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# Investigations of health and abundance of free-ranging wild boar (*Sus scrofa*) in Switzerland in a European context

**Inaugural-Dissertation**

to be awarded the Doctoral Degree of the
Vetsuisse Faculty University of Bern

submitted by

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2015

Approved by the Vetsuisse Faculty as inaugural dissertation on proposal from

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Bern,

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University of Bern

Für Vater und Grossvater, die mir die Liebe zur Natur eröffnet haben.

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## Summary

Wild boar have expanded all over Europe and are considered a threat to pig health. This project aimed at estimating wild boar abundance and assessing the health status of wild boar in Switzerland in comparison to other European countries: (1) three methods for abundance estimation (hunting bag analysis, faeces counts, animal counts by thermal imaging) were evaluated under Swiss conditions; (2) the seroprevalence of Aujeszky's disease virus (ADV) was estimated by ELISA in animals from selected study sites sampled from 2008-2012; and (3) available data on wild boar health in Switzerland and neighboring countries were reviewed. Faeces counts and thermal imaging did not seem to be appropriate for routine use since detectability of faeces and animals was limited in dense forests. Graduated maps based on recorded dead wild boar suggested the highest relative wild boar abundance along the northern country border and in the south of Ticino, and a numeric increase and spatial expansion of the wild boar population over the past decade. The serosurvey revealed an overall ADV seroprevalence of 0.57% (CI 95%: 0.32-0.96%), which was significantly less than previously documented. Except for *Brucella suis* and partly *Mycoplasma hyopneumoniae*, exposure to pathogens relevant to animal and human health have rarely been detected in wild boar in Switzerland. Overall, wild boar abundance and pathogen prevalence in this species appear to be lower in Switzerland than in many other European countries.



## Zusammenfassung

Wildschweine breiten sich in ganz Europa aus und werden als Gefahr für die Hausschweinegesundheit angesehen. Um das Vorkommen sowie den Gesundheitszustand der Wildschweine in der Schweiz abzuschätzen. wurden untersucht: (1) drei Methoden zur Bestandesschätzung von Wildschweinen (Jagstatistik, Kot-Zählungen und Wärmebildzählungen) auf ihre Tauglichkeit unter Schweizer Umweltbedingungen, (2) die Seroprävalenz des Aujeszky Virus (ADV) bei wildlebenden Wildschweinen mittels Serumproben aus fünf Studiengebieten aus den Jahren 2008-2012 und (3) der Gesundheitszustand des Schweizer Wildschweinebestandes im Vergleich mit dem angrenzenden Ausland mittels einer Literaturrecherche. Sowohl Kot- wie auch Wärmebildzählungen erwiesen sich in dicht bewaldetem Habitat als ungeeignet für einen routinemässigen Einsatz. Karten auf Basis von Jagd- und Fallwildzahlen zeigten eine Häufung von Wildschweinen entlang der nördlichen Landesgrenze und im südlichen Tessin sowie Bestandeszunahme und -ausbreitung während der untersuchten Zeitperiode (2004-2012). Die Seroprävalenz von ADV lag bei 0.57% (CI 95%: 0.32-0.96%) und damit signifikant tiefer als bei früheren Untersuchungen. Ausser *Brucella suis* und teilweise *Mycoplasma hyopneumoniae* wurden bei Wildschweinen nur vereinzelt Krankheitserreger mit einer Relevanz für Haustier und Menschen nachgewiesen. Insgesamt scheinen bei Wildschweinen der Schweiz sowohl die Abundanz wie auch die Prävalenzen von Pathogenen tiefer zu sein als in vielen europäischen Ländern.

## PUBLISHED ARTICLE I

***A picture of trends in Aujeszky's disease virus exposure in wild boar in the Swiss and European contexts***

This article was published by BMC Veterinary Research on November 7 2015

Meier et al. BMC Veterinary Research (2015) 11:277
DOI 10.1186/s12917-015-0592-5

BMC Veterinary Research

RESEARCH ARTICLE Open Access

# A picture of trends in Aujeszky's disease virus exposure in wild boar in the Swiss and European contexts

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## Abstract

**Background:** In parallel to the increase of wild boar abundance in the past decades, an increase of exposure to the Aujeszky's disease virus (ADV) has been reported in wild boar in several parts of Europe. Since high animal densities have been proposed to be one of the major factors influencing ADV seroprevalence in wild boar populations and wild boar abundance has increased in Switzerland, too, a re-evaluation of the ADV status was required in wild boar in Switzerland. We tested wild boar sera collected from 2008–2013 with a commercial ELISA for antibodies against ADV. To set our data in the European context, we reviewed scientific publications on ADV serosurveys in Europe for two time periods (1995–2007 and 2008–2014).

**Results:** Seven out of 1,228 wild boar sera were positive for antibodies against ADV, resulting in an estimated seroprevalence of 0.57 % (95 % confidence interval CI: 0.32–0.96 %). This is significantly lower than the prevalence of a previous survey in 2004–2005. The literature review revealed that high to very high ADV seroprevalences are reported from Mediterranean and Central-eastern countries. By contrast, an "island" of low to medium seroprevalences is observed in the centre of Europe with few isolated foci of high seroprevalences. We were unable to identify a general temporal trend of ADV seroprevalence at European scale.

**Conclusions:** The seroprevalence of ADV in wild boar in Switzerland belongs among the lowest documented in Europe. Considering the disparity of seroprevalences in wild boar in Europe, the fact that seroprevalences in Switzerland and other countries have decreased despite increasing wild boar densities and the knowledge that stress leads to the reactivation of latent ADV with subsequent excretion and transmission, we hypothesize that not only animal density but a range of factors leading to stress - such as management - might play a crucial role in the dynamics of ADV infections.


**Keywords:** Europe, Herpesvirus, Pseudorabies, *Sus scrofa*, Serosurvey, ELISA, Review, Switzerland

## Background

Aujeszky's disease (AD) or Pseudorabies is an economically important disease of domestic swine that causes substantial losses to the pig industry worldwide, due to decrease of productivity and trade restrictions [1]. In several European countries and North America AD does not occur in domestic swine owing to successful eradication programs [2, 3].

AD is caused by Aujeszky's disease virus (ADV) (syn. Suid Herpesvirus 1 or Pseudorabies virus), a Varicellovirus of the Herpesviridae family, subfamily Alphaherpesvirinae [4]. The only natural hosts of the virus are Suidae (*Sus scrofa scrofa*) including domestic swine, wild boar and their hybrids. In domestic swine the virus leads to varying clinical courses including high mortality and disorders of the respiratory, reproductive and central nervous systems [5]. Most other mammals (ungulates, carnivores, lagomorphs and rodents) are susceptible to infection but they represent dead-end hosts and die from infection [6]. Higher primates including humans are not susceptible to ADV [7]. A negative impact of ADV infections on free-ranging wild boar populations has not yet been demonstrated, except for two reported AD outbreaks [8, 9]. Experimental infections of wild boar with ADV showed that clinical signs depend on

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the virulence of the strain and the viral dose [10]. Characterized isolates of ADV from wild boar mostly belong to the genotype I and are of low virulence, whereas those from domestic swine mostly belong to the genotype II [11]. In agreement with these observations, a study conducted in Spain suggested that ADV seroprevalences in domestic pigs are not directly linked to ADV seroprevalences of wild boar in the same region [12]. However, it is widely recognized that free-ranging wild boar can act as an ADV reservoir [1, 12, 13] and it is of concern that transmission from wild boar to domestic swine could occur. Pathogen transmission from wild boar to domestic swine has been documented [14–16] and wild boar have been suspected to be the source of infection for an AD outbreak in domestic pigs in France [13]. In the past decades an increase of ADV seroprevalences has been observed in European wild boar [1, 3], locally reaching very high levels (e.g. 100 % in Spain) [17]. The dramatic increase of wild boar abundance in Europe during the same period [18] may have contributed to this process because high ADV seroprevalences seem to be associated with high wild boar population densities [19] and wild boar aggregation [20].

In parallel to the increasing ADV seroprevalences in wild boar, an increase of hunting dogs dying of AD after contact with hunted wild boar has occurred [21–26]. Furthermore, reports of fatal spillover of ADV on captive wild felids and canids after feeding on infected wild boar carcasses suggests that increased ADV occurrence in wild boar may represent a potential threat for protected large carnivores [27–29]. Therefore surveillance of ADV in wild ranging wild boar is strongly recommended [1, 3, 19, 30].

In Switzerland, a serosurvey of ADV in free-ranging wild boar performed in 2004/2005 revealed a seroprevalence of only 2.8 % (95 % confidence interval (CI): 1.9-4.0 %) [31]. Since then, hunting bag data have further indicated an increase in wild boar abundance and possibly densities [30] like elsewhere in Europe. Therefore, it has become of concern that ADV infection prevalence may have also increased.

The aims of this study were (i) to re-evaluate the status of ADV in the Swiss wild boar population using the methods recommended by the EMIDA-Eranet project APHAEA [32] and (ii) to compare our data with those from other European wild boar populations, considering two time periods (1995–2007 and 2008–2014).

## Results

### Serosurvey in Switzerland

Seven of 1,228 wild boar blood samples tested by enzyme linked Immunosorbent assay (ELISA) had antibodies against ADV, and the result of eight serum samples remained doubtful despite repeated testing. We obtained an overall estimated antibody prevalence of 0.57 % (95 % confidence interval CI: 0.32-0.96 %). This represents a significant decrease of seroprevalence ($P = <0.001$) in the Swiss wild boar population since the last serosurvey in 2004/2005 (2.83 %, 95 % CI: 1.91-4.02 %) [31]. The seven positive animals were of both sexes, of all age classes, from three different study units (A, B, E) and four years (2009, 2011, 2012, 2013) (Fig. 1). There were no significant differences among these categories or between the two wild boar populations (north: 0.44 %, 95 % CI: 0.2-0.89 %; south: 0.90 %, 95 % CI: 0.33-2.00 %).

### Review on AD in wild boar in Europe

ADV seroprevalences in wild boar populations strongly vary among European regions, ranging from 0 to 100 % [17, 33] (Fig. 2). The highest seroprevalences have been documented in Mediterranean countries including Spain (up to 100 %) [1, 17, 34–39], Italy (up to 51 %) [40, 41] and Croatia (up to 57 %) [42, 43], as well as in Romania (55 %) [44]; followed by central and eastern European countries such as Slovenia (31 %) [45, 46], Austria (38 %) [47], Czech Republic (30 %) [48] and northeastern Germany (up to 29 %) [19, 49]. In contrast, there is an area with low to moderate ADV seroprevalences in the centre and north of Europe: Switzerland (<4 %) [31, 50], the Netherlands (0 %) [51–53], Sweden (0 %) [33, 54–58], parts of France [13, 59–61] and of Germany [19, 49, 62–64]. Within this area of low seroprevalences, multiple regions with higher seroprevalences exist: Although the overall seroprevalence of continental France lies at 6 %, several provinces in the centre (Le Loir-et-Cher, le Loiret), in the northwest (l'Ille-et-Villaine), in the Mediterranean area (Corse) and the north-east of France (les Ardennes, la Meuthe-et-Moselle, la Meuse) reach levels between 21 and 54 % [60]. The provinces in the northeast of France seem to belong to a transnational wild boar population with moderate to high seroprevalences in Luxembourg (17 %) [65], Belgium (15-22 %) [65] and western Germany (9-26 %) [62]. Similar situations of strongly heterogeneous seroprevalences within the same country exist also in Spain [1, 37–39] and Italy [3].

While there is a good to very good data coverage of western Europe during the first time period, there is a lack of information for large parts of Europe during the second time period. Moreover, recent data partially originate from different geographical areas than those collected during the first period (Fig. 2), making comparisons difficult. Where such comparisons are possible, all conceivable courses are observed: decreasing in southwestern France [60, 61], stable-high in Spain [1] and increasing in Germany and Croatia [19, 43, 64]. A general pan-European trend was not detected due to this varying regional evolution of the seroprevalences.

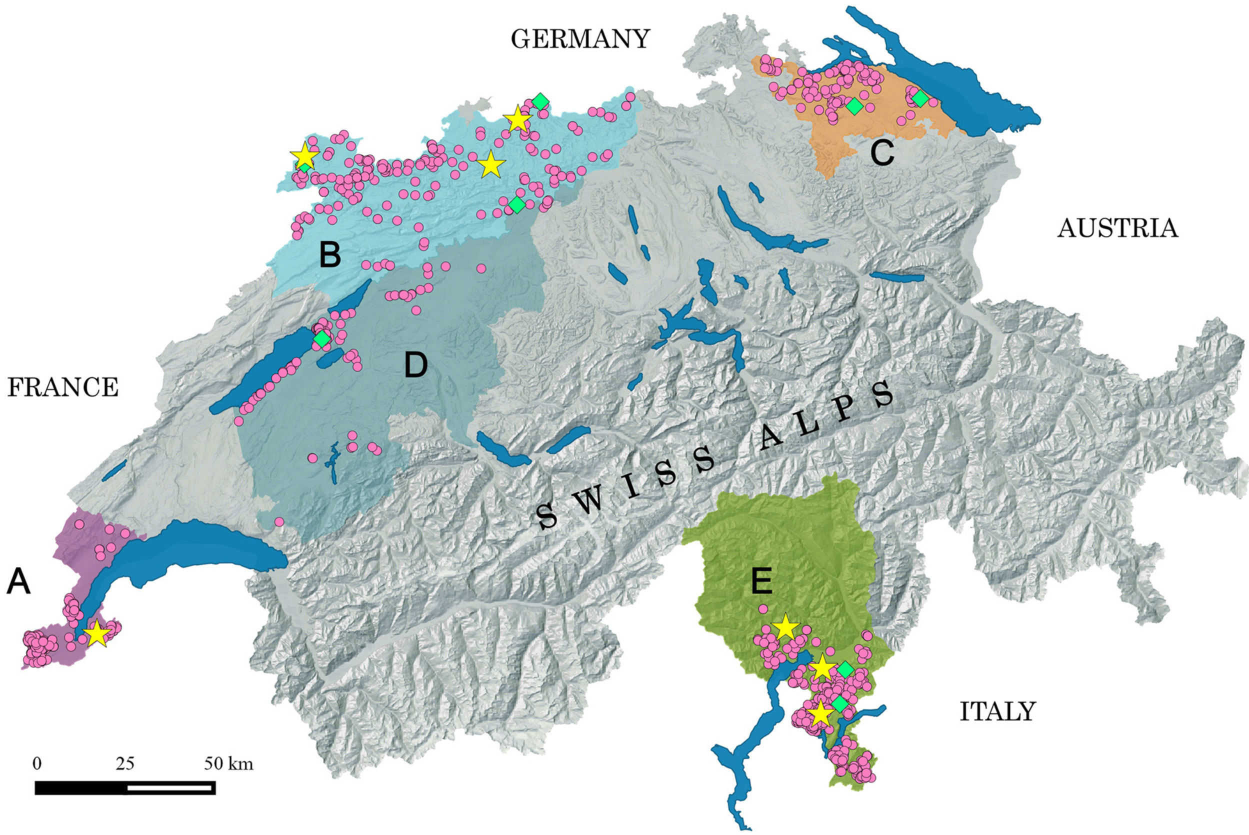


**Fig. 1** Map of Switzerland showing the study units and the origin of sampled wild boar. Shades of grey refer to the landscape relief and main lakes are indicated in plain blue. Letters and transparent colored surfaces refer to the five study units: *Purple*, **a** = Geneva; *Light blue*, **b** = Jura Mountains; *Orange*, **c** = Thurgovia; *Grey-blue*, **d** = Swiss plateau; *Green*, **e** = Ticino. Sera were tested by ELISA for antibodies against ADV. Colored dots, stars and diamonds indicate the location of the sampled wild boar (2008-2013): Pink dots = seronegative; Yellow stars = seropositive; Green diamonds = doubtful

## Discussion

The regional increase of ADV seroprevalence in various wild boar populations in Europe and the increasing number of reports of hunting dogs dying of ADV after exposure to ADV infected wild boar required a re-evaluation of the ADV status of wild boar populations in Switzerland. This study provides current seroprevalence data for Switzerland and sets the obtained results in a European context, examining published data from two time periods.

In Switzerland, domestic pigs have been officially free of AD since 2001 and there has been no report of AD in other species either during the past decade [66]. The obtained overall seroprevalence in wild boar was very low, which suggests that ADV infections only sporadically occur in wild boar populations in Switzerland. Compared to the results of the last serosurvey in 2004/2005, we documented a significant decrease from 2.8 % to 0.6 %. This decrease would also be observed if doubtful results were classified as positive (estimated prevalence of 1.2 %). Furthermore, the difference between the previous and present study is enhanced by the fact that seroprevalence had previously been estimated after applying a virus neutralization test on the ELISA-positive samples [31], thus increasing specificity but reducing sensitivity compared to our present results.

The seroprevalence estimated for Switzerland remains one of the lowest in Europe. The literature review revealed an inhomogeneous situation at continental scale and over time, with an “island” of low seroprevalences in central Europe, surrounded by medium to high seroprevalences in southern and central-eastern regions. This rough pattern together with the general inhomogeneity of seroprevalences at smaller scale raises the question of the major factors influencing ADV transmission among wild boar.

Wild boar density has been proposed as a factor influencing ADV seroprevalence [1, 19, 37, 39]. A comprehensive long-term study in eastern Germany showed a correlation between ADV seroprevalence and the

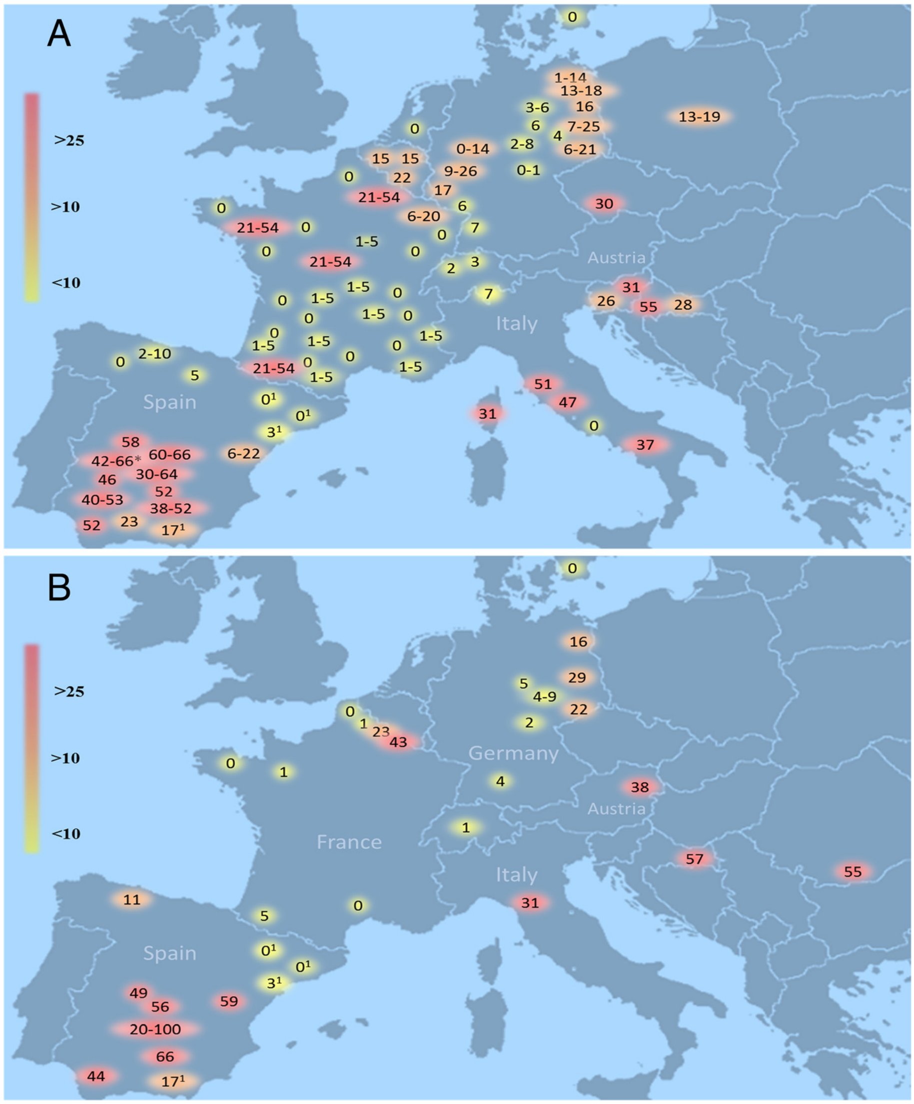


**Fig. 2** Seroprevalence of ADV in free-living wild boar in Europe from 1995-2014. Compilation of published data obtained by ELISA for two time periods: (**a**) 1995-2007 [1, 3, 8, 17, 19, 31, 34, 35, 37–43, 45–50, 59, 60, 62, 64, 65]; (**b**) 2008-2014 [1, 17, 19, 38, 43, 44, 47, 61, 63, 64, 82]. Numbers refer to estimated seroprevalences for the regions where they are placed.*Fenced animals included. [1]Data obtained over both time periods

"hunting index of population density" (HIPD, i.e. number of wild boar shot/km$^2$/year) [19]. In south-central Spain, where ADV seroprevalence in wild boar is particularly high, the wild boar is intensively managed for hunting purposes [1, 20]. Fencing, artificial feeding and translocations [35, 37] lead to extremely high animal densities of up to 90 individuals/100 ha and to a marked aggregation of wild boar around feeders [67]. Additionally, the scarcity of water in dry habitats results in animal aggregation around water holes [67]. However, high ADV seroprevalences have also been reported from other areas of Europe, e.g. north-eastern Germany, where industrial wild boar management is apparently uncommon. Furthermore, a general pan-European increase of ADV seroprevalence has not been observed, although a dramatic increase of wild boar has occurred in most parts of Europe since the 1950s, resulting in a wider distribution and higher densities of wild boar populations [3]. For example, high wild boar densities are associated with a low ADV seroprevalence in Catalonia in northern Spain [38]. Furthermore, it was documented in Germany that ADV spread in free-ranging wild boar is characterized by an inhomogeneous pattern with cluster formation [64]. Overall, these observations suggest that additionally to animal densities, other factors influence ADV prevalence in wild boar.

Intensified intraspecies contacts resulting from aggregation due to a range of factors (e. g. related to wildlife management, climate or social interactions) are expected to favor virus transmission. However, pathogen characteristics may also play a crucial role in this process. Since seropositive animals are infected lifelong by ADV [4], virus-carrying animals must exist in Switzerland and other regions with low seroprevalence. This raises the question as whether these animals shed the virus or not. Excretion of ADV and resulting infectiousness normally occur within several weeks after infection. However, Herpesviridae have the ability to undergo a latency in sensory ganglia, which inhibits the permanent replication and excretion of the virus [4, 68]. The virus may be reactivated later but this reactivation requires a modulation of the immune system, e.g. by a stressful experience [69–72]. Indeed, treatment of laboratory mice, domestic pigs and wild boar with immunosuppressive drugs such as dexamethasone, results in reactivation and excretion of ADV [10, 69, 73, 74]. Identified stressors enhancing ADV activity include concomitant disease conditions, transport, poor animal husbandry and farrowing in domestic pigs [69], as well as restraint, exposure to cold, and transport in laboratory mice [75]. In wild boar, mating has been proposed as possible source of stress generating ADV venereal excretion [76].

Considering the epidemiological picture of ADV infection in wild boar in Europe and the properties of ADV as a herpesvirus, we propose that factors causing stress may play a major role in the spread and distribution of ADV in wild boar populations. High animal densities, aggregation, overabundance, lack of possibilities to retreat, competition for food, confinement (e.g. fencing), high environmental temperatures, translocations, co-infections with other pathogens, as well as high hunting pressure, drive hunts, and other kinds of disturbance all represent conceivable sources of stress. However, to date it is not possible to identify associations between ADV seroprevalences and such stress factors across Europe due to the lack of information on population management and the inhomogeneity of data on wild boar abundance.

## Conclusions

ADV seroprevalence in wild boar in Switzerland has remained low since the last study and is among the lowest in Europe. Therefore, we had to reject our hypothesis that ADV seroprevalence would have increased in Switzerland in recent years. Moreover, we documented a general heterogeneity of estimated seroprevalences among countries which suggests that wild boar abundance alone does not explain the patterns of ADV spread. We propose that stress-inducing factors leading to reactivation of the latent virus may play a major role in the spread and maintenance of the virus in the wild. Harmonized methods in wildlife health surveillance and ecology, and risk factor analyses for ADV exposure, infection and shedding patterns in European wild boar populations are required to better understand ADV dynamics at the wildlife-domestic animal interface and design adequate disease control measures.

## Methods

### Study area

We selected five different study units (A-E, Fig. 1) in Switzerland (41,284 km$^2$) with the aims of: (1) covering the main wild boar habitat; (2) including northern and southern wild boar populations; (3) covering all representative bioregions of Switzerland, i.e. i) the Jura mountains (approx. 4,307 km$^2$), shaped by forests and pastures, ii) the densely populated Swiss Plateau (approx. 11,168 km$^2$), iii) the Alps (approx. 23,000 km$^2$), of which a large part reaches altitudes above the timber line, and iv) the part of Ticino located south from the Alps (approx. 2,812 km$^2$); (4) covering most of the Swiss border to France, Germany and Italy; and (5) complementing former studies on wild boar pathogens in Switzerland [77, 78]. Contacts are possible among wild boar in the study units A-D (i.e., northern population) whereas wild boar in study unit E (Ticino, i.e., southern population) are separated from the northern population by the Alps and can only interact with Italian wild boar populations.

