne når de mellem 7 og 22 måneder. Under "naturlige" forhold får søerne deres første kuld i 2. leveår (dvs. som 1-årige), hanner i deres 4.-5. leveår (dvs. som 3-4-årige), afhængig af bestandstæthed, fødetilgang og andre lokale betingelser i den enkelte bestand. Parringstiden strækker sig fra august til december, og drægtighedstiden er fire måneder (115 dage i gennemsnit). Omkring 78% af søerne farer i månederne februar-maj, heraf 30% alene i marts.

Kuldstørrelsen varierer meget, dels fra bestand til bestand, dels fra land til land, jf. Tabel 4. Hertil kommer en stærk sammenhæng mellem mellem soens alder og fødselsraten, jf. Tabel 5. Nahlik & Sandor (2003) angiver, at 1-års søer får 5-6 grise, og at fødselsraten derefter stiger med ca. 0,4 per år (Fig. 1). I den svenske vildsvinebestand fandt Lemel (1999) generelt mindre fødselsrater, idet de yngste, førstegangsdrægtige søer (1-årige) fik 2,71 grise per kuld, mens de 2 årige fik 4,45 grise per kuld og de ældste (over 2 år) fik 4,25 grise per kuld (Tabel 5). Årsagen til den lavere fødselsrate i den svenske bestand (3,9 grise per drægtig so) i forhold til den ungarske (6,7 grise per drægtig so) skal formentlig primært søges i forskelle i såvel det naturlige fødegrundlag som i fodringsintensiteten.

Tabel 5. Fødselsrate i forhold til soens alder

	Aldersgrupper (år)							
	1	2	2-3	3	4-5	6-7	≥7	Total
Jezierski, 1977	1,00		3,40		4,00	5,00		6,7
Nàhlik & Sandor, 2003	5,14		6,00		7,29	8,00	8,00	
De Vos & Sassani, 1977	4,20	5,60		6,50				
Podone et al. 1991	3,64	5,07		5,60				

Der foreligger kun få oplysninger om drægtighedsprocenten i bestande af fritlevende vildsvinebestande, men på grundlag af Lemel (1999) kan niveauet for den svenske bestand beregnes, dog med forbehold for det forholdsvis lille antal undersøgte dyr: 25% (7 ud af 28) blandt 0-1 årige søer, 58% (11 af 19) blandt de 1-2 årige og 67% (4 ud af 6) blandt de ældste søer (2 år og derover) (Tabel 6).

Ved fødslen er der oftest en kønsratio omkring 1:1, men afvigelser forekommer, jf. Tabel 7.

Tabel 6. Gennemsnitligt antal fostre og drægtighedsprocent blandt søer i forhold til alder

Alders-klasse	Gns. antal fostre i drægtige søer	Antal søer undersøgt	Heraf drægtige	Drægtigheds-procent
0-1 år	2,71	28	7	25
1-2 år	4,45	19	11	58
2 år og ældre	4,25	6	4	67

Kilde: Lemel, 1999

Figur 1. Fødselsrate i forhold til vildsvinesoens alder i en ungarsk vildsvinebestand. Efter Náhlik & Sandor 2003.
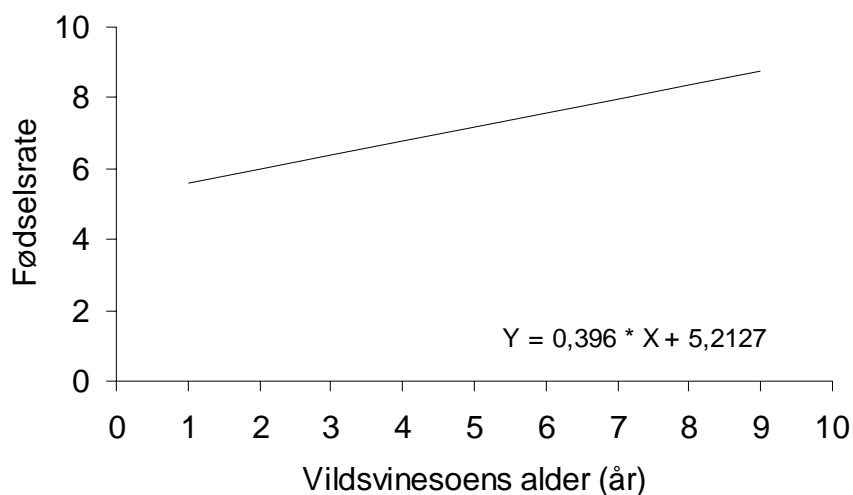
Tabel 7. Kønsfordeling på fødselstidspunktet

Land	Køns-ratio (%:&)	Kilde
Ungarn	1:1,2	Nàhlik & Sandor, 2003
Spanien	1:1,6	Abaigar, 1992
Frankrig	1:1	Aumaitre et al., 1984
Ungarn	1:0,88	Heltay et al.,1981

Overlevelse

Jagt er oftest den hyppigste dødsårsag i europæiske vildsvinebestande. Et højt jagttryk er som regel ensbetydende med en høj dødelighed og en hurtig bestandsomsætning, men samtidig kan jagt- og fredningsbestemmelser samt jagtformer og -traditioner have stor indflydelse på dødeligheden i de enkelte køns- og aldersgrupper.

Tabel 8 viser sandsynligheder for, at søer og orner når en bestemt alder, baseret på tal fra en svensk (Lemel 1999) og en tysk bestand (Stubbe *et al.* 1989). I den svenske bestand opnår henholdsvis 63,6% af søerne og 68,8% af ornerne i en kohorte at blive mindst 1 år gamle. Fra 1- til 2-års alderen er der endnu større forskel i overlevelsen mellem kønnene, idet 28,9% af søerne bliver mindst 2 år, men det gælder kun for 14,1% af ornerne. Denne forskel er hovedsagelig en følge af, at søer med grise er fredet, og at 1-2 årige orner løber en særlig risiko for at blive skudt eller dræbt i trafikken på grund af forhøjet aktivitet i forbindelse med udvandringen fra familiegrupperne.

Ligesom i den svenske bestand er søernes overlevelse i den yngste aldersklasse i den tyske bestand også 5-6% højere end ornernes, men på et niveau ca. 10% under det svenske (Tabel 8). For den anden aldersklasse er der imidlertid en iøjnefaldende forskel. Svenske og tyske søer har næsten lige store chancer (29-30%) for at blive mindst 2 år. Derimod er tyske orners chance for at blive mindst 2 år gamle betydelig højere end svenske orners, 33,9% mod 14,1%.

Forskellen skyldes formentlig, at der er store forskelle på i den måde, vildsvinejagten drives på i de to lande.

Tabel 8. Sandsynligheder for, at søer og orner i Sverige og Tyskland når en bestemt alder

| | Aldersklasse | | | | | | | |
	1	2	3	4	5	6	7	8
Søer, Sverige	63,6	28,9	22,4	13,5	3,6			
Orner, Sverige	68,8	14,1	5,4	1,1				
Søer, Tyskland	52,3	29,6	9,8	4,1	2,2	1,1	0,4	0,3
Orner, Tyskland	58,6	33,9	4,9	2,0	0,5	0,1		

Kilde: Lemel, 1999 og Stubbe et al.,1989.

Figur 2. Eksempel på neonatal dødelighed og sommerdødelighed i en vildsvinebestand. Efter Náhlik & Sandor 2003.
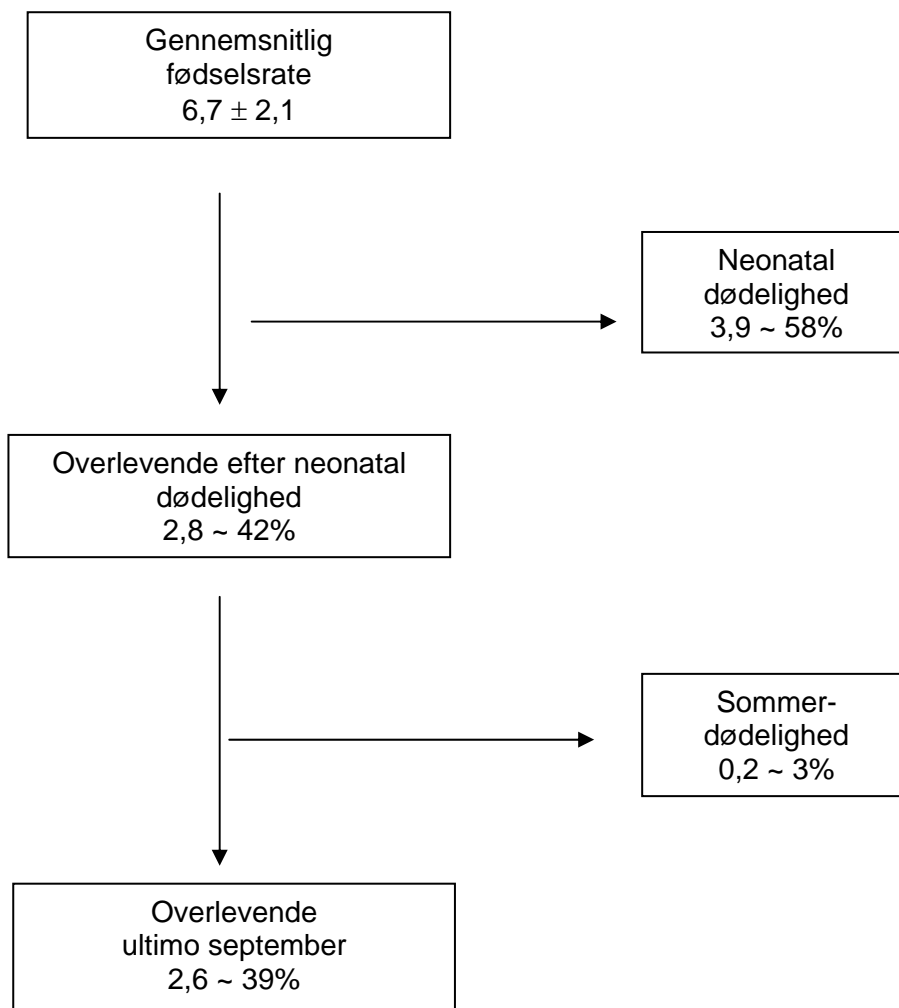
Dødeligheden i 1. leveår er sædvanligvis meget høj, ikke mindst fordi mange smågrise dør i den første tid efter fødslen. Náhlik & Sandor (2003) definerer denne såkaldte neonatale dødelighed for vildsvin.som dødeligheden efter de to første uger efter fødslen. For den tidligere omtalte, ungarske bestand angiver Náhlik & Sandor (2003) den neonatale dødelighed til 58%. Hen over sommeren dør der yderligere 3% af grisene ved den såkaldte sommerdødelighed, så ved udgangen af september er ca. 61% af årets tillæg faldet fra. Ud af de 6,7 grise, der i gennemsnit blev født per so i denne bestand, vil der således være 2,6 tilbage omkring 1. oktober (Fig. 2).

Fødevalg

Vildsvinet er en altædende generalist (omnivor). Føden består overvejende af planter og svampe suppleret med smådyr som snegle, orme, larver og biller samt lejlighedsvis padder, fugleæg, fugleunger og småpattedyr. Rester af større pattedyr forekommer også, idet vildsvinet gerne æder såvel slagteaffald – fx fra opbrækning af hjortevildt i forbindelse med jagt – som ådsler af selvdøde eller trafikdræbte dyr, herunder artsfæller.

Schley & Roper (2003) har sammenstillet en oversigt over vildsvinets fødevalg i Vesteuropa, hvor de især har koncentreret sig om at belyse landbrugsafgrøders rolle i den samlede kost og de skader, som svinenes foureringsaktivitet medfører. Vegetabilske fødeemner var langt de hyppigst forekommende, og de udgjorde også den største del af den samlede fødemængde. De vegetabilske fødeemner kunne groft opdeles i fire kategorier: Olden, rødder, grønne plantedele og landbrugsafgrøder. Afhængig af lokaliteten var der altid mindst ét særligt energirigt fødeemne i kosten: Agern, bog, kastanjer, oliven, korn, majs m.v. Fødevalget er bredt og varieret, men det er et gennemgående træk, at landbrugsafgrøder udgør en betydelig del af føden. Af animalske fødeemner var insekter, regnorme, fugle og pattedyr de mest almindelige, men padder, krybdyr, snegle og tusindben forekom også.

