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Wild boar population growth and expansion – implications for biodiversity, food safety, and animal health in Norway.

Opinion of the Norwegian Scientific Committee for Food and Environment

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Wild boar population growth and expansion in Norway - Implications for biodiversity, food safety and animal health in Norway

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Wild boar population growth and expansion – implications for biodiversity, food safety and animal health in Norway

Preparation of the opinion

The Norwegian Scientific Committee for Food and Environment (Vitenskapskomiteen for mat og miljø, VKM) appointed a project group to answer the requests from the Norwegian Environment Agency and the Norwegian Food Safety Authority. The project group consisted of three members of the VKM Panel on Biological Hazards, two members of the VKM Panel on Alien Organisms and Trade in Endangered Species (CITES), one member of the VKM Panel on Animal Health and Welfare, in addition to one member from Swedish University of Agricultural Sciences, one from Norwegian Institute for Nature Research, and three project leaders from the VKM Secretariat.

One external referee from the University of Veterinary Medicine in Hannover has evaluated and commented on the manuscript. The final report was assessed and approved by an assessment group consisting of three members representing the VKM Panel on Alien Organisms and Trade in Endangered Species (CITES), two members representing the VKM Panel on Biological Hazards, one members representing the VKM Panel on Animal Health and Welfare.

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Competence of VKM experts

Persons working for VKM, either as appointed members of the Committee or as external experts, do this by virtue of their scientific expertise, not as representatives for their employers or third-party interests. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

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Summary

Introduction: In Norway, wild boar is defined as an alien species and is considered by the Norwegian Biodiversity Information Centre (Artsdatabanken) to constitute a high ecological risk. Wild boar is, however, regarded as native in Sweden, and the population there has been rapidly expanding since the 1970s, resulting in influx of animals (about 1000 individuals today) to Norway along the border, particularly in Østfold county.

The establishment of wild boar in Norway has prompted the need for a scientific assessment of the potential for further spread and the environmental- and health risks associated with the species in Norway. The Norwegian Environment Agency and the Norwegian Food Safety Authority appointed a joint request for such an assessment to the Norwegian Scientific Committee for Food and Environment (VKM).

Method: VKM established a working group consisting of experts from Norway and Sweden, representing different fields of expertise including human-, and animal health, epidemiology and ecology to assess the potential impact from further spread and establishment of wild boar in Norway.

The working group has assessed relevant literature and used available data on wild boar occurrences and climate from abroad to model the potential distribution and population densities in Norway, both under current climate conditions and under future climatic scenarios.

The assessment of food safety and animal health considered the impact on food safety and animal health based on the assumption that wild boar is established in Norway, in significant numbers. The evaluation involved all relevant hazards with respect to animal-, and human health.

Results: Norway is currently in a similar situation to Sweden in the early 1980s, with a small population of wild boars mostly confined to one area. Unless drastic measures are implemented to control the population growth and expansion, the population will most likely double every three years, and continue to spread throughout lowland areas along the coast all the way up to Trøndelag.

Our estimates show that, based on climatic factors alone, the total population size could be 220.000 animals under current climatic conditions, which is similar to the present population size in Sweden. However, taking topography and habitat into account, a more realistic maximal carrying capacity is around 40.000 animals, spread out over 70.000km^2.

Under the prediction that temperatures will increase in the next 50 years, we find that there is a potential for increased wild boar population density, due to higher wither-survival rates, and that new areas will become inhabitable.

The ecological impact of wild boar relates to rooting and predation. Predation and herbivory might be detrimental to endangered species, while rooting might alter the structure and dynamics in various plant communities. Positive effects have been shown for early succession ephemeral plants, including alien species, while negative effects are more pronounced for perennials in more stable communities. The available literature does show both positive, negative and no effects of wild boar rooting, depending on the system under study. Wild boar will also have negative effects on agriculture through both rooting of pastures and meadows and seed predation on crops.

Discussion: Based on the experiences from Sweden and other relevant countries, it is obvious that the presence, spreading and establishment of wild boar is tightly linked to human interference. The species natural dispersal is about 2,5 km per year, but translocation of animals for hunting purposes have been widespread in other countries, leading to much longer dispersal distances and establishment of new sub-populations. Also, supplemental feeding have been shown to have a profound effect on the population growth and potential wild boar density. To what degree these measures are practiced in Norway will be decisive for how the distribution and local population densities will develop.

Based on a number of different criteria (e.g., presence in neighbouring countries and zoonotic potential) and evaluation of exposure pathways, we have identified seven novel agents likely to be introduced to Norwegian pig populations from wild boar. These can cause serious diseases like Classical-, and African Swine Fever and Foot and Mouth Disease. It is also expected that the prevalence of *Salmonella* ssp., *Trichinella* ssp. and *Taxoplasma gondii* will increase, which can result in higher transmittance to humans.

Conclusion: Unless drastic measures (i.e., culling) and ban on feeding are enforced within the next few years, the wild boar population will most probably grow significantly and spread to new areas in Norway, especially along the coast. Expected future climate conditions will be more suitable for wild boar, but the main factor influencing the population development will be human activity in terms of translocation and supplemental feeding.

Wild boar might have severe impacts on both agriculture and wild ecosystems. However, only a limited number of long-term studies exist, making it difficult to predict what will happen in Norway. There is also a lock of studies assessing the effects of contrasting wild boar densities, an aspect that is highly relevant for assessing the potential impact.

Biosecurity remains the most effective way to prevent disease transmission between wild boars and domestic pigs. The probability of direct transmission of African Swine Fever from wild boar to farmed pigs is very dependent on the biosecurity conditions of farmed pigs, as well as on density of wild boar. The probability of direct transmission from wild boar to farmed pigs is high if farmed pigs are kept in outdoor facilities, given that the disease enters the population through Sweden.

Key words: VKM, risk assessment, Norwegian Scientific Committee for Food and Environment, Norwegian Food Safety Authority, Norwegian Environment Agency, wild boar, population, growth, expansion

Sammendrag på norsk

Introduksjon: I Norge er villsvin definert som en fremmed art, og er vurdert av Artsdatabanken til å utgjøre høy økologisk risiko. I Sverige er villsvin imidlertid ansett for å være en del av den lokale faunaen, og populasjonen har vært i hurtig vekst siden 1970-tallet. Dette har ført til at villsvin har spredt seg til Norge langs grensen (om lag 1000 individer per i dag), spesielt i Østfold.

Etableringen av villsvin i Norge har utløst behov for en vitenskapelig vurdering av potensialet for videre spredning og av hvilken risiko villsvin kan innebære for helse og miljø. Miljødirektoratet og Mattilsynet har gått sammen om å be Vitenskapskomiteen for mat og miljø (VKM) om en slik vurdering.

Metode: VKM nedsatte en arbeidsgruppe med norske og svenske eksperter fra ulike fagområder og med ekspertise innen human- og dyrehelse, epidemiologi og økologi. Disse har vurdert den mulige påvirkningen som ytterligere spredning og etablering av villsvin kan ha på helse og miljø i Norge.

Arbeidsgruppen har vurdert relevant litteratur og tilgjengelige data om villsvinforekomst og klima for å modellere potensiell utbredelse og populasjonstetthet i Norge, både ved dagens klima og ved fremtidige klimascenarier.

Påvirkning på mattrygghet og dyrehelse er vurdert ut fra en antagelse om at villsvin vil etablere seg i Norge i betydelig omfang. Evalueringen inkluderte alle agens som er relevant for humanhelse og dyrehelse.

Resultat: Norge er i dag i tilsvarende situasjon som Sverige var på begynnelsen av 1980-tallet, med en liten populasjon av villsvin begrenset til ett område. Dersom det ikke settes i verk drastiske tiltak for å kontrollere vekst og utvikling, vil populasjonen sannsynligvis dobles hvert tredje år, og spres i lavlandet langs kysten opp til Trøndelag.

Modellering av mulig utbredelse, basert på klimatiske faktorer, viser at villsvinpopulasjonen vil kunne bli på ca. 220 000 dyr ved dagens klima. Det tilsvarer omtrent dagens populasjon i Sverige. Ved å ta topografi og habitat med i betraktningen, er det imidlertid mer realistisk med et anslag på omlag 40 000 dyr, spredt over 70.000km^2.

Dersom klimaet som forventet blir varmere og fuktigere i løpet av de neste 50 årene, vil det være potensial for økt tetthet av villsvin fordi flere dyr vil kunne overleve gjennom vinteren, og villsvin vil kunne etablere seg i flere områder.

Villsvinets påvirkning på økologi og biologisk mangfold er knyttet både til predasjon og til at de roter i jorda for å komme til planterøtter. Både predasjon og beiting kan ha skadelig effekt på truede arter, mens villsvinets roting etter røtter kan endre strukturen og dynamikken i ulike plantesamfunn. Det er vist at villsvin har positive effekter på tidlige

ettårige planter, inkludert fremmede arter, mens negative effekter er mer uttalt for flerårige planter i mer stabile plantesamfunn. Tilgjengelig litteratur viser eksempler på både positive og negative effekter av at villsvin roter i jorda, mens andre studier ikke finner noen effekter. Dette avhenger av hvilke habitater og samfunn som studeres.

Villsvin vil også ha negative effekter på jordbruk, både fordi de roter opp jorda på beitemark og enger, og fordi de spiser opp såkorn og avlinger.

Diskusjon: Basert på erfaringer fra Sverige og andre relevante land, er det åpenbart at tilstedeværelse, spredning og etablering av villsvin er nært knyttet til menneskelig aktivitet. Arten sprer seg naturlig ca. 2,5 km per år, men transport av dyr for jaktformål har blitt omfattende i andre land. Det har resultert i at villsvin har spredt seg over er spredt over betydelig lengre distanser og etablert nye sub-populasjoner. I tillegg har det vist seg at tilleggsfôring har stor effekt på utviklingen av og tetthet av villsvinpopulasjonen. I hvilken grad transport og fôring av villsvin vil bli praktisert i Norge, vil være avgjørende for hvordan populasjonene spres og utvikler seg.

VKM har identifisert flere smittestoff som kan overføres til norske grisebesetninger. Dette inkluderer noen alvorlige virussjukdommer som afrikansk svinepest, klassisk svinepest og munn- og klauvsjuke. I tillegg kan nivået av salmonellabakterier i norsk fauna og parasittene *Toxoplasma gondii* og trikiner øke. Det kan gi økt smittefare for mennesker.

Konklusjon: Dersom det ikke settes i verk drastiske tiltak i løpet av de kommende årene (avskytning, fôringsforbud osv.), vil villsvinpopulasjonen høyst sannsynlig vokse signifikant og spre seg til nye områder i Norge, spesielt langs kysten. Forventete fremtidige klimaforhold vil bli mer egnet for villsvin, men menneskelig aktivitet, som transportering og tilleggsfôring, er den faktoren som først og fremst vil ha betydning for utvikling av populasjonen.

Villsvin vil kunne ha alvorlig innvirkning på både jordbruk og naturlige økosystemer. Omfanget av langtids studier er imidlertid begrenset, noe som gjør det vanskelig å anslå hva som spesifikt vil skje i Norge. Mangelen på studier som har undersøkt effekten av ulike tettheter av villsvin gjør det også vanskelig å vurdere den potensielle effekten med større sikkerhet.

Biosikkerhet på gårder er den mest effektive måten å forebygge overføring av sykdom fra villsvin til tamsvin. Sannsynligheten for direkte smitte av afrikansk svinepest fra villsvin til tamsvin, avhenger i stor grad av biosikkerheten på gårdene, så vel som tetthet av villsvin. Det er stor sannsynlighet for direkte smitte fra villsvin til gris som holdes utendørs, gitt at sykdommer som afrikansk svinepest kommer til Norge fra Sverige.

Nøkkelord: VKM, risikovurdering, Vitenskapskomiteen for mat og miljø, Mattilsynet, Miljødirektoratet, villsvin, populasjon, vekst, utvikling.

Background as provided by the Norwegian Food Safety Authority and the Norwegian Environment Agency

Climate change impacts living conditions for livestock and wildlife. Ecological conditions for infectious agents and parasites are also changing. New knowledge about those changes is being accrued in many countries. Norway's geographical location means we are at the outer limit of conditions for many agents, and our situation needs to be assessed separately even when EFSA provides new knowledge. Diseases that can spread with "new" host species that cover a larger geographical area are an increasing threat.

The first known breeding of wild boar in Norway - in recent times - took place in 2005 in Østfold. In Norway, the wild boar is an alien species and is considered by the Norwegian Biodiversity Information Centre (Artsdatabanken) to constitute a very high ecological risk. At the same time, Sweden wants to establish this species for hunting purposes. We need a scientific basis for managing the environmental and health consequences of possible establishment of a wild boar population in Norway.

The Norwegian Environment Agency and the Norwegian Food Safety Authority are therefore requesting an assessment of expected population development and future spreading of wild boar in Norway, as well assessment of the extent to which it will be possible to influence this development. Further, based on the assessment of how wild boar populations will develop, it is important to also highlight and assess novel hazards that can influence animal health following an increased wild boar population in Norway.

Terms of reference as provided by the Norwegian Food Safety Authority and the Norwegian Environment Agency

The Norwegian Environment Agency and the Norwegian Food Safety Authority request the Norwegian Scientific Committee for Food and Environment (VKM) to assess and answer the following questions:

Growth and expansion of the wild boar population in Norway - Implications for biodiversity.

1. What is the predicted population trend for wild boar in Norway, based on experiences from Sweden and other relevant countries? In this context, the extent of historical and present supplemental feeding of wild boar in Sweden must be taken into consideration.

2. Can climate change impact wild boar population growth/trends, in a 20-year perspective, and toward year 2100 (cf. www.miljodirektoratet.no/no/publikasjoner/2015/September-2015/Klima-i-Norge-2100)?

3. Is it possible to quantify such population changes and to estimate the geographical distribution (in the same time frame)?

4. Can a rate of expansion of the wild boar population be estimated for Norway, and is it possible to identify factors that may increase or decrease this rate, based on experiences from other countries?

5. What negative consequences for biodiversity can be expected in the areas where wild boar is expected to increase in number and distribution?

6. Which measures may be taken to control the wild boar population growth/development and to limit negative consequences for biodiversity?

Growth and expansion of the wild boar population in Norway - Implications for food safety and animal health in Norway

1. **Introduction of infectious agents**
   a. Which novel hazards can be introduced to Norway, and what is the likelihood of outbreaks of diseases and parasites in humans or animals following establishment of wild boar in Norway?
   b. Have climatic-, or other factors changed, and thus increased the prevalence of relevant vectors and parasites in Norway?
2. **Assessment of probability for transfer of infection between wild boar and domestic pigs**
   a. What is the probability of disease transmission between wild boar and farmed pigs, given an increased population of wild boar in Norway, considering the normal risk reducing measures used in current traditional farming? Also, how effective would mandatory use of infection control sluices be at reducing transmission of disease from wild boar to pigs?
   b. What, if any, effective risk reducing measures can be taken to limit disease transmission from wild boar to farmed pigs kept outdoors (e.g., organic/ecological farming).
3. **African Swine Fever in Europe**
   a. What is the probability of disease transmission from a potentially infected population of wild boar to farmed pigs, either directly or through feeding?
   b. Which risk reducing measures are available to limit the probability of spread regarding African Swine Fever in Norway?

In order to best utilise resources, the project should be coordinated with ongoing work at the Norwegian Species Information Centre (Artsdatabanken) on updating the environmental risk assessment of wild boar from 2012.

1 Introduction

1.1 Biology and ecology of wild boar

1.1.1 Distribution and taxonomy

The Eurasian wild boar (*Sus scrofa* L, 1758) is the most widespread species of wild pig, with a distribution range covering Western Europe to the Far East and insular Southeast Asia. In addition, introduced populations are found on all continents except Antarctica. Earlier, many regional forms were described as full species, but a more comprehensive taxonomic evaluation has combined many of these forms as subspecies of *S. scrofa* (Livet, 2011). This taxonomy is, however, under revision. While most eastern subspecies are considered separate species, the western *S. scrofa* constitutes a single species with several subspecies (Albarella et al., 2007). The Central European boar (*S. scrofa scrofa)* is currently distributed across almost all of mainland Europe, except some northern areas in Scandinavia and European Russia, and the southernmost parts of Greece (Deinet et al., 2013). However, the recent demographic history of the wild boar in Europe has been greatly affected by humans and restocking of depleted populations has possibly caused introduction and mixing of several subspecies (Livet, 2011). The domestic pig (*S. scorfa domesticus*) is descended from *S. scrofa* and it is believed that most of the genetic divergence separating it from its ancestor developed during the last two centuries with intensive farming (Scandura et al., 2011). It is known that hybridization between wild boar and domestic pigs is commonly practiced on farms all around Europe, in order to increase reproduction and growth rates (Nikolov et al., 2017; Scandura et al., 2011). The impact of this hybridization on the genetic structure of the wild population remains undocumented (Goedbloed et al., 2013).

1.1.2 Climate tolerance

Wild boar is a very adaptable species, thriving under a wide range of climatic conditions, from the tropics and semi-deserts to the boreal forest and steppe (Mitchell-Jones, 1999) (Powell, 2004)). Snow depth and mean temperature during autumn and winter have been shown to be important determinants for their Northward expansion. However, wild boar can withstand long periods of starvation and cold, as they are found around Lake Baikal and the Amur region of Russia where snow depths are around 80 cm and mean monthly temperatures for January are around –20°C (Melis et al., 2006). Wild boars in these areas have shown great resilience, surviving winter temperatures below -50°C. However, frozen soil and deep snow limit food availability and, without supplemental feeding, harsh winters constitute the major density-independent cause of mortality for wild boar in temperate, boreal, and alpine parts of its range (Melis et al., 2006). See also figure 3.1-1 and 3.2-1 for predicted suitable regions in Norway under current and predicted future climates.

1.1.3 Diet

Wild boars are opportunistic omnivores, feeding mainly on various plant materials, including crops. Invertebrates, birds, mammals, and carrion can also constitute a substantial part of their diet, depending on availability. The diet of wild boar changes throughout the seasons and among habitats, and reflects the relative availability of different food types (Schley and Roper, 2003). Based on 21 studies of wild boar diets throughout Western Europe, Schley and Roper (2003) found that agricultural crops always represented an important component of the wild boar diet. In addition to feeding on aboveground biomass, wild boars root through soils searching for foods such as roots, acorns, worms, fungi, and even mice, causing significant damage to a variety of crops (Schley and Roper, 2003). In several countries in Europe, wild boar can be found in and around cities, where they feed on garbage, garden waste, and other organic material (Cahill et al., 2012; Podgórski et al., 2013).

1.1.4 Suitable habitats in Norway

A survey from Southeast Norway (Aremark) conducted in 2010 showed that old spruce forest was the preferred foraging ground for wild boar there (Haaverstad, 2011). Other studies have shown that a mixed landscape, consisting of agricultural fields and forest, is preferred, especially fields edging forests. Thus, mosaic landscapes, with many small fields providing both food and shelter, seem to be ideal for wild boar (Rosvold and Andersen, 2008; Thurfjell et al., 2009). Such habitats are found throughout the coastal areas of Norway, from Vestfold to Rogaland, but are less common along the border towards Sweden. Western Norway, from Rogaland to Sogn og Fjordane, could have an appropriate climate in the coastal regions, while the climate in mid-Norway corresponds to areas in Sweden with high population densities, such as Uppland and Södermanland. This shows that most of the Norwegian coastal areas up to Nordland County could potentially support populations of wild boars based on available habitat types (See 3.1.1 and 3.1.2)

1.1.5 Social structure, fecundity and home range

Wild boar live in family groups (sounders), where adult females cohabit with their offspring, up to yearlings, and in some cases also sub-dominant females. Mature males are solitary and return to sounders only for mating (Livet, 2011).

The reproductive rate of wild boar is high compared with that of other ungulates. This is due to their low age and size at sexual maturity (less than one year and 33-41% of full grown body mass) (Servanty et al., 2009), the high proportion of females breeding (20-90% for less than one-year olds, 70-100% for yearlings and adults) (Servanty et al., 2009), and large litter sizes (up to 12 offspring, average 4-7) (Frauendorf et al., 2016; Malmsten et al., 2017). Litter size has been shown to be positively correlated with female body size (Frauendorf et al., 2016) and latitude (Bywater et al., 2010). So within central Europe (from Italy to Northern Germay) there is a trend towards more offspring further north. The proportion of females reproducing is strongly affected by both spring and summer weather, with dry and cold springs and warm summers having a positive effect (Servanty et al., 2009).

Wild boars are largely stationary, with relatively small home ranges. The size of their home range depends mostly on food availability, although hunting and other anthropogenic disturbances can also play a role (Fattebert et al., 2017; Keuling et al., 2009). In general, solitary animals use larger home ranges than family groups, and yearlings move the centre of their home range between years more than adults (> 2 years) do. Yearlings also move their home ranges more between spring and summer (more than 2 km), compared with family groups (Keuling et al., 2008).

