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# Effectiveness of methods for controlling wild boar movements

ENETWILD Consortium[1], Pokorny Boštjan, Platovšek Zarja, Al Sayegh Petkovšek Samar, Broz Ludek, Bužan Elena, Duniš Luka, Occhibove Flavia, O'Mahony Kieran, Seferović Anesa, Šprem Nikica, von Essen Erica, Zanet Stefania, Ferroglio Ezio

in cooperation with

Agren Erik, Ballian Dalibor, Benatti Francesco, Belova Orgida, Berdión Oskar, Blanco Jose Antonio, Casaer Jim, Chiari Mario, Črnec Katja, Duradoni Daniele, Fabijanić Nera, Farkas Atilla, Gačić Dragan, Gavier Widen Dolores, Ionescu Ovidiu, Jarosil Tomáš, Jori Ferran, Kukas Hrvoje, Lavazza Antonio, Licoppe Alain, Nahlik András, Marsan Andrea, Mihalca Andrei, Parreira Perin Patricia, Plis Kamila, Podgorszki Tomasz, Rijsk Jolianne, Rotondaro Francesco, Scandura Massimo, Smith Graham, Spek Gerrit-Jan, Staubach Christoph, Stergar Matija, Tari Tamás, Van der Post Jens, Vicente Joaquin

## Abstract

In Europe, wild boars serve as the primary reservoir for African Swine Fever (ASF), and this requires strategies to control disease transmission, including the separation of their populations. This report provides an update on current knowledge on the efficacy of fencing and other population separation methods for wild boar across diverse eco-epidemiological scenarios. This was carried out by: (i) systematic analysis of peer-reviewed scientific literature and field experiences obtained through questionnaires distributed to relevant professionals across Europe, to gather evidence on the effectiveness of fences (solid/mesh and electric), natural barriers, and other methods such as repellents/deterrents in managing wild boar movement and ASF transmission; (ii) defining the most important influential cases (scenarios) for the application of fences and/or other methods in managing wild boar populations, considering factors such as fence types, ASF epidemiology, and different spatiotemporal variables. Evaluation of the method effectiveness relies on both published and unpublished data, including responses to a questionnaire received by end-users and stakeholders across Europe. The findings reveal that while certain barriers can reduce wild boar movements, their effectiveness is influenced by numerous factors such as fence characteristics and landscape features. The most relevant influential factors, determining effectiveness of methods for separating wild boar populations, are recognized, listed and critically discussed. This will enable responsible authorities / decision makers to select the most feasible and cost-effective measure for each situation, considering both epidemiological, ecological, and social factors.

**Key words:** ASF management, wildlife management, wildlife epidemics, fencing, repellents, wild boar separation, landscape fragmentation

[1]www.enetwild.com

**Correspondence:** biohaw@efsa.europa.eu

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# Summary

In Europe, wild boar is the major African Swine Fever (ASF) reservoir. In an effort to control the spread of this disease, management strategies include the separation of wild boar populations. In the context of the ENETWILD project, which specifically focuses on studying wildlife ecology and livestock-human-environment interactions to enhance disease surveillance, an update was requested to review the effectiveness of fencing methods or population separation methods for wild boar in different eco-epidemiological scenarios.

This report aims to assess the effectiveness of fences and other methods for controlling wild boar movement and, consequently, the spread of ASF, in different scenarios through: (1) Collecting scientific evidence from peer-reviewed scientific literature and field experiences on the effectiveness of fences (both solid/mesh and electric fences), natural barriers, and other methods (e.g., repellents/deterrents of different kinds) for controlling wild boar movement and ASF spread; (2) Identifying and defining scenarios for the use of fences and/or other methods to manage wild boar populations to help define those applicable in Europe, considering factors such as fence types, ASF epidemiology, and spatio-temporal variables of separation actions.

The effectiveness of methods is evaluated based on the available scientific literature and unpublished field experiences, taking into consideration categories such as types of fences, different spatiotemporal features, and eco-epidemiological scenarios with a focus on ASF in the EU. Analyses were carried out using both published (from literature review) and unpublished data from responses to a questionnaire obtained various end-users and stakeholders across Europe, who have experience using different methods to control wild boar movement in different contexts.

The systematic search of literature took place in January 2024. The final number of peer-reviewed papers included in the systematic literature review was 27. We extracted 14 different wild boar separation methods and/or barriers that might affect wild boar movements (in majority of cases, more than one method/barrier was evaluated in a single paper): solid fences (10 papers), traffic-related barriers (10), rivers (4), electric fences (3), and mountains (2); in a single paper, we found data also on the following methods/barriers or activities/traits for which a barrier effect was supposed to occur: gustatory repellents, settlements, natural fences, grates, guarding, distance to forest, vegetation clearings, and hunting.

Effectiveness of fences to control wild boar movement was evaluated in different countries. Majority of the reviewed studies showed that construction of fences can be effective tool for separating wild boar populations, but their success often depends on proper installation and maintenance. The most relevant published evidence to date on the effects of fences (electric and solid, respectively), accompanied by some other measures were obtained in the Czech Republic and Belgium, which both have become ASF-free after the implementation of measures. In both countries, where virus affected exclusively wild boar populations at a single point, fencing was used as one of the important measures after immediate zonation determining the infected zone, and surrounding buffer and control zones.

In some of the reviewed studies authors investigated how roads with accompanying fences and other structures affected the connectivity of the landscape. Various studies have shown that motorways and parallel structures (settlements, agriculture lands) often reduce gene flow between wild boar populations. Nevertheless, highways and motorways were rarely completely impermeable barriers, as wild boar often successfully cross them at unfenced areas (intersections with rivers/roads) or using underpasses. Indeed, several studies also reported that wild boar were frequent users of underpasses and wildlife crossings.

Potential of natural barriers, including sea, major waterways, forest discontinuity areas, plains and mountainous areas, for reducing wild boar migration was also evaluated in some of the reviewed papers. In several studies, it has been found that main (wide) rivers act as barriers to gene flow, as they reduced the genetic similarity between populations of wild boar on opposite sides of the waterways. Other separation methods were also taken into consideration in some peer-reviewed papers, including active and passive guarding, trenches, diversionary feeding, natural fences, distance to forest, hunting, and vegetation clearings. However, none of these methods have proved to be completely effective in limiting the movement of wild boar.

*Ad-hoc* questionnaires were distributed to relevant professionals (e.g., veterinary authorities / veterinarians, wildlife managers, wildlife scientists) across Europe. We received 69 relevant responses from 17 European countries. Number of answers per each method used for controlling/reducing wild boar movements is shown in Table 5.

For experiences with **solid (mesh) fences**, we received 40 responses (some of them were accompanied by other measures, mainly electric fences). ASF was the driver of installation of the fence in 11 cases, while in 27 cases it was not. In almost all areas where solid fences were implemented, wild boar was a target species. The height of the solid fence was from 0.8 m to 2.2 m (with one fence of even 4 m height), with variable height in some cases. Also mesh size openings were variable, in range between 5x5 cm and 20x20 cm. In almost all cases, bottom of the fence touched the ground, and in 22 cases (65% out of 34 answers) the fence was dug into ground. In almost all cases, the fence was metal, and in one case it was made from brick and concrete. In 12 cases (38% out of 32 answers), the solid fence was complemented by an electric fence.

From the summarised results regarding effectiveness of the solid fences in relation to the main aims of the implementation (Table 7) it is evident that solid fences are very effective tool for crop protection and forest protection (reasonable to completely effective: 85.7% and 90.0%, respectively), and to lesser extent also when aimed to increase road/railway safety or to reduce wildlife-livestock interactions (83.3% and 75.0%, respectively, with grades 3–5, i.e., reasonably, very or completely effective). Considering ASF control, however, they were ranked in the highest three grades in only half of cases, and in only 35.7% of cases solid fences were assessed to be very or completely effective for virus control.

For experiences with **solid fences aimed at ASF control and reducing interactions with livestock**, we received 14 responses. In almost all cases, wild boar was a target species. ASF was the driver of the installation of the fence in 10 cases. Considering ASF control only, the height of the fence was from 1.0 m to 2.2 m, with variable height (e.g. 1.5–2.0 m) in one case. Also mesh size openings were variable, in range between 5x5 cm and 20x20 cm. In almost all cases, bottom of the fence touched the ground, and in 7 cases (64% out of 11 answers) the fence was dug into ground. In all cases, the fence was metal, and in 4 cases (36%) the solid fence was also complemented by an electric fence.

From the obtained responses, it is evident that the effectiveness of solid fences for ASF controlling is questionable/controversial, as in only 3 cases (42.9%) solid fences were assessed to be very or completely effective for virus control, while in one case they were reported as completely ineffective. However, when considering reduction of wildlife-livestock interactions, in 4 cases out of 5 (80%) solid fences were reported as reasonably to completely effective. In 2 cases (out of 7 relevant; 29%) ASF has not spread so far beyond the fenced area; on the contrary, in 4 cases (58%) it has spread out, but with the important or moderate delay; in one case (14%), the virus spread out very fast, i.e., without any expected delay. Similarly, responses related to preventing the crossing of wild boar as a target species over the barrier indicated that solid fences aimed to reduce ASF virus spread and/or interactions with livestock have some potential to reduce crossing and, therefore, also disease transmission, but in general they can not completely stop crossings, particularly, not on a permanent basis as it would be desired considering the veterinarian/health issues.

For experiences with **solid fences aimed at crop/forest protection**, we received 16 responses. The height of the fence was from 0.8 m to 2.0 m, with variable height in some cases. Also mesh size openings were variable, in range between 5x5 cm and 20x20 (25x15) cm. In almost all cases, bottom of the fence touched the ground, and in 8 cases (57% out of 14 answers) the fence was dug into ground. In all cases, the fence was metal. In 5 cases (36% out of 14 answers), the solid fence was complemented by an electric fence. From results of the questionnaire, it is evident that solid fences (either alone or accompanied by electric ones) are effective tools for both crop protection and forest protection (reasonable to completely effective: 93% and 100%, respectively). Moreover, 11 out of 13 relevant responses (88%) showed that crop damage has been importantly or almost completely reduced after the solid fence construction, while in only 2 cases (12%) no effect was reported.

For experiences with **solid fences around hunting enclosures**, we received 6 responses. The size of the area enclosed by solid fences was in a range between 4 $km^2$ and 12 $km^2$. The height of the fence was from 1.6 m to 2.2 m, with variable height (e.g., 1.8–2.0 m) in one case. Also mesh size openings were variable, in range between 5x5 cm and 15x15 cm. In all cases, the bottom of the fence touched the ground, and in 3 cases (75% out of 4 relevant answers) the fence was dug into the ground. In all cases, the fence was metal. In 3 cases, solid fences were complemented by electric fences, in one case they were not, and 2 responses lacked that information. Responses related to preventing the crossing of wildlife over the barrier (n = 4) indicated that solid fences used for hunting enclosures are not completely impermeable barriers for wild boar. Indeed, in only one case individuals have never escaped beyond the fenced area, while in other three cases target species did escape, but only sporadically (<3 cases annually).

For experiences with **solid fences aimed at road/railway safety**, we received 7 responses. The length of the fence was between 25 km and 1800 km and the total height of the fence was from 1.5 m to 2.4 m. Mesh size openings were variable, in range between 5 x 5 cm and 20 x 15 cm, and in some cases with thickening/densification at the bottom. In all cases, the bottom of the fence touched the ground, and in 5 cases (83% out of 6 answers) the fence was dug into the ground. In all cases, the fence was metal. Responses related to road/railway safety indicated that solid fences are in general effective tools for increasing road/railway safety (very to completely effective: 75% answers). Moreover, 2 out of 3 relevant responses showed that roadkill was almost completely reduced and in one case it was importantly reduced after the construction of fences along roads. Responses related to preventing the crossing of wildlife over the barrier, i.e., fenced roads/railways (n = 6), indicated that solid fences aimed to increase road/railway safety are not fully impermeable barriers for wild boar. Indeed, no case of full prevention with no crossing was reported, while partial prevention with lower number of dispersing/migrating individuals than before was registered in 5 cases (83%), and no change was registered in one case (17%).

For experiences with **electric fences** (either used alone, as in the most cases of crop/forest protection, or in combination with solid fences/repellents, mainly in case of ASF control), we received 33 responses. ASF was the driver of installation of the electric fence (in majority of cases in combination with the solid fence) in 7 cases, while in 25 cases it was not. In the case of installation of electric fences solely (n = 13), the aim was in 12 cases crop protection and in one case golf court protection. The total height of the fence was from 0.3 m to 2.0 m (the total height in the cases where electric fences were the only method used was from 0.4 m to 1.2 m), with variable height in some cases. Number of electric wires was also variable, in range between 1 and 5 wires with height of the lowest wire in range between 5 cm and 40 cm above the ground. Distance between wires was in range between 15 cm and 50 cm and voltage was in range between 12 V and 220 V. Frequency of vegetation clearance along the fence was also variable, from weekly to once a year.

It is evident from the summarised results that electric fences (mostly alone or in combination with other methods) are very effective for crop and forest protection (reasonable to completely effective: 91% and 88%, respectively), and to lesser extent also when aimed to reduce wildlife-livestock interactions, ASF control or to increase road/railway safety (75%, 67% and 67%, respectively, with grades 3–5).

For experiences with electric fences as an accompanied measure with solid fences and aimed either at **ASF control or reducing interactions with livestock**, we received 8 responses. The total height of the fence was from 0.8 m to 1.2 m. Number of electric wires was variable, in the range between 2 and 4 wires, and the height of the lowest wire was between 20 cm and 40 cm above the ground. The distance between the wires was also variable, in range between 30 cm and 50 cm, and voltage was between 220 V and 230 V. Electric fences aiming at ASF control were mainly implemented as an additional measure parallel to the solid fence, therefore, reported outcomes in terms of effectiveness and/or changes in wild boar spatial behaviour overlapped between both measures and cannot be commented on electric fences solely. Nevertheless, it is evident that the use of electric fences for ASF controlling has some potential, as in 60% of areas where electric fences have been used respondents assessed them to be very or completely effective for virus control. However, only in one case (out of 6 relevant; 17%) ASF has not spread beyond the fenced area, and in other 5 cases (83%) it has spread out, but with the important or moderate delay. In the case of reducing wildlife-livestock interactions, electric fences have proven to be very efficient: in all 4 cases, they were reported as very or even completely effective. Similarly, responses related to preventing the crossing of wild boar as a target species over the barrier indicated that electric fences (when installed in parallel with solid fences) have some potential to reduce crossing and, therefore, disease transmission, but in general they can not completely stop/block wild boar movement across the landscape. Indeed, in all 6 reported cases, the number of dispersing/migrating individuals was lower than before which indicates partial prevention.

For experiences with **electric fences aimed at crop/forest protection**, we received 21 responses. The total height of the fence was from 0.4 m to 1.2 m (in majority of cases 0.6–0.8 m). Number of electric wires was variable, in the range between 2 and 5 and the height of the lowest wire was between 5 cm and 40 cm above the ground. Distance between wires was between 15 cm and 50 cm and voltage between 12 V and 230 V. From responses, it is evident that electric fences are a very effective tool for crop protection (reasonably to completely effective: 100%). Moreover, 10 out of 11 relevant responses (90.9%) revealed that crop damage has been almost completely reduced after the electric fence construction, while in one case damage was importantly reduced (9.9%). However, responses related to preventing the crossing of a target species over the barrier indicated that electric fences aimed to reduce damage in agriculture/forestry are very rarely impermeable barriers for wild boar. Indeed, in the case of electric fences alone (without combining them with solid fences or other methods) full prevention of crossings of target species was reported only in 3 cases out of 10 relevant responses (30%), while partial prevention with lower number of dispersing/migrating individuals than before was registered in 7 cases (70%).

In the joint group of **repellents**, we combined different types of deterrents, namely: chemical/odour, acoustic/sound, and visual. For experiences with them, we received 17 responses – 7 for odour, 7 for sound, and 3 for visual repellents, respectively. However, only in 5 cases repellents were considered as a stand-alone method; in all other cases, they were complemented with other methods. Considering all received responses, the most frequent driver for installation of repellents was crop/forest protection (8 cases), followed by road/railway safety (4), and ASF control (3). Repellents aiming at crop/forest protection were mainly implemented as an additional measure parallel to the electric and/or solid fences, therefore reported outcomes in terms of effectiveness and/or changes in wild boar spatial behaviour overlapped between both measures and cannot be commented on repellents solely. It seems from the summarised results that acoustic and visual deterrents are moderately effective for increasing road safety (in both two cases assessed as reasonably effective); similarly, odour repellents were in one case reported as reasonably effective for crop protection. However, it is very evident that in most cases deterrents were not effective tools neither for crop/forest protection (completely ineffective in 2 out of 3 cases) nor for ASF control (completely ineffective in the only relevant response) and reducing wildlife-livestock interactions (somewhat effective in the only response).

To understand the social effects and implications of implementing separation measures, a series of questions asked respondents to identify: (i) stakeholders involved in decisions to implement spatial separation methods; and (ii) stakeholders negatively affected by these. Questions also focused on how: (i) the general public responded to their implementation; (ii) the levels and type of opposition to fencing, and its motivation; and (iii) the social-political tensions that were present between different stakeholders. Respondents identified stakeholders who were negatively affected by the implementation of separation measures. Table 35 highlights the different stakeholders impacted by separation measures specifically targeting ASF control and reduced domestic-wild animal interactions. The reasons for the negative impacts vary according to stakeholder groups. For some, including hunting communities, farming communities, private enterprise and regional/local authorities, separation measures can generate economic costs and financial burden. This might be due to the movement restrictions put in place for people and animals, a moratorium on carrying out industry (such as forestry) in the fenced area and hence lost opportunity costs, or else the responsibility to maintain fencing or facilitate it on your land. As well as economic costs, negative impacts also occurred when different stakeholders were unable to carry out practices important to their everyday practices and identity. For example, when the public is no longer able to access land for recreation or for foraging for natural resources. Finally, negative impacts were also identified when separation measures clashed with the objectives and agendas of communities of practice engaged with wildlife ecology, such as forestry, conservation and wildlife protection. These results highlight that extraordinary and rapid responses carried out in the name of biosecurity can affect a range of interests and businesses beyond those specifically engaged with animal health management.

