Guidelines for the cost-effective prevention and control of African swine fever

<u>September 2015</u>

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What is African swine fever?

African swine fever (ASF) is a complex and devastating swine disease caused by a complex DNA virus, the only member of the *Asfaviridae* family (Dixon et al., 2005). There is not an effective, safe vaccine against this virus, neither any treatment. The disease affects domestic pigs (*Sus scrofa domesticus*) and wild boars (*Sus scrofa ferus*), being these latter very important in the current European scenario. The infection with ASF virus (ASFV) induces production of high amounts of specific antibodies in infected animals; however, these antibodies are not capable of completely neutralizing viral infection. Once the animal is infected, a wide range of clinical forms may develop, from hyperacute forms with high fever and death; to acute/subacute forms characterised by clinical signs of a haemorrhagic fever, or even, forms with non-apparent clinical sings (Sanchez-Vizcaino et al., 2014).

Prevention, control and eradication of ASF are mainly based on the early detection and the application of strict sanitary measures (Sanchez-Vizcaino and Arias, 2012). Moreover, the occurrence of ASF causes real significant socio-economic impact in affected countries due to the compulsory banning of animal movements the establishment of trace restrictions at national and international levels, among others (Mur et al., 2012).

ASFV presents a great genetic and antigenic variability, as well as a complex interaction with the host and environment. The routes of introduction of ASF into free regions can take place through:

- **Legal or illegal movement of live animals**:
    - Infected domestic pigs with or without clinical signs.
    - Infected wild boars with or without clinical signs that free range through natural corridors. This is the main route of introduction in the current European scenario (De la Torre et al., 2015)
- **Introduction of contaminated pig meat or other pork products** transported internationally by air or sea from infected regions, which are commonly used to feed pigs (e.g. Portugal in 1957 and 1960, France in 1964, Brazil in 1978, Belgium in 1985, Georgia in 2007...) → "swill feeding". So far, this has been the most common introduction route identified (Sanchez-Vizcaino and Arias, 2012).
- Other **contaminated fomites as trucks, vehicles, animal feed, veterinarians**, etc. which return from infected territories (Mur et al., 2012).
- Through feeding on contaminated animal feed due to the use of crops that come from areas where there are infected wild boars (under evaluation).
- Bites of **infected soft ticks** (*Ornithodoros* spp.) only at local levels (Sanchez-Botija, 1982).

ASF is one of the most complex viral diseases of swine.
It affects wild boars and domestic pigs.
No neutralizing antibodies. No vaccine. No treatment.

Currently, the movement of infected wild boars is the main route of ASF introduction and spread into free European Union areas.

What is the current situation in Europe?

ASF was first described in Kenya by E. R. Montgomery in 1921 (Eustace Montgomery, 1921) and traditionally it has been confined to the African continent. **Only three introductions, from Africa to Europe**, have been described so far. The first incursion in Europe was in **1957, when Portugal** was affected through leftovers contaminated with ASF-genotype I from international planes. ASF **re-entered Portugal in the 60's** from where it spread to the whole Iberian Peninsula and many other European and Latin American countries. All of them achieved eradication of ASF, except the Italian Island of Sardinia that has remained endemic since 1978 (*Figure 1*) (Sanchez-Vizcaino et al., 2013).

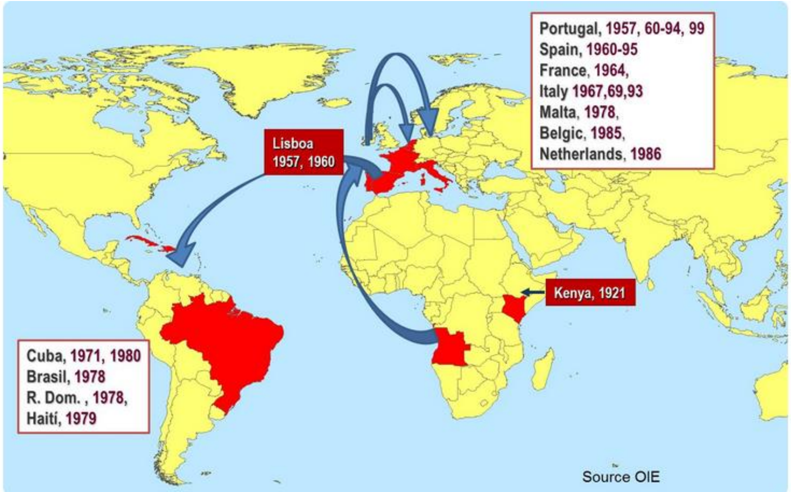

Figure 1: Disease distribution from 60's to 90's

A third introduction took place in 2007, ASF-genotype II was **introduced in Georgia** through Poti port. From Georgia, the disease spread rapidly to **Armenia, Azerbaijan and the Russian Federation** (*Figure 2)* (Sanchez-Vizcaino et al., 2013, Beltran Alcrudo et al., 2008).

Figure 2: Outbreak distribution in 2007

Since the Russian Federation was affected, the disease has progressively spread to Northern and Eastern regions mainly by the movement of infected wild boars (short-medium spread) and contaminated pig meat or other pork products (further spread) (*Figure 3, 4, 5 and 6*).

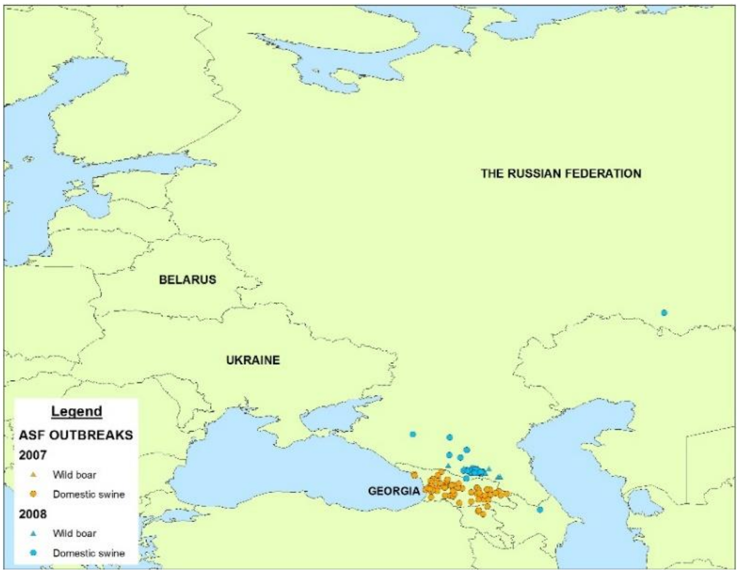

Figure 3: Outbreak distribution from 2007 to 2008

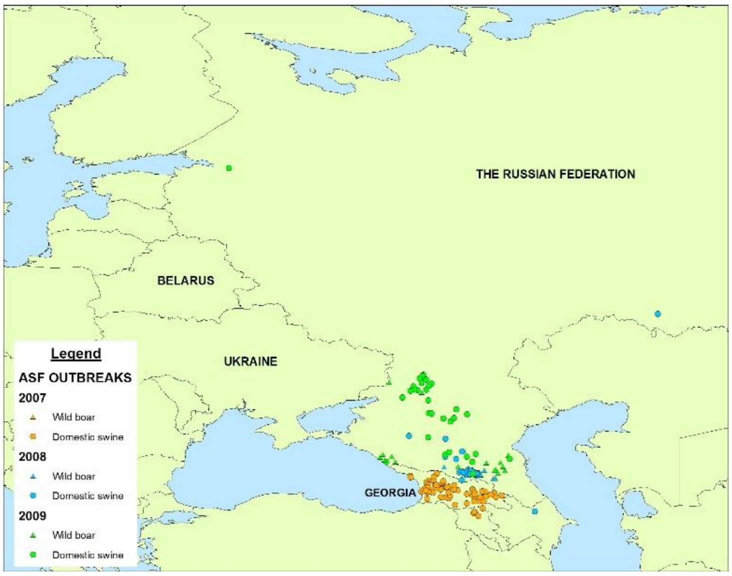

Figure 4: Outbreak distribution from 2007 to 2009

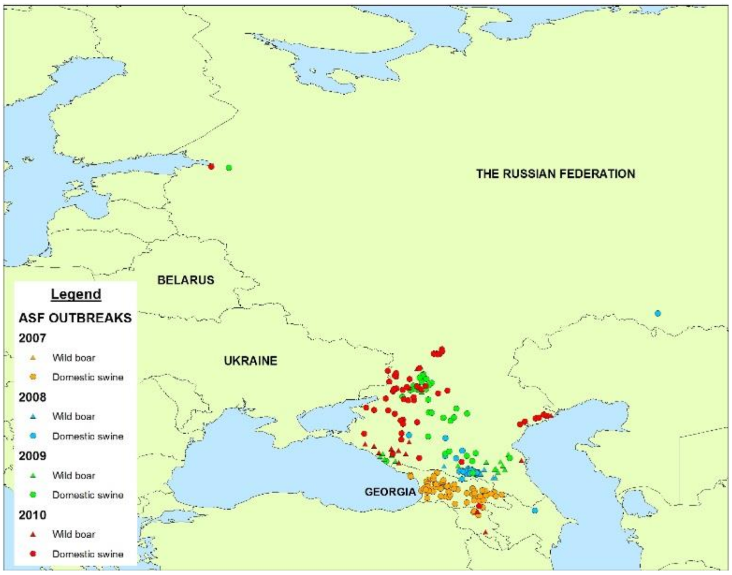

Figure 5: Outbreak distribution from 2007 to 2010

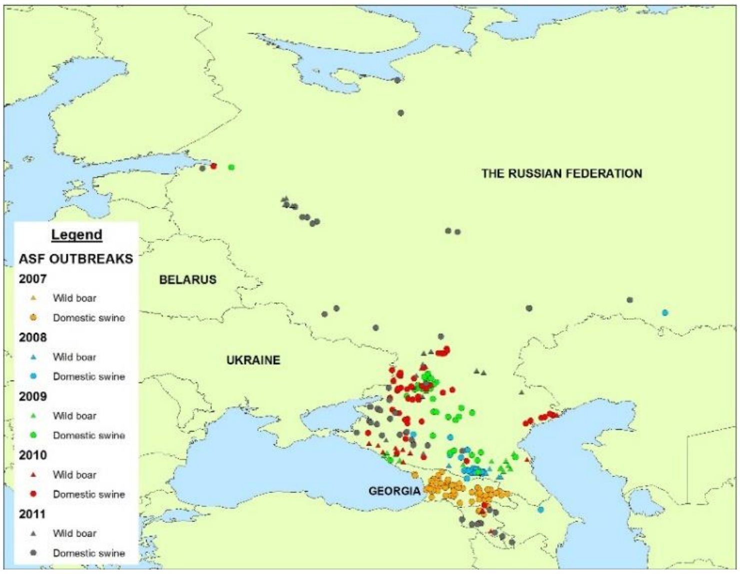

Figure 6: Outbreak distribution from 2007 to 2011

In 2012, Ukraine declared a first ASF outbreak in a subsistence farm located in the Southeast of the country (*Figure 7*). During this year, the Russian Federation notified 21 outbreaks which affected domestic pigs and wild boars. Most of them were located in northern areas, as the Tver region close to Moscow (Sanchez-Vizcaino et al., 2013).