### Sample collection and laboratory analysis

Blood samples collected from 1,228 wild boar over six hunting seasons (2008–2013) were available for this study. In accordance with the national hunting law [54] a hunting season was defined as lasting from July 1$^{st}$ to June 30$^{th}$ of the following year, with most of the hunting bag being harvested from December to February. Samples from wild boar shot before 2012 had been collected in the frame of former projects [30, 79] and stored in the archive of the Centre for Fish and Wildlife Health (FIWI Bern, Switzerland), while samples from 2012–2013 were collected for the purpose of the present study. Calculation of the target sample size per hunting season and study unit was derived from the regional hunting bags and performed with the WinEpiscope 2.0 software package. Since 2011 samples sizes have been calculated with the aim of estimating prevalence and assuming a prevalence of 50 %, with a confidence level of 95 % and an accepted absolute error of 5 % [78]. Efforts were made towards an even age and sex distribution among units. Blood samples were collected either by local hunters and game wardens with provided sampling kits and sent to the FIWI or were obtained by FIWI collaborators at game check points. Blood was collected from the thoracic cavity or the cavernous sinusoid [80].

This study did not involve purposeful killing or capture of animals and was exempt from ethical approval according to Swiss legislation. Samples originated from dead wild boar either shot for population regulation purposes (regular hunt, culling by professional game-wardens; 922.0 hunting law) or killed in traffic accidents. Nine samples originated from wild boar found dead submitted to the FIWI for pathological examination.

Information on weight, sex and body condition of the animals as well as the location, circumstances (found dead, hunted or culled) and date of sampling were systematically collected with a standardized datasheet. According to Hebeisen [81], wild boar were classified into four age classes: Piglets: <20 kg, striped coat, $n = 64$; Juveniles: 20-40 kg, reddish coat, $n = 342$; Subadults: 40-60 kg, black coat, $n = 370$; Adults: >60 kg, black or silver coat, $n = 385$; and no age data were delivered for 67 animals. Sex ratio of the sample was balanced, with 597 males and 611 females. Sex was undetermined for 20 animals.

Blood samples were centrifuged immediately after arrival at the FIWI. Serum aliquots were stored at -20 °C until analysis. Sera were tested for antibodies against ADV with a commercial competitive ELISA kit (IDEXX PRV/ADV gI, IDEXX, Inc., USA) successfully applied in former studies in Spain and Germany [1, 19, 34, 37]. According to the manufacturer's instructions, samples with a sample/negative (S/N)-value greater than 0.6 and less or equal to 0.7 were classified as doubtful, and samples with S/N-values greater than 0.7 as positive. All doubtful and positive samples were retested with the same ELISA.

### Literature review

We performed a review of internationally available scientific articles about serosurveys of ADV. In a first step, three online databases (PubMed, EBSCOhost and Google Scholar) were searched using the key words "wild boar", "*Sus scrofa*", "Aujeszky's disease" and "pseudorabies". In a second step, we screened references mentioned in the obtained publications selecting studies conducted between 1995 and 2014 on free-ranging wild boar in Europe and providing seroprevalences obtained by ELISA.

### Data management

Data handling and coding was carried out with Microsoft Office Excel 2010 (Microsoft Corporation, Redmond, Washington, USA). Two time periods were defined, both for the Swiss data and the literature review, starting arbitrarily 20 years ago and using the first year of the wild boar sampling campaign carried out by the FIWI as a threshold: 1995–2007 (historical data) and 2008–2014 (samples available for the current study). Prevalence calculations and statistical tests were performed with the NCSS 2007 software (J. L. Hintze, Kaysville, Utah, USA). Prevalences were calculated assuming test sensitivity and specificity of 100 % and excluding doubtful ELISA results. The Fisher's exact test (FET) was used to test for differences in seroprevalence among sexes, age classes, hunting seasons, study units and populations (north and south). Level of significance was set at $P < 0.05$.

Maps were designed with the free QGIS- Software (QGIS Development Team, 2012. Versions 1.8.0, 2.0.1 and 2.2.0; QGIS Geographic Information System. Open Source Geospatial Foundation Project, http://qgis.osgeo.org) and Microsoft PowerPoint 2010 (Microsoft Corporation, Redmond, Washington, USA).

#### Abbreviations

AD: Aujeszky's disease; ADV: Aujeszky's disease virus; ELISA: Enzyme linked Immunosorbent assay; CI: Confidence interval; HIPD: Hunting index of population density; FIWI: Centre for Fish and Wildlife Health; S/N: Sample/negative; FET: Fisher's exact test.

#### Competing interests

The authors declare that they have no competing interests.

#### Authors' contributions

RKM contributed to sample collection, performed the serological tests, analysed the data, reviewed the literature and drafted the manuscript. FRF contributed to the laboratory analyses and data interpretation. MPRD designed and coordinated the study, contributed to data analyses and drafted the manuscript. All authors critically read and approved the final version of the manuscript.

#### Acknowledgements

We thank all hunters, game wardens and cantonal hunting offices who contributed to the sample collection. We are grateful to Mainity Batista-Linhares, Natacha Wu, Chiara Menegatti, Malte Doherr, Nelson Marreros, Sohvi Blatter, Olivia Beerli, Francesco Origgi, Mirjam Pewsner and Miriam Sprick for their support during sampling campaigns. Many thanks go to Mariana Boadella and Christian Gortázar for logistical support, and to Christyn Bailey for checking the English grammar. Financial support was provided by the Federal Food Safety and Veterinary Office FSVO. Francisco Ruiz-Fons is funded by the Spanish Ministry for the Economy and Competitiveness through a 'Ramón y Cajal' research contract. This study is a contribution to the European project APHAEA (EMIDA ERA-NET).

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Received: 2 April 2015 Accepted: 3 November 2015
Published online: 07 November 2015

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## MANUSCRIPT I

***Estimation of wild boar abundance in Switzerland using methods potentially suitable for international harmonization***

This article was submitted for publication to 'Wildlife Biology in Practice' on October 15 2015

# Estimation of wild boar abundance in Switzerland using methods potentially suitable for international harmonization

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**Abstract**

Knowledge of abundance of wild boar populations is essential for a purposeful wildlife management and for epidemiological investigations. In Europe, a large variety of methods are in use for wild boar abundance estimations, leading to heterogeneity and incomparability of data. Here three methods with a promising potential for a wide application on their feasibility under Swiss environmental conditions were evaluated: analysis of hunting statistics of Switzerland from 2004 to 2012; faeces counts, and nocturnal counts of wild boar using a thermal imaging camera, both performed along random transects in two study areas (A and B) in the winter of 2014/15. Hunting statistics showed a spatial expansion and increase of the number of dead animals over the study period. Graduated maps based on dead wild boar occurrence in small geographical units for three time periods revealed the highest wild boar abundance along the northern and the most southern country borders. The number of dead wild boars/100 ha/yr varied from 0 to 19.1 with a national average of 0.2, suggesting that wild boar populations in Switzerland have a lower average density than in other continental European countries. The mean number of faeces/km was lower in area A (0.9) than B (2.0) and the number of wild boar/km detected by thermal imaging was higher in A (1.1) than B (0.3), although the local hunting bag was similar in A and B. Overall, hunting statistics (including all dead wild boar) supplied pictures that are in agreement with former data and appeared suitable to roughly monitor the spatial distribution and relative abundance of wild boar in Switzerland. By contrast, the results generated and the effort required of thermal imaging transects and faeces counts were not convincing and these methods did not seem to be appropriate for routine use.

## Key words

Census methods, faeces counts, hunting statistics, *Sus scrofa*, thermal imaging

## Introduction

The Eurasian wild boar (*Sus scrofa*) is one of the most widespread wild ungulates in the world [1]. After a massive population decline resulting from persecution and overharvesting in the past centuries, the wild boar population has dramatically increased and its territory expanded since the 1940s and the species is now widely distributed in most parts of Europe, occupying different types of habitats from Portugal to Russia and from Greece to the southern parts of Scandinavia [2]. In parallel to the geographical expansion, there has been an increase in wild boar hunting bags since the 1960s, indicating a massive increase of the population all over Europe, with a current overall annual hunting bag of over 2.2 million wild boar [1, 3-5]. This ongoing trend of increasing wild boar populations has led to growing conflicts with humans (e.g. damages to crops, vehicle collisions), to serious challenges in wildlife management, and to threats to animal and human health through pathogen transmission [6-12].

Data on wild boar population abundance are essential for epidemiological investigations including risk factor analyses and for the design of adequate population management plans [6, 13, 14]. However, due to the wild boar's life history, including its high, temperature- and food-dependent reproduction rate [15-17], its generally secretive behaviour and its nocturnal activity pattern [4], it is particularly challenging to record and predict wild boar population densities. A high variety of direct and indirect methods are currently applied for estimating wild boar population density or animal abundance [13, 14], all of which have, however, certain disadvantages.

Direct methods are based on counting individual animals, e.g. during drive hunts [18], by thermal imaging on pre-defined transects [19, 20] from vantage points using distance sampling [21, 22] and by photo-trapping without individual recognition [21, 23, 24]. Indirect methods relate signs of animal presence to animal density [13], e.g. pellet counts [25-27] or track counts [24, 28]. Methods using modified capture-mark-recapture (CMR) techniques measure the detection probability of individual animals and belong to the most reliable methods to estimate population size [13, 29]: e.g. counting of marked wild boars by camera traps [30, 31] or directly at feeding spots [20], or else by repeated genotyping of faeces or hair samples [32, 33]. However, all of these methods are associated with high costs and large time budgets and are only applied in small circumscribed areas [4, 24, 34]. Hunting bag data are therefore frequently used to estimate relative abundance on a larger scale and for longer time periods and in particular to identify population trends [3, 5, 29, 34-36]. The use of hunting bag analyses remains controversial because of bias due to multiple factors (e.g. hunting effort, management plans, habitat structure, weather conditions) [14, 25, 33] but they often represent the only available source of data on wild boar abundance [5, 34].

This plethora of methods in use results in a confusing heterogeneity of data, and efforts to harmonize methods across European regions are urgently required. The aim of this study was to evaluate three different, relatively simple and cheap methods of estimation of wild boar abundance under Swiss environmental conditions (i.e. a richly structured habitat with dense forests and underwood): (1) descriptive analysis of hunting statistics, both at a national and a local level; (2) faeces counts along transects, an established method in Mediterranean regions; and (3) thermal camera counts, as a potential and promising new approach. An important objective was to provide information that could be used for risk factor analyses among Swiss regions as well as for international comparisons.

## Material and Methods

### Study area

Switzerland (41,284km$^2$) is composed of 26 political units called cantons and can roughly be subdivided into four bioregions (Figure 1): the crescent-shaped Jura-mountains in the north-west of the country (ca. 4,307 km$^2$) characterized by high plateaus and ridges with rough valleys, extensive wooded areas and pastures; the Swiss Midlands, a densely populated region dominated by intensive farming and cultural landscape (ca. 11,168 km$^2$); the Alps with a mean altitude of 1,800 m above sea level (ca. 25,800 km$^2$); and the Alpine subregion "South" corresponding to the southern part of the canton of Ticino [37]. The Alps separate the northern wild boar population (Jura Mountains and adjacent Midlands from Geneva to Thurgovia) from the southern wild boar population (Ticino). The northern wild boar population is continuous with the population in adjacent French and German regions [16, 31], whereas the southern population is linked to the wild boar population in northern Italy [38].

Hunting in Switzerland is regulated by the federal hunting law (https://www.admin.ch/opc/de/classified-compilation/19860156/), which stipulates that culling wild boar is permitted from July 1$^{st}$ to January 31$^{st}$. From March 1$^{st}$ to June 30$^{th}$, only hunting outside forests and targeting wild boars younger than two years old is allowed (Jagdverordnung, https://www.admin.ch/opc/de/classified-compilation/19880042/index.html). The legal implementation of the hunting law is the responsibility of the cantons and varies considerably among cantons.

Switzerland applies two different hunting systems: the hunting ground system and the permit system. In the hunting ground system, a circumscribed area (hunting ground) is leased to a constant number of hunters (usually 5-20) for a period of 6 to 8 years; wild boar hunting is usually practiced during the entire allowed legal time period (i.e. 11 months) with a peak in winter; and most common hunting techniques are sitting game and large group drive hunts. This system is applied in nine cantons (Argovia, Basel-Landschaft, Basel-Stadt, Luzern, St. Gallen, Schaffhausen, Solothurn, Thurgovia, Zurich) in the north and north-east of Switzerland. In the remaining cantons, except of Geneva where hunting is prohibited (see below), the permit system is applied. In this case every hunter with a valid hunting license is allowed to hunt in the entire area of a canton; depending on the canton, the period of wild boar hunting is more or less restricted but usually limited to autumn and winter; and the common technique used is drive hunt in small groups of hunters (Konzept Wildschweinmanagement, http://www.wildschwein-sanglier.ch/pdf/concept_d.pdf). There are currently about 30,000 active hunters in Switzerland (Eidg. Jagdstatistik, 2013), of whom not all hunt wild boar. In the canton of Geneva (approx. 240 km$^2$) hunting was abolished after a public vote in 1974 [31] and the wild boar population is regulated by professional game wardens. All of the cantons record numbers of reported dead wild boar (hunted, culled or found dead) and registered damages attributed to wild boar in cantonal hunting statistics, which are subsequently merged in a federal hunting statistics database available online.

Hunting statistics data for the whole country were considered for this study. For the faeces count and thermal imaging trials, two study sites with expected high wild boar abundance were selected: Area A (Jussy, canton of Geneva) and Area B (Kleinlützel, canton of Soloth urn; Figure 1).

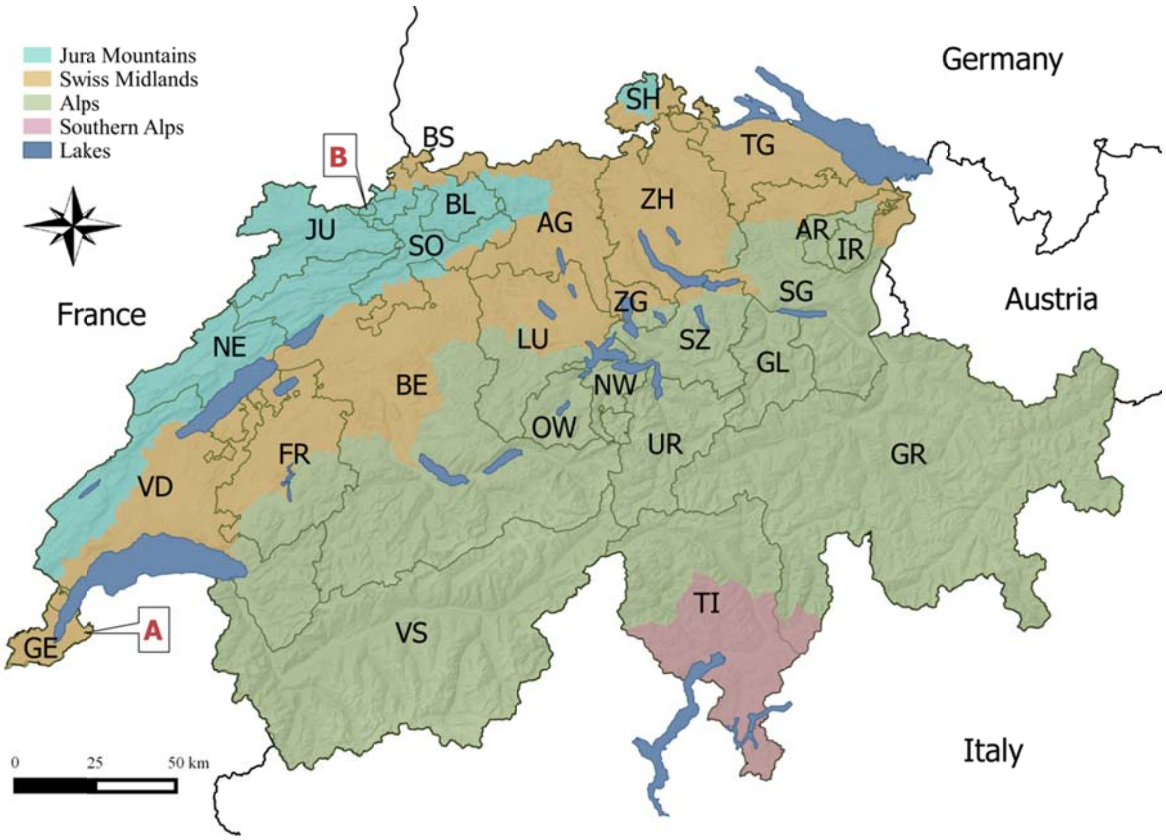


**Figure 1**: Map of Switzerland showing bioregions and cantonal borders (AG=Argovia, AI=Appenzell Innerrhoden, AR=Appenzell Ausserrhoden, BE=Bern, BL=Basel-Landschaft, BS=Basel-Stadt, FR=Fribourg, GE=Geneva, GL=Glarus, GR=Graubünden, JU=Jura, LU=Luzern, NE=Neuchâtel, NW=Nidwalden, OW=Obwalden, SG=St. Gallen, SH=Schaffhausen, SO=Solothurn, SZ=Schwyz, TG=Thurgovia, TI=Ticino, UR=Uri, VD, Vaud, VS=Valais, ZG=Zug, ZH=Zurich). The two study areas selected for the faeces counts and thermal-imaging counts are marked with red letters.

## Hunting statistics

In a first step the freely available Swiss federal online hunting statistics (http://www.wild.uzh.ch/jagdst/index.php) were used to obtain an overview of the national hunting bag, wild boar damages and traffic accidents from 1992-2012 and to identify the cantons with at least one wild boar shot or found dead between 2004 and 2012 (most recent available statistic at the beginning of this study). In a second step data on the location of all dead wild boar were used, per year and at the smallest possible geographical resolution, from the cantons with registered wild boar mortality (all but three: Schwyz, Uri, Zug) for the mentioned time period. "Dead wild boar" included wild boar hunted (shot by hunters on regular hunt or culled by game wardens for regulation purposes or because of disease signs) and found dead (due to traffic accidents, disease and other causes). For seven cantons it was possible to extract the required data from the hunting statistics available on the websites of the cantonal hunting authorities. For the remaining cantons the cantonal hunting authorities were personally contacted.

The resolution of the obtained data ranged from precise coordinates for every individual up to a global number of dead wild boar per year and canton. For three cantons only global data were available (Geneva, Neuchâtel and Basel-Stadt). However, these cantons belong to the smaller cantons of Switzerland with a size corresponding to districts (Local administrative unit (LAU)-1). Overall, it was possible to work with geographical units (n= 1980) of the size of a district (LAU-1), municipality (LAU-2) or hunting ground (size usually similar to LAU-2) for all Swiss cantons. For one canton (Vaud), high resolution data on dead wild boar was not available before 2008. The average size of the geographical units was 1355.53 ha (range: 0.28-137,354.70 ha).

Data were compiled into a single database in Microsoft Office Excel 2010 (Microsoft Corporation, Redmond, Washington, USA). To dampen expected fluctuations of the hunting success driven by uncontrollable environmental factors (such as the location of wild boar as a result of food availability or the influence of weather conditions) which may change from year to year, the data were pooled into three time periods (2004-2006, 2007-2009, and 2010-2012). The density of dead wild boar per geographical unit was finally expressed as an index calculated as follows:

$$D = \frac{[(n_1+n_2+n_3)_u / 3]}{A_u} \times 100$$

where D stands for the density of dead wild boar per 100ha per year (ind/100ha/y), $n_1$-$n_3$ represent the numbers of dead wild boar in the geographical unit u for three consecutive years (1,2,3) and A stands for the size of the corresponding geographical unit in hectares.

Mapping was performed with the free QGIS- Software (QGIS Development Team, 2012; version 2.8, QGIS Geographic Information System, Open Source Geospatial Foundation Project, http://www.qgis.org/de/site/). Using the variable D, graduated coloured maps were produced to illustrate the distribution of dead wild boar per geographical unit and the difference in the numbers of dead wild boar between the different time periods. The underlying geodata (SHP-layers) of the hunting grounds were provided by the cantonal hunting authorities. Geodata of municipalities and districts were downloaded from the Swiss federal geoportal (geo.admin.ch). Using the data obtained for period 3, an additional map showing general trends at a more regional level was generated. Borders were drawn considering the densities of dead wild boar in the geographical units with a 2 km buffer zone and following bioregion borders when appropriate.

Data on damages attributed to wild boar (amount of compensated losses in Swiss francs) were available online for all relevant cantons for the years from 1992 to 2012. The way these data are acquired differs from canton to canton, hampering intercantonal comparisons (Eidgenössische Jagdstatistk, http://www.wild.uzh.ch/jagdst/index.php). A possible correlation of the hunting bag (defined here as the sum of wild boars hunted and culled) with damages and with the number of wild boar found dead was assessed by calculating a Spearman's rank correlation coefficient ($r_s$) using the NCSS software (NCSS 9 Statistical Software (2013). NCSS, LLC. Kaysville, Utah, USA, ncss.com/software/ncss.).

### Faeces and night vision counts

In the winter of 2014/2015 (when decidual trees had lost their leaves and visibility in forested areas was expected to be highest) faeces counts were carried out on eight randomly chosen transects of approximatively 1.2 km length for each of the two study sites (areas A and B). Then the frequency of faecal droppings found on the transects (frequency-based indirect index, FBII) and a spatial aggregation index Z were calculated according to Vicente et al. [34] and Acevedo et al. [25].

In addition, vehicle-operated counts were performed at night along transects on forest and field roads using a thermal imaging camera (FLIR T 640). These transects of 16 km (area A) and 21 km (area B) were driven three times at three weeks intervals. To estimate the relative wild boar abundance in the study areas, a "scanned area" was defined as the area at sight distance to the left and to the right of the transect paths, which corresponded to approximately 30 meters width in forest areas and 150 meters width in open field. The maximal number of animals observed per transect was then divided by the "scanned area" and finally extrapolated to the number of animals/100ha.

# Results

## Hunting statistics

In the past decade, dead wild boar (including all animals shot and found dead) were regularly registered in most parts of the Jura Mountains and the adjacent region of the Swiss Midlands, as well as in the southwest of the canton of Valais (Alps) and in the canton of Ticino (Figures 2 and 3). The relative number of dead wild boar showed large variations among geographical units, ranging from 0 to 19.1 ind/100ha/yr. The highest numbers were recorded at the southern foothills of the middle and northern parts of the Jura Mountains, with the national freeway A1 obviously acting as a barrier (Figures 3). Record numbers were found in the hunting grounds Olsberg-Nord (19.1 ind/100ha/yr) and Magden-West (14.1 ind/100ha/yr) in the canton of Basel-Landschaft. By contrast, so far only a few wild boar carcasses have been reported from regions of the Swiss Midlands which are distant from the Jura as well as from the Alps.

Temporal trends are illustrated in Figures 4 and 5. At a national level, all indices (damages, wild boar found dead and hunting bag) steadily increased over the past two decades. The number of damages and the number of wild boar found dead (whereof a mean of 72 % were traffic kills) both positively correlated with the number of shot wild boar ($r_s$=+0.64 and $r_s$=+0.88, respectively). At a local level, an increase in the number of dead wild boar was observed in 66 % of the units with a wild boar occurrence between periods 1 and 3, with a mean increase of 0.32 ind/100ha/yr, while only 28 % of the units experienced a decrease in the number of dead wild boar numbers from periods 1 to 3 (Figure 4). Dead wild boar were newly recorded in 9.8 % of the geographical units during either period 2 or 3, suggesting a geographical expansion of the species within the past decade: eastwards in the canton of Valais, and southwards in the cantons of Zurich and St. Gallen.

The national average density of dead wild boars was 0.68 (period 1), 0.80 (period 2) and 1.00 ind/100ha/yr (period 3) when considering only units with wild boar occurrence, or 0.14 (period 1), 0.17 (period 2) and 0.20 ind/100ha/yr (period 3) when considering the entire area of the country.

At a national level dead animals consisted of about 90% shot wild boar and 10% wild boar found dead. At the level of the geographical units, the percentage of wild boar found dead varied from 0 up to 100%.

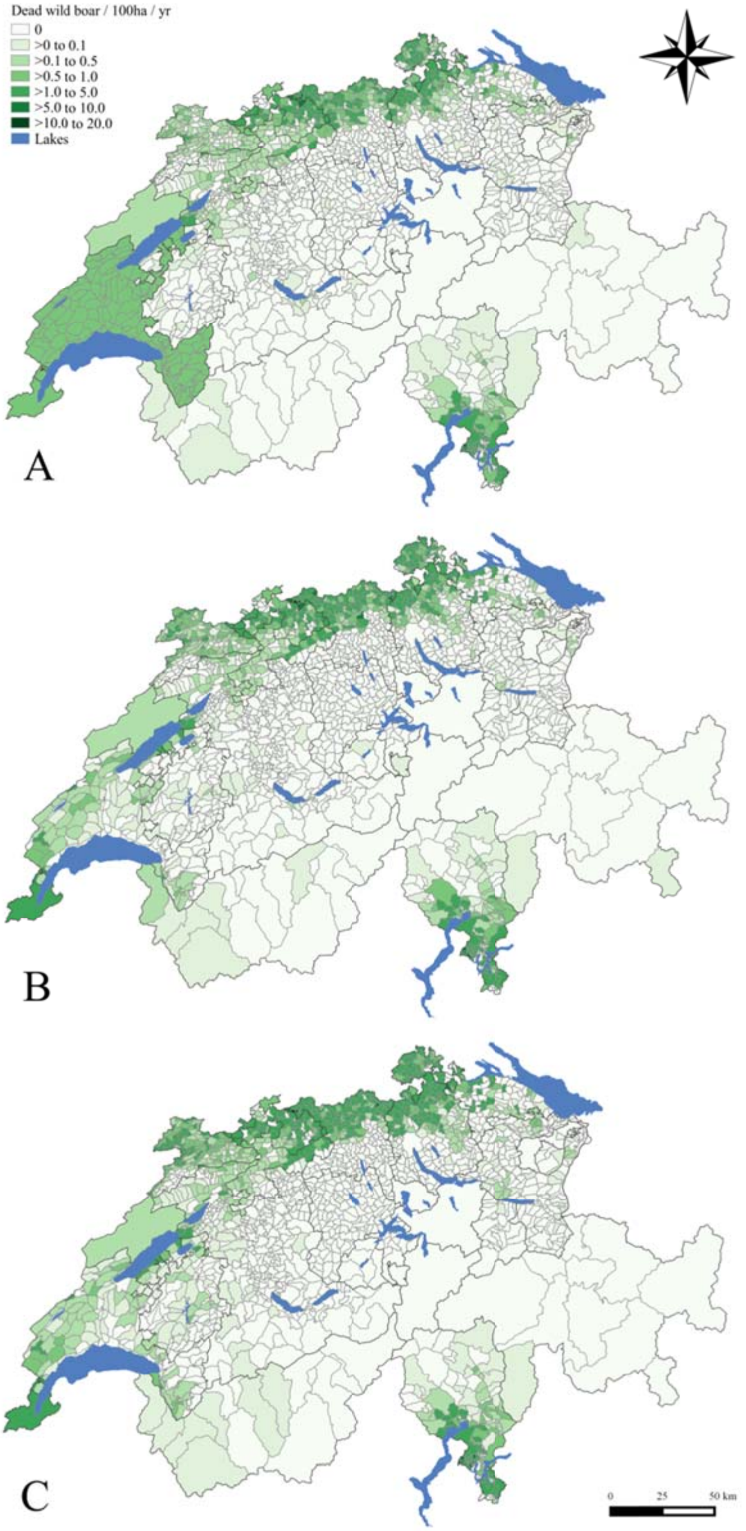


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**Figure 2**: Graduated maps illustrating the number of dead wild boar/100ha/yr in Switzerland for three time periods (A: 2004-2006, B: 2007-2009; C: 2010-2012) in 1924 geographical units of varying size.