Undersøgelse af maveindholdet hos 57 vildsvin fra en bestand i det sydøstlige Sverige viste, at 86% af fødeemnerne var af vegetabilsk oprindelse og 14% var animalske (Lemel 1999). Svinene æder både over- og underjordiske plantedele samt frø og frugter. Især om efteråret og vinteren udgør olden sammen med underjordiske plantedele med oplagsnæring en vigtig del af føden.

Vildsvin fouragerer såvel på den naturlige vegetation som på landbrugsafgrøder, men i mange tilfælde vil en større eller mindre del af den samlede fødemængde stamme fra udlagt foder. I den svenske bestand var 30% af den totale fødemængde af "naturlig" oprindelse, mens 70% stammede fra udlagt foder, og i ni ud af 10 maver udgjorde foderet fire femtedele af indholdet (Lemel 1999).

Fodringen benyttes mange steder som led i den daglige/årlige forvaltning af vildsvin, dels i et forsøg på at opretholde en vis bestand og samtidig begrænse dyrenes fouragering og aktivitet på landbrugsarealer, dels for at give bedre jagtmuligheder. Afhængig af formålet er der stor variation i fodringsintensiteten, fra rigelig fodring hver dag (1 kg foder per svin, Náhlik & Sándor 2003) til stærkt tidsbegrænset og målrettet fodring, fx med henblik på at lede svinene til bestemte steder på reviret i jagtsæsonen.

Markskader

Vildsvin kan forvolde omfattende skader på land- og skovbrugsarealer, dels ved at æde afgrøderne, dels ved at rode i jorden. Visse landbrugsafgrøder er mere attraktive for vildsvinene end andre. I Sverige synes svinene især at foretrække korn og ærter, mens afgrøder

som majs og kartofler sammen med forskellige kornsorter er registreret som de vigtigste i fx Polen og Tyskland. Fødevalget afspejler formentlig svinenes præferencer, men vil dog først og fremmest afhænge af, hvad der er til rådighed på den enkelte lokalitet. Overordnet set påvirker vildsvinene måske kun en mindre del (4-5%) af de arealer, som de færdes på, men derfor kan skaderne alligevel være mærkbare for den enkelte landmand eller skovbruger. I enkelte tilfælde kan der endog være tale særdeles voldsomme skader. Fra Sverige er der et konkret eksempel på, at 20 vildsvin rodede jorden op og åd fremspirende ærter på en nysået ærtemark i et sådant omfang, at det forventede høstudbytte blev reduceret med 75% (Lemel 1999). Schley & Roper (2003) konkluderede på grundlag af fødevalgsundersøgelser fra hele Vesteuropa, at vildsvin forvolder betydelig skade på landbrugsafgrøder: De opsøger landbrugsafgrøderne, fordi de er afhængige af energirige fødekilder, og i kraft af deres kropsstørrelse og en tilbøjelighed til at rode i jorden og nedtrampe afgrøderne, vil de uvægerligt ødelægge noget af afgrøden ud over den mængde, som de direkte æder.

Der er også eksempler på, at vildsvin kan have positive effekter på deres omgivelser, idet oprodningen af jorden dels kan forøge den botaniske artsrigdom, dels kan fremme den naturlige foryngelse af skoven (Welander 2000). Situationen er dog ikke entydig. I følsomme områder kan vildsvinenes fourageren være en trussel mod sårbare plantearter, og under visse betingelser kan svinene æde alle de fremspirende planter, herunder dem, der skulle bidrage til selvforyngelsen!

Det er dog muligt at gøre forskellige tiltag for at forhindre eller begrænse skaderne. Vildsvin kan i nogen grad holdes borte fra sårbare arealer ved at udlægge foder eller anlægge fodermarker. Dog synes visse afgrøder, især havre og hvede i de tidlige modningsstadier, at være så attraktive, at hverken fodring eller gængse skræmmemidler er nok til at holde svinene væk. Derimod er der i Sverige gode erfaringer med at holde vildsvin ude fra attraktive afgrøder ved hjælp af specielle, elektriske hegn.

Forslag til kriterier for udvælgelse af potentielle leveområder for vildsvin i Danmark

Ifølge World Conservation Unions anbefalinger (IUCN 1995) bør der gennemføres en række undersøgelser og tiltag før, under og efter enhver reintroduktion. Da der ikke foreligger en egentlig forundersøgelse for reintroduktion af vildsvin i Danmark, vil det af hensyn til modellering af risikoen for spredning af svinepest være nødvendigt at benytte kvalificerede gæt med støtte i litteraturoplysninger i stedet for mere sikkert estimerede parametre vedrørende forskellige biologiske og bestandsmæssige forhold hos fritlevende vildsvin i det danske landskab.

Mange undersøgelser af vildsvin kan bidrage til denne udredning, men umiddelbart virker det mest oplagt at støtte sig særligt til de erfaringer og resultater, der foreligger vedrørende den "nye" svenske bestand (Lemel 1999).

Konkrete værdier for en række af de vigtige parametre kan findes i de foregående afsnit, så de vil ikke blive gentaget her. Men med hensyn til kriterier for udvælgelse af potentielle vildsvineområder er det svært at finde støtte i litteraturen, da Danmark ikke ligner andre "vildsvinelande" på grund af landets forholdsvis lille areal, hvoraf en stor del er opdyrket og en forholdsvis lille del er dækket af skov, som tilmed er opdelt i mange mindre skove, samt en en stærkt udbygget infrastruktur og en høj befolkningstæthed.

Det vurderes, at de biologiske forudsætninger for vildsvin, dvs. basale krav med hensyn til føde og dækning, vil kunne opfyldes mange steder i landet landet. Derfor vil det afgørende for

vildsvinets muligheder for at etablere sig og opbygge en levedygtig bestand sandsynligvis ikke være begrænset af disse basale krav, men derimod af den generelle og lokale tolerancetærskel med hensyn til markskader.

Som udgangspunkt for udvælgelsen af potentielle vildsvineområder i forbindelse med risikovurderingsmodellen foreslås det at søge efter områder på 100, 200 eller 400km^2, alle med min. 25% skovareal. Hver enkelt vildsvinegruppes arealkrav sættes til 5-15km^2 skov, og forårsbestandstætheden til 1-4 svin pr.km^2 skov, med den øvre grænse som max bæreevne, jf. Tabel 9. Af hensyn til begrænsning af markskader må bestandstætheden holdes under bæreevnen ved hjælp af jagt/regulering. Det vil samtidig have den effekt, at formerings- potentialet vil blive udnyttet, dvs. mange søer bliver drægtige som 1-årige, og udvandringen begrænses til hovedsageligt at omfatte de unge orner.

Tabel 9. Skøn over arealkrav og bestandstætheder i forbindelse med udvælgelse af potentielle vildsvineområder i Danmark.

Totalareal km^2	Skovareal km^2	Antal grupper min-max	Antal vildsvin min-max
100	25	2-5	25-100
200	50	3-10	50-200
400	100	7-20	100-400

I forbindelse med vurdering af muligheden for at reintroducere vildsvin til Skotland, anbefalede Leaper *et al.* (1999), at afstanden fra udsætningsområdet til bymæssig bebyggelse skulle være mindst 5km, afstanden til dyrkede landbrugsarealer mindst 5km og afstanden til større veje mindst 1km. Disse krav er svære eller direkte umulige at overføre direkte til Danmark. Fx vil det vil stort set være umuligt at operere med et fast afstandskrav i forhold til landbrugsarealer. I risikovurderingsmodellen anbefales det derfor at arbejde uden afstandskrav i forhold til landbrugsarealer, og så forudsætte markskadeproblematikken løst gennem fx en kompensationsordning. En mere konkret fastlæggelse af kriterier for udvælgelse må i givet fald afvente en egentlig forundersøgelse.

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14.3 Classical swine fever virus (CSFV) and infection of wild boar

- A literature review carried out by Åse Uttenthal , Senior Research Officer, DFVF, Lindholm.

Classical swine fever (CSF) is a very important viral disease of swine. Calculations on the 1997-98 outbreaks in domestic pigs in the Netherlands estimated the economic losses for lost income, veterinary services, cleaning, rendering and repopulation to be 2.3 billion US dollars (Meuwissen et al., 1999). Ten million pigs were killed before the country could be declared free from CSF. The disease is caused by infection by a pestivirus, classical swine fever virus (CSFV) belonging to the Flaviviridae family. CSFV infects mainly pigs, however, other species such as rabbits (Chenut et al., 1999) may be infected by this virus. Pigs of all breeds, including wild boar are susceptible to the infection (Chenut et al., 1999; Depner et al., 1995). This literature survey is based partly on pathological data obtained from domestic pigs. As the wild boar is a wild animal, it is not easy to keep in isolation units for experimental infections. Epidemiological data, however, can be obtained from populations of free ranging wild boar.

Free ranging pigs are mainly wild boar, but also domestic pigs that have escaped from herds (feral pigs) or crossings between different breeds of pigs could be found in the free ranging pig populations. As all kinds of feral pigs, whether escapee from domestic pigs or pure breed wild boar pose the same problems; they will in this review be treated as one group hereafter called "wild boar".

This literature review has this structure:
1. Description of classical swine fever disease manifestations in pigs
2. Present status and epidemiological data obtained from CSFV in wild boar in EU
3. When to get a suspicion of CSFV in a population of wild boar
4. CSFV infection will die out in a normal wild boar population
5. Introduction of CSFV from wild boar to domestic pigs and vice versa
6. Methods to eradicate CSFV if introduced into the wild boar population

Description of classical swine fever disease manifestations in pigs

The infection, dissemination and spread of CSFV in wild boar have only been studied in few experiments, as the wild boar is difficult to handle. However, in the limited experiments the infection in wild boar has proceeded exactly as what is seen in domestic boar (Depner et al., 1995). Following a short incubation period where the virus multiplies in the lymphoid tissues, mainly tonsils and lymph nodes, the pigs have increased body temperatures for 1-3 weeks.

Classical swine fever is characterized by an acute depletion of leucocytes causing increased bleeding tendencies and a general immune suppression often leading to fatal secondary infections. During the hyperthermic period CSFV is detected in the blood of the pigs – the so-called viremia. After the viremic period the pigs may die from disease or survive and produce antibodies to CSFV; the pigs then have the **acute form of CSF**.

The duration of the viremic period may be as short as one week (Uttenthal et al., 2003). In a study of 128 domestic pigs experimentally infected by a low pathogenic Belgian CSFV isolate, the usual virus excretion period was determined to be 10.6 days (Dewulf et al., 2004).

The more recent CSFV strains in Europe tends to give less typical clinical signs; and for several strains the occurrence of clinical signs which will rise a suspision for CSFV are delayed up to 14 days after infection (Floegel-Niesmann et al., 2003).

The outcome of disease, whether the pigs die or survive depends on the breed of pigs, the age of the pig at the time of infection and of the virulence of the CSFV infecting the pig (Handel et al., 2004). In some pigs the virus is not cleared but the pigs survive for a longer period displaying the **chronic form of CSF** (Dahle and Liess, 1992)**;** where the pig excrete large amount of virus until succumbing to the infection several weeks after infection. The prolonged period where virus excretion is observed for more than 10 days is not unusual in experimentally infected domestic pigs, where 40% of the pigs had prolonged periods of CSFV viremia (Uttenthal et al., 2001). Why some pigs die in the acute form and other live to have the chronic form of CSF in not known.

If pregnant sows (both wild boar and domestic pigs) are infected with CSFV the offspring may have a **congenital persistent swine fever infection** (van Oirschot and Terpstra, 1977; Depner et al., 1995; Frey et al., 1980). The surviving piglets are clinically normal and produce antibodies to unrelated antigens but they seem to have tolerance to CSFV (van Oirschot, 1977). The persistenly infected pigs may live up to one year during which they chronically excrete virus. This situation resembles the persistent infection (PI) in calves observed in Bovine viral diarrhoea virus (BVDV) infected herds (McClurkin et al., 1984).

The occurrence of PI animals in pigs requires that the mothers are antibody negative at the time of conception; therefore the risk of having persistently infected piglets is highest in herds with primary infections. Experimental infections in domestic pregnant sows have shown that the infection must take place between day 68-90 of gestation (Meyer et al., 1981), corresponding to late second trimester of the gestation period. An increase in foetal mortality was observed in the infected pregnant pigs and only half of the piglets were born alive. Virus could be detected predominantly in liver, kidney and Kupffer cells (Richter-Reichhelm et al., 1980); tonsils were not analysed. After birth the mortality rate of the PI animals was high, and most of the viremic pigs died during the first 8 weeks. Recovery and elimination of the virus from the peripheral blood was not found in any of these cases (Meyer et al., 1981).