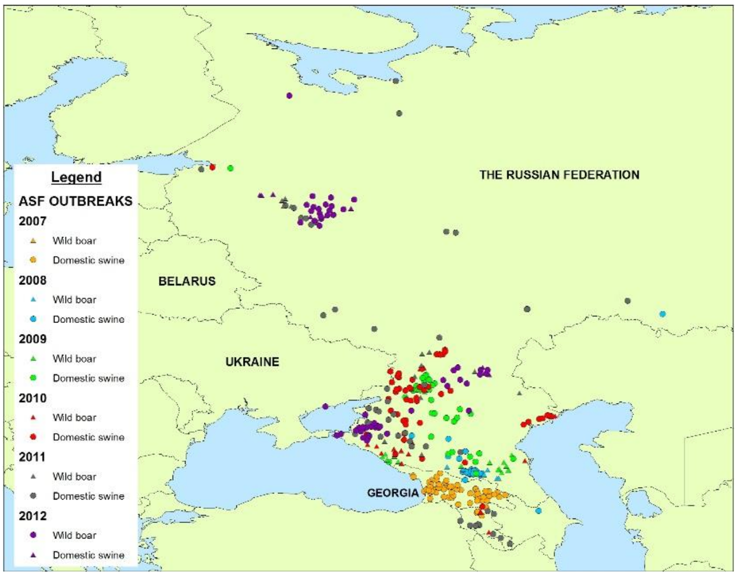

Figure 7: Outbreak distribution from 2007 to 2012

One year later, Belarus became infected. In this case, the suspected sources of infection was the introduction of contaminated feed from the Russian Federation and the potential contact between susceptible animals and sick wild boars from the neighbouring Rostov Oblast region where ASF is present in wild boars and domestic pigs since 2009 (*Figure 8*) (EFSA, 2014).

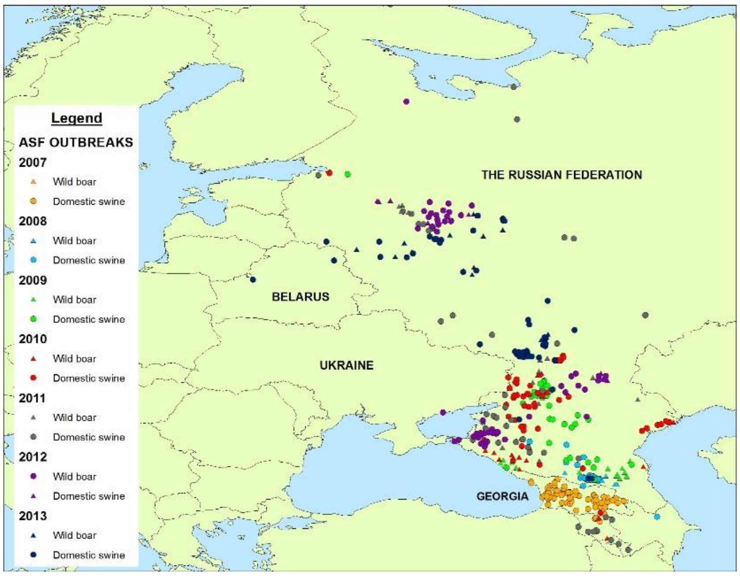

Figure 8: Outbreak distribution from 2007 to 2013

In 2014, four European Union (EU) states namely **Estonia, Latvia, Lithuania and Poland** have also become infected. The first cases of ASF were notified in Lithuania and Poland where some dead wild boars were found infected with virus genetically identical to Ukrainian and Belarusian isolates. These countries were followed by Latvia where the first outbreak was identified near the Belarusian border in a backyard farm. Finally, in September 2014, Estonia notified the first outbreak of ASF in wild boar (*Figure 9*) (WAHID).

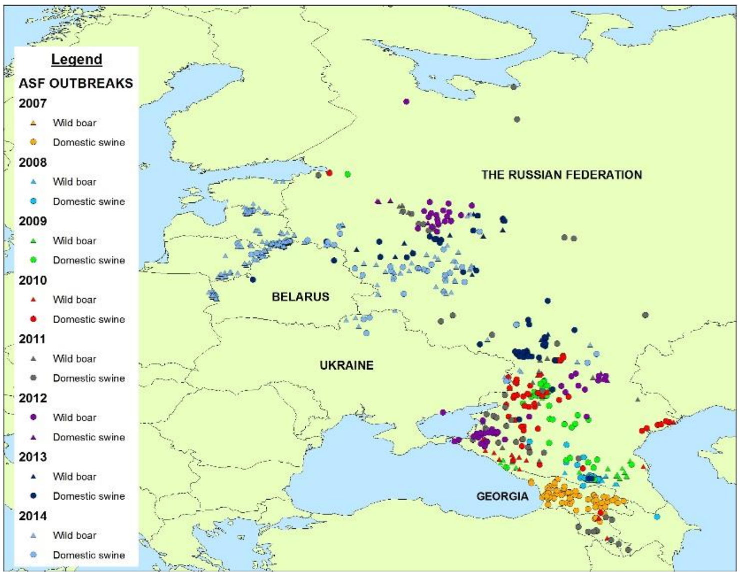

Figure 9: Outbreak distribution from 2007 to 2014

So far, the epidemiological situation in Ukraine and especially in Belarus is not well known, due to both countries stopped notifying outbreaks shortly after disease introduction. By mid-2014, Ukraine re-started notifying ASF outbreaks in neighbouring areas of Belarus and the Russian Federation; although, Belarus is still not informing about ASF events.

In the EU, ASF is currently spreading through Estonia, Latvia, Lithuania and Poland despite the prevention and control measures established (Council Directive 2002/60/EC of 27 June 2002); in addition, the number of outbreaks during 2015 has exceeded the historical maximum registered with more than 800 outbreaks in wild boars and domestic pigs (95 % in wild boars). Most outbreaks were notified between June and September, achieving maximums in July-August depending on the year (*Figure 10).*

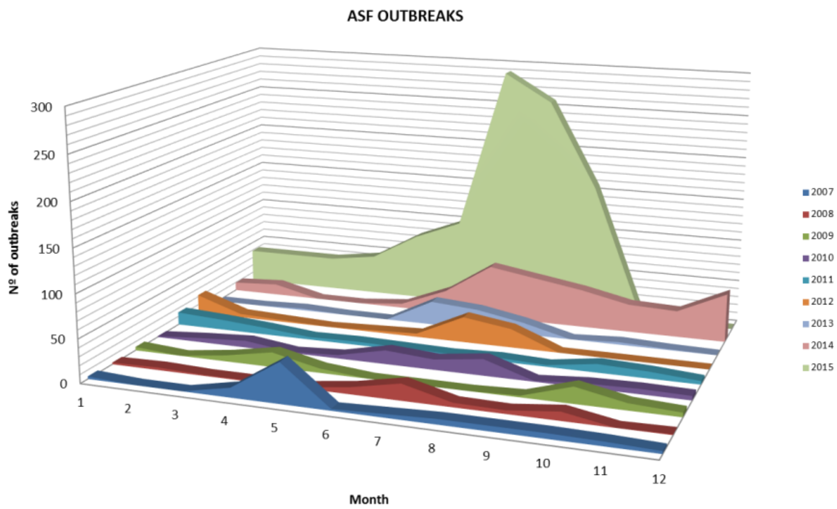

Figure 10: Outbreak notifications from 2007 to October 2015

With reference to disease spread, a curious epidemiological pattern of "short-spread" occurs in Poland, which is confining all outbreaks at the Polish border, while Estonia, Latvia and Lithuania are suffering an intense spread along their territories.

The following map illustrates ASF evolution from 2007 to October 2015 in the affected European states (*Figure 11*). In addition, clicking on this link http://asforce.org/blog/110 you can watch a video (done by CISA-INIA) where ASF evolution is shown.

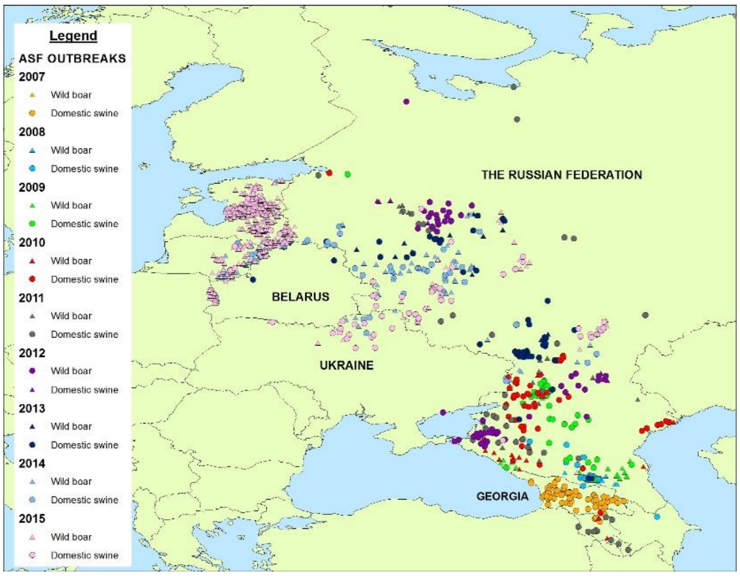

Figure 11: Outbreak distribution from 2007 to 2015

How can ASFORCE project help?

“Target research effort on African swine fever” or ASFORCE project is an European project funded by the European Union’s Seventh Framework Programme (FP7/2007/2013) under grant agreement nº 311931. The consortium brought together a team of 18 partners from Bulgaria, France, Germany, Italy, Portugal, the Russian Federation, Spain, Switzerland, United Kingdom and the Food Agriculture Organization of the United Nations (FAO) as an intergovernmental organisation.

The ASFORCE project, aims at contributing among others, to identify and solve main relevant issues regarding the prevention of ASF entry in the European Union, mainly focusing on the threat posed by the occurrence and spread of the disease in Eastern Europe. The participation of different partners has given to this project a multidisciplinary approach that provides a strong scientific and technological basis towards the establishment of these guidelines.

Research work developed under Theme 2 of the project (Prevention, Control and Eradication models for ASF), aims at providing essential information to design more cost-effective surveillance and control strategies for ASF into the different risk scenarios, providing valuable tools for policy makers, administrations, veterinarians and pig producers. **Theme 2 compiles three specific objectives**: **first**, to evaluate the existing production systems and the spatial and temporal patterns in pig trade within several European countries; **Secondly**, to analyze the genetic properties of ASFV isolates currently circulating and the geographical and molecular spatial-temporal patterns of geographic viral dissemination; **The last objective** aims at reviewing cost-benefit analysis of the surveillance and control strategies for ASF in Sardinia, Corsica and Russian Federation, and the evaluation of existing surveillance strategies and contingency plans in Eastern European countries. **The ultimate goal** is to better prevent and control ASF and minimize the economical loses on endemic or on potentially new infected areas.

Results obtained from this project and specifically from Theme 2 provide very useful tools as well as interesting data in order to establish cost-effective guidelines for prevention and control measures against ASF.

Generated outcomes of studies developed are summarized and presented in these guidelines.