1.1.6 Natural dispersal

The natural spread of the Scandinavian wild boar population appears to be quite slow. Swedish studies suggest that the population, in general, spreads about 3 km/year, with individual females spreading up to almost 5 km/year (Truvé et al., 2004). However, another study from Sweden reported a mean dispersal of 10-16 km (up to 100 km) for younger animals of both sexes (Truvé and Lemel, 2003), and there are reports of males migrating as far as 250 km in Poland (Andrzejewski and Jezierski, 1978). In Sweden, the population is expected to expand mostly in the western parts of the country, as far north as Värmland. Northward expansion is also expected on the eastern coast of Sweden. Dispersal to Norway through mountainous areas is considered less likely, as there is no historic evidence of wild boar in the Scandes (Rosvold et al., 2010).

1.1.7 Human influence on wild boar

Supplemental feeding during winters plays a major role in wild boar abundance, particularly in Northern countries where food is relatively scarce (Oja et al., 2014). Being a capital breeder, well-fed wild boars have more litters per year and more piglets per litter than less well-fed wild boar (Malmsten et al., 2017). In Estonia, the high densities of wild boar are sustained by extensive supplemental feeding (Oja et al., 2014). Release and translocation of animals, combined with supplemental feeding, have probably led to the accelerated population growth in Sweden (Lemel, 1999; Lemel and Truvé, 2008). Today, there are areas in Sweden where feed is practically unlimited, exceeding 100 kg per hectare per year (Jonsson, 2017). It has also been documented that wild boars have escaped from enclosures and have also been illegally released into new areas (Truvé and Lemel, 2003).

Denmark has culled feral wild boars since 1997, and, in June 2018, it was announced that a 68 km fence will be built on the German border to prevent wild boar from bringing African swine fever (ASF) into the country (BBC, 2018)

Finland has also attempted to keep its wild boar population controlled to a minimum, culling immigrating animals in order to avoid the introduction of ASF from Russia. In February 2018, a nationwide 'wild boar weekend' with collective hunting was organised for population control (Valtioneuvosto, 2018).

1.2 Historical and current distribution

1.2.1 Wild boar in Europe

Wild boar originated in Southeast Asia about 3 million years ago and, based on archaeological or molecular data, the first occurrence in Europe is estimated to have been between 1.5 and 0.4 million years ago (Scandura et al., 2011). The large-scale population genetic structure of wild boar in Europe has been shaped by post-glacial colonization patterns (Scandura et al., 2011). During the 19th century the species became extinct in parts of Western Europe due to heavy hunting and deforestation (Melis et al., 2006). Subsequently, conditions for wild boar improved, with hunting restrictions, reforestation, and a warmer climate, and, at the same time, reintroductions of wild boar were undertaken all over Europe (Kusza et al., 2014). The population started to increase after World War II, and rapid growth and range expansion have been seen since the 1960s when wild boar farming gained popularity (Sáez- Royuela and Telleriia, 1986) (Goedbloed et al., 2013). The population densities currently follow a latitudinal gradient that declines northwards in Northern Baltics and Scandinavia (Melis et al., 2006).

1.2.2 Wild boar in Sweden

Wild boar became extinct in Sweden in the 17th century, but were later reintroduced to the royal hunting grounds on Öland in the 18th century. Due to complaints by farmers of damage to crops, the population was eradicated a few years later. In the early 20th century wild boar were present in Scania (Skåne), probably introduced for hunting, but farmers quickly hunted the population to extinction. In the late 1970s, the wild boar that founded the current population seem to have escaped from hunting enclosures in Södermanland and Scania. This time, despite complaints by the farmers, they were not hunted to extinction (Jägerförbundet, 2017; Naturvårdsvärket, 2010).

By the late 1970s, hunting had decreased due to a combination of stricter hunting regulations and fewer farmers. The Swedish government had apparently accepted wild boar on a couple of estates, and after the wild boar population had begun to increase and spread, it became difficult to control. In 1988, the Swedish Parliament decided to accept wild boar as being part of the Swedish fauna as they had already established and, historically, were part of the native fauna (Lemel and Truvé, 2008). Since then, the population has increased almost exponentially, as indicated by the harvest data collected by the Swedish Hunters' Association (www.viltdata.se), although the rate of population rise now appears to be slowing down. The highest natural densities of wild boar today (up to 2 animals per km^2) are found mainly in the areas where the population first established, in Scania and Södermanland. A relatively dense population with a long history is also found in Eastern Uppland (Thurfjell, 2011). However, even higher densities (up to 4.5 animals per km^2) have been observed in areas where supplemental feeding take place (Thurfjell, 2011). The total population size is estimated to be 2-3 times the number of animals shot annually (Thurfjell, 2011), so between 220-330.000 animals in 2016 (Figure 1.2.2-1)

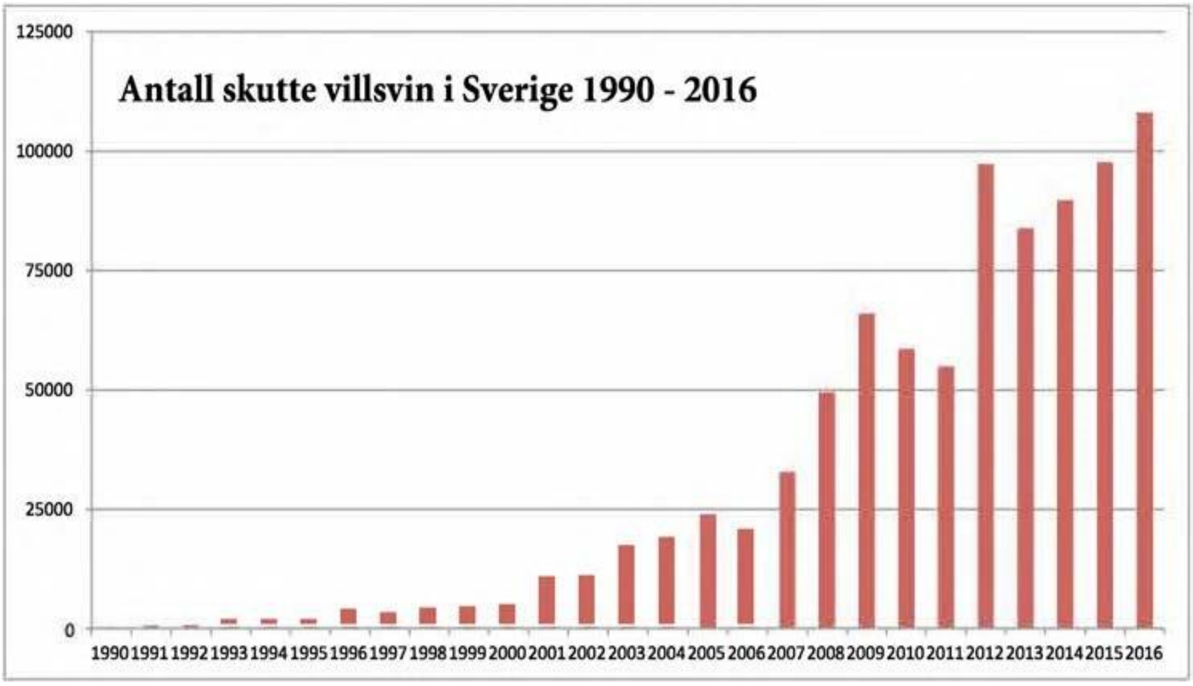

Figure 1.2.2-1 Recorded harvests of wild boar in Sweden for the last 26 years, as provided by the Swedish hunting association (Svenska Jägareförbundet, Handlingsplan vildsvin, 2017).

1.2.3 **Wild boar in Norway**

Archaeological excavations have shown that wild boar were found in Norway until around 1000 AD (Rosvold et al., 2010), after which it was eradicated from the Norwegian fauna, probably as a result of higher hunting pressure and better hunting techniques. Although it has been suggested that wild boar may have disappeared during the Bronze Age as an effect of habitat changes, this has not been verified (Rosvold et al., 2010).

Wild boar were reintroduced to Norway as a game park species in 1886 and individuals have regularly escaped captivity ever since then, but without establishing permanent wild populations (Bevanger, 2005). Free-living wild boars were first observed in 1994, in Halden municipality (Hardeng, 2004). Around the same time, the Swedish population was reported to have reached areas close to the Norwegian border (Lemel and Truvé, 2008). Today it is reasonable to believe that wild boar that originally immigrated from Sweden regularly reproduce in the Halden and Aremark municipalities. Moreover, sows with piglets have occasionally been observed in other parts of Østfold, Akershus, and the southern parts of Hedmark county (Haaverstad, 2011; NINA, 2017; Pedersen et al., 2018; Rundtom, 2017; SSB, 2018) . The 2018 assessment of ecological impacts of alien species for Norway suggests that the current wild boar population is between 400 and 1200 individuals (Pedersen et al., 2018).

1.2.4 Farming of wild boar in Norway

The entry into force of the Regulations relating to farming of wild game in Norway in 1999 provided the opportunity for wild boar faming. However, several of the initial farms shut down after only a few years due to the high expenses associated with fencing, the relatively low price obtained for wild boar meat, and difficulties acquiring new sows for breeding. Wild boar farming is recorded under the same industry code as standard pig farming, so there is no central register of wild boar farms in Norway today. However, according to the Norwegian Veterinary institute and the Norwegian Food Safety Authority, about ten farms are currently in operation for producing wild boar meat. These farms are evenly distributed along the coastal areas of Norway, but not further north than Ålesund. In total, wild boar farming in Norway assumed to constitute a few hundred individuals, including all age classes.

1.2.5 Wild boar as game

Wild boar is a very popular game species, and in many European countries (e.g., Croatia, the Czech Republic, Slovakia, Poland, Germany, and the Baltic countries) organized hunting is a profitable business with longstanding traditions. In recent years, Sweden has also become an attractive destination for wild boar hunting, especially for Norwegians. In Norway, wild boar hunting now is available in Østfold, where animals from the Swedish population are establishing. The hunting is mostly conducted using bait, but dogs can also be used to drive the boars out into the open (Naturvårdsvärket, 2010). The bait can be food (usually maize), but also olfactory attractants are regularly used. For instance, several brands of beech tar (the smell resembles that of resin that pigs use to rid themselves of ectoparasites) are sold in Norway. According to web sites for hunters, automatic feeders are usually used for providing feed at hunting sites. The exact magnitude of wild boar hunting in Norway is unknown, but according to Statistics Norway (www.SSB.no), during the hunting seasons from 2014-2016, there were 70, 115 and 140 animals shot in the respective years (Figures 1.2.5-1, 1.2.5-2 and 1.2.5-3) (SSB, 2018).

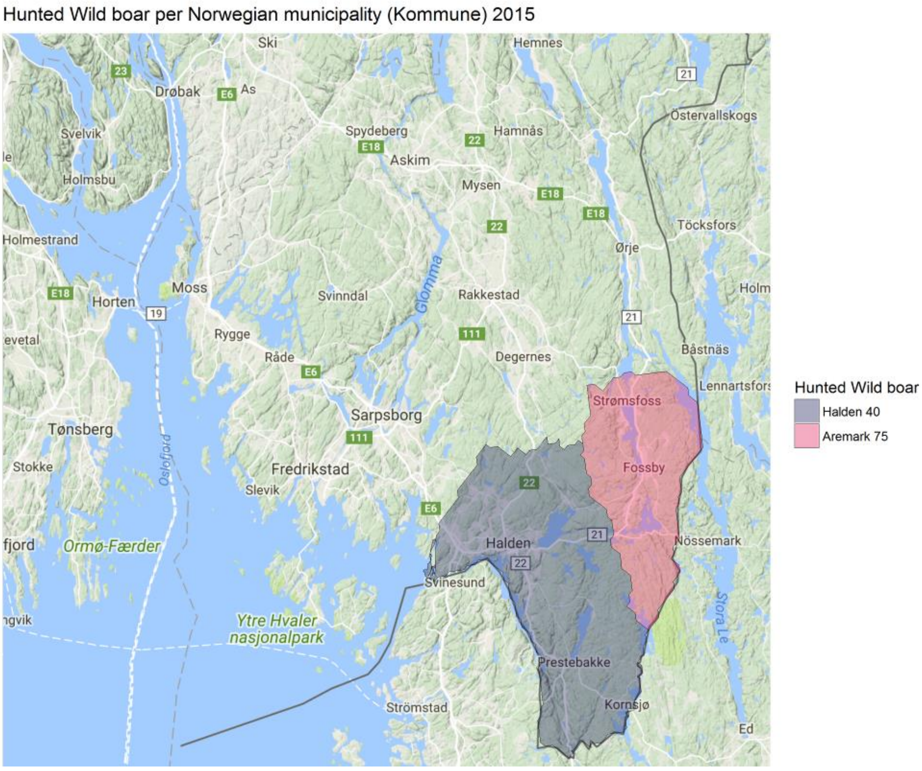

Figure 1.2.5-1 Recorded harvest of wild boar in Norway, 2014.

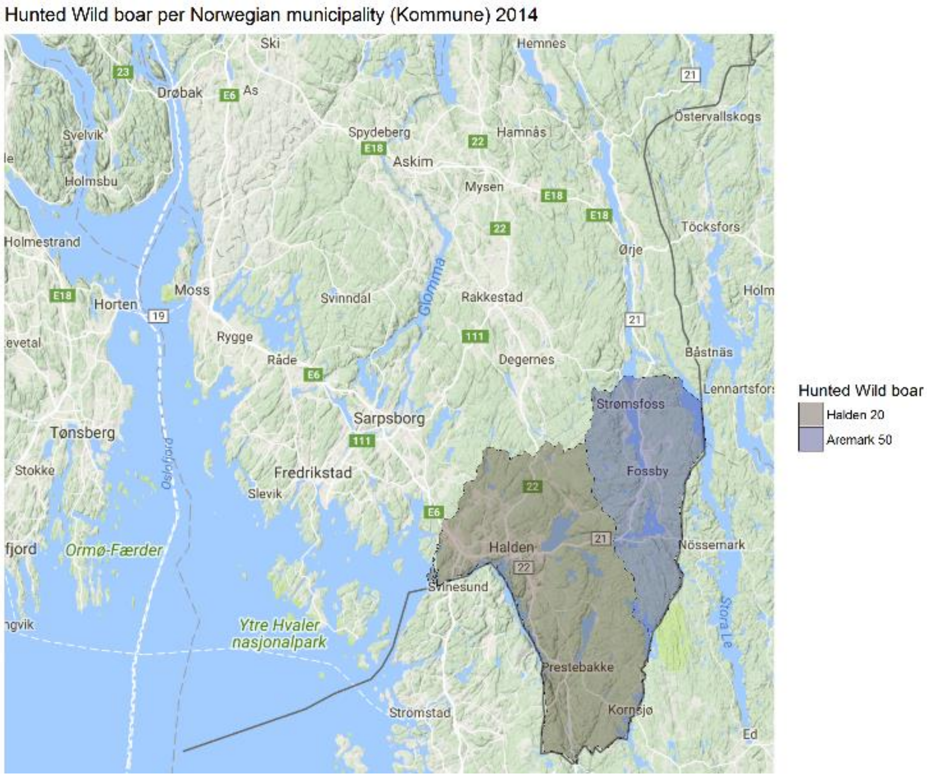

Figure 1.2.5-2 Recorded harvest of wild boar in Norway, 2015

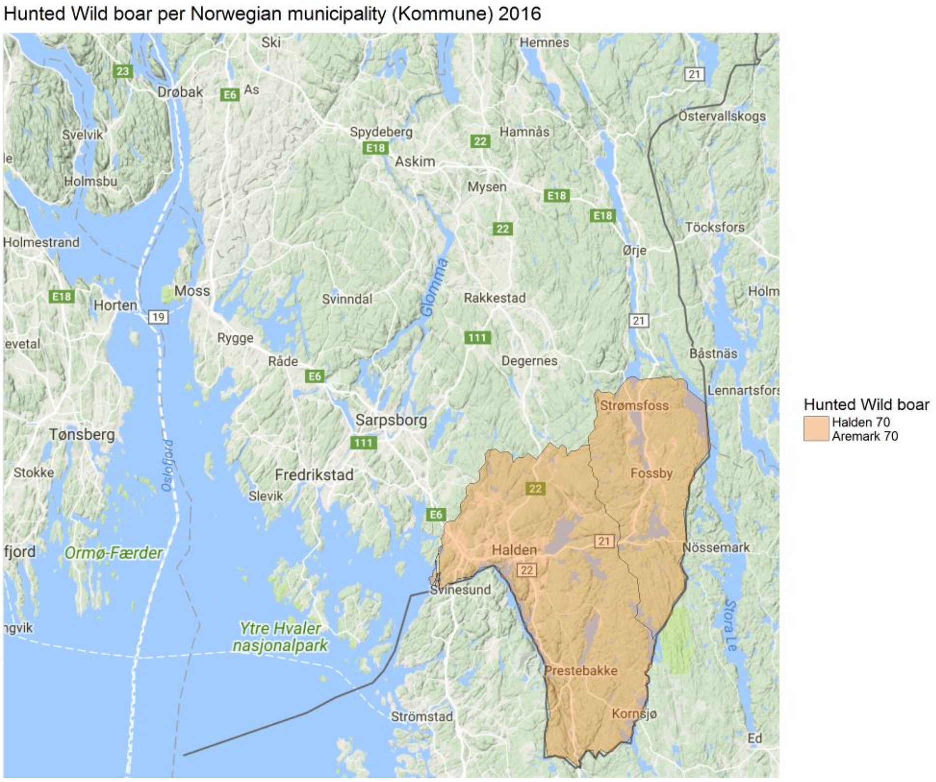

Figure 1.2.5-3 Recorded harvest of wild boar in Norway, 2016

These data are derived from only the Halden and Aremark municipalities, but over the last decade a number of local newspapers have also reported shootings of wild boars in other parts of Østfold, as well as Akershus, Buskerud, and Hedmark counties. Thus, it seems likely that the numbers reported to SSB are substantially lower than the actual number of animals shot (Rundtom, 2017).

1.3 Impacts of wild boar

1.3.1 Impact on biodiversity

Wild boar can have profound effects on biodiversity, community structure, and ecosystem services, particularly in areas where it has been introduced (Barrios-Garcia and Ballari, 2012; Massei and Genov, 2004; Pedersen et al., 2018). A recent review revealed that impacts of wild boar on biodiversity can be negative, but also positive and neutral (Genov et al., 2018). This is in accordance with the conclusion in the NBIC review (Pedersen et al., 2018). In particular, they emphasize that most of the documented negative effects stem from its introduced range. They also highlight the general lack of long-term studies and that most studies investigate short-term effects in fragile habitats. A further key finding was that none of the studies reviewed had included relevant numbers on wild boar densities. They conclude that managers should engage in long-term monitoring programmes, gathering data on both population densities and the behaviour of individuals, as well as effects on biodiversity over longer time periods.

The native distribution of wild boar covers a wide range of environmental conditions (Baskin and Danell, 2003), and its highly plastic and opportunistic diet can vary greatly both in space and time (Baubet et al., 2004; Baubet et al., 2003). Thus, wild boar is a highly flexible species that can utilize whatever resources are available; their effects on ecosystems are therefore highly dependent on local conditions. A key feature of wild boar foraging is their rooting behaviour. In searching for belowground food items, such as plant parts, fungi, and invertebrates, wild boar overturn extensive areas of soil (Baubet et al., 2003; Cushman et al., 2004). This behaviour affects soil structure and processes, and, due to the marked ecosystem-level effects, wild boar are considered ecosystem engineers (Crooks, 2002). However, few studies have explored rooting effects on soil properties, and the available literature report highly variable results. Some studies have shown increased soil mixing (Singer et al., 1984) and greater nitrogen availability (Siemann et al., 2009; Singer et al., 1984), whereas other studies have found no effects of rooting on soil texture, pH, moisture, organic matter, or nitrogen mineralization (Bruinderink and Hazebroek, 1996; Cushman et al., 2004; Mitchell et al., 2008; Moody and Jones, 2000; Tierney and Cushman, 2006). However, there are few studies addressing these issues, and those available are from a limited number of plant communities. Additionally, they all have a limited temporal extent. It is therefore hard to draw some general conclusions on the effects of wild boar rooting behaviour on soil properties (Barrios-Garcia and Ballari, 2012). Studies addressing the effects of rooting on soil microbial communities have either found no effects (Wirthner et al., 2011) or a positive effect on soil respiration and microbial and fine root biomass that disappeared within two years after the disturbance event (Risch et al., 2010). These results suggest that soil microbial communities are resilient to disturbance from rooting, although the limited number of studies indicates a need for more research.