53 responses addressed whether there was opposition to any methods of separation, and the reasons for this. 24 responses (45%) stated there was no opposition. Of the 29 responses (55%) stating there was opposition, several factors were highlighted. This question allowed multiple answers, reflecting the fact that opposition can often be attributed to more than one factor. Most commonly, opposition was cited in relation to: restrictions over access (11 cases); negative impacts on hunting/game management (11 cases); economic concerns (11 cases); and negative ecological impacts (9 cases). Distrust of authorities/decision-makers and the welfare impacts of target and non-target species were less significant drivers of opposition (3 cases each). In contrast, separation measures relating to ASF and the reduction of wildlife-livestock interactions caused proportionally more opposition. Out of 17 relevant answers, only 3 (18%) did not generate some form of stakeholder opposition, compared to 14 (82%) which did, highlighting that responses to ASF can generate controversy among different stakeholders. Of these, the most notable reasons related to the restrictions on access and concerns about economic impacts (7 cases each). These were followed by the negative impacts caused to hunting and game management (4 cases), and on ecology (2 cases).

Regarding responses relating to measures for ASF control and reducing wildlife-livestock interactions, 5 out of 17 respondents (29%) said there was no opposition. Reflecting the results of the overall outcomes, the most frequent forms of opposition were moderate in nature, whether defying requests and instructions (6 cases) or publicly criticising measures (3 cases). There were two cases of severe opposition materialising as damage or sabotage, and two cases where public responses were overlooked. These results highlight that opposition is, firstly, more common than not. Secondly, they also highlight how it manifests in different forms, sometimes in any given situation. While moderate opposition is most frequent, this might involve behaviours which compromise biosecurity, such as ignoring instructions and guidance.

Respondents were offered an open question to reflect on the tensions that separation methods can cause between different stakeholder groups. A total of 27 respondents addressed this question, with 13 (48%) stating there was either no, or minimal, social-political tension present in the cases they describe. On the other hand, 14 respondents (52%) stated that tensions did exist between stakeholders. Multiple tensions were highlighted by respondents regarding the different relations between authorities (national and regional), specific communities of practice (e.g., agriculture and/or hunting) and other stakeholders.

Effectiveness of both solid and electric fences for separating wild boar populations is affected by different environmental as well as technical influential factors. By combining both outcomes of the literature review and questionnaire, we can define the following factors/scenarios that determined effectiveness of fences (with emphasis on ASF control), which should be therefore carefully considered when constructing fences for ASF control:

- **Aim of the fencing**: Focal fencing at smaller and concrete locations, aimed at enclosing susceptible wild boar groups and virus inside infected area or its close vicinity (i.e., restricted zones) should be implemented, while longline transboundary fencing, aimed at protection of large areas or even countries against dispersing individuals from other areas/countries should be omitted.
- **Optimal size of the area enclosed**: The size should consider the spatial ecology of wild boar; fenced area should neither be too small nor too large (i.e., optimal size 50–200 $km^2$).
- **Effect of topographic characteristics**: Effectiveness of solid fences is dependent on orography, being higher in flat land, where fence construction is a much easier task.
- **Landscape type**: The forest coverage pattern should be considered and is of strategic importance to install fences and delimiting the area of containment, as the wave-front velocity is expected to be faster in forest areas and slower in non-forest areas; open land actually slows down the ASF progression throughout a non-continuous wild boar population. Moreover, mountainous terrain also negatively affects the effectiveness of the solid fence to stop the ASF spread.
- **Presence of different landscape features (water bodies, villages, longline infrastructure)**: Generally, the presence of rivers and streams as well as anthropogenic corridors increases the permeability of the fence, and, consequently, increases also wild boar crossing and virus spread. Moreover, watercourses were identified as vulnerable points of fences.
- **Inclusion of other (manmade, natural) barriers in the fence network**: Roads as a longline infrastructure barrier (particularly fenced highways) can be effectively included in the network of fences and can contribute to decrease ASF virus dispersal and wave-front velocity. Similarly, rivers (but only wide ones, with high discharge) can act as an important barrier for the spread of the ASF virus.

- **Culling of wild boar inside/outside the fence**: In case of infection, intensive cull of wild boar on both sides of the fence, strictly following biosecurity measures, is mandatory to provide an effective outcome of the fence, i.e., to stop the virus spread.
- **Quality/type of the solid fence**: Height, together with maintenance, importantly affects efficiency of the solid fences for preventing wild boar crossing; for example, 2.0 m high well-maintained fences that were weekly maintained were on average 30% more efficient than 1.2-1.5 m high livestock fences.
- **Digging the solid fence into the ground**: When comparing two scenarios (dug vs. not dug fences), responses to the questionnaire did not strongly confirm usual idea that buried fence would be less permeable for wild boar in comparison with non-buried ones.
- **Complementary use of electric fences along solid ones**: According to responses to the questionnaire, addition of electric fences did not affect general effectiveness of solid fences.
- **Number of wires in case of electric fences**: A minimum of two wires installed between 25 and 50 cm above ground level is required to deter wild boar movements across the fence; however, some responses indicated that using three instead of two wires would importantly increase the effectiveness of electric fences in specific areas where they were used.
- **Costs and cost-effectiveness**: Implementation of electric fences is much cheaper in comparison with solid fences; however, costs of maintenance of electric fences are higher as they need regular checking of electricity power and cleaning of the vegetation.
- **Maintenance of the fence**: Proper maintenance of the fences (both solid and electric ones) is a key for their long-lasting effectiveness, and in the case of solid and electric fences, 33% and 38% of respondents, respectively, reported lack of adequate maintenance over time as the main reason why fences were understood to be ineffective.

Based on these scenarios, it is essential that authorities before making the decision where, how, and which measure will be implemented check all these factors (and potentially also some locally important additional ones), and on the basis of comprehensive analysis select the proper method, which will ensure desired outcomes in the most cost-effective way. However, the decision should not be partial and based only on solving veterinarian-related issues (i.e., ASF or other disease control), but has to holistically consider also all ecological effects of fencing (e.g., impact on habitat connectivity and gene flow within populations of other species) as well as attitudes of public and acceptance of selected measure by different stakeholders (which will, among others, influence up-following possibility of long-lasting maintenance of the implemented measure). Due to this, neither findings nor measures can be transferred to any given country or specific area without major adjustments based on the ecological, epidemiological, and social context.

# Table of content

# 1 Introduction

African Swine Fever (ASF) is a viral highly lethal infectious disease that affects pigs and wild boar, with no existing vaccine to combat the virus (Sauter-Louis et al., 2021). Wild boar populations have been identified as playing an important role in initiating outbreaks and as major reservoir of the disease (Tarasiuk & Giżejewski, 2021; Cadenas-Fernández et al., 2022); whilst human-related activities are mainly favouring the long distant spread (Guberti et al., 2022). Although the significance of various transmission modes in epidemiology remains unclear, several management strategies have been proposed, including those related to the reduction and separation of wild boar populations (EFSA AHAW Panel, 2018). For some of them (including fencing), feedbacks (and in some cases publications) on field experiences are available after implementation of control measures in affected areas (e.g., Charvátová et al., 2019; Dellicour et al., 2020; Licoppe et al., 2023; reviewed in Jori et al., 2021).

In wildlife epidemic management, an important intervention is the separation of target (sub)populations from protected goods and other populations (Lee, 2023). Some examples are the veterinary cordon fence for mitigating foot-and-mouth disease in Namibia (Schneider, 2012), or specific natural barriers and fences in ASF-management in Europe (Pejsak et al., 2018; Licoppe et al., 2023). In the last case, other strategies have been employed as alternatives, such as the use of olfactory and gustatory repellents, or light and sound deterrents (EFSA AHAW Panel, 2018; reviewed in Jori et al., 2021). However, their effectiveness varies depending on numerous factors such as fence characteristics (high, robustness, electrified or not), the timing of fence implementation, the extent, the context, and the landscape scale. The proliferation of ASF across various regions around the globe, accompanied by the significant increase in wild boar populations (in both native and introduced range), has incentivised the development of management plans and research projects to control its spread.

Systematic reviews provide thorough compilations of existing evidence pertinent to specific, well-defined questions, utilising standardised and predetermined methods to identify, critically appraise, and collate data from relevant studies (EFSA, 2010). This methodology presents an opportunity to ensure that the collection, documentation, and analysis of data from the incorporated studies are conducted rigorously and systematically. Thus, in this specific context, it allows for the evaluation of the effectiveness of various management strategies that have been implemented in recent years, specifically those related to controlling wild boar movement through separation methods and using different deterrents.

EFSA has reviewed the existing scientific evidence on the topic with the main conclusions that no large fences have been effective for the containment of wild suids (EFSA AHAW Panel, 2018). At the time of that report, some new large-scale fences were under construction, so an updated review of the available literature is an opportunity to evaluate their effectiveness in separating wild boar populations. Observations were provided on natural barriers, such as large rivers, as they have shown to reduce, but not completely prevent, the movements of wild boar (EFSA AHAW Panel, 2018). Due to the spread of ASF Virus (ASFV), and the high interest of the international community, new evidence has been made available. Therefore, the objective of the present work is to update the knowledge available until 2018, and to identify different influential factors (scenarios) affecting the effectiveness of those barriers. The scenarios were identified according to type of separation method, extent, landscape, timeline of implementation, aim of separation, epidemiological situation, outcome, and human-related factors, in an attempt to be consistent with EFSA AHAW Panel (2018) and retrieve additional knowledge on the subject.

## 1.1 Background and terms of reference

The contract entitled "Wildlife and One Health: wildlife ecology, health surveillance and interaction with livestock, human population, and environment" (framework contract number: OC/EFSA/BIOHAW/2022/01) was awarded to the Universidad of Torino by EFSA. From here, we refer to this framework contract as to the ENETWILD project. The specific objective 1 (SO1) of the framework contract refers to "Wildlife ecology, health surveillance and interaction with livestock, human population and environment".

Due to the Art. 31 mandate from the European Commission about ASF risk factor analysis, EFSA requested ENETWILD consortium an update (to integrate the Scientific Opinion reported in EFSA AHAW Panel, 2018) regarding fencing methods, or population separation methods, available for wild boar (*Sus scrofa*) in different scenarios (e.g., type of separation method, extent, landscape, timeline of implementation, etc.) and implemented for different objectives (e.g., ASF control, crop protection, etc.). Therefore, the effectiveness of the different methods used for separating wild boar is evaluated based on information found in recent scientific literature (published since 2018), through a systematic review, and an ad hoc questionnaire distributed to relevant professional profiles (e.g. veterinary authorities/veterinarians, wildlife managers, landowners, wildlife scientists) across Europe. Specifically, deliverable 6.1b aims at collecting scientific evidence (literature review) for the effectiveness of fences and other methods (e.g., repellents of different kinds) for controlling wild boar movement and, consequently, the spread of ASF, considering the previous work from EFSA AHAW Panel (2018); deliverable 6.1c aims at identifying and defining the different scenarios existing for the use of fences and other separation methods to manage wild boar populations, considering types of barriers, aims of separation, epidemiological situations of ASF, location characteristics (orography, land use, etc).

## 1.2 Scope of the report

The report aims at updating the current knowledge on effectiveness of methods to separate wild boar populations and limit their movement with particular emphasis on practices from the field aimed at ASF control, crop protection, and wildlife management.

# 2 Methodology

The ENETWILD consortium collected (i) the scientific evidence from published literature with a semi-automated systematic literature review and (ii) expert/experience-based knowledge that both assessed and synthesised research on the effectiveness of fences, deterrents and functional, symbolic, as well as natural barriers for controlling wild boar movements.

The identification of scenarios was carried out primarily extracting relevant data from the identified publications, expanding the methodology used in EFSA AHAW Panel (2018). The work plan and scenario definition is also available at this link https://zenodo.org/records/10516616 . The parameters used to identify and define the scenarios were collected in the following macro categories:

- types of fences (solid/mesh, electric, razor-wired) and other methods (repellents etc);

- aim of separation (e.g., ASF control, crop protection, road/railway safety etc);

- spatial features, including extent, permeability, and surrounding landscape characteristics (e.g., orography, land cover, land use, etc);

- eco-epidemiological context with a focus on ASF in the EU (e.g., other wildlife populations, information on pig/wild boar interface, etc);

- human-related factors, including social and economic implications;

- outcome, including metric used to measure it.

Despite the limited time period analysed (2018-2023), the number of relevant published scientific publications amounted to 27. In the previous systematic review (EFSA AHAW Panel, 2018), which encompassed a much longer period of time (first included paper dating 1986), only 18 publications were included. This shows a growing interest toward the topic of fencing and separation methods. To further evaluate and understand the feasibility and effectiveness of fences and other separation methods to manage wild boar populations, we sided the literature review with direct data collection from professionals that have first-hand experiences on wild boar movement control through fencing or other natural or artificial barriers. To collect relevant data, we elaborated a specific questionnaire to identify and collect unpublished field experiences and applied wild boar separation methods. This questionnaire with responses received helped to reveal aspects that in many cases are not fully reported in publications, but are relevant to evaluate effectiveness, also in terms of different contexts, of wild boar separation methods. The questionnaire was distributed to various professionals from all EU countries and some other European countries by the ENETWILD consortium (see Table 4). Respondents were contacted directly, i.e., individually, through the ENETWILD partners network (mailing list, shared online folders), and in some cases guided interviews were conducted to maximise data collection outcome. The results obtained were presented in an on-line workshop (3 Apr 2024, record saved at: https://unito.webex.com/unito/ldr.php?RCID=a2743d77e7ddf5257862fcf1a0311d56), where they were discussed among participants (i.e., ENETWILD consortium members and stakeholders that have participated in questionnaires/interviews and expressed their interest for participation). This allowed the integration of valuable additional data in the review, avoiding bias (positive) expected from the analysis of official publications.

The effectiveness of separation methods was evaluated using the metrics as well as all relevant descriptions provided in literature for the published data and, for outcomes identified through questionnaires, the feasibility/effectiveness were finally evaluated through expert opinion and discussion at the on-line workshop. A critical appraisal of the final, integrated (literature and questionnaire/workshop) results is provided in this report.

## 2.1 Systematic literature review

For the semi-automated review of the scientific literature, we conducted the following process (see also Figure 1) and also it is available at this report at this link https://zenodo.org/records/10516616 :

- Creation of a naïve search string based on a priori knowledge of the topic and review question (Table 1), based on keywords and strings from EFSA AHAW Panel (2018), who have already reviewed and evaluated the existing scientific literature on wild boar population reduction measures, wild boar movement restriction, and wild boar population separation methods until 2018.
- Definition of inclusion and exclusion criteria (Table 2).
- Extension of the search by new keywords.
- Identification of relevant databases like PubMed, Web of Science, Embase, Scopus, and Scholar based on the formerly used databases (EFSA AHAW Panel, 2018).
- Search in a subset of databases with naïve strings and exportation of results.
- Analysis of results by using the *litsearchr* package (Grames et al., 2019) in R (R Core Team, 2023), and, after eliminating duplicates, extraction of real keywords and keywords detected through a function using the Rapid Automatic Keyword Extraction (RAKE) algorithm (a domain independent keyword extraction algorithm which tries to determine key phrases in a body of text by analysing the frequency of word appearance and its co-occurrence with other words in the text). We plotted a document feature matrix and chose a cut-off to analyse the resulting list of keywords.
- Optimisation of definitive string search based on cut-off optimisation (long composite strings elimination and manual analysis by terms group; *sensu* Jaspers et al., 2018), in addition to the comparison with the string used in EFSA AHAW Panel (2018) to create more complex and direct strings (see overview in Table 1).
- Search in the identified relevant databases from 2018 (included) and analysis of results with the revtools R package (Westgate, 2019): the package eliminates duplicates by title and DOI, eliminate citations, reviews, and conference papers to retain only original work in articles, theses, and book chapters, keeping only relevant languages.
- Screening of remaining articles by topic (using Latent Dirichlet Allocation model), title and abstract (reiteratively if necessary), according to the inclusion and exclusion criteria (Table 2). We used this approach for a first screening to avoid the risk of eliminating relevant articles. Latent Dirichlet Allocation (LDA) is a Bayesian algorithm used in Natural Language Processing (NLP), which is a machine learning technique to analyse human language. NLP is a specific component of Text Mining (TM), which performs a special kind of linguistic analysis that comes down to helping a machine read text. Once the articles are transformed into a suitable input format the machine-learning algorithm, in this case LDA, can be employed to determine which of the retrieved articles are relevant for the study and which articles can be omitted in any further analysis (*sensu* Jaspers et al., 2018).
- Screening of full-text articles to refine the selection according to inclusion and exclusion criteria (Table 2).

- Data extraction from final included papers through a data model (Table 3) comparable with EFSA AHAW Panel (2018).
- Snowballing, by following citations from included papers to find additional ones (*sensu* Jaspers et al., 2018).
- Adding the secondary scientific sources which were considered if other papers (in addition to the primary sources found by the procedure described above) were retrieved by relevant information provided by the questionnaire respondents or by manual searches. Secondary information sources were considered to ensure inclusion of all available literature by including additional papers not directly found by the primary searches. The additional papers found as supplementary sources of information were used if they met the eligibility criteria or if they complemented some information already achieved through the primary source of information, and their main findings are summarised in the Results section.
- Finalised critical appraisal of the final bibliography, data synthesization designing a comparable table to Table A.5 in Appendix A.2 from EFSA AHAW Panel (2018) and listing of the different scenarios existing for the use of fences/barriers to manage/separate wild boar populations.