Pig production in Europe

Pig production within European Union is a diverse and multifaceted industry comprising highly engineered farms, backyard holdings and small family owned farms. This diversity results in different densities of pig farming, varying biosecurity standards and different possibilities of contact to wild species depending on the scenario. Germany, Spain, Georgia, Romania, Bulgaria and the Russian Federation, were selected as representative examples of European pig producers and were divided into three groups (densely populated, backyard systems and both systems). Their pig production was evaluated through questionnaires to pig producers with regard to pig density, structure, herd size, management, biosecurity, possible contact with wild boars and related trade.

1. ***Densely populated*** *(Germany and Spain)*

Germany: is the first pig producer in Europe with roughly 28 million pigs, most of them are fattening pigs (12,382,500 pigs) and piglets (8,219,100 pigs), followed by breeding pigs (over 50 kg) (2,082,700 pigs), breeding sows (2,057,700 pigs) and boars for breeding (25,000 pigs). Germany is also an important importer of pigs in Europe; pig producers usually acquire pigs from the Netherlands, Denmark and France. Pig production is especially concentrated in the North Western part of Germany where densely populated areas were identified (see *Figure 12*).

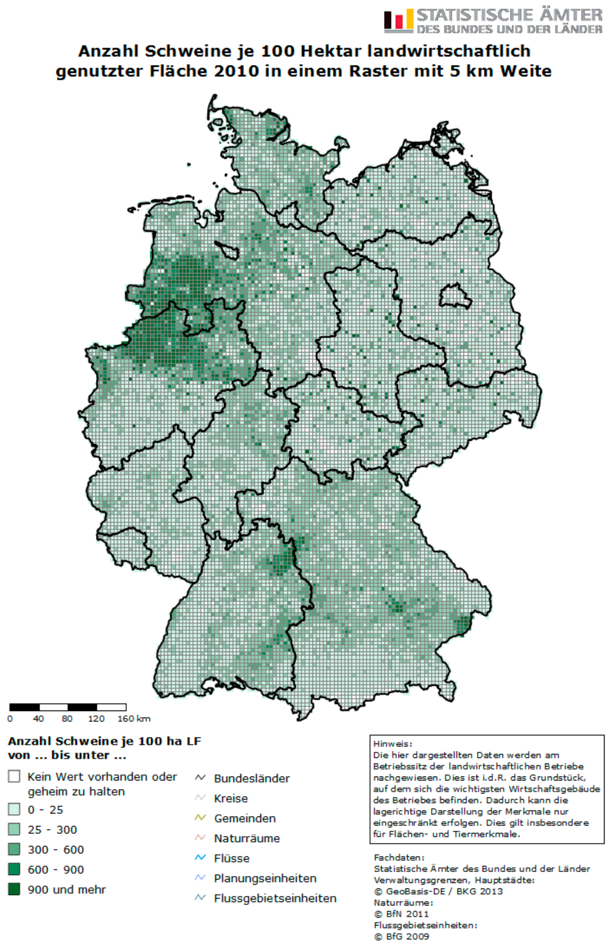

Figure 12: pig density in Germany (data obtained from the Federal Statistical Office and the Statistical Office of the Länder)

Evaluating the responses obtained in the questionnaires several risk factors were recognised:

- Proximity between farms: more than 50 % of pig holdings are located closer than 1 km to another pig farm.
- Information on pig owner: more than 25 % of German pig farmers have strong links to hunting activities and approximately 7 % had personnel or relatives that were hunters. When the question was focused on hunting activities abroad, 7 % answered that they were going for hunting to Eastern Europe.
- Information on the holding and its management: less than 50 % of pig owners reported regular laboratory diagnosis to confirm or rule out diseases.
- Wild boar contact: more than 50 % answered that there are wild boars near their farms. When they were asked about the distance to wild boars, around 25 % reported that there are wild boars within less than 100 m and most of them mentioned fences to avoid the contact.

Spain: is the second pig producer in Europe with 25.4 million pigs. Most of the farms (72 %) are managed in intensive production systems whereas 21.8 % are extensive farms (mostly Iberian pigs) and 1.9 % mixed (remaining 4.4 % not identified). Intensive production systems are mostly located in areas as Cataluña, Aragón, Castilla y León and Murcia, whereas extensive production systems area mainly located in the North-Western part of Andalucía, Extremadura and the South-Western provinces of Castilla y León. The following figure (*Figure 13*) represents the distribution of pig farms in Spain.

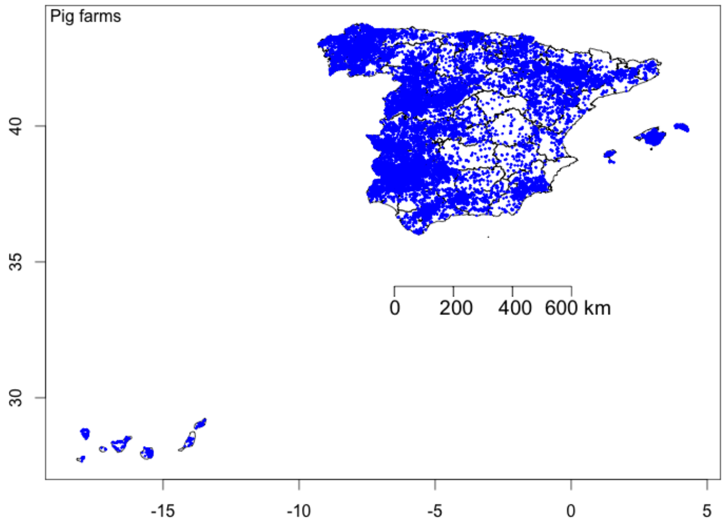

Figure 13: pig farms in Spain (data provided by the Ministry of Agriculture, Food and Environment, MAGRAMA)

Questionnaires were also conducted in Spain and the main risk factor identified was associated with extensive production systems (mostly Iberian pig production):

- Wild boar contact: wild boars are in the surroundings of extensive farms and the most common interaction takes place during "montanera" period (animals use pasture in free-ranging areas).

2. ***Backyard systems*** *(Georgia, Romania and Bulgaria)*

Georgia: before 2007, this country had a total pig census of 517,000 animals although this number was dramatically decreased after ASF outbreaks (2007-2008). Since 2010, the pig population started increasing but traditional methods of pig keeping still remains very popular. Pig population is mostly concentrated in the East and West of the country although there is a lack of data in several regions (*Figure 14).*

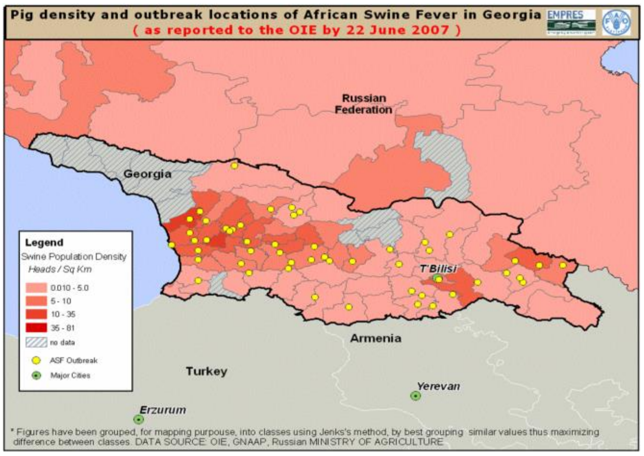

Figure 14: heads per square kilometre and ASF outbreaks in Georgia

All Georgian farms were classified as backyard holdings that kept the pigs enclosed all year round (67.6 %), allowing them to scavenge during the day (30.6 %) or to scavenge for days or months (2.3 %). Therefore, pigs have free access to waste including slaughter and kitchen disposal.

Pig slaughtering is usually carried out at home (83 %) and uneatable pork parts can end in different ways: buried, burnt, thrown away (3.7 %), fed back to the pigs (0.8 %) or to dogs/cats (40.3 %). In addition, other risky practices as swill feeding are also popular in Georgia; pigs feed usually on leftovers (43.3 %) being not boiled/heat-treated prior feeding them in 36.1 % of the cases (in 20.6 % the owner did not know).

Romania: the total number of pigs in Romania was 2,312,045 being 30 % of them backyard pigs (source Bulgarian Food Safety Agency, BFSA). The highest number of backyard pigs was reported in Dolj and Olt regions (*Figure 15*).

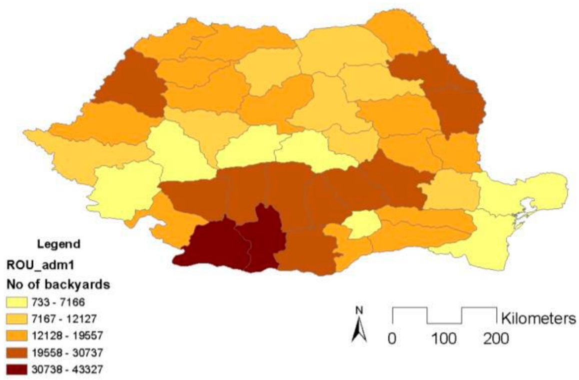

Figure 15: total number of backyard pigs in Romania (data provided by BFSA)

<u>Bulgaria</u>: in Bulgaria there are industrial farms, family farms and backyard farms although the last type of farms constitutes the 96 % of Bulgarian pig production. Backyard farms are heterogeneously distributed along the country as shown in the following figure (*Figure 16*).

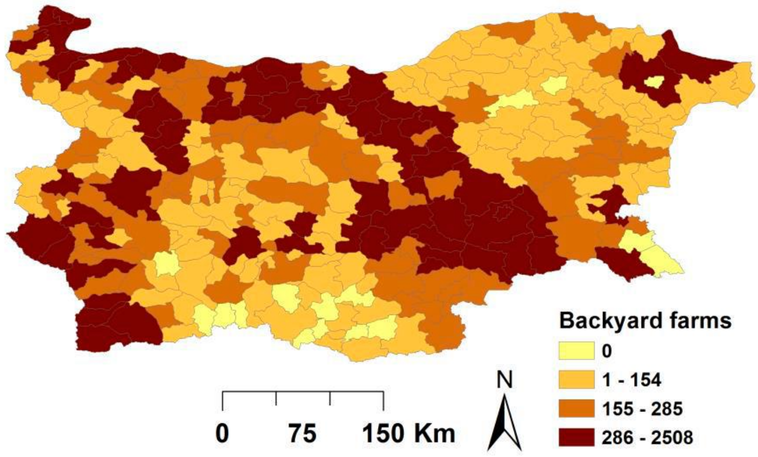

Figure 16: total number of backyard farms in Bulgaria (data obtained from BFSA)

Therefore, low biosecurity family farms and backyard farms are common in Bulgaria and Romania. Both kind of farms could constitute a risk of viral perpetuation and may play a role in facilitating the entrance of an infectious disease, for example ASF. In addition, the entrance of the disease could happen through wild boar contact due to free ranging domestic pigs are reared in several areas of these countries and they could have direct and indirect contact with wild boars.

3. ***<u>Both systems</u>*** *(the Russian Federation)*

<u>The Russian Federation (RF)</u>: the Russian pig census is roughly 17.5 million pigs, which are kept in specialised breeding holdings (63 %), peasant farms of small businesses, holdings administered by the executive bodies of the RF (Ministry of Defence, the Federal Penitentiary Service, etc.) as well as in backyard farms (27 %).