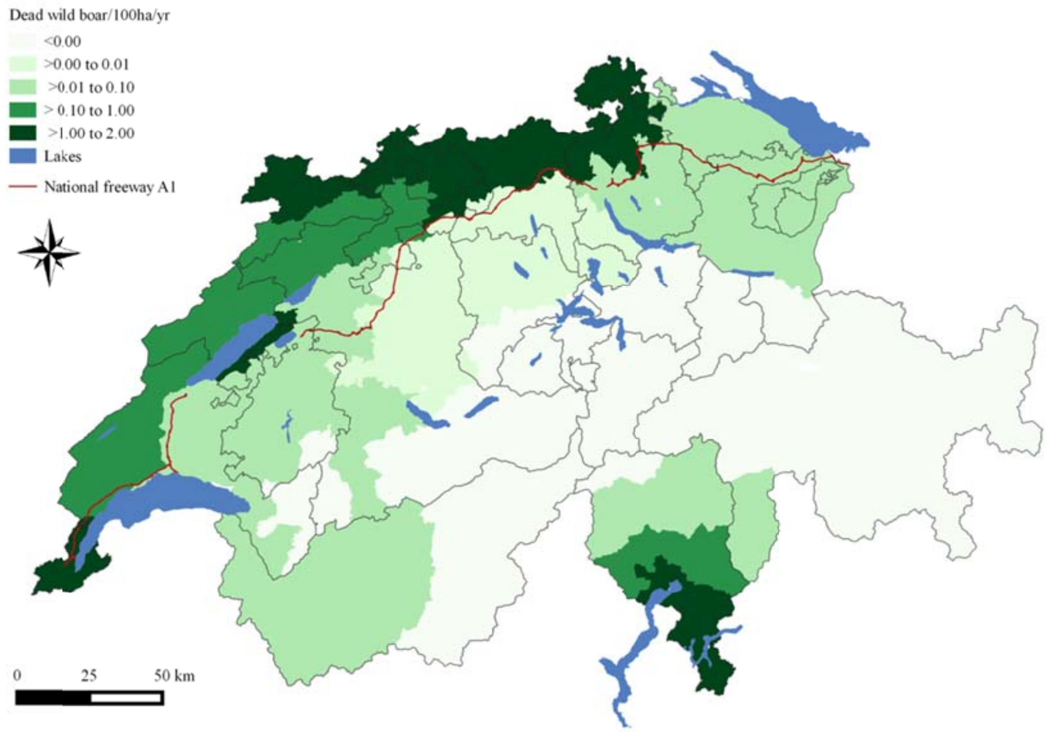


**Figure 3**: Map of Switzerland summarizing the number of dead wild boar/100ha/yr at a regional level for the most recent time period (2010-2012).

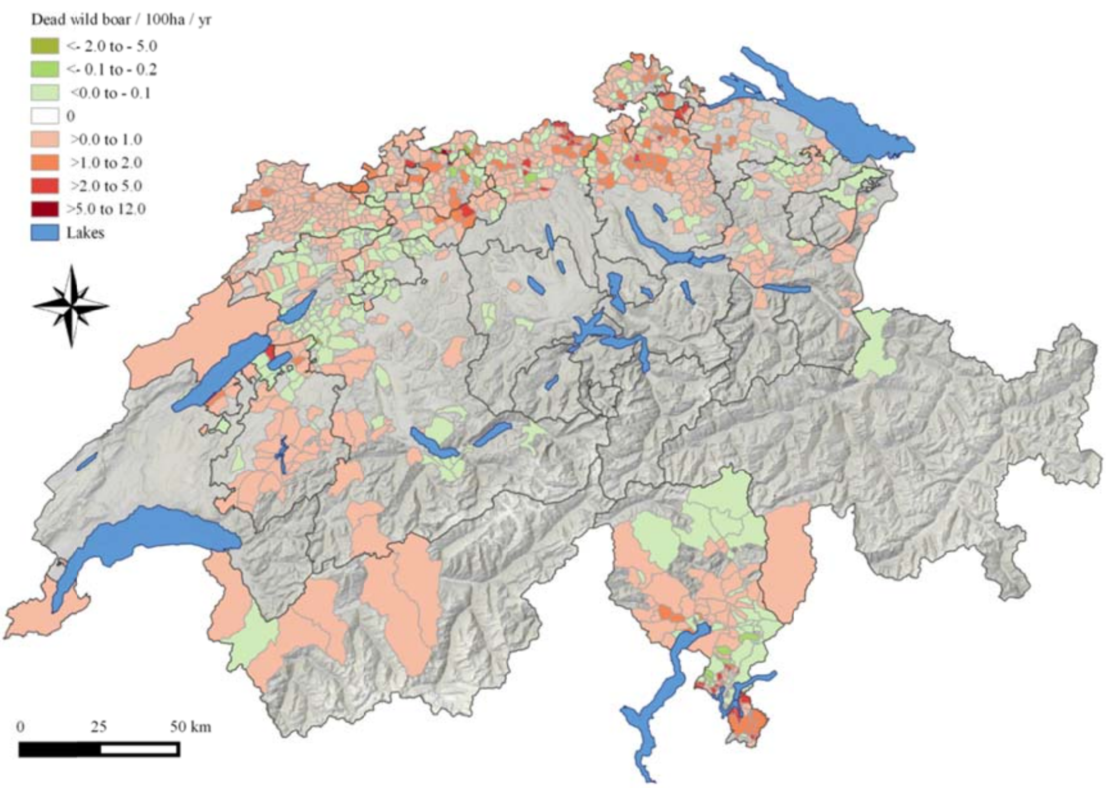


**Figure 4**: Map of Switzerland showing the trends of dead wild boar/100ha/yr between time periods 1 and 3.

### Faeces and thermal imaging counts

The number of faeces counts ranged from 0 to 6 pellets per kilometer with a mean of 0.9 and 2.0 in units A and B, respectively. These numbers resulted in an FBII of 0.09 in area A and 0.2 in area B. Estimated aggregation indices Z were 0.33 (area A) and 1.2 (area B).

Thermal imaging counts fluctuated from 1 to 17 and 0 to 6 individuals per trial in area A and B, respectively, resulting in a maximum number of 1.1 (area A) and 0.3 (area B) wild boar/km. Although 80% and 72% (in areas A and B, respectively) of the transect paths were in the forest, only 31% of the observed wild boar were observed there. The estimated relative wild boar abundance was 10.0 and 2.3 wild boar/100ha for Area A and B, respectively. In the same areas (A and B) mean hunting bag over the past three years (2012-2014) was 2.6 and 2.9 wild boar/100ha/yr, respectively.

## Discussion

In this study we assessed the potential of three different methods for estimating wild boar abundance and provided first data on wild boar abundance in Switzerland at a national scale. The lack of a methodological gold standard and the scarcity of in-depth investigations of wild boar population density impede the evaluation of the validity of the obtained data. However, the overall trend of the hunting bag was similar to that of registered damages and wild boar that were found dead. Similarly, the obtained wild boar distribution map was largely in accordance with the data on wild boar presence formerly obtained by questionnaire survey [39]. The homogeneity obtained with multiple geographical units within a region on the graduated maps also supports the validity of the data at a regional level. Finally, the moderate to high abundance of dead wild boars in Geneva was in agreement with a CMR study previously performed in that canton [31]. Although hunting methods and hunting periods vary among Swiss cantons, the general strategy of all cantonal hunting authorities is to limit the increase of wild boar populations and to prevent damages, resulting in a comparable, abundance-related hunting pressure, and explaining the good correlation between damages and hunting bag. Interestingly, while the number of wild boars found dead (including traffic kills) is expected to be dependent on animal population density (and road net density) but independent of hunting effort, it also correlated with the hunting bag (Figure 5). This was in agreement with former studies on this topic [16, 36].

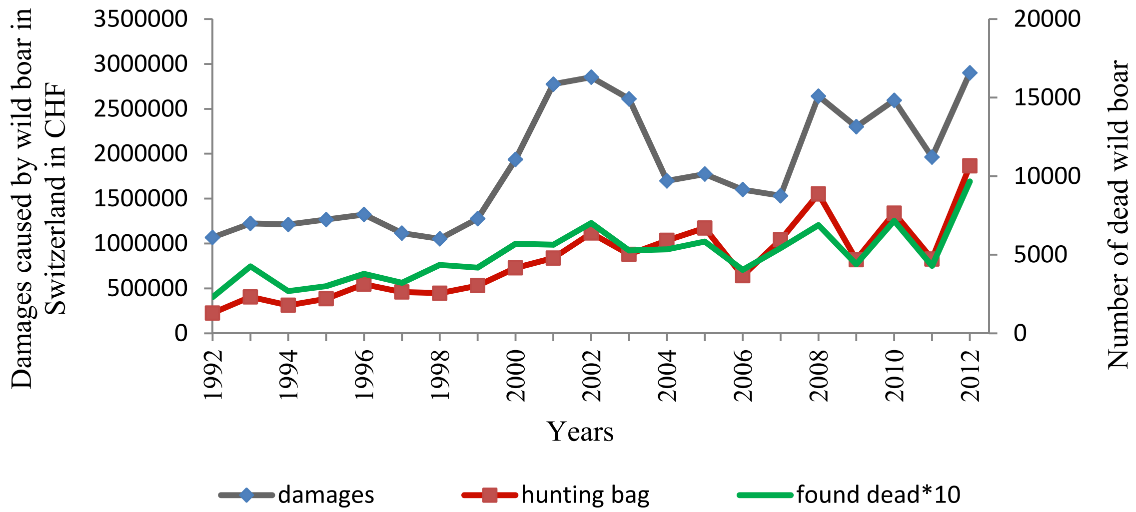


**Figure 5**: Graph showing temporal trends of reimbursed damages attributed to wild boar (blue), the wild boar hunting bag (red) and the number of wild boar found dead (x10) in Switzerland from 1992 to 2013 (data source: http://www.wild.uzh.ch/jagdst/index.php).

Therefore we assume that analysis of hunting statistics provides a realistic general picture of wild boar relative abundance in Switzerland. It is known that the reliability and precision of abundance estimations based on hunting bags can be improved when factors like hunting pressure, damages, environmental and habitat conditions, climate and population characteristics are included in the analysis [16, 34, 40-42]. However, detailed data on hunting pressure are currently not available in Switzerland. Furthermore, we wanted to analyze data as simply as possible because our aim was to find a method with a wide applicability among European countries, including those in which the availability of such additional information may be limited. Fluctuations of the hunting bag can be marked from one year to another (Figure 5) but we propose to pool several years to reduce bias. Additionally, we recommend including all dead wild boar in the dataset when describing wild boar occurrence, especially in regions where wild boar are not yet abundant, or when considering relative abundance on a smaller scale.

Our results indicate that the wild boar population in Switzerland continues to increase and suggests both an expansion of the wild boar range and an increase in animal population densities within already occupied areas. Signs of increasing abundance were found in most regions with wild boar occurrence, the highest increase and the highest relative abundance being observed along the national borders to Germany and to Italy (southern tip of Ticino). Data also suggested a moderate to high abundance in Geneva, at the border to France.

The national relative abundance based on dead wild boar (ind/100ha/yr) in Switzerland was lower than the abundance estimated with hunting bags in other parts of Europe, both at a national and at a cantonal level (Table 1) and despite the inclusion in the calculation of animals found dead. Although high numbers of dead wild boar were observed in single geographical units in Switzerland, overall wild boar abundance may be surprisingly low compared to other European countries. However, such comparisons between numbers of shot animals per country or region are currently difficult as data are only available for geographical areas as a whole, rather than solely for the area occupied by wild boar. This difference is likely to be important especially in in Switzerland because of the high proportion of areas over 2000 meters above sea level.

**Table 1**: Comparison of hunting bags (animals/100ha/yr) from different European countries calculated with data obtained from national hunting statistics or scientific publications. Data from Switzerland marked with an asterisk also include wild boar that were found dead.

| Country | Hunting bag/100ha, entire country | Hunting bag/100ha, geographical unit | Reference units | Year(s) | Source |
|---|---|---|---|---|---|
| Austria | 0.6 | >0 - 3.2 | Bundesländer (NUTS-2) | 2012 | [45] |
| France | 1.1 | >0 - 4.18 | Départements (NUTS -3) | 2012 | [46] |
| Germany | 1.8 | >0 - 4.0 | Bundesländer (NUTS-1) | 2012 | [47] |
| Hungary | 0.4 | - | - | 1995 | [48] |
| Italy | no nationwide data available | 1 - 24.9 | Province (NUTS-3) | 2003-2009<br>2011-2014 | [17, 49] |
| Spain | no nationwide data available | 0 - 156.5 | hunting estates | 2006-2010 | [34] |
| Switzerland | 0.15<br>0.17* | 0 - 1.5<br>0 - 1.6* | cantons (NUTS -3) | 2010-2012 | [50] |

Regarding faeces counts, we obtained FBIIs which tended to be higher (0.09 and 0.20) than FBIIs reported from open hunting areas in Spain (0.05 ± 0.05) but clearly lower than FBIIs from fenced (0.44±0.2) or intensively managed hunting areas (1.48±0.8) [26], which is reasonable since densities in our study areas are expected to be relatively high for unfenced conditions. By contrast, the marked difference between the two Swiss study areas is not in agreement with our assumption that wild boar population densities are similar in both areas. We suspect that this difference as well as the observed variations in counts per transect are related to the existence of faeces clusters resulting from the heterogeneity of the habitat and associated variable animal distribution. Furthermore, we assume that on densely covered forest ground faeces have a lower rate of detectability than in Spain where the dehesas (savannah-like habitats) ensure good detectability of the droppings, which in turn might bias comparisons between regions with different environmental characteristics. Estimated aggregation indices for the Swiss study areas lay within the lowest range of the values obtained in Spain

(2.91±3.11)[25], and it is indeed realistic to think that wild boar population densities in these areas correspond to those of unfenced Spanish areas. Comparison of our results with density calculations based on faeces counts in Czech Republic [43, 44] was not possible because of different prerequisites (e.g. study unit cleaned from faeces in advance).

Detectability of wild boar with thermal imaging cameras was good in open scrubland but very limited in dense forests despite winter conditions. Furthermore, repeatability of the night vision transect counts was very low (0-17 animals/trial), suggesting that the results obtained by thermal imaging are strongly linked to the particular location of the wild boar at the time of the drives (i.e. forest vs. open land). The extrapolated relative abundance differed greatly between the two study sides, indicating very high densities in area A and five time lower densities in area B. This was not in agreement with the hunting bag and the field observations of local game managers and in contrast with the data obtained with faeces counts.

Globally, it would be necessary to adjust both counting methods by increasing the number of transects per site: for thermal imaging this requires an increase of runs, for faeces counts an increase of the transect density. However, this would result in a higher time and personnel budget and consequently decrease the attractiveness of the methods for routine application. Furthermore, a comparison with an established method such as CMR should validate the reliability of these methods. Nevertheless, thermal imaging and feaces counts turn out to be largely unsuitable methods to count wild boars in densely forested areas, considering their poor detectability in such habitats.

In conclusion, despite the bias inherent in hunting statistics, under Swiss conditions this data source appears to represent an interesting, inexpensive tool for illustrating spatio-temporal trends of wild boar abundance and expansion, allowing comparisons among regions with similar hunting management. Although this method certainly lacks accuracy it may well provide sufficient information for the identification of risk factors for infections at a regional level in different geographical areas. At a local level and for more accurate analyses, direct or indirect methods remain necessary but they require to be validated for different environments before being applied for harmonization purposes.

## Acknowledgements

We thank all cantonal hunting authorities for providing their detailed hunting statistics. A special thank you goes to the hunting authorities, game wardens and hunters from Geneva and Solothurn for their logistical support, to Mirjam Pewsner (FIWI) for contributing to the night vision transects, and to Joaquin Vicente (IREC, Spain) and Nelson Marreros (FIWI) for their technical support. Funding was provided by the Swiss Federal Food Safety and Veterinary Office (FSVO). This study is part of the EMIDA-Eranet project "APHAEA". The copyright of the GIS-layers of the hunting districts belongs to the cantonal authorities.

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# MANUSCRIPT II

***Wild boar and infectious diseases: evaluation of the current risk to human and domestic animal health in Switzerland – a review***

This article was submitted for publication to 'Schweizer Archiv für Tierheilkunde'
on December 8 2015

# Wild boar and infectious diseases: evaluation of the current risk to human and domestic animal health in Switzerland – a review

R. K. Meier, M.-P. Ryser-Degiorgis

## Abstract

The Eurasian wild boar is widely distributed in Europe and hunting bags reveal a massive increase in the population. Since wild boar and domestic pigs are susceptible to the same pathogens and can infect each other, free-ranging wild boar populations are increasingly considered to be a threat to the pig industry. Switzerland has an outstanding veterinary health situation due to its official free-of-disease status for many diseases, and the role that wildlife could play as a source of infection for domestic animals is of particular concern. This article provides an overview of the current knowledge on wild boar health in Switzerland and discusses the health risk to domestic animals and humans currently posed by wild boar. It places the data in the context of the situation in neighbouring countries. The threat currently posed by wild boar in Switzerland is largely limited to swine brucellosis. To preserve this outstanding status and prevent pathogen transmission between wild boar and domestic pigs, it is essential to pursue efforts in four areas: disease surveillance in domestic pigs; biosecurity on pig farms; disease surveillance in wild boar; and sustainable wild boar management.

Keywords: health, pathogen, *Sus scrofa*, prevalence, Switzerland

# Wildschweine und Infektionskrankheiten: Einschätzung des gegenwärtigen Risikos für die Gesundheit von Menschen und Haustieren in der Schweiz - eine Literaturübersicht


## Zusammenfassung

Das Wildschwein ist in Europa verbreitet und nimmt gemäss Abschussstatistiken massiv zu. Da Wild- und Hausschweine für die gleichen Krankheitserreger empfänglich sind und eine gegenseitige Ansteckung möglich ist, werden Wildschweine vermehrt als Bedrohung für die Schweineindustrie angesehen. Die Schweiz ist offiziell frei von verschiedenen Infektionskrankheiten und geniesst einen guten veterinärmedizinischen Status. Als mögliche Quelle von Infektionskrankheiten für Haustiere werden Wildtiere deshalb mit Besorgnis betrachtet. Dieser Artikel skizziert das aktuelle Wissen zur Gesundheit des Wildschweines in der Schweiz, vergleicht diese mit dem angrenzenden Ausland und diskutiert Gesundheitsrisiken für Menschen und Haustiere. Das grösste vom Wildschwein ausgehende Risiko besteht gegenwärtig in einer Übertragung der porzinen Bruzellose. Um diesen aussergewöhnlichen Gesundheitsstatus zu bewahren und die Übertragung von Krankheitserregern zwischen Wild- und Hausschweinen zu verhindern, sind Anstrengung in vier Bereichen nötig: Krankheitsüberwachung bei Hausschweinen, Biosicherheit bei Hausschweinebetrieben, Krankheitsüberwachung bei Wildschweinen sowie angemessenes Wildschweinmanagement.



Schlüsselwörter: Gesundheit, Pathogen, *Sus scrofa*, Prävalenz, Schweiz

## Introduction

The Eurasian wild boar (*Sus scrofa*) is widely distributed in most parts of Europe and hunting bags over the past 50 years have revealed a massive increase in the population, with a current annual continental hunting bag of over 2.2 million wild boar (Massei et al., 2015). This trend is also valid for Switzerland, where available data on wild boar presence and abundance suggest both a geographical expansion and increasing abundance of the species (Meier et al. submitted).

Since wild boar and domestic pigs are members of the same species (*Sus scrofa*), they are susceptible to the same pathogens and can infect each other (Ruiz-Fons et al., 2006, Ruiz-Fons et al., 2008a). As a result, infected wild boar populations may represent a threat to the pig industry and to international trade. Known examples of diseases transmitted from wild boar to pigs are swine brucellosis and highly contagious notifiable diseases such as African and classical swine fever (Artois et al., 2002, Rossi et al., 2005, Ruiz-Fons et al., 2008a, Gavier-Widén et al., 2015). Wild boar can also represent a source of infection for other livestock such as cattle, as it is known for bovine tuberculosis (Naranjo et al., 2008), as well as for companion animals and other wildlife (Gortazar et al., 2007, Meng and Lindsay, 2009, Martin et al., 2011). For example, hunting dogs and wild carnivores have died of Aujeszky's disease virus (SuHV-1) infection after contact with wild boar (Zanin et al., 1997, Cay and Letellier, 2009, Leschnik et al., 2012). Finally, wild boar are a possible source of pathogens affecting humans (Meng and Lindsay, 2009, Ruiz-Fons, 2015), including hepatitis E virus (Li et al., 2005), *Leptospira* sp. (Jansen et al., 2007), *Trichinella* sp. (Faber et al., 2015) and bacteria known to cause foodborne diseases (Wacheck et al., 2010, Vieira-Pinto et al., 2011, Jay-Russell et al., 2012).

Nevertheless, the wild boar does not always act as a pathogen reservoir: Its epidemiological role varies from dead-end over spill-over up to maintenance host (Martin et al., 2011) depending on a range of different factors such as the pathogen properties, the local wild boar density and management, and the sanitary status of the local domestic pig population (Artois et al., 2002, Gortazar et al., 2007, Ruiz-Fons et al., 2008a, Martin et al., 2011, Ruiz-Fons, 2015).

Switzerland has an outstanding veterinary health situation due to its official free-of-disease status for many infectious diseases, thanks to diverse eradication and control programs, intensive surveillance and early warning systems, or simply because some diseases have never been noticed in this country (Anonymus, 2014). Consequently, the role that local and immigrating wildlife could play as a source of infection for domestic animals is of particular concern. Importantly, the parallel expansion of wildlife populations and increasing tendency towards green farming represent a growing risk of interactions between wildlife and domestic animals. Therefore, during the past decade the Federal Food Safety and Veterinary Office (FSVO) has actively promoted research on wild boar health, with the aim of documenting the presence or absence of selected pathogens in free-living populations and of elucidating the role of wild boar in the epidemiology of important diseases of domestic livestock.

This article provides an overview of the current knowledge on wild boar health in Switzerland and discusses the health risk to domestic animals and humans currently posed by wild boar. It also places the available data in the context of the situation in neighbouring European countries.

## Wild boar occurrence and management

There are two separate wild boar populations in Switzerland (41,284km$^2$): The northern population ranges from Geneva to St. Gallen, covering most parts of the Jura Mountains and the adjacent regions of the Swiss Midlands, and is continuous with the wild boar populations in neighboring Germany and France (Fig. 1). The southern population is distributed in the southern parts of the canton Ticino and interacts with the northern Italian wild boar population. Based on the number of wild boar shot or found dead, the highest densities are found in the cantons of Geneva, Solothurn, Basel-Landschaft, Aargau, Zurich, Schaffhausen and Ticino (Meier et al., submitted). Over the past decades, an increase in and spatial expansion of wild boar populations have been observed in Switzerland (Meier et al., submitted), similarly to what has been reported from most other parts of Europe (Massei et al., 2015). Between 2010 and 2013 the average national hunting bag in Switzerland has amounted around 6700 wild boar per year.

Wild boar hunting is regulated by the national hunting law (https://www.admin.ch/ch/d/sr/922.0) and – with restrictions – permitted from March 1$^{st}$ to January 31$^{st}$. The implementation of the law varies between cantons and depends mainly on the three hunting regimes currently applied in Switzerland: the hunting ground system in the cantons of Argovia, Basel-Landschaft , Basel-Stadt, Luzern, St. Gallen, Schaffhausen, Solothurn, Thurgovia and Zurich; the hunting permit system in the rest of the country except for Geneva; where hunting, as a result of a public vote, has been prohibited since 1974 (Hebeisen et al., 2008) but where professional game-wardens cull wild boar for population regulation. Nevertheless, in all cantons the goal is primarily to prevent damages and to control population growth. This goal, however, is difficult to achieve through hunting and culling, due to the wild boar life history (e.g. a high reproduction rate (Keuling et al., 2013).