The occurrence of CSFV persistently infected pigs is seldom observed, as any detection of CSFV in domestic herds will result in a quick culling of the herd. The original paper describing the case story of congenital persistent swine fever infection in a domestic pig herd describes one pregnant sow out of 16; giving birth to a litter of weak pigs where some were persistently infected (van Oirschot and Terpstra, 1977). The experimental study of transplacental transmission of CSFV resulted in a much higher rate of persistently infected piglets (Frey et al., 1980); the reason for the higher rate of successful infection experimentally is probably that all the pregnant sows were kept antibody negative until the time of infection. The PI-piglets are clinically healthy and as their littermates are naïve they will be infected and ease the spreading within the population (Depner et al., 1995; Meyer et al., 1981) (C.Griot 1999 Speech at the USAHA meeting). PI pigs will not have antibodies to CSFV; only detection of virus will be possible.

No solid data are available on PI wild boar found in the wild (Artois et al., 2002), but even in small numbers they may play a key role in the spread of CSFV. Data from Brandenburg (Kern et al., 1999) showed that CSFV infection was not interrupted in spite of simultaneous bait vaccination against CSFV. In addition a remarkably high number of piglets under 3 months of age (22%) were virus positive before the eradication campaign. The authors interpret this as the existence of persistently infected animals that harbour CSF virus for at prolonged period, and still cannot be vaccinated.

Present status and epidemiological data obtained from CSFV in wild boar in EU

The wild boar population is estimated to be roughly 1 mill heads within the "old members" of EU (Laddomada, 2000). Based on the estimates given by each country in Table 1 the number of animals may be 1.5 or 2 million wild boar. In Europe there seem to be general increase in numbers of animals for several reasons (Moennig et al., 2003; Laddomada, 2000; Artois et al., 2002):

1. the deliberate introduction and winter feeding of wild boar by hunters
2. the increased availability of food from kitchen waste
3. lack of predators
4. the good adaptability of the wild boar

Areas with thick forests are optimal habitats for wild boar especially if cultivated areas are bordering these forests. Unfortunately, national borders are often in areas with very few human inhabitants, but often excellent habitats for wild boar. Therefore, the central European countries often share the CSFV outbreaks by wild boar populations having their habitat in several countries. Table 1 shows the estimated wild boar population in 2002 for each country and the number of cases where CSFV has been isolated from wild boar for European (mainly EU) countries.

Table 1. The estimated number of wild boar and the number of CSFV positive animals shot or found dead in each country

Country	Wild boar population	No. of CSFV positive wild boar shot/found dead in year						
		1997	1998	1999	2000	2001	2002	2003
Austria	30,000	n.i.	n.i.	0	7	2	0	0
Belgium	15,000	n.i.	n.i.	0	0	0	0	0
Denmark	250	0	0	0	0	0	0	0
Finland	45,000	n.i.	n.i.	0	0	0	0	0
France	750,000	n.i.	n.i.	0	0	0	n.i.	116
Germany	418,667	181	219	409	174	373	451	37
Greece	n.i.	n.i.	n.i.	n.i.	0	0	0	n.i.
Irland	n.i.	n.i.	n.i.	n.i.	0	0	0	n.i.
Italy	n.i.	n.i.	42*	69	25	3	0	0
Luxembourg	10,000	0	0	0	0	7	65	81
The Netherlands	3,000	0**	0**	0	0	0	0	0
Portugal	n.i.	n.i.	n.i.	0	0	0	0	0
Spain	n.i.	n.i.	n.i.	0	0	n.i.	0	0
Sweden	8,000	0	0	0	0	0	0	0
United Kingdom	600	n.i.	n.i.	0	n.i.	0	0	0
Norway	500	0	0	0	0	0	0	0
Switzerland	>10,000	0	138	38	0	0	0	0

n.i. = no information. No data were reported from these countries but wild boar could be present.
The data are obtained from the annual swine fever meetings.
* based on (Zanardi et al., 2003), ** based on (Elbers et al., 2000).

The number of EU members with CSFV infection in wild boar is expected to increase with the widening of the European Union as the borders moves eastwards. During 1990-1998 relapses in the EU wild boar population have been seen in 6 German areas, one French area, 2 areas of Austria. Furthermore, 3 mainland areas of Italy have been infected and on Sardinia the disease is still endemic in combination with African swine fever (Laddomada, 2000).

Looking at the figures for the present members of the EU only Germany seem to have an endemic CSFV infection in wild boar. The French wild boar population is larger than the German, but seems to be free from CSFV (Albina et al., 2000).

In several countries, like Germany, Sardinia, Croatia, Hungary, Slovakia, Estonia, Poland, Czech Republic (Kern et al., 1999; Zupancic et al., 2002; Stadejek et al., 1997; Lowings et al., 1999; Bartak and Greiser-Wilke, 2000), CSFV infected wild boar have been detected during the last decade.

The presence of CSF in the free ranging boar population is of major concern to EU and the handling of infected populations is laid down in 2001/89/EC. If CSFV infected pigs are found in the national wild boar population a plan must be described for the measurement of the problem, describing how many pigs are infected, and if the infection is increasing or decreasing.

One major problem is that the actual number of wild boar in the area is unknown. As an estimate 400-1000 heads are expected for each 200km^2 (Anonymous, 2002) but it must be emphasised that this is a very rough estimate.

Furthermore a decision must be made on how to eradicate the infection. The plan must include establishment of surveillance and observation zones for the area. Often these plans include several countries like the CSFV 1997-2001 epidemic in Italy including Swiss veterinary services (Zanardi et al., 2003).

The establishment of "risk-zones" for wild boar aims at keeping all infected (here defined as virus positive) inside the risk area, whereas antibody positive pigs are accepted in the surveillance (non-risk zone) (Schnyder et al., 2002).

The plans for surveillance and eradication of CSF in wild boar populations are often not published in peer-reviewed papers, as they are not considered to be "real science". However, lots of information may be gained from the meetings in the different committees in the EU where these data are communicated. The data below are collected from the annual National Swine Fever Laboratories (NSFL) meetings or from the Standing Committee of Food Chain and Animal Health (SCOFCAH); both meetings are intended for dissemination of results from campaigns and to discuss the different approaches among experts.

From the data presented we can obtain information on how different eradication strategies work; the diagrams below are obtained by processing the raw data presented especially from the new member states of the EU.

The eradication of CSFV in wild boar is a long lasting process. Figure 1 describes the situation in the Czech Republic; where targeted hunting reduced the occurrence of CSFV positive wild boar from 1996 to 1999. The removal of CSFV positive wild boar is mirrored first in the reduced number of domestic pig herds infected in the area, in 1996 and 1997, two herds were infected each year, both situated in the focal area for the infected wild boar population. From 2000 all wild boar analysed were free from CSFV, but still 2% of the wild boar were antibody carriers. The positive animals were found among 4000 to 8000 wild boar analysed per year, giving a more precise estimate of the antibody level of the population.

The eradication process of CSFV in wild boar lasts several years, and a detailed study of the age of the antibody positive animals is needed to assure that all antibody positive animals

in 2003 were pigs above 5 years of age, who will remain antibody positive for the rest of their life.

At the peak of infection about 70 virus positive animals were detected, still only 5% of the shot animals had antibodies to the infection. Even when a large number of susceptible animals are present the targeted hunting reduces the number of wild boar with antibodies. After 7 years the population was almost naïve again, and a new introduction will restart the epidemic.

The situation in epidemics in domestic pigs the situation is very different. If one positive pig is detected, the entire herd is eradicated. Therefore the eradication of even huge outbreaks like the 1996 epidemic in the Netherlands was successful within a year, but with tremendous losses (Elbers et al., 1999).
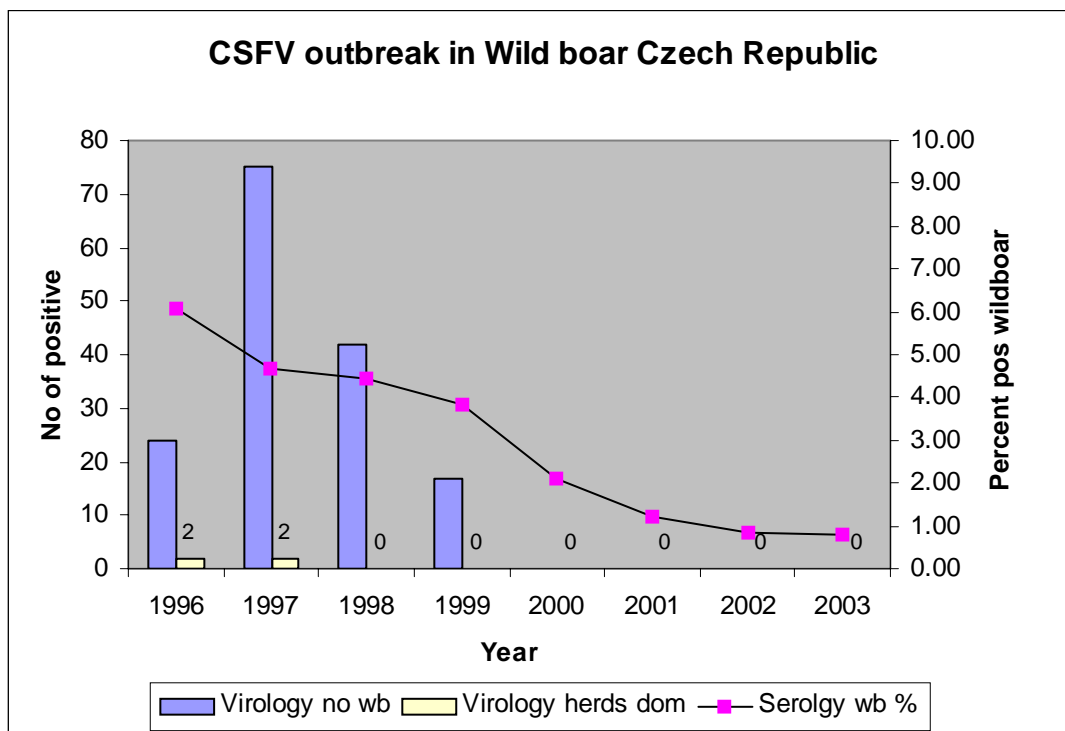
Figure 1. Eradication of CSF in a wild boar population in Czeck Republic (data reported from SCOFCAH meeting with kind permission from Dr. Holejšovský, SVA, CR.).

Explanation to Figure 1: Virus positive wild boars were found until 1999, and a low number of wild boar were still antibody positive in 2003. Virology no wb-: Number of wild boar found CSF virus positive. Virology herds dom: Number of domestic pig herds found CSF virus positive, the number is shown above the column. Serology wb %: Percentage CSFV antibody positive serum samples obtained from wild boar.
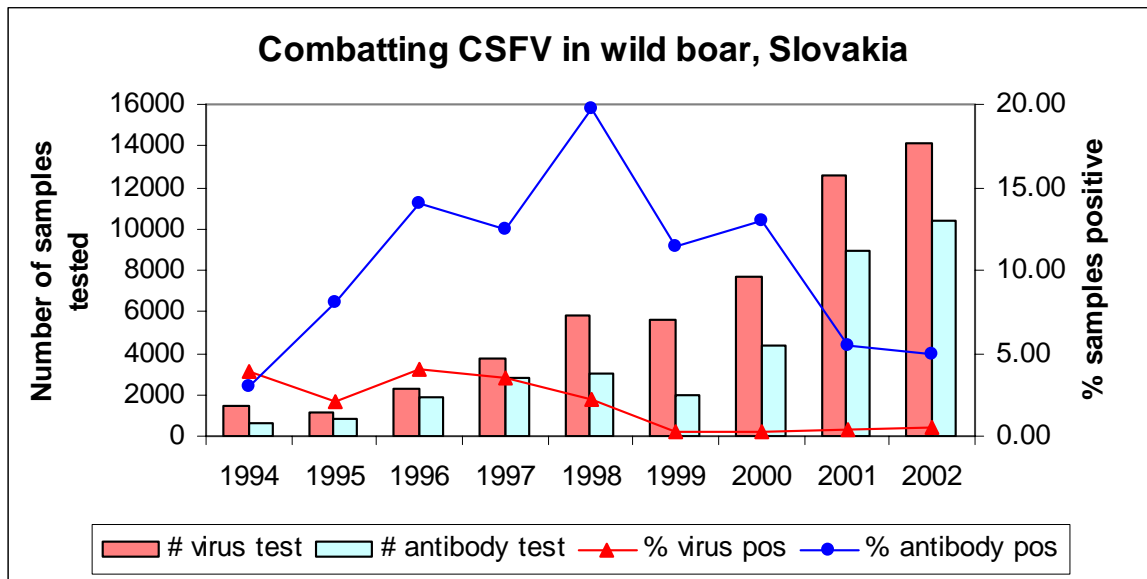
Figure 2. Data on CSFV detection and CSFV antibody detection in wild boar shot in Slovakia (data reported at SCOFCAH, with the kind permission from State Veterinary Administration of Slovakia)

Explanation for Fig. 2: Vaccination was forbidden in 1994, but was reintroduced in 1998 in the domestic pig herds. The removal of CSFV infected domestic pig herds, and the increase in the number of sera tested from wild boar reduced the number of positive wild boar.