Although wild boar are highly omnivorous, normally about 90% of their diet is comprised of plant matter, and they appear to prefer particular plant species and specific parts of plants (see Barrios-Garcia and Ballari (2012) and references therein). In its introduced range, studies have shown that rooting can affect up to 80% of the surface area of the forest floor (Singer et al., 1984). Depending on the plant community's resilience to disturbance, this might have negative effects on plant community composition, reducing plant abundance and diversity (Massei and Genov, 2004). In particular, plant communities subject to grazing over time might change towards dominance of species with traits related to resistance to herbivory i.e., spinescence, clonality, endozoochory, underground storage organs, and low height values (Burrascano et al., 2015). Studies have documented that the quality of natural or semi-natural meadows (that are harvested for forage) may be reduced by wild boar rooting (Haaverstad et al., 2014; Sundberg, 2017). Semi-natural meadows are relatively species-rich habitats, often containing rare or threatened species, and are therefore of high conservation value (Wehn et al., 2018). Physical disturbances from wild boar rooting might therefore be detrimental for already rare and threatened plant species in these meadows. In contrast, surveys in Sweden have shown an increase in species richness of vascular plants in rooted areas (Welander, 1995), suggesting again that wild boar can both increase and reduce biodiversity and that the effects are site specific (see also (Dück, 2013)) Other studies have shown that wild boar might act as dispersal agents of exotic plants (Dovrat et al., 2012) and that rooting might facilitate their establishment (see Barrios-Garcia and Ballari (2012) and references therein). Wild boar might also affect plant reproduction through their consumption of fruits and seeds, and studies have shown that rooting can negatively affect tree growth (Bruinderink and Hazebroek, 1996). Other aspects of wild boar behaviour potentially affecting plant biodiversity include rubbing against tree trunks (to remove parasites), ultimately causing the death of the affected trees (Campbell and Long, 2009; Graves, 1984) and accumulation of seeds from plants from non-forest ecosystems (Heinken et al., 2006). Plants might also be killed by uprooting of saplings by females to build nests (Ickes et al., 2005). Whether these behaviours are common, or have the potential to have a negative impact in Norwegian ecosystems, has not, to date, been studied.

Wild boar may feed on fungi, but the extent to which this might negatively affect fungal populations has never been studied. In addition, wild boar rooting has been found to stimulate the fructification process and spread the spores of hypogenous fungi (Ławrynowicz et al., 2006), potentially affecting fungal community structure and genetic mixing (Génard et al., 1988).

Wild boar can potentially also affect aquatic systems, in a similar manner to how they might affect terrestrial communities, by altering the composition of the aquatic plant and animal communities, changing water quality and chemistry, and dispersing plants, animals, and pathogens to isolated systems. Their effect on aquatic communities has, however, received little attention (Barrios-Garcia and Ballari, 2012). The wild boar diet may include aquatic resources, such as seaweed, mussels, and crayfish, but we are not aware of any study that investigates effects on biodiversity in aquatic ecosystems (Barrios-Garcia and Ballari 2012 and references therein).

Animal matter might constitute up to 30% of the wild boar diet, depending on the ecosystem and season, but they seem to have no particular prey preference (Barrios-Garcia and Ballari 2012 and references therein). Numerous studies have documented the wide variety of prey, but studies on how wild boar might affect populations of other animal species are scarce. Predation by wild boar has been shown to reduce the abundance of soil meso- and macro-fauna (including insect larvae, beetles, snails, centipedes, and earthworms) by between 40 and 90% (Barrios-Garcia and Ballari, 2012). It has also been shown that wild boar may prey on vertebrates, such as amphibians, reptiles, birds, and mammals, including game species such as ground nesting birds and young roe deer (Carpio et al., 2016; Haaverstad et al., 2014; Oja et al., 2017). Singer et al. (1981) observed a dramatic decline in the presence of ground-dwelling mammals, the southern red-backed voles (*Clethrionomys gapperi*) and northern short-tailed shrews (*Blarina brevicauda*), in an area rooted by wild boar (Singer et al., 1981). An undergraduate thesis from Bjørund (2013) investigated associations between the increased Swedish wild boar population and the numbers of red fox (*Vulpes vulpes*), badger (*Meles meles*), and western capercaillie (*Tetrao urogallus*) shot in the period from

1997 to 2010. A significant positive correlation between wild boar and red fox was observed, and a negative correlation between wild boar and capercaillie, but there was no correlation with badger numbers (Ytrehus and Vikøren, 2012). The increase in red foxes in areas with wild boar was considered to result from food availability (feeding posts, offal, and carcasses), whereas the decline in capercaillie was suggested to represent a secondary effect of generalist predator increase.

In Norway, the grey wolf (*Canis lupus*) is the only large predator that has an impact on wild boar mortality (Massei et al., 2015), and an increase in the wild boar population will increase the potential forage resource base for the wolf. The grey wolf population in Norway is currently small (<100) (Rovdata, 2018), and will most likely have only a limited effect on wild boar expansion.

When the wild boar was given a score of HI (high risk) by NBIC in 2018 (Pedersen et al., 2018) the main reason was the long expected population lifetime and relatively high expansion rate, and to a lesser extent the risk for transmission of *Trichinella* to species such as red fox (*Vulpes vulpes*), and lynx (*Lynx lynx*), which was highlighted in the 2012 report (Gederaas et al., 2012) For information on *Trichinella* and human and domestic animal health see 7.1.5.10.

1.3.2 **Impact on ecosystem services**

The presence of wild boars can affect ecosystem services, in particular through their effects on biodiversity. Rooting might destroy bumblebee nests, affecting pollination, but this has, as far as we know, never been studied. The recreational use of forests can also be seen as an ecosystem service that can be negatively impacted by wild boar. These impacts include aesthetic aspects, as well as a reduction in berries and mushrooms for harvesting. Some people are afraid of wild boar, and their presence may limit the use of forests by these people for recreational purposes. However, others might consider the presence of wild boar as an additional value to the wilderness they seek to explore (Rosvold and Andersen, 2008).

Hunting wild boar as a game species is another ecosystem service that is appreciated by many, and also provides a novel food source. Increasing populations of wild boar will, however, add a further element to the conflict between farmers, hunters, and wildlife (Naturvårdsvärket, 2010), as already occurring in areas of Norway where large carnivores are protected. Some of these areas overlap with areas currently experiencing a rising wild boar population (Østfold, Akershus, and Hedmark counties).

1.3.3 **Impact on agriculture**

Probably the main problem with wild boar for farmers, is that they root in cultivated land. The rooting can be in the form of predation on newly planted seeds or in hey meadows causing contamination of hey with soil microbes. The latter issue may also cause damage to silage bales if the rooting occur in their vicinity. In some areas, the damage caused may result in the farmers abandoning certain fields (Gren, 2017). In Sweden, the cost to agriculture from wild boar damage in 2015 was estimated to be 1.560 billion SEK (Gren, 2017).

The impact on agriculture with regards to infectious agents are discussed in detail in chapters 7 – 9 of this report.

1.3.4 **Additional costs associated with wild boar**

Traffic accidents caused by wild boar are not yet a big problem in Norway, with only 20 animals reported to have been hit by cars - and two by trains - since 2008 (https://www.hjorteviltregisteret.no/Fallvilt/). However, in Sweden, the cost of damage from traffic accidents involving wild boars in 2011 was estimated to be approximately 60 million SEK (Häggmark Svensson et al., 2014). The number of wild boar hit by motor vehicles in Sweden was 6081 in 2017 alone (https://jagareforbundet.se/vilt/vildsvinsbarometern/). The number of dogs reported to have been killed by wild boar in Sweden ranges from 96-160 in the years 2012-2017 (https://www.agria.se/pressrum/statistik-om-djur-djurvard-och-djurhalsa/vad-sager-statistiken-om-skador-vid-jakt/).

1.4 **Basis for management**

Species introduced to Norway after 1800 are not considered native; thus, wild boar is regarded as an alien species (Gederaas et al., 2012). So far, no management plan for wild boar in Norway has been established at a national level (Lund, 2017). However, such a plan was prepared for Østfold county (Fylkesmannen, 2015) in 2016 and sent to public hearing by different stakeholders. To our knowledge, the management plan is not yet implemented.

As described by the Norwegian Biodiversity Information Centre (NBIC, http://www.biodiversity.no), risk assessment of an alien species involves evaluating its ability to establish populations (i.e., survive and reproduce) in nature, it's potential for spread, and its potential to have a negative effect on Norwegian species and habitats. Based on such assessments, alien species are classified into one of the following risk categories: no known impact, low impact, potentially high impact, high impact, or very high impact in terms of negative effect on Norwegian ecosystems.

The NBIC evaluation corresponds to the approach used by the VKM Panel of Animal Health and Welfare (VKM, 2013). The wild boar is likely to be listed as having a potential for serious consequences (effect on environment or animal health or welfare) and a high probability (>50%) of negative effects occurring. The probability of negative consequences occurring would be expected to be high (P = 0.5-1.0).

Wild boar was scored as having "unknown impact" in the assessment of ecological impacts of alien species listed by NBIC in 2007 (Gederaas et al., 2007). However, in 2012 wild boar was scored as "very high impact" and hence a "black listed" species (Gederaas et al., 2012). In

2018, wild boar is listed on the "Alien species list", but the risk posed to Norwegian biodiversity has been reduced from "very high" to "high" (Pedersen et al., 2018).

NBIC has no role in implementing the management of alien species, and the alien species list does not instruct the National authorities on whether the species is wanted in Norway or not. The alien species list is, however, a knowledgebase that is used by the authorities to make decisions related to management of a species.

In a special regulation on the ban on introducing specific species of plants and animals (LOVDATA, 2015), wild boar is not listed. Thus, import of wild boar is not banned and it is possible to apply for a permit to raise wild boars in captivity (LOVDATA, 1999).

Hunting wild boars is regulated by law (LOVDATA, 2017). According to the hunting regulations, wild boar can be hunted all year round, but with the exception that it is forbidden to hunt sows with striped piglets (3-6 months old). In this instance, the sows are protected but the piglets can be hunted.

2 Methodology and Data

2.1 Literature

2.1.1 Scientific literature on wild boar ecology and biology, and impact on biodiversity

Literature searches were undertaken in Web of Science and Scopus using Advanced Search Builder. Search terms used in Title/Abstract fields were "wild boar", "population, "spread", "Scandinavia" and "Baltic". Search strings were built using Boolean operators AND and OR. No limitations on language were used, but the publication period was set to 1998-2017. The search returned 60 hits. The titles and abstracts of all search results were scanned for relevance to the terms of reference. Articles were excluded if they did not relate to the terms of reference. The reference lists in the selected articles formed the basis for identifying additional articles or reports within the topics listed in the terms of reference.

Regarding the effects of wild boar on biodiversity we used a recent review (Genov et al. 2018) as an overview of known studies on ecological impact studies.

2.1.2 Scientific literature on food safety and animal health

The literature search for assessment of food safety and animal health was conducted in PubMed and Web of Science using the search strings presented in Appendix II.

2.1.3 Reports and theses

Important sources of information for this project have been reports from the Norwegian Biodiversity Information Centre, The Swedish University of Agricultural Sciences, and reports from the Norwegian University of Science and Technology (NTNU University Museum Zoological Report). Also, the doctoral thesis of Henrik Thurfjell (2011), the Master theses of Haaverstad (2011) and Magnusson (2010), the Bachelor thesis of Bjørnerud (2013) and the doctoral thesis of Oja (2017) have provided important insights into the relevant problems. The reference lists in in those reports and theses were scrutinized to identify additional articles or reports.

2.2 Statistical data

2.2.1 Climate data

All 19 bioclimatic variables based on current global climate (Hijmans et al., 2005) with a spatial resolution of ~1 km^2 were downloaded from the worldclim database (WorldClim,

2018) through R, using the package dismo (Hijmans et al., 2017). In addition, projected future climates according to Max Planck Institute Earth System Model (MPI-ESM) and greenhouse gas concentration pathways RCP85 for the years 2050 (average for 2041-2060), with a spatial resolution of ~1 km^2 were downloaded.

2.2.2 Wildlife distribution data

All available occurrence data on "*Sus scrofa*" were downloaded from the GBIF database (GBIF, 2018) through R using the package dismo (Hijmans et al., 2017).

Data on wild boar hunting in Norway were downloaded from Statistics Norway (SSB, 2018), using StatBank Open data API (Application Programming Interface) in R using the packages httr (Wickham, 2014) and rjstat (Schumacher, 2016).

2.3 Statistical methods

The maximum-entropy approach (MaxEnt) (Phillips et al., 2017) was chosen to model the potential distribution of *S. scrofa* because it has been shown to outperform other species-distribution modelling methods, and can handle presence-only data. MaxEnt (Version 3.4.1) was run in R through the dismo package (Hijmans et al., 2017).

3 Assessment of the wild boar population growth and expansion – implications for biodiversity in Norway

3.1 Expected development of the wild boar population in Norway

It is reasonable to assume that feeding and human-mediated translocation of wild boar will have a greater impact on the development of the Norwegian wild boar population than climatic conditions, habitat, and natural dispersal. We have therefore explored scenarios with and without feeding. We have not considered human-mediated translocation (escape from farms and intentional movement of animals) due to the lack of data and predictability pertaining to these factors.

3.1.1 Model of suitable habitats in Norway based on climate, without supplemental feeding.

Using available data on the climate factors from areas inhabited by wild boar worldwide, the MaxEnt model was used to model areas with suitable habitats in Norway, based on climatic factors. The model performed well, with an average test area under curve (AUC) for the 10 replicate runs of 0.754, and a standard deviation of 0.144. The environmental variables that were found to have the highest influence on suitability were "minimum temperature of coldest month", "precipitation in coldest quarter", and "annual precipitation". Figure 3.1.1-1 illustrates the outcome of this model for the current climate conditions, based on the data available from the last 30 years.

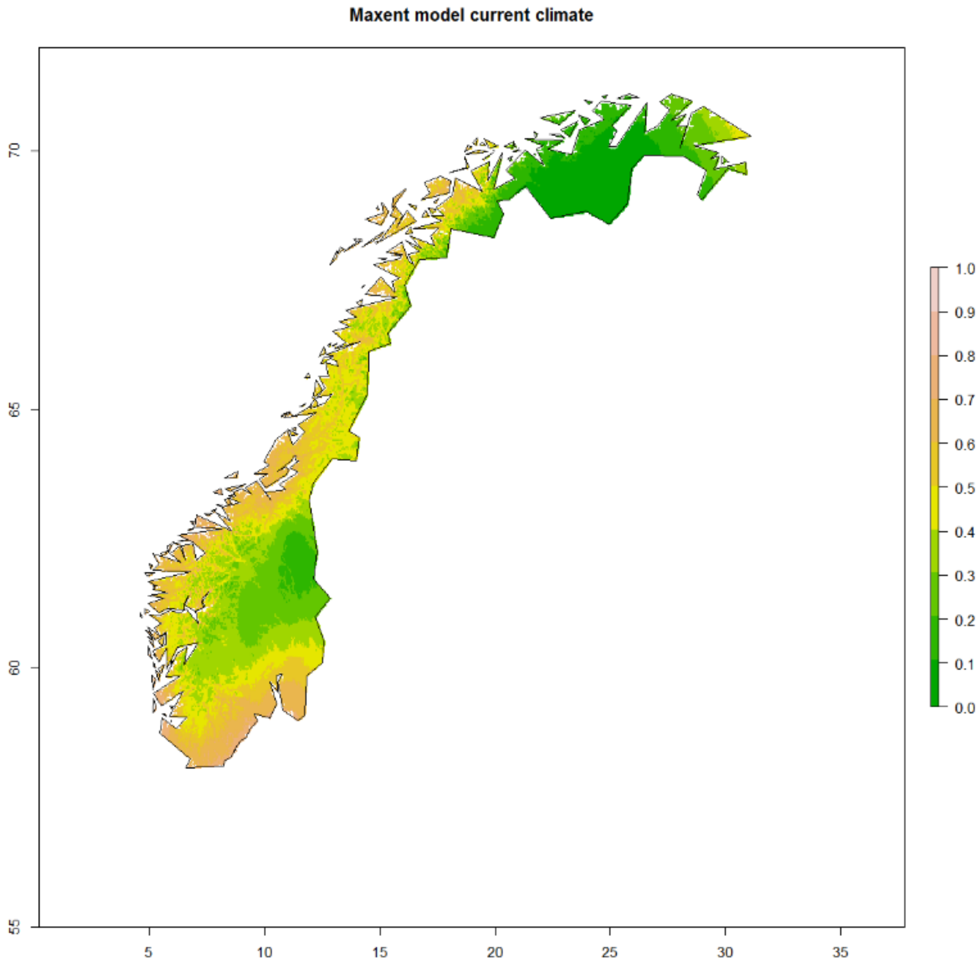

Figure 3.1.1-1 Maxent model for the predicted potential distribution of wild boar in Norway today, based on current climatic conditions. Colours indicate the probability of presence between 0 (low probability=green) and 1 (high probability=red).

The model shows that suitable climate is found in coastal areas in large parts of southern and central Norway, all the way to Trøndelag, and this suggests that wild boar could potentially establish populations here. This is in accordance with previous reports from Rosvold & Andersen (2008) and Pedersen (2017). However, the model also indicates that, based on climatic factors alone, the coastal areas north of Trondheim, except some regions in Finnmark, could also be habitable by wild boar.

Presently wild boar inhabit only a limited area of eastern Norway and migrating animals would need to cross densely populated urban areas in order to access suitable new habitats. The Oslo Fjord would be expected to slow down the spread of wild boar along the coast initially; but the fjord is less than 1000 meters wide at its narrowest point, a distance that wild boar can easily swim (Elsa, 2009). Should the fjord be crossed by several individuals, we expect wild boar to establish rapidly in this new habitat. In Germany, a similar pattern of development was observed after the Kiel Canal was crossed around year 2000. It is, however, assumed that the spread of the German wild boar population was also influenced by illegal releases (Keuling, 2017). In Norway, illegal releases and/or escapes from wild boar farms west of Oslo could also lead to a more rapid population expansion, than a natural spread north of the Oslofjord and then to the southwest.

3.1.2 **Impact of feeding on population growth and expansion**

Food availability is considered the most important factor for population growth in wild boar, and when provided with food these animals can survive in almost any environment, as long as water and shelter is also available. In Norway, high adult mortality in harsh winters would be expected to regulate population growth, but with supplemental feeding, winter mortality will decrease.

Feeding may be categorized as intentional or unintentional. Feeding is commonly done to attract animals to hunting sites, both to establish groups that can be hunted and to improve hunting success of these elusive, nocturnal mammals. Additionally, feeding is used to try to entice wild boar away from crops (dissuasive feeding). Different studies have come to various conclusions regarding the success of this practice, which requires a continuous supply of high-energy food (see Massei et al. 2011 for summary). Dissuasive feeding can also be used to attempt to discourage wild boar from going on to roads and close to human settlements. In general, it is recommended that all feeding (and hunting) takes place distant from infrastructure. Unintentional feeding occurs when wild boar consume agricultural waste (e.g., ruptured bales of silage) or as a secondary effect of supplemental feeding of other ungulates. Importantly, regardless of purpose, feeding may have complex unintended effects on non-target species and can enhance the risk of disease transmission to both famed and wild animals (Milner et al., 2014) (see 1.3.1 for more background information).

In Sweden, where feeding is widespread, there has been an approximate doubling of the wild boar population every three years (Massei et al., 2015). The variation in population density is high, as reflected by the harvest sizes in different areas, ranging from 5 wild boars harvested annually per km^2 in Scania to 1.5 in Uppland (www.viltdata.se). Although the variability is extensive, extrapolation from these numbers can be used to estimate what might be expected in Norway. Without supplemental feeding, we could expect a slower population growth and a smaller population (Melis et al., 2006; Oja, 2017). Estimated population sizes, with and without supplemental feeding, is discussed further in 3.3.

The rapid growth and expansion of the Swedish wild boar population is partly explained by supplemental feeding, and, in 2016, the Swedish Government suggested a ban on feeding game species. The development of the Norwegian wild boar population is closely linked to the development in Sweden, but will also rely heavily on the national policies regarding food supply. Given supplemental feeding, wild boar will be able to immigrate from Sweden at higher latitudes than today, and in these locations dispersal to favourable habitats on the west coast will not be hindered by the Oslo Fjord.

In sum, the consequences of supplemental feeding is and increased population growth rate and hence the total population size, in addition to increased rate of spread and establishment in new areas much faster than would be the case without supplemental feeding.

3.2 Anticipated effects of future climate change

In an examination of large-scale and long-term effects of climate change on local population dynamics of wild boar in Europe, Vetter et al. (2015) concluded that climate change drives population growth of wild boar directly, by relaxing the negative effect of cold winters on survival and reproduction (Vetter et al., 2015). It also drives population growth indirectly by increasing food availability. However, there are region-specific threshold temperatures for the onset of exponential growth, meaning that different regions throughout southern Norway might show different growth rates for wild boar populations exposed to the same increase in winter temperature.

Expected climate changes (increase in temperature, precipitation, and growing season days) from the period 1960-1990 and towards year 2068 under the CO_2 emission scenarios RCP4.5 (emission peak 2040-2050, then decline) and RCP8.5 (business as usual) indicate a general temperature increase in Norway at 2.2 °C (RCP4.5) to 3.3 °C (RPC8.5) and an extension of the growing season up to 60 days. (Source: www.klimaservicesenter.no). These anticipated changes are dramatic, and will expand the habitat suitable for wild boars.

To explore the potential distribution of wild boar under climate change, MaxEnt was run with IPCC5 climate projections from global climate models for RCP8.5. The model performed well, with an average test AUC for the 10 replicate runs of 0.720, and a standard deviation of 0.110. The three most important environmental variables that were found to have the highest influence on suitability were: "minimum temperature of coldest month", "precipitation in coldest quarter", and "temperature seasonality". The model shows that the predicted changes in climatic factors will have a positive impact on the wild boar population as larger areas show higher probability of being suitable for wild boar. The results are shown in Figure 3.2-1.