**Table 1:** Summary of review questions, the naïve string searches, and the definitive strings.

| Review question | Target | Terms group | Naïve string | Definitive string |
|---|---|---|---|---|
| Effectiveness (incl. practical applicability, cost-effectiveness and efficiency) of fencing methods, or other population separation methods (as well as natural barriers), available for wild boar in different scenarios (e.g. for protecting forest, farmland, pig holdings, urban areas, highways) in the context or prevention and control of ASF | topic (title, abstract, keywords) | population | "feral pig" OR "feral pigs" OR boar* OR swine OR hog OR hogs OR scrofa OR wildboar* OR "wild boar*" OR "wild pig" | "feral pig" OR "feral pigs" OR "wild pig" OR boar* OR swine OR hog OR hogs OR scrofa OR wildboar* OR "wild boar*" OR "wild pig" |
| | topic (title, abstract, keywords) | method | fenc* OR barrier* OR repel* OR odor fence OR odour fence OR optical fence OR acoustic repel* OR restrain* OR trench* OR ditch* OR channel* OR river* OR "management strateg*" OR gunning OR shoot* OR trap* OR snar* OR hunt* OR track* OR harvest* OR poison* OR feed* OR bait* OR steriliz* OR sterilis* OR "fertility control*" OR permeability | fenc* OR barrier* OR repel* OR restrain* OR "natural barrier*" OR "management strateg*" OR shoot* OR trap* OR hunt* OR track* OR harvest* OR poison* OR feed* OR bait* OR steriliz* OR sterilis* OR "fertility control*" OR "separation method*" OR permeability |
| | topic (title, abstract, keywords) | process | separat* OR move* OR moving OR dispers* OR "population structur*" OR control OR "population management" OR "population density" OR "population reduction" OR "population separation" OR decreas* | separat* OR dispers* OR "population structur*" OR "population control" OR "population management" OR "population density" OR "population reduction" OR "population separation" |

| | | | |
|---|---|---|---|
| | | OR lower* OR limit* OR depopulat* OR cull* OR eliminat* OR extermin* | OR decreas* OR lower* OR limit* OR depopulat* OR cull* OR eliminat* OR extermin* |

**Table 2:** List of inclusion and exclusion criteria for the worldwide literature review to gather comparable results to EFSA AHAW Panel (2018), so that results can integrate existing knowledge and can be compared to identify differences across time.

| **Inclusion criteria** | ***Exclusion criteria*** |
|---|---|
| *Separation methods for wild boar or feral pig populations* | *Separation methods for other wildlife populations* |
| *Quantitative or qualitative evaluation of a natural or artificial barrier, reviews excluded* | *Discussion of a natural or artificial barrier without clear evaluation of barrier effectiveness and review articles* |
| *Publication dated 2018 (incl.) onwards (as to compare to results of EFSA AHAW Panel 2018)* | *Publication older than 2017 (included)* |
| *Inclusion criteria (additional discussion)* | |
| *Separation methods for other ungulate populations (incl. deer and warthog)* | |
| *Also use publication older than 2018* | |

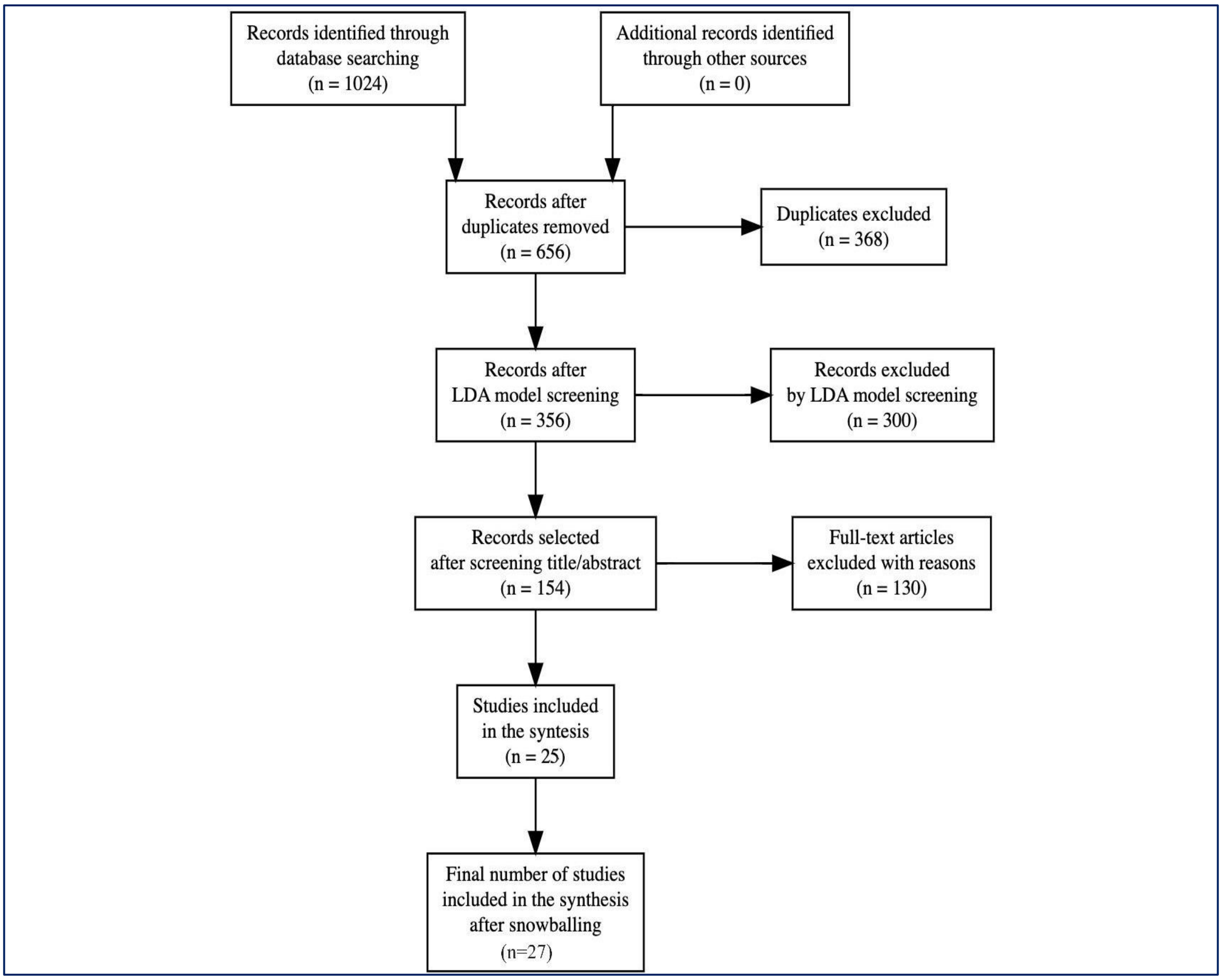



**Figure 1:** PRISMA figure. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

**Table 3:** Example of a spreadsheet which was provided to partners for data extraction (modified from Table A5 in Appendix A.2 in EFSA AHAW Panel, 2018) and for designing the summary table of literature review[#].

| Reviewer | Reference | Type of study | Method | | | | | | | | Method description | Location* | | Area size | Species | | Type of response: population (specify density, abundance etc.) | Type of response: Behaviour of animals | | Other effects (target and other species, please specify) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Electric fence | Solid fence | Odour | Sound | Light | Gustatory | Natural barrier (specify) | Other (specify) | Describe all methods included in the study | Country | Locality (coordinate) | km² | Target species | Secondary species (specify) | Specify density, abundance etc., name numbers if applicable | Describe methods how behaviour of animals was measured | Describe how animals reacted | Population separation (ecological aspects) | Genetic inference | Hindered migration | Other (specify) |

| Landscape | Scenarios identification as reported in EFSA AHAW Panel (2018) | Period | | Method estimation effectiveness | Separation measures | Results | ASF-infected area | Economic information | Short comment |
|---|---|---|---|---|---|---|---|---|---|
| e.g., forest/agricultural/etc | Summary of the scenario evaluation as reported in the above reference | Start (MMYYYY) | Stop (MMYYYY) | Describe parameter(s) | Parameter(s) quantified to estimate results | Quantitative data or qualitative remarks | Y/N (if yes, zone type) | costs in €, $ etc. | Additional notes |

[#]Different scenarios for type of study, country, landscape, specification, etc. were included in drop down menus. Vocabulary and definitions were also included. For example, for ENETWILD partners filling the table*: "If multiple/paired study sites (e.g., with different scenarios, control, before-after) within one reference, please fill one row per study site/situation if applicable".

## 2.2 Questionnaire and workshop

In January/February 2024, we prepared the on-line questionnaire in the questionnaire-dedicated platform 1KA (https://1ka.arnes.si/), which enables user-friendly responses as well as data management. The questionnaire, which can be found at https://1ka.arnes.si/a/887329ac, was approved by EFSA and distributed to wildlife experts and other relevant professionals, primarily via the ENETWILD network whose members were requested to contact relevant experts in their countries individually and conduct guided interviews if necessary. Moreover, apart from contacting relevant experts and stakeholders in countries included in the ENETWILD network, the Consortium also contacted –via personal scientific network– several wildlife scientists from other European countries. Aiming to increase the number of respondents, we extended the deadline for answering several times, and stopped collecting answers on 10 Apr 2024. The majority of responses were collected on-line, i.e., directly in the application 1KA, but we also allowed submitting filled questionnaire in Word, aiming to include respondents with less skills in on-line working arene as well as those who asked for translated questionnaires in native language of respondents (in such cases, translation from English was made by relevant member of the ENETWILD network). In case of receiving responses in Word (<10% of cases), we imported all of them in the application 1KA by ourselves, which enabled us consistent data storage and analyses using the 1KA data management tools.

On 3 Apr 2024, we organised the on-line (Zoom) workshop, which was participated by several members of the ENETWILD network and stakeholders that had sent their responses and indicated the interest in the questionnaire to join the workshop. At this event, we presented participants with preliminary results, and afterwards discussed questionnaire outcomes and verified them (the link to the workshop is available at: https://unito.webex.com/unito/ldr.php?RCID=a2743d77e7ddf5257862fcf1a0311d56). As there were no controversial opinions and/or disagreements among participants on presented results, there was no need for additional consensus using Delphi approach.

The questionnaire consisted of 85 questions divided into 7 sections: General background information, Information on separation method, Information on the area where the measures are implemented, Social effects and implications, Responses of target species, Effectiveness, and Additional notes. In order to get the most relevant answers, different types of questions were used, including open-ended questions, multiple choice questions, rating scale questions, and matrix questions.

We received 69 responses from 17 European countries. The number of responses per country is presented in Table 4 and maps of the locations where different methods for various main aims of (wild boar) population segregation have been implemented are shown in Figures 2-4. Most (62%) of the areas where measures were implemented were/are not part of the NATURA 2000 network or under any other form of protection.

**Table 4:** Number of relevant responses (received questionnaires) by country.

| Country | *N* | *Percentage (%)* |
|---|---|---|
| Italy | 21 | 30.9 |
| Spain | 9 | 13.2 |
| Slovenia | 6 | 8.8 |
| Sweden | 5 | 7.6 |
| Hungary | 5 | 7.6 |
| Croatia | 4 | 5.9 |
| Romania | 3 | 4.4 |
| Czech Republic | 3 | 4.4 |
| Bosnia and Herzegovina | 3 | 4.4 |
| Portugal | 2 | 2.9 |
| France | 2 | 2.9 |
| Latvia | 1 | 1.5 |
| Lithuania | 1 | 1.5 |
| Netherlands | 1 | 1.5 |
| Serbia | 1 | 1.5 |
| Denmark | 1 | 1.5 |
| Belgium | 1 | 1.5 |

We received responses from various experts, authorities, and end-users as follows: wildlife scientist – ecologist (10 responses), wildlife scientist – other (12), hunting ground manager (8), landowner – agriculture (8), veterinary authority/veterinarian from state agency (5), wildlife officer/ranger in protected area/wildlife park (3), veterinary authority/veterinarian in regional authority (3), wildlife officer/manager in protected area/wildlife park (2), wildlife scientist – epidemiologist (1), landowner – forestry (1) and other (12). Respondents who did not find their expertise in predefined choice of answers and selected option "other", gave the following answers: state official, state forest service, department of hunting, Slovenian infrastructure agency, wildlife consultant, Croatian hunting federation, Confagricoltura member, game management planner, affairs inspector (hunting and forestry), private company for fencing and enclosures, wild boar farmer, and head gamekeeper.

In most cases, aim of the method implemented for the wildlife (wild boar) movement control was crop/forest protection (40.5%), followed by ASF control (16.7%), road or railway safety (11.9%), reduced interaction between wildlife and livestock (10.7%), hunting enclosure (8.3%), wildlife or national park (4.8%), and national border security (3.6%), respectively. Respondents also listed 3 other aims of the implementation of the method: hunting ground establishment in historical times, wild boar farm, and golf court protection. Figure 3 shows a map of locations where crop/forest protection was the main aim, and Figure 4 a map of the locations where the implemented method has been primarily used for ASF control.


**Figure 2:** Map of the locations of the implementation of different methods for controlling wild boar movements (general overview, regardless the method used). The exact locations are marked in red, larger areas/entire countries in blue, and unknown locations in black.

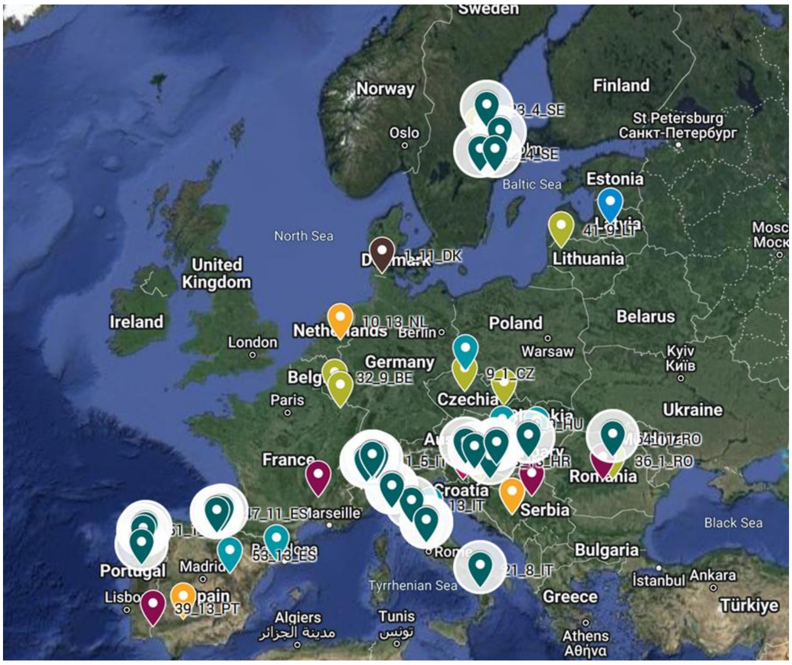



**Figure 3:** Map of the locations of the implementation of different methods for controlling wild boar movements. Locations, where the primary aim was crop/forest protection, are emphasised (with a white circle).

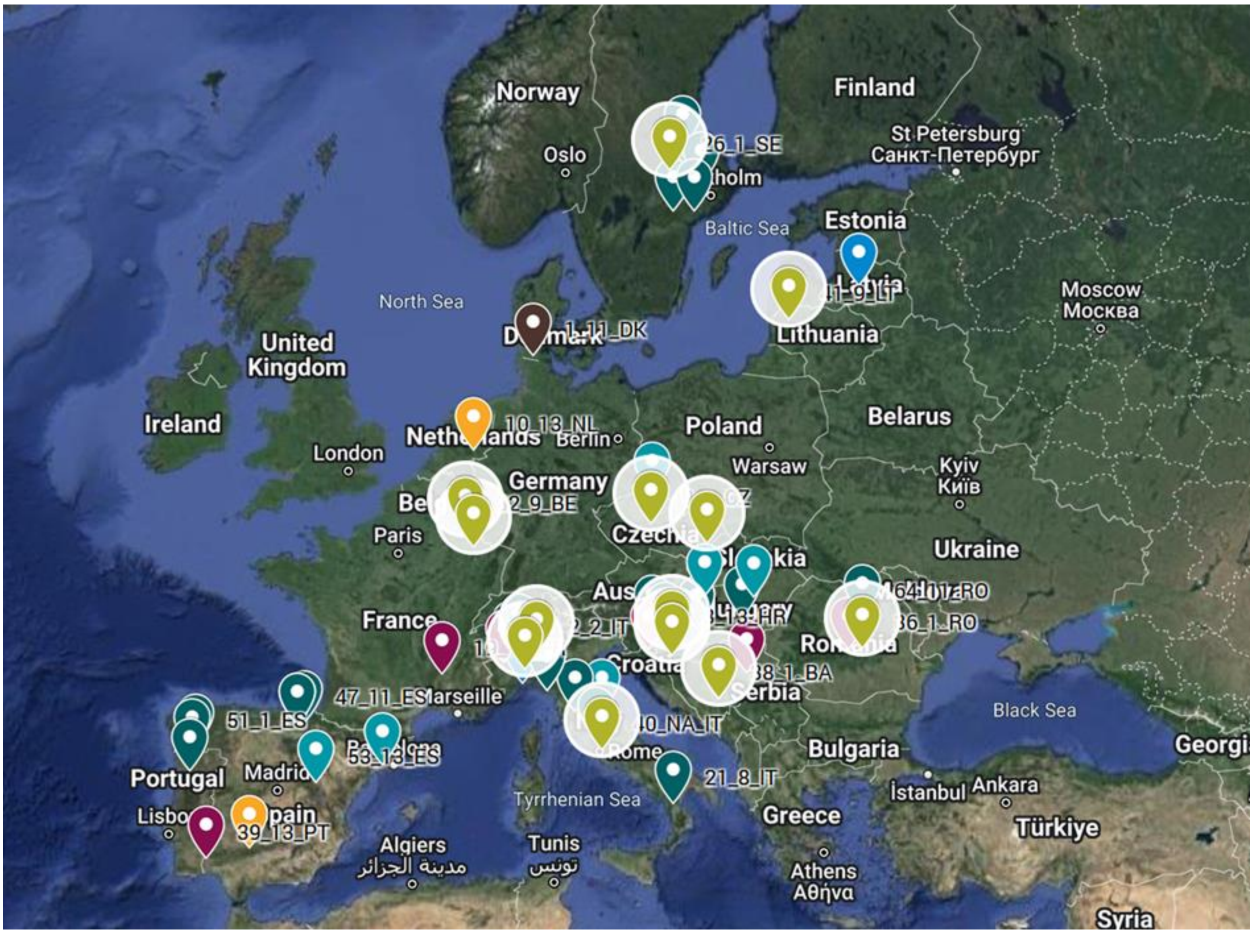



**Figure 4:** Map of the locations of the implementation of different methods for controlling wild boar movements. Locations, where the primary aim has been ASF control, are emphasised (with a white circle). Other aims are indicated by the following colours: crop/forest protection (dark green), road/railway safety (purple blue), reduced wildlife-livestock interactions (yellow), hunting enclosure (red).