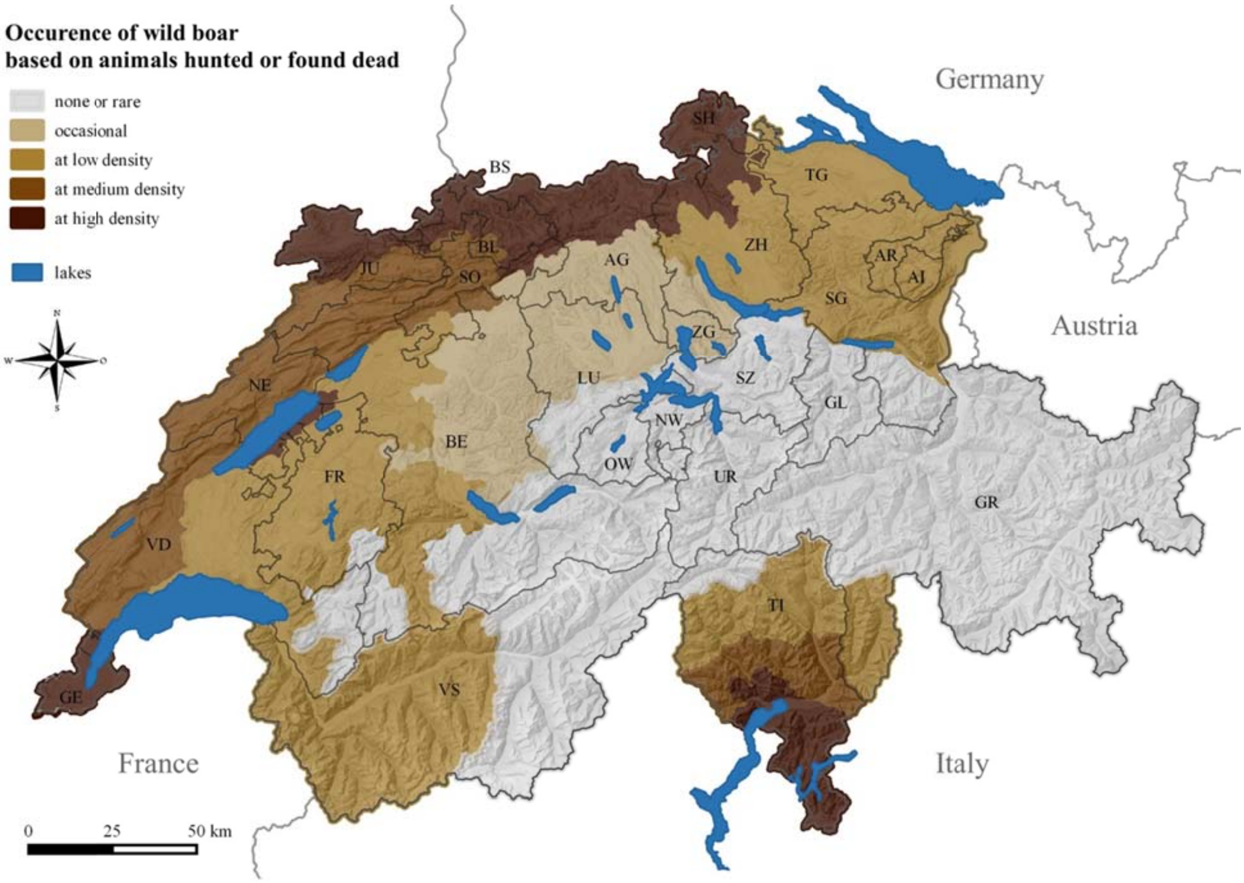


**Figure 1:** Map of Switzerland showing the occurrence of wild boar based on the records of wild boar found dead, culled and hunted (Meier et al. submitted). Abbrevations: AG=Argovia, AI=Appenzell Innerrhoden, AR=Appenzell Ausserrhoden, BE=Bern, BL=Basel-Landschaft, BS=Basel-Stadt, FR=Fribourg, GE=Geneva, GL=Glarus, GR=Graubünden, JU=Jura, LU=Luzern, NE=Neuchâtel, NW=Nidwalden, OW=Obwalden, SG=St. Gallen, SH=Schaffhausen, SO=Solothurn, SZ=Schwyz, TG=Thurgovia, TI=Ticino, UR=Uri, VD, Vaud, VS=Valais, ZG=Zug, ZH=Zurich).

### Health surveillance in wild boar

The national law stipulates that the hunters are responsible for the hygiene status of the meat from hunted wild boar and other game (concept of self-monitoring) and professional meat inspections are normally not required (Verordnung über das Schlachten und die Fleischkontrolle VSFK; https://www.admin.ch/opc/de/classified-compilation/20051437/index.html; and Verordnung des EDI über die Hygiene beim Schlachten VHyS; https://www.admin.ch/opc/de/classified-compilation/20051438/index.html). The only exception is the compulsory inspection of wild boar for *Trichinella* sp. when the carcass is not privately consumed (i.e. consumed by the hunter himself and/or his/her close family members living in the same apartment; VSFK). Furthermore, since 2014 hunters and game wardens have been obliged by law to report to the veterinary authorities any outbreak of notifiable disease or lesions hinting at the occurrence of such a disease (Article 61 of the

Tierseuchenverordnung, https://www.admin.ch/opc/de/classified-compilation/19950206/index.html). Like any other free-ranging wildlife species, dead wild boar or their organs may be submitted free of charge to the Centre for Fish and Wildlife Health in Bern for post-mortem investigation within the framework of the national scanning surveillance program for wildlife health(Ryser- Degiorgis and Segner, 2015). During the past decade only a few wild boar per year have been submitted to the FIWI within the framework of this program.

### Interactions between wild boar and domestic pigs

The highest risk of interactions between outdoor pigs and wild boar was identified for the geographical area at the junction between the Jura Mountains (where wild boar occurrence is the highest) and the Swiss Midlands (where most outdoor piggeries are located) (Wu et al., 2011). Contacts between free-ranging wild boar and outdoor domestic pigs, which can be considered as a proxy for the risk of pathogen transmission, were documented by questionnaire surveys (Wu et al., 2012): 31% of the participating game wardens and 25% of the pig owners indicated to have observed or documented such interactions (Fig. 2) . Contacts were reported in all of the 17 Swiss cantons where wild boar were present at that time. Cross-breeding, which is the type of contact carrying the highest risk of pathogen transmission, was registered in 5% of the piggeries included in that study (Fig. 3). The following risk factors for contact were identified: a distance larger than 5m between pig enclosures and piggery buildings, a large distance between pig enclosures and other houses (> 500 m), proximity of a forest (< 500 m), electric fences and fences lower than 60cm. In general, the risk was higher for piggeries with pasture than for those with concrete ground and the risk of cross-breeding was highest for the Mangalitza breed (Wu et al., 2012).

**Figure 2:** Intrusion of a young wild boar infected with *Brucella suis* in a breeding sow enclosure in May 2008 in Switzerland. (Picture: Fritz Maurer).


**Figure 3:** Crossbred animals domestic pig x wild boar (A-C) and pure domestic pigs of the Mangalitza breed (D-F: juvenile animal, adult sow and boar). A and B: Two different phenotypes of crossbred animals of first generation (half-wild boar, half Mangalitza). C: Crossbred animal of second generation (1/4 wild boar, 1/4 Mangalitza). (Picture A: Rosmarie Langjahr; Pictures C-F: Natacha Wu).

## Exposure of other domestic animals and humans to wild boar

The occurrence of interactions between wild boar and domestic animals other than pigs have not been investigated in Switzerland so far. Cattle on open pastures in areas with wild boar occurrence may potentially interact with wild boar and their pathogens, directly or indirectly (Richomme et al., 2010, Barasona et al., 2014), but physical contacts seem less likely than is the case for pigs, which may mate with wild boar. Besides ungulate species, hunting dogs regularly get in close contact with wild boar, licking at fresh carcasses (Fig. 4) and eating their meat (Muylkens et al., 2006).

Humans may be exposed to wild boar pathogens via different pathways, including direct contact when handling live wild boar or carcasses and by consumption of raw or undercooked meat or meat products from hunted wild boar, and indirect contact by intake of pathogens from contaminated water, food or the environment (Meng and Lindsay, 2009, Ruiz-Fons, 2015). Therefore the persons exposed to the highest risk include game wardens, hunters, butchers and other wildlife professionals (Ruiz-Fons, 2015). In Switzerland, there are about 30,000 active hunters not all of whom hunt wild boar (Eidgenösische Jagdstatistik, http://www.wild.uzh.ch/jagdst/index.php). Hunting bags and, accordingly, the number of consumed animals, are steadily increasing. Game meat is often consumed at home or sold to friends and restaurants.

**Figure 4:** Close contact of a domestic dog and a dead wild boar during hunting activities.

## Pathogens affecting pigs and other domestic animals

To date, only two pathogens relevant to domestic pigs have been documented to be highly prevalent in the wild boar population: *Brucella suis* and *Mycoplasma hyopneumoniae*.

*Brucella suis*, the bacterium causing porcine brucellosis, leads to reproductive disorders in pigs and mortality in hares (*Lepus europaeus*) whereas infection usually remains subclinical in wild boar(Godfroid, 2002). Additionally to these main hosts, *B. suis* occasionally infect other domestic animals and humans, although its zoonotic potential depends on the involved Biovar. The seroprevalence of *B. suis* in wild boar in Switzerland has significantly increased from 2004 to 2010, reaching 35.8% (CI: 30-42; ELISA and/or Rose Bengal Test) (Köppel et al., 2007, Leuenberger et al., 2007, Wu et al., 2011). Shedding of bacteria (only *B. suis* Biovar 2, which is characterized by a lower zoonotic potential than Biovars 1 and 3) in urine and infections of the genital organs were documented in 6.7% and 25% of the investigated animals, respectively (Wu et al., 2011) but associated lesions were not observed. Although the domestic pig population is officially free of swine brucellosis, the available data indicate that *B. suis* biovar 2 is widespread and maintained in the wild. In 2009, swine brucellosis was detected on two outdoor pig farms where a boar had been exchanged following a reduced reproductive performance on one of the farms. These observations had been preceded by the birth of cross-bred piglets after some of the pigs had roamed free in the forest (Wu et al., 2012). Although strain analysis failed to reveal evidence for a spillover of *B. suis* from wild boar to pigs (Abril et al., 2011), field investigations nevertheless suggested that it may have been the case (Wu et al., 2012) and another source of infection for the pig farms was not found.

*Mycoplasma hyopneumoniae*, the agent of enzootic pneumonia (EP) in domestic pigs, was also shown to be widespread in the Swiss wild boar population (an estimated overall prevalence of 26% in nasal swabs). In contrast to brucellosis, wild boar infected with *M. hyopneumoniae* usually develop EP lesions but to date there is no indication of a potential health impact of the disease at the population level. Prevalence in wild boar shows notable variations among geographical regions, being highest where interactions with outdoor pigs are most likely. Occurrence of EP outbreaks in domestic pigs, young age and high wild boar density were identified to be risk factors for infection in wild boar. Furthermore, the collected data suggested that prevalence in wild boar increased after an EP outbreak in pigs and re-decreased later on but data were available for a too short time period for obtaining significant differences among years and to draw clear conclusions (Batista Linhares et al., 2015). A parallel study based on genotyping of *M. hyopneumoniae* from pig lungs from EP outbreaks and lungs from wild boar from the close proximity of the affected pig farms indicated that mutual transmission between domestic pigs and wild boar occurs. Interestingly, in one EP outbreak in domestic pigs the *M. hyopneumoniae* genotype found in pigs could not be detected in wild boar samples collected before the outbreak but it was frequently found after the outbreak, suggesting that wild boar were infected by domestic pigs. Furthermore, it was shown that the mycoplasma load in wild boar is much lower than in affected domestic pigs, implying that for transmission of *M. hyopneumoniae* from wild boar to pigs direct contact is necessary, whereas the high load of mycoplasma from an affected pig farm would be sufficient for aerial transmission (Kuhnert and Overesch, 2014). Although prevalence and risk factor studies in domestic pigs are currently lacking, available data indicate that a transmission of *M. hyopneumonia*e from domestic pigs to wild boar is more likely than vice versa.

Sarcoptic mange, a skin condition caused by the burrowing mite *Sarcoptes scabiei*, has recently been detected in wild boar in several Swiss cantons (Haas et al., 2015). Since sarcoptic mange occurs in domestic pigs, outdoor pigs represent one of several potential sources of infection for wild boar (Haas et al., 2015). Genetic analyses comparing mites from affected wild boar with those from different hosts and prevalence studies documenting the current spread of infection in the wild boar population remain to be carried out to elucidate the origin of the mites recently found in wild boar.

Several prevalence studies (antibody and/or antigen detection) suggest that the agents of Aujeszky's disease (AD; (Köppel et al., 2007, Leuenberger et al., 2007, Meier et al., 2015), Classical Swine Fever (CSF; (Köppel et al., 2007), Porcine Reproductive Respiratory Syndrome (PRRS;(Wu et al., 2011) and bovine tuberculosis (Schöning et al., 2013, Beerli et al., 2014) do not circulate in Swiss wild boar, being either absent from the population or present at only low prevalence - likely a too low prevalence for pathogen maintenance.

### Pathogens relevant to human health

Hepatitis E is an emerging human viral disease transmitted via the faecal-oral route with a proposed main reservoir in domestic pigs and wild boar (Pavio et al., 2010). Antibodies to Hepatitis E Virus (HEV) were found in only 12.5% of investigated wild boar from the Swiss Jura Mountains and adjacent Midlands compared to 58.1% in domestic pigs (Burri et al., 2014). Toxoplasmosis, caused by the protozoan *Toxoplasma gondii*, is a disease affecting animals and humans which can be acquired by consumption of oocysts shed by definitive hosts (cats) in the environment or infected raw meat of intermediate hosts such as wild ungulates. Seroprevalence of *Toxoplasma gondii* was found to be significantly lower in wild boar (6.7%) than in domestic pigs (23.3%), cattle (45.6%) and sheep (61.6%)(Berger-Schoch et al., 2011). Thus, both for HEV and *T. gondii*, the risk posed by wild boar is significantly lower than that of domestic livestock.

Investigations of wild boar from the canton of Geneva revealed the occurrence of a range of potential pathogenic bacteria in tonsillar tissue including *Yersinia enterocolitica* (35%), *Y. pseudotuberculosis* (20%), *Salmonella* spp. (12%), stx-positive *Escherichia coli* (9%) and *Listeria monocytogenes* (17%), while *Campylobacter* was not detected. Nevertheless, only *Y. enterocolitica* (5%) and *L.*

*monocytogenes* (1%) were detected in faecal samples (Fredriksson-Ahomaa et al., 2009, Wacheck et al., 2010), suggesting that carriage in tonsils may not be a good indicator of the transmission risk.

Trichinellosis is a serious, potentially fatal disease in humans which is acquired by the consumption of infected meat, whereas infected animals do not display disease signs. *Trichinella* sp. has not been detected in any Suidae including numerous tested wild boar in Switzerland for decades but a seroprevalence of 0.2% was documented in wild boar, revealing a rare but occurring exposure to the parasite (Frey et al., 2009a).

## Comparison with neighbouring countries

A comparison of prevalences for the above mentioned wild boar pathogens with the situation in the neighbouring countries Austria, Germany, France and Italy is challenging because publicly available data are incomplete for several pathogens and countries (Table 1a-c).

Similarities between the situation in Switzerland and neighbouring countries (regions close to the Swiss border) were found for several pathogens. All countries bordering Switzerland are officially free of CSF (Anonymus, 2015a). The disease had been locally endemic in wild boar for a decade in northeastern France (Rossi et al., 2011) but it was finally eliminated thanks to vaccination campaigns (Rossi et al., 2015). Reported seroprevalences are low for HEV (Schielke et al., 2009, Carpentier et al., 2012, Caruso et al., 2015), and AD virus (data available for southern Germany  and eastern France;(Payne et al., 2011). Antibodies against PRRS virus were rarely detected in France (Albina et al., 2000) and in the south of Germany (Hammer et al., 2012) but, by contrast, seroprevalence was high in southern Italy (Montagnaro et al., 2010a). Cases of sarcoptic mange are known to occur in France, Italy and Germany but prevalence data are lacking and the situation at the Swiss border is not known (Rasero et al., 2010, Haas et al., 2015). Frequent exposure to *M. hyopneumoniae* has been documented in wild boar from France (Marois et al., 2007) and Italy (Chiari et al., 2014).

Seroprevalence of *Toxoplasma gondii* in wild boar is lower in Switzerland than in Italy (Magnino et al., 2011) France (Beral et al., 2012) and in an earlier study from Germany (Lutz, 1997). *Trichinella* sp. has not been documented in wild boar from Austria (Duscher et al., 2015) but occasional infections of wild boar have been documented in France (Gari-Toussaint et al., 2005), Germany (Faber et al., 2015) and Italy (Fichi et al., 2015). No data are available on the occurrence of bovine tuberculosis in wild boar in Austria and Germany but it is known that *M. caprae* circulates among red deer (*Cervus elaphus*) in the bordering parts of Austria (Fink et al., 2015). Seropositive wild boar were detected in bordering French regions (Jura; Richomme et al., 2013) and *M. bovis* has been found in wild boar in northwestern Italy (Dondo et al., 2007).

In Switzerland, exposure of wild boar to *Brucella suis* seems to occur more frequently than in Germany and Italy (Melzer et al., 2007, Bergagna et al., 2009) but comparably or less often than in the bordering regions of France (Payne et al., 2011). However, seroprevalences are generally increasing all over Europe. Medium to high prevalences were documented in Croatia, Czech Republic, Italy, Germany, Spain, Denmark and France (Garin-Bastuji and Delcueillerie, 2001, Godfroid, 2002, Vengust et al., 2006, Bergagna et al., 2009, Cvetnić et al., 2009, Montagnaro et al., 2010a, Muñoz et al., 2010, Payne et al., 2011).Besides one report of the highly zoonotic Biovar 3 in Croatia (Cvetnić et al., 2009), only Biovar 2, which is characterized by a low zoonotic risk, has been documented in European wild boar to date (Godfroid, 2002).

Only a few prevalence studies are available from bordering countries for bacteria associated with food-borne diseases but they yield data comparable to those collected in Switzerland: Antibodies against *Yersinia* sp. (62.6%) were detected in wild boar in Germany (Al Dahouk et al., 2005); and *Salmonella* sp. (3.9 -26%) and *Y. enterocolitica* (7%) were cultivated from faeces in Italy (Magnino et al., 2011, Vieira-Pinto et al., 2011).

## Discussion

This article shows that the health status of the wild boar population in Switzerland can be qualified as generally good. Classical Swine Fever does not currently occur. Exposure to AD virus, PRRS virus, mycobacteria of the *Mycobacterium tuberculosis* complex and to *Trichinella* sp. is rare. These data suggest that the wild boar is currently not a maintenance host for these agents and thus not of serious concern as a source of infection for animals and man. This is in accordance with the condition of the domestic animal population, which has an official status of freedom from these diseases. Nevertheless, the occurrence of *Trichinella* sp. in wild carnivores (Frey et al., 2009b) indicates its presence in the environment. Wild boar may occasionally become infected by *T. britovi*, e.g. through scavenging on dead foxes, and subsequently become a possible source of human infection (Gari-Toussaint et al., 2005), justifying the further testing wild boar meat for *Trichinella* sp. prior to consumption.

First data on the occurrence of bacteria potentially causing foodborne infections in humans indicate their occurrence in wild boar tonsils but these tissues are not consumed and faecal shedding appears to be rare. Since investigations were performed in only one canton, no information is currently available on the distribution of these pathogens at the country level. Comparison with data on domestic animals suggests a higher occurrence of *Listeria* sp. and *Salmonella* sp. but a lower occurrence of *Yersinia* sp., stx-positive *Escherichia coli* (9%) and *Campylobacter* in wild boar than in pigs (Table 1). Similarly, the risk of infection with *Toxoplasma gondii* and HEV through contacts with wild boar is lower than via domestic animals, both because prevalence is lower in wild boar than in pigs and because less wild boar meat than pork is consumed.

The situation of *M. hyopneumoniae* is more serious as the infection is moderately prevalent in wild boar from some Swiss regions. However, recent studies revealed that pigs are a far a more serious source of infection than wild boar.

Currently, the pathogen causing the most concern at the wild boar-livestock interface in Switzerland is *Brucella suis* Biovar 2. First, wild boar obviously maintain the pathogen in the wild, representing a potential source of infection for domestic animals and eventually humans, and prevalence even shows an increasing trend. Second, this situation is opposite to that in domestic pigs, which are officially free of brucellosis. Third, close interactions between wild boar and pigs including cross-breeding have been documented, proving that a transmission of *B. suis* (which is mainly transmitted through mating) from wild boar to pigs  is possible under Swiss conditions (Wu et al., 2011, Wu et al., 2012). Transmission of *B. suis* from wild boar to outdoor pigs has been documented in France and Denmark (Rossi et al., 2008) and the origin of a recent outbreak in pigs with a history of cross-bred piglets born on a farm in Switzerland was not definitively elucidated (Wu et al., 2012). Nevertheless, considering the prevalence in wild boar and the fact that no further outbreaks have been documented in pigs so far, the risk of transmission in the field appears to be low.

### Risk represented by wild boar crossing the Swiss border

Wild animals do not respect political borders and it is of concern that animals moving from regions beyond the border may introduce pathogens into the Swiss territory. As an example, in the late 1990ies wild boar migrating from Italy were considered to have been the most likely source of the last outbreak of CSF in Switzerland (Schnyder et al., 2002). Currently, the situation in the bordering regions of Austria, France, Germany and Italy (Table 2) is generally similar to that in Switzerland. Higher exposure of wild boar to *T. gondii* in all of the neighbouring countries is not expected to be relevant for the epidemiological situation in Switzerland.  Factors potentially causing differences in seroprevalence of *T. gondii* in the wild include distance to human settlements (more specifically to domestic cats), the presence of wild cats (*Felis silvestris*) and climatic factors such as episodes of cold temperatures (Ryser-Degiorgis et al., 2006, Berger-Schoch et al., 2011, Beral et al., 2012). More importantly, bovine tuberculosis and PRRS are both reported from bordering regions, either in wild boar or in domestic animals. However, it is unclear whether *M. bovis* is maintained in the wild boar population in northern Italy and which epidemiological role the wild boar plays in these regions. Also, the occurrence of the PRRS virus has not yet been reported in wild boar from bordering regions and to date there is no indication that PRRS virus is maintained in free-ranging wild boar populations in any region of Europe (Ruiz-Fons et al., 2008a). Up to now, documented seroprevalences for PRRSV in wild boar in Europe have been very low (Hammer et al., 2012, Fabisiak et al., 2013, Rodríguez-Prieto et al., 2013, Štukelj et al., 2014). Nevertheless, since the virus is widespread in domestic pigs in Europe, infection of wild boar by domestic pigs might occur.

More distant regions of Europe are characterized by a very different disease pattern. On the Iberian Peninsula, for instance, several harmful pathogens such as *Mycobacterium bovis* and *M. caprae* (Naranjo et al., 2008) are widespread and maintained in the wild boar population (Ruiz-Fons et al., 2008a). Similarly, antibodies to AD virus are highly prevalent in many regions of Europe (Meier et al., 2015, submitted). Management practices like fencing and supplemental feeding (typically resulting in overabundance and aggregation) as well as translocations are driving factors for pathogen transmission and introduction, respectively, and contribute to the spread of pathogens such as *M. bovis/caprae*, CSF virus and AD virus in the wild (Gortazar et al., 2006, Gortazar et al., 2007, Ruiz-Fons et al., 2008b, Schöning et al., 2013). In contrast to many other European countries, such management practices do not exist in Switzerland (Blatter, 2013, Schöning et al., 2013).

## Further potentially important pathogens in wild boar

Several studies have revealed high seroprevalences for *Leptospira* sp. in wild boar in Europe and warn of an increased risk of transmission to humans due to the growing wild boar population and the habitat expansion of wild boar to more urban areas (Deutz et al., 2002, Jansen et al., 2007, Meng and Lindsay, 2009, Vale-Gonçalves et al., 2014). Leptospirosis is still often considered to be an “exotic” disease but it is emerging in temperate regions including Switzerland and is likely underreported in domestic pets and humans (Major et al., 2014, Schreiber et al., 2015). A prevalence study in selected wild mammals from all of Switzerland including wild boar is currently under way at the FIWI to assess the potential reservoir role of wildlife for pathogenic leptospires.

In a current outbreak of African Swine Fever (ASF) spreading from Russia via Belarus, Estonia, Latvia, Lithuania to Poland, wild boar have become infected via spillovers from pigs (EFSA and Welfare), 2015). An endemic situation seems to have developed locally in wild boar in certain areas, which may represent a serious risk to pig health in the future (Woźniakowski et al., 2015). However, many studies carried out in other ASF infected areas in Europe suggest that ASFV tends to disappear from wild boar populations when the interaction with infected domestic pigs is limited(EFSA and Welfare), 2015). Infected wild boar rapidly die of the disease (Blome et al., 2012) and infectiousness of the virus appears to be lower than originally assumed, possibly explaining the observed low disease spread in the wild (Woźniakowski et al., 2015).

Japanese encephalitis virus (JEV) is a mosquito-transmitted pathogen of high zoonotic relevance and for which birds and swine including wild boar represent the main reservoir (Van den Hurk et al., 2009, Ruiz-Fons, 2015). The virus  is endemic in south eastern Asia but recently JEV genetic material was detected in mosquitoes and birds in northern Italy (Ravanini et al., 2012), suggesting that it might well occur in wild boar in our regions in the future (Ruiz-Fons, 2015). On the same line, the wild boar shows low prevalences for Influenza A virus in Europe (Vicente  et al., 2002, Kaden et al., 2009, Vittecoq et al., 2012) but as Suidae it is a possible host for the reassortment of Influenza viruses (Vittecoq et al., 2012).

The risk arising from wild boar as a possible source of other swine pathogens such as porcine parvovirus (PPV), porcine circovirus-2 (PCV-2) and transmissible gastroenteritis virus (TGEV) is considered to be low because these pathogens are more widespread in domestic pigs than in wild boar in Europe (Ruiz-Fons et al., 2008a). PCV-2 and PPV occur in domestic pigs in Switzerland (Handke et al., 2012), there is, however, there is no information on the prevalence of these viruses. Swiss pigs are officially free from TGE virus (http://www.blv.admin.ch/gesundheit_tiere/01065/01456/01477/index.html?lang=de) and it apparently occurs only very rarely elsewhere in Europe (Vengust et al., 2006, Ruiz-Fons et al., 2008a, Sedlak et al., 2008, Kaden et al., 2009).