In 2013, 85.4 % of <u>pig population</u> is concentrated in four federal districts: the Central (28.8 %), the Volga (25.4 %), the Siberian (17.2 %) and the Southern (14.4 %) with pig densities higher than 4 animals per Sq km (see *Figure 17*).

On the other hand, <u>backyard farms</u> (27 % of Russian pig census) are mainly located in Southern regions of the RF (see *Figure 18*). In Krasnodarskiy kray, Rostovskaya oblast, Tverskaya oblast and Voronezskaya oblast this population has been decreased because of the implementation of several control and preventing measures over the past 2-3 years.

In addition, <u>free range production</u> is seasonally practiced in South Ossetia and parts of the North Caucasian and Southern federal districts.

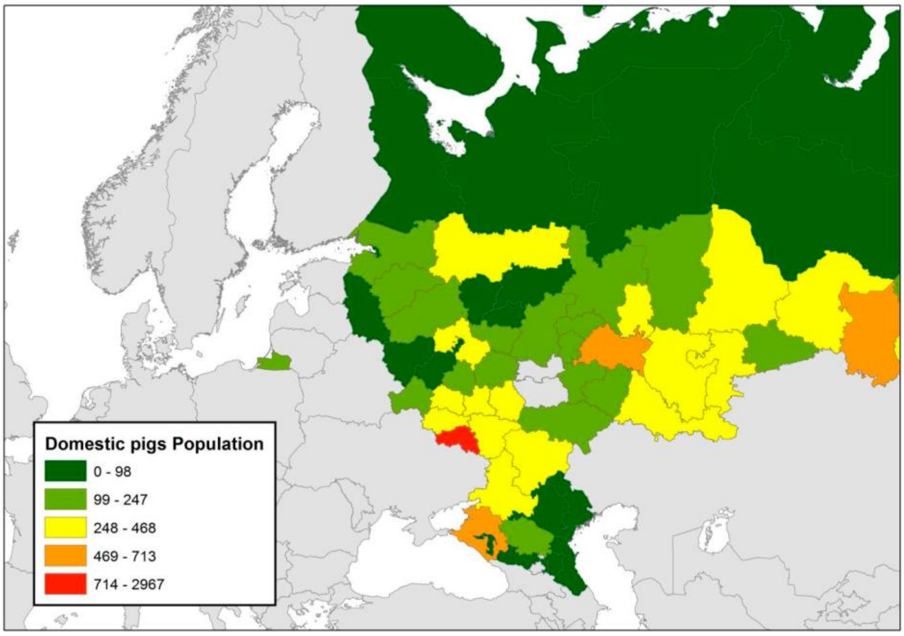

Figure 17: thousand heads per region (data obtained from the National Research Institute for Veterinary Virology and Microbiology of Russia, VNIIVViM)

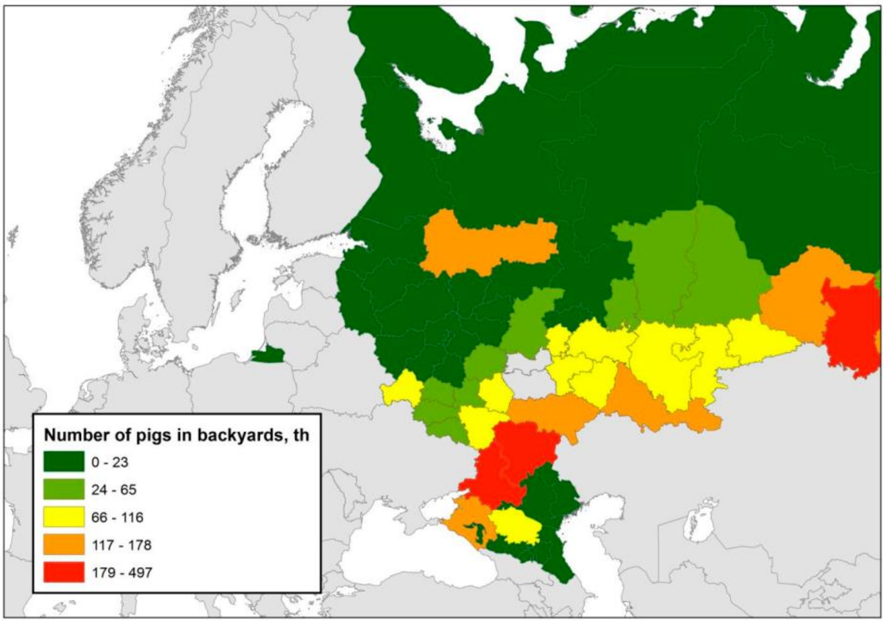

Figure 18: thousand heads per region (data provided by, VNIIVViM)

Currently, low biosecurity production systems (backyard farms and small farms) constitute the main risk of ASF in the RF. Prevention and control of infectious diseases is more challenging in this scenario due to lower levels of awareness, low biosecurity standards, inadequate monitoring of veterinary services, lack of transparency in its production (vaccination, treatments, movements, etc.) and absence of animal identifications and traceability systems.

To all of the above it must be added that these holdings commonly practice risk activities as the use of swill as supplementary feed (swill feeding), often including untreated ASF-contaminated pig meat or pork products. Moreover, low biosecurity production systems do not receive or not have access to much institutional support to deal with animal diseases as ASF.

Evaluation of driving forces in pig trade

As previously mentioned, Germany and Spain are the two countries with the largest number of pigs as well as the main producers in the European Union (EU). With regard to trade, Germany is the main importer of young pigs (77 % of EU imports) and breeding animals (46 % of EU imports), while Denmark is the main exporter with 74 % and 23 % of EU exports, respectively.

For the evaluation of driving pig forces in pig trade, two different scenarios (four countries: Bulgaria, Italy, France and Spain) were selected according to existing pig production system:

- Scenario 1:
    - Bulgaria and Italy (Centre and South): predominance of backyard pig production
    - Corsica and Sardinia (French and Italian islands): mostly free-range production
- Scenario 2:
    - France and Spain: countries with high pig density

Data collected for the analysis of pig trade patterns were obtained from BFSA in Bulgaria, data base of pig movements in France (BD-PORC), Istituto Zooprofilactico Sperimentale (IZS) in Italy, and MAGRAMA in Spain.

For this assessment, several factors such as management systems, socio-cultural factors, economical factors, price differentials and animal movement legislation were investigated.

Scenario 1

Areas with backyard or free-range production (Bulgaria, mainland Italy, Sardinia and Corsica): in all these countries two peaks on the number of animal movements **to slaughterhouses** were observed in autumn and winter. It could be due to cold temperatures are required as natural method for preserving meat during butchering and the increased demand for pork products in Christmas festivities. In Sardinia, two additional peaks were identified in spring and summer, most likely associated with Easter celebration and tourist arrival, respectively. Furthermore, since 2012 Sardinia show an increase in the number of movements reported to slaughterhouses without altering the seasonal pattern. It might be due to the change in legislation regarding pig movements in December 2011, with an expansion of the high risk area for ASF to the entire territory of the island (new restrictive measures and the ban of exportations have been established).

Pig movements to slaughterhouses by country/region are summarized as follows:

- In Bulgaria, less than 1 % of pig holdings reported to be involved in sending pigs to slaughterhouses. Most of shipments came from industrial farms (74.2 %) and family farms with high biosecurity levels and medium size, they were sent in most of the cases to the same oblast or to adjacent oblasts. Distance of shipments to slaughterhouses was in 50 % of the cases less than 32.2 km (75 % < 80 km and 95 % < 244.7 km).

- In Italy, only 11 % of pig holdings reported moving pigs to slaughterhouses. Most of these movements came from finishing (56.4 % in 2011) and breeding farms (39.1 % in 2011), with an increase in the number of reported movements between 2006 and 2013. The majority of movements went to slaughterhouses located in Northern and Central regions, followed by slaughterhouses located in Southern region of Campania.
- In Corsica Island, the number of pig shipments to slaughterhouses increased from 2010 to 2013 and almost 24 % of pig holdings reported this kind of movement. No shipments were reported to be sent outside the island.
- In Sardinia Island, almost 24 % of pig holdings reported to be involved in moving pigs to slaughterhouses. Most of them came from Sardinian holdings (96 %) and few of them (3 %) from the northern regions of Italy mainland (Lombardia, Emilia Romagna and Veneto).

The animal movements **between farms** showed a seasonal pattern in Italy. Two peaks were observed in April and one in September, most likely associated to supply backyard farms for Easter and fattening farms for Christmas. This pattern was not observed in the other areas. In Corsica, pig farmers mostly trade reproductive animals during the year and buy fattening pigs before the slaughter season if it is needed, i.e. if they did not achieve to produce a sufficient amount of finishing pigs.

Movements between farms by country/region are summarized as follows:

- In Bulgaria, most of farms that reported to be involved in pig shipments were backyard farms (84 % of active farms) which mostly received and sent pigs from/to other local backyard farms. In most of the cases, the suppliers of backyard farms were family farms with high-to-low biosecurity levels. On the other hand, when industrial farms sent/received animals they came from/go to other industrial farms. There were also identified specific trade relations from Varna region to Shumen oblast, and from Shumen to Blagoevgrad, Plovdiv and Sofia oblasts that might play a role in the diffusion of pathogens.
- In Italy, between 2006 and 2013 there was an increase in the number of animal movements, with less than 36 % of holdings reporting moving pigs to other farms. Most of pig shipments reported during these years came from breeding (53 %) and finishing (36 %) farms, which mostly sent animals to finishing and backyard farms located in the same region. The distance of moving pigs between farms was in 50 % of the cases less than 22 km. In addition, there was identified a flow of pigs followed a North-to-South axis and long-distance flows of pigs from North-Western and North-Eastern regions to Southern regions.
- In Corsica Island, only farrow-to-finish farms and "other types of farm" (farms not registered as artificial insemination centre, breeding, farrow-to-grow, farrow-to-finish, growing, grow-to-finish neither finishing) reported animal movements. The number of movements was increased from 2010 to 2012 and most of them

(53 %) were sent by finishing herds from France mainland to farrow-to-finish farms and “other types of farm” in Corsica.

- In Sardinia Island, no shipments were reported to be sent outside the island. The trading chain was mostly concentred in breeding farms and minority in backyard holdings, finishing farms and other farms. Few movements (7 %) from Northern regions of Italy mainland were also reported (Lombardia, Elimia Romagna and Veneto). In the same way that mainland Italy, pig movement in Sardinia increased from 2006 to 2012, with less than 6 % of holdings reporting movements.

Animal movements to slaughterhouses and between farms were grouped weekly and were summarized in the graphics shown below (*Figures 19*, *20*, *21* and *22*).