Methods that were used for controlling/reducing wild boar movements were as follows (multiple answers were possible, therefore, the total number of answers is higher that the number of filled questionnaires as in several cases two or more methods were implemented in parallel): solid (mesh) fences (39 cases, 33.3%), electric fences (33 cases, 28.2%), chemical/odour repellents (9 cases, 7.7%), acoustic/sound repellents (9 cases, 7.7%), in person guarding/shepherding/patrolling (7 cases, 6%), visual repellents such as fladry/flags (4 cases, 3.4%), razor-wired/barbed wire fence (3 cases, 2.6%), gustatory/food method (3 cases, 2.6%), complementary use of natural barriers (2 cases, 1.7%), combination of different methods (8 cases, 6.8%), and other (3 cases: hunting; restrictions of access expect using roads; no barriers implemented).

In addition, data obtained from the questionnaire were matched with the results of a preliminary questionnaire sent by EFSA to the Members of the EFSA Animal Health Network and discussed during the network meeting in autumn 2023 (Minutes of 22nd- EFSA Scientific Network on Risk Assessment in Animal Health and Welfare, 21-22 Sept. 2023).

# 3 Results

## 3.1 Results from the systematic literature review

### 3.1.1 Description of the dataset

The final number of peer-reviewed papers included in the systematic literature review was 27 (Figure 1). The complete data model summarising details of the evaluated separation methods is provided as supplementary material to this report, while a summary of this information is provided as Appendix A. In total, from the 27 papers, we extracted 14 different wild boar separation methods and/or barriers that might affect wild boar movements (in majority of cases, more than one method/barrier was evaluated in a single paper): solid fences (10 papers), traffic-related barriers (10), rivers (4), electric fences (3), and mountains (2); in a single paper, we found data also on the following methods/barriers or activities/traits for which a barrier effect was supposed to occur: gustatory repellents, settlements, natural fences, grates, guarding, distance to forest, vegetation clearings, and hunting (Figure 5).

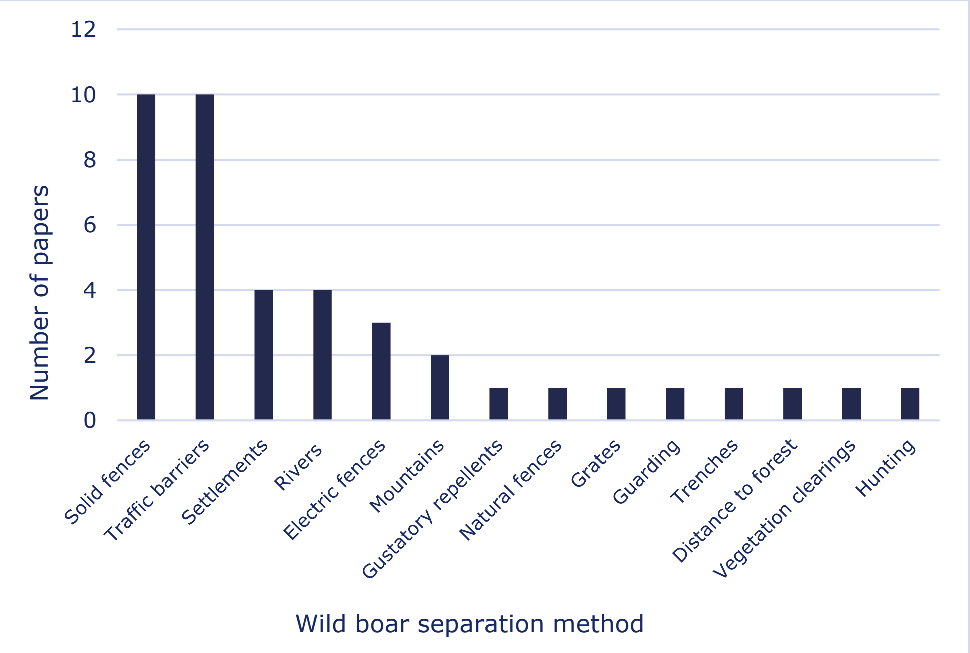



**Figure 5:** Number of wild boar separation methods or traits with potential barrier effect as extracted from peer-reviewed papers, published since 2018.

Majority of the studies that met the inclusion criteria examined separation methods in European countries – most of them were from Spain (5 papers), followed by Italy (3), Poland (3), and Germany (2). For the following EU countries, we found one relevant paper per country: Belgium, Croatia, Hungary, Lithuania, and Sweden. Among non-European countries, 3 studies on separation methods were conducted in Japan, 2 in Australia and one in New Zealand, Zambia, Nepal, India, and Tanzania (Figure 6).

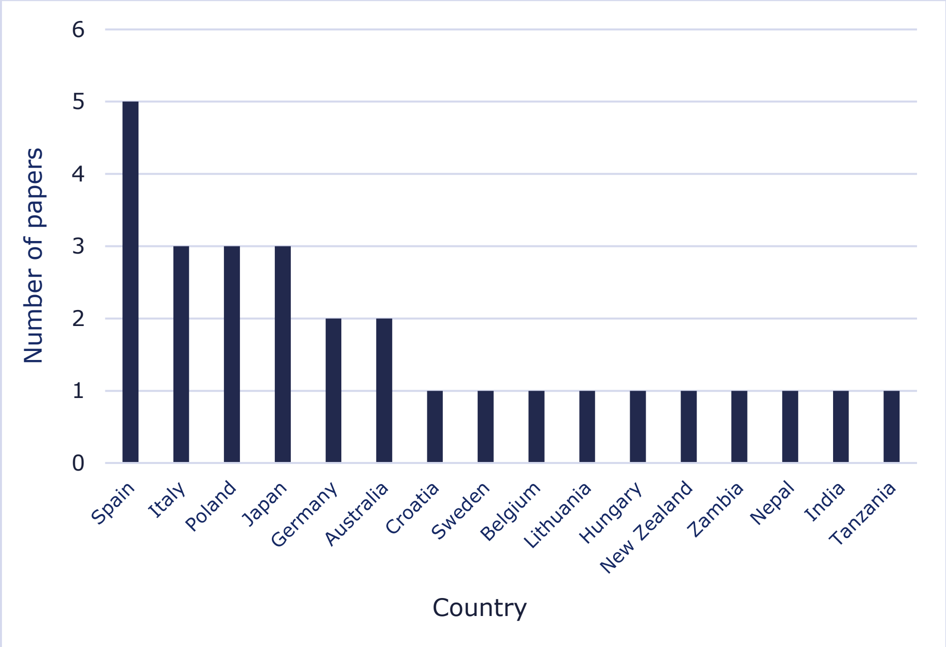



**Figure 6:** Number of relevant peer-reviewed papers by country.

The most represented landscape type in the relevant peer-reviewed papers was mosaic (13 papers), followed by forest (3). For all other types (residential, wetland, mountain, coastal) only one paper per each type was included, while for 5 studies no data on landscape type was provided (Figure 7).

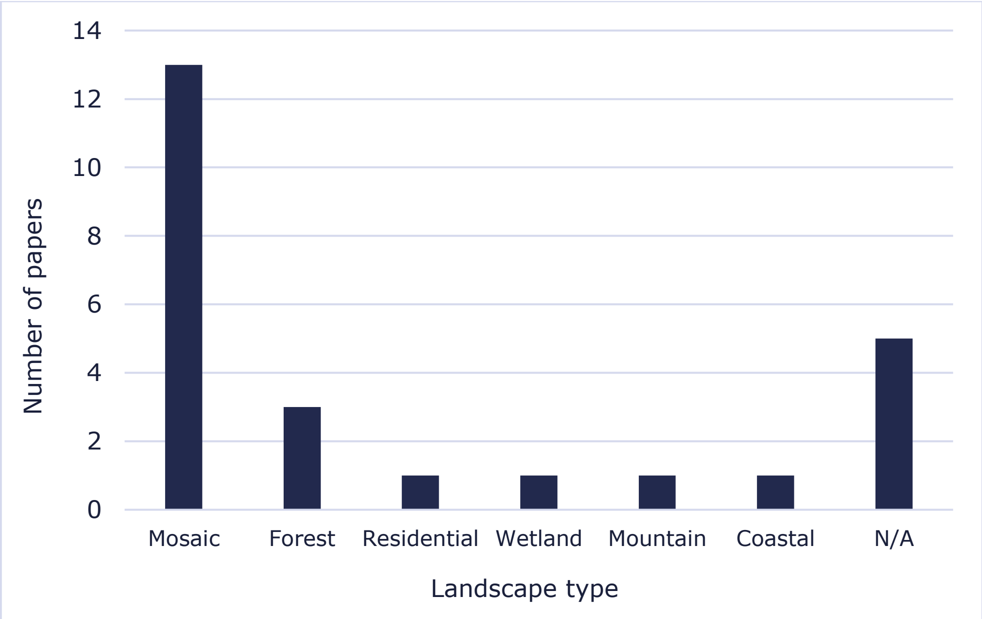



**Figure 7:** Number of relevant peer-reviewed papers by landscape type.

In the majority of studies that met the inclusion criteria, ASF was not present (14 papers). Infection was present in 3 cases, while 8 papers was without information on the ASF status (Figure 8).

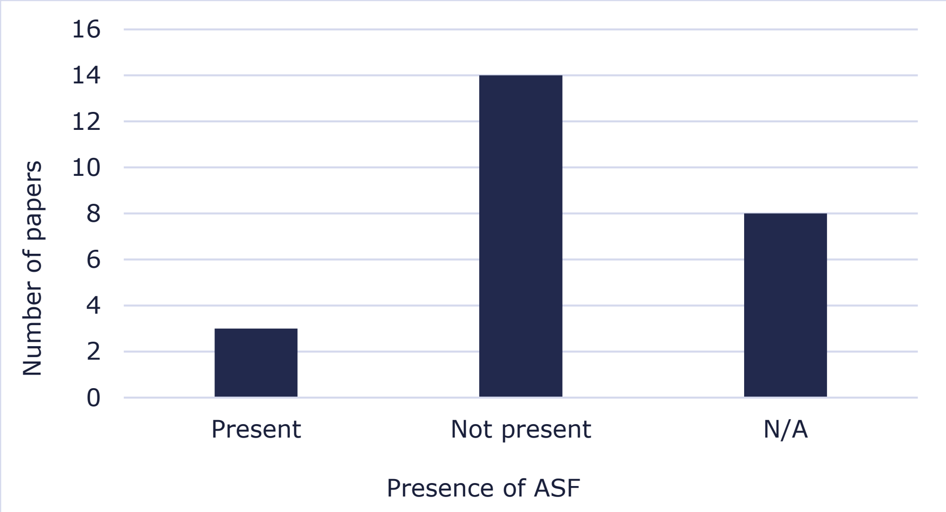



**Figure 8:** Number of relevant peer-reviewed papers by presence/absence of ASF.

### 3.1.2 Fencing (solid and electric)

Fences are one of the most widespread manmade features in nature, constituting an artificial limitation to the movement of wildlife and are one of the most effective tools to prevent human-wildlife conflicts. In addition to the initial cost of installing, their effectiveness is highly dependent on the maintenance status, especially when they are intended to retain wildlife populations (Vercauteren et al., 2006; Lindsey et al., 2012). Their effectiveness may be compromised by some vulnerable points (e.g., intersection with a river/road), consequently, they are almost always permeable to a certain degree. The effectiveness of a fence to exclude wild boar movement requires continuous fence monitoring and maintenance (Negus et al., 2019). Currently, there is no evidence of affordable fence designs that are 100% wild boar proof on a large scale and for a prolonged period (EFSA, 2018); however, positive experiences from the Czech Republic and Belgium (reviewed in Dixon et al., 2019; Jori et al., 2021; see also Chapter 3.2) indicated that in spite of this fences (either electric or solid ones) could in combination with other methods effectively contribute to the ASF control and prevent the spread of the disease.

Indeed, the most relevant published evidences to date on the effects of fences, accompanied by some other measures (zonation, intensive cull of wild boar, systematic search for carcasses, restrictions to public access, inclusion of highways, complementary use of odour repellents and gustatory methods) were obtained in these two countries, which both have become ASF-free after implementation of measures, and therefore they provide one of the best case studies in context of a very this exercise. Although we obtained for both countries some additional information via responses to the questionnaire, which are included in the Chapter 3.2, we summarise here main published data/results about these two case studies from two review papers (Dixon et al., 2019; Jori et al., 2021), and for results obtained in Belgium from two original scientific papers (Dellicour et al., 2020; Licoppe et al., 2023).

In both countries, where virus affected exclusively wild boar populations at a single point, fencing was used as one of important measures after immediate zonation determining the infected zone, and surrounding buffer and control zones. In the Czech Republic, the infected zone was physically isolated with electric fences to reduce the risk for natural spread of the disease in wild boar and to delineate the restricted areas. A construction of a massive wire fence had been discussed in the beginning but finally discarded because of its high costs and the long time needed for its deployment. Therefore, 10 km of electric fence (6,500-11,000 V) combined with odour repellents were placed on the outer periphery of the highest-risk area (57 $km^2$). In the infected and buffer zones, feeding and hunting bans were established to cause minimal disturbance to the affected and at-risk populations. Effective wild boar carcass surveillance aimed at efficiently detecting and removing infected carcasses were promoted. In the control zone, strict wild boar depopulation strategies were recommended to reduce wild boar densities as much as possible with minimal disturbance. All these measures were implemented successfully, and the Czech Republic was the first country to regain official freedom from disease, 19 months after the first incursion of the disease in June 2017. Although it was difficult to assess the contribution of fences to the eradication of the disease (there were 11 positive animals detected outside the fenced area, suggesting potential fence leakage in some places in the neighbourhood of a village that could not be entirely fenced off), given the successful general outcome it was assumed they had a positive effect (Dixon et al., 2019; Jori et al., 2021).

In Belgium, installation of fences (a standard 1.2 m high wire mesh; unburied) was part of the ASF control strategy from the first case notification in September 2018. 237 km of fences aimed at ASF control were erected in 2018–2019, complementing the 70 km of pre-existing fences that flanked the nearby highway. An additional 40 km of fences were constructed outside the management area. After connecting to fences erected in France (132 km) and Luxembourg (10 km), the complete network created 20 enclosures. These fences contained multiple weak points, such as gates and rivers, which were not secured. The hoped-for interruption of wild boar movements was achieved, but fence crossings did occur especially in rural areas where the number of gates was higher. This resulted in an expansion of the infected area on three occasions in early 2019, and each enlargement automatically resulted in the installation of new fences to contain these new incursions. During the epidemic, in the infected areas, organised searches for carcasses and trapping were the only operations conducted (until May 2019). During the post-epidemic (after May 2019), night shooting with generalised use of baiting points and camera alerts was also implemented to cull the remaining wild boar. The combination of these techniques, consistently applied within the fenced areas, allowed almost complete reduction of the population of wild boar. The development of a dynamic fence network, in combination with depopulation measures and organised search for carcasses, considerably helped to reduce the spread of the disease (Jori et al., 2021; Licoppe et al., 2023).

Some more details about outcomes of ASF fencing in Belgium are provided by Licoppe et al. (2023). In order to measure the effect of fencing on the spatial spread of the virus, the 10 fence segments closest to the positive cases were selected. In total, 6 of the 10 segments directly exposed to the spatial expansion front of the virus successfully contained the virus and were not crossed by wild boar, although positive cases were found close to the fence. Conversely, four fence segments were found to be porous. Despite the fact that an absolute seal was not observed, observations showed that the spatial expansion of the infected polygon was powerfully impeded by the erection of the network of fences. The median rate of spread was <2.0 km/month between emergencies (October 2018) and February 2019. After February 2019, the number of virus-positive animals found outside the infected polygon and the distance these animals crossed beyond the fences drastically decreased until a final stop of the expansion of ASF in the summer of 2019. The effect of the fence network on decelerating the spatial spread of the virus was amplified by the collapse of wild boar densities, both inside the infected area due to the mortality rate associated with the infection, and outside due to depopulation operations.

Aiming to understand the positive effects of fences in Belgium more into details, Dellicour et al. (2020) employed data on GPS-collared wild boar and large set of infection cases to analyse the permeability of barriers (fences installed during the ASF outbreak, the motorway segment crossing the study area, and roads or urban areas along which no fence was installed) to ASF dispersal. They revealed that both forest and barriers have significant impact on the wave-front velocity as follows: it progressed faster within forest areas and was significantly slowed down by the presence of barriers. Analyses confirmed the efficiency of the installed network of fences which -–complemented by pre-existing barriers (roads, urban areas)– impacted both the effective ASF virus dispersal and the wave-front velocity. However, the wave-front velocity was higher within forest areas and needed more time to cross non-forest areas which is probably a consequence of less frequent wild boar movement outside a forest environment as indicated by GPS telemetry. This is in line with a scenario where open land actually slows down the ASF progression throughout a non-continuous wild boar population. Therefore, in the context of an ASF outbreak, considering the forest coverage pattern is of strategic importance to install fences and delimiting the area of containment.

Again, in Belgium, the effectiveness of fences to prevent the spread of ASF was studied in two management zones: in a non-infected zone and in an ASF-infected zone which was fenced off from the surrounding ASF free zones. The camera trapping survey confirmed that fences placed at the infected/non-infected boundary act as an effective barrier throughout the entire study period, resulting in abrupt changes in occupancy from one zone to the other. This suggests that wild boar movement across this barrier was severely impeded, preventing inflow of the ASF to the non-infected zones (Bollen et al., 2021).