### Lack of data on domestic pigs

Domestic pigs are much more numerous and have a much higher economic impact than wild boar. Surprisingly, in contrast to the literature on wild boar health, internationally available data on the health situation in domestic pigs (such as prevalence or risk factor studies) are often either missing or else difficult to find. Frequently, the only available sources of information are reports or notices from the European Food Safety Authority (EFSA) or the World Organisation for Animal Health (OIE) in which local circumstances and detailed backgrounds are usually not mentioned or updated information on disease occurrence is missing (e.g. no report on bovine tuberculosis in Austria since 2010 is to be found in the online database of the OIE, http://www.oie.int/wahis_2/public/wahid.php/Countryinformation/Animalsituation).

To identify key players in the epidemiology of transmissible diseases at the wildlife-livestock interface, it is essential to obtain background information, prevalence studies and new insights on the situation in livestock (Boadella et al., 2011). It is evident that wildlife can act as a reservoir for a wide range of pathogens and that a number of wild species pose a high risk for domestic animal health and economics (Gortazar et al., 2007, Meng and Lindsay, 2009, Ruiz-Fons, 2015). However, it has to be considered that initial infection of wild populations can come from domestic animals (spillover), potentially resulting int maintenance in the wild and subsequent transmission back to domestic livestock (spillback). Bovine tuberculosis, for instance, was in most cases first introduced from infected cattle to susceptible wild populations before wildlife reservoirs developed (Palmer, 2007).

### Three major issues when assessing the epidemiological role of wild boar

Considering the data presented above, three major issues arise. First, infections at the wild-domestic interface can be bi-directional and biosecurity measures are not only indicated to prevent pathogen transmission from wild boar to domestic pigs (e.g. porcine brucellosis) but also to prevent infection of wild boar by domestic animals and a potential subsequent reservoir establishment in the wild (e.g. bovine tuberculosis, ASF). Since eradication of pathogens from wildlife populations are impossible or involve a huge effort (Gortazar et al., 2015) and sampling procedures and control measures are much more practicable in domestic animals, prevention should start in domestic animals. This includes adequate health surveillance in domestic pigs, early warning strategies and prevention of interspecies contacts between wild boar and domestic pigs (Wu et al., 2012).

Second, the epidemiological role of wild boar can vary from spillover to reservoir host depending, inter alia, on the density of the host population and on animal aggregation. High densities mean a higher number of susceptible individuals and favour aggregation of animals (and therefore closer and more frequent contacts among animals), and management measures such as feeding or fencing of wildlife leads to high densities and animal aggregation. Aggregation is the main risk factor for maintenance of bovine tuberculosis in wildlife (Schöning et al., 2013), and high densities and aggregation are positively correlated with high (sero-)prevalences of AD virus, CSF virus, PCV-2 and the incidence of multi-pathogen infections in wild boar (Gortazar et al., 2006). Therefore, it is of the highest importance to pursue an adequate wild boar management including control of population growth and minimizing aggregation.

Third, it is important to be cautious when initiating investigations and interpreting diagnostic results in wild boar. For example, one may think that the detection of *Yersinia enterocolitica* by PCR in 36% of the tested wild boar suggests that wild boar are an important source of infection with this pathogen. However, detection does not mean excretion, and, indeed, faeces samples from the same animals revealed only one positive individual, i.e. only one shedder out of 73 animals (Wacheck et al., 2010), thus relativizing the first findings. Similarly, the detection of *M. hyopneumoniae* in wild boar lungs or seropositivity to *B. suis* do not mean that the animal is currently shedding these bacteria and is infectious to others (Kuhnert and Overesch, 2014, Batista Linhares et al., 2015). Also, depending on the infection dynamics in the host, targeted investigations on hunted animals may not be appropriate for surveillance purposes. For example, early detection of ASF requires the investigation of sick or dead animals(Gavier-Widén et al., 2015). Therefore it is essential to be aware of the pathogen features, host-specific characteristics and the local epidemiological situation to carefully evaluate the choice of the diagnostic tools according to the question to be addressed and to interpret the results in a meaningful way.

## Conclusion

The potential health threat currently posed by wild boar in Switzerland is largely limited to swine brucellosis. Considering that only one outbreak has been recorded in pigs since 1991, the risk of transmission appears to be low. To preserve this outstanding health status of wild boar in Switzerland and to prevent pathogen transmission between wild boar and domestic pigs, it is essential to pursue efforts in four areas: 1) disease surveillance in domestic pigs, especially in the case of importations; 2) biosecurity on pig farms; 3) disease surveillance in wild boar, including general surveillance (i.e. the investigation of dead and potentially sick animals) and targeted investigations where appropriate; 4) sustainable wild boar management, preventing excessive densities and aggregation. Here, collaboration between hunters, game wardens, hunting authorities, swine farmers, veterinarians, food and veterinary administrations and wildlife scientists is essential. Furthermore, to minimize the risk of infection of hunting dogs by AD virus from wild boar, dogs should be kept from getting in close contact with wild boar (e.g. licking and consuming excretions and raw tissues) (Muylkens et al., 2006). Last but not least, exposed persons like hunters, game wardens, wildlife veterinarians and biologists should be aware of the risk of pathogen exposure when manipulating wild boar or their carcasses. Despite the currently low disease risk in Switzerland, it is important to remember that wild boar meat is safest when thoroughly cooked, and to respect good hygiene practices such as wearing gloves for the evisceration of hunted animals in case of skin wounds, washing hands thoroughly after handling animals, excising portions of meat which have come in contact with intestinal content.

## Acknowledgements

This study is a contribution to the European project APHAEA (EMIDA ERA-NET). Financial support was provided by the Federal Food Safety and Veterinary Office (FSVO) and the veterinary service of the Swiss Armed Forces.

**Table 1a:** Compilation of epidemiological information on selected pathogens affecting wild boar (WB) and domestic pigs (DP). *notifiable disease in Switzerland

| Disease | Pathogen | Clinical significance on WB | Epidemiological role of WB | Infectious for domestic animals others than swine | Zoonoses: infection route to humans |
|---|---|---|---|---|---|
| **CSF*** | Pestivirus | high mortality | possible reservoir | no | - |
| **AD** | Aujeszky's disease virus (Suid Herpesvirus-1) | clinical disease rare | possible reservoir | fatal infections in most mammals | - |
| **PRRS*** | Porcine reproductive and respiratory syndrome virus | no impact suggested | no evidence for reservoir | no | - |
| **Hepatitis E** | Hepatitis E Virus | no | possible reservoir | possible | foodborne, close contact (excretions) |
| **Brucellosis*** | *Brucella suis* | clinical disease rare | possible reservoir | possible | close contact |
| **bTB*** | *Mycobacterium bovis, M. caprae* | same clinical signs as DP | possible reservoir | yes | close contact |
| **EP*** | *Mycoplasma hyopneumoniae* | same clinical signs as DP | unclear | no | - |
| **Yersiniosis*** | *Yersinia enterocolitica, Y. pseudotuberculosis* | negligible | unknown | possible | foodborne |
| **STEC*** | Shiga-toxin positive *Escherichia coli* | negligible | unknown | possible | foodborne |
| **Salmonellosis*** | *Salmonella* sp. | negligible | possible reservoir | possible | foodborne, peroral intake |
| **Listeriosis*** | *Listeria monocytogenes* | negligible | unknown | possible | foodborne |
| **Campylobacteriosis*** | *Campylobacter* sp. | negligible | unknown | neglible | foodborne |
| **Trichinellosis*** | *Trichinella spiralis, T. britovi* | no | possible reservoir | yes | foodborne |
| **Toxoplasmosis*** | *Toyoplasma gondi* | clinical disease rare | unknown | yes | peroral intake, foodborne pathogen |
| **Sarcoptic mange** | *Sarcoptes scabiei* sp | high morbidity, low mortality | possible reservoir | interspecies transmission discussed | (improbable; physical contact) |

**Table 1b:** Situation of selected pathogens listed in table 1a in domestic pigs (DP) in Switzerland and its bordering countries Austria (A), Germany (D), France (F) and Italy (I)

| Disease | DP: situation in CH | DP: situation in neighboring countries |
|---|---|---|
| **CSF** | free-from-disease[1] | free-from-disease; D: last outbreak in 2006 [12] |
| **AD** | fee-from-disease[1] | A: not present[12]<br>D, F, I: presence within last five years; now absent[12] |
| **PRRS** | free-from-disease; sporadic outbreaks, last outbreak 2014[1,2] | widespread [12, 13, 14] |
| **Hepatitis E** | 58.1% (ELISA, serum, 2006, 2011)[3], 60%(ELISA, meat juice, 2011)[4] | A: 5.8% (PCR, serum, liver, bial, mesenteric lymphonodes, faeces, kidney )[15]<br>D: 49.8% (ELISA, serum, 2007/2008)[16]<br>F: 65% (ELISA, serum, 2008/2009)[17]<br>I (north): 50.2% (ELISA, serum, 2008)[18] |
| **Brucellosis** | disease very rare[4], three outbreaks in 2009[2] | A: last report in 2010<br>D: clinical disease occurs<br>I: disease limitied to areas<br>F: clinical disease occurs[12, 19] |
| **bTB** | free-from-disease[1] | disease present in all countries[12] |
| **EP** | free-from-disease[5]; sporadic outbreaks (n= approx. 9/yr)[2] | A: no data available<br>D: 65% (ELISA, serum, 2003)[20]<br>F:69.3 (PCR, lung, 2011)[21]<br>I: 22% (PCR, nasal swabs, 2008/2009)[22] |
| **Yersiniosis** | *Y. enterocolitica*: 88% (PCR, tonsils, 2006)[6] | A: no data available;<br>D: *Y. enterocolitica*:8.4% (culture, faeces, <2007)[23]<br>F: *Y. enterocolitica*: 13.7% (culture, tonsills, 2010)[24]<br>I: *Y. enterocolitica*: 32% , *Y. pseudotuberculosis*: 1%; (culture, tonsils, 2005/2007)[25] |
| **STEC** | O 157: 7.5%, STEC: 22% (PCR, faeces, 2004-2005)[7] | A: no data available,<br>D: 16.7% (culture, 2013)26<br>F: no data available<br>I: no detection[26] |
| **Salmo-nellosis** | 0.8% (PCR, Tonsils, 2011)[8]; 4%(ELISA, meat juice, 2011)[9]; rare outbreaks[2] | A: low;<br>D: 7-18% (2013)[27]<br>F: no data available<br>I: 0-89% (2013)[27] |
| **Listeriosis** | 5.6% (culture, tonsills, 2011)[8] | A: no data available<br>D: 32%(culture, tonsils, 2004)[28]<br>F: 11%/14.5% (culture, faeces, 2008)[29]<br>I: 0.2% (culture, faeces, <2012)[30] |
| **Campylobacteriosis** | 65% (culture, faecel swabs, 2013)[4] | A: 50% (2008)[19]<br>D: 62% (culture, faeces, 2004)[28]<br>F:50.2% (culture, stomach, 1999)[31]<br>Italy: 63.5% (culture, rectal swabs, 2000)[32] |
| **Trichinellosis** | free-from-disease[4] | A: no cases[33]<br>D: rare cases[34]<br>F: rare cases [35]<br>I: rare case[12] |
| **Toxo-plasmosis** | 23.3% (ELISA, meat juice, 2006-2008)[10] | A: pathogen documented[19], 20.6%(ELISA, Serum, 2001/2002)[36]<br>F: no data available,<br>I: pathogen documented[37] |
| **Sarcoptic mange** | pathogen reported[11] | A: pathogen reported[38]<br>D: 19.1% (digestion method, scrapings, 1997)[39]<br>F: no data available<br>I: pathogen reported[40] |

**Table 1c:** Situation of selected pathogens listed in table 1a in wild boar (WB) in Switzerland and its bordering countries Austria (A), Germany (D), France (F) and Italy (I)

| Disease | WB: situation CH | WB: situation in in neighboring countries |
|---|---|---|
| **CSF** | Last outbreak, 1998-2000 (eradicated)[41,] 0.0%(ELISA, serum, 2004/2005)[42,] | A: no data available<br>D: local outbreaks recorded[53]<br>F: local outbreaks recorded[54]<br>I: local outbreaks recorded[55] |
| **AD** | 0.57%(ELISA, serum, 2008-2013)[43] | regional presence in all countries; low prevalences in neighboring regions in F and D[43] |
| **PRRS** | 0.43% (ELISA, serum, 2008-2010)[44] | A: no data available<br>D: 0.5% (ELISA, serum, 2008-2009)[56], 1.2% (ELISA, serum, <2012)[57]<br>F: 3.3% (ELISA, serum, 1993-1995)[58]<br>I(south): 37.7%(ELISA, serum, 2005-2006)[59] |
| **Hepatitis E** | 12.5% (ELISA, serum, 2008-2012)[3] | A: pathogen recorded[15]<br>D:14.9% (PCR, liver, <2009)[60], 33% (ELISA, serum, 2011)[61]<br>F: 14% (ELISA, serum, 2000-2004)[62]<br>I: 1.9-3.7% (PCR, liver, 2012-2013)[63,64] |
| **Brucellosis** | 35.8% (RBT/ELISA, serum, 2008-2010)[44], 28.8%(PCR/Culture, spleen, sex organs, blood, 2008-2010)[44] | A: pathogen recorded[65]<br>D: 0-28.5% (ELISA, serum, <2007)[65]<br>F: 1-80% (ELISA, serum, 2009-2010)[66]<br>I (north): 19.8% (RBT/CFT, serum, 2001-2007)[67], 10.8% (Culture, spleen, genital organs, 2002-2007)[68] |
| **bTB** | 3.6% (PCR(MTBC), lymphondes/ tonsills,2009-2011)[45], 2.4% (ELISA, serum, 2008-2013)[46] | A: no data available<br>D: no data available<br>F (Normandie): 42% (Culture, lung/lymphonodes, 2005-2006)[69]<br>I: pathogen recorded[70] |
| **EP** | 26% (PCR, nasal swabs, 2011-2013)[47] | A: no data available<br>D: no data available<br>F: 58% (ELISA, serum, 2002-2003)[71]<br>I: 30% (ELISA, serum, 2008-2013)[72] |
| **Yersiniosis** | 65% (ELISA, tissue juice, 2007-2008), 44% (PCR, tonsils, 2007-2008), 5% (PCR,faeces, 2007-2008)[48,49] | A: no data available<br>D: 62.6% (western blot, serum, 1995-1996)[73]<br>I: 15.4% (culture, muscle swabs, 2008-2010)[74]<br>F: no data available |
| **STEC** | 9%(PCR, tonsils, 2007-2008), 0%(PCR, faeces, 2007-2008)[49] | A, D, F, I: no data available |
| **Salmo-nellosis** | 12%(PCR, tonsils, 2007-2008), 0%(PCR, faeces, 2007-2008)[49] | A: no data available,<br>D: pathogen reported[75]<br>I: 30.7%(ELISA, serum, 2005-2006)[76], 10.8% (culture, faeces, 2010-2012)[77]<br>F: no data available |
| **Listeriosis** | 17%(VIDAS, tonsils, 2007-2008), 1%(culture, faeces, 2007-2008)[49] | A: no data available<br>D: 5.5%(Culture, Meat punch, 2007)[78]<br>I: No data available<br>F: No data available |
| **Campylo-bacteriosis** | 0% (culture, VIDAS, tonsils, 2007-2008)[49] | A: no data available<br>D: no data available<br>I: 0%(culture, meat, <2014)[79]<br>F: no data available |
| **Trichi-nellosis** | 0.2% (ELISA, meat juice, 2005-2007)[50] | A: no report but risk is present[32]<br>D: pathogen occurs [80]<br>F: cases occur[81]<br>I: cases occur[82] |
| **Toxo-plasmosis** | 6.7% (ELISA, meat juice, 2006-2008)[51] | A: 19.3% (serum, 1990-1993)[83]<br>D: 25% (IFAT, serum, 1993-1994)[84]<br>F: 23% (MAT, serum, 2003-2004)[85,]<br>I: 33.3% (ELISA, serum, 2005-2009)[86] |
| **Sarcoptic mange** | cases reported[52] | A: no data available<br>D: no data available<br>F: pathogen recorded[87]<br>I: pathogen recorded[87] |

Footnotes table 1a-1c:
**Abbreviations**: AD= Aujeszky's disease, bTB= bovine tuberculosis, CFT= complement fixation test, CSF= Classical swine fever, ELISA= Enzyme linked immune sorbent essay, EP= Enzootic pneumonia, IFAT: immunofluorescence antibody test, MAT= Modified agglutination test, PCR= Polymerase chain reaction, PRRS= Porcine reproductive respiratory syndrome, RBT= Rose Bengal test, STEC= Shiga Toxin–Producing *Escherichia coli*, VIDAS®= Automated enzyme-linked fluorescent immunoassay (BioMérieux, Nuertingen, Germany)
**References**: [1](Anonymus, 2014), [2](Anonymus, 2015c), [3](Burri et al., 2014), [4](Wacheck et al., 2012), [5](Anonymus, 2013a), [6](Anonymus, 2013b), [7](Fredriksson-Ahomaa et al., 2007), [8](Kaufmann et al., 2006), [9](Sarno et al., 2012), [10](Berger-Schoch et al., 2011), [11](Anonymus, 2015d), [12](Anonymus, 2015a), [13](Anonymus, 2004b), [14](Anonymus, 2015f), [15] (Zwettler et al., 2012), [16](Baechlein et al., 2010), [17](Rose and Pavio, 2014), [18](Martinelli et al., 2011), [19](Much et al., 2013), [20](Grosse Beilage et al., 2009), [21](Fablet et al., 2012), [22](Villareal et al., 2010), [23(]von Altrock et al., 2007), [24](Fondrevez et al., 2014), [25](Ortiz Martínéz et al., 2011), [26](EFSA et al., 2015a), [27](EFSA et al., 2015b), [28](Fredriksson-Ahomaa et al., 2009), [29](Boscher et al., 2012), [30](Prencipe et al., 2012), [31](Payot et al., 2004), [32](Pezzotti et al., 2003), [33](Duscher et al., 2015), [34](Anonymus, 2015b), [35](Anonymus, 2015e), [36](Hintersdorf, 2013), [37](Tenter et al., 2000), [38](Anonymus, 2004a), [39](Damriyasa et al., 2004), [40](Gualandi et al., 1994), [41](Schnyder et al., 2002), [42](Köppel et al., 2007), [43](Meier et al., 2015), [44](Wu et al., 2011), [45](Schöning et al., 2013), [46](Beerli et al., 2014), [47](Batista Linhares et al., 2015), [48](Fredriksson-Ahomaa et al., 2009), [49](Wacheck et al., 2010), [50](Frey et al., 2009a), [51](Berger-Schoch et al., 2011), [52](Haas et al., 2015), [53](Leifer et al., 2010), [54](Simon et al., 2013), [55](Biagetti et al., 2001), [56](Hammer et al., 2012), [57](Sattler et al., 2012), [58](Albina et al., 2000), [59](Montagnaro et al., 2010b), [60](Schielke et al., 2009), [61](Denzin and Borgwardt, 2013), [62](Carpentier et al., 2012), [63](Caruso et al., 2015), [64](Serracca et al., 2015), [65](Bagó et al., 2011), [66](Melzer et al., 2007), [67](Payne et al., 2011), [68](Bergagna et al., 2009), [69](Zanella et al., 2008), [70](Dondo et al., 2007), [71](Marois et al., 2007), [72](Chiari et al., 2014), [73](Al Dahouk et al., 2005), [74] (Avagnina et al., 2012), [75](Methner et al., 2010), [76](Montagnaro et al., 2010a), [77](Zottola et al., 2013), [78](Atanassova et al., 2008), [79](Decastelli et al., 2014), [80](Pannwitz et al., 2010, Pannwitz et al., 2012) , [81](Gari-Toussaint et al., 2005), [82](Fichi et al., 2015), [83](Edelhofer and Aspöck, 1996), [84](Beral et al., 2012), [86](Magnino et al., 2011), [87](Rasero et al., 2010)

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# Acknowledgements

Different people supported me during the last three years. I warmly thank:

My supervisor Marie-Pierre Ryser-Degiorgis for her guidance and advice on compiling my manuscripts. Her generosity allowed me to meet exciting people all over Europe and to see behind the scenes of wildlife health research. Her unremitting commitment to wildlife health is admirable.

Francesco Origgi explained to me the underlying passion of a real scientist, something I'm not blessed with but I enjoyed talking about. I thank him for his engagement, solidarity and his constantly open door.

Helmut Segner's exceptional leadership keeps the FIWI together and provides room for creativity.

Claude Fischer supported me in the field and was a pleasant travel partner. During night talks he encouraged me to critically evaluate the impact of our research.

Fran Ruiz-Fons supplied me with scientific background at all hours. He's a generous and modest expert of his field.

Mariana Boadella, Joaquin Vicente, Jose Angel Barasona and Christian Gortazar from the IREC in Ciudad Real for the hospitality, technical support and the insight in their work.

All hunters, game wardens and hunting authorities who supported our sample collection and kindly provided their hunting bag data.

The game wardens from Geneva and the hunters in Solothurn, especially Marius Schneider, for their collaboration and help in the nightly transect trials.

Nelson Marreros, Ezgi Akdesir, Mainity Batista-Linhares, Malte Doherr, Julia Wimmershof, Rebecca Hari, Olivia Beerli, Sohvi Blatter, Chloé Haas, Manuela Weber and Samoa Giovannini for their help in collecting and proceeding samples as well as for sharing daily routine  and providing a warm and friendly work environment.

The Federal Food Safety and Veterinary Office (FSVO) for funding.

Thomas Kalbermatter and the Vet service of the Swiss army for their support and funding.

Hans Gantenbein and Toni Läderach for the technical help and the enjoyable discussions.

Christyn Bailey the 1st and Mirjam Pewsner for their friendship with spectacular hours of colloqui, brewskiology and mutual understanding.

My parents, grandparents, brothers and sister and their families for the infinite support, trust and backing.

My friends Manu, Lucas, Alex, Samuel and Küde for distraction and critical reflection.

Miriam Sprick for sharing life.

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# APPENDIX A

*APHAEA protocols for Aujesky's disease Virus (ADV) and wild boar (Sus scrofa)*

# Aujeszky's Disease

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**Last update**

25.11.2015

**Etiology**

Suid Herpesvirus 1 (SuHV-1). Double-stranded DNA virus of the genus *Varicellovirus,* subfamily: *Alphaherpesvirinae;* Family: Herpesviridae; Order: *Herpesvirales*. (synonym: pseudorabies virus: PrV; Aujeszky's disease virus: ADV).

**Affected species** (wildlife, domestic animals, humans)

Swine are the only natural host and reservoir for PrV, although it can infect other mammals including carnivores, ruminants, and rodents causing fatal disease. Reports of horses contracting PrV are very rare. Humans are resistant against natural PRV infection.

**Epidemiological characteristics and disease course**

PrV can be transmitted through secretions, excretions (saliva, nasal discharge), sexual encounters, aerosols and from eating contaminated feed/carcasses. Within wild/feral swine PrV appears to be preferentially transmitted by oro-nasal and venereal route. Incubation period in swine normally range between 1-8 days up to 3 weeks. Usually, after oro-nasal and venereal infection of the natural host and primary replication in epithelial cells of the upper respiratory and genital tract, respectively, the virus gains access to the olfactory, trigeminal and glossopharyngeal nerves. A hallmark of PrV is their capacity to persist for the lifetime in their host in a latent state. Trigeminal ganglia, sacral ganglia and tonsils are the most common sites of PrV latency. Whereas highly virulent PrV strains are predominantly neuroinvasive, strains of moderate or low virulence exhibit weak neuroinvasiveness, but distinct pneumotropism. Despite successful elimination of PrV from domestic pigs in several parts of the world including large regions in Western and Central Europe, PrV is widespread in populations of wild/feral swine across the world.

**Clinical signs**

**Domestic swine:** Presence and severity of clinical signs as well as morbidity and mortality vary depending on age, immunological status, route of infection, and virulence of the PrV strain. In fully susceptible swine PrV infection results in high morbidity and mortality, especially in juveniles which develop predominantly meningoencephalitis and viremia-associated signs.

Neonatal pigs (< 7 days): sudden death with few, if any, clinical signs.

Weaning and post-weaning pigs, (2 to 3 week old): severe signs of central nervous system affliction (shivering, incoordination, convulsion, tremor, ataxia, and paralysis) with mortality rates up to 100%.

3 to 20 weeks old: may still show neurological signs, but usually develop age-dependent resistance-reduced mortality of 50% up to 5% in 4 week and 5 months old pigs. Co-infections with other swine viruses often result in severe and fatal proliferative and necrotizing pneumonia. Generally, high fever is followed by anorexia, listlessness, excessive salivation, vomiting, coughing, sneezing, dyspnoea, and aspiration pneumonia, trembling and eventually marked incoordination (hind legs).

Adult swine: high morbidity due to predominantly respiratory signs. Clinical signs can be present for 6 to 10 days. Most animals recover within a few days but present with less weight. In finishing and fattening pigs, clinical signs can amplify and animals often die from secondary bacterial pneumonia. Signs in gilts and sows depend on phase of gestation and include embryonic death, resorption of foetuses, mummified foetuses, abortion, or stillbirth, in addition to respiratory signs and fever.

**Wild/feral swine:** clinical signs are rare indicating a high adaptation of prevailing PrV variants to the host population. Cases of spontaneous disease clinically and pathologically identical to AD in domestic pigs are rare.

**Other mammals:** peracute fatal course of disease with incubation periods of only 2 to 3 days is characteristic with predominantly progressive neurological signs. Often extreme pruritus which can result in severe automutilation, is the only clinical sign.