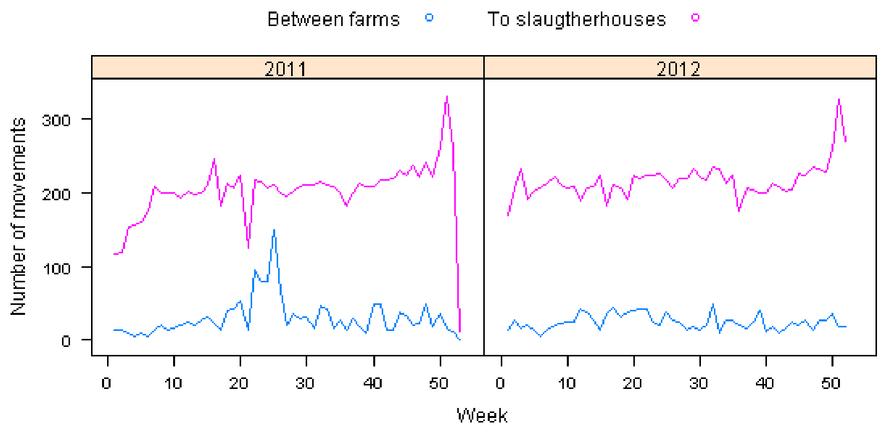

Figure 19: Nº of weekly pig movements between farms and to slaughterhouses in Bulgaria, 2011-2012

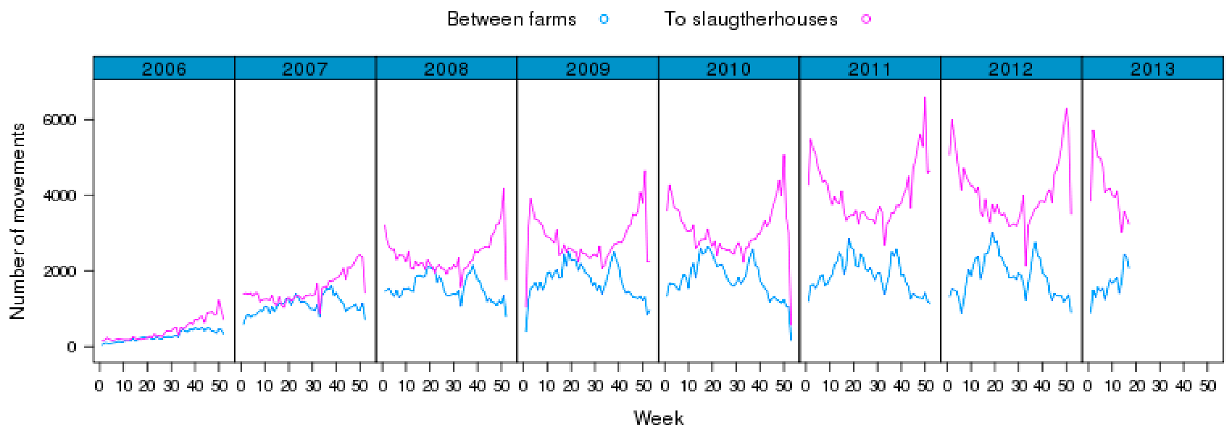

Figure 20: Nº of weekly pig movements between farms and to slaughterhouses in Italy, 2006-2013

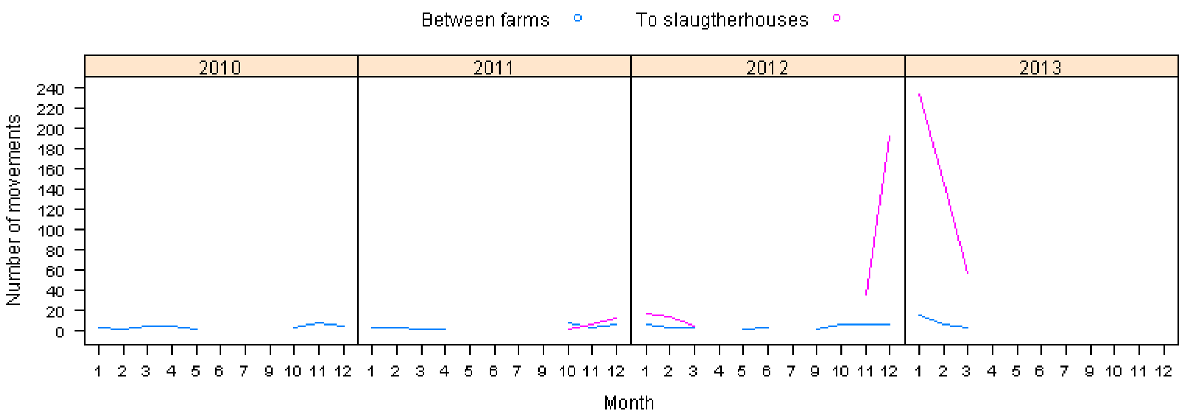

Figure 21: Nº of weekly pig movements between farms and to slaughterhouses in Corsica, 2010-2013

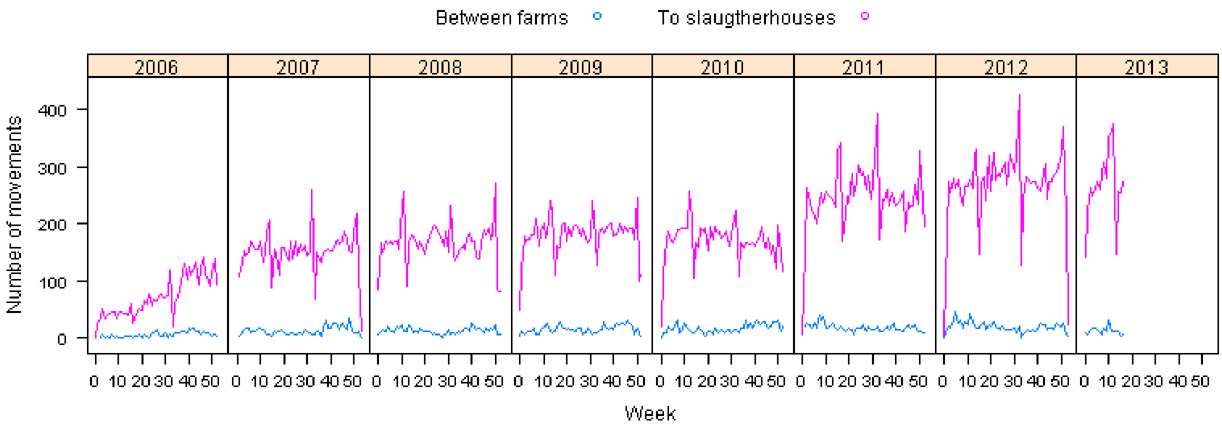

Figure 22: Nº of weekly pig movements between farms and to slaughterhouses in Sardinia, 2006-2013

Scenario 2

Areas with industrial pig production (France and Spain): in both countries the number of animal movements to **slaughterhouses** and between **farms** oscillated during the years under study without clear seasonal patterns. In Spain, the highest number of pig movements seemed to be concentrated around December-January, most likely associated to Christmas celebration.

Pig movements to slaughterhouses and between farms are summarized as follows:

- In France, most of shipments between farms (69 %) came from farrow-to-finish farms and were sent to farrow-to-finish, finishing and grow-to finish farms and to dealer holdings, most of them at regional level. Dealer holdings sent mostly pigs to foreign sites as Belgium or Germany. Likewise, few shipments came from Germany, Belgium and Spain to fattening farms. On the other hand, animal movements to slaughterhouses were reported by almost 66 % of pig holdings. Most of pig shipments came from breeding and fattening farms. The distance of these shipments were similar to those between farms, in 50 % of the cases less than 50 km.

- In <u>Spain</u>, most of movements (64.6 %) occurred within regions and between production-reproduction farms, whereas 27.7 % occurred between this type of farms and slaughterhouses. Most of origin movements (37.4 % of movements between farms) came from Castilla y León and Aragón and they were sent to Castilla y León and the Southern region of Andalucía.

Likewise, animal movements to slaughterhouses and between farms were grouped weekly and were summarized in the graphics shown below (*Figures 23* and *24*).

Figure 23: Nº of weekly pig movements between farms and to slaughterhouses in France, 2010-2013

Figure 24: Nº of weekly pig movements between farms and to slaughterhouses in Spain, 2010-2011

Molecular characterization of current European ASFV isolates and new genome markers described

An initial genetic characterization was performed by using extracted DNA directly from clinical specimens or primary cell cultures. These phylogenetic studies were based on the routinely used genome segments as C-terminal end of p72 gene, the full sequence of p54 gene and the central variable region within the B602L gene. Furthermore, in order to discriminate between closely related ASFV strains, it was necessary to study other genome marker, which was included for deeper subtyping analysis of Sardinian and Eastern European isolates (Gallardo et al., 2014). It is located between the 173R and 1329L genes and characterized by the presence of TRS. This new marker has been proved to be useful in ASFV from Eastern Europe.

In order to determine the dynamic of the infection, 473 ASFV isolates from Eastern Europe and Sardinia were molecularly characterised. The results obtained are summarized below:

a) ***Eastern European ASFV isolates***. A total of 408 Eastern European ASFV isolates obtained since 2013 up to September 2015 from domestic pigs and wild boar were characterised. The viruses selected for genotyped comprised 80 Russia ASFV isolates, 84 Estonia ASFV isolates, 29 Latvia ASFV isolates, 107 Lithuania ASFV isolates, 104 Poland ASFV isolates, 3 Belarus ASFV isolates and 1 Ukraine ASFV isolate.

   The sequences obtained were compared with already available sequences at CISA and VNIIVViM from 25 genotype II ASFVs that were isolated from wild and domestic pigs in Russia and the Caucasus region during April 2007–December 2012. **The main conclusions were**;

   - All Eastern European ASFV isolates affecting the domestic pig and wild boar clustered within p72 genotype II indicating **a single introduction in East Europe since 2007 from East Africa.**
   - Deeper subtyping throughout the sequence analysis of the intergenic region between the I73R and I329L genes (IGRI73R-I329L) revealed the presence of **two genetic variants** [GII-IGR-1 and GII-IGR-2] co-circulating in the Russia Federation since 2012.
   - The new genetic variant was identified in April 2012 in Tulskaya region (GII-IGR-2) and it was characterised by a TRS insertion which was absent in previous Eastern European ASFV isolates. The results showed that the virus responsible of the outbreak occurred three months later in Ukraine in domestic pig had this TRS insertion.
   - Further subtyping analysis of Russian ASFV isolates has allowed determining that **the viruses with TRS insertion prevail among current disease outbreak in both wild and domestic animals as well as is that one currently circulating in the four EU countries affected.**

- The CVR amplification included in the standardized genotyping procedures, allowed recently to find **a new genetic CVR variant** (named GII-CVR-2) recently **circulating within the wild boar population in Estonia.**

b) ***Sardinian ASFV isolates.*** For the purpose of this study, pig macrophage cell culture isolates and clinical specimens obtained from 65 ASF Sardinian outbreaks occurred during the period 2011–2015 were selected and sequenced. The viruses analysed were 36 from domestic pigs and 29 collected from wild boar. **The main conclusions were;**

- The Sardinian viruses were placed in the largest and most homogeneous p72 genotype I together with viruses from Europe, America and West Africa. **This data indicates a single introduction in 1978.**
- The analyses of the amino acid tetramer repeats sequences within the CVR of Sardinian isolates, revealed the presence of 12 repeats identical to those included into the previously defined CVR sub-group X which is represented by viruses collected from 1990 up to 2010.
- Deeper subtyping analysing the inter-genic region among I73R and I329L genes showed 100 % of homology among all ASFV isolates.
- These results combined with that obtained by the classical genotyped indicated **a low-rate evolution in the Sardinian viruses having a field presence of 25 years** (1990–2015).