Laguna et al. (2022) evaluated the permeability of 4 different types of fences (livestock-type fence, poorly-maintained big game proof type fence, moderately-maintained big game proof type fence, well-maintained big game proof type fence) for wild boar in Montes de Toledo, central Spain. They found that well-maintained big game proof type fences were the most effective in reducing wild boar crossings, followed by moderately and poorly maintained big game proof fences and livestock type fences. 200 cm high well-maintained big game proof type fences with tightened horizontal and vertical wires (minimum 15×15 cm) that were weekly maintained were on average 30% more efficient than livestock-type fences (height between 120 and 150 cm with horizontal and vertical wires and wooden or steel posts). Authors also found that wild boar crossing success was higher for males than females, during the food shortage period and around watercourses, which were identified as vulnerable points of fences, where the frequency of crossings was higher than expected by chance.

The effect of border fence on wild ungulates mortality (and indirectly on crossing ability) was tested across the Hungary-Croatia border (Safner et al., 2021). The authors recorded 64 ungulates that died entangled in the razor-wire fence installed alongside (in parallel) with a high solid/mesh fence in a 28-month period, including three wild boar. The presence of a 4-metre high solid mesh fence on the Hungarian side trapped the animals in between the two fences and increased the mortality risk. When comparing results with similar study along Slovenia-Croatia border (Pokorny et al., 2017), where only razor-wire fence was installed, authors noted that the razor-wire fences alone are not as important disrupting factor for large mammal movements and population connectivity as when they are combined with solid mesh fences, which are in such construction (height of 4 m, dug into soil, very solid construction) completely impermeable for large mammals and may seriously diminish the connectivity of populations. Indeed, along the Hungary-Croatia border fence no crossing of wild ungulates (including wild boar) were registered, and huge herds of several 100s red deer (*Cervus elaphus*) were recorded several times when wandering along the fence in a search for possible migration corridor (Safner et al., 2021). On the contrary, along >170 km of razor-wire fence at Slovenia-Croatia border despite many mortality cases of red deer, several crossings or wild boar and no mortality of this species were registered (Pokorny et al., 2017).

Outside Europe, in the study on the effectiveness of fences in 12 wetlands in the Archer River catchment of Cape York Peninsula, Australia, Negus et al. (2019) found that exclusion fences (in this case constructed as taut fixed-mesh wire (approximately 10 $cm^2$) with several strands of barbed wire at and near the base of the fence) can prevent wild boar damage in wetlands if they are designed specifically for pigs and are properly maintained (i.e., being complete and promptly repaired in case of damage). Similar findings were also reached by Cox et al. (2022), who showed that properly maintained fences were successful in preventing wild pig dispersal and reinvasion on Auckland Island, New Zealand.

### 3.1.3 Road (highway) fencing and traffic barriers

Among linear infrastructure, roads are some of the most ubiquitous, and are often found in conjunction with fences (van der Ree et al., 2015). Roads, especially fenced highways, have multiple impacts on the environment. They reduce the habitat of the animals and plants, isolate parts of extant populations from each other, and block migration routes. Although roads have been extensively studied as barriers to connectivity, the importance of highway fences has only been recently acknowledged, despite having a greater extent than roads in many areas.

Botting et al. (2023) used red deer and wild boar as model species to assess how roads, fences and wildlife passages affect the connectivity of Doñana Biosphere Reserve in Spain. They found that fences had the greatest impact on reducing connectivity and the addition of road fences (2 m high, single mesh wire with 5 cm span) to the model prevented movement between the core of the reserve and the west sub-area, which had suitable habitats for ungulates. Livestock fences (usually 1.5 m high, made of horizontal wooden poles with 20 cm span among them) also restricted movement by 80%. Reiner et al. (2021) used genetic data from different wild boar hunting grounds in Rhineland-Palatinate, Germany, to assess the connectivity and differentiation of wild boar populations in a region threatened by ASF from neighbouring regions. They found that the Rhine River was the strongest barrier to gene flow among wild boars, followed by the freeways and their accompanying structures. Although freeways are not fenced on most of the sections, major A6 freeway is largely fenced, but still leads over viaducts or to parallel structures (settlements, agriculture lands). For this reason, the authors noted that it remains unclear how much of this effect is due to the freeways themselves. Indeed, it was also possible that the barrier effect was due to natural/landscape barriers which might have a higher resistance to wild boar movements and be the real barrier to gene flow (Frantz et al., 2012). In another European study, Mihalik et al. (2018) investigated the impact of the M3 highway in Hungary on the genetic diversity of wild boar populations. The research revealed that the M3 highway reduced gene flow between wild boar populations on either side of the road, although they detected only minor differences in allele frequencies and heterozygosity values between subpopulations. This may be due to the recent building of M3, which started only 40 years ago, or to the functioning wildlife underpasses and the good mobility of wild boars. However, the authors of the study cautioned that there exists an isolation effect, which can be intensified in time. On the contrary, Griciuvienė et al. (2021) did not find significant genetic differentiation or population structure among wild boar from four different regions in Lithuania: $F_{ST}$ (fixation index) analysis showed no evidence of genetic differentiation between subpopulations living on opposite sides of the motorway. However, analysis using the Mantel test did show weak correlation between western and eastern sampling areas which suggests that weak differentiation could occur due to habitat fragmentation by the main motorways: E67 (Vilnius-Klaipėda) and the E85 "Via Baltica" motorway connecting Lithuania and Poland. The E67 and E85 are the busiest roads in Lithuania (6873 and 9523 vehicles per day, respectively), therefore, high volumes of traffic, fencing and contiguous urban areas can reduce gene flow and affect the population structure. However, population genetic structure of wild boar in Lithuania is uniform, indicating there may be no larger barriers hindering dispersal across the landscape. The reason may be that wild boar often successfully cross highways, also fenced ones, at unfenced areas (intersections with rivers/roads) or using underpasses. Honda et al. (2020) evaluated techniques and strategies for improving the effectiveness of fences in such vulnerable areas. They developed grates with slanted steel panels which induced slippage of ungulate hooves down into the grates; therefore, ungulates couldn't normally walk on the grates which were laid directly on the road. Results of the study showed that no wild boar was able to pass the type 2 grates (85/100 mm height, 55° angle, and 100 mm distance between slant panels, inducing hoof slippage and prevented normal walking by wild boar), but could walk on some other types of grates with lower height, smaller angle, or larger drain space.

In some studies, authors have monitored the use of underpasses by wild animals, including wild boar. Iwiński et al. (2019) evaluated the use of wildlife crossings by wild ungulates under the expressway S11 in Napchanie, Poland. Monitoring by camera traps showed that wild boar were the most frequent users of the wildlife crossings and that they migrated through the entire width of the crossing, without paying attention to any possible danger. Also, human presence did not significantly affect their movements, although there was a decrease in the number of animal crossings immediately after humans passed through the underpass. However, in a 24-hours perspective, the number of crossings did not change. In another study in Poland, Ważna et al. (2020) evaluated the use of underpasses by animals on a fenced expressway S3 in a suburban area in the western part of the country (Lubuskie province). They found that wild boar were frequent users of the underpasses, despite their small size and low openness index which indicates that they can adapt to difficult conditions of mobility and use available passages to cross the road. Specifically, it did not use all underpasses with the same frequency, preferring the type IV (25 m long, 7 m wide, 160 $m^2$ raked area). Authors also reported that wild boar used the underpasses mainly in spring and rarely in winter, which may be related to their seasonal breeding and feeding patterns, as well as the availability of food resources in the surrounding areas. They also observed that wild boar preferred dry underpasses and avoided those where rainwater stagnated periodically. In a similar study, Bhardwaj et al. (2022) investigated the use of one at-grade fauna passage by wild ungulates in southern Sweden. They found that wild boar were the most frequent users of the passage, using it regularly throughout the year, but less so from January to May. They also found that wild boar on average spent less time at the at-grade fauna passage than roe deer and red deer, crossed the road mostly at night and preferred to use the passage when there was no traffic. In the study in Doñana Biosphere Reserve, authors found that wild boar could use all the underpasses in the study area, whereas red deer could not use some of them due to their low openness index (Botting et al., 2023).

### 3.1.4 Natural barriers

Patterns of genetic differentiation within and among populations might vary due to the simple effect of distance or landscape features hindering gene flow. An assessment of how landscape connectivity affects gene flow can help guide management, especially in fragmented landscapes (Lecis et al., 2022). Geographical wildlife patterns also reflect historical range expansion, connectivity of populations and possible presence of natural barriers.

Effects of geographic distance, main roads, and land cover on the genetic differentiation among subpopulations of wild boar was tested on Sardinia (Italy). Lecis et al. (2022) found that main roads and urban settings were the most important barriers to gene flow, while natural habitats such as forests and shrublands facilitated animal movements. They also found that geographic distance had a weaker effect than landscape features on genetic structure of the species. Sawai et al. (2023) analysed the genetic population structure and migration patterns of wild boar in Japan, covering their entire habitat range. They identified 15 genetic clusters, each structured within a range of approximately 200 km, suggesting isolation by distance and limited gene flow among subpopulations. They detected six potential geographic barriers to migration, including the sea, plains, forest discontinuity areas and mountainous areas, that shaped the genetic diversity and population dynamics of wild boar in Japan. In a study performed in the administrative district of Arnsberg, Germany, Methner et al. (2018) investigated different strains of *Salmonella choleraesuis*, isolated from 46 wild boar. Because a specific cluster of *S. choleraesuis* occurred almost exclusively in only certain regions of the district, authors assumed that both natural barriers (mountains, mountain ranges and wide rivers) as well as artificial ones (major roads) cause the separation of wild boar and their pathogens.

The potential of main rivers to restrict dispersal of wild boar has also been described in some studies. As already mentioned, Reiner et al. (2021) used genetic data to assess the connectivity and differentiation of wild boar populations in Rhineland-Palatinate, Germany. Among the two rivers that cross the region, the Moselle River is about 40 m wide with an average discharge of 313 $m^3$/second, which allows enough wild boar to cross the river, thus limiting detectable genetic differentiation and potentially allowing expansion of ASF. In contrast, the Rhine River with a width of 150–250 m has an average discharge of about 2,000 $m^3$/second, which makes it more difficult for wild boar to cross, so authors assumed that it can act as an important barrier for the spread of the ASF virus.

In the study performed in north Queensland, Australia, Ryan et al. (2023) also found that major waterways such as the Herbert River acted as barriers to gene flow, as they reduced the genetic similarity between populations of feral pigs on opposite sides of the waterways. However, the main cause of genetic differentiation seemed to be isolation by distance, meaning that populations that are farther apart tend to be more genetically different. Saito et al. (2022) found that the wild boar population in Fukushima Prefecture (Japan) is genetically divided into two groups by the Abukuma River, which runs through the central part of the prefecture. They assumed that this river and the urbanised area along it likely act as barriers to migration and dispersal of wild boar, reducing the gene flow between the two groups.

### 3.1.5 Other separation methods

Other separation methods were also taken into consideration in some peer-reviewed papers, including active and passive guarding, trenches, diversionary feeding, natural fences, distance to forest, hunting, and vegetation clearings.

Pascual-Rico et al. (2018) investigated the effectiveness of diversionary feeding in mitigating human-wildlife conflicts. They found that wild boar were frequent visitors to the feeding sites, but only temporal, and not spatial, segregation was recorded with other species accessing the same sites. Castillo-Contreras et al. (2018) investigated behaviour of wild boar in urban environments, focusing on the city of Barcelona. Results showed that wild boar enter urban areas from nearby natural habitats using corridors, such as streams, looking for available food (thus intensifying access during births and dispersion seasons). Following the results of this study, management measures such as vegetation cleaning 100 m wide fringe in the limit between the Collserola massif and the urban area have been implemented to create a less comfortable transition, in addition to wild boar population and anthropogenic food availability reduction.

In a large-scale study, Gross et al. (2018) investigated the effectiveness of traditional and advanced guarding in reducing crop losses due to wildlife (including wild boar) in different areas in Africa and Asia. They found that traditional crop protection measures (other than communal, strategic guarding systems) were ineffective in reducing crop damage costs, while advanced guarding, when applied as a communal system, showed promise in mitigating damage costs caused by wildlife.

## 3.2 Results from the questionnaire

### 3.2.5 Description of the dataset

Number of answers per each method used for controlling/reducing wild boar movements is shown in Table 5. Main results for each method are presented in the up-following sections. For the most common separation methods used (i.e., solid (mesh) fences, electric fences, chemical/odour repellents, and acoustic/sound deterrents), results are presented also sub-structurally, i.e., considering different aims of the implementation (ASF control + reduced interaction between wildlife and livestock, crop/forest protection, road/railway safety, hunting enclosures), for which we received adequate number of responses. Moreover, for some of these measures, comparison of outcomes in relation to both technical details of implementation and environmental features is provided, enabling more detailed evaluation of effectiveness and feasibility of measures.

**Table 5:** Frequency of methods used for controlling/reducing wild boar movements (multiple answers were possible).

| Separation method | n[1] |
|---|---|
| Solid (mesh) fence | 39 |
| Electric fence | 33 |
| Chemical/odour repellents | 9 |
| Acoustic/sound deterrents | 9 |
| In person guarding/shepherding/patrolling | 7 |
| Visual repellents (e.g., fladry/flags) | 4 |
| Razor-wired / barbed wire fence | 3 |
| Gustatory/food method | 3 |
| Complementary use of natural barriers[2] | 2 |
| Artificial light deterrents | 0 |
| Combination of methods[3] | 8 |
| Other[4] | 3 |

**Notes:**
[1] Although ‘combination of methods’ was provided as a predefined answer in the questionnaire, several respondents also indicated different methods per response, therefore, the number of methods for which we received data is higher as was the number of filled questionnaires.
[2] Natural barriers, which were complementary used: lake, high.
[3] Combination of methods: mesh + electric fence; färist (cattle grid) + road grid; fence + controlling + electric fence + repellents; solid (mesh) fence with electric lining at around 20 cm; electric fence + repellents (odour/sound); dogs + guns.
[4] Other methods: hunting; restrictions of access except using roads; no barriers implemented.

### 3.2.6 Solid (mesh) fences

For experiences with solid fences, we received 40 responses from 15 countries (some of them were accompanied by other measures, mainly electric fences): Italy (11), Spain (7), Hungary (5), Bosnia and Herzegovina (2), Croatia (2), France (2), Romania (2), Slovenia (2), Belgium (1), Czech Republic (1), Denmark (1), Latvia (1), Netherlands (1), Serbia (1), and Sweden (1). The first of these fences was built already in March 1944, and three more were built before 2000, while the majority have been implemented since 2015. Data for the implementation costs for solid fences were provided in 14 cases, and they ranged from 4,000 EUR to 20,000,000 EUR (mean: 2,080,000 EUR), while the annual maintenance costs (n = 10) were in the range from 1,000 EUR to 200,000 EUR (mean: 26,900 EUR). Aims of installing solid fences are presented in Table 6.

**Table 6:** Frequency of aims of the installation of solid (mesh) fences (multiple answers[1]).

| **Aim of the installation of solid fences** | **n** |
|---|---|
| Crop/forest protection | 17 |
| ASF control | 8 |
| Reduced interaction between wildlife and livestock | 7 |
| Road/railway safety | 7 |
| Hunting enclosure | 6 |
| National border security | 2 |
| Wildlife/national park | 2 |
| Other[1] | 3 |

**Notes:**
[1] Due to multiple answers, *n* provided here might exceed *n* for each aim as presented in subchapters.
[2] Other aims: enclosure/hunting ground for the Savoyards; protection of wild ungulates in the park; wild boar farm.

ASF was the driver of installation of the fence in 11 cases, while in 27 cases it was not. Similarly, at the time of implementation, ASF was present in 10 areas (only in wild boar: 7 cases; in both wild boar and domestic pigs: 3 cases), while in 28 areas it was not present. Currently, ASF is present in 14 areas of interest (only in wild boar: 11 cases; in both wild boar and domestic pigs: 4 cases), while in 25 areas it is not present. Here we should stress that fences are used in these areas for different purposes (see following subchapters), therefore, the increase of the number of areas with ASF present per se does not indicate ineffectiveness of solid fences for controlling spread of ASF virus. More information on solid fences in relation to responses, relevant to ASF control, are provided in Subchapter 3.2.2.1.

In almost all areas where solid fences were implemented, wild boar was a target species: in 35 cases it was a primary target species, and in 3 cases it was targeted together with other wild ungulates). Only in one case (related to border security), the target species was another, i.e., humans (to prevent illegal migrations). In all cases where secondary target species apart from wild boar were mentioned, those were wild ruminants, mainly cervids (fallow deer (*Dama dama*), red deer, roe deer) and in one case mouflon (*Ovis gmelini musimon*).

In 16 cases (39%), fences were used as a linear barrier, and in 21 cases (51%) as an enclosure; for two cases, no data on the shape of the fence was provided. For areas for which data was provided, the size of the area enclosed by solid fences was in a range between 0.5 ha and 600 $km^2$, while in case of linear barrier the length was between 2 km and 270 km. The height of the fence was from 0.8 m to 2.2 m (with one fence of even 4 m height), with variable height (e.g., 1.2–1.5 m, 1.5–2.0 m, 1.6–1.8 m, and 1.8–2.0 m) in some cases. Also mesh size openings were variable, in range between 5x5 cm and 20x20 cm. In almost all cases, bottom of the fence touched the ground (only in two cases there was an open space of 5–10 and 20 cm, respectively), and in 22 cases (65% out of 34 answers) the fence was dug into ground. In almost all cases, the fence was metal (in some cases also galvanised or reinforced to be more impact resistant), and in one case it was made from brick and concrete. In 12 cases (38% out of 32 answers), the solid fence was complemented by an electric fence.

Predominant landscape type/land use was mixed forest-farmland (mosaic) with 25 cases out of 34 responses (61%), followed by forests (n = 7; 17%). Residential (suburban) landscape and other (i.e., forest and heather landscape) were reported by one case each, while no fence was installed in farmland or wetland. Considering typical topographical character, dynamic/variable topography prevailed (17 cases; 41% out of 33 answers), followed by flat land (n = 12; 29%), steep slopes (n = 3; 7%), and other (variable) by one case. In 19 responses, either natural or artificial elements were used as a part of the barrier system as follows (multiple answer possibility): highways (10; 53%), villages/urban areas (6; 32%), main roads (5; 26%), rivers (5; 26%); streams, mountains, sea (coast), hunting estate, and existing fenced natural park by one case each.