## Gross lesions

No typical gross lesions, at least not in terms of being characteristic for the disease. Multifocal tissue necrosis, exudative kerato-conjunctivitis, serous to fibrinonecrotic rhinitis, necrotizing laryngotracheitis, bronchointerstitial pneumonia, necrotizing tonsillitis, and leptomeningeal hyperemia (CNS) may be present. Multiple small foci of acute hemorrhagic necrosis may be seen in organs and placenta. In aborted sows, necrotizing placentitis and endometritis are observed; aborted fetuses may be macerated or, occasionally, mummified (SMEDI). In fetuses or neonatal pigs, necrotic foci in liver and spleen, lungs and tonsils are common. In carnivores, parts of the body and particularly the upper extremities are often characterized by widespread skin eruption due to automutilation.

## Histological lesions

Microscopic lesions reflect neuroinvasive and epitheliotropic properties of PrV. Evidence of non-specific histological lesions can be observed when brain tissues from diseased animals are examined microscopically: nonsuppurative meningoencephalomyelitis, ganglioneuritis of trigeminal and paravertebral ganglia, panencephalitis (piglets), encephalomyelitis with perivascular cuffing. In swine, other histological lesions may include epithelial lesions in parenchymatous organs; necrosis of bronchial, bronchiolar, and alveolar epithelium; multifocal to diffuse lymphohistiocytic endometritis and vaginitis; necrotic placentitis; degeneration of seminiferous tubules; necrotic foci in the tunica albuginea of testicles; spermatozoa abnormalities; necrosis in parenchymatous organs (aborted or stillborn piglets together). Additionally, presence of intranuclear eosinophilic inclusion bodies, which are more common in lesions outside the nervous system is considered characteristic for AD.

## Differential diagnosis

Swine: Rabies (lyssavirus), porcine polioencephalomyelitis (teschovirus infection), classical (CSF – pestivirus) and African swine fever (ASF – Asfarvirus), swine influenza, encephalomyocarditis (EMC), infections with highly virulent strains of porcine reproductive and respiratory syndrome virus (PRRSV) and porcine circovirus type 2 (PCV 2), Japanese encephalitis, hemagglutinating encephalomyelitis, bacterial meningoencephalitis including *Streptococcus suis* infection, salt poisoning, hypoglycemia, organic arsenic or mercury poisoning, congenital tremor, other diseases causing abortion.

Other mammals: Rabies, scrapie (sheep), bovine spongiform encephalopathy (BSE) and diseases or conditions causing CNS symptoms e.g. persistent itching need to be excluded.

## Criteria for diagnosis

Detection of viral antigens directly in infected organ tissue, or isolation of virus, detection of viral DNA (PCR, etc.), detection of gE (field strains specific) antibodies (latent infection)

## Recommended diagnostic method(s) and preferred samples (incl. recommended amount and appropriate storage)

Post mortem diagnosis should be performed on fresh organ tissues, preferably from brain, nervous ganglia (trigeminal/sacral), tonsils, lungs, fetuses and/or placenta. Viral antigen can be detected using immunoperoxidase and/or immunofluorescence staining with polyclonal or monoclonal antibodies on cryosections of tissues. Diagnosis is confirmed by virus isolation in cell cultures. PCR (conventional, real-time) is the method of choice for detection of viral DNA. Indirect or competitive ELISAs, seroneutralisation (SNT), latex agglutination tests (LAT) and immunoblotting detect PrV specific antibodies. Rabies diagnostics should be performed in parallel for suspect specimens.

Shipment and sample storage: Specimens for diagnosis should be shipped refrigerated or frozen, (temperature: +4 °C or –20 °C) according to the national and international regulations for shipment of infectious substances to avoid exposure. For long-distance shipment of isolates or tissues, proper packing and freezing on dry ice or in liquid nitrogen is recommended. Upon arrival in the laboratory, specimens preferably should be stored refrigerated or frozen (-20°C) for a short period before testing.

## APHAEA protocol (for harmonization at large scale)

ELISA (i.e. the most reliable, specific, sensitive, cheap and quick method to estimate the status of PrV infections in wild/feral swine populations, and applicable to poor quality and haemolysed sera).

## Laboratories that can be contacted for diagnostic support

Institute of Molecular Biology, Friedrich-Loeffler Institute, Südufer 10, 17493 Greifswald - Insel Riems, Germany (http://www.fli.bund.de )

ANSES – OIE Reference Laboratory for Aujeszky's Disease Laboratoire de Ploufragan- Plouzané, Unité de Virologie et Immunologie Porcines BP 53 « Les Croix » 22440 PLOUFRAGAN (uvip@anses.fr)

## Recommended literature

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# Eurasian wild boar, *Sus scrofa*

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**Last update**

26.11.2015

**Brief description of the species/group of species: basic ecology and its relevance from an epidemiological perspective**

The wild boar (*Sus scrofa*) is a widespread native Palaearctic ungulate whose population has sharply increased in the last decades. It is one of the terrestrial mammals with the widest geographical range in Europe (Apollonio et al. 2010). Both through natural expansion and human (re)introductions, the species now occurs in all continents except Antarctica, and on many oceanic islands (Mitchell-Jones et al. 1999; Oliver & Leus 2008).

It occupies a wide variety of habitats, from semi-desert to tropical rain forests or temperate woodlands (e.g. Oliver & Leus 2008), and often uses agricultural land to forage (e.g. Herrero et al. 2006). Its ecological plasticity and growing population trends generate human-ungulate conflicts (Putman et al. 2011), as wild boar may cause significant damage to crops and natural vegetation (e.g. Schley et al. 2008; Bueno et al. 2009), biodiversity (Carpio et al. 2014), road traffic (e.g. Lagos et al. 2012) and livestock and public health (e.g. Gortázar et al. 2007).

This card refers specifically to Eurasian wild boar and not feral domestic swine, but the methods would apply equally to feral pigs. From an epidemiological perspective, wild boar (and feral pigs) are reservoirs for many viral, bacterial and parasitic infections (e.g. Ruiz-Fons et al. 2008).

**Recommended method(s) for most accurate population estimation**

The estimation of wild boar population density is a difficult task. Traditional methods are neither precise nor accurate enough as for being considered as a gold standard. Methods based on direct observation are limited due to the nocturnal habits of the species. Thus, in this section we are highlighting methods that are not yet well assessed but that, according to the pioneer experiences on this species and their success in monitoring other ungulates, are considered as the most promising tools for wild boar monitoring. One of these methods is the nocturnal line transect using thermal imaging (Franzetti et al. 2012; but see Gill & Brandt 2010). This is a highly demanding method in terms of effort and budget and thus, currently, it is scarcely applied outside the research (for details see Franzetti et al. 2012). Another potentially relevant method is the use of camera trapping to estimate population density without the need for individual recognition (for details see Rowcliffe et al. 2008; Rovero & Marshall 2009).

**Mini-review of methods applied in Europe**

General reviews

A review was recently published on methods to monitor wild boar (and feral pig) populations (Engeman et al. 2013). Comparisons of several methods have taken place mostly in Central Europe and the Iberian Peninsula (Acevedo et al. 2007; Briederman 2009; Plhal et al. 2011). Most were based on indirect methods, but some focused on the application of direct methods to estimate wild boar population density (e.g. Focardi et al. 2002; Franzetti et al. 2012).

Direct methods (i.e. based on the direct observation of animals)

- *Line transects*: In woodlands, line transect methods are not easily applied and they are usually applied if animals are attracted to open space, for example to feeders. The absence of a reflecting tapetum lucidum makes spotlight counts more difficult as compared to cervids. Nevertheless, in Italy

Franzetti et al. (2012) successfully solved this problem by using infrared cameras. Even if the method works well in Italy, it was suggested that using infrared technologies wild boar detection decreases as distance to observer increases (Gill & Brandt 2010), and thus more efforts are needed for a broader use of this method. The price of new-generation infrared cameras is now more attainable which can increase the cost-effectiveness and applicability of this method once it is fine-tuned.

- *Camera trapping*: Indirect observation of animals with camera traps was recently identified as a promising method to estimate an index of abundance (Rovero & Marshall 2009) and population density, even without the need of individual identification (Rowcliffe et al. 2008). This makes it different from traditional capture-recapture methodologies (Hebeisen et al. 2008). First experiences are available (Plhal et al. 2011), but the procedure needs refinement. Recently, using distance sampling, promising results were obtained applying camera trapping to estimate population density without the need for individual recognition (Gómez-Alfaro et al. in prep.). Further studies are required to define an adequate camera-trapping protocol to monitor wild boar populations, for which a precise data on wild boar movement parameters in a range of different situations in the European context need to be gathered.

- *Drive counts*: Drive counts (e.g. Borkowski et al. 2011) are frequently used to estimate population densities in ungulates inhabiting forested areas. Hunters can be used as experienced observers and therefore the hunting activity, if carried out by instructed and motivated personel, can be a cost-effective alternative to monitor ungulates (e.g. Mysterud et al. 2007). For instance, drive counts by hunters is a method currently used to monitor wild boar population in Atlantic Spain and the Czech Republic (Plhal et al. 2010; Segura et al. 2014).

<u>Indirect methods (i.e. based on the detection of presence signs, but not animals)</u>

- *Pellet counts*: Pellet counts are frequently used to monitor wildlife species. There are lots of methods based on counting the number of pellets or their frequency, along transects or in plots. Some of them are used for wild boar (e.g. Massei et al. 1998). One method successfully evaluated for wild boar is the frequency of feces found on linear transects (Vicente et al. 2004; Acevedo et al. 2007). A proxy of the population aggregation can also be estimated from this method by statistically analyzing the dispersion of feces along the transects (Acevedo et al. 2007). Population abundance and aggregation are two key parameters for epidemiology. Therefore, this method is widely applied in epidemiological studies. Nonetheless, variations of dung persistence rate, which can be very local, need to be assessed in order to make results comparable and to be converted into estimates of wild boar population density.

Pellets can be collected and genetically analyzed for individual genotyping, providing an indirect way to count and indentify individuals in a given population (Broquet et al. 2007). Ebert et al. (2012) developed a first experience with wild boar under a mark-recapture framework. Although costs for DNA analyses have been decreasing in the last years, analyses of multiple samples (as requested to apply mark-recapture approaches) are time-consuming and expensive and therefore this method is scarcely used for wild boar management.

- *Snow tracking*: Transects on snow covered ground have been used to evaluate population abundance and density (e.g. Plhal et al. 2011; Bobek et al. 2014) and could be used, using footprint dimension, also to estimate population structure (Briederman 2009).

<u>Hunting bags (i.e. indices based on data derived from hunting activities)</u>

In hunted populations, bag data analysis (number, sex and age) remains a valid and suitable method to evaluate abundance and also population dynamics and structure. Wild boar age can be calculated based on tooth eruption, and records of reproductive parameters (e.g. number of foetuses) are valuable proxies of population dynamics (e.g. Gethöffer et al. 2007); both parameters can be easily recorded from hunted animals.

On broader scales, hunting statistics can provide time trends on population abundance, but generally no data on actual density. The problems with hunting bags include bias due to (1) different hunting traditions and hunting methods; (2) changes in hunting effort, quotas and hunter saturation; and (3) variability due to non-hunted populations in urban and protected areas. To overcome these barriers, hunting effort should be maintained/standardized and properly defined. In Italy hunting statistics were widely explored by Boitani et al. (1995) and subsequently used to investigate long time-trend series of wild boar (Imperio et al. 2010). In the Iberian Peninsula hunting bag data of wild boar were correlated with indirect methods for a broad range of densities (Acevedo et al. 2007).

<u>Others (i.e. include other relevant methods – direct or indirect – applied or susceptible to be applied on the target species)</u>

Statistical modelling is another way to estimate wild boar population abundance. Modelling allows relating data on the species (presence/absence, abundance, fitness, etc.) with environmental variables in order to obtain an output that is related with the habitat suitability for the species (e.g. Honda &

Kawauchi 2011). Model predictions should be validated with independent data since there are several factors modulating that relation. In the context of epidemiological studies, the distribution of wild boar abundance in Spain was recently obtained using spatially explicit modelling procedures and hunting bag data (Bosch et al. 2012; Acevedo et al. 2014). Future attempts might explore combining modelling with alternative source data, such as camera trapping.

Determining the effective population size by genetics is possible if appropriate sampling and corrections based on population dynamics parameters are applied, nonetheless this approach is time demanding and relatively expensive (Luickart et al. 2010).

**APHAEA protocol** (for harmonization at large scale)

At large scales, i.e. regions or countries, hunting bag data are currently the only Europe-wide available index of relative wild boar abundance. Such data can be of use for time trend analyses (provided hunting effort is constant). However, hunting methods and available information are too variable and do not allow comparisons among countries. Good documentation to characterize the hunting effort should be available in order to improve data harmonization. At least, in addition to the number of hunted animals basic information should include: hunting days, total number of hunters and hunting modality.

Given the known limitations of hunting bag data, APHAEA therefore recommends using at local scale density estimations, based on scientifically robust and repeatable techniques such as thermal imaging and distance sampling, camera-trapping or drive counts, among others.

Although it is difficult to generalize for a broad range of settings, densities below 1 individual per square km will represent low densities in a European context; those between 1 and 5 wild boar per square km will represent medium densities; and those above this limit will represent high densities. This division, although arbitrary, has important implications for epidemiology and disease control.

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## Tables

See next page.

**Table 1.** Peculiarities of the species that modulate the methods to be used.

| **Characteristic** | **Observations** |
|---|---|
| Distribution | This species has one of the widest geographic distributions of all terrestrial mammals. Wide distribution in Europe, present in all countries except Cyprus, Iceland and Malta (Mitchell-Jones et al. 1999; Oliver & Leus 2008). |
| Population trends | Generally increasing throughout Europe (e.g. Saéz-Royuella & Tellería 1986; Apollonio et al. 2010; Keuling et al. 2013). |
| Density range | From 1 to over 20, exceptionally up to 90 per km2 (e.g. Melis et al. 2006; Acevedo et al. 2007; Plhal et al. 2011). Densities from 1 to 10 per km2 are usual in natural environment; densities of over 10 occur locally in feed-supplemented hunting estates or exceptionally favourable availability of natural or cultivated food. |
| Main habitat | From semi-desert to tropical rain forests or temperate woodlands (e.g. Oliver & Leus 2008). |
| Introduction-Releases | Translocations of wild boar are frequent in some countries – not in all regions is allowed – due to hunting interests. This includes trans-frontier movements of both farm reared and wild captured individuals (e.g. Fernandez-de-Mera et al 2003). |
| Activity rhythms | In general nocturnal with seasonal variation mainly in extreme environments. |
| Detectability | Low due to the harsh environment, nocturnal activity and lack of a reflectant tapetum lucidum. |
| Gregarism | Spatio-temporal segregation between sexes excepting piglets and the rutting season. They usually live in familiar group composed by a female and her progeny of the last 2-3 years with their offspring whilst males are solitary (e.g. Fernandez-Llario et al. 1996). |

**Table 2**. Classification of the different methods (all cited in this species' review, incl. the recommended method(s) for most accurate results) based on desirable characteristics for monitoring populations from an epidemiological perspective (1- very low, 5-very high).

| Method | Line transects (IR cameras) | Camera trapping (capture_ recapture) | Random encounter model (camera trapping) | Capture-Recapture | Kilometric abundanc e index | Hunting bags |
|---|---|---|---|---|---|---|
| **A**bundance / **D**ensity | D | A/D | A | D | A | A |
| **T**emporal / **S**patial trends | T/S | T/S | T/S | T/S | T | T/S |
| Info on population structure (Y/N) | y | Y | Y | y | y | n |
| Precision | 5 | 5 | 5 | 5 | 2 | 4 |
| Seasonal independence | 2 | 5 | 1 | 4 | 2 | 2 |
| Visibility independence | 4 | 4 | 4 | 4 | 2 | 5 |
| Effort effectiveness | 1 | 4 | 4 | 2 | 2 | 5 |
| Budget effectiveness | 2 | 3 | 3 | 1 | 4 | 4 |
| Ease of learning | 2 | 4 | 2 | 1 | 5 | 5 |
| Applicable at large scales | 1 | 2 | 4 | 1 | 3 | 4 |
| Useful at very low density | 2 | 2 | 4 | 2 | 4 | 1 |
| Useful at very high density | 5 | 5 | 5 | 5 | 4 | 5 |

# APPENDIX B

*Disease information sheet*

# Merkblatt AUJESZKY'SCHE KRANKHEIT

R. K. Meier und M.-P. Ryser-Degiorgis

*Die Aujeszky'sche Krankheit – auch Pseudowut oder auf Englisch Aujeszky's Disease (AD) genannt - ist eine virale Erkrankung, die vor allem Schweine, aber auch die meisten anderen Säugetiere (ausser den Menschen) befallen kann. AD führt weltweit zu massiven ökonomischen Einbussen in der Hausschweine-industrie. Es ist eine auszurottende Tierseuche.*

**Erreger**
Der Erreger der Krankheit ist das Schweine-Herpesvirus 1 (SuHV-1), oft auch als Aujeszky's disease virus (AD-Virus) bezeichnet. Dieses Virus gehört zu den Alphaherpesviren und hat - wie auch andere Herpesviren - die Fähigkeit, sich ins Nervensystem zurückzuziehen und zu einer sogenannten latenten Infektion zu führen. In einer Stresssituation kann das Virus reaktiviert werden und es kommt zu klinischen Symptomen.

**Übertragung**
Die Erregerverbreitung zwischen Schweinen erfolgt oronasal bei direktem Kontakt, durch perforierende Bissverletzungen, beim Deckakt oder indirekt durch kontaminierte Geräte oder Futter. Andere Säugetiere werden durch direkten oder indirekten Kontakt mit Virus-ausscheidenden Schweinen angesteckt oder sie nehmen das Virus durch die Aufnahme von Virus-haltigem Fleisch auf.

**Symptome**
Beim Hausschwein sind die klinischen Symptome abhängig vom Alter des Tieres. Bei Ferkeln kommt es zu einer hohen Sterblichkeit infolge zentralnervöser Störungen und zu Erbrechen. Bei Aufzuchtferkeln stehen Symptome des Atmungsapparates im Vordergrund und bei adulten Muttersauen führt die Krankheit zu Fehlgeburten, Aborten, Mumienbildung und missgebildeten Ferkeln. Dazu gibt es Tiere, die den Virus in sich tragen und ausscheiden aber nicht daran erkranken (latente Infektion).
Wildschweine sind zwar empfänglich für das Virus, zeigen aber normalerweise keine Symptome. Zwei Fälle von Wildschweinen mit neurologischen Symptomen wie mangelnde Scheu, Orientierungslosigkeit und Kopfzittern wurden allerdings in Deutschland beschrieben.
Bei allen übrigen empfänglichen Säugetieren führt eine Infektion mit dem Virus innert wenigen Tagen zu einer Entzündung des Gehirns und zum Tod des Tieres. Im Krankheitsverlauf kann es zu neurologischen Störungen, Speicheln und zu starkem Juckreiz kommen. Diese Symptome sind ähnlich wie bei der Tollwut, weshalb die Aujeszky'sche Krankheit auch Pseudowut genannt wird.

**Epidemiologie**
Schweine sind die Hauptwirte des AD-Virus und fungieren als Virusreservoir. Andere Säugetiere, die mit dem Virus infiziert werden können, sterben innert kurzer Zeit und gelten daher als sogenannte Fehlwirte.
In vielen europäischen Ländern wurden in den letzten Jahren Ausrottungsprogramme durchgeführt. Unsere Nachbarländer Österreich, Deutschland und das Fürstentum Lichtenstein gelten als frei, in Italien und Frankreich gelten Landesteile als frei. Während sich die Situation bei den Hausschweinen verbessert hat, hat sich in gewissen Gebieten Europas die Lage bei den Wildschweinen ins Negative verändert. In den meisten umliegenden Ländern konnte in den letzten Jahren eine massive Zunahme der Verbreitung des AD-Virus festgestellt werden. In Deutschland hatten bis zu 18% der getesteten Wildschweine Antikörper gegen das Virus, in Italien bis zu 31% und in Niederösterreich gar bis zu 60% der Tiere. Zudem gab es mehrere Berichte von Jagdhunden aus Österreich, Deutschland und Frankreich, die nach Kontakt mit Wildschweinen an der Aujeszky'schen Krankheit gestorben waren.
Eine genauere Betrachtung der Situation hat allerdings ergeben, dass es keine generelle Zunahme der Infektionen mit dem AD-Virus beim Wildschwein gegeben hat, sondern die Häufigkeit der Infektion variiert stark von Gebiet zu Gebiet. Hohe Zahlen werden in Zusammenhang mit dem starken Anstieg der Wildschweinpopulation gestellt und eine mögliche Rolle der Wildschweine als Virus-reservoir wird diskutiert. Jedoch wird auch vermutet, dass Stress-erzeugendes Wildschweinmanagement zur Aktivierung und Übertragung des Virus beitragen könnte.

**Gefahr für den Menschen**

Das AD-Virus stellt keine Gefahr für die menschliche Gesundheit dar.

**Situation in der Schweiz**

Die Hausschweinpopulation in der Schweiz ist seit 1993 offiziell frei von dieser Krankheit.
Ersten Untersuchungen zur Verbreitung des AD-Virus in der Schweiz stammen aus den Jahren 2004-2005. Damals wurden im Blut von 2.8% der 1060 beprobten Wildschweine Antikörper gegen das AD-Virus gefunden. Erneute Untersuchungen mit Proben aus den Jahren 2008-2014 haben dokumentiert, dass die Häufigkeit der Infektion bei Wildschweinen mit 0.6% signifikant gesunken ist.
Auch im Ausland in der Nähe der Schweizer Grenze sind die dokumentierten Zahlen beruhigend.


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## APPENDIX C

*Instructions and field protocol for sera samples in German*

**Zentrum für Fisch- und Wildtiermedizin**

**Abteilung Wildtiere**

Institut für Tierpathologie, Universität Bern, Länggass-Strasse 122, Postfach 8466,
CH-3001 Bern, Tel. 031 631 24 43 oder 031 631 24 00, Fax 031 631 26 11

# Anleitung zur Probenentnahme
## Projekt Aujeszky'sche Krankheit (AD)

1. ***HYGIENE*:** Handschuhe anziehen!

2. ***BLUT***

Bitte beide Röhrchen (1 weisses und ein rotes) zu 3/4 mit Blut füllen.

Am einfachsten gelingt dies mit der beigelegten Spritze direkt beim Aufbrechen.

Nach dem Füllen die Röhrchen 5 mal kippen (nicht schütteln).

Bitte versuchen Sie möglichst unverschmutztes Blut zu sammeln (zB sollte bei einem Schuss in die Gedärme eher Blut aus dem Brustkasten entnommen werden).

3. ***PROTOKOLL:***

Bitte die Rückseite dieser Anleitung möglichst vollständig ausfüllen.

4. ***EINSENDEN:***

Die Blutröhrchen in die Kunststoffhülle legen und zusammen mit dem Protokoll in das wattierte Couvert stecken, zukleben und in den nächsten Briefkasten werfen. (Das Couvert ist frankiert und adressiert).

Vielen herzlichen Dank für Ihre Mitarbeit!!!
Sie leisten damit einen wesentlichen Beitrag zur Erforschung des Gesundheitszustandes unseres Schwarzwildes.
Guten Anblick und Weidmannsheil!

**Zentrum für Fisch- und Wildtiermedizin**
**Abteilung Wildtiere**
Institut für Tierpathologie, Universität Bern, Länggass-Strasse 122, Postfach 8466, CH-3001 Bern, Tel. 031 631 24 43, Fax 031 631 26 11

# Wildschwein AD-Projekt

*1. Probennummer:*

*2. Proben (zutreffendes ankreuzen):*

O Blut (Serum und EDTA)
O Anderes: ..............................................................

*3. Informationen zum Wildschein der eingesandten Proben:*

**Geschlecht:** O Weibchen O Männchen

**Alter** (siehe Kasten unten): O Frischling (gestreift)
O Juvenil/rothaariger Frischling
O Subadult/Überläufer
O Adult
O Unbestimmt

**Gewicht (kg):** ganz:............. ausgeweidet:............

**Nährzustand:** O gut / sehr gut O mässig O abgemagert

*4. Fund/Erlegungsdatum:* ...................................

*5. Todesursache:* O Jagd O Hegeabschuss O Tot aufgefunden
O Erlegt wegen Krankheitssymptomen
O Erlegt in Hausschweinbetrieb
O Anderes: ..................................................

*6. Fund/Erlegungsort:*

Lokalname: ...............................................
Gemeinde: ...............................................
Kanton: ..............................
Koordinaten: ............................/.............................

O Es gibt in der Nähe einen Hausschweinbetrieb mit Freilauf: ........................ Meter

*7. Besonderheiten/Kommentare:*

*8. Probenentnahme durch:*

Name, Vorname: ..............................................................
Adresse: ..............................................................
Telefon: ..............................................................

## Vielen Dank für Ihre wertvolle Hilfe

**ALTERSKLASSEN beim Wildschwein :**

| Bezeichnung | Fellfarbe | Gewicht | Alter in Monaten |
|---|---|---|---|
| Frischling (gestreift) | gestreift | < 20 kg | bis ca. 6 |
| Juvenil (rothaariger Frischling) | rot | 20-40 kg | 6-12 |
| Subadult / Überläufer | dunkelbraun-schwarz | 40-60 kg | 12-24 |
| Adult | schwarz oder silbern | > 60 kg | > 24 |

## APPENDIX D

*Field protocols for nocturnal thermal imaging and feaces counts on linear transects*

# Protocol wild boar night vision counting

Number:

Location: Canton: Date:

Writer: Observer: Weather:

| Nr. | x | y | species | number | adult =n | young =n | moving yes/no | habitat | comment: |
|---|---|---|---|---|---|---|---|---|---|
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**Nr.** = Nummer der Beobachtung/nombre d'observation; **X** = x-Koordinate/ coordonnée x; **Y** = y-Koordinate/ coordonnée y; **species** = Tierart/espèce; **number** = Anzahl Tiere/nombre d'animaux; **adult** = Anzahl adulte Tiere/nombre d'animaux adultes; **young** = Anzahl Jungtiere/ nombre de juveniles; **moving** = Tiere in Bewegung (ja/nein)/ animaux en mouvement (oui/non); **habitat** : Habitattyp (Weide/Wald)/type d' habitate (prairie/forêt), **comment** = Kommentar/ commentaire

Centre for Fish and Wildlife Health
FIWI
University of Bern

# Protocol ‚Linear transect'

Date:

Town:

Location:

Habitat:

Location:

Habitat:

Location:

Habitat:

Location:

Habitat:

Location:

Habitat:

Location:

Habitat:

Location:

Habitat:

Location:

Habitat:

Habitat: 1: dichter Wald, 2: offener Wald, 3: Unterholz, 4:Weide, 5: Landwirtschaftsfläche, 6: Geröll

## APPENDIX E

*Completed questionnaires on Aujeszky's disease virus and abundance of wild boar for five study units in Switzerland*

Questionnaires established and distributed by the Friedrich-Löffler-Institute, Insel Riems, Germany in the framework of the APHAEA work package 3 subobjective 1: wild boar and Aujeszky's disease virus.