Preventing Measures against ASF: "ASF Master Chef"

A group of 14 representatives of the chief veterinary officers (CVOs) from 11 European countries (Austria, Denmark, Finland, Germany, Latvia, Netherlands, Norway, Poland, Slovakia, Switzerland and United Kingdom) ranked in order of importance 20 preventing measures which were classified into three main sections: early detection (8 measures), contingency plan (10 measures) and training and education (2 measures). This way, questionnaires aimed to identify the priorities within each section by comparing between elements that integrate each section. Furthermore the collaboration of these ratters allowed the inclusion of important extra-measures to the list of measures.

1. **Early detection**
    a. Control of animal movements and social network analysis
    b. Be aware of ASF
    c. ASF knowledge
    d. Diagnosis program adequate to the risk
    e. Information about farms: census, location and biosecurity level
    f. Early field detection by active and passive surveillance program (RBS)
    g. Risk factors for each country
    h. Communication between laboratories and field
2. **Contingency plan**
    a. To establish the restriction area and farms related
    b. Wild life evaluation
    c. Safe slaughter program and carcasses destruction
    d. A complete manual of all different actions
    e. Study all potential farms that could be affected by distance or epidemiological relations
    f. Animal inspection and sampling of suspected animals
    g. Field action team
    h. Cleaning and disinfection program
    i. Evaluation of the presence of ticks
    j. Surveys: to evaluate potential entrance and possible spread
3. **Continuing education and training**
    a. Training of veterinary services
    b. Training simulations: theoretical, field and digital
    c. Farmers' education
4. **Extra-measures**
    a. Communication to media, press, people, etc.
    b. Hunters' education

In order to compare the results obtained, the mode (most voted rank value), as well as, the variability of responses relative to the mode for each measure (consensus) was calculated.

For early detection (see Table 1), awareness, knowledge on ASF and on its risk factors were ranked higher than other measures. There was a higher consensus for awareness than for the two other factors. Communication between laboratories and the field was ranked last in importance for early detection.

Table 1: preventing measures for early detection

EARLY DETECTION	Mode	Consensus
BE AWARE	1	0.625
KNOWLEDGE	2	0.375
RISK FACTORS	2	0.267
DIAGNOSIS PROGRAM	3	0.267
SURVEILLANCE	4	0.313
FARMS	5	0.4
SOCIAL NETWORK ANALYSIS	6	0.6
COMMUNICATION	8	0.5

For contingency (Table 2), a complete manual of all different actions, sampling of suspected animals, field action team and restriction area were ranked higher than the other measures. The consensus for all measures was low except for ticks, which were ranked last in importance with the highest consensus.

Table 2: preventing measures for contingency plan

CONTINGENCY PLAN	Mode	Consensus
COMPLETE MANUAL	1	0.4
SAMPLING	2	0.375
FIELD TEAM	2	0.267
AREA	2	0.25
SURVEY	3	0.333
POTENTIAL FARMS	3	0.25
SLAUGHTER/CASCASSES	4	0.375
WILD LIFE	5	0.25
C+D	7	0.25
PRESENCE OF TICKS	10	0.93

Finally**, for training and education** (Table 3) training veterinary services and farmer's education were ranked first and second position respectively, for both measures the consensus was very high.

Table 3: preventing measures for training and education

TRAINING AND EDUCATION	Mode	Consensus
VETERINARY TRAINING	1	0.75
FARMER EDUCATION	2	0.75

Then, in order to estimate the epidemiological weight, experts were asked to weight each measure from 1 to 5 according to its importance (being 5 the most important measure). In this case, the variability of responses relative to the mode and the median were evaluated.

For early detection, the highest epidemiological weight, with a high consensus, was attributed to be aware of ASF, followed by early field detection by active and passive surveillance program, **ASF knowledge, a diagnosis programme adequate to the risk and risk factor for each country**. With medium importance were control of animal movements and social network analysis and communication between laboratories and field. Finally, the lowest weight was given to information about farms.
It is interesting to note that for the two countries that have experienced ASF outbreaks, Poland and Latvia, be aware of ASF was classified with a low weight. Similarly, for these two countries and for Norway, active and passive surveillance also was weighted low. Risk factors, even if most frequently weighted as very important presented a high variability in responses (from 1 to 5); for the affected countries, risk factors were weighted between 3 and 4. For Latvia, the highest weight corresponded to diagnosis and communication.

As for the contingency plan, sampling of suspected animals and presence of ticks presented the highest consensus score. Sampling of suspected animals had the highest weight and ticks had the lowest weight. However, for Latvia and one of the German colleagues, ticks had the highest weight. The highest variability in weight was obtained for wild life evaluation, maybe because of the difference in wild life population by country. This way, for the UK and for Norway, wild life was scored as very low, whereas for Latvia and Switzerland, it was scored as very high. Although a complete manual of all different actions was scored as very important by the majority of countries, the median was finally not the highest value because for Latvia (1), one of the German ratters (1) and Switzerland (2), it scored either 1 or 2.

Finally, for the training section, the consensus between CVOs was more homogeneous. The two measures proposed were scored with a high weight by most of the countries (except for Latvia, one German CVO and the colleague from Switzerland).

The following table (Table 4) summarizes these results.

Table 4: epidemiological weigh of preventing measures proposed

	MEASURES	MEDIAN	CONSENSUS
EARLY DETECTION	BE AWARE	5	0.714
	SURVEILLANCE	4.5	0.5
	KNOWLEDGE	4	0.357
	DIAGNOSIS PROGRAM	4	0.429
	RISK FACTORS	4	0.357
	SOCIAL NETWORK ANALYSIS	3	0.5
	COMMUNICATION	3	0.429
	FARMS	2.5	0.429
CONTINGENCY PLAN	SAMPLING	5	0.714
	AREA	4	0.429
	SLAUGHTER/CASCASSES	4	0.357
	COMPLETE MANUAL	4	0.357
	POTENTIAL FARMS	4	0.429
	FIELD TEAM	4	0.429
	C+D	4	0.357
	WILD LIFE	3	0.357
	SURVEY	3	0.286
	TICKS	1	0.786
TRAINING	VET TRAINING	5	0.786
	FARMER EDUCATION	4.5	0.5

ASF in Europe: risk zones and control strategies

A zone was defined as a clearly part of a territory containing an animal subpopulation with a distinct health status with respect to a specific disease for which surveillance and intervention strategies should be defined (OIE, 2015).

Two different zones were considered according to current ASF situation in Europe:

- <u>ASF-free zone</u>: area in which no evidence of ASF infection has been found but which is at risk of introduction due to sharing borders with infected zones, buffer zone, illegal animal trade with infected areas, etc.
- <u>ASF-infected zone</u>: area where ASF outbreaks occurred either in domestic pigs, wild boar or both.

Mitigation strategies against ASF will be specified for each scenario taking into account the existing differences between both scenarios above identified.

- In <u>ASF-free zones</u> the main objectives of control strategies should be:
  - To remain free for ASF through preventive measures and targeted surveillance.
  - To detect the introduction of the virus as early as it has been introduced in order to minimize the economic impact of the disease.
  - To prevent further spread in case of introduction.

- In <u>ASF-infected zone</u> the mitigation strategies will be focused on:
  - To contain ASF outbreaks and eradicate the disease.
  - To establish measures that allow to reduce/stop ASF spread.
  - To know epidemiological situation (distribution and occurrence of the disease) through surveillance systems.

Then, **ASF management options** were identified from published and unpublished literature and evaluated by 57 ASF experts (36 from the ASFORCE project and 21 external experts) on the basis of their practicality and effectiveness under the two ASF scenarios described.

Firstly, a <u>practical strategy</u> was defined as likely to be feasible in real circumstances; this includes a component of cost, logistic implementation and acceptability. Then, an <u>effective strategy</u> was defined as successful in producing the intended result, such as reducing the likelihood of ASFV introduction and spread, detecting ASFV introduction as early as possible, containing as many outbreaks as possible and minimising the economic impact of ASF disease. Finally, 21 surveillance strategies and 22 intervention strategies were selected and ranked by experts. Results obtained were collected in the following tables (Table 5 and Table 6) and all strategies have been listed and defined in annex 1 (Table 7 for surveillance strategies and Table 8 for intervention strategies).

Table 5: numbered list of the surveillance strategies

Number	Surveillance strategy
1	Active surveillance of pigs at abattoirs and rendering plants
2	Active surveillance of pigs at sentinel abattoirs and rendering plants
3	Active surveillance of pigs at farms
4	Active surveillance of pigs at sentinel farms
5	Passive surveillance of pigs at farms
6	Enhanced passive surveillance of pigs at sentinel farms
7	Syndromic surveillance of pig mortality
8	Active surveillance of pig products at butchers, markets and supermarkets
9	Active surveillance of pig products confiscated at the border
10	Active surveillance of fomites
11	Passive surveillance based on inconclusive CSF testing
12	Active surveillance of ticks in tick habitats
13	Active surveillance of ticks in pig farms
14	Active surveillance of ticks in sentinel pig farms
15	Passive surveillance of ticks at farms
16	Enhanced passive surveillance of ticks in sentinel pig farms
17	Active surveillance of wild boar
18	Passive surveillance of hunted wild boar
19	Passive surveillance of wild boar found dead
20	Enhanced passive surveillance of hunted wild boar and wild boar found dead
21	Awareness campaigns for stakeholders

Table 6: numbered list of the intervention strategies

Number	Intervention strategy
1	Culling of all infected herds
2	Intensive monitoring of neighbouring herds
3	Culling of neighbouring herds
4	Intensive monitoring of traced herds
5	Culling of traced herds
6	Heat treatment followed by consumption of neighbouring or traced herds
7	Movement bans for neighbouring herds
8	Movement bans for traced herds
9	Ban of swill feeding
10	Thorough cleaning and disinfection of buildings, transport vehicles and PPE
11	Health and safety regulations on farms
12	Farm entrance restrictions on people
13	Containment of pigs
14	Ban of live animal markets
15	Health and safety regulations at border
16	Ban of large-scale drive hunting of wild boar
17	Supplementary feeding of wild boar
18	Ban of supplementary feeding of wild boar
19	Targeted hunting of wild boar
20	Carcass removal of wild boar
21	Exclusion/Fencing of wild boar
22	Wild boar deterrents

Once strategies were fixed, experts ranked surveillance and control strategies under the two risk scenarios. Experts originating from countries where ASF outbreaks have been notified were assumed to be more aware of the control strategies that should be implemented for this scenario. Therefore, 27 experts were assigned to the ASF-free scenario and 29 experts to the ASF-infected scenario. Nevertheless, all experts were also encouraged to take the other survey.

Results were re-scaled in order to allow comparison and were represented by figures showing the average scores of effectiveness (dark colour) and practicality (light colour) for surveillance and control strategies.

Strategies for ASF-free zone:

Surveillance strategies: enhanced passive surveillance of hunted wild boar and wild boar found dead (nº 20), awareness campaigns for stakeholders (nº 21) and syndromic surveillance of pig mortality (nº 7) were identified as the **most effective** surveillance strategies. Passive surveillance of wild boar found dead (nº 19), passive surveillance based on inconclusive CSF testing (nº 11) and syndromic surveillance of pig mortality (nº 7) were selected as the **most practical** surveillance strategies.

Results are summarized in the figure shown below (*Figure 25*).