As there is no modelled IPCC data for the timeframe beyond 50 years, we have not modelled the distribution and expansion beyond 50 years and towards year 2100. However, it is reasonable to believe that the trend for the next 50 years will continue, although will perhaps not be as pronounced, should emissions decline after 2050.

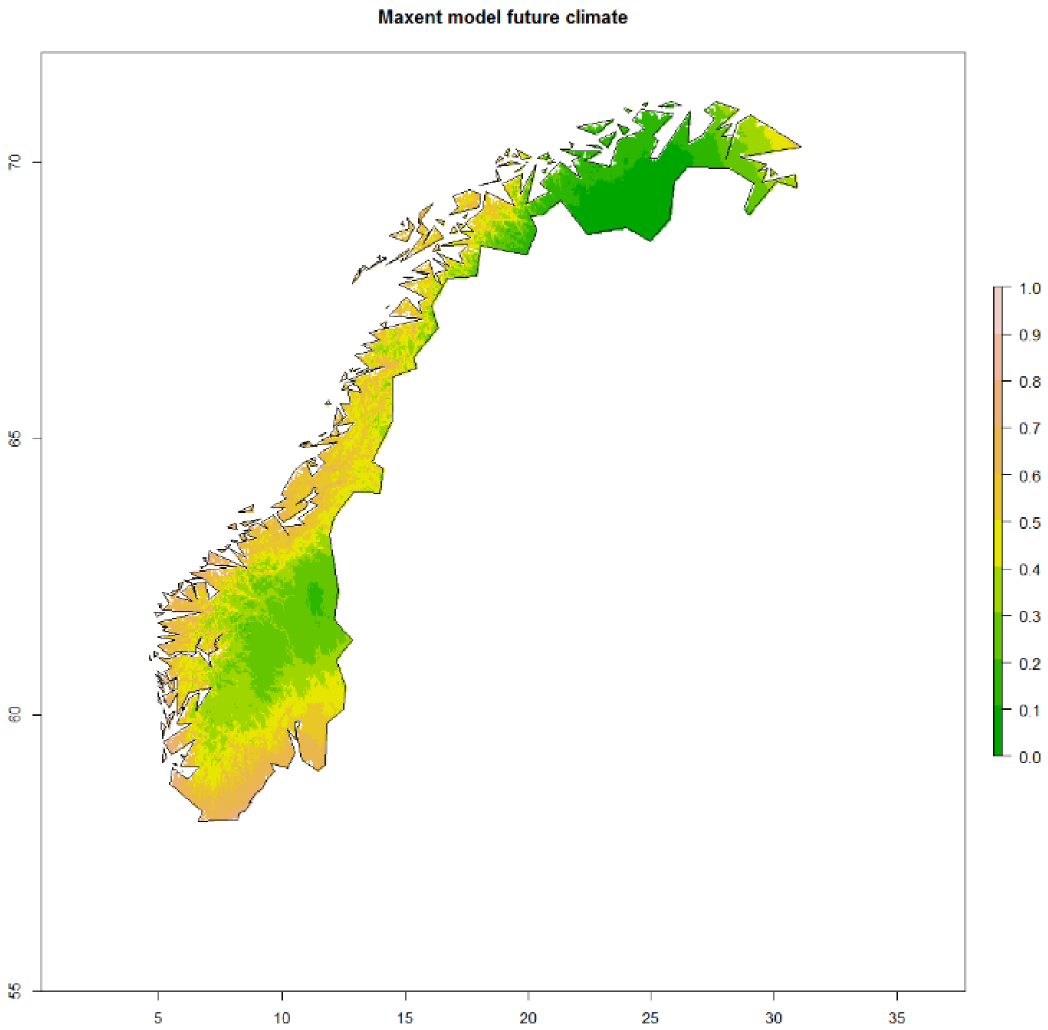

Figure 3.2-1 MaxEnt model for the predicted maximal potential distribution of wild boar in Norway for the year 2050, based on IPCC5 climate projections. Colours indicate the probability of presence between 0 (low probability=green) and 1 (high probability=red).

3.3 Quantification of population changes and geographical distribution

Climate modelling predicts that the most suitable wild boar habitats in eastern Norway (see 3.1 and 3.2) correlate with mixed forest containing mast-producing trees (Rosvold et al., 2010). Similar forests sustain high densities of wild boar over large parts of southern Sweden. In addition, different feeding and hunting practices by different landowners are important factors affecting the likelihood of wild boar reaching high population densities (Frank et al., 2015; Keuling et al., 2016; Saito et al., 2012). High population densities are likely to increase the rate of spread of the wild boar population (Vetter et al., 2015)

Based on the population model outlined by Melis et al (2006), where population density is correlated with the average temperature of the coldest month, under current climate conditions the maximum number of wild boar in Norway could have been ~200.000. Figure 3.3-1 shows the theoretical maximum geographic distribution and the predicted maximum densities of wild boar in Norway, ranging from 0 - 1.8 animals per km^2. The total area identified as suitable for sustaining >0.5 individuals is about 70,000 km^2, which is in accordance with Pedersen et al. (2017).

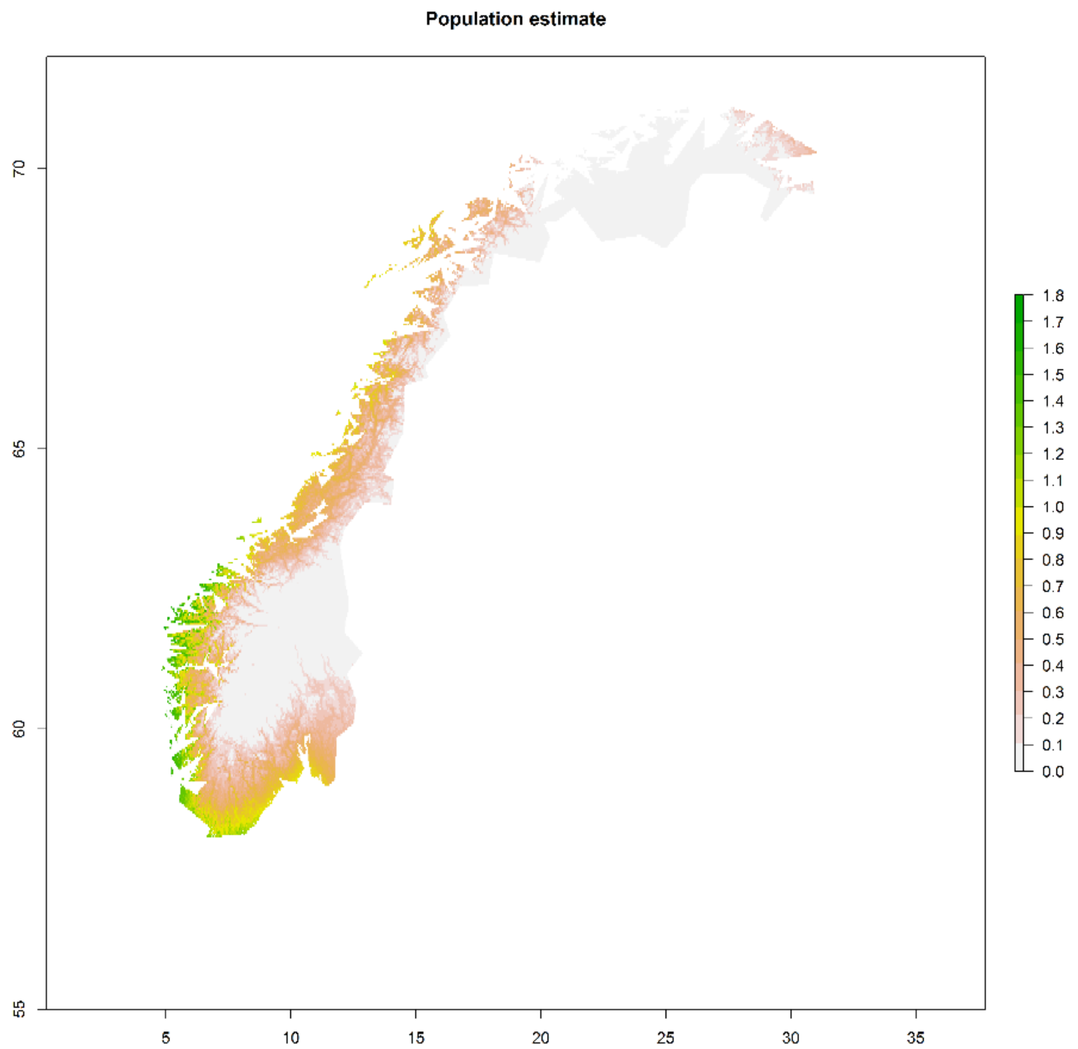

Figure 3.3-1 Estimated potential maximum number of wild boar per square kilometre in Norway, based on minimum temperature of January under current climate conditions. Colours indicate density of wild boar between 0 (low density=white) and 1.8 (high density=green).

Based on the expected temperature development in the next 50 years, with milder winter temperatures (expected 5°C warmer minimum temperature, and 4°C median increase), the population could reach up to ~440.000 animals. More habitats will be suitable for wild boar, and the survival rates are expected to be higher. Figure 3.3-2 shows the predicted geographic distribution of wild boar densities in Norway, ranging from 0 – 2.2 animals per km². According to the climate data predictions, the total area identified as suitable for sustaining >0.5 individuals will increase to 157,000 km² within this timeframe.

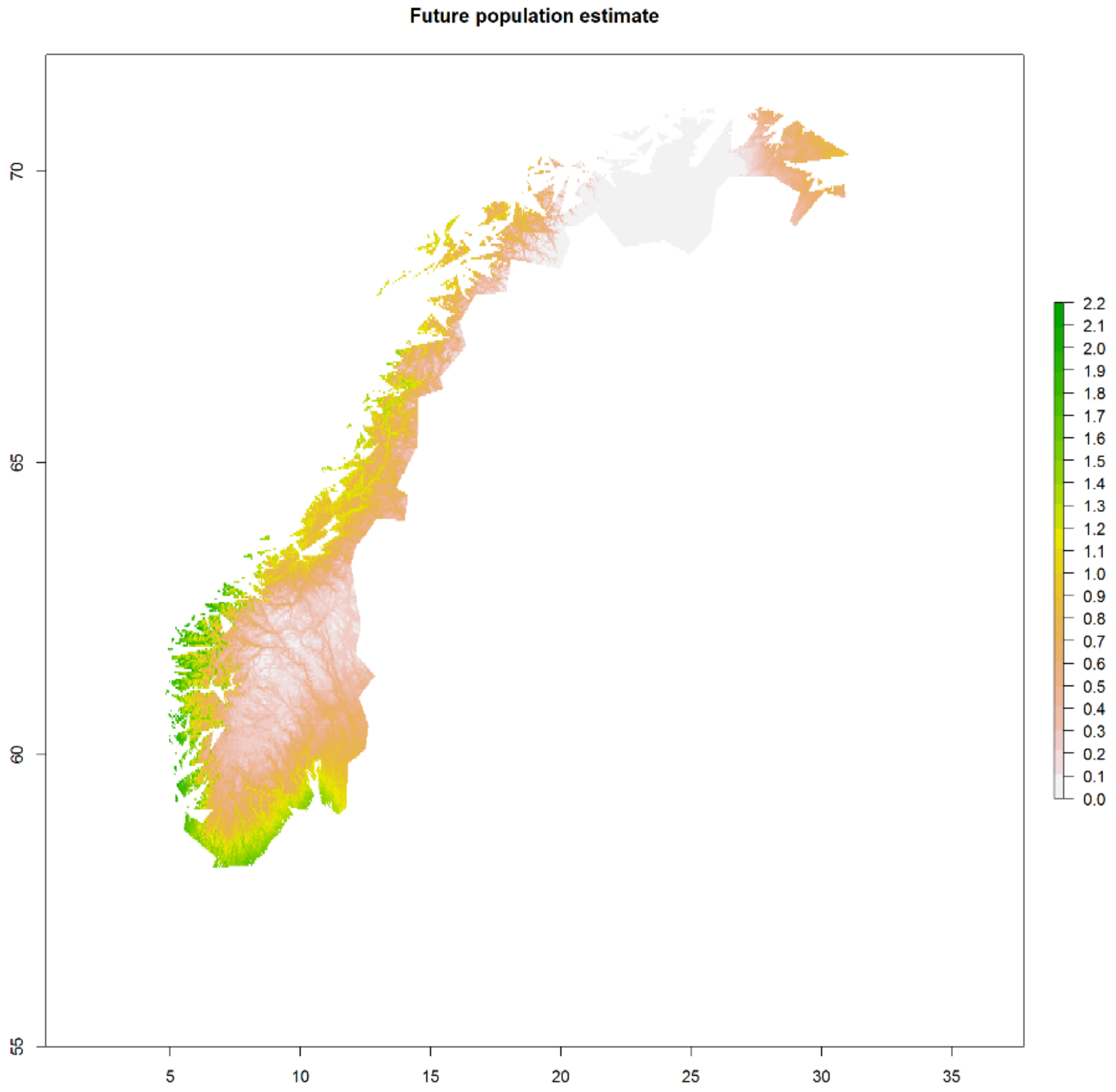

Figure 3.3-2 Estimated potential maximum number of wild boar per square kilometre in Norway, based on a predicted minimum temperature of January for the year 2050. Colours indicate density of wild boar between 0 (low density=white) and 2.2 (high density=green).

3.3.1 **Realized niche vs fundamental niche**

We have estimated the fundamental niche of wild boar in Norway to cover about 70,000 km² under current climate conditions, and have predicted that this area will increase to 157,000 km² within the next 50 years (See 3.2 and 3.3). However, this is the fundamental niche, and we do not expect this to be filled, as it is highly unlikely that wild boar will inhabit all suitable areas. This also reflects the total number of wild boar that can be sustained under both current and future climate scenarios. The NBIC estimate that the total carrying capacity in Norway under current conditions would realistically be around 40,000 animals (Pedersen et al., 2018). This is coherent with the output of our models, considering that large areas, both inland, on islands, and coastal areas north of Trondheim will likely not be inhabited by wild boar, even if the climate is suitable.

Importantly, the calculations presented here are based on the assumption that no supplemental feed is provided. If supplemental feeding becomes common, especially during winters, much higher densities (5 animals per km^2 rather than ~2) can be expected in some areas.

3.4 Factors influencing the dispersal rate of wild boar in Norway

It is difficult to estimate the natural dispersal rate of wild boar as human-mediated dispersal has played such an important role. However, based on experiences from other European countries, a spread of 2-3 km per year could be expected (Rosvold and Andersen, 2008; Truvé et al., 2004). In Norway, the population is anticipated to expand mostly along the coast where suitable habitats are found. Thus, without any human intervention, it could take about 30 years before the population in Aremark would have expanded to Rygge, and another 30 years before the population reached Larvik (should the wild boar cross the Oslo Fjord). However, as mentioned in section 1.1.6, some studies have recorded much longer dispersal distances (average 10 km and maximum 250 km), implying that faster expansion is possible.

3.4.1 Development of the Swedish population

The development of the Norwegian wild boar population, at least in the next 5-10 years, will be strongly influenced by how the Swedish population develops and is managed. With the current growth of the wild boar population in Sweden, it is very likely that the numbers of animals migrating to Norway will also increase dramatically. Culling immigrating animals may slow down the growth of the Norwegian population to some extent, but will not prevent further immigration.

Swedish measures to control the growth of the wild boar population (e.g., with a possible feeding ban, as suggested by the government) will clearly assist Norway's efforts towards population management.

3.4.2 **Human influences**

The wild boar population in Norway is currently limited, in terms of both geographic distribution and population size. Intensive hunting in the relevant areas (See 1.2.3 and 1.2.5) can potentially reduce spread. However, several wild boar farms already exist in different parts of the country (See 1.2.4) and, based on experiences from Sweden (and other countries), animals are likely to escape and have the potential to establish local populations. It is also possible that humans (also in Norway) will capture animals and transport them to other locations with the intention of establishing local populations for game hunting.

As discussed throughout this report, supplemental feeding enables wild boar to disperse through and establish in habitats that are not optimal, and this activity will undoubtedly play a major role in the development of the Norwegian wild boar population.

3.4.3 **Habitat and topography**

The wild boar is a species with high reproductive capacity, and, in a suitable environment, the population will increase rapidly until an ecological threshold, linked to food availability and climate, is reached (Vetter et al., 2015). It is, however, to be expected that the rugged topography along the Norwegian coast, with steep mountain sides and long fjords, will reduce the rate of spread in these areas, compared with spread in the flat and contiguous habitats in eastern Norway and Sweden.

3.4.4 **Climate**

Climate conditions, particularly the mean temperature in the coldest months (see 1.3.3 and 3.1 – 3.2), are the main determining factor for wild boar population growth (excluding human influences). Although predictions for future climate indicate milder winters overall, some hard winters are to be expected and could severely impact smaller wild boar populations.

4 Assessment of the risk of negative impact on biodiversity in Norway

4.1 Impact of increased wild boar populations on biodiversity in Norway

Wild boar might affect biodiversity and ecosystem services by habitat alterations from rooting and reductions in populations of plants, fungi, and animals due to herbivory and predation. The studies that have addressed the effects that wild boar might have on local plant and animal communities indicate that the effects, where present, are highly variable in both time and space. Although some studies have shown that the number of species of vascular plants, including invasive species, can increase somewhat where wild boar root, rooting also has negative impacts on soil-dwelling fauna and red-listed plant species. Of relevance to Norway, Brunet et al. (2015) studying a forest area in Southern Sweden, showed that rooting by wild boar decreased the ground cover of some species (spring ephemeral geophytes), while species richness of summer green forbs generally increased. Frequency and richness of spring ephemeral and woody species remained unchanged. The extent of rooting and the strength and direction of the effects were highly variable within the relatively small area under study, suggesting that the effects of wild boar on biodiversity depends on local conditions and the preference for particular patches by the individual wild boar. The opportunistic diet of wild boar also suggests that they feed on the food that is currently most available, and this might be highly variable within and among years. Rooting in both pastures and hey meadows may make farming with livestock grazing less favourable, leading to less open land and loss of biodiversity associated with this agricultural practice. No consistent negative effects on plants, fungi, or animals have been documented, although examples from defined areas at certain times have been reported. See section 1.3.1 for more detailed information, and the evaluation by Pedersen et al. (2018).

Diseases and parasites transmitted by wild boar to humans and livestock are covered fully in chapters 7 through 9. It is however worth mentioning here that some infectious diseases can also be transmitted from wild boar to the Norwegian fauna. Especially cloven-hoofed species (red and roe deer and moose in Norway) are susceptible to these diseases. These include foot-and-mouth virus (See 7.1.5.3), *Toxoplamsa gondii* (See 7.1.5.9) and *Dermatophytes* (See Table 14-1). Wild boar is also a carrier of *Trichinella* spp. which can be transmitted to several native wild species (See 1.3.1). However, as both *Toxoplasma gondii* and *Trichinella* spp. is already present in other wildlife populations in Norway, the establishment of wild boar is not considered to present a novel threat to the biodiversity with regard to these pathogens, although they could be a significant threat to domestic pigs (See 7.1.5.10).

4.2 Possible measures to control wild boar population growth and reduce impact on Norwegian biodiversity

As the Swedish wild boar population expands, and milder and wetter winter climates result in less snowfall in Scandinavia, the probability of establishment of viable populations of wild boar in Norway will increase. No measures have yet been implemented to manage wild boar in Norway, with the exception of a year-round hunting season. Volunteer hunting has thus so far been regarded as sufficient to limit population establishment and growth.

Through a large study of the efficacy of different management methods to reduce crop damage (fencing, feeding, and hunting) in the Thurgau canton in Switzerland, Geisser & Reyer (2004) concluded that hunting alone results in a clear reduction in wild boar damage; the authors recommended developing new harvest models among local hunting groups. The study further demonstrated that fencing can be an efficient method of protecting smaller areas against damage from wild boar rooting (Geisser and Reyer, 2004).

4.2.1 Culling

Experience from other countries indicates that hunting alone is not sufficient to control population growth when the population size has reached a certain threshold, and that the most control is achieved by targeting piglets and sexually mature females (Hohmann, 2017; Keuling et al., 2013; Keuling et al., 2016; Toigo et al., 2008). However, shooting females in the presence of striped piglets (3-6 months old) is considered unethical in Scandinavian countries (Malmsten et al., 2017) and is therefore illegal. The piglets, however, can be shot year round (LOVDATA, 2017).

It has also been shown that hunting can influence the spatial behaviour of wild boar and cause increased levels of crop damage from fleeing individuals. Thurfjell et al. (2013) suggest that drive hunts should only be performed after harvesting.

Traps can be used to capture whole groups of wild boars that then can be culled. Some models have been approved by the Swedish Environmental Protection Agency and are considered ethical to use (Naturvårdsvärket, 2010). However, they are generally not accepted by the Swedish Hunters' Association (usually for ethical/sportsmanship reasons).

Modelling suggests that even intense culling will not be sufficient to eradicate wild boar in areas with immigration (Pepin et al., 2017). Several non-lethal methods (fertility control, fencing, repellents (olfactory, acoustic, gustatory), dissuasive feeding, and translocation) can be used to enhance the effect of culling to reduce wild boar population growth and to hinder immigration (Massei et al., 2011; Pepin et al., 2017).