# Wild boar & Aujeszky's disease virus
# Questionnaire on population data and samples

## Guidelines for data usage

This questionnaire is designed to collect information regarding historical records, data currently available or potentially accessible in the future. After potential co-operation partners have been identified on basis of the answers in the questionnaire, we will provide further information, protocols and Excel-sheets to facilitate data exchange.

Any data you provide to the APHAEA project will be treated as strictly confidential and will only be used within the framework of the project for the selection of feasible studies for the evaluation of harmonized sampling protocols. It is planned to publish the harmonization efforts, strengths and maybe occurred problems of the protocols based on the evaluation of the provided data. The manuscript will be send to the data providers prior to publication and your co-authorship will be recognized. In any case, it is planned to share the results of the questionnaire evaluation in an aggregated, anonymous form among the participants of the survey.

If there are any questions, please do not hesitate to contact us for further information via feedback@aphaea.eu.

## Content

## Personal information

**1.1** Country: Switzerland

**1.2** Full name: Ryser, Marie-Pierre; Meier, Roman

**1.3** Organization: Centre for Fisch- and Wildlife health,

**1.4** Email: marie-pierre.ryser@vetsuisse.unibe.

**1.5** If it is not yet the case, would you be willing to have your name / organization listed in the external partners' list on the APHAEA website (www.aphaea.org)?

Name: ◯ yes ◯ no

Organization: ◯ yes ◯ no

## Wild boar & Aujeszky's disease virus

## Population related questions

**2.1** Please describe **the region considered for the study.** If there is more than one region considered, please fill the questionnaire several times.

Name of region: Geneva

Size (in sqkm): 282 km2

Comment:

**2.2 Which data sources exist in your country** providing information on the wild boar density (multiple choices are possible)**?**

- [x] Official hunting statistics (collected through official sources)
- [ ] Hunting association data (collected through private associations)
- [x] Research data (…s) capture-mark-re-capture, phototraps
- [ ] Other:

**2.3** What kind of **hunting strategy / scheme** is performed in the considered region? Please fill in text for explanation.

- [ ] Year-round ( e.g. constant, seasonal peaks )
- [ ] Hunting season (from month to month )
- [x] Other: Only decimation of the population

**2.4 Is the wild boar density information marked in 2.2** available **for the region considered in 2.1** for at least 5 years **(2012 and previous years)?**

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Yes | (•) | ( ) | (•) | ( ) |
| No | ( ) | (•) | ( ) | ( ) |

**2.5** On which **regional scale** is the wild boar density information available for the region considered in 2.1 (please see table 1 in the Appendix section for more details)?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| NUTS 1 | ☐ | ☐ | ☐ | ☐ |
| NUTS 2 | ☐ | ☐ | ☐ | ☐ |
| NUTS 3 | ☐ | ☐ | ☐ | ☐ |
| LAU 1 | ☐ | ☐ | ☐ | ☐ |
| LAU 2 | ✓ | ☐ | ✓ | ☐ |
| Other: e.g. hunting grounds, GPS | ☐ | ☐ | ☐ | ☐ |

**2.6** On which **time scale** is the wild boar density information available for the region considered in 2.1?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Month | ✓ | ☐ | ✓ | ☐ |
| Quarter | ☐ | ☐ | ☐ | ☐ |
| Year | ☐ | ☐ | ☐ | ☐ |
| Other: | ☐ | ☐ | ☐ | ☐ |

**2.7** Which **additional information** is collected in the wild boar density information?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Age class (see Appendix) | ✓ | ☐ | ✓ | ☐ |
| Weight | ✓ | ☐ | ✓ | ☐ |
| Sex | ✓ | ☐ | ✓ | ☐ |
| Type of carcass (see Appendix) | ✓ | ☐ | ✓ | ☐ |
| Other: | ☐ | ☐ | ☐ | ☐ |

**2.8** Are your hunting statistics of wild boar recorded in the EU Reference Laboratory **„Classical swine fever in wild boar surveillance database"** (http://public.csf-wildboar.eu)?

○ yes ● no

Would it be possible to get the **permission to use data** of the hunting bag from this database?

● yes ○ no

## Disease related questions

All questions refer to **Aujeszky's disease in wild boar** and the region mentioned in 2.1. If there are disease related data only for a sub region of the considered area, please specify the size of the sub region in sqkm:

**2.9** Did or does **Aujeszky's disease in wild boar** occur within the region considered above?

● Endemic infection ○ Epidemic infection ○ Freedom from disease

☐ Historical data available ☐ Ongoing actual data ☐ No investigations / studies conducted in the area

What is the source of your information? research data

**2.10** Could data from former, ongoing or future **investigations about Aujeszky's disease virus in wild boar** from the region (or a sub region) mentioned in 2.1 be available for the APHAEA project?

| | | | | |
|---|---|---|---|---|
| Ongoing | (●) yes | ( ) no | from 2008 | to 2014 |
| Finished | (●) yes | ( ) no | from 2001 | to 2005 |
| Permanent | ( ) yes | ( ) no | since | |
| Planned | ( ) yes | ( ) no | from | to |

**2.11** Please fill in the **number of collected samples** that could be used within the APHAEA project referring to the investigations mentioned in 2.10.

| | Ongoing | Finished | Permanent | Planned |
|---|---|---|---|---|
| Sample size for serological investigations | 275 | -- | | |
| Sample size for PCR | 0 | -- | | |

**2.12** If there are planned investigations of Aujeszky's disease virus, **would you be able to investigate samples** at your laboratory?

✓ **Serologically** ☐ **Virologically** by e.g. PCR or virus isolation

**2.13** If there are historical, ongoing, permanent or planned wild boar sample collections in your country but you do not have the possibility to test the samples for Aujeszky's disease virus, would it be possible **to send sera and/or tissue samples to another laboratory**?

Sera samples: (●) yes ( ) no
Tissue samples: ( ) yes ( ) no

**2.14** Would you have the possibility to **provide historical laboratory test results** of a former investigation regarding Aujeszky's disease virus in wild boar from the considered region?

(●) yes ( ) no

**2.15** If there are samples (ongoing, historical or planned for future), which **information** is / will be available?

| | Ongoing | Historical | Planned |
|---|---|---|---|
| Age class | ✓ | | |
| Sex | ✓ | ✓ | |
| Date | ✓ | | |
| Location<br>on which regional scale (see 2.5 and Appendix) | ✓ | | |
| Carcass (see Appendix) | ✓ | | |
| Results of **serological investigations** (if performed) | ✓ | | |
| Results of **virological investigations** (if performed) | | | |
| Other: | | | |

## General questions

**2.16** Please list any **publications concerning wild boar population data and Aujeszky's disease** within the considered region and time.

Köppel C., L. Knopf, M.-P. Ryser, R. Miserez, B. Thür, K. D. C. Stärk. Serosurveillance for selected infectious disease agents in wild boars (Sus scrofa) and outdoor pigs in Switzerland. European Journal of Wildlife Research, August 2007, p. 212-220
Leuenberger R., P. Boujon. B. Thür, R. Miserez, B. Garin-Bastuji, J. Rüfenacht, K. D. C. Stärk. Prevalence of classical swine fever, Aujeszky's disease and brucellosis in a population of wild boar in Switzerland. Veterinary Record, 2007, p. 362-368

**2.17** Additional comments:

## Personal information

**1.1** Country: Switzerland
**1.2** Full name: Marie-Pierre Ryser, Roman Meier
**1.3** Organization: Centre for Fish- and Wildlife health,
**1.4** Email: marie-pierre.ryser@vetsuisse.unibe.
**1.5** If it is not yet the case, would you be willing to have your name / organization listed in the external partners' list on the APHAEA website (www.aphaea.org)?

Name: ◯ yes ◯ no
Organization: ◯ yes ◯ no

## Wild boar & Aujeszky's disease virus

## Population related questions

**2.1** Please describe **the region considered for the study.** If there is more than one region considered, please fill the questionnaire several times.

Name of region: Jura
Size (in sqkm): 4185.28
Comment: Contains the cantons SO, JU, BL,

**2.2 Which data sources exist in your country** providing information on the wild boar density (multiple choices are possible)**?**

- [x] Official hunting statistics (collected through official sources)
- [ ] Hunting association data (collected through private associations)
- [ ] Research data ( …s) e.g. capture-mark-re-capture, pellet
- [ ] Other:

**2.3** What kind of **hunting strategy / scheme** is performed in the considered region? Please fill in text for explanation.

- [ ] Year-round ( e.g. constant, seasonal peaks )
- [x] Hunting season (from july to februarry )
- [ ] Other: Depending on the region

**2.4 Is the wild boar density information marked in 2.2** available **for the region considered in 2.1** for at least 5 years **(2012 and previous years)?**

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Yes | (●) | ( ) | ( ) | ( ) |
| No | ( ) | ( ) | ( ) | ( ) |

**2.5** On which **regional scale** is the wild boar density information available for the region considered in 2.1 (please see table 1 in the Appendix section for more details)?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| NUTS 1 | ☐ | ☐ | ☐ | ☐ |
| NUTS 2 | ☐ | ☐ | ☐ | ☐ |
| NUTS 3 | ✓ | ☐ | ☐ | ☐ |
| LAU 1 | ☐ | ☐ | ☐ | ☐ |
| LAU 2 | ☐ | ☐ | ☐ | ☐ |
| Other: e.g. hunting grounds, GPS | ☐ | ☐ | ☐ | ☐ |

**2.6** On which **time scale** is the wild boar density information available for the region considered in 2.1?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Month | ☐ | ☐ | ☐ | ☐ |
| Quarter | ☐ | ☐ | ☐ | ☐ |
| Year | ✓ | ☐ | ☐ | ☐ |
| Other: | ☐ | ☐ | ☐ | ☐ |

**2.7** Which **additional information** is collected in the wild boar density information?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Age class (see Appendix) | ✓ | ☐ | ☐ | ☐ |
| Weight | ☐ | ☐ | ☐ | ☐ |
| Sex | ✓ | ☐ | ☐ | ☐ |
| Type of carcass (see Appendix) | ✓ | ☐ | ☐ | ☐ |
| Other: | ☐ | ☐ | ☐ | ☐ |

**2.8** Are your hunting statistics of wild boar recorded in the EU Reference Laboratory **„Classical swine fever in wild boar surveillance database“** (http://public.csf-wildboar.eu)?

○ yes ● no

Would it be possible to get the **permission to use data** of the hunting bag from this database?

○ yes ○ no

## Disease related questions

All questions refer to **Aujeszky's disease in wild boar** and the region mentioned in 2.1. If there are disease related data only for a sub region of the considered area, please specify the size of the sub region in sqkm:

**2.9** Did or does **Aujeszky's disease in wild boar** occur within the region considered above?

● Endemic infection ○ Epidemic infection ○ Freedom from disease

✓ Historical data available ✓ Ongoing actual data ☐ No investigations / studies conducted in the area

What is the source of your information? e.g. official hunting statistics, research data

**2.10** Could data from former, ongoing or future **investigations about Aujeszky's disease virus in wild boar** from the region (or a sub region) mentioned in 2.1 be available for the APHAEA project?

| | | | | | | |
|---|---|---|---|---|---|---|
| Ongoing | (●) yes | ( ) no | from | 2008 | to | 2014 |
| Finished | (●) yes | ( ) no | from | 2001 | to | 2005 |
| Permanent | ( ) yes | ( ) no | since | | | |
| Planned | ( ) yes | ( ) no | from | | to | |

**2.11** Please fill in the **number of collected samples** that could be used within the APHAEA project referring to the investigations mentioned in 2.10.

| | Ongoing | Finished | Permanent | Planned |
|---|---|---|---|---|
| Sample size for serological investigations | 190 | -- | | |
| Sample size for PCR | 0 | -- | | |

**2.12** If there are planned investigations of Aujeszky's disease virus, **would you be able to investigate samples** at your laboratory?

☑ **Serologically** ☐ **Virologically** by e.g. PCR or virus isolation

**2.13** If there are historical, ongoing, permanent or planned wild boar sample collections in your country but you do not have the possibility to test the samples for Aujeszky's disease virus, would it be possible **to send sera and/or tissue samples to another laboratory**?

Sera samples: (●) yes ( ) no

Tissue samples: ( ) yes (●) no

**2.14** Would you have the possibility to **provide historical laboratory test results** of a former investigation regarding Aujeszky's disease virus in wild boar from the considered region?

(●) yes ( ) no

**2.15** If there are samples (ongoing, historical or planned for future), which **information** is / will be available?

| | Ongoing | Historical | Planned |
|---|---|---|---|
| Age class | ✓ | ✓ | |
| Sex | ✓ | | |
| Date | ✓ | | |
| Location<br>on which regional scale (see 2.5 and Appendix) | ✓ | ✓ | |
| Carcass (see Appendix) | ✓ | | |
| Results of **serological investigations** (if performed) | ✓ | | |
| Results of **virological investigations** (if performed) | | | |
| Other: | | | |

## General questions

**2.16** Please list any **publications concerning wild boar population data and Aujeszky's disease** within the considered region and time.

Köppel C., L. Knopf, M.-P. Ryser, R. Miserez, B. Thür, K. D. C. Stärk. Serosurveillance for selected infectious disease agents in wild boars (Sus scrofa) and outdoor pigs in Switzerland. European Journal of Wildlife Research, August 2007, p. 212-220
Leuenberger R., P. Boujon. B. Thür, R. Miserez, B. Garin-Bastuji, J. Rüfenacht, K. D. C. Stärk. Prevalence of classical swine fever, Aujeszky's disease and brucellosis in a population of wild boar in Switzerland. Veterinary Record, 2007, p. 362-368

**2.17** Additional comments:

## Personal information

**1.1** Country: Switzerland

**1.2** Full name: Marie-Pierre Ryser, Roman Meier

**1.3** Organization: Centre for Fish- and Wildlife health,

**1.4** Email: marie-pierre.ryser@vetsuisse.unibe.

**1.5** If it is not yet the case, would you be willing to have your name / organization listed in the external partners' list on the APHAEA website (www.aphaea.org)?

Name: ○ yes ○ no

Organization: ○ yes ○ no

## Wild boar & Aujeszky's disease virus

### Population related questions

**2.1** Please describe **the region considered for the study.** If there is more than one region considered, please fill the questionnaire several times.

Name of region: Northwestern-midlands

Size (in sqkm): 3373.14

Comment: Contains the canton FR and parts

**2.2 Which data sources exist in your country** providing information on the wild boar density (multiple choices are possible)**?**

- [x] Official hunting statistics (collected through official sources)
- [ ] Hunting association data (collected through private associations)
- [ ] Research dat[…]s) e.g. capture-mark-re-capture, pellet
- [ ] Other:

**2.3** What kind of **hunting strategy / scheme** is performed in the considered region? Please fill in text for explanation.

- [ ] Year-round ( e.g. constant, seasonal peaks )
- [x] Hunting season (from August to January )
- [ ] Other:

**2.4 Is the wild boar density information marked in 2.2** available **for the region considered in 2.1** for at least 5 years **(2012 and previous years)?**

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Yes | (●) | ( ) | ( ) | ( ) |
| No | ( ) | ( ) | ( ) | ( ) |

**2.5** On which **regional scale** is the wild boar density information available for the region considered in 2.1 (please see table 1 in the Appendix section for more details)?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| NUTS 1 | ☐ | ☐ | ☐ | ☐ |
| NUTS 2 | ☐ | ☐ | ☐ | ☐ |
| NUTS 3 | ✓ | ☐ | ☐ | ☐ |
| LAU 1 | ☐ | ☐ | ☐ | ☐ |
| LAU 2 | ☐ | ☐ | ☐ | ☐ |
| Other: e.g. hunting grounds, GPS | ☐ | ☐ | ☐ | ☐ |

**2.6** On which **time scale** is the wild boar density information available for the region considered in 2.1?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Month | ☐ | ☐ | ☐ | ☐ |
| Quarter | ☐ | ☐ | ☐ | ☐ |
| Year | ✓ | ☐ | ☐ | ☐ |
| Other: | ☐ | ☐ | ☐ | ☐ |

**2.7** Which **additional information** is collected in the wild boar density information?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Age class (see Appendix) | ✓ | ☐ | ☐ | ☐ |
| Weight | ☐ | ☐ | ☐ | ☐ |
| Sex | ✓ | ☐ | ☐ | ☐ |
| Type of carcass (see Appendix) | ✓ | ☐ | ☐ | ☐ |
| Other: | ☐ | ☐ | ☐ | ☐ |

**2.8** Are your hunting statistics of wild boar recorded in the EU Reference Laboratory **„Classical swine fever in wild boar surveillance database"** (http://public.csf-wildboar.eu)?

○ yes ● no

Would it be possible to get the **permission to use data** of the hunting bag from this database?

○ yes ○ no

## Disease related questions

All questions refer to **Aujeszky's disease in wild boar** and the region mentioned in 2.1. If there are disease related data only for a sub region of the considered area, please specify the size of the sub region in sqkm:

**2.9** Did or does **Aujeszky's disease in wild boar** occur within the region considered above?

● Endemic infection ○ Epidemic infection ○ Freedom from disease

☐ Historical data available ✓ Ongoing actual data ☐ No investigations / studies conducted in the area

What is the source of your information? e.g. official hunting statistics, research data

**2.10** Could data from former, ongoing or future **investigations about Aujeszky's disease virus in wild boar** from the region (or a sub region) mentioned in 2.1 be available for the APHAEA project?

| | yes | no | | | | |
|---|---|---|---|---|---|---|
| Ongoing | (•) yes | ( ) no | from | 2008 | to | 2014 |
| Finished | ( ) yes | (•) no | from | | to | |
| Permanent | ( ) yes | (•) no | since | | | |
| Planned | ( ) yes | (•) no | from | | to | |

**2.11** Please fill in the **number of collected samples** that could be used within the APHAEA project referring to the investigations mentioned in 2.10.

| | Ongoing | Finished | Permanent | Planned |
|---|---|---|---|---|
| Sample size for serological investigations | 110 | | | |
| Sample size for PCR | 0 | | | |

**2.12** If there are planned investigations of Aujeszky's disease virus, **would you be able to investigate samples** at your laboratory?

✓ **Serologically** ☐ **Virologically** by e.g. PCR or virus isolation

**2.13** If there are historical, ongoing, permanent or planned wild boar sample collections in your country but you do not have the possibility to test the samples for Aujeszky's disease virus, would it be possible **to send sera and/or tissue samples to another laboratory**?

Sera samples: (•) yes ( ) no

Tissue samples: ( ) yes (•) no

**2.14** Would you have the possibility to **provide historical laboratory test results** of a former investigation regarding Aujeszky's disease virus in wild boar from the considered region?

(•) yes ( ) no

**2.15** If there are samples (ongoing, historical or planned for future), which **information** is / will be available?

| | Ongoing | Historical | Planned |
|---|---|---|---|
| Age class | ✓ | | |
| Sex | ✓ | | |
| Date | ✓ | | |
| Location<br>on which regional scale (see 2.5 and Appendix) | ✓ | | |
| Carcass (see Appendix) | ✓ | | |
| Results of **serological investigations** (if performed) | ✓ | | |
| Results of **virological investigations** (if performed) | | | |
| Other: | | | |

## General questions

**2.16** Please list any **publications concerning wild boar population data and Aujeszky's disease** within the considered region and time.

**2.17** Additional comments:

## Personal information

**1.1** Country: Switzerland

**1.2** Full name: Marie-Pierre Ryser, Roman Meier

**1.3** Organization: Centre for Fish- and Wildlife health,

**1.4** Email: marie-pierre.ryser@vetsuisse.unibe.

**1.5** If it is not yet the case, would you be willing to have your name / organization listed in the external partners' list on the APHAEA website (www.aphaea.org)?

Name: ○ yes ○ no

Organization: ○ yes ○ no

## Wild boar & Aujeszky's disease virus

## Population related questions

**2.1** Please describe **the region considered for the study.** If there is more than one region considered, please fill the questionnaire several times.

Name of region: Thurgau

Size (in sqkm): 865.37

Comment: Canton Thurgovia

**2.2 Which data sources exist in your country** providing information on the wild boar density (multiple choices are possible)**?**

- [x] Official hunting statistics (collected through official sources)
- [ ] Hunting association data (collected through private associations)
- [ ] Research data (…s) e.g. capture-mark-re-capture, pellet
- [ ] Other:

**2.3** What kind of **hunting strategy / scheme** is performed in the considered region? Please fill in text for explanation.

- [x] Year-round ( seasonal peaks )
- [ ] Hunting season (from to )
- [ ] Other:

**2.4 Is the wild boar density information marked in 2.2** available **for the region considered in 2.1** for at least 5 years **(2012 and previous years)?**

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Yes | ● | ○ | ○ | ○ |
| No | ○ | ○ | ○ | ○ |

**2.5** On which **regional scale** is the wild boar density information available for the region considered in 2.1 (please see table 1 in the Appendix section for more details)?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| NUTS 1 | ☐ | ☐ | ☐ | ☐ |
| NUTS 2 | ☐ | ☐ | ☐ | ☐ |
| NUTS 3 | ✓ | ☐ | ☐ | ☐ |
| LAU 1 | ☐ | ☐ | ☐ | ☐ |
| LAU 2 | ☐ | ☐ | ☐ | ☐ |
| Other: e.g. hunting grounds, GPS | ☐ | ☐ | ☐ | ☐ |

**2.6** On which **time scale** is the wild boar density information available for the region considered in 2.1?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Month | ✓ | ☐ | ☐ | ☐ |
| Quarter | ☐ | ☐ | ☐ | ☐ |
| Year | ☐ | ☐ | ☐ | ☐ |
| Other: | ☐ | ☐ | ☐ | ☐ |

**2.7** Which **additional information** is collected in the wild boar density information?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Age class (see Appendix) | ✓ | | | |
| Weight | | | | |
| Sex | ✓ | | | |
| Type of carcass (see Appendix) | ✓ | | | |
| Other: | | | | |

**2.8** Are your hunting statistics of wild boar recorded in the EU Reference Laboratory **„Classical swine fever in wild boar surveillance database“** (http://public.csf-wildboar.eu)?

○ yes ● no

Would it be possible to get the **permission to use data** of the hunting bag from this database?

○ yes ○ no

## Disease related questions

All questions refer to **Aujeszky's disease in wild boar** and the region mentioned in 2.1. If there are disease related data only for a sub region of the considered area, please specify the size of the sub region in sqkm:

**2.9** Did or does **Aujeszky's disease in wild boar** occur within the region considered above?

● Endemic infection ○ Epidemic infection ○ Freedom from disease

☐ Historical data available ☑ Ongoing actual data ☐ No investigations / studies conducted in the area

What is the source of your information? e.g. official hunting statistics, research data

**2.10** Could data from former, ongoing or future **investigations about Aujeszky's disease virus in wild boar** from the region (or a sub region) mentioned in 2.1 be available for the APHAEA project?

| | yes | no | | | | |
|---|---|---|---|---|---|---|
| Ongoing | (●) yes | ( ) no | from | 2008 | to | 2014 |
| Finished | (●) yes | ( ) no | from | 2001 | to | 2005 |
| Permanent | ( ) yes | (●) no | since | | | |
| Planned | ( ) yes | (●) no | from | | to | |

**2.11** Please fill in the **number of collected samples** that could be used within the APHAEA project referring to the investigations mentioned in 2.10.

| | Ongoing | Finished | Permanent | Planned |
|---|---|---|---|---|
| Sample size for serological investigations | 107 | -- | | |
| Sample size for PCR | 0 | -- | | |

**2.12** If there are planned investigations of Aujeszky's disease virus, **would you be able to investigate samples** at your laboratory?

☑ **Serologically** ☐ **Virologically** by e.g. PCR or virus isolation

**2.13** If there are historical, ongoing, permanent or planned wild boar sample collections in your country but you do not have the possibility to test the samples for Aujeszky's disease virus, would it be possible **to send sera and/or tissue samples to another laboratory**?

Sera samples: (●) yes ( ) no

Tissue samples: ( ) yes (●) no

**2.14** Would you have the possibility to **provide historical laboratory test results** of a former investigation regarding Aujeszky's disease virus in wild boar from the considered region?

(●) yes ( ) no

**2.15** If there are samples (ongoing, historical or planned for future), which **information** is / will be available?

| | Ongoing | Historical | Planned |
|---|---|---|---|
| Age class | ✓ | | |
| Sex | ✓ | | |
| Date | ✓ | | |
| Location<br>on which regional scale (see 2.5 and Appendix) | ✓ | | |
| Carcass (see Appendix) | ✓ | | |
| Results of **serological investigations** (if performed) | ✓ | | |
| Results of **virological investigations** (if performed) | | | |
| Other: | | | |

## General questions

**2.16** Please list any **publications concerning wild boar population data and Aujeszky's disease** within the considered region and time.