Considering harvesting of the target species in the case of enclosures, we received 26 answers for culling within the enclosed area (intensive cull: 15 cases (58%); hunting at normal intensity: 3 cases (12%); without culling: 8 cases (31%)), and 28 answers for culling outside the enclosed area (intensive cull: 9 cases (32%); hunting at normal intensity: 18 cases (64%); without culling: 1 case (4%)).

In general (regardless of the aim of the implementation and influential factors), construction of solid fence affected population abundance/density of wild boar in 9 cases out of 31 responses to this question (29%), while in 22 cases (71%) no effect was reported. In some cases, respondents indicated higher density as before due to the following reasons (citation of direct answers): (i) the fence was built to get a game preserve so densities are higher than outside the fence; (ii) population density of enclosed animals increased; (iii) the production goal at this wild boar farm is 5 offspring/female. On the contrary, some respondents reported lower density as before due to: (i) population reduction; (ii) fencing and culling eliminated all wild boar within enclosure; (iii) limited migration combined with intensive culling: the fences created some large enclosures, so it was possible to adapt the culling method according to the epidemiological status (the virus stopped spreading thanks to the fences and drastic decrease of the population); (iv) reduction in population density inside the fenced zone, where lethal actions were carried out, while outside the population remained at a high density; there were few penetrations of animals from outside to inside, but they were quickly culled because they were not habituated to night shooting.

In comparison with the effect on population density, solid fences were much more effective when considering their impact on spatial behaviour of wild boar. Indeed, in 20 out of 32 relevant answers (63%) respondents reported such an effect, and concrete answers were as follows:

- The fence prevented the passage of ASF for a certain amount of time;
- Animals avoided or renounced to visit the area;
- Animals migrated to parts where there was no implementation;
- Changes especially in temporal behaviour: because human activity in the forest came to a halt, the ungulates became active at daytime. With regards to the spatial behaviour, deer mostly walk along the fence to find an opening, while wild boar are strong and trend to pass underneath the fence;
- Animals no longer cross the fence; piglets might go through the 20x20 cm fence, but they do not cause damage or come out quickly if the sow cannot get through;
- Restriction of wild boar migration;
- Animals did not pass the fence;
- Migration, dispersal and home range size of enclosed animals decreased;
- Impossible for animals to escape;
- Animals first searched for passages in the fence, then avoided the area which was exposed (and which became a danger zone at night with night shooting);
- Animals were restricted to the enclosure;
- Animals tried to overcome barriers, in some cases succeeding in doing so;
- It seems to reduce, but not prevent, wild boar access in areas of potential contact with livestock. Above all, it limits the movement of livestock and reduce contact with wildlife;
- Animals (presumably red deer) start gathering in a very huge herd;
- Animals try to penetrate the fenced areas and may become entangled in the electric fence and even die. The proliferation of fences has led to a significant reduction of suitable habitat;
- After the construction of the fence, mammals tried to cross the fence, later they got used to it, but in some cases smaller mammals can go through.

Changes in animal movements were measured (e.g., with telemetry) only in 7 (22%) of these areas, and change in spatial behaviour was confirmed by the following observations (directly cited from responses): (i) tracking with game trail cameras, and tracking manually when snow cover; (ii) the denser distribution of GPS telemetry positions (fixes) along the fence showed that wild boar were trying to penetrate the fenced area; (iii) GPS telemetry showed that wild boar were trying to enter the fenced area as positions were clustered along the fence.

In spite of the scarcity of scientific methods used for determining changes in spatial behaviour of target species, 16 respondents reported the following effects of fences on wild boar that were (according to their opinion) scientifically confirmed (multiple answers were allowed): hindered migration/dispersion (7 responses), population separation (4), genetic differentiation of populations (3), while 2 indicated other plausible response which was relevant to the question (i.e., genetic selection/purity, change in damage (before vs. after)).

Respondents were also asked to assess the effectiveness of the solid fences in relation to the main aims of the implementation (Table 7). Although there is some mismatch in number of answers, showing difficulties of some respondents to clearly understand that they should provide answer only for the primary aim and, therefore, some of them assessed the effectiveness also in relation to some secondary outcomes (i.e., fences implemented for ASF control might also have some positive effects on crop protection etc.), it is evident from the summarised results that solid fences are very effective tool for crop protection and forest protection (reasonable to completely effective: 85.7% and 90.0%, respectively), and to lesser extent also when aimed to increase road/railway safety or to reduce wildlife-livestock interactions (83.3% and 75.0%, respectively, with grades 3–5, i.e., assessed as reasonably, very, or completely effective). Considering ASF control, however, they were ranked in the highest three grades in half of cases, and in only 35.7% of cases solid fences were assessed to be very or completely effective for virus control.

**Table 7:** Assessment of the general effectiveness of the solid (mesh) fences in relation to different aims[1] (1 = completely ineffective, 2 = somewhat effective, 3 = reasonably effective, 4 = very effective, 5 = completely effective; N/A = not relevant; number of responses and % considering all relevant answers are presented).

| | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 | N/A | All relevant answers |
|---|---|---|---|---|---|---|---|
| ASF control | 3 *(21.4%)* | 4 *(28.6%)* | 2 *(14.3%)* | 3 *(21.4%)* | 2 *(14.3%)* | 6 | 14 |
| Crop protection | 1 *(4.8%)* | 2 *(9.6%)* | 8 *(38.1%)* | 7 *(33.3%)* | 3 *(14.3%)* | 6 | 21 |
| Forest protection | 1 *(10.0%)* | 0 | 4 *(40.0%)* | 4 *(40.0%)* | 1 *(10.0%)* | 11 | 10 |
| Reducing wildlife-livestock interactions | 2 (16.7%) | 1 *(8.3%)* | 1 *(8.3%)* | 5 *(41.7%)* | 3 *(25.0%)* | 10 | 12 |
| Road/railway safety | 2 (16.7%) | 0 | 2 *(16.7%)* | 3 *(25.0%)* | 5 *(41.7%)* | 8 | 12 |
| National border security | 2 *(33.3%)* | 0 | 1 *(16.7%)* | 2 *(33.3%)* | 1 *(16.7%)* | 10 | 6 |

**Notes:**
[1] In some cases, respondents also included secondary aims beside the primary one (multiple answer possibility), therefore the number of responses per aim differs from the frequency of each aim as reported in Table 6.

In accordance with this, there were also responses (n = 31) on a very firm effect, i.e. related to preventing the crossing of a target species over the barrier: fully prevention with no crossing registered was reported in 4 cases (13%), while partial prevention with lower number of dispersing/migrating individuals than before was registered in 21 cases (68%). On the contrary, no changes were registered in 2 cases (6%), while in 4 cases (13%) this data is lacking as crossing frequency was not monitored. Main reasons why in some cases solid fences were assumed to be ineffective for the designed purpose are presented in Table 8.

**Table 8:** Main reasons why solid fences are/were understood to be ineffective.

| Reasons | N | % |
|---|---|---|
| Lack of adequate maintenance over time | 7 | 33% |
| Inappropriate type of method for the objective | 3 | 14% |
| Poor design | 1 | 5% |
| Badly constructed | 1 | 5% |
| Bad timing of the original implementation | 0 | 0% |
| Sabotage | 0 | 0% |
| Other[1] | 9 | 43% |
| All relevant answers | 21 | 100% |

**Notes:**
[1] Other reasons: bad timing of the original implementation and lack of adequate maintenance over time (two very the same answers); poor design and badly constructed; badly constructed, very heavy snows reduce usefulness; other species as vectors; lack of maintenance, sabotage, trees falling; shortage of staff employed and intermittent capture action; presence of rivers, even large ones, that cross the fence.

Finally, to provide a check-crossing of responses on effectiveness of different methods, we asked in the questionnaire about methods potentially used for estimating the effectiveness of different separation measures for wild boar. In case of solid fences (27 responses for this question), effectiveness was estimated in 10 cases (37%), using one of the following parameters/methods: camera traps / trail cameras, damage estimation (economically), observations at baiting stations and feeding sites used to ensure plenty of feed for remaining wild boar, number of ASF positive wild boar detected at the other side of the fence, spreading of disease/infection outside the fenced area, ASF presence in the enclosures, monitoring along the fence, and the claim for crop damage that has been almost reduced to zero. On the basis of their own methods/parameters used, the respondents reported the outcomes as follows:

- No movement of wild boar over the barrier was registered;
- 70–90% damage reduction;
- No observed break-out through fence, no entrance of wild boar either; in systematic searches in enclosure and surrounding areas, no further carcasses were found;
- ASF was present in the enclosure;
- There was a significant delay, but finally ASF was present;
- The infected animals were immediately closed inside the fence: in the first year, the infection did not spread outside the fence, in the second year it spread to areas outside the fence;
- Found dead animals in the razor-wire fence along the solid fence.

#### *3.2.2.1 Solid fences: ASF control and reducing interactions with livestock*

For experiences with solid fences aimed at ASF control and reducing interactions with livestock (although these two aims were stated separately in the questionnaire, we decided to pool them due to similar ratio behind as well as to increase the sample size of responses), we received 14 responses from 10 countries: Italy (3), Spain (2), Bosnia and Herzegovina (2), Belgium (1), France (1), Latvia (1), Netherlands (1), Romania (1), Serbia (1), and Sweden (1). Considering ASF control only, we received 7 answers from 6 countries (Italy (2), Belgium, France, Romania, Serbia, Sweden), and considering reduction of wildlife-livestock interactions, 7 responses from 5 countries (Bosnia and Herzegovina, Latvia, Netherlands, Romania, Spain), with one overlap between both aims. Although it is clearly evident from responses that almost all fences aimed at ASF control were complemented by other measures (mainly electric fences, also odour repellents in some cases), we present below results related to solid fences as obtained from 1KA application (i.e., for each case where solid fence was implemented as –assuming so– the main measure), but in case of clear indication whether they were accompanied by electric fence or not (specific question) we also provide comparisons of outcomes between both scenarios. However, in independent subchapter we present outcomes when a combination of methods was used; although this causes some redundancy in presenting results, it is the only way to include the two possibilities (solid fence alone and solid fence with parallel electric fence vs. combination of different measures, including solid fences).

One of the fences (related to reducing interactions with livestock) was built in 2001, while all others have been implemented since 2018. Data for the implementation costs were provided in 7 cases (6 in the case of ASF control), and they ranged from 15,000 EUR to 20,000,000 EUR (mean: 4,120,000 EUR), while the annual maintenance costs (n = 4 in both cases) were in the range from 2,000 EUR to 200,000 EUR (mean: 97,000 EUR).

In almost all cases, wild boar was a target species: in 11 cases it was a primary target species (certainly in all cases, issued to ASF control), and in two cases aimed in reducing interactions with livestock it was targeted together with other ungulates. ASF was the driver of installation of the fence in 10 cases. At the time of implementation, ASF was present in 9 areas (only in wild boar: 7 cases; in both wild boar and domestic pigs: 2 cases), while in 4 areas it was not present. In 4 cases (36% out of 11 relevant answers), fences were constructed in the infected zone (according to the EU zoning policy) and in 2 cases (18%) in the restricted zone II; with one case each, fences were also implemented in: (a) the restricted zone III, (b) the restricted zones I, II and outside, and (c) in unrestricted zone. Domestic pigs are present in 11 of the relevant areas (4 indoor only; 7 indoor and outdoor – among them, in 2 cases pigs are also free-ranging). Currently, ASF is also present in 9 areas of interest (only in wild boar: 6 cases; in both wild boar and domestic pigs: 3 cases). In one case (Belgium), the area has become an ASF free area, presumably also because of the successful reduction of wild boar movements due to implementation of the fence.

In 6 cases (55%), fences were used as a linear barrier, and in 5 cases (45%) as an enclosure; for two cases, no such details were provided. Considering ASF control only, the size of the area enclosed by solid fences was in a range of 12 $km^2$ to 100 $km^2$, while in case of linear barrier the length was between 2 km and 270 km. The height of the fence was from 1.0 m to 2.2 m, with variable height (e.g., 1.5–2.0 m) in one case. Also, mesh size openings were variable, in range between 5x5 cm and 20x20 cm. In almost all cases, bottom of the fence touched the ground (only in one case there was an open space of 5–10 cm), and in 7 cases (64% out of 11 answers) the fence was dug into ground. In all cases, the fence was metal, in some cases also galvanised, and in one case with the following additional description: "skirt" of 6 cm mesh metal wire fence added angling into enclosure, laid on ground, not buried, to avoid wild boar lifting fence bottom; moreover, poles of wood at 2 m high aimed at adding electric wire higher up in case of deep snow cover". In 4 cases (36%), the solid fence was complemented by an electric fence, for example as an electric lining at around 20 cm.

Predominant landscape type/land present in the area was mixed forest-farmland (mosaic) with 6 cases out of 11 responses (45%), followed by forests (n = 3; 27%). Residential (suburban) landscape and other (i.e., forest and heather) were reported by one case each, while no fence was installed in farmland or wetland. Considering typical topographical character, flat land prevailed (6 cases; 55%), followed by dynamic/variable topography (n = 5; 45%). In 8 responses, either natural or artificial elements were used as a part of the barrier system as follows (multiple answer possibility): highways (6; 43%), villages/urban areas (5; 36%), main roads (4; 29%), rivers (3; 21%); streams, mountains, hunting estate, and existing fenced natural park by one case each.

Considering harvesting of wild boar in the case of enclosures aiming both at ASF control and reducing interactions with livestock, we received 9 answers. Culling within the enclosed areas was as follows – intensive cull: 5 cases (56%), hunting at normal intensity: 3 cases (33%), without culling: 1 case (11%); culling outside the enclosed areas – intensive cull: 4 cases (44%), hunting at normal intensity: 4 cases (44%), without culling: 1 case (11%). Considering ASF control only, the harvesting of wild boar was much more intensive, i.e.: (a) within the enclosed areas (6 responses) – intensive cull: 5 cases (83%), hunting at normal intensity: 1 case (17%); no area without culling; (b) outside the enclosed areas (5 responses) – intensive cull: 4 cases (80%), and hunting at normal intensity: 1 case (20%), respectively.

Construction of solid fences for ASF control or reducing interactions with livestock affected population abundance/density of wild boar in 4 cases out of 11 responses (36%), while in 7 cases (64%) no effect was reported. When considering ASF control only (7 responses), population density was affected (i.e., decreased) in 3 cases (43%). The decrease in density was a complex consequence of the measure (fencing), i.e., due to limited migration combined with intensive culling as was the case in Belgium, where the fences created some large enclosures (approx. 20 together with French and Luxembourgish network), so it was possible to adapt the culling method according to the epidemiological status. Similarly, according to another response, reduction in population density inside the fenced zone was accompanied with lethal actions carried out there; in case of (few) penetrations of animals from outside to inside, wild boar were quickly culled because they were not habituated to night shooting.

In general, solid fences (mainly accompanied by other measures, e.g. electric fences) aimed at ASF control and reducing interactions with livestock have been more efficient when considering change of the spatial behaviour of wild boar; indeed, 9 out of 11 relevant answers (82%) reported such an affect, as follows: (i) animals did not pass the fence; (ii) impossible for animals to escape; (iii) animals tried to overcome barriers, in some cases succeeding in doing so; (iv) it seems to reduce, but not prevent, wild boar access in areas of potential contact with livestock; (v) animals first searched for passages in the fence, then avoided the area which was exposed (and which became a danger zone at night with night shooting); (vi) the fence prevented the passage of ASF for a certain amount of time. However, changes in animal movements were measured only in one (7%) of these areas, i.e., by tracking with game trail cameras and snow tracking. Nevertheless, several respondents reported effects of fences on wild boar that were (according to their opinion) scientifically confirmed (multiple answers were allowed): hindered migration/dispersion (4 responses), population separation (2), genetic differentiation of populations (1), reduction of the population – an answer given as an explanation beyond other effects.

Respondents were also asked to assess the effectiveness of the solid fences in relation to ASF control and reducing interactions with livestock as the primary aims of the implementation (Table 9) as well as to assess the effect on ASF spreading beyond the fenced area (Table 10). Data on the effectiveness of fences in relation to their main aims were presented also in general presentation of the responses on the effectiveness of solid (mesh) fences (Table 7), but there some respondents obviously assessed effectiveness in relation to the secondary aims, therefore, results when using only preselected primary aims (ASF control; reducing interactions with livestock) are more relevant. Again, it is evident that the effectiveness of solid fences for ASF controlling is questionable/controversial, as in only 3 cases (42.9%) solid fences were assessed to be very or completely effective for virus control, while in one case they were reported as completely ineffective. However, when considering reduction of wildlife-livestock interactions, in 4 cases out of 5 (80%) solid fences were reported as reasonably to completely effective (Table 9).

**Table 9:** Assessment of the effectiveness of the solid (mesh) fences in relation to ASF control and reducing wildlife-livestock interactions as their primary aims (1 = completely ineffective, 2 = somewhat effective, 3 = reasonably effective, 4 = very effective, 5 = completely effective; N/A = not relevant; number of responses and % considering all relevant answers are presented).

| | **Grade 1** | **Grade 2** | **Grade 3** | **Grade 4** | **Grade 5** | **N/A** | **All relevant answers** |
|---|---|---|---|---|---|---|---|
| ASF control | 1 *(14.3%)* | 1 *(14.3%)* | 2 *(28.6%)* | 1 *(14.3%)* | 2 *(28.6%)* | 0 | 7 |
| Reducing wildlife-livestock interactions | 0 | 1 *(20.0%)* | 1 *(20.0%)* | 2 *(40.0%)* | 1 *(20.0%)* | 0 | 5 |

However, it is important to note that in 2 cases (out of 7 relevant; 29%) ASF has not spread beyond the fenced area; on the contrary, in 4 cases (58%) it has spread out, but with the important or moderate delay; in one case (14%) the virus spread out very fast (Table 10).