4.2.2 **Fertility control**

It has been shown that after a single injection with immunocontraceptives, wild boar sows may remain infertile for several years (Massei et al., 2012). So far only injectable forms of immunocontraceptives are available and this measure for population control therefore requires trapping and handling the animals, but boar-specific delivery systems could possibly provide an approach to distribution of oral contraceptives (Massei et al., 2010). However, results so far suggest that this method has limited impact (Massei and Cowan, 2014; Quy et al., 2014), but one potential benefit of this control method is that the infertile individuals occupy resources within an area and thereby limit the immigration of new individuals, as would be expected to occur after culling (Pepin et al., 2017).

4.2.3 **Limiting feeding**

Supplemental feeding is one of the main determinants for establishment and population growth rate in an area (See 1.1.7 and 3.1.2). Limiting the availability of feed, or restricting the use of feed to aggregate animals for hunting, could thus restrict both the spread and population expansion of wild boar in Norway. Minimizing supplemental feeding during the winters especially will reduce individual/population growth rate, as wild boar reproduce when they have reached a certain weight (Malmsten and Dalin, 2016). Limited winter feeding could also result in more synchronized birth rates in sows (Bieber and Ruf, 2005; Fonseca et al., 2004). This would allow more efficient hunting of females during winter as the chances of piglets following them is decreased, and thus hunters would be able to comply with modern hunting ethics, while also reducing the population.

Restrictions on feeding, particularly unintentional feeding, could be challenging to manage and monitor, but developments towards less frequent use of silage bales for environmental reasons could possibly benefit areas where control of wild boar population growth is desired (NRK, 2018).

4.2.4 **Population monitoring**

Regardless of measures taken, wild boar in Norway will continue to inhabit areas of Norway close to the border with Sweden. It will therefore be increasingly important to obtain accurate population estimates from the relevant counties. In particular, it will be important to survey establishment of family groups and escapees from wild boar farms within both countries. One way of monitoring population growth and dispersal of wild boar could be through camera traps, as suggested by Pedersen et al. (2016). During the autumns of 2015 and 2016, wild boars were regularly recorded by camera traps installed to monitor the population of lynx in Østfold and Akershus counties (NINA, 2017; Odden, 2017).

5 Uncertainties – Implications for biodiversity

The data from Sweden are sufficient to indicate with high certainty that a dramatic increase in the Norwegian population of wild boars can be expected unless the spread from districts bordering Sweden can be halted. However, in terms of population expansion we have limited data on:

- the current populations in Norway and Sweden.
- the frequency with which wild boars cross the areas of less suitable habitat along the Swedish border.
- the way Norwegian farmers and hunters will respond to wild boars (i.e., translocate and supply additional food or hunt to achieve local extinction).

There is also high uncertainty related to the effects of wild boar on biodiversity and ecosystem services in general as:

- few studies have been conducted in areas comparable to Norway, and results from available studies are sometimes contradictory.
- there is a lack of long-term studies on the effects of wild boar
- there is a lack of studies on the effects of wild boar at different densities

In relation to the modelling presented on wild boar distribution and densities, several factors contribute to increase the uncertainty:

- the number of registered wild boar in different environments is limited
- there is high uncertainty regarding the future climate data
- the model itself, and the settings chosen by the user, contribute to the uncertainty

6 Conclusions and answers to the terms of reference from The Norwegian Environment Agency

6.1 What is the predicted population trend for wild boar in Norway, based on experiences from Sweden and other relevant countries? In this context, the extent of historical and present supplemental feeding in Sweden has to be accounted for.

The Norwegian wild boar population can be expected to grow, and with supplemental feeding, a doubling of the population every three years can be expected, with densities potentially reaching up to 4.5 animals per km^2 in some regions, as observed in Sweden.

Climate modelling indicates that a large proportion of coastal areas (about 70,000 km^2) is suitable for wild boar at densities of 0.5 animals per km^2. Nevertheless, in a scenario without supplemental feeding and translocations the expansion of the population is likely to be confined to South East Norway.

The development of the Norwegian wild boar population is tightly linked to the development in Sweden as immigration can only occur from areas of high density close to the border. However, it will also be heavily influenced by national policies regarding food supply and population management.

6.2 Can climate change effects affect wild boar population growth/trends, in a 20-year perspective, and towards year 2100?

It is expected that climate change will accelerate growth of the Norwegian wild boar population in a 20-year perspective and towards year 2100.

It is expected that the climate in Norway will become more favourable for wild boar over the next 50 years, and that an area of about 157,000 km^2 will be suitable for sustaining wild boar populations by 2068. The predicted climate change will increase the maximum density of wild boar from 0.5 to up to 2.2 per km^2, without supplemental feeding.

6.3 Is it possible to quantify such population changes and to estimate the geographical distribution (in the same period)?

The model presented in this report suggests that the potential maximum of animals could theoretically increase from 200,000 animals to almost 450,000 animals in 50 years. It is important to note that this estimate assumes that all suitable areas in Norway are inhabited.

Expansion of the population is to be expected over the next 50 years, but in the absence of human-mediated dispersal and feeding, wild boars are not expected to cross the Oslo Fjord within this period.

6.4 Can a rate of expansion be estimated for Norway, and is it possible to identify factors that may increase or decrease this rate, based on experiences from other countries?

It is reasonable to expect a similar rate of natural dispersal as in Sweden (about 3 km/year) will occur in South East Norway. Most of the suitable habitats in Norway are found in coastal areas where the topography is likely to limit the expansion rate. Urban and semi-urban areas with high human populations and the physical barrier of the Oslo Fjord are also expected to slow down the dispersal rate.

Human-mediated translocation, supplemental feeding, and animals escaping from farms are factors that could lead to much faster expansion of the Norwegian wild boar population.

6.5 What negative consequences for biodiversity can be expected in the areas where wild boar is expected to increase in number and distribution?

Wild boar might affect biodiversity through habitat alterations caused by rooting. Rooting may have negative impacts on soil-dwelling fauna and red-listed plant species, but also positive effects on ephemeral, early succession, species. In addition, wild boar might reduce populations of plants, fungi, and animals due to herbivory and predation.

Rooting in hey meadows and on pastures may make livestock farming based on local forage resources less favourable, leading to less open land and the loss of biodiversity associated with this farming practice.

Only a limited number of long-term studies exist, and we have found no study assessing the effect of contrasting wild boar density on biodiversity and ecosystem services. Long-term effects and effects under contrasting wild boar densities are crucial to understand the impact of wild boar on biodiversity and ecosystem services.

6.6 Which measures may be taken to control the wild boar population growth/development and to limit negative consequences for biodiversity?

The Norwegian wild boar population is still relatively small, and intensive harvesting and culling may be used for population control, but will not prevent new immigrations from Sweden.

Fertility control may be a measure to reduce population growth and simultaneously discourage immigration of new wild boar into these territories.

Feeding might be used to attract animals to hunting sites, but is one of the main determinants for establishment and population growth rate in an area.

Monitoring feeding practices and monitoring the establishment of family groups and escapees from wild boar farms will be important during establishing control of the development of the Norwegian wild boar population.

7 Assessment of the wild boar population growth and expansion – implications for food safety and animal health in Norway

7.1 Hazard identification/characterisation

7.1.1 Animal and Public Health Hazards

In this report all relevant hazards were evaluated in the context of potential animal health and/or public health hazards. For animal health hazards, a literature search was used to identify published studies of relevance. For public health hazards, an Opinion from EFSA regarding meat inspection from farmed game was the starting point, which was then complemented with literature searches. The EFSA opinion is described in detail below.

7.1.2 EFSA Scientific Opinion on the public health hazards to be covered by inspection of meat from farmed game

The long list (Table 14-1) from the EFSA Scientific Opinion on the public health hazards to be covered by inspection of meat from farmed game (EFSA, 2013) was used as the basis for our selection of zoonotic agents that should be considered. In that Opinion, the hazards considered are those in which at least one publication has reported the presence of the hazard in farmed game (deer, reindeer, ostrich, wild boar or rabbit), in the EU. Hazards in the long list were then evaluated by EFSA regarding whether the hazard could be transmitted to humans through the handling, preparation and/or consumption of farmed game meat and the presence of the hazard in farmed game in Europe. From this list, we selected the zoonotic agents associated with wild boar and used these as the basis for our survey of literature. The short-listed agents for wild boar are presented in Table 3 in the EFSA Opinion (EFSA, 2013) and consisted of *Campylobacter* spp., *Salmonella* spp., pathogenic VTEC, *Yersinia enterocolitica*, *Toxoplasma gondii*, *Trichinella* spp. and hepatitis E virus (HEV).

When EFSA identified a hazard as causing a high incidence and/or severity of illness in humans, and when strong evidence existed for farmed game meat being an important risk factor for human disease, then that agent was characterised by EFSA as being of 'high' priority (EFSA, 2013). Considering the limitations of the data available for the priority ranking, this risk category could be regarded as combining both the medium- and high-risk categories of the risk ranking carried out in a comparable. EFSA characterised a hazard as being of 'low' priority when a hazard was identified as not being associated with a high incidence and a high severity of human disease or if, despite the hazard causing a high incidence and/or severity in humans, there was insufficient evidence that meat from farmed game was an important risk factor for human disease. If the data available for the assessment of a given biological hazard were insufficient to conclude on the ranking, EFSA characterised the priority as "undetermined". All hazards in the low-priority category were further evaluated to determine whether this ranking was due to currently applied controls (i.e., any hazard-specific control measure implemented at farm and/or slaughter level before chilling of the carcass, including meat inspection procedures). If this was not the case, then the hazard was not considered further. However, if this was the case then any proposed changes to current meat inspection procedures that would increase the risk posed by the hazard were evaluated.

The Opinion's conclusion on the priority ranking in EFSA (2013) were as follows:

- *Salmonella* spp. and *T. gondii* were ranked as high priority, while pathogenic VTEC was ranked as low priority for meat inspection.
- *Y. enterocolitica* and *Trichinella* spp. were ranked as low priority because of their low incidence and/or severity in reported human cases. Current control measures were not considered to be responsible for the low-priority ranking of pathogenic VTEC and *Y. enterocolitica*.
- *Trichinella* spp. control by meat inspection was considered the main reason for the low number of human cases.
- For *Campylobacter* spp. and (HEV), the priority was characterised as undetermined due to insufficient data. EFSA recommended that further studies should investigate the prevalence of HEV in farmed wild boar.

7.1.3 **Other EFSA opinions of relevance**

A scientific report on African swine fever (ASF) in 2017, EFSA concluded that: "ASF control in wild boar may require strategic measures applied over areas of several hundreds of square kilometres, for at least two to five years" (Abrahantes et al., 2017). "In theory, the following combination of alternative strategies would be effective in halting the spread of ASF in wild boar: immediate exclusion of contact with carcasses within a 50 km radius of the affected area combined with intensification of conventional hunting which would reduce reproduction in the following year by 30–40 %". These measures could be considered appropriate for a potential outbreak in Norway. Geography may pose an additional challenge to implementing these measures in the Norway, but the assumed lower densities of both wild boar and domestic pigs and fewer chances for contact between these would assist in containment.

It should be noted that another report from EFSA on ASF published in 2017, commented that the efficacy of control measures may be limited in situations where ASF is already geographically widespread and where very rapid implementation of control measures is not feasible (Thulke and Lange, 2017).

A further scientific opinion from EFSA in 2017 (2017)on the public health risks associated with HEV as a foodborne pathogen, emphasised the importance of HEV regarding public health in both Europe and elsewhere and summarized several outbreaks reports that demonstrate the importance of both wild boar meat and deer meat as sources of infection.

On further EFSA opinion (EFSA, 2009), used in the current assessment describes the implications of the presence of *Yersinia enterocolitica* O:9 for serological screening of pigs and cattle for brucellosis.

7.1.4 **Evaluation criteria**

Evaluation criteria that were used for agents considered in this assessment are: zoonotic potential, presence in European domestic pigs, presence in European wild boar, presence in wild boar in Sweden or Finland, presence in Norway in pigs or other species, occurrence of other relevant vectors / reservoirs, evidence/role of transmission from wild boar to domestic pigs (Table 14-1).

7.1.5 **Animal and public health hazards considered**

Based on the literature survey, taking into account the considerations in EFSA (2013) and the evaluation criteria listed above, it was determined that the agents listed below should be considered further in the current assessment. The following text is based upon agents selected from the long list presented in Table 14-1 and assessment of the agent in the context of the evaluation criteria. References used for assessment of the agents are presented in Table 14-1.

7.1.5.1 African Swine Fever Virus (ASFV)

African swine fever (ASF) is a highly contagious haemorrhagic disease of pigs, European wild boar, and American wild pigs. All age groups are equally susceptible. The mortality in pigs may be as high as 100%. There is currently no effective vaccine against ASF.

ASF is present in many African countries, but had been eradicated from Europe (with the exception of Sardinia), until its reintroduction to Georgia in 2007 through the port of Poti (Rowlands et al., 2008), perhaps via contaminated food that was used to feed pigs. Detection of ASF requires immediate notification to the World Organization of Animal Health (OIE), and its presence leads to immediate restrictions in the pig and pork trade.

Pigs usually become infected by direct contact with infected pigs or by ingestion of garbage containing unprocessed infected pig meat or pig meat products. The stability of ASFV in organic matter and meat products is of particular epidemiological importance. ASFV can also be spread to susceptible animals via biting flies and ticks, or contaminated premises, vehicles, equipment, or clothing.

ASFV replicates in soft ticks of the genus *Ornithodoros* spp., which act as virus reservoirs (Diaz et al., 2012; EFSA, 2010), and where ASFV is able to persist for as long as 1 year (Endris et al., 1987; Hess et al., 1989). Transmission via this tick is of epidemiological relevance only in the Iberian Peninsula and Mediterranean basin (current tick range). No studies indicate that this tick may pose a relevant transmission threat for northern Europe in the near future. Studies on ASFV in other tick species are scarce. Strict biosecurity measures are extremely important to prevent the spread of ASF. The disease poses no threat to humans or animal species other than pigs (including wild boar).

ASF has never been reported in wild boars or domestic pigs in Fennoscandia, but, at the time of writing, is endemic in wild boars in several countries in Eastern Europe (including the Baltic countries, Poland, Hungary, Romania, and the Czech Republic).

7.1.5.2 Classical swine fever virus (CSFV)

Classical swine fever (CSF), commonly known as hog cholera, is a contagious viral disease, infecting only swine and wild boar under natural conditions; experimental studies have shown it can be transmitted to other species.

Transmission of CSF between domestic pigs and wild boars has been documented from over 50-years ago (Brugh et al., 1964). Detection of CSF requires immediate notification to the OIE, and its presence leads to immediate restrictions on the pig and pork trade.

Pigs usually become infected by the oral and oro-nasal routes, both by direct contact with infected pigs or by ingestion of garbage containing unprocessed infected pig meat or pig meat products. CSFV may survive for a considerable period in protein-rich environments (Edgar et al., 1952; Helwig and Keast, 1966), possibly leading to indirect transmission through carcass consumption. The disease poses no threat to humans.

CSFV has a global distribution in both wild boars and domestic pigs, but is mostly absent in Western and Central Europe. In some European countries, CSFV has been periodically reintroduced into domestic pigs via contact with infected wild boars (Le Potier MF, 2006). Despite this and the fact that wild boars are easily infected with CSFV, their role in the transmission of CSFV remains controversial. A vaccine (bait vaccine) is available and has been used successfully in the control of CSF in wild boar.

CSFV is currently not present in wild boar in Fennoscandia, and was last reported in domestic pigs in Norway in 1963.

7.1.5.3 Foot-and-mouth virus (FMV)

Foot and mouth disease (FMD) is a highly contagious viral disease that can infect all cloven-hoofed species, both domestic and wild (e.g., cattle, pigs, sheep, goat and deer).

FMD is one of the most important diseases affecting animals, and its detection requires immediate notification to the OIE. Its presence leads to strict quarantine and eradication measures.

Pigs usually become infected by the oral and oro-nasal routes, both by direct contact with infected animals and by inhalation of aerosolized virus, and by ingestion of infected meat products. FMV is relatively resistant and, depending upon environmental conditions, can survive for several days or more on fomites and even longer in animal products. The disease poses no threat to humans.

FMD is endemic in parts of Asia, Africa, Middle East, and South America, but is usually absent in Europe and North America. In the wild, the disease is endemic exclusively in African Cape buffalos (*Syncerus caffer*). In Europe, two outbreaks have been reported in the last 12 years (on in 2007 in the UK and on in 2011 in Bulgaria). In 2011, Bulgaria confirmed the presence of FMD in three wild boars that had been shot, with the disease thereafter spreading to cattle. A further study in 2013 in the same area revealed the presence of antibodies against FMV in 6.9% (n=812) of the tested wild boars.

FMD has not been reported in Fennoscandia since the 1960s.

7.1.5.4 Influenza A virus **(SIV)**

Swine influenza is a highly contagious viral infection of pigs causing respiratory disease. In some instances, swine influenza is associated with reproductive disorders such as abortion. Despite being an enveloped virus, swine influenza virus (SIV) has been reported to survive for long periods in the environment, particularly when the temperature is low.

Swine influenza is caused by influenza A viruses, RNA viruses of the *Orthomyxovidirae* family. The domestic pig is considered to be a major reservoir of H1N1 and H3N2 influenza viruses (Brown, 2000). SIV is found mainly in pigs, but has also been found in other species, including humans, turkeys, and ducks. The zoonotic potential of SIN has been clearly demonstrated.

The primary route of transmission is through pig-to-pig contact via the nasopharyngeal route, most probably through nose-to-nose contact or direct contact with mucus. SIV is shed in nasal secretions and disseminated through droplets or aerosols. The role of wild boar in transmission of SIV is likely density-dependent, and in high density areas (e.g., farms or semi-captive situations), SIV may circulate easily, become endemic, and be easily transmitted to domestic pigs (Ruiz-Fons et al., 2008). The role of the wild boar in relation to the highly pathogenic avian H5N1 influenza virus should be considered.

SIV has a global distribution in both domestic pigs and wild boar. Serological data are available from European wild boar and feral pig populations. Seroprevalence varies greatly, depending on the country or region and SIV subtype.

SIV has been reported in domestic pigs in Fennoscandia (Forberg et al., 2013; Metreveli et al., 2011; Nokireki et al., 2013; Watson et al., 2015). However, despite many wild boar surveys in Europe, there is very limited information on the presence of SIV in the Swedish and Finnish wild boar populations. A recent study in Swedish wild boar found a SIV seroprevalence of 3.8% (Malmsten et al., 2018). In Norway, the only reported type of swine influenza (a notifiable pig disease in Norway) in the commercial pig population is H1N1pdm09, after introduction in 2009; active serosurveillance is conducted annually (Hofshagen et al., 2017).

7.1.5.5 Hepatitis E virus (HEV)

Hepatitis E virus (HEV) is responsible for enteric viral hepatitis in humans worldwide. Although often asymptomatic, HEV infection can sometimes cause acute hepatitis, with higher mortalities in pregnant women, or chronic hepatitis in immunocompromised people. HEV is a positive single-stranded, non-enveloped RNA virus belonging to the *Hepeviridae* family. HEV infects humans and a variety of animals, including both domestic pigs and wild boar. Four main genotypes are recognised: 1 and 2 often linked to waterborne faecal-oral transmission (circulating mostly in humans) and 3-4 that are linked to foodborne transmission (circulating in both humans and animals). Type 3 is the most prevalent genotype in Europe. Several studies have noted the capacity of HEV to survive in water, soil, and food products over long periods of time, which may facilitate transmission. Several studies in Europe have reported the presence of HEV in wild boar (for a review please see the EFSA (2017b), Table 2), and several outbreaks in humans have been linked to consumption of undercooked pig meat (EFSA, 2017b).

Information on transmission of HEV between wild boar and domestic pigs is scant, but given the number of outbreaks in both domestic and wild swine populations and the close contact between these species in some countries in Europe, it might be assumed that transmission does occur. A study in Corsica exemplified the flow of HEV between domestic, wild, and hybrid pigs, and clearly demonstrated its zoonotic potential (Jori et al., 2016).

In Norway there is little information on HEV, but a study by Lange and colleagues in 2017 revealed a high prevalence of HEV in both domestic pigs (90% of tested animals) and humans (around 13%) (Lange et al., 2017). This might indicate that, as in many other countries in Europe, HEV is widely distributed in both human and animal populations. HEV has also been described in pigs in Sweden (Widen et al., 2011) and Finland (Kantala et al., 2015). Information on HEV in wild boar in Fennoscandia is scarce.

7.1.5.6 Porcine respiratory and reproductive syndrome virus (PRRSV)

Porcine reproductive and respiratory syndrome (PRRS), also known as blue-ear pig disease, is characterised by reproductive failure of sows and respiratory problems in piglets and growing pigs. PRRS is considered one of the most common viral causes of reproductive failure in domestic pigs. The pig (domestic or feral) is currently the only known susceptible species, but other members of the *Suidae* family may be susceptible.