Köppel C., L. Knopf, M.-P. Ryser, R. Miserez, B. Thür, K. D. C. Stärk. Serosurveillance for selected infectious disease agents in wild boars (Sus scrofa) and outdoor pigs in Switzerland. European Journal of Wildlife Research, August 2007, p. 212-220
Leuenberger R., P. Boujon. B. Thür, R. Miserez, B. Garin-Bastuji, J. Rüfenacht, K. D. C. Stärk. Prevalence of classical swine fever, Aujeszky's disease and brucellosis in a population of wild boar in Switzerland. Veterinary Record, 2007, p. 362-368

**2.17** Additional comments:

## Personal information

**1.1** Country: Switzerland

**1.2** Full name: Ryser; Marie-Pierre;

**1.3** Organization: Centre for Fisch and Wildlife health,

**1.4** Email: marie-pierre-ryser@vetsuisse.unibe.

**1.5** If it is not yet the case, would you be willing to have your name / organization listed in the external partners' list on the APHAEA website (www.aphaea.org)?

Name: ◯ yes ◯ no

Organization: ◯ yes ◯ no

## Wild boar & Aujeszky's disease virus

### Population related questions

**2.1** Please describe **the region considered for the study.** If there is more than one region considered, please fill the questionnaire several times.

Name of region: Ticino

Size (in sqkm): 2821km2

Comment:

**2.2 Which data sources exist in your country** providing information on the wild boar density (multiple choices are possible)**?**

- [x] Official hunting statistics (collected through official sources)
- [ ] Hunting association data (collected through private associations)
- [ ] Research data (...s) e.g. capture-mark-re-capture, pellet
- [ ] Other:

**2.3** What kind of **hunting strategy / scheme** is performed in the considered region? Please fill in text for explanation.

- [ ] Year-round ( e.g. constant, seasonal peaks )
- [x] Hunting season (from Septembe to February )
- [ ] Other:

**2.4 Is the wild boar density information marked in 2.2** available **for the region considered in 2.1** for at least 5 years **(2012 and previous years)?**

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Yes | ● | ○ | ○ | ○ |
| No | ○ | ○ | ○ | ○ |

**2.5** On which **regional scale** is the wild boar density information available for the region considered in 2.1 (please see table 1 in the Appendix section for more details)?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| NUTS 1 | ☐ | ☐ | ☐ | ☐ |
| NUTS 2 | ☐ | ☐ | ☐ | ☐ |
| NUTS 3 | ✓ | ☐ | ☐ | ☐ |
| LAU 1 | ☐ | ☐ | ☐ | ☐ |
| LAU 2 | ☐ | ☐ | ☐ | ☐ |
| Other: e.g. hunting grounds, GPS | ☐ | ☐ | ☐ | ☐ |

**2.6** On which **time scale** is the wild boar density information available for the region considered in 2.1?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Month | ☐ | ☐ | ☐ | ☐ |
| Quarter | ☐ | ☐ | ☐ | ☐ |
| Year | ✓ | ☐ | ☐ | ☐ |
| Other: | ☐ | ☐ | ☐ | ☐ |

**2.7** Which **additional information** is collected in the wild boar density information?

| | Official hunting statistics | Hunting association data | Research data | Other |
|---|---|---|---|---|
| Age class (see Appendix) | ✓ | ☐ | ☐ | ☐ |
| Weight | ☐ | ☐ | ☐ | ☐ |
| Sex | ✓ | ☐ | ☐ | ☐ |
| Type of carcass (see Appendix) | ✓ | ☐ | ☐ | ☐ |
| Other: | ☐ | ☐ | ☐ | ☐ |

**2.8** Are your hunting statistics of wild boar recorded in the EU Reference Laboratory **„Classical swine fever in wild boar surveillance database“** (http://public.csf-wildboar.eu)?

○ yes ● no

Would it be possible to get the **permission to use data** of the hunting bag from this database?

○ yes ○ no

## Disease related questions

All questions refer to **Aujeszky's disease in wild boar** and the region mentioned in 2.1. If there are disease related data only for a sub region of the considered area, please specify the size of the sub region in sqkm:

**2.9** Did or does **Aujeszky's disease in wild boar** occur within the region considered above?

● Endemic infection ○ Epidemic infection ○ Freedom from disease

✓ Historical data available ✓ Ongoing actual data ☐ No investigations / studies conducted in the area

What is the source of your information? e.g. official hunting statistics, research data

**2.10** Could data from former, ongoing or future **investigations about Aujeszky's disease virus in wild boar** from the region (or a sub region) mentioned in 2.1 be available for the APHAEA project?

| | | | | | |
|---|---|---|---|---|---|
| Ongoing | (●) yes | ( ) no | from | 2008 | to 2014 |
| Finished | (●) yes | ( ) no | from | 2001 | to 2005 |
| Permanent | ( ) yes | ( ) no | since | | |
| Planned | ( ) yes | ( ) no | from | | to |

**2.11** Please fill in the **number of collected samples** that could be used within the APHAEA project referring to the investigations mentioned in 2.10.

| | Ongoing | Finished | Permanent | Planned |
|---|---|---|---|---|
| Sample size for serological investigations | 277 | -- | | |
| Sample size for PCR | 0 | -- | | |

**2.12** If there are planned investigations of Aujeszky's disease virus, **would you be able to investigate samples** at your laboratory?

☑ **Serologically** ☐ **Virologically** by e.g. PCR or virus isolation

**2.13** If there are historical, ongoing, permanent or planned wild boar sample collections in your country but you do not have the possibility to test the samples for Aujeszky's disease virus, would it be possible **to send sera and/or tissue samples to another laboratory**?

Sera samples: (●) yes ( ) no

Tissue samples: ( ) yes (●) no

**2.14** Would you have the possibility to **provide historical laboratory test results** of a former investigation regarding Aujeszky's disease virus in wild boar from the considered region?

(●) yes ( ) no

**2.15** If there are samples (ongoing, historical or planned for future), which **information** is / will be available?

| | Ongoing | Historical | Planned |
|---|---|---|---|
| Age class | ✓ | ✓ | |
| Sex | ✓ | ✓ | |
| Date | ✓ | ✓ | |
| Location<br>on which regional scale (see 2.5 and Appendix) | ✓ | ✓ | |
| Carcass (see Appendix) | ✓ | ✓ | |
| Results of **serological investigations** (if performed) | ✓ | ✓ | |
| Results of **virological investigations** (if performed) | | | |
| Other: | | | |

## General questions

**2.16** Please list any **publications concerning wild boar population data and Aujeszky's disease** within the considered region and time.

Köppel C., L. Knopf, M.-P. Ryser, R. Miserez, B. Thür, K. D. C. Stärk. Serosurveillance for selected infectious disease agents in wild boars (Sus scrofa) and outdoor pigs in Switzerland. European Journal of Wildlife Research, August 2007, p. 212-220
Leuenberger R., P. Boujon. B. Thür, R. Miserez, B. Garin-Bastuji, J. Rüfenacht, K. D. C. Stärk. Prevalence of classical swine fever, Aujeszky's disease and brucellosis in a population of wild boar in Switzerland. Veterinary Record, 2007, p. 362-368

**2.17** Additional comments:

# APPENDIX F

*Valorization of this thesis*

Abstract and poster presented at the ‘European Wildlife Disease Association conference’ from August 24th to 29th 2014 in Edinburgh, UK

## SEROSURVEY OF AUJESZKY’S DISEASE VIRUS IN THE SWISS WILD BOAR POPULATION

**ROMAN KASPAR MEIER**[1, 3], FRANCISCO RUIZ-FONS[2] and MARIE-PIERRE RYSER-DEGIORGIS[1]

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In parallel to the control programs for Aujeszky’s Disease (AD) in domestic pigs in Europe, a prevalence increase of AD virus (ADV) infection has been observed in wild boar (*Sus scrofa*). Furthermore, AD cases have been reported in hunting dogs after contact with wild boar. In Switzerland, domestic pigs are AD-free. A serosurvey performed in wild boar in 2004/2005 had revealed a prevalence of 2.8% (95% confidence interval CI: 1.9-4.0%). Considering the locally increasing wild boar abundance and assuming that ADV prevalence may be density-dependent, we wanted to re-estimate the ADV seroprevalence in Swiss wild boar. As this study is part of a European project (APHAEA) with the aim to harmonize procedures in wildlife health investigations, we used the same diagnostic test as previous ADV serosurveys in Spain and Germany. So far, 945 serum samples from free-ranging wild boar collected over 5 hunting seasons (2008-2012) from 5 different study areas in Switzerland were included in this study. Samples were analyzed by a commercial ELISA kit (IDEXX PRV/ADV gI Ab Test) for detecting antibodies against Suid Herpesvirus-1. An overall prevalence of 0.7% (95% CI: 0.3-1.5) was obtained, with additional 6.1% doubtful samples that will be retested. These preliminary data indicate that the prevalence of ADV infection in the Swiss wild boar population has remained low so far and that the influence of animal density on AD prevalence is less important than originally assumed.

# SEROSURVEY OF AUJESZKY'S DISEASE VIRUS IN THE SWISS WILD BOAR POPULATION

ROMAN KASPAR MEIER[1, 3], FRANCISCO RUIZ-FONS[2] and MARIE-PIERRE RYSER-DEGIORGIS[1]

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## Introduction:

- Wild boars (*Sus scrofa*) are a true reservoir for the Aujeszky's disease virus (ADV)[1] and pathogen transmission between wild boar and domestic swine is possible[2]. Seroprevalence of ADV in wild boar depends, inter alia, on population density and other aspects of wild boar population dynamics [3].
- ADV seroprevalence in wild boar has increased in several European regions[1,4] and fatal cases of Aujeszky's disease in hunting dogs and other carnivores with a history of contact to wild boar have increasingly been reported[5-8].
- In Switzerland, a serosurvey on ADV in wild boar in 2004/2005 had revealed a low antibody prevalence of 2.8% (95% confidence interval (CI): 1.9-4.0%)[9] but because abundance and likely population density of wild boar have dramatically augmented in the past decades, we hypothesized that ADV seroprevalence may have also increased in the wild boar population.
- The aims of this study were to re-evaluate the ADV situation in Swiss wild boar using harmonized methods according to the European project APHAEA (www.aphaea.eu), and to compare our data with those from other European regions considering two time periods.

## Material and Methods:

- Blood samples were collected from 1,228 free-ranging hunted wild boar from five different study areas (A-E; Fig. 1) in Switzerland (41,284km$^2$) from 2008-2013: 67 piglets (< 6 months), 342 juveniles (6-12 months), 370 subadults (12-24 months), 385 adults (≥24 months), and 67 animals of unknown age; 611 females, 597 males and 20 animals of unknown sex.
- Sera were analyzed with a commercial ELISA (IDEXX PRV/ADV gI Ab Test). According to the manufacturers' instructions, doubtful and positive samples were re-tested with the same ELISA. Chi-square-tests were applied to test for differences in seroprevalences.
- Data on ADV seroprevalence (ELISA) in free-ranging wild boar in other countries were retrieved from the scientific literature for two time periods: 1995-2007 and 2008-2014.

## Results:

**Serosurvey:**

Seven wild boar tested seropositive, i.e. estimated **overall antibody prevalence was 0.6%** (95% CI: 0.2-1.1%). Eight animals showed doubtful results despite repeated testing. This result represents a significant decrease of the ADV seroprevalence since the last serosurvey in 2004/2005 (P=0.00).

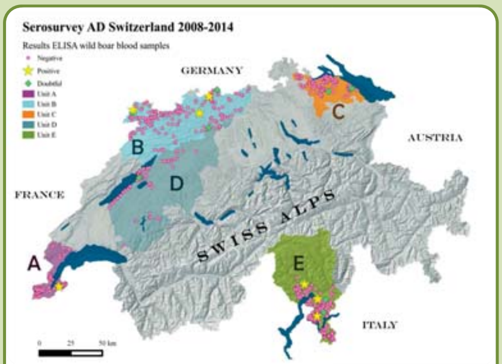


Fig. 1: Map of Switzerland: Results of serosurvey on ADV with ELISA

**Review:**

Overall, ADV seroprevalence in wild boar varies widely among European regions, ranging from 0 to 69%.The highest seroprevalences have been documented in the Mediterranean countries followed by Eastern Europe. In contrast, there is an "island" with low to moderate seroprevalences in central Europe, except for a hotspot at the border of France, Belgium and Germany (Fig. 2). However, in most areas with low seroprevalences small regions with high seroprevalences have been documented, and vice versa.

Most available data were collected in the first time period, and more recent data partially originate from different geographical areas, making comparisons difficult. A general European trend could not be detected due to varying evolution of the ADV seroprevalences: increasing trend in Croatia[10] and northeastern Germany[4], stable- high in Spain[11], decreasing in southwestern France[12,13] and Switzerland .[9,]

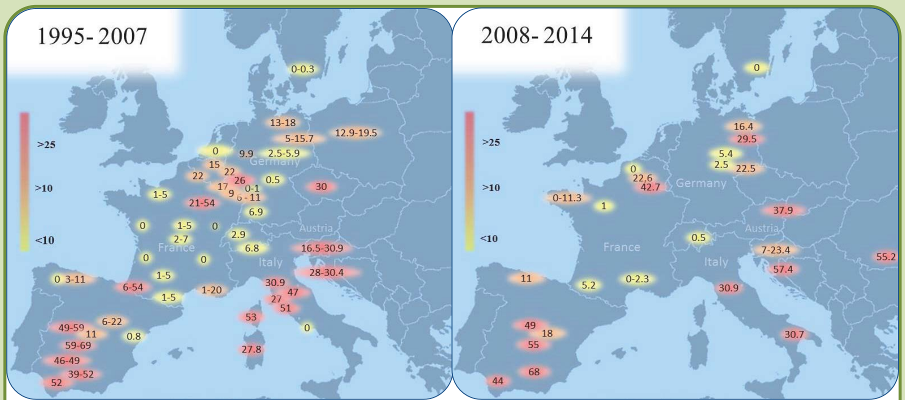


Fig. 2: Maps of Europe illustrating data on seroprevalences of ADV in wild boar for two time periods. All data base on ELISA. Yellow shaded numbers: low seroprevalences (<10%), orange: moderate (10 - 25%) , red: high (>25 %).

## Discussion:

- ADV seroprevalence in Swiss wild boar has decreased despite increasing wild boar abundance and locally high densities (10.6ind /100ha)[15].
- In Europe there are large differences regarding ADV seroprevalence in wild boar not only among countries but also among different regions within a country, suggesting that local factors may play an important role in this process.
- It has been proposed that risk factors like intense wild boar management with high densities, artificial feeding and fencing, aggregation and translocation of wild boar [14,16] lead to a higher contact rate and a larger number of susceptible hosts[17] and therefore to higher seroprevalences of ADV. However, because ADV is a Herpesvirus, virus excretion is expected to depend on immune modulations of the host. We propose that stress could be a driving factor for the spread and maintenance of ADV and that intense wild boar management practices may be stressful to wild animals and thus contribute to ADV maintenance.
- Comparing the available data on ADV and wild boar abundance and management in Switzerland and Spain, the situation is highly different (Spain:higher ADV prevalences, much higher wild boar densities of up to 90 ind/100ha[17], and livestock-like wild boar management) and may support the "stress hypothesis". In contrast, comparison with other regions with high seroprevalences (e.g. northeastern France) suggests that other stressors or risk factors may play a role. Unfortunately, despite the large amount of data on ADV seroprevalence in Europe, the considerable lack of data on wild boar densities, management practices and environmental conditions largely impedes the identification of risk factors for the maintenance of ADV in free-ranging populations. There is an urgent need to fill this gap, for AD and other important diseases.

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We thank the cantonal hunting authorities, game wardens, hunters and FIWI collaborators for their contribution to sampling. Funding was provided by the Swiss Federal Good Safety and Veterinary Office (FSVO). This study is part of the EMIDA-Eranet project "APHAEA". F. Ruiz-Fons is funded by the Spanish Ministry for the Economy and Competitiveness.

Abstract for a poster presented at the 'final meeting of the APHAEA project' from March 17th to 19th 2015 in Utrecht, Nederland

**EVALUATION OF METHODS FOR ESTIMATING WILD BOAR ABUNDANCE IN SWITZERLAND**

Meier, Roman K[1]; Fischer, Claude[2]; Ryser-Degiorgis, Marie-Pierre[1]

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Key words: Census, hunting statistics, pellet counts, thermal imaging, *Sus scrofa*

BACKGROUND: A large number of direct and indirect methods are applied for estimating wild boar abundance, resulting in a confusing heterogeneity of data. Efforts to harmonize methods among European regions are thus required. The aim of this study was to evaluate three methods for wild boar abundance estimation under Swiss environmental conditions (richly structured habitats with dense forests): hunting statistics, a widespread but controversial method; faeces counts along transects, an established method in Mediterranean regions; and night vision counts, a promising new approach.

METHODS: We pooled data on dead wild boar (shot and found dead) from Switzerland (2004-2013) into three time periods and produced graduated color maps, representing the average number of dead animals/100ha/year. In winter 2014/2015 we applied additional methods in two study sites: Per site we carried out faecal counts on six randomly chosen transects of approx. 1 km length and performed three night vision counts with a FLIR thermal imaging camera on one transect of approx. 18 km.

RESULTS: Data from the hunting statistics revealed large differences at local scale (LAU-1) ranging from 0.0 to 19.1 ind/year/100ha, with a national average of 0.17 ind/year/100ha for the whole period. We observed an increasing number of dead wild boar at national and regional scales and a geographic spread. The number of faeces ranged from 0 to 3/km and night vision counts fluctuated between 0-17 individuals per trial (mean 2.8 ind/10km ±3.7). Detectability of wild boar in forests was low.

CONCLUSIONS: Despite the bias inherent in hunting bags, they represent an interesting tool to illustrate spatio-temporal trends of wild boar abundance and occurrence allowing comparisons among regions with similar hunting management and pressure. Detectability of wild boar by night vision and of faecal droppings was low in forests and therefore could be deemed unsuitable under Swiss conditions.

# EVALUATION OF METHODS FOR ESTIMATING WILD BOAR ABUNDANCE IN SWITZERLAND

**Meier, Roman K[1]; Fischer, Claude[2]; Ryser-Degiorgis, Marie-Pierre[1]**

[1]Centre for Fish and Wildlife Health, University of Bern
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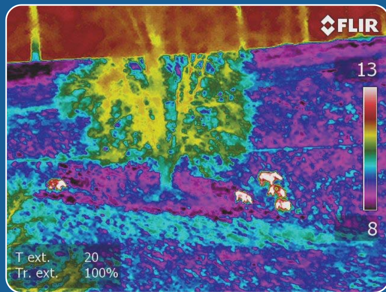
## Background

In the past decades the wild boar (*Sus scrofa scrofa*) has experienced a dramatic expansion and increase in most parts of Europe, leading to big challenges in wildlife management and health surveillance. Estimating and predicting wild boar population density is very difficult due to the species' life history (e.g. secretive behavior, high reproduction rate influenced by food availability, complex social structure). A large number of different methods to estimate population abundance are in use, leading to a confusing heterogeneity of data: direct methods (e.g. direct counts, drive hunt counts), indirect methods (e.g. track and faecal counts), statistical methods (e.g. hunting bag analysis, habitat modelling) and capture-recapture methods (e.g. camera traps, genotyping). Efforts to harmonize methods among European regions are thus required. The aim of this study was to evaluate three different methods for wild boar abundance estimation under Swiss environmental conditions (richly structured habitat with dense forests and underwood): (1) Analysis of hunting statistics, a widespread but controversial method, (2) faeces counts along transects, an established method in Mediterranean regions, and (3) thermal camera counts, a promising new approach.

## Methods

**Hunting statistics**: Data on dead wild boar (shot and found dead) from 2004-2013 were obtained from most cantonal hunting authorities in Switzerland. These data were pooled into three time periods to produce a graduated color map in a resolution of LAU2 or LAU-1, respectively, in order to show the average number of dead animals/100ha/year for each period.

In winter 2014/2015 we applied two different methods in two study sites with expected high wild boar abundance (Unit A: Jussy, canton of Geneva, Unit B: Kleinlützel, canton of Solothurn): We carried out **faecal counts** on eight randomly chosen transects of approx. 1.2 km length and calculated the FBII (frequency of faecal droppings found on transects) and a spatial aggregation index Z according to Acevedo et al. (2007). In addition, we performed vehicle-operated **thermal camera counts** along transects on forest and field roads using a forward-looking infrared-camera (FLIR T 600). The transects of 16 and 21 km, respectively, were repeated three times after time breaks of three weeks.



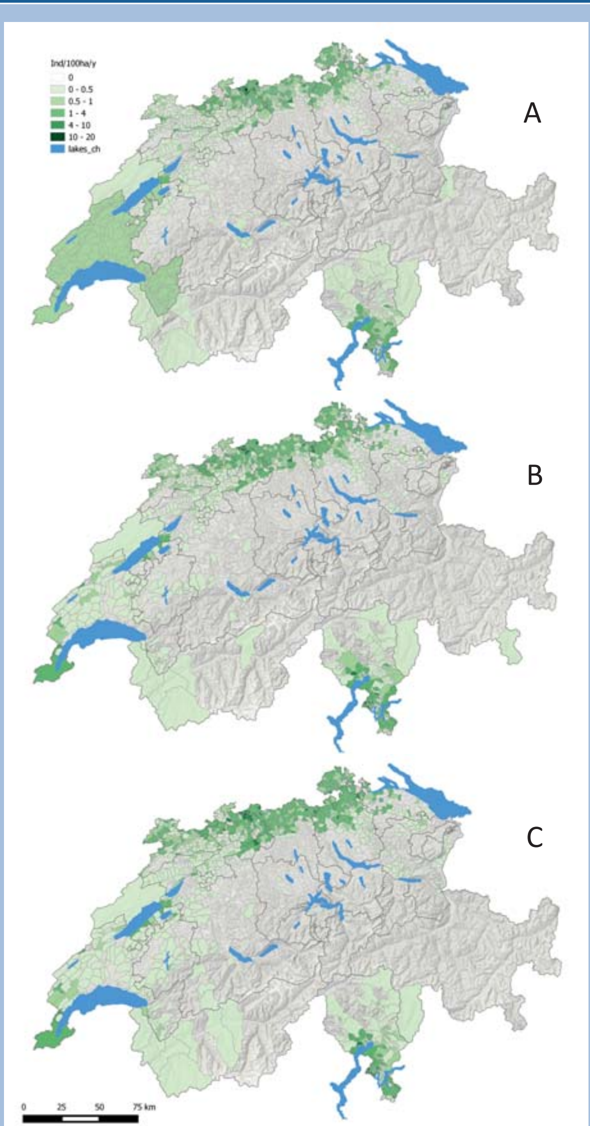




Fig.1: Dead wild boar (shot and found dead) from Switzerland over three time periods: A: 2004-2006, B: 2007-2009, C: 2010-2012. Shades of green correspond to an estimated density of death animals/100ha/year.

## Results

Data from the hunting statistics revealed large differences ranging from 0.0 to 19.1 dead wild boar/year/100ha, with a national average of 0.17 ind/year/100ha for all three periods (Fig. 1). We observed an increasing number of dead wild boar (shot or found dead) and a geographic spread in most regions (Fig. 2).

The number of faeces counts ranged from 0 to 6 pellets/km resulting in an FBII of 0.09 in Unit A and 0.2 in Unit B. Estimated aggregation indexes Z were 0.33 (Unit A) and 1.2 (Unit B).

Night vision counts fluctuated between 0 and 17 individuals per trial resulting in a mean of 4.4 (±4.4; Unit A) and 1.0 (± 1.3; Unit B) wild boar/10km. Although 80% and 72% (Units A and B, respectively) of the transect routes were in the forest, only 31% of the observed wild boar were observed therein.

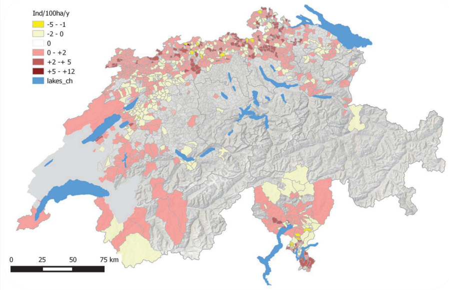



Fig.2: Increase/decrease dead animals/100ha/year between period 1-3.

## Conclusions

Despite the bias inherent in hunting bags, they represent an interesting tool to illustrate spatio-temporal trends of wild boar abundance and expansion allowing comparisons among regions with similar hunting management and pressure (Fig 1.).

We obtained similar FBII in Unit A (0.09) and a slightly higher FBII in Unit B (0.2) compared to the FBII from non-fenced hunting areas from Spain (0.05 ± 0.05; Vicente et al. 2004). Estimated aggregation indices laid within the range of the values obtained in Spain (2.91±3.11; Acevedo et al. 2007). Nevertheless, we consider that on densely covered forest ground, faeces have a low detectability, resulting in an underestimation of abundance compared to Spain, where the dehesas (savannah-like habitats) ensure good detectability of the droppings. Furthermore, we noticed large differences in counts per transect likely due to the existence of clusters related to the inhomogeneity of the habitat and variable animal distribution. Thus we propose to adjust the method by increasing the number (i.e. the density) of transects per site.

Detectability of wild boar with thermal cameras was good in open scrubland but very limited in dense forests. Since this method is newly in use, to date no data from other areas are available in the literature for comparison. Repeatability of the night vision transect counts was very low (0-17 animals/trial), suggesting that the results are strongly linked to the particular location of the wild boars at the time of the drives (i.e. forest vs. open land) and that repeated counts are necessary to obtain a better representativity of the data.

Overall, we assume that both faecal and night vision transects lead to an underestimation of animal abundance under Swiss conditions. While the necessary effort to obtain reliable results with thermal imaging appears to be disproportionate, the faecal count method may represent a promising approach on the condition that a higher number of transects per site are scanned for pellets than in regions with open habitats.

Acknowledgements:
We thank all cantonal hunting authorities for providing their detailed hunting statistics. A special thank goes to the hunting authorities and game wardens and Revier tenants, respectively, from Geneva and Solothurn amd to Mirjam Pewsner (FIWI) for supporting the night vision transects as well as to Joaquin Vicente for his hospitality and technical support. Funding was provided by the Swiss Federal Food Safety and Veterinary Office (FSVO). This study is part of the EMIDA-Eranet project "APHAEA". The copyright of the GIS-layers of the hunting districts lies with the providing cantonal authorities.

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