**Table 10:** Reported effects on ASF spread beyond the fenced area after the solid fence construction.

| Effect | N | % |
|---|---|---|
| No spread of ASF outside the fenced area | 2 | 28.6% |
| Very fast spread, without any expected delay | 1* | 14.3% |
| Moderate delay (<3 months after implementation) | 3 | 42.9% |
| Important delay (>3 months after implementation) | 1 | 14.3% |
| All relevant answers | 7 | 100% |

[1] The fence was constructed in Alessandria Province (Northern Italy).

Similarly, responses related to preventing the crossing of wild boar as a target species over the barrier (n = 12) indicated that solid fences aimed to reduce ASF virus spread and/or interactions with livestock have some potential to reduce crossing and, therefore, also disease transmission, but in general they can not completely stop crossings, particularly not on a permanent basis as it would be desired considering the veterinarian/health issues. Indeed, while at one side 2 cases (17%) of fully prevention with no crossing registered was reported, at the opposite side no changes in crossings was reported in one case (8%), while the majority of respondents indicated partial prevention with lower number of dispersing/migrating individuals than before (7 cases; 58%); in 2 cases (17%) this data is lacking as there was no possibility to monitor crossing frequency. In case of ASF control solely (7 responses), these figures are as follows: fully prevention, no crossings registered (2 cases; 29%), partial prevention with lower number of dispersing/migrating individuals than before (4 cases; 57%), and no changes in crossing frequency (1 case; 14%), respectively.

Main reasons for ineffectiveness of solid fences (in some cases) as a measure for ASF control or reducing wildlife-livestock interactions are, according to the opinion of respondents (N = 8), as follows: lack of adequate maintenance over time (4), poor design (1), badly constructed (1), inappropriate type of the method for the objective (1), and others (unfortunately, without any further specification; 1).

Effectiveness of solid fences aimed at ASF control or reducing wildlife-livestock interactions (10 responses) was estimated in 5 cases, using the following methods/tools/parameters: (i) camera traps; (ii) trail cameras, observations at baiting stations and feeding sites; (iii) number of ASF positive detected at the other side of the fence; (iv) spreading of disease; (v) the spread of the infection outside the fenced area. The respondents reported the outcomes as follows: (a) no movements of wild boar over the barrier; (b) no observed break-out through fence, no entrance of wild boar either; in systematic searches in enclosure and surrounding areas, no further carcasses were found; (c) ASF was already present in the enclosure; (d) the infected animals were immediately closed inside the fence: in the first year, the infection did not spread outside the fence, in the second year it spread to areas outside the fence.

Unfortunately, the number of responses on using solid fences for ASF control is rather low, therefore relevant analysis of explanatory/influential factors (scenarios), enabling firm conclusions, is impossible. However, we can extract from the more sub-structured analysis (i.e., by adding some additional factors) some findings presented below:

1. When/where solid fence was complemented by electric fence, they affected spatial behaviour of wild boar, and the method was assessed either as somehow or reasonably effective, with partially preventing wild boar from crossing; moreover, they caused moderate or important delay of ASF spread beyond the fenced area. For comparison, when/where solid fence was not complemented by electric fence, it affected spatial behaviour of wild boar in 3 out of 5 cases, and effectiveness of the method was assessed along the whole diapason of provided answers. High variabilities were reported also when considering effects on wild boar crossing, and the effect on ASF spread beyond the fenced area, i.e., from preventing the spread over the fence (two cases) to only moderate delay (Tables 11, 12). Obviously, implementation of the electric fence along the solid fence did not affect general effectiveness of solid fences.

**Table 11:** Comparison of the assessed effectiveness of the solid fences aimed to ASF control in respect to the complementary use of the electric fence (1 = completely ineffective, 5 = completely effective).

| | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 | N/A | All relevant answers |
|---|---|---|---|---|---|---|---|
| Accompanied with electric fence | 0 | 1 (*50%*) | 1 (*50%*) | 0 | 0 | 0 | 2 |
| Without accompanied electric fence | 1 (*20%*) | 0 | 1 (*20%*) | 1 (*20%*) | 1 (*20%*) | 1 (*20%*) | 5 |

**Table 12:** Comparison of reported effects of solid fences –in respect to the complementary use of the electric fence– on preventing wild boar from crossing and ASF spread.

| Effect | Electric fence YES | Electric fence NO |
|---|---|---|
| ***Effect on wild boar crossing*** | | |
| Fully, no crossing was registered | 0 | 2 (*40%*) |
| Partially, the number of dispersing/migrating individuals was lower than before | 2 (*100%*) | 2 (*40%*) |
| No changes were registered | 0 | 1 (*20%*) |
| Unknown, not possible to monitor | 0 | 0 |
| **All relevant answers** | **2** | **5** |
| ***Effect on ASF spread beyond the fenced area*** | | |
| No spread of ASF outside the fenced area | 0 | 2 (*40%*) |
| Important delay (>3 months after implementation) | 1 (*50%*) | 1 (*20%*) |
| Moderate delay (<3 months after implementation) | 1 (*50%*) | 1 (*20%*) |
| Very fast spread, without any expected delay | 0 | 0 |
| **All relevant answers** | **2** | **4** |

2. For 7 responses, we were able to separate reported outcomes in respect to digging the fence into the ground (Table 13, 14). These outcomes are somehow controversial and do not confirm that digging the fence has any important effect on separating wild boar populations. Indeed, when considering assessed effectiveness of fences, two out of three of the most favourable outcomes (very and completely effective) were related to fences not being dug, while in one case such a fence was found to be completely ineffective (Table 13). On the contrary, no crossings of wild boar as well as no spread of ASF after implementation of fences were reported in both scenarios (dug vs. not dug; one area per each). However, a very fast spread of ASF outside the fenced area as well as no changes in wild boar crossing were registered once only in a case without digging (Table 14), indicating that this action might on a short-term basis have a beneficial effect.

**Table 13:** Comparison of the assessed effectiveness of the solid (mesh) fences aimed to ASF control in respect to digging it into the ground (1 = completely ineffective, 2 = somewhat effective, 3 = reasonably effective, 4 = very effective, 5 = completely effective; N/A = not relevant; number of responses and % considering all relevant answers are presented).

| | **Grade 1** | **Grade 2** | **Grade 3** | **Grade 4** | **Grade 5** | **N/A** | **All Relevant answers** |
|---|---|---|---|---|---|---|---|
| Dug into the ground | 0 | 1 *(25%)* | 2 *(50%)* | 0 | 1 *(25%)* | 0 | 4 |
| Not dug into the ground | 1 *(33%)* | 0 | 0 | 1 *(33%)* | 1 *(33%)* | 0 | 3 |

**Table 14:** Comparison of reported effects of solid fences –in respect of digging it into the ground– on preventing wild boar from crossing and ASF spread beyond the fenced area.

| **Effect** | **Dug into ground YES** | **Dug into ground NO** |
|---|---|---|
| ***Effect on wild boar crossing*** | | |
| Fully, no crossing was registered | 1 *(25%)* | 1 *(33%)* |
| Partially, the number of dispersing/migrating individuals was lower than before | 3 *(75%)* | 1 *(33%)* |
| No changes were registered | 0 | 1 *(33%)* |
| Unknown, not possible to monitor | 0 | 0 |
| **All relevant answers** | **4** | **3** |
| ***Effect on ASF spread beyond the fenced area*** | | |
| No spread of ASF outside the fenced area | 1 *(25%)* | 1 *(50%)* |
| Important delay (>3 months after implementation) | 1 *(25%)* | 0 |
| Moderate delay (<3 months after implementation) | 2 *(50%)* | 0 |
| Very fast spread, without any expected delay | 0 | 1 *(50%)* |
| **All relevant answers** | **4** | **2** |

3. For 7 responses, we were also able to separate reported outcomes in respect to typical topographic characteristics of the area of interest (Table 15, 16). These outcomes indicated important differences in effectiveness of fences in different landscapes. Indeed, all favourable/desired outcomes were from flat land, where in three cases the implemented measure was found to be very or even completely effective (Table 15), and it importantly affected both wild boar crossing (i.e., fully preventing, no crossing was registered) and ASF spread (i.e., no spread of ASF outside the fenced area). On the contrary, no such outcomes were reported in areas characterised by dynamic/variable topography, where solid fencer either did not prevent wild boar crossings or prevent it only partially, and where ASF in all cases has spread beyond the fenced area (Table 16). Although also in case of flat land solid fences might be completely ineffective (one case, where ASF spread beyond the fenced area with moderate delay), it is clear that effectiveness is dependent on orography, being higher in flat land, where solid fence construction is a much easier task.

**Table 15:** Comparison of the assessed effectiveness of the solid (mesh) fences aimed to ASF control in respect to typical topographic character (1 = completely ineffective, 5 = completely effective).

| | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 | N/A | All relevant answers |
|---|---|---|---|---|---|---|---|
| Flat land | 0 | 0 | 1 *(25%)* | 1 *(25%)* | 2 *(50%)* | 0 | 4 |
| Dynamic, variable topography | 1 *(33%)* | 1 *(33%)* | 1 *(33%)* | 0 | 0 | 0 | 3 |

**Table 16:** Comparison of reported effects of solid fences –in respect to typical topographic character – on preventing wild boar from crossing and ASF spread beyond the fenced area.

| Effect | Flat land | Dynamic topography |
|---|---|---|
| ***Effect on wild boar crossing*** | | |
| Fully, no crossing was registered | 2 *(50%)* | 0 |
| Partially, the number of dispersing/migrating individuals was lower than before | 2 *(50%)* | 2 *(66%)* |
| No changes were registered | 0 | 1 *(33%)* |
| Unknown, not possible to monitor | 0 | 0 |
| **All relevant answers** | **4** | **3** |
| ***Effect on ASF spread beyond the fenced area*** | | |
| No spread of ASF outside the fenced area | 2 *(66%)* | 0 |
| Important delay (>3 months after implementation) | 0 | 1 *(33%)* |
| Moderate delay (<3 months after implementation) | 1 *(33%)* | 1 *(33%)* |
| Very fast spread, without any expected delay | 0 | 1 *(33%)* |
| **All relevant answers** | **3** | **3** |

### *3.2.2.2 Solid fences: crop/forest protection*

For experiences with solid fences aimed at crop/forest protection, we received 16 responses from 5 countries: Italy (7), Spain (4), Hungary (3), Croatia (1), and Latvia (1). Also in these cases, some fences were accompanied by electric fences, but the majority were not. The first of these fences was built in 1998, while the majority have been implemented since 2005. Data for the implementation costs were provided in 6 cases, and they ranged from 4,000 EUR to 100,000 EUR (mean: 38,900 EUR), while the annual maintenance costs (n = 4) were in the range from 3,500 EUR to 15,000 EUR (mean: 9,100 EUR). At the time of implementation, ASF was present in one of these areas (in both wild boar and domestic pigs); there, ASF presence was also a driver for the implementation of the method. Currently, ASF is present in 3 areas of interest (only in wild boar: two cases; in both wild boar and domestic pigs: one case). In almost all cases, wild boar was a target species: in 16 cases it was a primary target species, and in one case it was targeted together with other species (i.e., the answers on the target species: wild ungulates). In all cases where secondary target species apart from wild boar were mentioned (7 cases), those were cervids: red, fallow and roe deer.

In 4 cases (24%), fences were used as a linear barrier, and in 12 cases (71%) as an enclosure; for one case, no data on the shape of the fence was provided. The size of the area enclosed by solid fences was in a range between 0.5 ha and 100 ha, while in case of linear barrier the length was between 20 km and 40 km. The height of the fence was from 0.8 m to 2.0 m, with variable height (e.g., 1.2–1.5 m and 1.6–1.8 m) in some cases. Also mesh size openings were variable, in range between 5x5 cm and 20x20 (25x15) cm, and in some cases with thickening/densification at the bottom in the case of special braided/flexible nets. In almost all cases, bottom of the fence touched the ground (only in one case there was an open space of 20 cm), and in 8 cases (57% out of 14 answers) the fence was dug into ground. In all cases, the fence was metal. In 5 cases (36% out of 14 answers), the solid fence was complemented by an electric fence.

Predominant landscape type/land use was mixed forest-farmland (mosaic) with 13 cases out of 14 responses (93%), and in one case the fence was built in forest (7%). Considering typical topographical character, dynamic/variable topography prevailed (8 cases; 62% out of 14 answers), followed by flat land (n = 3; 23%), and steep slopes (n = 2; 15%). Natural or artificial elements were generally not used as a part of the barrier system: only in one case, sea (coast) was reported to be included. Considering harvesting of the target species, we received 14 answers for culling within the enclosed area, which might in this case be understood also as a protected area on the cultivated side of the fence (intensive cull: 6 cases (43%); hunting at normal intensity: 1 case (7%); without culling: 7 cases (50%)), and another 14 answers for culling outside the enclosed area (intensive cull: 3 cases (21%); hunting at normal intensity: 10 cases (71%); without culling: 1 case (7%)).

Construction of solid fences affected population abundance of wild boar in one case out of 14 responses to this question (7%), while in 13 cases (93%) no effect was reported. In the case of the change of the density, it actually increased as “where there were no fences and guarding, there were more wild boar as they all went there” (direct citing from the response).

In general, solid fences aimed at crop/forest protection have not changed importantly the spatial behaviour of wild boar; nevertheless, 5 out of 14 relevant answers (36%) reported such an affect, e.g.: (i) animals avoided or renounced to visit the area; (ii) animals migrated to parts where there was no implementation of fences; (iii) animals no longer cross the fence; piglets might go through the 20x20 cm fence but they do not cause damage or come out quickly if the sow cannot get through; (iv) impossible for animals to escape; and (v) animals try to penetrate the fenced areas and may become entangled in the electric fence and even die; the proliferation of fences has led to a significant reduction of suitable habitat. However, changes in animal movements were measured (e.g., with telemetry) only in 2 (14%) of these areas, and change in spatial behaviour was confirmed by the following and very similar observations (directly cited from responses): (i) the denser distribution of GPS telemetry positions (fixes) along the fence showed that wild boar were trying to penetrate the fenced area; (ii) GPS telemetry showed that wild boar were trying to enter the fenced area as positions were clustered along the fence. One respondent reported hindered migration/dispersion as the effect of fences on wild boar that was (according to his/her opinion) scientifically confirmed; another one added change in damage (before vs. after) as another plausible response of wild boar.

From Table 17, it is evident that solid fences (either alone or accompanied by electric ones) are effective tools for both crop protection and forest protection (reasonable to completely effective: 93% and 100%, respectively). Moreover, 11 out of 13 relevant responses (88%) showed that crop damage has been importantly or almost completely reduced after the solid fence construction, while in only 2 cases (12%) no effect was reported (Table 18).

**Table 17:** Assessment of the effectiveness of the solid (mesh) fences in relation to crop/forest protection as their primary aim (1 = completely ineffective, 5 = completely effective).

| | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 | N/A | All relevant answers |
|---|---|---|---|---|---|---|---|
| Crop protection | 0 | 1 *(6.7%)* | 6 *(40.0%)* | 5 *(33.3%)* | 3 *(20.0%)* | 0 | 15 |
| Forest protection | 0 | 0 | 1 *(20.0%)* | 3 *(60.0%)* | 1 *(20.0%)* | 4 | 5 |

**Table 18:** Reported effect on crop damage after the solid fence construction.

| Effect | N | % |
|---|---|---|
| Not relevant | 1 | 7% |
| Damage was almost completely reduced (>75%) | 8 | 57% |
| Damage was importantly reduced (25–75%) | 3 | 21% |
| Damage was moderately reduced (<25%) | 0 | 0% |
| No effect | 2 | 12% |
| All relevant answers | 14 | 100% |

However, responses related to preventing the crossing of wildlife over the barrier (n = 11) indicated that solid fences aimed to reduce damage in agriculture/forestry are not impermeable barrier for wild boar. Indeed, no case of full prevention with no crossing was reported, while partial prevention with lower number of dispersing/migrating individuals than before was registered in 8 cases (73%). On the contrary, no change was registered in one case (9%), while in 2 cases (18%) this data is lacking as there was no possibility for monitor crossing frequency. Main reasons why in some cases solid fences are/were understood to be ineffective or only partially effective for reducing crop/forest damage are, according to the opinion of respondents (N = 8), as follows: lack of adequate maintenance over time (3), inappropriate type of the method for the objective (2), and others (3: bad timing of the original implementation and lack of adequate maintenance over time (two very the same answers); shortage of staff employed and intermittent capture action).

Effectiveness of solid fences aimed at crop/forest protection (11 responses) was estimated in 2 cases only (18%): (i) by damage estimation (economically); (ii) the claim for crop damage that has been almost reduced to zero, i.e., by 70–90%.

#### *3.2.2.3 Solid fences: hunting enclosures*

For experiences with solid fences around hunting enclosures, we received 6 responses from 5 countries: Slovenia (2), Bosnia and Herzegovina (1), France (1), Romania (1), and Serbia (1). Data for the implementation costs were provided in 2 cases (15,000 EUR and 20,000 EUR), while the annual maintenance costs (n = 3) were in the range from 1,000 EUR to 15,000 EUR (mean: 6,800 EUR), respectively. At the time of implementation, ASF was present in one of these (assuming broader) areas (in both wild boar and domestic pigs). Currently, ASF is present in 2 areas of interest (in both wild boar and domestic pigs), while in 3 areas it is not present (1 response lacking that info). In all cases, wild boar was a target species. In 2 cases where secondary target species apart from wild boar were mentioned, those were fallow deer and mouflon.

The size of the area enclosed by solid fences was in a range between 4 $km^2$ and 12 $km^2$. The height of the fence was from 1.6 m to 2.2 m, with variable height (e.g., 1.8–2.0 m) in one case. Also mesh size openings were variable, in range between 5x5 cm and 15x15 cm. In all cases, the bottom of the fence touched the ground, and in 3 cases (75% out of 4 relevant answers) the fence was dug into the ground. In all cases, the fence was metal (in one case also galvanised). In 3 cases, solid fences were complemented by electric fences, in one case they were not, and 2 responses lacked that info.