In Slovakia, bordering to the Czech Republic, the CSFV situation in wild boar has also greatly improved since mid 1990s. From 1999 less than 0.5% of the wild boar analysed were CSF virus positive (see figure 2). At the same time the number of samples tested have increased to 14000 samples per year; giving a much better awareness of the problem. The size of the wild boar population is estimated to 26 000 breeding animals, the domestic pig population is about 1.5 mill, these numbers have been relatively unchanged since 1998.

In Slovakia CSFV has been present in domestic pigs peaking at 70 herds infected in 1994 shortly after prophylactic vaccination was forbidden. In 1998 a compulsory mass vaccination was initiated, which reduced the number of CSFV cases in domestic herds, and from end of 2000 vaccination was successfully forbidden. In Fig 2 the CSFV infected wild boar decreases when the infections in domestic herds are controlled in 1999, indicating that in Slovakia domestic pig herds infected the wild boar.

Figure 3 shows that males and females are equally represented among the CSFV positive animals; but mainly the young pigs are found positive. The age distribution of positive animals is very close to the expected age population of a normal hunting bag; where 70% of the animals are piglets, 20% are yearlings and only 10% are adult animals (M. Petrak, LÔBF, Bonn; presented at Wild boar symposium, Greifswald 2000). The high number of infected piglets will increase the dissemination of disease if they are not hunted and removed from the herd.

CSFV pos wild boars, Slovakia 2002
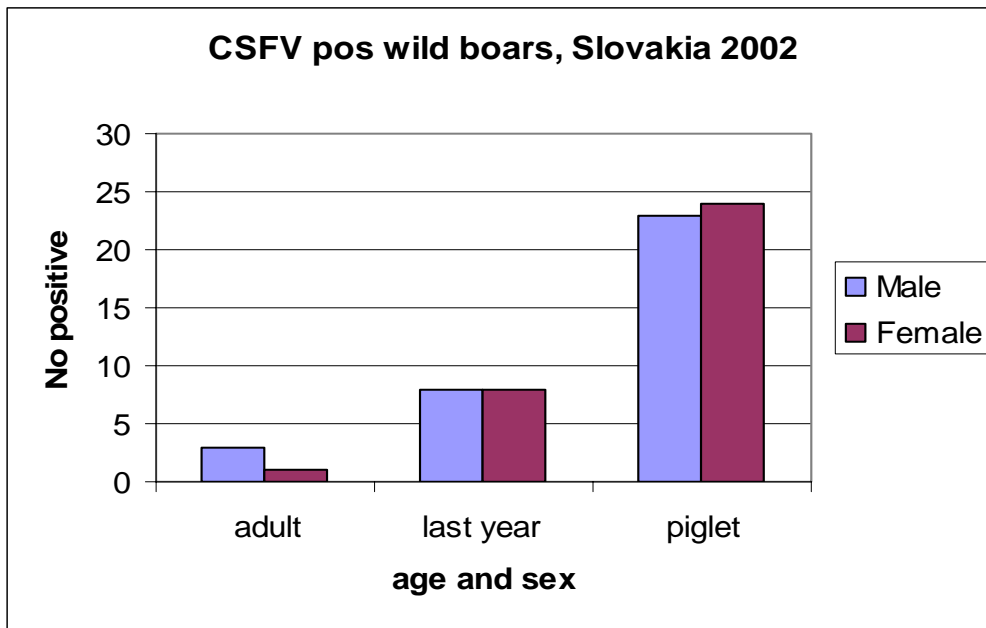
Figure 3. Sex and age distribution of wild boar found positive for CSFV in Slovakia 2002. The normal distribution in a hunting bag is 70% piglets, 20% yearlings and 10% adult pigs, the CSFV positive animals seem to be distributed evenly in the virus positive age groups (data reported at SCOFCAH, with the kind permission from State Veterinary Administration of Slovakia)

Recently the handling of the European wild boar populations has been coordinated in a new, common database. The cooperation was prompted by the 2002 epidemic where CSFV infected wild boar populations were crossing borders and caused CSFV infections in domestic pig herds in Germany, Luxembourg, France and Belgium (Staubach et al., 2004). This database is an improvement to the previously sparse communication to the EU commission. The participants in the web-based database can obtain detailed information on all wild boar analysed in all countries. The definite geographical location of the animal and the laboratory data are present. During the first 2 years of its existence data from 90 000 wild boar have been entered, mainly from German wild boar. The database will later be available for other EU members.

When to get a suspicion of CSFV in wild boar

The clinical symptoms of CSFV are increased body temperature, apathy, vomiting and haemorrhages of the skin. In the late stage of infection central nervous disturbances resulting in unusual movement patterns and dead animals are found. In wild boar increased mortality in the population will be the primary observation. Unusual behaviour and central nervous disturbances such as seizures may be observed. Due to the coarse hair and the pigmentation of the skin, petechial bleedings of the skin will not be observed even in pigs found dead.
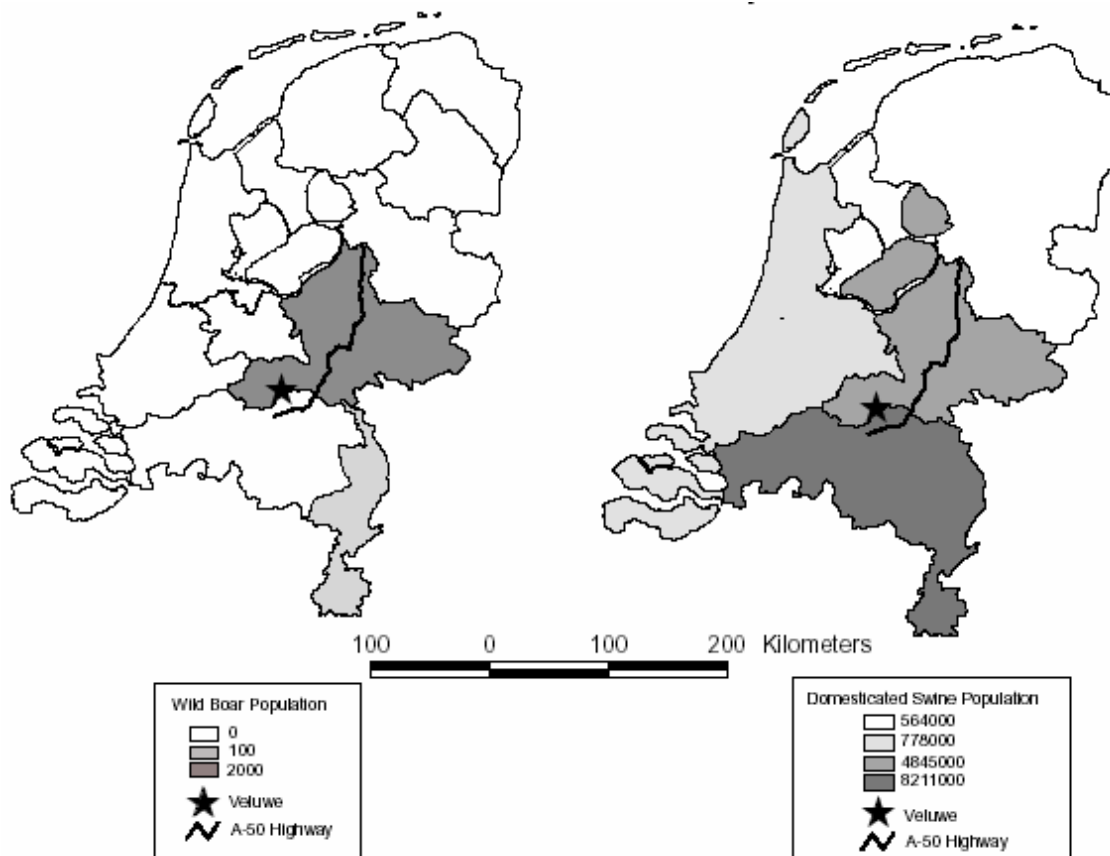
Figure 4. The spatial distribution of wild boar (left-hand map) and domestic pigs (right-hand map) in the Netherlands. From USDA, Veterinary Services www.aphis.usda.gov/vs/ncie/swine_manual.

In most EU member states the wild boar population is monitored for CSFV by serosurveillance. The proportion of wild boar serum samples analysed depends on the population size and if the population is expected to be infected with CSFV. The most common reason for CSFV suspicion is epidemiological risk through contact with infected animals. Following the CSFV epidemic in the Netherlands a survey of wild boar sera did not reveal any antibody positive wild boar (Elbers et al., 2000). As the Dutch areas of high domestic pig density are situated geographically close to the areas with a large wild boar population the speculation of a CSFV reservoir in wild boar was wise (see Fig 4). However, the CSFV outbreak was handled by culling all infected herds, and due to the high density of domestic pig herds in the area the hygienic measures to keep all contaminated carcasses away were enforced (Elbers et al., 1999).

Most often CSFV is detected in wild boar during routine serological or virological analysis of serum samples; these samples are obtained from apparently healthy animals shot by hunters. If serum samples are obtained from hunting parties very few animals are CSFV infected (Table 2), even if they derive from an area with known CSFV infection. However in areas with CSFV infection and a large wild boar population a high proportion of dead or sick animals are infected and therefore found to be virus positive.

Table 2. Analysis of wild boar and detection of CSFV virus or antigen in wild boar from Federal state of Brandenburg, 1995-1997 (Kern et al., 1999). If the pigs are hunted healthy or killed in car accidents the proportion of infected animals is low, 30-40 % of dead or sick animals are CSFV positive. This study did not include analysis of the antibodies in the wild boar

Pigs tested for CSF	Found dead	Hunted sick	Car accident	Hunted healthy
No. tested	152	189	175	8829
No. virus positive	52	78	3	76
% positive	34.2	41.3	1.7	0.9

CSFV infection will not persist in an undisturbed wild boar population

To maintain a swine fever infection in any pig population there must be enough susceptible animals, the constant introduction of newborn piglets are important to maintain the virus in the herd. If a small herd of wild boar is infected they may die from the disease and be removed from the population or they will survive the infection and become immune for the rest of their life. In nature wild boar live in small families, which do not tend to migrate unless they are disturbed by man-made factors (Cousse, 2000); P.Hald Mortensen, AVJF, personal communication). These man made factors are hunting, where the wild boar migrate to find a more quiet place; the disturbance is increased if hunting is carried out with dogs (Laddomada, 2000). Other authors advice that hunting for all animals including other species like hares in the area using dogs should be forbidden (Zanardi et al., 2003).

In the United States deliberate infection of wild boar by CSFV were done in the 1950s to eradicate the wild boar populations. Later serological analysis have shown that the virus disappeared among the wild boar when it was controlled in domestic pigs (Nettles et al., 1989).

Deliberate feeding of the wild boar to increase the number of heads for hunting purposes above what the habitat can sustain will also increase the risk of migration as the population density grows. A rather new problem is that the feeding habits of wild boar have changed toward crops of corn that are easily accessible from the surrounding agricultural areas. Thereby the population increases and some of the animals migrate to find a better territory for living. As also the natural predators of wild boar; brown bear, wolf, fox and lynx have decreased or disappeared the population density increases. These partly man-made changes have increased the risk of maintaining a CSF in the wild boar population. In many cases the definite reason for infection of wild boar cannot be determined but the feeding of wild boar on garbage bins in populated areas or in rest areas at the highways is an easy way of infecting naïve herds. Also the close proximity among free-range domestic pigs and high density populations of wild boar in provinces in Sardinia have given rise to CSFV endemics that are out of control (Laddomada et al., 1994).