Vertical transmission has been demonstrated. Pigs can be infected either by direct contact or indirectly through fomites. Exposure to PRRSV occurs by the respiratory and oral routes, and through the mucosa or percutaneously (Pileri and Mateu, 2016). It is unknown whether PRRSV is present in the same tissues and fluids in wild boar. PRRSV survival in aerosols is higher at lower temperatures and lower relative humidities (Zimmerman et al., 2010), suggesting that aerosol transmission in nature is influenced by climate. Arthropod vectors can maintain PRRSV for short periods, but are not considered important reservoirs. The disease poses no threat to humans.

PRRSV is present worldwide in domestic pigs. Although knowledge of PRRSV in wild boar is limited, the presence of PRRSV has been reported in wild boar in France, Germany Lithuania, Poland, and Spain. Transmission of PRRSV from domestic swine to wild boar currently seems more probable than vice versa, for which the role of wild boar as reservoir for PRRSV may be limited (Ruiz-Fons et al., 2008).

PRRSV is currently not present in wild boar in Fennoscandia and has not been reported in domestic pigs, apart from in Sweden in 2007 (Albina et al., 2000; Carlsson et al., 2009; Fabisiak et al., 2013; Reiner et al., 2009; Rodriguez-Prieto et al., 2013; Stankevicius et al., 2014).

7.1.5.7 Suid herpesvirus 1 (SuHV-1)

Aujeszky's disease (AD), pseudorabies or "mad itch" is a neurological/respiratory disorder that affects a wide range of mammals, except humans and tailless apes. It is caused by suid herpesvirus type 1 (SuHV-1), an enveloped, large DNA virus of the genus *Varicellovirus*, family *Herpesviridæ*.

AD is associated primarily with pigs, the natural host, which remain latently infected following clinical recovery. As the pig is the only species able to survive a productive infection, it serves as the reservoir host. There are, however, several reported incidents of AD causing deaths in dogs used in wild boar hunting across Europe.

Transmission between domestic pigs and wild boars has been documented and can be a considerable problem in areas of extensive production of domestic pigs, where contact with wild boars is common. SuHV-1 strains circulating in many European wild boar populations are attenuated and are thus of low virulence. Detection of AD requires notification to the OIE.

Pigs usually become infected by the oral and oronasal routes, but venereal transmission has also been reported. The virus does not survive well in the environment. The disease poses no threat to humans.

AD has a global distribution in both wild boars and domestic pigs. Several surveys in Europe have shown the virus to be circulating among wild boar populations. AD has never been reported in Finland or Norway. Its last occurrence in Sweden was in domestic pigs in 1995, and in Denmark in wild boar in 1991.

7.1.5.8 Transmissible gastroenteritis coronavirus (TGEV)

Transmissible gastroenteritis (TGE) is a highly contagious, enteric disease of swine caused by a virus closely related to porcine respiratory coronavirus (PRCV).

TGEV is spread via aerosol and direct contact between pigs, with pigs usually infected via the oral/oronasal routes. This usually occurs post-weaning, when maternally derived antibody-mediated protection begins to decline. Transmission may also occur in growers/finishers when TGEV-naïve pigs are introduced.

Little information is available regarding coronavirus infections in European wild boars and feral pigs, hence the potential for transmission between wild boar and domestic pigs remains mostly unknown. The disease poses no threat to humans.

TGEV is present in most countries worldwide, but its importance has decreased over time as PRCV infection immunizes pigs against TGEV infection (Saif and Sestak, 2006). As PRCV is enzootic in European domestic pigs, this has led to a significant decrease in the economic impact of TGE (Laude et al., 1993; Pensaert and Cox, 1989).

Serological investigations have suggested that infection with TGEV is absent, or at very low prevalence, in wild boars, e.g., in Slovenia, (Vengust et al., 2006). The variant PRCV is present in pigs in Sweden. TGEV has never been reported in wild boar in Sweden, Finland, or Norway.

7.1.5.9 Toxoplasma gondii

Toxoplasma gondii is arguably one of the most successful parasites globally, with an extremely high number of potential intermediate host species (all warm-blooded animals). Felids are the definitive hosts, and the primary ecological cycles are usually linked to various rodents.

T. gondii, the only species within this genus, is now divided into various clones or types, that seem to have differing geographic distributions, and also different virulences and pathogenicities in different host species. In North America and Europe there are three genetic clonal types (I, II, III), of which Type I strains tend to be lethal to outbred mice, whereas Type II and III strains are significantly less virulent. In South America, particularly

Brazil, atypical types seem to predominate and some of these show high virulence in mice and other animals, including humans. In most of Europe, Type II predominates. Although this is of lesser virulence to mice, and does not seem to be associated with high virulence in the immunocompetent and non-pregnant humans, it is still associated with abortions in sheep, and clinical problems in the immunocompromised and foetuses of pregnant women first exposed during pregnancy. In the Netherlands, *Toxoplasma* has been judged to be one of the foodborne pathogens with the greatest disease burden in DALYs (along with rotavirus and *Campylobacter* spp.) (Mangen et al., 2015).

The seroprevalence associated with *Toxoplasma* in the human population of Norway is low compared with in many other countries; the most recent study, a cross-sectional study of almost 2000 pregnant women from two different counties, reported a seroprevalence of under 10% (Findal et al., 2015). This indicates that although the Norwegian population is exposed to the parasite, there may be vulnerability in the more high risk groups such as pregnant women.

Among animals in Norway, seropositivity is common in sheep, goats, and wild cervids, and also in pigs, especially those reared outdoors (Kapperud, 1978; Skjerve et al., 1998; Vikøren et al., 2004). Norwegian carnivores and scavengers are also infected (Stormoen et al., 2012), and the seroprevalence amongst Norwegian cats is around 40% (Saevik et al., 2015), but may be expected to higher among farm cats, or other cats that are used to keep rodent populations under control.

Regarding the relevance of serological results to the actual occurrence of infective tissue cysts in pigs, it has been determined that the concordance between serology, bioassay, and PCR-based detection is fair if cardiac fluid is used for serological assay, with concordances of 0.66 (with bioassay), 0.46 (with PCR digest), 0.23 (with magnetic capture-PCR) and 0.41 (any direct detection methodology) (Opsteegh et al., 2016). However, detection of *T. gondii* in seronegative pigs was higher than expected, with 23.9 % positive by PCR on heart digest and 10.2% MC-PCR on diaphragm (10.2%). Thus, seronegative pigs may nevertheless harbour *T. gondii* (Opsteegh et al., 2016).

In a meta-analysis from 2017, (Rostami et al., 2017) reported a seroprevalence of toxoplasmosis in wild boars to be 26% in Europe, and that wild boar may have an important role in human infection and the epidemiological cycle of *T. gondii* infection. Reports from Estonia (Jokelainen et al., 2015; Santoro et al., 2017), Poland (Witkowski et al., 2015), Latvia (Deksne and Kirjusina, 2013), Finland (Jokelainen et al., 2015), the Czech Republic (Bartova et al., 2006) also document the occurrence of *T. gondii* in wild boars.

A study from Sweden (Wallander et al., 2015), found 34% of young wild boars and 55% of adults seropositive for *T. gondii*. The highest seroprevalence, 65%, was recorded in South Sweden but varied in other regions from 29% in Stockholm to 46% in Central-East Sweden. If, as in pigs, seronegative animals may harbour the parasite, it is possible that the proportion of infected animals is even higher than these data indicate.

In Norway, the *Toxoplasma* status of wild boars has yet to be investigated, but the situation will probably be similar to that of Sweden. Thus, wild boar may be a further driver to the level of toxoplasmosis in wildlife. However, given the parasite lifecycle, there is no reason why wild boar should be any greater threat to domestic pigs than from other infected animals.

As many hunted wild boar are likely to be infected, consumption of undercooked or raw meat from wild boars carries a risk of infection transmission.

7.1.5.10 Trichinella **spp***.*

Trichinella spp. causes trichinellosis or trichinosis, a zoonotic disease with the potential to cause severe disease in humans, and may be fatal. The genus consists of several species/ genotypes, with *T. spiralis* ,*T. britovi,* and *T. nativa* of primary relevance for Norway. Transmission occurs by ingestion of the viable larvae encysted in the tissue of a previously infected host, and therefore is primarily associated with carnivores and omnivores. Importantly, *T. britovi* larvae have a mild cold resistance, although not as extreme as the Arctic-associated *T. nativa.*, and therefore freezing cannot be guaranteed to inactivate larvae in infected meat. Trichinellosis was common also in pigs in Norway until strict regulations on swill feeding of pigs was introduced, and is now extremely rare in domestic pigs (the last case in domestic pigs was reported in 1994).

Around 4.5% of Norwegian red foxes were found to be infected, with 18 of the 19 different *Trichinella* spp. identified as *T. nativa* and one as *T. britovi* (Davidson et al., 2009). In 2017, *T. nativa* was found in a wild boar in Poland (Bilska-Zajac et al., 2017), adding to the concern about the public health hazards linked to consumption of undercooked or raw meat. In Norway, *Trichinella* was detected in a hunted wild boar in 2015 (Norwegian Veterinary Institute, 2016), but the species was not identified. Although freezing is often an efficient way to kill tissue parasites (e.g., *Toxoplasma*), this may not be sufficient for inactivating *Trichinella*, due to the freeze-resistance in some species. All wild boar meat should be examined for *Trichinella.*

Although infected wild boars may come into contact with domestic pigs reared outdoors, transmission will only occur if the pigs ingest the larvae in the wild boar tissue. It is theoretically, possible, however that scavengers, such as rats, may become infected from eating dead wild boar containing *Trichinella* larvae, which may then be ingested by domestic pigs. This theoretical route may possibly lead to more cases in domestic pigs, especially those raised outside.

The epidemiological link between disease in humans and consumption of wild animals is clear (Rostami et al., 2017) and many outbreaks have been linked to consumption of wild boar, as exemplified by the many reports, including from our neighbour countries (Bartuliene et al., 2009; Borza et al., 2012; Dubinsky et al., 2016; Faber et al., 2015; Hurnikova and Dubinsky, 2009; Jansen et al., 2008; Oivanen et al., 2000; Pannwitz et al., 2010; Reiterova et al., 2007; Rostami et al., 2017; Turiac et al., 2017). In 2014, a restaurant-associated outbreak of trichinosis occurred in Belgium that was due to wild boar meat imported from Spain (Cacciò et al., 2018; Messiaen et al., 2016). This outbreak was due to *T. spiralis*; this species of *Trichinella* is more infective to domestic pigs than *T. britovi* and *T. nativa* (both of which occur in red foxes in Norway), and has not been identified in Norwegian red foxes. The last time that *T. spiralis* was identified in domestic pigs in Norway was over two decades ago. Thus, wild boar may represent a threat towards re-introduction of this species.

In summary, *Trichinella* in wild boars represents a public health hazard of major concern, and with an increasing number of animals, we might expect more infections in people.

7.1.5.11 Brachyspira **spp.**

The main disease-causing species in the genus *Brachyspira* in pigs is *Brachyspira hyodysenteriae*, the predominant agent causing swine dysentery (SD) (Zimmerman et al., 2006b). SD affects mainly grower and finisher pigs, and is characterized by diarrhoea (with mucus and blood), partial anorexia, fever, dehydration and emaciation. In outbreaks of SD, morbidity in weaner pigs may approach 90%, and mortalities of 30% can be observed if treatment is delayed.

Although some members of the *Brachyspria* genus are zoonotic, *B. hyodysenteriae* is not. *B. hyodysenteriae* naturally infects pigs (including wild boars and feral pigs) and occasionally some species of birds (chickens, ducks and geese).

B. hyodysenteriae is relatively resistant in moist faeces, especially at low temperatures, where a maximum survival time in pig faeces of 112 days has been reported (Boye et al., 2001).

B. hyodysenteriae is mainly transmitted via the faecal-oral route, but, due to its prolonged survival time in faeces, indirect transmission through contaminated clothes or footwear is also relevant.

B. hyodysenteriae is present in wild boars and domestic pigs in Europe, and has been found in domestic pigs in Sweden, Finland, and Norway. However, SD is rare in Norway and typically only 1-4 herds are found positive annually. SD is normally eradicated by the pig production sector whenever found in commercial pig holdings in Norway. As there are other relevant reservoirs (including birds and rodents), transmission from wild boar to domestic pigs is possible.

7.1.5.12 Brucella suis

Brucella suis biovars 2 (BS2) infections in wild boars and/or European hares (*Lepus europaeus*) have been described in almost all European countries, except Sweden and Norway (EFSA, 2012; Godfroid et al., 1994.; Malmsten et al., 2017). Spillover of BS2 from wild boars to free-ranging pigs has been reported in several European countries (EFSA, 2012; Jungersen et al., 2006).

BS2 is known to have very low pathogenicity to humans with only two case reports in the literature. However, seven human cases were identified between 2004 and 2016 in France. These findings suggest that BS2 might be an emerging pathogen in hunters with massive exposure during the dressing of wild boar carcasses (Mailles et al., 2017).

In addition to BS2, *B. suis* biovar 3 has been isolated from wild boars in Croatia. This was the first report of *B. suis* biovar 3 in swine and wild boar in Europe, and may represent an issue of serious concern for public health, as this biovar is known as an important human pathogen (Cvetnic et al., 2009).

7.1.5.13 Campylobacter **spp***.*

Campylobacter spp. are zoonotic bacteria causing campylobacteriosis. At the European level, *Campylobacter* spp. were not detected in faecal and tonsillar samples in hunted wild boar in Switzerland (n = 153) (Wacheck et al., 2010). In Germany, in one study only 3 of 127 (2.1%) hunted wild boar carcasses tested positive for *Campylobacter* spp. (Atanassova et al., 2008), whereas another study reported *Campylobacter* spp. in 2.9 % (2/70) of hunted wild boar (Atanassova et al., 2008; Ziegenfuss, 2003). In a Swedish study, *Campylobacter* spp. were isolated from 12 of 66 wild boars, with both *C. jejuni* and *C. coli* represented (Wahlstrøm et al., (2003). *Campylobacter* spp. are detected very frequently among Norwegian pigs (Nesbakken et al., 2003). In conclusion*, Campylobacter* is present in wild boars and domestic pigs in Europe, as well as in wild boar in Sweden, but not as frequently as in pigs. Other relevant reservoirs include many species, in particular birds. Pigs with outdoor life may be infected.

7.1.5.14 Methicillin-resistant Staphylococcus aureus (MRSA)

This zoonotic agent is responsible for transfer of antimicrobial resistance, but its survival in the environment is very limited (Rørvik and Granum, 2015).

It has been isolated only a few times from wild boars in Europe according to a recent VKM report (2018). Although antimicrobial resistance in wildlife has the potential for dissemination, MRSA is already common in domestic pigs in Europe. It is probably rare in wild boar in Sweden, and is also rare in pigs and other animal species in Norway (Veterinærisntituttet, 2018). Other relevant reservoirs include many species. Pigs with outdoor life may be infected.

7.1.5.15 Mycoplasma hyopneumoniae

Mycoplasma hyopneumoniae is a member of the class Mollicutes, which are bacteria that lack cell walls and are the smallest known cells able to propagate in a cell-free medium. *M. hyopneumoniae* causes porcine enzootic pneumonia and is not zoonotic. Transmission of *M. hyopneumoniae* in field conditions most commonly occurs through nose-to-nose contact, but aerosol transmission has been demonstrated at distances of up to 3.2 km (Zimmerman et al., 2006a).

M. hyopneumoniae causes chronic bronchopneumonia directly, and enables establishment of secondary infections with bacteria and certain viruses through suppression of innate and acquired pulmonary immunity. When introduced to naïve herds, *M. hyopneumoniae* causes epizootic disease, where morbidity reaches 100% and is characterized by acute respiratory distress, fever, and where death may also occur (especially as a result of secondary bacterial superinfections). A more insidious endemic form typically follows after 2-5 months, with a dry non-productive chronic cough, and a reduction in growth rates and feed uptake.

The agent has been reported from wild boars and domestic pigs in Europe, and is most likely also present in wild boar in Sweden and Finland. The last report from Norway was in 2008 after a national stakeholder-run eradication campaign. Annual serosurveillance at the Norwegian Veterinary Institute funded by the Pig Health Service has demonstrated freedom since 2008. There are no other relevant reservoirs or vectors.

7.1.5.16 Salmonella spp.

Salmonella spp. is a zoonotic pathogen, causing salmonellosis in humans and other species. It survives in the environment. It is present in wild boars and domestic pigs in Europe, and is apparently common in free-living wild boars. A study of 153 wild boars from Switzerland by Wacheck et al. (2010) reported a *Salmonella* spp. detection rate of 12%. The *Salmonella* serotypes detected include: *S.* Enteritidis (75%) followed by *S.* Stourbridge and *S.* Veneziana. A Portuguese study of 77 animals found *S.* Typhimurium and *S.* Rissen carriage rates of 64.7 % and 35.3 %, respectively (Vieira-Pinto et al., 2011). *S. enterica* subspecies enterica serovar Choleraesuis, the swine-adapted serovar, is rarely found in Western Europe. However, the regional laboratory of the federal state Thuringia in Germany that examined diseased wild boars routinely, isolated the serovar *S*. Choleraesuis from 24 animals between 2006–2008, and the occurrence of the identical epidemiological groups in wild boars and domestic pigs indicates a possible mutual exposure to the pathogen (Methner et al., 2010).

In Sweden, tonsils, ileocaecal lymph nodes and faecal samples were collected from 88 Swedish wild boars and analysed for *Salmonella* spp. using a combination of cultivation and PCR detection. Overall, 10% of individuals were positive for *Salmonella* spp, with isolates belonging to *S.* enterica subspecies enterica (I) serovar 4.5:-:1.5 (n=3), *S.* enterica subspecies enterica (I) serovar Typhimurium (n=1) and *S.* enterica subspecies diarizonae (IIIb) serovar O42:r:- (n=2). The pathogen was most commonly detected in tonsil samples (Sanno et al., 2014). In a Swedish survey of 66 samples from wild boars, *Salmonella* was not detected (Wahlstrøm et al., (2003).

In conclusion, *Salmonella* is present in wild boars and domestic pigs in Europe as well as in wild boars in Sweden, but it is seldom present in pigs or other species in Norway (Norwegian Veterinary Institute, date??). Other relevant reservoirs include many species. Pigs with outdoor life may be infected from wild boars.

7.1.5.17 Yersinia enterocolitica

In general, *Y. enterocolitica* is zoonotic, cold-adapted, and survives in the environment. The human pathogenic serotypes that most often cause yersiniosis in Europe are, in particular, O:3, but also O:9; pigs are often carriers of these serotypes (Nesbakken, 2012).

According to data reported by EU member states in the framework of the Zoonoses Directive (2003/99/EC), 5.1 % of wild boars were infected with *Y. enterocolitica* in 2004–2011. In Switzerland, *Y. enterocolitica* was isolated from 35% of tonsillar samples and 5% of faecal samples from feral wild boar (Wacheck et al., 2010). The serotypes identified are those associated with human disease, representing serotypes O:3, O:5,27, and O.9 (Fredriksson-Ahomaa et al., 2009; Wacheck et al., 2010).

In Sweden, tonsils, ileocaecal lymph nodes and faecal samples were collected from 88 Swedish wild boars and analysed for the presence of *Y. enterocolitica* by a combination of cultivation and PCR. Overall, 20% of sampled individuals were positive for *Y. enterocolitica*, with most common detection in tonsil samples (Sanno et al., 2014).

In conclusion, *Y. enterocolitica* is present in wild boars and domestic pigs in Europe, including wild boar in Sweden, and is frequently detected in pigs in Norway (Nesbakken, 2009). The human pathogenic serotypes seem to have limited occurrence in other animal species. Pigs with outdoor life may be infected.

The strong serological cross-reaction between *Y. enterocolitica* O:9 and several *Brucella* species (Wauters, 1981) should be noted, as it may result in false positive serological reactions, particularly in cattle and pigs. This issue that might have practical and economic implications concerning *Brucella* control, including the use of such resuts as a basis for import/export bans etc.

7.1.5.18 Yersinia pseudotuberculosis

Among *Yersinia pseudotuberculosis* serotypes*,* serotype O:I is by far the most common serotype associated with human and animal infections in Europe (Nesbakken, 2012). This organism infects a wide range of species, including ruminants, pigs, dogs, and cats, but rodents are the main reservoir. *Y. pseudotuberculosis* is zoonotic, and human infection is usually related to the consumption of contaminated water or vegetables (EFSA, 2013), reflecting to some extent that it is cold-adapted and survives in the environment.

According to data reported by EU Member States in the framework of the Zoonoses Directive (2003/99/EC) in 2004–2011, 0.4 % of wild boars were infected with *Y. pseudotuberculosis*. *Y. pseudotuberculosis* has been reported in 20% of wild boar tonsillar samples (Wacheck et al., 2010). Among positive samples, serotype O:I was identified, which is associated with human disease (Fredriksson-Ahomaa et al., 2009; Wacheck et al., 2010).

In Sweden, tonsils, ileocaecal lymph nodes and faecal samples were collected from 88 Swedish wild boars and analysed for the presence of *Y. pseudotuberculosis* by a combination of cultivation and PCR. Overall, 20% of sampled individuals were positive for *Y. pseudotuberculosis*, and the pathogen was most commonly detected in tonsil samples (Sanno et al., 2014).