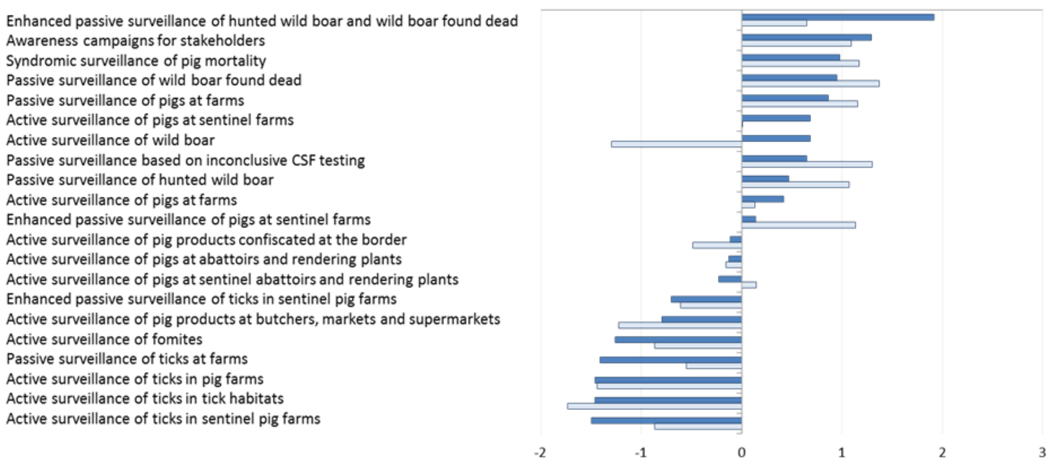

Figure 25: effectiveness (dark blue) and practicality (light blue) scores for surveillance strategies for ASF-free zone

Furthermore, nine strategies were scored positively both in terms of effectiveness and practicality (optimal surveillance strategies). **Optimal surveillance strategies** were ranked in this way:

1. Enhanced passive surveillance of hunted wild boar and wild boar found dead (nº 20)
2. Awareness campaigns for stakeholders (nº 21)
3. Passive surveillance of wild boar found dead (nº 19)
4. Syndromic surveillance of pig mortality (nº 7)
5. Passive surveillance based on inconclusive CSF testing (nº 11)

6. Passive surveillance of pigs at farms (nº 5)
7. Passive surveillance of hunted wild boars (nº 18)
8. Enhanced passive surveillance of pigs at sentinel farms (nº 6)
9. Active surveillance of pigs at farms (nº 3)

Intervention strategies: culling of all infected herds (nº 1), movement bans for traced herds (nº 8) and carcass removal of wild boar (nº 20) were estimated to be the **most effective** intervention strategies. Farm entrance restrictions on people (nº 12), movement bans for neighbouring herds (nº 7) and movement bans for traced herds (nº 8) were identifies as the **most practical** planned intervention strategies.

Results are collected in the figure shown below (*Figure 26*).

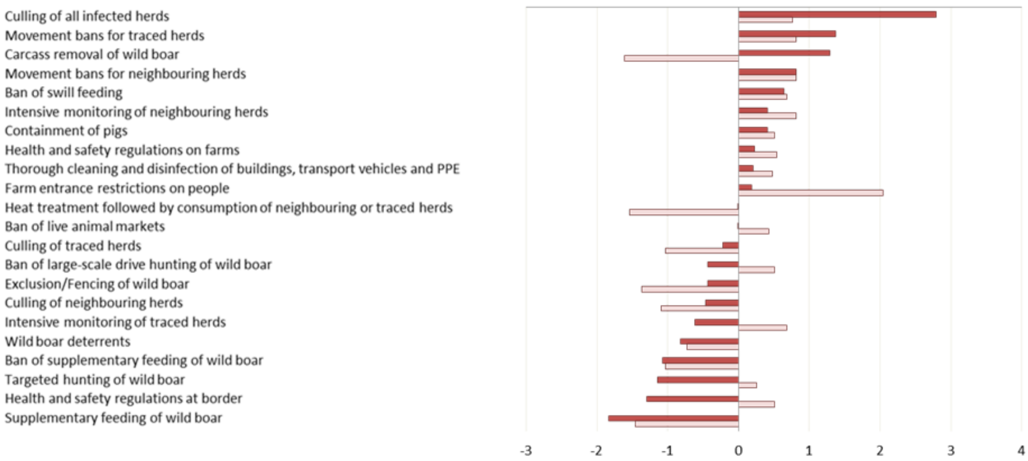

Figure 26: effectiveness (dark red) and practicality (light red) scores for intervention strategies for ASF-free zone

As in the surveillance strategies above mentioned, nine intervention strategies were scored positively in terms of effectiveness and practicality. These **optimal intervention strategies** were scored thus:

1. Culling of all infected herds (nº 1)
2. Farm entrance restrictions on people (nº 12)
3. Movement bans for traced herds (nº 8)
4. Movement bans for neighbouring herds (nº 7)
5. Ban of swill feeding (nº 9)
6. Intensive monitoring of neighbouring herds (nº 2)
7. Containment of pigs (nº 13)
8. Health and safety regulations on farms (nº 11)
9. Through cleaning and disinfection of buildings, transport vehicles and PPE (nº 10)

Strategies for ASF-infected zone:

Surveillance strategies: syndromic surveillance of pig mortality (nº 7), enhanced passive surveillance of hunted wild boar and wild boar found dead (nº 20) and active surveillance of pigs at farms (nº 3) were identified as the three **most effective surveillance** strategies. Then, enhanced passive surveillance of pigs at sentinel farms (nº 6), enhanced passive surveillance of hunted wild boar and wild boar found dead (nº 20) and syndromic surveillance of pig mortality (nº 7) were estimated as the **most practical** surveillance activities.

In the same way, results have been summarized in the following figure (*Figure 27*).

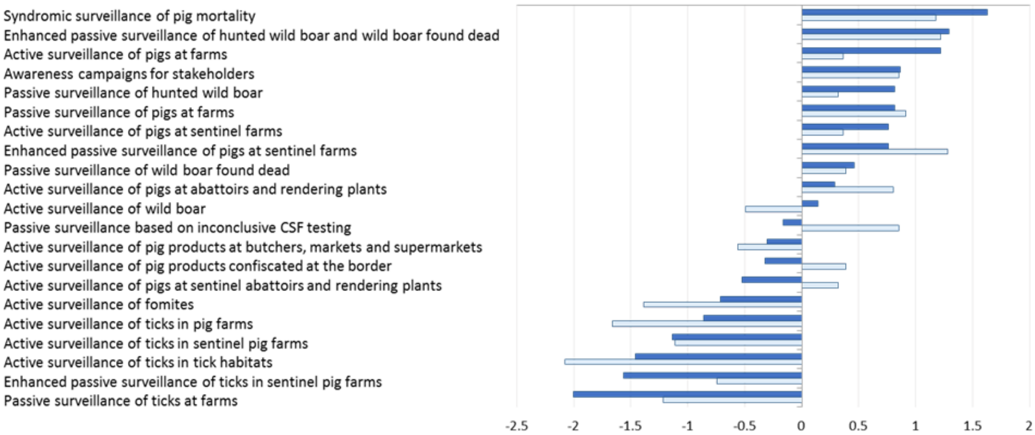

Figure 27: effectiveness (dark blue) and practicality (light blue) scores for surveillance strategies for ASF-infected zone

In this case, ten strategies were identified as **optimal surveillance strategies** against ASF in the infected scenario:

1. Syndromic surveillance of pig mortality (nº 7)
2. Enhanced passive surveillance of hunted wild boar and wild boar found dead (nº 20)
3. Enhanced passive surveillance of pigs at sentinel farms (nº 6)
4. Active surveillance of pigs at farms (nº 3)
5. Passive surveillance of pigs at farms (nº 5)
6. Awareness campaigns for stakeholders (nº 21)
7. Passive surveillance of hunted wild boars (nº 18)
8. Active surveillance of pigs at abattoirs and rendering plants (nº 1)
9. Active surveillance of pigs at sentinel farms (nº 4)
10. Passive surveillance of wild boar found dead (nº 10)

Intervention strategies: culling of all infected herds (nº 1), carcass removal of wild boar (nº 20) and health safety regulations on farms (nº 11) were considered as the **most effective** intervention strategies. In addition, health safety regulations on farms (nº 11), culling of all infected herds (nº 1), containment of pigs (nº 13) and movement bans for neighbouring herds (nº 7) were estimated as the **most practical** intervention strategies.

The following figure (*Figure 28*) sums up effectiveness and practicality scores for intervention strategies.

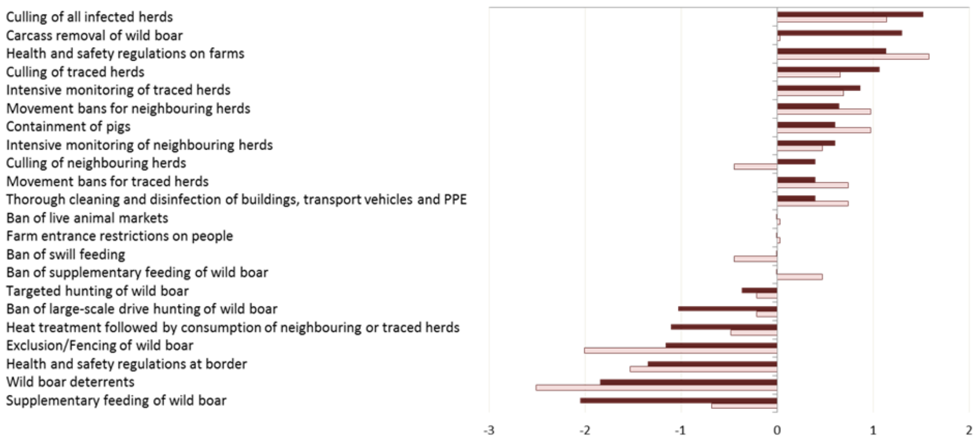

Figure 28: effectiveness (dark red) and practicality (light red) scores for intervention strategies for ASF-infected zone

Finally, nine strategies were considered **the optimal intervention strategies** which were ranked:

1. Health safety regulations on farms (nº 11)
2. Culling of all infected herds (nº 1)
3. Culling of traced herds (nº 5)
4. Movement bans of neighbouring herds (nº 7)
5. Containment of pigs (nº 13)
6. Intensive monitoring of traced herds (nº 4)
7. Movement bans for traced herds (nº 8)
8. Thorough cleaning and disinfection of buildings, transport vehicles and PPE (nº 10)
9. Intensive monitoring of neighbouring herds (nº 2)

Other interesting ASFORCE information

1. Online course on African swine fever (http://asforce.org/course/)
    a. Module 1: Suspicion
    b. Module 2: Confirmation, control and eradication
    c. Module 3: Prevention and biosecurity
2. Video "African swine fever awareness" (http://asforce.org/blog/111). It addresses:
    a. Main characteristics of the disease (etiology, clinical signs)
    b. Geographical spread
    c. Routes of transmission
    d. Good practices to control ASF
3. Overview on ASF spread in Eastern Europe and European Union states since 2007 up to September 2015 (http://asforce.org/blog/110)