If wild boar is infected with a very highly pathogenic virus strain the majority of pigs may die but the remaining will produce a new population; if the strain has a very low pathogenicity the dissemination of disease will be slower, but in small populations the close contact will allow virus to spread to all individuals (Cousse, 2000).

Introduction of CSFV from domestic pigs to wild boar and vice versa

The mere presence of wild boar is not a threat to the domestic pig populations. Accordingly the increase in the wild boar population in Germany, just south of the Danish border is no problem, if they do not have CSFV (personal communication, Danish Food and Veterinary Administration). If, however, CSFV is introduced in the domestic pig population the presence of a very effective reservoir host is a major problem. Infection of wild boar by domestic pigs infected by CSFV has been reported (Artois et al., 2002).

Once CSFV is established in the wild boar population the introduction of CSFV in domestic pig herds is often caused by direct or indirect contact to wild boar. Fritzemeier (Fritzemeier et al., 2000) analysed 327 herds which were infected by CSFV in Germany during 1990-1998. Among the 327 outbreaks 93 were index cases; i.e. infection of domestic pigs in an area expected to be free from CSFV. Introduction of CSFV in a previously not infected area is of major concern as the virus can spread freely until the zones are determined and an approach to prevent further spreading is initiated. In total 55 index cases (59%) were caused by CSFV infected wild boar; 21 (23%) were caused by feeding domestic pigs by uncooked waste food (swill feeding); in the remaining 17 herds the reason for the infection could not be traced. When CSFV is isolated in domestic pig herds the virus strain is sequenced and the origin is found. In 1998 the largest German pig herd (60,000 animals) became infected by CSFV; the introduction from wild boar was confirmed by sequence analysis (Moennig et al., 2003). In the Lombardy region 5 domestic pig herds were culled in 1997 after they were infected by CSFV from wild boar (Zanardi et al., 2003).

The help of humans in transferring the disease is sometimes impressive; in Hessen in 1989 a pig farmer nursed a sick young wild boar, which was captured in the nearby forest in his holding. After the recovery of the animal it was set free in the forest and shortly after CSF was confirmed in the holding (Dahle and Liess, 1992).

In 1990 to 1992 several herds were culled in Italy after CSFV infection. Based on phylogenetic data the introduction seem to have occurred at least twice and that virus had been transmitted between domestic pigs and wild boar (Lowings et al., 1994). One of the index cases were recorded in a herd where the "owner of the captive wild boar not only fed the pigs swill, but also imported wild boar meat" (Lowings et al., 1994).

In table 3 the number of domestic pig herds culled after detection of CSFV in EU member countries are listed. Observe for this table that the numbers of herds are reported; whereas for wild boar the numbers of animals are counted. Comparing the tables for wild boar and for domestic pigs show that Germany having CSFV in the wild boar population also have CSFV in their domestic populations. For all other EU members with CSF epidemics during the last 8 years the source of virus has been not been wild boar. The only exception is the 2002 epidemic in wild boar that crossed borders as described previously. It seems possible to maintain a free ranging wild boar population that stay free from swine fever. But once they get infected it is really important to remove all infected animals fast. If not, the domestic pig population may get infected. The hunters and people working in the forest areas must be educated: "manage the people first, then the wild boar" (Laddomada, 2000).

For ethical and economical reasons the coming CSFV epidemics within the EU may be treated by marker vaccination of domestic pigs. Thereby the risk of spreading the disease may increase as vaccinated herds may be virus positive for several weeks, before they can be detected as antibody postive (Uttenthal et al., 2001).

Table 3. The size of the domestic pig population in each country and the number of domestic pig herds culled after infection by CSFV

Country	Pig population	No. of domestic pig herds culled in year							
		1996	1997	1998	1999	2000	2001	2002	2003
Austria	3,800,000	0	0	0	0	0	0	0	0
Belgium	7,000,000	0	7	0	0	0	0	NR	0
Denmark	10,000,000	0	0	0	0	0	0	0	0
Finland	2,000,000	0	0	0	0	0	0	0	0
France	14,000,000	0	0	0	0	0	0	NR	0
Germany	25,800,000	4	44	11	6	2	6	11	1
Greece	2,000,000	0	0	0	0	0	0	0	0
Irland	1,800,000	0	0	0	0	0	0	0	0
Italy	8,000,000	49	55	18	9	3	6	0	1
Luxembourg	81,569	0	0	0	0	0	0	12	1
The Netherlands	15,000,000	0	429	5	0	0	0	0	0
Portugal	3,000,000	0	0	0	0	0	0	0	0
Spain	20,000,000	0	78	21	0	0	33	16	0
Sweden	4,060,000	0	0	0	0	0	0	0	0
United kingdom	6,900,000	0	0	0	0	16	0	0	0
Norway	1,390,000	0	0	0	0	0	0	0	0

NR- not reported.

The second most important risk of CSFV introduction was swill feeding, this has led to an EU ban on swill feeding (Regulation 1774/2002 laying down health rules concerning animal by-products not intended for human consumption). The CSFV epidemics in Spain and The Netherlands were expected to be caused by improperly cleaned vehicles following an introduction to Germany by swill feeding (Edwards et al., 2000). The Italian and UK epidemics were speculated to be caused by swill feeding. Unfortunately when swill feeding is considered for introduction of infection in domestic herds it can very seldom be proven. The fact that the owner could have caused the infection by a using illegal feed combined by the long incubation period of CSFV at a herd level will make the elucidation almost impossible.

Methods to eradicate CSFV if introduced into the wild boar population

Vaccination trials have been made to eradicate CSFV in wild boar by vaccination (Kaden et al., 2000). In this trial a live vaccine (strain C) was used as oral vaccination imbedded in cereal bait. The baits were deposited at the usual feeding places of the wild boar partly buried to reduce the possibility that other animals ate the bait. To analyse the uptake of the vaccine oxytetracycline (OTC) was added to the vaccine matrix; the presence of OTC could be detected in the bones of pigs at least 4 months after uptake. The older animals mainly ate the vaccine; with repeated immunizations adult wild boar were 100 % covered whereas among the young below 1 year of age only 50% were vaccinated. The reason for the lower success was speculated to be the size of the blister that was difficult to handle for the young individuals. The number of animals seroconverting were even lower. In average only 50% of the wild boar had antibodies to CSFV by then end of 4 vaccination campaigns. In domestic pigs the oral vaccination was 100 % effective 10 days after 1 bait vaccination (Kaden and Lange, 2001); unfortunately these promising data could not be reproduced in the field trial. These inadequate sero-conversion rates and the fact that the antibody response from vaccinated animals cannot

be distinguished from naturally infected animals make vaccination problematic (Artois et al., 2002).

Targeted hunting where the young wild boar are selectively shot reduces the number of animals that are naïve and therefore can get infected have reduced the transfer of disease (Laddomada, 2000; Anonymous, 2002). At the end of the hunting period also young adult females should be hunted to reduce the overall population.

For the dissemination of CSF in wild boar populations the presence of wild boar that die while virus positive will be an important factor to infest the disease as dead animals are usually eaten by wild boar. CSFV is a rather stable virus when kept in proteinaceous materials such as blood or tissues. Depending on the initial virus load CSFV may stay infectious at room temperature for several weeks if it is kept shaded from direct sunlight. Heat inactivation of CSFV requires more than 60 degrees for several hours (Edwards, 2000), so in the natural habitat of wild boar virus may remain infective for long periods in pork tissues or carcasses from dead wild boar. To reduce the risk the hygienic measures must be inforced in areas where CSFV is endemic in wild boar (Laddomada, 2000); carcasses from shot wild boar will be found rapidly by other wild boar if they are left in the forests.

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14.4 Disease spreading within an infected wild boar population – model assumptions

Modelling Wild Boars and Classical Swine Fever Infection

The simulation model applied in WILDRISK-project

Parameters and Rules

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14.4.1. Parameterisation of the WildBoarVirus Model

Parameter Identifier	Default	Explanation
CONST_timestep	52	Weeks per year
CONST_dimX; CONST_dimY	200	SimArea max 255
Boar biology		
CONST_TimeOfSplit	28	Week if split is checked
CONST_MaxSubFemalesForNoSplit	1	If 2 or more, split starts
CONST_RadiusFemDisp	3	Radius of movement
CONST_TimeStillPiglet	34	Piglet: week 0-34
CONST_TimeStillYearling	2 years	Sub-Adult: week 35-104
CONST_MaxAge	11	Maximum Age
CONST_SurvivalAdultMean	0.64	
CONST_SurvivalAdultStd	0.24	
CONST_SurvivalAdultMinAllowed	0.28	
CONST_SurvivalYearlg	0.65	
CONST_SurvivalPigletMean	0.48	
CONST_SurvivalPigletStd	0.37	
CONST_SurvivalPigletMinAllowed	0.1	
CONST_Repro	Array[1..52]	Weekly Gestation Rate
CSF epidemiology		
CONST_ImmunePigletsDueToMatAnt	12	Weeks Piglets Immune by MABs (but see PAR_tmatant)
CONST_ProbOfPrenatalInfection	0.5	Prob.of Prenatal Infections
CONST_EndOfInfectiousPeriode	1	Duration of Infectious Period if Boar survives
CONST_EndOfLatentPeriode	1 + 3	Weeks until Immune Response established
CONST_FertilityReductionIfIll	10/16	
Technicals		
CONST_IniPopStru (38,24,15,9,6,3,2,1,1,1,0)	Array[1..11]	Initial % per age-class
CONST_normdistmean3dot5sd1dot5 (0.01,0.07,0.16,0.25,0.25,0.16,0.07, 0.02,<0.01,<0.01,<0.01)	Array[0..10]	Prob. Distribution of Litter Sizes

14.4.2. Variables (with Defaults) of the WildBoarVirus Model

Identifier	Meaning	Default	Val
PAR_tmatant	Existence of maternal antibodies in weeks (<u>piglet not necessarily immune!!!</u>)	CONDEF_TimeMABexist	52
PAR_transient	Proportion of all infections with lethal course (virulenceA)	CONDEF_ProportionNotTransients	0.2
PAR_maxlethal	Max weeks of chronic infected until dead (virulenceB)	CONDEF_MaxSurvOfLethalInfected	22
PAR_expo	Steepness of mortality after infection (virulenceC)	CONDEF_VirulenceExponent	1
SIMPAR_beta	Within group probability of transmission per week	CONDEF_Inf_prob	0.5
SIMPAR_between	Between group probability of transmission per week Percentage of SIMPAR_beta	CONDEF_Inf_prob_beetwHerds	10%
SIMPAR_splitrad	Search radius of sub-adult groups in cells	CONDEF_SplitRadFemales	3
SIMPAR_virrel	Actual week of initial infection	CONDEF_TimeOfvirrel	273; 300

14.4.3. The simulation run comprises:

Initialisation:

IniPopulation

Timestep:

A:

  1. Week of every year (year defined by *CONST_timestep = 52*):

      Age-dependent mortality adjusted by annually varying stochastic component

      See: **ReadYearlyParameters**

B:

  Exactly one time (SIM_virrel) virus release:

Inivirus(*CONDEF_HerdsToInfect*)

  //vaccination 2 months after infection:

Vaccination

C:

  //----Regular pop biology per timestep

  Reproduction: **Reproduction**

  Disease transmission: **Infection**

  Natural mortality: **Death**

  28. Week of every year: **SplitFemales**

  Aging boars and infection: **Update**

  PopulationCensus: **CountIndividuals**

D:

  Write results and Refresh Graphics

E:

 //----Stop the program---------

  If either Boars or Virus went extinct

14.4.4. Reproduction

Parameter: ***LocalBreedingDensity***
          CONST_repro [1…52]
          CONST_PigletsMean := 3.5; CONST_PigletsStddev := 1.5

INPUT:
    Breeding Capacity Regression on Forest Coverage
    Seasonal Distribution of Fecundity
    Litter-size Distribution

Each sow can breed only once per year. The number of sows breeding per group is determined by the local habitat quality. The quality gives the maximum number of sows their successful breed is supported (breeding capacity). Older sows breed first. Breeding capacity is derived from density forecast following Jedrzejewska et al (1994) who found for boar density in Polish forests the relation:

    Individual Density = ForestCover * (0.76 + 0.05*%DecidiousForest)

Remove all piglets and males from the expected individuals:
    Breeding density = Individual density * 0.66(no piglets) * 0.5(no males)

Proportion of sows breeding over time (***CONST_repro*** [1…52])

0.06	0.1	0.23	0.34	0.07	0.08	0.06	0.03	0.03	0
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct+Nov+Dec