In conclusion, the agent is present in wild boars and domestic pigs in Europe, including wild boar in Sweden and pigs in Norway (Nesbakken, 1992; Nesbakken et al., 1994). Other relevant reservoirs include many species, particularly rodents. Pigs with outdoor life may be infected.

8 Exposure assessment

Humans, domestic animals, and wildlife may be exposed to agents from wild boars by a variety of routes, as summarized in the sections below.

8.1 Direct contact

Humans in direct contact with wild boar are most likely to be hunters handling shot animals, but may also include farmers raising wild boar, veterinarians, abattoir workers etc. Handling and evisceration outdoors, including disposal of in the field, represent a hygienic challenge, even for skilled and experienced hunters. *Campylobacter* spp. with a low infectious dose, and even zoonotic bacteria with a higher infectious dose such as *Salmonella* spp.*, Y. enterocolitica,* and *Y. enterocolitica* are potentially infectious agents that may be encountered in the intestinal tract, including the oral cavity. These hazards may present infection risks during handling, evisceration, and de-boning of wild boars. Hunters might even be exposed for MRSA by contact in this setting. The probability of transmission of swine influenza virus is might also be higher in these situations.

Otherwise, wild boar normally avoid humans, such that direct contact is unlikely to occur. In contrast, unless kept inside (as is the normal situation for most pig rearing in Norway), domestic pigs may be more likely to come into contact with wild boar. Male wild boar, in particular, may break in to mate with sows in heat. As wild boar can grow quite large, and are often stronger and more agile than domestic pigs, even quite sturdy doors and pens might be broken, dug under, or jumped over by a male wanting to mate. Other animals that might come into direct contact with wild boar are cervids, mostly at places where the wild boar are fed or baited, predators such as wolves, or scavengers such as foxes and birds of prey.

8.2 Indirect contact

Indirect contact may occur through biological vectors, such as insects, or transport hosts such as rodents. Those agents that survive in the environment and that can be transmitted via the soil can often be found in high concentrations around feeding and baiting sites where many different animals feed, and thus indirect transmission from and to wild boar from different wild animals may occur. If baiting sites are located near running water, downstream water may be contaminated.

8.3 Food products

This document addresses the spread of agents between wild boars and humans and wild boars and other animals due to direct and indirect contact following the migration and establishment of wild boar populations in Norway. Agents that may spread through foods include those associated with wild boar meat, or foods contaminated with faeces from wild boar. Thus, the infections occurring in the wild boar define those agents that may be transmitted further.

If wild boar meat is undercooked, various zoonotic agents might infection humans such as *Toxoplasma gondii* and *Trichinella* spp. In addition, cross-contamination of food that is not heat-treated may occur.

An important threat is meat of wild boars imported from regions that might have another disease panorama than Norway. In particular, import with private persons might result into serious consequences both for humans (for instance HEV) and for livestock (for instance ASFV, CSFV, FMV, PRRSV) in Norway.

Foods may be consumed, but a particular risk is linked to the spread of agents through food waste. Of particular concern here would be animal diseases as ASF/ CSF and FMD, where explosive spread has been linked to transport of wild boar meat.

Meat inspection of wild boar carcasses shot during hunting, killed in traffic accidents, or found dead could play a role in determining those agents present significance for animal health and public health such that appropriate measures can be implemented. However, meat inspection is not mandatory if the meat is for private consumption. Submission of carcasses or samples of wild boar to the Norwegian Veterinary Institute in cases of suspected infection is assumed to occur rarely, although data are lacking. Border controls seldom detect illegal imports of carcasses that could result in infections entering the country that are subsequently spread by wild boar.

8.4 **Human activities**

We expect the spread of wild boars to depend heavily on how we interact with the population. Active transport of live boars into and within Norway, providing feed to them, and hunting them are all activities that might affect development of the wild boar population in Norway. Development of the population, together with importing infected meat, might affect the transfer of different agents. Other possibilities by which infectious agents may enter Norway that are subsequently disseminated by wild boar could be entry of contaminated soil or faeces on boots and other hunting equipment.

See also last section under “Food products” (8.3).

9 Probability characterisation

The assessment of food safety and animal health associated with wild boar does not rely directly on the findings of the assessment of the population growth and spread. In this chapter the impact on food safety and animal health is assessed based on the assumption that wild boar become established in Norway in significant numbers.

Our characterisation is based on literature review data and descriptions presented in Table 14-1, where **a short list of relevant agents (in bold)** have been extracted from the original long list. The agents on the short list are described in greater detail in the chapter 7.1.5. In Table 9-1, the probability characterisation is provided as a product of the dominant exposure routes (direct contact, indirect contact, food products and human activities) and relevance of each of these. We also add a dimension linked to the main evaluation criteria used (zoonotic potential, presence in European domestic pigs, presence in European wild boars, presence in wild boar in Sweden or Finland, presence in Norway in pigs or other species, occurrence of other relevant vectors / reservoirs, evidence/role of transmission from wild boar to domestic pigs). We finally add a dimension on ranking as Animal Health (AH) and Public Health (PH) hazard that includes food safety.

Ranking scale is from 0 (no importance) to 5 (potentially very high importance). The following factors were considered for scoring the different pathogens:

- **0 points**
    - **For AH**: the pathogen has no effect on animal health of wild or domestic animals in Norway
    - **For PH**: the pathogen has no zoonotic potential
- **1-2 points**
    - **For AH:** the pathogen may or may not be already present in Norway; wild boars are not very likely to contribute towards transmission, and/or the impact on animal health, even after introduction to Norway, is very restricted, and/or where the role of wild boar in transmission of the agent is unclear.
    - **For PH**: the pathogen can be transmitted to humans, but is unlikely to cause relevant clinical diseases, and/or spread in the population and can easily be treated/eradicated, and/or the zoonotic potential of the pathogen is not yet fully clarified and no human cases have been reported.
- **3-4 points**
    - **For AH**: the pathogen may or may not be already present in Norway, the transmission potential via wild boar can be small to high, the impact on species other than pigs is limited, the impact on pig health can be medium to high, there may be international regulations regarding quarantine and eradication measures (OIE listed).

- For PH: the pathogen can be transmitted readily from wild boar to humans and lead to clinical diseases that may or may not be easy to treat, and the pathogen may also lead to long-term infections.

- **5 points**
    - **For AH:** the pathogen is not present in Norway, but it may be introduced via wild boar (confirmed role of wild boar in transmission), once in the country can spread easily to pigs or other species, may lead to serious disease outbreaks with medium-high mortalities, may survive in the environment (resilient), and there are international regulations with strict quarantine and eradication measures (OIE listed).
    - **For PH:** the pathogen is highly infectious to humans, spreads easily between humans, and potentially other animals, and causes serious disease outbreaks with medium-high mortalities, and is difficult to treat/eradicate.

Table 9-1. Probability characterisation of relevant agents

Agent	AH Rank	PH Rank	Comments
ASFV	5	0	ASF causes clinical disease in both wild boar and domestic pigs, spreads very easily, and is highly resistant in the environment. It can also easily spread via meat products, transport vehicles, unwashed equipment etc. Its introduction and establishment in wild boars in Norway would represent a serious risk for Norwegian animal health.
CSFV	5	0	Both wild boars and domestic pigs are susceptible to infection with CSFV, but the role of wild boar in transmission is not fully clarified. However, given Norway's current CSFV-free status, its introduction via wild boar could have serious consequences for Norwegian animal health.
FMV	5	0	FMV is responsible for serious disease outbreaks in many animal species, is resilient in the environment, and transmitted via aerosols. Although wild boar have only once been reported with FMV in Europe, the health hazard for pigs and other species is high, and represents a substantial challenge for eradication, with complex quarantine procedures and high economic costs.
Influenza A virus	3	4	Influenza A is present in domestic pigs in Norway and has been reported in wild boars in Europe. Given that the virus can easily be transmitted between populations, and has a high mutation rate, its presence in wild boar in Norway may represent an additional health hazard for domestic pigs and other susceptible species. Transmission to and from humans/pigs is an important part of the dynamics.

Agent	AH Rank	PH Rank	Comments
PRRSV	4	0	Although domestic pigs may be more likely to infect wild boar than vice versa, given that PRRSV is absent in Scandinavia, its introduction via wild boar (known to be susceptible) may represent an increased hazard for animal health in Norway. The disease represents a serious concern for domestic pig production.
SuHV1	4	0	Both wild boar and domestic pigs are susceptible, and the virus can cause clinical outbreaks with economic consequences. Given Norway's current SuHV1-free status, its introduction could have important consequences for animal health.
TGEV	3	0	Although present in domestic pigs in Europe, it is absent in Norway. The importance of wild boar in transmission of TGEV to domestic pigs remains largely unknown, but the disease is important in pigs and reportable.
HEV	2	3	Although HEV is already present in Norway, wild boar can contribute towards transmission of HEV to other domestic pigs, as well as other animal species, such as deer species. This may then contribute to a higher chance of transmission to humans.
Toxoplasma gondii	2	4	This ubiquitous parasite may infect a wide range of animals, and seroprevalences in Norwegian wild and domestic animal populations are relatively high. The seroprevalence in humans is relatively low; below 10%. *Toxoplasma* is important as a cause of abortions in ruminants, particularly sheep, and can also cause abortions and birth defects in humans. Eating rare or undercooked meat from wild boar may therefore represent a significant health risk for some individuals.
***Trichinella* spp.**	1	4	Present in Norwegian wildlife (red foxes) and also identified in a wild boar shot in Norway. Infected wild boars may increase the infection levels in rodents, and thereby, potentially, animal husbandry. Trichinellosis is a serious zoonotic disease. Infection occurs through consumption of rare or under-cooked meat. Note that larvae of some *Trichinella* species survive freezing. AH importance is limited, but other animals may be infected if offal is not disposed of properly by hunters in the field. Meat from wild boar that is not just for consumption by the hunter must be checked for *Trichinella* by a standard method.

Agent	AH Rank	PH Rank	Comments
***Brachyspira* spp.**	3	0	Previously reported in Norway, and wild boar can be both infected and transmit the agent further. It may cause clinical outbreaks in pigs with economic impact. Wild boar may contribute towards the spread of the disease among domestic pigs.
***Brucella suis* biovar 2**	3	1	Infections in wild boars and/or European hares (*Lepus europaeus*) have not been described in Sweden or Norway.
***Campylobacter* spp.**	1	4	*Campylobacter* can infect wild boars, but is not as frequent as in pigs. *Campylobacter* spp. were assessed as being a low risk in the EFSA Opinion on meat inspection in swine (EFSA, 2011) due to the effect of drying during blast chilling. However, both slaughtered farmed wild boars and wild boars shot during hunting are more often skinned than scalded, and this could result in more possibilities for direct infection of humans (due to a low infectious dose) and cross-contamination of the carcass. Furthermore, many facilities and abattoirs slaughtering wild boar may not have blast chilling facilities, resulting in survival of *Campylobacter* spp. An indirect route of transmission to humans via food and cross-contamination is also possible.
MRSA	2	4	MRSA is probably not prevalent in wild boars, but the situation might change with an increasing and expanding population. Wild boars have potential as carriers, as pigs living outdoors may be infected. There is also a possibility for a direct route of infection of humans during handling and evisceration of wild boars. In Norway, the pig population is virtually free from MRSA, and it is important to ensure that the Norwegian pig population is adequately protected.
Mycoplasma hyopneumoniae	3	0	The pathogen has been reported previously in Norway and is thought to circulate in wild boars, perhaps even in Sweden. Its presence in Norwegian wild boar might represent a threat to domestic pigs and result in more rapid spread of the infection.

Agent	AH Rank	PH Rank	Comments
Salmonella	4	4	Pigs living outdoors may be infected. There is a possibility for transmission to humans via direct contact during handling and evisceration, and indirectly via food and cross-contamination. In the EFSA Opinion on public health hazards in farmed game (EFSA, 2013), it was concluded that *Salmonella* spp. should be ranked as high priority. Norwegian pig herds are presently virtually free from *Salmonella*, and it is important to ensure that the Norwegian pig population is adequately protected against this agent.
Y. enterocolitica **and** ***Y. pseudotuberculosis***	1 (3*)	4	Pigs living outdoors may be infected. Although most Norwegian pigs are carriers of *Y. enterocolitica,* and sometimes of *Y. pseudotuberculosis,* other human pathogenic serotypes of these two species might be introduced. There is a possibility for direct transmission to humans during handling and evisceration and also via an indirect route through food and cross-contamination. **Y. enterocolitica* serotype O:9 is given a higher rating due to serological cross-reactions with *Brucella* and possible practical and economic implications for control of *Brucella* including import/export ban etc.

10 Uncertainties – Implications for food safety and animal health

This report is based on the scenario that assumes considerable numbers of wild boars will have established in Norway within a few years. Many data gaps and uncertainties have been identified. Beyond the areas bordering Sweden, we expect that the spread of wild boar will be more linked to human activities, such as moving animals and feeding, than real ecological spread.

For some of the infectious agents discussed, the occurrence in wild boars is now well documented, but for several the potential importance of wild boars is unresolved and sometimes controversial.

Introduction of ASF to Norway may be more likely to occur due to import of meat and meat products from other (endemic) countries, than as a consequence of migration of animals from Sweden (currently ASF-free). However, these immigrant wild boar may have a direct consequence regarding dissemination of ASF, regardless of how it is introduced to Norway.

Uncertainties in this assessment are due to the lack of data concerning both animal health and public health issues. Surveillance and testing programmes, together with close collaboration with Sweden may assist in filling some of those data gaps.

Other uncertainties concern human behaviour that might impact on spreading of diseases via more rapid spread of the wild boar than ecologically expected. An intensive information programme that is targeted towards hunters and tourists might reduce this impact.

11 Conclusions and answers to the terms of reference from The Norwegian Food Safety Authority

11.1 Introduction of infectious agents

a. *Which novel hazards can be introduced to Norway, and what is the likelihood of outbreaks of disease in humans or animals following establishment of wild boar in Norway?*

Novel hazards that may be introduced/re-introduced to Norway following establishment of the wild boar population are:

- In the pig population: ASFV, CSF, FMV, PRRSV, TGEV, SuHV and *B. suis* biovar 2
- In the human and animal population: *Trichinella spiralis*

Our assessment in Table 9-1 is based on the probability of introduction of the agents, as well as transmission to humans and other animals, severity of infection, etc.

b. *Have climatic-, or other factors changed, and thus increased the prevalence of relevant vectors and parasites in Norway?*

Very few of the short-listed pathogens have relevant vectors for transmission. For ASF there is no evidence that ticks of the *Ornithodoros* spp. will reach Norway in the foreseeable future.

There is a general concern that climatic changes may potentiate the range extension of various vector species, and that these vectors may carry pathogens to new areas and new naïve species. In addition, under warmer climates development within arthropod vector species is more likely to be successful. For the pathogens short-listed in this report, literature addressing potential range expansions in Norway and that is relevant to the topic is scant.

11.2 Assessment of probability for transfer of infection between wild boar and pigs

a. *What is the probability of disease transmission between wild boar and farmed pigs, given an increased population of wild boar in Norway, considering the normal risk reducing measures used in traditional farming? Also, how effective would mandatory use of infection control sluices be?*

Given an increase in the population of wild boar in Norway, the probability of disease transmission between wild boar and farmed pigs will depend greatly on the relevant agents and their transmission routes, and the biosecurity measures employed, the type of production units, and the health status of the wild boar (the diseases or infectious agents that they may carry). Commercial indoor pig production today uses high levels of biosecurity that should, in principle, prevent transmission of most pathogens. However, an outdoor pig production unit would be at a higher probability of being exposed to novel and existing agents, as infection control sluices are less relevant for outdoor production. The health status of this "increased" population is also a relevant factor to consider. As of today, Swedish wild boar (only likely source for an increased number of animals in Norway) are free from many of the serious pathogens listed in this report (although for some the status is unknown). Given the very low number of disease outbreaks in wild boar in Sweden, the probability of disease transmission from descendent of these animals does not seem particularly likely. It should be noted that pathogens may also be indirectly transmitted (contact with carcasses, contaminated food products, or equipment etc.), and an increased wild boar population may act to disseminate infectious agents further that have entered Norway via another route (e.g., with food or contaminated equipment). The probability of transmission might increase as the number of potentially infected wild boar increases. Furthermore, wild boar may also transfer pathogens to a variety of other wild animals in Norway, and it is possible that some of these, particularly rodents, may be better positioned to represent an entry point with regard to further transmission on to domestic pigs.

The mandatory use of infection control sluices, as a part of biosecurity measures already employed by commercial indoor pig production, should reduce the probability of transmission of infectious agents between wild boar and pigs.

b. *What, if any, effective risk reducing measures can be taken to limit disease transmission from wild boar to farmed pigs kept outdoors (i.e., with regards to ecological farming).*

Biosecurity remains the most effective way to prevent transmission of infectious agents between wild boars and domestic pigs. Animals kept outdoors are at a higher probability of infection than those kept in closed facilities. Fences, while reducing the chance of direct contact between wild boar and pigs, may be ineffective at containing pathogens that can survive in the environment or be transmitted via aerosols, water etc. Furthermore, wild boars have been shown to dig under such fences. In situations where wild boar are infected with a particular pathogen, the most effective measures may continue to be reducing the wild boar numbers (culling), avoiding contact with carcasses or other potentially, infected products, and, whenever possible, limiting the outdoor exposure of domestic pigs for a pre-determined period. Considering that many pathogens can be transmitted indirectly (vectors, contaminated equipment, boots, clothes, etc.) it is also important that strict biosecurity rules are followed when, for example, entering and exiting outdoor production facilities. It is important that wild boar carcasses shot during hunting, killed in traffic accidents, or found dead are inspected at an approved control station and/or sent to the national reference laboratory for swine diseases if there is any suspicion of infection.

11.3 African Swine Fever in Europe

a. *What is the probability of disease transmission from a potentially infected population of wild animals to farmed pigs, either directly or through feeding.*

This issue has been extensively covered by EFSA in recent years. The probability of direct transmission from wild boar to farmed pigs is dependent on the biosecurity conditions in place for farmed pigs, as well as on animal densities. If farmed pigs are kept in outdoor facilities (fences may not prevent contact between animals), the probability of direct transmission from wild boar to farmed pigs is high. However, the probability of direct transmission from wild boar to farmed pigs will decrease considerably if farmed pigs are kept in indoor facilities, that observe strict rules of biosecurity (such as those commonly in place in commercial indoor production units in Norway). If these biosecurity measures are properly implemented and followed there is a reduced chance of direct contact between animals, and thus transmission of ASF.

The probability of disease transmission from a potentially infected population of wild animals to farmed pigs through feeding and other indirect routes should also be considered high. Feeding farmed pigs with infected meat products / feeds is a known route for ASF transmission, and this situation may increase as the disease spreads through Europe. The same applies to other indirect routes of transmission. A special focus should be on hunters returning to Norway from infected areas with contaminated boots, clothes, or equipment. Again, the probability of transmission will be highly dependent on the biosecurity measures present at different production units (both intensive and extensive systems).

b. *Which risk reducing measures are available to limit the probability of spread regarding African Swine Fever in Norway?*

During the past 3-4 years, EFSA has produced several documents/opinions addressing this question. Measures must be carefully considered and modified to the different outbreak scenarios, which are often dependent on both wild boar densities and domestic pig densities. It is also important to differentiate between single outbreaks (single or few foci with limited geographical spread) or a more generalized infection.

It is important that wild boar carcasses shot during hunting, killed in traffic accidents, or found dead are inspected at an approved control station and/or sent to the national reference laboratory for ASF, if there is any suspicion of ASF. Efficient border controls that put rigorous efforts towards preventing illegal import of carcasses and meat are also important.

Considering that wild boar is currently listed as an alien species in Norway, and absent from most of the country, a relevant measure to reduce the risk of introduction of ASF may be ensuring that the number of animals (population size) is kept as low as possible (via hunting or other suitable methods). Culling (at different intensities) is one of the measures currently used in areas where ASF is present in Europe, and may also be especially important in Norway as a preventative measure ahead of a possible ASF introduction.

Biosecurity measures remain one of the best available tools to avoid/reduce the probability of spread (direct or indirect) of ASF from wild boar to domestic pigs. Ensuring that hunters travelling abroad are provided with information on how to prevent accidental import of ASF may also be a relevant measure.

12 Data gaps

To understand the effects of wild boar on biodiversity in Norway there is an urgent need for long-term monitoring of the development of the wild boar population and any effects associated with its establishment and expansion. Long-term studies are important as other studies have shown that negative effects might not last more than a few years. The population density of wild boar is an important parameter in studies assessing potential effects of wild boar, but has, to our knowledge, never been studied. The contrasting effects of wild boar from other parts of its range suggest that these are probably of limited value for predicting the effects that may occur under Norwegian conditions.