ANNEX 1

Table 7: Definitions of the 21 surveillance strategies selected for ASF

Measure	Definition/Example	References
Surveillance in domestic pigs		
Active surveillance of pigs at abattoirs and rendering plants	This consists in the repeated collection of data from randomly selected abattoirs and rendering plants to identify changes in pig health status (i.e. performing clinical inspections, sample collection, laboratory tests, etc.). The difference with "*active surveillance of pigs at sentinel abattoirs and rendering plants*" is that here, the abattoirs and rendering plants are expected to change over time.	(Beltrán-Alcrudo et al., 2008; RISKSUR, 2013)
Active surveillance of pigs at sentinel abattoirs and rendering plants	This consists in the repeated collection of data from selected abattoirs and rendering plants to identify changes in pig health status in abattoirs and rendering plants (i.e. performing clinical inspections, sample collection, laboratory tests, etc.). The difference with "*active surveillance of pigs at abattoirs and rendering plants*" is that here, the selected abattoirs and rendering plants are expected to remain the same over time and have been identified as high risk of disease introduction.	(Beltrán-Alcrudo et al., 2008; RISKSUR, 2013)
Active surveillance of pigs at farms	This consists in the repeated collection of data from randomly selected farms to identify changes in pig health status (i.e. performing clinical inspections, sample collection, laboratory tests, etc.). The difference with "*active surveillance of pigs at sentinel farms*" is that here, the farms are expected to change over time.	(Beltrán-Alcrudo et al., 2008; RISKSUR, 2013)
Active surveillance of pigs at sentinel farms	This consists in the repeated collection of data from selected farms to identify changes in pig health status in farms (i.e. performing clinical inspections, sample collection, laboratory tests, etc.). The difference with "*active surveillance of pigs at farms*" is that here, the selected farms are expected to remain the same over time and have been identified as high risk of disease introduction.	(Beltrán-Alcrudo et al., 2008; RISKSUR, 2013)
Passive surveillance of pigs at farms	Farmers and animal workers report voluntarily the suspicion of ASF on their farm to the competent authority. Suspicion can come from the close monitoring of pig production data (e.g. syndromic surveillance mortality at farm level).	(Beltrán-Alcrudo et al., 2008; RISKSUR, 2013)
Enhanced passive surveillance of pigs at sentinel farms	Farmers and animal workers report voluntarily the suspicion of ASF on their farm to the competent authority. The difference with "*passive surveillance of pigs at farms*" is that here, farms identified as high risk of disease introduction, are more likely to report a suspicion. Enhancement may come	

	from financial incentives, improved awareness of ASF clinical signs, current legislation, etc.	
Syndromic surveillance of pig mortality	Systematic collection and monitoring of pig mortality data at zone level to detect any unusual increase.	(Perrin et al., 2010)
Active surveillance of pig products at butchers, markets and supermarkets	This consists in the repeated collection of data from pig products at butchers, markets and supermarkets to identify changes in pig product status (i.e. performing sample collection, laboratory tests, etc.) and to detect if infected pig products have entered the food chain.	
Active surveillance of pig products confiscated at the border	This consists in the repeated collection of data from pig products at airports, ports and land borders, particularly when originating in infected countries.	
Active surveillance of fomites	This consists in the repeated collection of data from trucks that transport pigs, but also agricultural products that could be infected (feedstuff) to identify virus contamination.	
Passive surveillance based on inconclusive CSF testing	Investigation of classical swine fever-suspect farms for which a confirmation or laboratory diagnosis has not been reached.	
Surveillance in ticks		
Active surveillance of ticks in tick habitats	This consists in the repeated collection of ticks in tick habitats (such as rodent burrows etc.) for being tested for ASF diagnosis.	
Active surveillance of ticks in pig farms	This consists in the repeated collection of ticks in randomly selected pig farms for being tested for ASF diagnosis.	(Diaz et al., 2012)
Active surveillance of ticks in sentinel pig farms	This consists in the repeated collection of ticks in selected pig farms for being tested for ASF diagnosis. The difference with "*active surveillance of ticks at farms*" is that here, the selected farms have been identified as high risk for ASFV maintenance in ticks because of contacts between ticks and pigs have been identified by performing serological testing against tick bite in domestic pigs (to find antibodies against the salivary glands of *Ornithodoros* ticks).	(Canals et al., 1990; Oleaga-Pérez et al., 1994)
Passive surveillance of ticks at farms	Farmers and animal workers report voluntarily the presence of ticks on farm to the competent authority for being tested for ASF diagnosis.	

Enhanced passive surveillance of ticks in sentinel pig farms	Farmers report voluntarily the presence of ticks on selected farm to the competent authority for being tested for ASF diagnosis. The difference with "*passive surveillance of ticks at farms*" is that here, farms identified as high risk for ASFV maintenance in ticks, are more likely to report the presence of ticks. These farms were selected because of contacts between ticks and pigs have been identified by performing serological testing against tick bite in domestic pigs (to find antibodies against the salivary glands of *Ornithodoros* ticks). Enhancement may come from financial incentives, improved awareness of ASF clinical signs, current legislation, etc.	
Surveillance in wild boar		
Active surveillance of wild boar	This consists in the repeated captures (by trapping, hunting, etc.) of wild boar to identify changes in wild boar health status (i.e. performing clinical inspections, sample collection particularly with the use of non-invasive sampling, laboratory tests, etc.).	
Passive surveillance of hunted wild boar	Hunters report voluntarily hunted wild boar to the competent authority for collection of samples being tested for ASF diagnosis.	(Beltrán-Alcrudo et al., 2008; RISKSUR, 2013)
Passive surveillance of wild boar found dead	Hunters (but also farmers, walkers, etc.) report voluntarily wild boar found dead to the competent authority for collection of sample being tested for ASF diagnosis.	(Beltrán-Alcrudo et al., 2008; RISKSUR, 2013)
Enhanced passive surveillance of hunted wild boar and wild boar found dead	Hunters (but also farmers, walkers, etc.) of selected areas report voluntarily hunted wild boar and wild boar found dead to the competent authority for being tested for ASF diagnosis. The difference with "*passive surveillance of wild boar*" is that here, selected forests have been identified as high risk for disease introduction. Enhancement may come from financial incentives, improved awareness of ASF clinical signs, current legislation, etc.	
Awareness campaigns for stakeholders	This consists in training and educating stakeholders (such as farmers, middlemen, hunters, etc.) about the significance of ASF to help them to identify symptoms of ASF and to encourage them to cooperate with veterinary authorities.	

Table 8: Definitions of the 22 intervention strategies selected for ASF

Measure	Definition/Example	References
Interventions in domestic pigs		
Culling of all infected herds	All infected herds are culled. This also includes proper disposal of all dead pigs and financial compensation for culled and dead pigs.	(Arias et al., 2008 ; Beltrán-Alcrudo et al., 2008)
Intensive monitoring of neighbouring herds	Herds, which are located within a defined radius around infected herds, are subjected to intensive monitoring of mortality. This is an alternative to "*culling of neighbouring herds*".	
Culling of neighbouring herds	Culling of herds which are located within a defined radius around infected herds. This also includes proper disposal of all culled pigs. This is an alternative to "*intensive monitoring of neighbouring herds*".	(Backer et al., 2009 ; Tildesley et al., 2009)
Intensive monitoring of traced herds	Herds, which did trade pigs with the infected herds, are subjected to intensive monitoring of mortality. This is an alternative to "*culling of traced herds*".	
Culling of traced herds	Culling of herds which did trade pigs with the infected herds. This also includes proper disposal of all culled pigs. This is an alternative to "*intensive monitoring of traced herds*".	
Heat treatment followed by consumption of neighbouring or traced herds	This is an alternative strategy in countries where there are no funds for financial compensation and so where reporting of outbreaks by the farmers are completely discouraged. Heat processing of the culled (healthy) animals into sausages, canned meat, etc. would allow some sort of compensation.	
Movement bans for neighbouring herds	Ban on animal movements (and products) for herds which are located within a defined radius around infected herds. This might be associated with intensive monitoring of neighbouring herds.	(Fèvre et al., 2006; Velthuis and Mourits, 2007)
Movement bans for traced herds	Ban on animal movements (and products) for herds which did trade pigs with the infected herds.	
Ban of swill feeding	Pigs should be not fed with swill that might contain contaminated remains of pigs. This also includes proper disposal of waste food.	(Beltrán-Alcrudo et al., 2008)

Thorough cleaning and disinfection of buildings, transport vehicles and PPE	From farm-to-farm and from abattoir-to-farm. PPE: Personal Protective Equipment, e.g. clothing, boots, masks, etc.	(Carrieri et al., 2002; Arias et al., 2008; Beltrán-Alcrudo et al., 2008; Mannion et al., 2008; Lowe et al., 2014)
Health and safety regulations on farms	This consists in improving the sanitary barriers: quarantine of pigs at farm entrance (i.e. physical isolation of pigs entering the farm for period of time) and measures to ensure the safe purchase of pigs, (such as vet inspection certificates, testing of pigs, adoption of basis measures of hygiene, etc.). This also implies improved awareness of farmers on ASF clinical signs.	
Farm entrance restrictions on people	Restrictions for public access in all farms. Access to farmland (via footpaths) restricted during outbreaks.	
Containment of pigs	Installation of pens and barriers in all farms for the prevention of contacts with wild boar and reduction of scavenging behavior. This includes the ban of free ranging pig.	(Vicente et al., 2007; Wyckoff et al., 2009; Mur et al., 2014a)
Ban of live animal markets	This could be either a permanent measure or a temporary measure when outbreaks are reported in the area.	
Health and safety regulations at border	This is to prevent the entry of the disease into a zone with luggage inspection, use of dogs, awareness of passengers through posters, random inspections, etc.	
Interventions in wild boar		
Ban of large-scale drive hunting of wild boar	This is a ban on the massive depopulation of wild boar.	(Sodeikat and Pohlmeyer, 2003; Boadella et al., 2012)
Supplementary feeding of wild boar	This consists in supplying feed to wild boar to attract them for contact hunting purposes. This could be used to increase the contact rate and disease transmission in sub-populations. This sub-population would quickly die in a restricted area rather than spreading the disease to nearby populations.	(Geisser and Reyer, 2004)
Ban of supplementary feeding of wild boar	This is a ban on the provision of limited supply of feed to attract wild boar for contact hunting purposes.	(Beltrán-Alcrudo et al., 2008; Sorensen et al., 2014; Lange, 2015)
Targeted hunting of wild boar	The size of the hunting bag remains similar although the population of piglets at early ages and adult females is targeted for hunting in order to reduce the population	(Kramer-Schadt et al., 2007; Toïgo et al.,

	reproduction rate. This also consists in reducing the density population before the risk of disease introduction increases in order to reduce the likelihood of disease spread.	2008; Keuling et al., 2013; Lange, 2015)
Carcass removal of wild boar	This means the collection of carcasses and proper disposal of them.	(Selva et al., 2005; Lange, 2015)
Exclusion/Fencing of wild boar	This consists in the installation and maintenance of (electric) fences to prevent wild boar from entering an area.	(Santilli and Mazzoni della Stella, 2006; Schley et al., 2008; Vidrih and Trdan, 2008)
Wild boar deterrents	This consists in the installation of devices (ex. scare crows) and repellents (ex. olfactory, gustatory) to make wild boar move away from farms.	(Brooks et al., 1988; Schlageter and Haag-Wackernagel, 2011, 2012b, a)

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