If a sow reproduces THIS week the number of piglets is drawn from a cut Normal distribution $N_{cut}(3.5,1.5)$ (***CONST_PigletsMean := 3.5; CONST_PigletsStddev := 1.5***)

Pigs	0	1	2	3	4	5	6	7	8	9	10
Prob	0,01	0,07	0,16	0,25	0,25	0,16	0,07	0,02	0,009	0,0009	0,0001
Cum	0,01	0,08	0,24	0,49	0,74	0,90	0,97	0,99	0,999	0,9999	1

14.4.5. Infection

Parameter:

CONST_ImmunePigletsDueToMatAnt	*:=*	*12*	
CONST_probofprenatalinfection	*:=*	*0.5*	
CONST_endofinfectiousperiode	*:=*	*1*	
CONST_endoflatentperiode	*:=*	*1 + 3 weeks*	
CONST_fertilityreductionifill	*:=*	*10/16*	

Infection is reported via the following individual states:

Susceptible   healthy animal

Immune   With AB either MAB, survived infection or after vaccination

Transient   Surviver - CONST_endofinfectiousperiode weeks shedder, until
               CONST_endoflatentperiode not-shedder but not yet immune

Lethal   Eventually dying from infection

Lethalweek of an individual infected is defined by virulence, as it is the ratio Transient vs. Lethal (PAR_transient, PAR_maxlethal, PAR_expo)

Formula defining Lethalweek after a Lethal infection occurred:

   Lethalweek = 1 + Integer(PAR_maxlethal * {1 - (rand[0..1] ^ (1/PAR_expo))})

If the individual gets infected either by group member or from a neighbouring group:

 MAB positive   Result: infected "viremic"
                                   shedding 1 week (i.e. corresponds transient)

 MAB negative   Result: infected - …

   According to PAR_transient the infections is either transient or lethal
        piglets ==> more often lethal; yearling ==> medium; adult ==> less often
i.e.
piglet: square(PAR_transient); yearling: PAR_transient; adult: sq.root(PAR_transient)

14.4.6. Death

Parameter: *CONST_maxage*   *: =*   *11 years*
                     CONST_survivaladultmean   *:=*   *0.64*
                     CONST_survivaladultstd   *:=*   *0.24*
                     CONST_survivaladultminallowed   *:=*   *0.28*
                     CONST_survivalyearlg   *:=*   *0.65*
                     CONST_survivalpigletmean   *:=*   *0.48*
                     CONST_survivalpigletstd   *:=*   *0.37*
                     CONST_survivalpigletminallowed   *:=*   *0.1*

Operating weekly mortality := 1- 52nd Root of annual survival

INPUT:
Adults: Focardi et al.: survival: mean: 0.64; stddev: 0.24
Yearlings: Focardi et al.: survival: 0.65
Piglets: Focardi et al.: survival: mean: 0.48; stddev: 0.37

ReadYearlyParameters
Determine annual stochastic deviation of the mean from observed value
Annual survival THIS year drawn from:
InvNormal(mean,stddev) Cutted below Minimum
Expert opinion: Highly "erratic" population dynamics due to mast years etc.

14.4.7. SplitFemales – The dispersal of subadult females

Parameter: *CONST_timeofsplit*   :=   *week 28*
          CONST_radiusfemdisp   :=   *3 cells*
    CONST_maxSubFemalesForNoSplit1   :=   *1*

Always at week 28 each herd is checked whether there are at least two sub-adults AND the total number of females exceeds the habitat capacity (i.e. not all females would be able to reproduce). If so, then the neighbourhood of the group defined by a maximum search radius is scanned for empty habitat cells and the sub-adult group is moved together into one of these randomly (uniformly distributed, no distance no quality aspect). If no free space is available the group of sub-adults remains in (i.e. returns back to) the maternal group.
Expert opinion: All sub-adults of a group move together if split occurs. Single sub-adults do not disperse. Majority of movements are less then 6km.

14.4.8. Update – Aging of Individuals and Infections

Parameter: *CONST_timestillpiglet*   :=   *34 weeks*
          CONST_timestillyearling   :=   *104 weeks*

Boars age by one week and are counted into age-classes: Piglets 0-34; Yearlings 35-104; Adults: all above.

If an individual is infected the infection state changes according to the following rules:
If susceptible :: remains susceptible until Death or infection
If **immune** ::
   AND **piglet of age CONST_ImmunePigletsDueToMatAnt**
               Result: Susceptible + but MAB$^+$
   AND **piglet of age PAR_tmatant**
               Result: Susceptible + MAB$^-$
If **transient** ::
   AND **was infectious for CONST_endofinfectiousperiode weeks**
   AND **was infectious+non-infectious for CONST_endoflatentperiode weeks**
               Result: Immune
If lethal :: remains infectious until Death

14.4.9. Wild boar population model parameters

	Published value Without hunting	With hunting	symbol
Demographic model			
Carrying capacity of females in group home range (4 km² or without dimension)	40 (ca. 20 females + piglets) [1]	5-10	CC_G
Density [boar/km²]		3 [13], 5 [16]	
HR males (solitary living)			
Maximum age	11 [3]	9 (females), 6 (males) [2]; 4 [3]	
Reproduction rate (= prob. of giving birth)	General: 0.11-0.9 [3] Year 1 (older than 8 months): 30.3%, sd 21.8 [8] Year 2: 69.8%, sd 17.4 [8] Older: 85.8%, sd 16.9 [8]		P_{birth}
Number of piglets per female	3.2, sd 1.68 [1]; 1.5-4.5 [3]; 4.95, se 0.42 (14) 6, sd 2 (15)		N_{piglet}
Sex ratio of piglets	1:1 [2][5]		$ratio_s$
Survival rate of piglets in first 3 months		0.75-0.85 [2] (i.e. mort 15-25%)	
Survival rates of piglets	0.48, sd 0.37 [1]	0.60-0.65 [7]	SR_{piglet}
Survival rate of yearlings ("Überläufer")	0.65 [7]	< 0.5 [2]; 0.26-0.47 [7]	$SR_{yearling}$
Survival rates of adults	0.64, sd 0.24 [1]	0.38 (males), 0.2 (females) [7]	SR_{adult}
Net daily dispersal distances of young males	mean = 8 km, max = 17 km [2] mean = 7 km [6]	mean 3.4 sd 2, max 11.4 [12]	d_{netm}
Seasonal distances of young males		12-250 km [3] up to 300 km [4] 5-23 km [11], mean 7,4 [12] 67% resident [12]	$d_{seasonm}$
Dispersal distances of female group		Up to 100 km [2] max 10 km [10] but rare! [11] 85% resident (bis 3km), 2 sows 6.4 to 13.2 km [12]	d_{group}

[1] (Focardi et al. 1996), [2] (Stubbe et al. 1989), [3] (Jezierski 1977), [4] (Spitz and Janeau 1990), [5] (Boisaubert and Klein 1984), [6] (Janeau and Spitz 1984), [7] (Gaillard et al. 1987), [8] (Ahrens 1984), 9 (Vassant et al. 1988), 10 (Sodeikat and Pohlmeyer 2002) 11 (Sodeikat and Pohlmeyer 2003b) 12 (Sodeikat and Pohlmeyer 2003a) 13 (Zanardi et al. 2003) 14 (Boitani et al. 1995) 15 (Ahmad et al. 1995) 16 (Howells and Edward-Jones 1997)

14.5 Transmission of CSFV through garbage to wild boar -original

The infected garbage route

Wild boar are omnivorous and feed on items that are easy accessible. Therefore it is likely that they would eat meat remnants left in nature or in a dumpster. Hereby, infected meat might result in transmission of CSF virus to a wild boar. The problem occurs because CSF virus is stable in fresh meat and meat products that have not undergone heat-treatment. Meat products like ham and dry-cured sausages that can be kept for long-time periods are of particular interest as they can be highly contagious for weeks or months. A detailed description of virus survival in meat is given in section 4.

One way of introducing CSF to a Danish wild boar population could be through contaminated meat products left accessible to wild boars. The meat could be brought here and left by e.g. foreign tourists, truck drivers or Danes returning from vacation abroad. However, no data exist regarding the probability of tourists or truck drivers bringing in their own food and leaving remnants behind. And likewise no data on Danes returning from vacations abroad exists.

The pathway illegally imported meat has received increased attention. In 2004, the Danish Veterinary and Food Administration carried out a campaign in cooperation with the customs, the tax authorities, and the police from September to December 2004. The task was to prevent illegal import of foodstuffs. The findings were surprisingly large and approximately 12 tons of illegally imported meat where seized and destroyed. This was mainly meat from chicken, turkey, duck and lamb (Rosenørn, E, personal comment, 2005). These types of meat do not constitute a risk in relation to CSF, which only involves pigs and pork. Meat from pigs was only found in processed products. These could of course constitute a risk of bringing in CSF but due to limited knowledge of the findings these are not included in the further analysis.

Therefore foreign tourists are used in the further analysis and the risk of transmission through garbage is then illustrated by the risk of transmission through tourists. In order to investigate this risk it is necessary to obtain information on tourist behaviour and on the habitats of the wild boar.

The probability of CSF infection originating from meat left in nature consists of:
1) The probability that the meat in a meat product is infectious,
2) The probability leftovers are dropped in nature,
3) The probability that a wild boar finds it and eats it and
4) The probability that the wild boar is subsequently infected.

All these 4 probabilities should be multiplied together.

However, we cannot estimate the probabilities of the meat being infected, and neither that a wild boar is subsequently infected, and therefore we cannot calculate the full probability that a CSF infection in wild boars will occur from eating meat. But the probability of the meat being dropped and the probability that it is then eaten by a wild boar can be estimated, relative between the Danish counties: The theoretical probability of meat left in nature is approximately proportional to the number of stays in the county, since each stay is assumed to produce the same number of meat product leftovers. For modifications for stays at hotels, hostels and Holliday centers, see later in this section. The probability of this meat being eaten by wild boars is similarly approximately proportional to the density of wild boars. It turns out that when calculating the relative risk of infection between counties (ie. what is the probability

of having an infection in county i_0, given that an infection has occurred from tourists somewhere in Denmark), all factors except these two cancels out, and the probability is therefore estimable. This way, it is possible to estimate the relative risk of infection in counties, thus identifying the areas where an infection is most likely to occur, and similarly to compare the risk from tourists in counties where the percentage of suitable boar habitats are close to each other, suggesting equal opportunities for wild boars.

Data about tourists in Denmark and legal background for registration

The data available to estimate the risk of tourists exposing and subsequently infecting a Danish wild boar with CSFV originates from Statistics Denmark, who registers "bed nights spend" on the different types of stay, time period, county and nationality of tourist. The Danish Tourist Board publishes this data on the internet. Data to use in this section were obtained from Statistics Denmark (extracted of June 28, 2004 from the Danish Tourist Board; see www.danskturisme.dk).

There are some limitations in the data since length of stay is not registered and therefore there is no direct knowledge of the number if stays. The recorded tourist nationality is shown in table 14.5.1. The exact nationality is not recorded for all tourists; some are grouped into rather broad categories (e.g. "Other south-east Asian countries"). It is not possible to include tourists from these countries since we do not know whether they come from a country with reported CSF or one without. There is also no knowledge at all about the travel routes used by tourists who comes to Denmark. Therefore, we chose to include tourists who come from countries that have reported CSF to OIE during the last decade (1994-2003) in either wild boar or domestic pigs as an illustration of who could bring in contaminated meat in a future situation where an outbreak unknowingly has occurred abroad and free-range wild boar are present in Denmark. Therefore, tourists from Germany, United Kingdom, The Netherlands, Belgium, France, Italy, Spain, Austria, Switzerland, and Poland were included.

CSF may occur in many other countries as reports from the OIE does not imply the presence of future outbreaks, nor does no reports to the OIE imply that no outbreaks will take place in the future. No reports to the OIE only imply that the disease has not been discovered. The estimated exposure of a Danish wild boar population to CSF due to tourists might change if we had had more exact knowledge of disease status of the countries of origin of all tourists. But since tourists from the countries included in our analysis accounts for 74% of all tourists, such a change will probably be minor, and we consider the included countries as our best guess of a tourist stream from countries that are potentially infected. However, if all tourists travelling to Denmark were included, the resulting ranking of counties according to their relative risk would differ for what regards the county that are most likely to harbour any given outbreak. Then the highest relative risk is found in the north-eastern part of Zealand (København, Frederiksborg and Roskilde). This is because the north-eastern part of Zealand is visited by a lot of tourists but they mainly stay in hotels, which as discussed further on in this section, is believed to constitute a lower risk of bringing in contaminated food.