Major data gaps discovered in this assessment include:

- the lack of reliable data on wild boar population size
- the lack of reliable data on wild boar hunting and traffic accidents involving wild boars
- the lack of long term effects of wild boar rooting on biodiversity
- the lack of population density impact on biodiversity
- the lack of data on the role of wild boar in the transmission of several pathogens
- the lack of data on prevalence of several pathogens in the Scandinavian wild boar populations
- the lack of data on outdoor pig production (including wild boar farming) in Norway

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14 Appendix I

Table 14-1. The following table is based on an extensive literature search. A few major reviews on wild boar diseases, as well as books, have also been used (2012; Meng et al., 2009; Miller et al., 2017; Ruiz-Fons et al., 2008). Due to the large number of published articles it is not possible, nor intended, to document the information provided in the table with individual references. References are only provided for information believed to have special relevance, or is of limited access/knowledge. It should be noted that when "No" is listed regarding occurrence, this may indicate that the agent has never been reported but may be present or that is currently absent. **Agents in bold font are those included in the short list**

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
VIRUSES									
African Swine Fever Virus*	ASF African swine fever	No	Yes	Yes - widely	No	No	Yes - *Ornithodoros spp.* soft ticks	Yes (Bosch et al., 2017; Depner et al., 2017; Guinat et al., 2016)	Stable flies (*Stomoxys calcitrans*) or other insects may mechanically transmit the virus.
Classical swine fever virus (CSFV)*	CSF – Classical swine fever / hog cholera	No	Yes	Yes	No	Not since 1963	No	Yes (Artois et al., 2002; Le Potier MF, 2006)	

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
Foot-and-mouth virus (FMV)*	FMD – Foot and mouth disease	Yes	No but 1 report in Bulgaria (Alexandrov et al., 2013)	No but 1 report in Bulgaria (Alexandrov et al., 2013)	No	No	Yes	Not well documented	
Hepatitis E virus (HEV)	Hepatitis E	Yes	Yes	Yes (Anheyer-Behmenburg et al., 2017; Aprea et al., 2018; Burri et al., 2014; Carpentier et al., 2012; de Deus et al., 2008)	Yes (Widen et al., 2011)	Yes (Lange et al., 2017)	No	Yes possible (Schlosser et al., 2014; Schlosser et al., 2015)	
Influenza A virus**	SIV – Swine influenza	Yes	Yes	Yes		No	Yes		
Nipah virus (NiV)*	Nipah virus encephalitis	Yes	No	No	No	No	No	No	Only found in Malaysia and Singapore

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
Porcine Circovirus type 2 (PCV2)	PMWS - Postweaning multisystemic wasting syndrome / PCVAD porcine circovirus-associated disease	No	Yes - widely	Yes but limited to some countries(Bhide et al., 2014; Csagola et al., 2006; Ellis et al., 2003; Fabisiak et al., 2013; Hammer et al., 2012; Schulze et al., 2003; Sedlak et al., 2008; Vicente et al., 2004)	Yes. Finland (Halli et al., 2012)	Yes (Oropeza-Moe et al., 2017)	No	Yes (Rose et al., 2012; Segales et al., 2005)	Unclear role of wild boar in disease maintenance
Porcine epidemic diarrhoea virus (PEDV)	PED - Porcine epidemic diarrhoea	No	Yes	Unknown	No?	No		No	Unclear

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
Porcine parvovirus (PPV)	Infectious infertility	No	Yes - widely	Yes - widely	Yes. Finland (Halli et al., 2012)	Yes	No	Yes, but with limited relevance	
Porcine respiratory and reproductive syndrome virus (PRRSV)*	PRRS - Porcine reproductive and respiratory syndrome / blue-ear pig disease	No	Yes	Reported in e.g. France (Albina et al., 2000), Germany (Reiner et al., 2009), Lithuania (Stankevicius et al., 2014), Poland (Fabisiak et al., 2013) and Spain (Rodriguez-Prieto et al., 2013)	No	No	No	Unclear. Likely circulating in free-ranging domestic pigs	Mechanical vectors (houseflies and mosquitoes) In pigs in Sweden; outbreak in 2007

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
Suid herpesvirus 1 (SuHV1)*	ADV – Aujeszky's disease / PRV - pseudorabies	No	Yes – widely	Yes - widely	No	No	Yes (Banks et al., 1999; Cay and Letellier, 2009; Masot et al., 2016)	Yes – well documented	Sweden - domestic pigs; 1995 Denmark - wild boar; 1991
Swine vesicular disease virus (SVDV)	SVD - Swine vesicular disease	Yes reduced	Yes – Last outbreaks Italy and Portugal	No	No	No	No	Never assessed	All wild boar studies negative Czech Republic (1999), Lithuania (2004), Slovenia (2003) and the Netherlands (1994, 1996)(EFSA, 2012)
Tick-borne enchephalitis virus (TBEV)	Tick-borne encephalitis fever	Yes	No	No	No	Yes in other ruminants	Ticks, mainly *Ixodes ricinus*	No	Rodents and small game are main reservoirs

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
Toque teno virus (TTV)	-	No	Yes (McKeown et al., 2004)	Yes in Spain (Martinez et al., 2006)	No	No	No	Not assessed	
Transmissible gastroenteritis coronavirus (TGEV)	TGE - Transmissible Gastro Enteritis	No	Yes	No (but some PRVC reported in Slovenia (Vengust et al., 2006))	No (but PRCV in Sweden in wild boar)	No	No	Little apparent impact	Porcine respiratory coronavirus (PRCV) is closely related. PRCV present in pigs in Sweden. In Finland last in 1980
Vesicular stomatitis virus (VSV)	Vesicular Stomatitis	Yes	Yes	Mostly unknown	No	No	Sand flies (*Phlebotomus* and *Lutzomyia* species), black flies (*Simuliidae* family), and mosquitoes (*Aedes* spp.)	Unknown	May complicate control if introduced in domestic animals

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
West Nile Virus (WNV)*	WNF – West Nile fever	Yes	No	No	No	No	Mosquitoes (*Aedes*)	No	Slaughtered chicken may be a reservoir
PARASITES									
*Alaria alata***	Alariosis	Unknown; no human cases reported. *Alaria americana* is known to be zoonotic, and *A. alata* also has a wide intermediate host range.	Unknown – probably only in those with outdoor production	Yes in several EU countries (Portier et al., 2014; Riehn et al., 2012)	Yes	Unknown	Many species known to be susceptible	Not assessed	Found in wild boars in Germany and Sweden, also in feral cats and badgers in Denmark. Likely to be present in Norwegian fauna.

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
Ascaris suum	Roundworm	Yes	Yes	Yes	Yes. Documented from Poland and Estonia	Yes	Yes	Not assessed	Human infections in industrialised countries may be due to transmission from pigs; however, *A. lumbricoides* infection may also occur.
*Chrysomya bezziana***	Old world screwworm	Yes	No	No	No	No	No	No	Tropical/sub-tropical zoonosis of no relevance here

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
Cryptosporidium spp.	Cryptosporidiosis	Yes	Yes	Yes	Not known	Yes	Different species of *Cryptosporidium* have different host specificities. Almost 30 species are currently recognised infecting a range of hosts. Some *Cryptosporidium* species are host-specific, but some (e.g. *C. parvum*) are not.	No	*Cryptosporidium suis* is common in young pigs, and also found in wild boars. *Cryptosporidium scrofarum* is usually detected in older animals. There is no reliable epidemiological link of this species to human infections. But *C. parvum* is zoonotic, and may be found in both pigs and humans

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
*Echinococcus multilocularis***	Alveolar echinococcosis	Yes	Unknown	Unknown	Unknown	No (in foxes and rodents on Svalbard)	Mainly linked to wild canids, dogs and rodent intermediate hosts	No	Pigs not documented to be of importance.
*Echinococcus granulosus***	Cystic echinococcosis (hydatid disease)	Yes	Unknown	Unknown	Unknown	No	Mainly linked to wild canids, dogs and ruminant intermediate hosts	No	Pigs not documented to be of importance
Encephalitozoon cuniculi		Yes	No	No	No	Yes, rabbits, farmed Arctic foxes, farmed mink	Yes, rabbits, farmed Arctic foxes, farmed mink	No	Pigs unlikely to be of importance

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Giardia duodenalis	Giardiasis	Yes	Yes	Unknown	Unknown	Common in various animal species in Norway (e.g., sheep, cattle, dogs, deer, etc.	Different genotypes / assemblages associated with different hosts	Not assessed	Pigs not documented to be of importance
Leishmania spp.**	Leishmaniosis	Yes	No	No	No	No – sometimes in imported dogs	Dogs; sandflies are essential vectors in lifecycle	No	Unlikely to be of importance
Sarcocystis suihominis	Sarcosporidiosis	Yes	Yes	Yes	Probably	Yes	No	No	Linked to consumption of raw pork; rarely diagnosed

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
Sarcoptes scabiei (var. ***suis***)	Scabies Sarcoptic mange	Some haplotype s	Yes	Yes (Pence and Ueckerman n, 2002)	Probably	Occasionall y – closely related type common in foxes	Yes	Yes	There is no indication that wild boars will represent any zoonotic problem (Haas et al., 2015; Haas et al., 2018)
*Taenia solium***	Cysticercosis and taeniasis	Yes	No	No	No	No	No	No	Globally important parasite; should be aware of the potential for its import by infected humans, then spread via wild boar. Cysticercosis is considered the most important foodborne parasitic infection globally.

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
Trichinella* spp.*	Trichinellosis Trichinosis	Yes	Yes	Yes	Yes but rare (SVA, 2018)	Yes, but extremely rare in pigs (last 1994); found in foxes; found in wild boar in Norway in 2016.	Yes; found in foxes in Norway	Uncertain	Rare in Norwegian pigs, common in Baltics/ Poland etc. Infected rodents could be gateway hosts
Toxoplasma gondii	Toxoplasmosis	Yes	Yes	Yes	Yes	Yes– all warm-blooded animals can act as intermediat e hosts	Yes – all warm-blooded animals can act as intermediate hosts	Yes	Pigs living outdoors may be infected
BACTERIA									
Actinobacillus lignieresii		?	Yes	?	Yes	Yes	Yes	No	Not significant
Aeromonas spp.		Yes	No	No	No	No	Yes	No	Not significant
*Bacillus anthracis***	Anthrax / Botulism	Yes	Yes	Yes	Yes	Yes	Yes	No	Hygienic aspects connected to food production

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
Bacillus cereus		No	Yes	Yes	Yes	Yes	Yes	No	Hygienic aspects connected to food production
***Brachyspira* spp.**		Some species	Yes	Yes	?	?	Yes	Unknown	
Brucella* spp.*	Brucellosis	Yes	Yes	Yes	Yes, in Finland	No	Yes	No	Problems connected to serological cross reactions with *Y. enterocolitica* O:9 and some *Salmonella serotypes*
***Campylobacter* spp.**	Campylo-bacteriosis	Yes	Yes, in particular *C. coli*	Yes	Yes	Yes	Many species, in particular birds	Yes	Pigs with outdoor life may be infected. Possible direct and indirect route of infection of humans
Clostridium botulinum		Yes	Yes	Yes	Yes	Yes	Many species	No	Hygienic aspects connected to food production
*Clostridium difficile******		Yes	Yes	Yes	?	?	Yes	No	Not significant

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
Clostridium perfringens		No	Yes	Yes	Yes	Yes	Yes	No	Not significant
*Coxiella burnetti***	Q Fever	Yes	Yes	Yes	Yes	Yes	Many species	No	Not significant.
Extended-spectrum and/or AmpC β-lactamases (ESBL/AmpC) gene-carrying bacteria* **		Yes	Yes	Yes	Yes	Yes	Many species	No	Unclear, probably not significant
*Francisella tularensis***	Tularemia	Yes	No	Yes	No	Not in pigs, but lagomorphs	Crayfish, voles, wild rabbits, hares and muskrats as well as some domestic animals.	No	Not significant
Leptospira (spp.?) interrogans	Leptospirosis	Yes	Yes	Yes	?	No	Many species, in particular rodents	No?	Not significant

Agent	**Common disease name / nomenclature**	**Zoonotic**	**In European domestic pigs?**	**In European wild boars?**	**Present in wild boar in Sweden or Finland? *********	**Present in Norway in pigs or other species?**	**Other relevant vectors and susceptible species**	**Evidence/ role of transmission from wild boar to domestic pigs?**	**Comments**
Listeria monocytogenes	Listeriosis	Yes	Yes	Yes	Yes	Yes, including food production animals	Many species included food production animals	Only indirectly as with other animals	Hygienic aspects connected to food production
Methicillin-resistant *Staphylococcus aureus* (MRSA)		Yes	Yes	Yes	Yes	Yes, seldom due to monitory program	Also other species	Yes	Pigs with outdoor life may be infected. Possible direct and indirect route of infection of humans.
*Mycobacterium bovis***	Tuberculosis	Yes	No	Yes	No?	No	Also other species, in particular cattle	No?	Infection route through meat is not important
tuberculosis and avium	Avian tuberculosis	Yes	Yes	Yes	Yes	Yes	Also other species, wild birds	Yes	Infection route through meat is not important
Mycoplasma hyopneumoniae	Porcine enzootic pneumonia	No	Yes	Yes	?	Not since 2008	No	?	

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
***Salmonella* spp.**	Salmonellosis	Yes	Yes	Yes	Yes (Sanno et al., 2014)	Seldom	Also other species	Yes	Pigs with outdoor life may be infected. Possible direct and indirect route of infection of humans
Staphylococcus aureus		Yes	Yes	Yes	Yes	Yes	Yes	No	Only significant as MRSA
Pasteurella multocida	Pasteurellosis / Atrophic rhinitis	No	Yes	Yes	Yes	Yes but rare	Yes	No	Not significant
Pathogenic verotoxigenic *Escherichia coli* (VTEC)		Yes	Seldom, depending on contact with ruminants	Probably seldom, depending on contact with ruminants	Probably seldom, depending on contact with ruminants	Seldom in pigs, reservoir in ruminants	Also other species	No	Not significant
*Streptococcus suis type 2**** *		Yes	Yes	Yes	x	No	Yes	No	Not significant

Agent	Common disease name / nomenclature	Zoonotic	In European domestic pigs?	In European wild boars?	Present in wild boar in Sweden or Finland? *******	Present in Norway in pigs or other species?	Other relevant vectors and susceptible species	Evidence/ role of transmission from wild boar to domestic pigs?	Comments
Yersinia enterocolitica	Yersiniosis	Yes	Yes	Yes	Yes	Yes	Many species in particular rodents	Yes	Pigs with outdoor life may be infected. Possible direct and indirect route of infection of humans
Yersinia pestis	Plague	Yes	No	No	No	No	Many species in particular rodents	Possible	Does not occur in our region
Yersinia pseudo-tuberculosis	Yersiniosis	Yes	Yes	Yes	Yes	Yes	Many species in particular rodents	Yes	Pigs with outdoor life may be infected. Possible direct and indirect route of infection of humans
				Fungi					
Dermatophytes (***Microsporum nanum***)	Ringworm	?	No	No	No	No	Yes, other species, farmed deer etc.	No	Not significant

* OIE listed disease depending on virus type

** OIE Listed disease

Comment to *Francisella*: Human infection occurs through a variety of mechanisms such as bites from infected ticks or mosquitoes; direct contact or ingestion of water, food or soil contaminated by reservoirs; handling of animal tissues or fluids or undercooked contaminated meat; and inhalation of infective aerosols (EFSA, 2013).

*** ESBL/AmpC gene-carrying bacteria have been isolated from many farm species of food-producing animals. However, evidence of direct transmission of ESBL- and/or AmpC-producing *E. coli* or *Salmonella* isolates from food-producing animals or food to humans is limited. Few studies support the theory that transfer of ESBL- and/or AmpC-producing organisms from food animal production to humans is likely to be taking place (Lavilla et al., 2008; Smet et al., 2009). One study described the occurrence of ESBL-carrying bacteria in a wild bird (black-headed gull) (Bonnedahl et al., 2010). Very few studies report ESBL-carrying *E. coli* in wild boar and rabbit. As there is no evidence that farmed game meat is a transmission route for ESBL/AmpC carrying bacteria to humans, they were excluded from ranking (EFSA, 2013)

**** *Streptococcus suis* is a zoonotic bacterial pathogen that has been reported in tonsillar samples from farmed wild boar (Bonmarchand et al., 1985). In a few sporadic cases of human disease, handling/butchering of wild boar carcasses has been implicated as a causative factor (Bonmarchand et al., 1985). The mode of infection is generally agreed to be direct contact, and bacteria may infect humans via skin wounds/abrasions or via mucosal membranes. There is no documented evidence that consumption of contaminated pork would cause infection in humans (ECDC, 2012)

***** *Clostridium difficile* has been isolated from fresh pork but there is currently no evidence of human disease attributable to this source (Smith et al., 2011). C. difficile is traditionally considered to be a hospital-acquired infection but has been isolated from many domestic and wild animals. Evidence of food-borne transmission is limited and there are no data supporting the hypothesis that C. difficile is a hazard associated with farmed game with the exception of ostriches, although this organism has been reported to have caused illness in a small number of ostrich chicks in the USA (Frazier et al., 1993; Shivaprasad, 2003). As there is no documented evidence that C. difficile is a risk associated with the consumption, preparation or handling of farmed game meat in Europe, this bacterium was excluded from further consideration (EFSA, 2013).

****** *Leptospira* spp. are commonly found in domestic animals, mainly dogs, cattle, swine and horses. Rodents are the most common carriers. Exposure is through contact of mucous membranes or skin with urine-contaminated water or feed. Another source is milk from acutely infected cows. *Leptospira* spp. cause leptospirosis but have not been identified as a farmed game meat-related hazard and are not considered meatborne. *Leptospira* spp. were excluded from ranking (EFSA, 2013).

******* Finnish wild boar population is, in epidemiological terms, closer to Baltic wild boar population than Swedish due to unfavourable migration conditions.

15 Appendix II

Search strings Pubmed

#21,"Search ((((((((((wild boar OR feral pig)) AND taenia solium))))))))",52,07:50:41

#20,"Search (((((((((wild boar OR feral pig)) AND hepatitis e)))))))",169,07:50:12

#18,"Search ((((((((wild boar OR feral pig)) AND campylobacter)))))",46,07:49:36

#17,"Search (((((((wild boar OR feral pig)) AND trichinella))))",218,07:49:16

#16,"Search ((((((wild boar OR feral pig)) AND yersinia)))",42,07:48:53

#15,"Search (((((wild boar OR feral pig)) AND (VTEC OR STEC)))",35,07:48:30

#13,"Search (((wild boar OR feral pig)) AND toxoplasma)",76,07:47:56

#6,"Search (((wild boar) OR feral pig)) AND salmonella",188,07:28:37

#12,"Search ((wild boar OR feral pig))",19909,07:47:37

#11,"Search (((((((wild boar) OR feral pig)) AND (salmonella OR toxoplasma OR Yersinia OR Trichinella OR VTEC OR STEC OR campylobacter OR hepatitis e OR taenia solium)))))",795,07:41:18

#9,"Search (Search (((((wild boar) OR feral pig)) AND (salmonella OR toxoplasma OR Yersinia OR Trichinella OR VTEC OR STEC OR campylobacter OR hepatitis OR taenia OR)))AND (salmonella OR toxoplasma OR Yersinia OR Trichinella OR VTEC OR STEC OR campylobacter OR hepatitis OR taenia OR anthracis OR brucella OR ESBL OR MRSA OR francisella OR leptospira OR Listeria OR mycobacterium OR streptococcus suis OR ascaris OR cryptosporidium OR giardia OR parapox))))",5,07:40:13

#8,"Search (((((wild boar) OR feral pig)) AND (salmonella OR toxoplasma OR Yersinia OR Trichinella OR VTEC OR STEC OR campylobacter OR hepatitis OR taenia OR anthracis OR brucella OR ESBL OR MRSA OR francisella OR leptospira OR Listeria OR mycobacterium OR streptococcus suis OR ascaris OR cryptosporidium OR giardia OR parapox)))",1305,07:38:22

#7,"Search ((((wild boar) OR feral pig)) AND (salmonella OR toxoplasma OR Yersinia OR Trichinella OR VTEC OR STEC OR campylobacter OR hepatitis OR taenia anthracis OR brucella OR ESBL OR MRSA OR francisella OR leptospira OR Listeria OR mycobacterium OR streptococcus suis OR ascaris OR cryptosporidium OR giardia OR parapox))",1238,07:36:50

#5,"Search (((zoonoses or zoonosis))) AND ((wild boar) OR feral pig)",338,07:25:29

#4,"Search (zoonoses or zoonosis)",26084,07:25:07

#3,"Search (zoonoses) AND ((wild boar) OR feral pig)",265,07:24:

Search strings Web of Science

Restricted to field selection on titles that contain relevant words.

REVIEWS

(TI=("wild boar*" OR "wild pig*")) AND DOCUMENT TYPES: (Review)

Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.

36 hits

ALL ARTICLES

TI=("wild boar*" OR "wild pig*") AND TI=("disease*")

Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.

74hits

TI=(wild boar* OR wild pig* OR feral pig*) AND TI=("bacteria*" OR "parasite*")

Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.

41hits

TI=(wild boar* OR wild pig* OR feral pig*) AND TI=("fung*")

Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.

8hits

TI=(wild boar* OR wild pig* OR feral pig*) AND TI=("virus*" OR "viral*") NOT TI=("pigeon*")

Timespan: 1997-2018. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.

177hits

Eventually for some single handed articles:

TI=(wild boar* OR wild pig* OR feral pig*) AND TI=("DISEASE NAME)