The Danish Tourist Board has made an analysis on business and pleasure travels. The results are based on 28,858 interviews with travellers in Denmark (Danmarks Turistråd, 1998), and to sum up:

1. The tourists come to Denmark mainly because of the nature
2. The most bed night where spend at camping grounds or in summer cottages
3. They come in small groups of 1-4 persons
4. They stay for 4-12 night

The fact that the nature was the most important reason to come to Denmark is also an argument that the CSF infection of Danish wild boars by garbage cannot be ruled out. In a subsequent report from The Danish Tourist Board (Danmarks Turistråd, 2000) camping was investigated in further details. The picture was similar to the result of the first. Both of these investigations showed that Germans were the largest group of tourists and table 14.5.1 shows that this is still the case in 2003.

It is compulsory for hotels, motels, inns, holiday centres, and pensions (with >40 beds) and camping grounds (with >75 camping units) to report bed night spent to Statistics Denmark. A bed night equals one person in one night (Departmental order nr. 595 of June 22, 2000). The majority of youth hostels also have to report bed night spent to Statistics Denmark. The larger bureaus renting out summer cottages (with >25 cottages) also report bed night spent. These hold about 80% of the market (www.dst.dk/vejviser). It is voluntarily for harbours to report visits by yachts/pleasure boats. There is a high response rates for the different categories are (in general >90%). This means that the data provides a reliable estimate of what tourism in Denmark looks like (Brandt, C.Ø, personal comment, 2004).

Table 14.5.1 Distribution of bed nights spent by foreign tourists in Denmark in 2003.

Nationality	Bed nights spent	Percentage
Sweden	2,084,523	9.1
Norway	2,346,351	10.2
Finland	138,522	0.6
Germany*	14,859,398	64.6
United Kingdom*	492,069	2.1
The Netherlands*	1,047,099	4.6
Belgium*	70,187	0.3
France*	124,99:	0.5
Italy*	195,650	0.9
Spain*	77,768	0.3
Austria*	29,360	0.1
Switzerland*	91,427	0.4
Poland*	63,377	0.3
Other European countries	321,788	1.4
USA	311,429	1.4
Canada	33,862	0.2
Other American countries	24,903	0.1
Japan	96,848	0.4
Other Southeast Asian countries	85,222	0.4
Other countries	519,060	2.3
Total	23,013,835	100.00

* Countries that has reported CSF to OIE in the period 1994 till 2003.

Calculation of the risk associated with tourists

Table 14.5.1 shows the sum of bed nights spend in hotels, holiday centres, hostels, camping grounds and in summer cottages on all tourists in the different Danish counties. Whether tourists bring in food depends on the type of stay: It is not likely that tourists staying at hotels bring food since they would have no cooking facilities and since the point of staying at hotels is to have a high level of comfort. Hostels are very similar to hotels. Often with half board included and visitors are comparable with hotel visitors (Danmarks Turistråd, 1998). At Holiday centres facilities like restaurants is present but each apartment also has it own kitchen.

This means that visitors might bring their own food. Visitors to summer cottages and camping grounds are likely to bring food since this type of holiday normally includes cooking your own dinner.

CSF may occur in many other countries as reports from the OIE does not imply the presence of future outbreaks, nor does no reports to the OIE imply that no outbreaks will take place in the future. No reports to the OIE only imply that the disease has not been discovered. The estimated exposure of a Danish wild boar population to CSF due to tourists might change if we had had more exact knowledge of disease status of the countries of origin of all tourists. But since tourists from the countries included in our analysis accounts for 74% of all tourists, such a change will probably be minor, and we consider the included countries as our best guess of a tourist stream from countries that are potentially infected. However, if all tourists travelling to Denmark were included, the resulting ranking of counties according to their relative risk would differ for what regards the 3 counties that are most likely to harbour any given outbreak.

It is not likely that tourists will bring food for the whole holiday but only for the first few days. The figure "bed nights spend" does not say anything about how many tourists are coming and for how long they stay. The figure "number of stays" would overcome this problem and equal one stay to one chance of CSF exposure. This figure can be estimated by using the figure "mean number of bednights pr stay" (Danmarks Turistråd, 1998), and divide the number of bed nights by this. Since the figures about tourism are almost the same in 1998 and 2003 (Danmarks Turistråd, 1998, www.danskturisme.dk on 2004-09-10) the mean from 1998 was used on the actual figures in 2003. The information on the tourists was compared with the calculated density of wild boars in the county.

The proportional risk of infection in any county was determined by the following equation:

$$14.5.a \quad PR = \frac{P(\text{infection occurs in county}_{i0})}{\sum P(\text{infection occurs in county}_i)} = \frac{E_i}{\sum_i E_i}$$

That is, the relative risk is the probability that infection occurs in county i_0, relative to that infection occurs at all. The Probability that infection occurs is approximately proportional to the risk measure **E**, with the coefficient of proportionality being independent of the particular county considered. Therefore, they cancel out in formula 14.5.a, and we can therefore replace the probabilities in formula 14.5.a by the corresponding measures of exposure, ie.

$$14.5.b \quad E_i = \sum_j \left(\frac{B_{ij}}{S_j} \right) \times F_j \times D_i$$

Where E_i is the exposure in county i,
B is the sum of bed nights spend in stay type j in county i,
S is the mean length of stay in stay type j,
F is the factor used to assess the risk of the type of stay, according to the probability of a tourist bringing in food from his/her native country or from a country that he/she travelled through on the way to Denmark and leaving it accessible to wild boars
And D is the estimated wild boar density in county i.

The wild boar density is estimated by formula 14.5.c.

$$14.5.c. \quad D_i = \frac{W_i}{A_i} \times CC$$

Where D is density of wild boars in county i,
W is the estimated habitat for wild boars in county i (see section 5.2),
A is the total area of county i
and CC is the carrying capacity for the wild boar population

The result of formula 14.5.b leads to table 14.5.2. Regarding the carrying capacity section 5.1 recommends 1 to 5 animals pr. km^2 is for modelling purposes. In this section 2.5 animals pr. km^2 is used to calculate the density of wild boars.

Table 14.5.2. The relative risk of infection with Classical swine fever virus associated with tourism - by county and type of stay in Denmark, 2003

County		wild boar density (animals/km^2)	Type of stay					Proportional Risk	Relative Risk
			Hotel	Holiday centre	Hostel	Camping	Summer Cottage		
	Mean length of stay(nights)		3.8	4.7	5.6	11.9	10.9		
	Relative risk factor		0.01	0.2	0.01	1.0	1.0		
	København	0.28	2,475	575	105	10,199	13,028	0.03	1.0
	Frederiksborg								
	Roskilde								
	Vestsjælland	0.19	54	6,198	17	10,449	58,716	0.06	2.0
	Storstrøm								
	Bornholm	*	225	1,595	6	7,844	36,514	*	*
	Fyn	0.10	115	1,160	17	21,739	52,110	0.03	1.0
	Sønderjylland	0.11	61	3,286	27	61,349	103,670	0.07	2.3
	Ribe	0.21	170	4,947	16	48,431	272,477	0.27	9.0
	Ringkøbing	0.23	60	2,985	7	23,180	283,578	0.29	9.7
	Vejle	0.27	358	1,726	32	11,560	71,835	0.09	3.0
	Århus								
	Viborg	0.20	37	660	5	5,898	52,385	0.05	1.7
	Nordjylland	0.16	155	4,078	16	29,472	150,826	0.12	4.0

*: The suitable wild boar habitat on Bornholm was not estimated

It is seen that the relative risk of exposure is greatest in the two counties that make up the western part of Jutland (Ribe RR=9.0; Ringkøbing RR=9.7) and the northern part of Jutland (Nordjylland RR=4.0) compared to Copenhagen, Frederiksborg and Roskilde that make up North and Eastzealand (RR=1). The latter was used as a comparison. In Nordjylland and Ringkøbing there are many tourists and rather large possible habitats. In Ribe the possible habitat is smaller but this is where the highest number of bednights in summer cottages and at camping grounds is spent. This is illustrated in Figure 14.5.1.
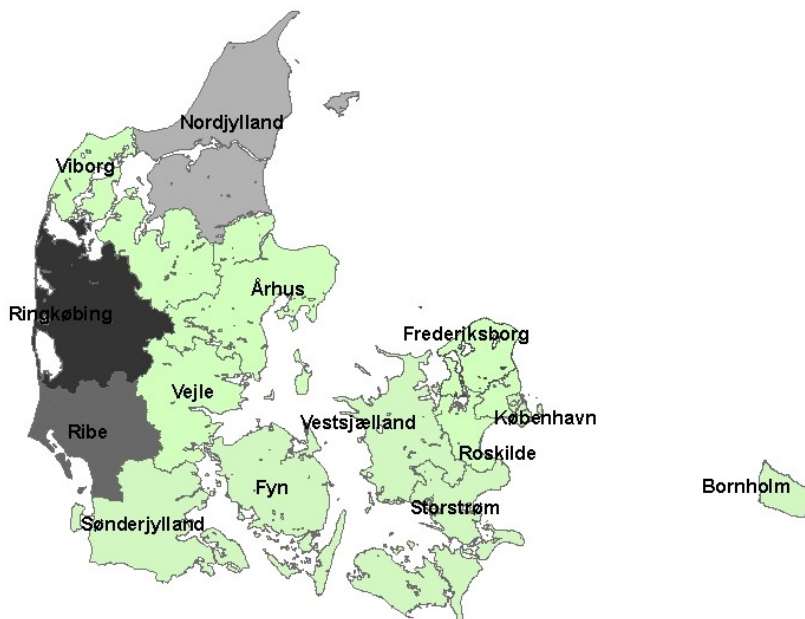
Figure 14.5.1. Geographical representation of the relative risk of tourists infecting wild boar with CSFV, by counties in Denmark. The darker the colour, the higher is the risk.

Seasonality

The yearly variation should also been taken into consideration. In the autumn (cf. section 5.1) the pigs are more actively migrating, because the young boar is leaving the family group. This means that there is a larger probability of contact to contaminated garbage during this period, this could be compensated by the lower intensity of tourism during this season, but it should be taken into account that virus can survive for app. 1 – 2 months in e.g. sausages and salamis (Bronsvoort et al., 2004) meaning that food left in late summer could be still infectious in autumn. We have chosen not to include these factors in out analysis, as the data available are already coarse, and modeling in the detail described above might lead to claiming an accuracy that is misleading.

> **Conclusion on the CSF-exposure to wild boars by garbage**
>
> Wild boar is likely to include easy accessible garbage in their diet, and meat remnants can contain CSFV for longer time periods. CSFV-contaminated meat can be brought in by e.g. tourists and leftovers left accessible to wild boar. Tourists from countries that have had CSF during the most recent decade were used to illustrate who might bring in contaminated food. The likelihood of bringing in food also depends on the type of the stay. The types of stays that were considered to constitute the highest risk are stays at camping grounds and in summer cottages. The wild boar habitat size in a county were also incorporated by multiplying with the expected wild boar density (animals per km^2). The relative risk of exposure was greatest in the two counties that make up the western part of Jutland (Ribe and Ringkøbing). The risk in these counties was 9-10 times the risk in North and East Zealand that had the lowest risk. The northern part of Jutland (Northern Jutland) had the third highest risk (4 times the risk in North and East Zealand).

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14.6 InterSpreadPlus – model assumptions

The InterSpreadPlus software programme was used to model the spread of CSF between domestic pig herds and wild boar. The scenarios that were run are presented in Table 14.6.1.

Table 14.6.1. Description of scenarios used in simulations of spread of Classical swine fever in Denmark with and without the presence of wild boar

Description of scenario	Name of scenario
Index case a domestic herd situated in Northern Jutland 0.5km from the wild boar habitat in Rold Forest. Control strategy for wild boar is separation and shooting.	Rold
As Rold scenario but without free-range wild boar in the model.	RoldNoWild
Index case a domestic herd situated 5km from the wild boar habitat in Rold forest. Control strategy for wild boar is separation and shooting.	Rold5km
As Rold5km scenario but without free-range wild boar in the model.	Rold5kmNoWild
As Rold scenario but with vaccination as the control strategy for wild boar instead of shooting	RoldVacc
As Rold scenario but with no control strategy for wild boar	NoWildControl
Index case a group of wild boar in the forests near Silkeborg. Control strategy for wild boar is separation and shooting	WildStart
As WildStart scenario but with vaccination as control strategy for wild boar	WildStartVacc
As WildStart scenario but with no control strategy for wild boar	WildStartNWC
As NoWildControl scenario but with probability of contacts between wild boar and domestic pigs modelled as a Poisson distribution with a lambda of 0.2 instead of 0.1	Poisson02_NWC
As NoWildControl scenario but with probability of contacts between wild boar and domestic pigs modelled as a Poisson distribution with a lambda of 0.05 instead of 0.1	Poisson005_NWC
As NoWildControl scenario but with probability of contacts between wild boar groups modelled as a Poisson distribution with a lambda of 0.4 instead of 0.5	Wild-Wild04_NWC
As NoWildControl scenario but with probability of contacts between wild boar groups modelled as a Poisson distribution with a lambda of 0.6 instead of 0.5	Wild-Wild06_NWC
As basic scenario, but with lower risk of transferring CSFV from wild boar to domestic pigs due to fencing of all domestic swine herds within 16km of free-range wild boar habitats (probability of transmission changed from 0.27 to 0.1 or from 0.027 to 0.01)	Fence01
As basic scenario, but with lower risk of transferring CSFV from wild boar to domestic pigs due to fencing of all free-range domestic swine herds within 16km of wild boar habitats (probability of transmission changed from 0.27 to 0.1)	FenceFree01
As basic scenario, but with higher risk of transferring CSFV (probability of transmission changed from 0.27 to 0.5 and from 0.027 to 0.05)	Transmission05

Scenarios marked in grey are scenarios without wild boar – used as comparison

Information on herd level

The simulations were based on the herd data collected in one file. This farm file consisted of the following:

- A unique herd-ID number
- Class defining production type (breeding station, boar station, free-range pigs, organic, production, 7-30-kg production)
- Class defining herd size (see Table 14.6.2)
- Class defining herd status – SPF or conventional
- The number of animals in the herd
- Movement data for each herd (weaners, sows and finishers, respectively)

Most of this information was collected from the CHR except from information on movements, which was found in the movement database. The size-related category was created from the criteria described in Table 14.4.2.

Table 14.5.2. Description of size-related categories used in simulations of spread of Classical swine fever

Category	Sows	Finishers
1	100-199	<500
2	>=200	<1000
3	>=5 finishers per sow	
4	<20	
5	<100	<20
99	0	

These categories were used to group the herds according to how often they sell weaners, or if they sell or buy pigs from markets. Category 1 and 2 typically only receive pigs from breeding herds, while category 3 and finisher herds (99) receive pigs from other production herds. All categories sell pigs to markets, while only category 3 and 4 and finisher herds purchase pigs from markets (this information is found from extracts from the movement database).

No real data exists for the wild boar. We therefore created two fictive wild boar populations, one in Rold Forest and one in a forest near Silkeborg. The reason for selecting these areas was that they offer a large coherent suitable habitat. A 2x2km^2 grid was placed on top of the map of the two areas, and the coordinates for each corner of each cell were registered as the "wild boar family" coordinates. The number of animals in the cell was set by the author to be 4 sows with offspring for a cell with only forest, 2 sows with offspring if 50% of the cell was covered by forest, and so on (please see section 14.1).

Epidemic history

This file describes the first case (index case). There was an option also to let the model pick a random index case, but in order to compare different scenarios and to be sure that a farm close to the wild boar gets infected, we chose to randomly pick a farm in the area around the wild boar.

The index case was described as infected on day 1, showing clinical signs on day 7, and detected at day 42. We chose to run with the same settings no matter which farm was chosen as the index case. The 42 days was chosen as a worst case scenario, as this was the time that

past before the first case was diagnosed in the Netherlands in 1997 (Elbers et al., 1999). The seven days between infection and clinical signs was based on Uttenthal et al. (2003).

Movement files
Twelve movement types were described in twelve different movement files.

Movement of weaners (movement type 1)
A Poisson distribution described the number of movements of weaners from each farm. Lambda was calculated as the average daily number of movements to other farms (based on information in the movement database). For each farm, the lambda was registered in the farm file. Of the 18,000 herds in the CHR, only approximately 4,000 moved weaners.

The distance for each movement was drawn from a distribution. This distribution was calculated as direct lines for this specific type of movement from the movement database. If the model did not find a farm within the distance drawn, it was allowed to retry 1000 times (assuming that if a farm produces weaners, they will have to be sold as there is not capacity to keep them until slaughter)

The probability of transmission of classical swine fever virus (CSFV) was set to 0.277 based on a simulation of the epidemic in the Netherlands (Mangen, 2002).

Based on data from the movement database, restrictions were made on which herd types can deliver weaners to which herd types. For example, the likelihood of an SPF herd receiving weaners from a conventional herd was small.

Movement of finishers (movement type 2)
The collecting of finishers for the abattoir was described as a fixed route. The length of the route was modelled as a probability distribution based on data from the movement database. The maximum length of the route was set to 150km, and the route was travelled every seventh day.

Movement of sows (movement type 3)
A Poisson distribution was created the same way as for weaners. The risk of transmitting CSFV was the same as for weaners.

Only breeding herds were modelled to move sows. The differentiation between sows and weaners was due to the difference in the distance the animals are moved. Sows from breeding herds are moved further than weaners. Sows that eventually are moved from production herds were modelled as weaners, assuming that sows from this herd type will only be moved for short distances (the same distance as weaners).

Movements from and to markets (Movement types 4 and 5)
All farm types can move pigs to markets but with varying probabilities. However, only smaller herds and herds with mostly finishers (category 3, 4 and 5) will purchase pigs from markets (based on data from movement database). Also the distance of movements to and from markets was calculated from the movement database. The number of movements to and from markets was calculated as an average for each herd type and this average was used as lambda in a poisson distribution.

People as carriers (movement types 6 and 7)
People can act as carriers of the virus between farms. The model operated with medium and low risk persons. Persons with a medium risk are persons going from one farm to another,

such as veterinarians etc. Persons with a low risk are persons visiting only one herd. This person type would normally not pose a risk, but due to the fact that they might have been in contact with pigs earlier the same day, they were still counted as a risk, albeit a low risk. Both contact types were modelled as poisson distributions, but here the same distribution was used for all herd types. The lambdas in these distributions were calculated from a study from 1999-2000 in which the biosecurity of 226 herds was investigated (Boklund et al., 2004).

Migration of wild boar (movement types 8, 9, 10, 11 and 12)

As mentioned, we have no data on wild boar – neither on their contacts with each other or with domestic pigs. Nor in the literature is anything written about these contacts.

We therefore modelled contacts between wild boar and free ranging herds (movement type 8) and between wild boar and indoor herds (movement type 9) by the same poisson distribution In the basic scenarios we used a Poisson distribution with lambda 0.1 for the contact between wild boar and indoor domestic pigs as well as for the contact between wild boar and free ranging pigs. In the scenarios Poisson02NWC and Poisson005NWC we changed the lambda in the distribution in order to see how influential this parameter was. The results were not sensitive to these changes in lambda.

Contact between groups of wild boar (movement type 10) was modelled as a poisson distribution with lambda 0.5.

The contact from wild boar to domestic pigs is not the same as from domestic pigs to wild boar. The model will only simulate movements from infected herds, and therefore if a domestic herd is infected, we will have to model a movement from the domestic herd to a wild boar group (movement type 11 (free ranging) and movement type 12 (indoor)) even though the contact will in reality be the other way around. The probability of a contact from a wild boar to a specific domestic herd will differ with the herd density in the area. Still, we used the same Poisson distribution for the contact from domestic pigs to wild boar as for the contact from wild boar to domestic pigs. As the scenarios Poisson02NWC and Poisson005NWC did not show a significant change in the outputs when the parameter in the poisson distributions was changed the results did not seem to be sensitive to the choice of distribution function.

The distance of contacts between domestic herds and wild boar, and vice versa, was based on the literature review carried out by Asferg and ranges from 1-16km.

The risk of transmitting CSFV from wild boar to domestic pigs will probably be much higher in outdoor pig herds than in indoor herds. We assumed that wild boar would climb any fence if they smell sows in heat, and accordingly, for free-range herds we used the same probability for transmission of the virus from wild boar as if the herd purchased pigs (0.277). For indoor herds we reduced the risk by a factor ten. The risk of the wild boar entering an indoor herd must be very small, but still, after the wild boar has circled around the buildings all night, there will be a risk that the virus is carried into the herd by rats, mice, humans etc.

From the contact group there was a desire to look at changes in the epidemic if domestic herds were fenced in order to avoid contact with wild boar. This was simulated by reducing the probability of transmitting CSFV, assuming that the wild boar would still be attracted to the domestic herds (scenarios Fence01 and FenceFree01).

Local spread

The virus was modelled to spread within 2km from the infected herd based on data from the Netherlands. Within 500 meters, the probability of spread was set to 0.0122, from 500 m to 1km it was 0.004 and up to 2km it was 0.00003 (Mangen, 2002).

Infectivity

The time from infection to clinical signs appear was modelled as a negative binomial distribution with a mean of 28 days. No clinical signs appear before day 7 (Uttenthal et al., 2003).

Controls

The control mechanisms were modelled as surveillance, tracking, depopulation and vaccination in different zones. For domestic pigs, the controls would be the same for all scenarios, while for wild boar the controls would differ between depopulation (separation and shooting), vaccination and nothing.

Domestic pigs:

All detected farms were assumed depopulated as first priority. It is estimated that 15,000 finishers and 3,000 sows can be slaughtered per day, and these resources are shared between all depopulation types.

Traced farms (high-risk contacts) would be depopulated as second, while neighbours within 500 meters would be depopulated as third priority.

Within 3km from a detected farm, all farms would be surveyed for 40 days. Each farm within the 3-km zone would be visited once and have a 0.9 probability of being detected (if infected).

Within a 10-km zone, farms would also be surveyed for 40 days, but here only 10% of the farms are visited and only with a 50% chance of detection.

The time from clinical signs to detection was modelled as the following distribution:

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cumulative probability	0	0	0	0	0	0	0	0.001	0.0056	0.011	0.023	0.039	0.069	0.104	0.142

16	17	18	19	20	21	22	23	24	25	26	27	28
0.188	0.234	0.284	0.334	0.389	0.448	0.503	0.558	0.610	0.661	0.706	0.746	0.782

29	30	31	32	33	34	35	36
0.818	0.853	0.887	0.919	0.943	0.967	0.984	1

The background surveillance was modelled as the chance of detecting an infected herd on a given day, assuming that the herd was not allready detected on an earlier day. We set the probability to 1 on the day 30 - assuming that all herds will be detected.

Day	1	2	3	4	5	6	7	8	9	10
Probability of detecting an infected herd	0	0	0	0	0	0	0	0.1	0.1	0.2

11	12	13	14	15	16	17	18	19	20	21	22

| 0.25 | 0.3 | 0.4 | 0.5 | 0.5 | 0.6 | 0.6 | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 |

23	24	25	26	27	28	29	30
0.85	0.85	0.85	0.90	0.9	0.9	0.95	1

A standstill was modelled for all domestic farms for the first 3 days after detection (72 hours).

Within the 10-km zone 98% of animal movements (not wild boar) would be restricted for 40 days (until the zone is lifted).

No other movements were modelled as restricted.

Contacts would be surveyed depending on the risk posed by the contacts type. All high-risk contacts would be surveyed, but as they are also depopulated this is in reality not necessary. Of the medium risk contacts (professional persons visiting the farm) 30% would be surveyed and there is a 90% chance of detecting the clinical symptoms if present. Of the low risk contacts (non-professionals visiting) only 10% would be surveyed, but still with a 90% chance of recognising the disease if clinical symptoms are present.

Wild boar:

Basic

The basic scenario was modelled with the control strategy for wild boar being separation and shooting all of the population.

This was modelled as a 100-km zone around the infected farm. The 100km were chosen just to be sure that all wild boar groups are included. The model worked with depopulation, which means that a group of animals (a wild boar family group) would be depopulated at a time. In order to simulate that not all wild boar would be depopulated at the same time (it is probably difficult to find them all), the selection probability was set to 0.5.

Vaccination

We modelled that wild boar within a 100-km zone were vaccinated. Again, the selection probability was set to 0.5 illustrating that not all animals would eat the baits. The immunity function was modelled as a function describing that on day 0 (day of vaccination) no immunity would be developed, on day 2, 50% of the vaccinated animals would have developed immunity, on day 9, 75% would have developed immunity and on day 10, 100% would have developed immunity.

No wild boar control

In this scenario no control strategy towards the wild boar is simulated.

References

Please, see section 13.