Predominant landscape type/land use was forest with 4 cases out of 5 responses, and in one case the enclosure was built in mosaic landscape (mix of forest and farmland). Considering typical topographical character, dynamic/variable topography prevailed (4 cases), and in one case the enclosure was on steep slopes. Considering harvesting of the target species, we received 5 answers for culling within the enclosure (intensive cull: 3 cases; hunting at normal intensity: 1 case; without culling: 1 case), and 4 answers for culling outside the enclosed area (intensive cull: 1 case; hunting at normal intensity: 3 cases).

In all cases with relevant answer (n = 4), solid fences have changed importantly the spatial behaviour of wild boar; e.g.: (i) migration, dispersal and home range size of enclosed animals decreased; (ii) animals were restricted to the enclosure. Three respondents reported hindered migration/dispersion as the effect of fences on wild boar that was (according to his/her opinion) scientifically confirmed; moreover, two respondents reported genetic differentiation of population, one reported population separation, and another one added genetic selection (purity) of wild boar.

Responses related to preventing the crossing of wildlife over the barrier (n = 4) indicated that solid fences used for hunting enclosures are not completely impermeable barriers for wild boar. Indeed, in only one case individuals have never escaped beyond the fenced area, while in other three cases target species did escape, but only sporadically (<3 cases annually). Main reasons why in some cases solid fences are/were understood to be ineffective or only partially effective for hunting enclosures, according to the opinion of respondents (n = 3), are as follows: lack of adequate maintenance over time (2), bad maintenance, sabotage, and falling trees that damaged the fence.

### *3.2.2.4 Solid fences: road/railway safety*

For experiences with solid fences aimed at road/railway safety, we received 7 responses from 5 countries: Spain (2), Hungary (2), Czech Republic (1), Italy (1), and Latvia (1). All fences have been built since 2005. Data for the implementation costs was provided in one case (10,000 EUR), while the annual maintenance costs were approx. 3,500 EUR.

At the time of implementation, ASF was present in one of these areas (wild boar and domestic pigs) and in 5 of them, ASF was not present. Currently, ASF is present in 4 areas of interest (only in wild boar: 3 cases; in both wild boar and domestic pigs: 1 case), while in 3 areas it is not present. In majority of the cases, wild boar was a target species: in 4 cases it was a primary target species, and in 3 cases it was targeted together with other species (i.e., answers as follows: large mammals, large ungulates). In all cases where secondary target species apart from wild boar were mentioned, those were cervids: red, fallow and roe deer.

The length of the fence was between 25 km and 1800 km and the total height of the fence was from 1.5 m to 2.4 m. Also mesh size openings were variable, in range between 5 x 5 cm and 20 x 15 cm, and in some cases with thickening/densification at the bottom in the case of special braided/flexible nets. In all cases, the bottom of the fence touched the ground, and in 5 cases (83% out of 6 answers) the fence was dug into the ground. In all cases, the fence was metal.

Predominant landscape type/land use was in all reported cases (n = 5) mixed forest-farmland (mosaic). Considering typical topographical character, dynamic/variable topography prevailed (4 cases), and in one case landscape type was flat land.

In general, solid fences aimed at road/railway safety have changed the spatial behaviour of wild boar; 3 out of 4 relevant answers (75%) reported such an affect, e.g.: (i) restriction of wild boar migration; (ii) after the construction of the fence, animals tried to cross the fence but only smaller species of mammals were able to get through in some cases; (iii) the system has been designed to redirect wildlife that has crossed the fences out of the risk zone, using a system of gates and sensors that lead the wildlife out of the infrastructure. One respondent also reported population separation as the effect of fences on wild boar.

From Table 19 it is evident that solid fences are in general effective tools for increasing road/railway safety (very to completely effective: 75% answers). Moreover, 2 out of 3 relevant responses showed that roadkill was almost completely reduced and in one case it was importantly reduced after the construction of fences along roads (Table 20).

**Table 19:** Assessment of the effectiveness of the solid (mesh) fences in relation to road/railway safety as their primary aim (1 = completely ineffective, 2 = somewhat effective, 3 = reasonably effective, 4 = very effective, 5 = completely effective; N/A = not relevant; number of responses and % considering all relevant answers are presented).

| | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 | N/A | All relevant answers |
|---|---|---|---|---|---|---|---|
| Road/railway safety | 1 *(25%)* | 0 | 0 | 2 *(50%)* | 1 *(25%)* | 1 | 5 |

**Table 20:** Reported effect on roadkill after the solid fence construction.

| Effect | N | % |
|---|---|---|
| Not relevant | 1 | 25% |
| Roadkill was almost completely reduced (>75%) | 2 | 50% |
| Roadkill was importantly reduced (25–75%) | 1 | 25% |
| Roadkill was moderately reduced (<25%) | 0 | 0% |
| No effect | 0 | 0% |
| All relevant answers | 4 | 100% |

Responses related to preventing the crossing of wildlife over the barrier, i.e., fenced roads/railways (n = 6), indicated that solid fences aimed to increase road/railway safety are not fully impermeable barriers for wild boar. Indeed, no case of full prevention with no crossing was reported, while partial prevention with lower number of dispersing/migrating individuals than before was registered in 5 cases (83%), and no change was registered in one case (17%). Main reasons why in some cases solid fences are/were understood to be ineffective or only partially effective for increasing road/railway safety are, according to the opinion of respondents (n = 3): bad construction (2), poor design, heavy snow, and personnel shortage.

### 3.2.3 Electric fences

For experiences with electric fences (either used alone, as in the most cases of crop/forest protection, or in combination with solid fences/repellents, mainly in case of ASF control), we received 33 responses from 12 countries: Italy (9), Hungary (3), Slovenia (3), Romania (3), Sweden (3), Spain (2), Czech Republic (2), France (2), Bosnia and Herzegovina (1), Croatia (1), Latvia (1), and Serbia (1); two responses lacking that info. The first of electric fences was built in April 1966, and two more were built before 2000, while the majority have been implemented since 2015. Data for the implementation costs for electric fences were provided in 14 cases, and they ranged from 1,000 EUR to 100,000 EUR (mean: 23,600 EUR), while the annual maintenance costs (n = 13) were in the range from 500 EUR to 15,000 EUR (mean: 5,400 EUR). In some cases of the highest implementation and maintaining costs, we can not exclude the possibility that those costs were actually given for the combination of methods, i.e., as a sum of costs together with the costs of solid fence. Aims of installing electric fences are presented in Table 21.

**Table 21:** Frequency of aims of the installation of electric fences (multiple answers).

| Aim of the installation of electric fences | n |
|---|---|
| Crop/forest protection | 21 |
| ASF control | 6 |
| Hunting enclosure | 6 |
| Reduced interaction between wildlife and livestock | 4 |
| Road/railway safety | 1 |
| National border security | 1 |
| Wildlife/national park | 1 |
| Other[1] | 2 |

**Notes:**
[1] Other aims: golf court protection; wild boar farm.

ASF was the driver of installation of the electric fence (in majority of cases in combination with the solid fence; an exception was in the Czech Republic, where electric fence was implemented in combination with odour repellents) in 7 cases, while in 25 cases it was not (one response lacking that info). In the case of installation of electric fences solely (n = 13), the aim was in 12 cases crop protection and in one case golf court protection. At the time of implementation, ASF was present in 7 areas where electric fences were installed (only in wild boar: 5 cases; in both wild boar and domestic pigs: 2 cases), while in 24 areas it was not present (without information provided: 2 cases). Currently, ASF is present in 10 areas of interest (only in wild boar: 7 cases; in both wild boar and domestic pigs: 3 cases), while in 22 areas it is not present. In almost all areas where electric fences were implemented, wild boar was a target species: in 32 cases it was a primary target species and only in one case the target species was another, i.e., not specified large ungulates. Secondary target species were in most cases cervids (fallow, red and roe deer), in one case mouflon, and in one case large carnivores (brown bear (*Ursus arctos*), grey wolf (*Canis lupus*)).

In 6 cases (20%), fences were used as a linear barrier, and in 24 cases (80%) as an enclosure; for 3 cases, no data on the shape of the fence was provided. For areas for which data was provided, the size of the area enclosed (or complemented) by electric fences was in a range between 0.5 ha and 12 $km^2$, while in case of linear barrier the length was between 6 km and 200 km. The total height of the fence was from 0.3 m to 2.0 m (the total height in the cases where electric fences were the only method used was from 0.4 m to 1.2 m), with variable height (e.g., 1.0-1.2 m, 1.8-2.0 m) in some cases. Number of electric wires was also variable, in range between 1 and 5 wires with height of the lowest wire in range between 5 cm and 40 cm above the ground. Distance between wires was in range between 15 cm and 50 cm and voltage was in range between 12 V and 220 V. Frequency of vegetation clearance along the fence was also variable, from weekly to once a year.

Predominant landscape type/land use was mixed forest-farmland (mosaic) with 21 responses (72%), followed by forests (n = 5; 17%). Residential (suburban) landscape and other (i.e., golf court, mix of suburban and mosaic) were reported by one case each, while no fence was installed in farmland or wetland. Considering typical topographical character, dynamic/variable topography prevailed (18 cases; 64%), followed by flat land (n = 6; 21%), steep slopes (n = 3; 11%), and other by one case. In 19 responses, either natural or artificial elements were used as a part of the barrier system as follows (multiple answer possibility): highways (4; 21%), villages/urban areas (4; 21%), main roads (4; 21%), rivers (3; 16%); streams (1), mountains (1), sea (1), and lake (1). As electric fences were several times installed in parallel with solid fences (and in all cases related to ASF control), we received huge overlap with responses presented in the chapter 3.2.1, therefore, at this spot we do not present more info about environmental/population features in areas of interest.

In general (regardless of the aim and influential factors/scenarios), construction of electric fences affected population abundance/density of wild boar in 7 cases out of 27 responses to this question (26%), while in 20 cases (74%) no effect was reported. However, reasoning behind is almost the same as in case of solid fences (chapter 3.2.1), indicating again that these effects were related to joint use of both measures and not of electric fences per se. The same holds true also when considering impact of electric fences on spatial behaviour of wild boar (20 out of 27 relevant answers (74%) reported such affect), where the following new answers (connected with using only electric fences, mainly aimed to crop/forest protection) appeared:

- Wild boar avoided the fence, entering suburban area;
- Animals have become habituated to following different paths and no longer crossed fields;
- Wild boar did not cross the fence when 3 strands of wire were used, with 2 wires some individuals still crossed;
- Wild boar could not cross the fields, resulting in more road crossings (warning signs were put up);
- Animals movement was restricted;
- Wild boar completely and permanently avoided entering the fenced meadows.

Changes in animal movements were measured (e.g., with telemetry) only in 3 (12%) of these areas, all being fenced also by solid fences, therefore, we cannot connect findings/observations (i.e., the denser distribution of GPS telemetry fixes along the fence; GPS telemetry showed that the wild boar were trying to enter the fenced area as positions were clustered along the fence) with direct effects of electric fences.

The effectiveness of the electric fences in relation to the main aims of the implementation is presented in Table 22. It is evident from the summarised results that electric fences (mostly alone or in combination with other methods) are very effective for crop and forest protection (reasonable to completely effective: 91% and 88%, respectively), and to lesser extent also when aimed to reduce wildlife-livestock interactions, ASF control or to increase road/railway safety (75%, 67% and 67%, respectively, with grades 3–5).

**Table 22:** Assessment of the general effectiveness of the electric fences in relation to different aims[1] (1 = completely ineffective, 2 = somewhat effective, 3 = reasonably effective, 4 = very effective, 5 = completely effective; N/A = not relevant; number of responses and % considering all relevant answers are presented).

| | **Grade 1** | **Grade 2** | **Grade 3** | **Grade 4** | **Grade 5** | **N/A** | **All relevant answers** |
|---|---|---|---|---|---|---|---|
| ASF control[2] | 1 *(11.1%)* | 2 *(22.2%)* | 1 *(11.1%)* | 2 *(22.2%)* | 3 *(33.3%)* | 7 | 9 |
| Crop protection | 1 *(4.5%)* | 1 *(4.5%)* | 8 *(36.4%)* | 9 *(40.9%)* | 3 *(13.6%)* | 3 | 22 |
| Forest protection | 1 *(12.5%)* | 0 | 3 *(37.5%)* | 3 *(37.5%)* | 1 *(12.5%)* | 8 | 8 |
| Reducing wildlife-livestock interactions | 2 (25.0%) | 0 | 0 | 3 *(37.5%)* | 3 *(37.5%)* | 7 | 8 |
| Road/railway safety[2] | 2 (33.3%) | 0 | 2 *(33.3%)* | 0 *(33.3%)* | 2 *(33.3%)* | 8 | 6 |
| National border security[2] | 1 *(33.3%)* | 0 | 1 *(33.3%)* | 0 | 1 *(33.3%)* | 9 | 3 |

**Notes:**

[1] In some cases, respondents also included secondary aims beside the primary one (multiple answer possibility), therefore the number of responses per aim differs from the frequency of each aim as reported in Table 21.

[2] In case of ASF control, road/railway safety and national border security, electric fences were mainly used as an addition to solid fences, therefore results presented here showed a comprehensive effect of both measures; due to this, we do not analyse and comment more into details the effect of electric fences in connection to these two aims.

Full prevention of crossings of target species with no crossing registered after implementation of electric fence was reported in 5 cases out of 24 relevant responses (21%), while partial prevention with lower number of dispersing/migrating individuals than before was registered in 17 cases (52%). In 2 cases (6%) this data is lacking. Main reasons why in some cases electric fences or their combination with solid (mesh) fences are/were understood to be ineffective are lack of adequate maintenance over time (6 responses; 38%) and inappropriate type of method for the objective (3; 19%); among other reasons, a very concrete technical details of implementation was also mentioned (i.e., start with 2 strands of wire which was not as effective in comparison with 3 wires, which is much better).

For estimating the effectiveness of electric fences (alone or in combination with solid fences) for reducing wild boar movement/activity, respondents (n = 7) were using the following: monitoring with thermovision cameras on drones and helicopters, damage estimation (economically), ASF presence in the enclosures, monitoring if the virus has spread outside the fenced areas. Regarding the main aims of the electric fence implementation (crop/forest protection; ASF control and reducing interactions with livestock), outcomes of the questionnaires are presented in the following subchapters, but we focused only on crop/forest protection where electric fences were in majority of cases used alone, while for ASF control they were as a rule used together with solid fences, therefore, results would overlap with outcomes, presented in Chapter 3.2.2.

#### *3.2.3.1 Electric fences: ASF control and reducing interactions with livestock*

For experiences with electric fences as an accompanied measure with solid fences and aimed either at ASF control or reducing interactions with livestock, we received 8 responses from 6 countries: Czech Republic (2), Romania (2), France (1), Bosnia and Herzegovina (1), Latvia (1), and Serbia (1). Considering ASF control only, we received 5 responses from 4 countries (Czech Republic (2), France, Romania, Serbia), and considering the aim of reducing interactions with livestock, 4 respondents were from 3 countries (Romania (2), Bosnia and Herzegovina, Latvia). All of the fences have been implemented since 2017. Data for the implementation costs were provided in 2 cases (both in the case of ASF control) and they amounted 20,000 EUR and 50,000 EUR, while the annual maintenance costs (n = 3) were in the range from 2,000 EUR to 10,000 EUR (mean: 5,400 EUR).

ASF was the driver of installation of the (combined) fence in 6 cases. At the time of implementation, ASF was present in 6 areas (only in wild boar: 5 cases; in both wild boar and domestic pigs: 1 case), while in 2 areas it was not present. In 2 cases, fences were constructed in the infected zone (according to the EU zoning policy) and in another 2 cases in the restricted zone II; fences were also implemented in the restricted zone (1), and in infected zone which became a restricted zone II during the implementation of the fence (1). Domestic pigs are present in all 6 ASF-affected areas (1 indoor only; 5 indoor and outdoor and among them in 1 case pigs are also free-ranging). Currently, ASF is still present in all 6 areas of interest (only in wild boar: 4 cases; in both wild boar and domestic pigs: 2 cases). In all cases except one, wild boar was a primary target species (in all cases, issued to ASF control), and in one case it was targeted together with other ungulates.

In 3 cases (43%), (combined) fences were used as a linear barrier, and in 4 cases (57%) as an enclosure; for one case, no data on the shape of the fence was provided. The size of the area enclosed by electric fences was in a range between 0.8 $km^2$ and 58 $km^2$, while in case of linear barrier the length was between 16 km and 200 km. The total height of the fence was from 0.8 m to 1.2 m. Number of electric wires was variable, in the range between 2 and 4 wires, and the height of the lowest wire was between 20 cm and 40 cm above the ground. The distance between the wires was also variable, in range between 30 cm and 50 cm, and voltage was between 220 V and 230 V. Vegetation clearance along the fence was in all cases weekly or monthly.

Predominant landscape type/land use was mixed forest-farmland (mosaic) with 4 cases (57%), followed by forests (n = 1; 14%), residential (suburban) landscape (n = 1; 14%), and other (mix of mosaic and suburban; 1), while no fence was installed in farmland or wetland. Dynamic/variable topography was the most represented (6 cases; 86%) and in one case typical topographical character was flat land. In 15 responses (multiple answer possibility), either natural or artificial elements were used as a part of the barrier system as follows: villages/urban areas (4; 27%), main roads (4; 27%), rivers (3; 20%), highways (2, 13%); streams and mountains by one case each.

Electric fences aiming at ASF control were mainly implemented as an additional measure parallel to the solid fence, therefore, reported outcomes in terms of effectiveness and/or changes in wild boar spatial behaviour overlapped between both measures and cannot be commented on electric fences solely. Nevertheless, it is worth mentioning that electric fences together with solid fences, aimed at ASF control or reducing wildlife-livestock interactions, in all reported cases (n = 6) have changed spatial behaviour of wild boar. Apart from answers presented in Chapter 3.2.2, a respondent reported that wild boar looked for ways of avoiding the fence. Respondents also reported some effects on wild boar that were (according to their opinion) scientifically confirmed, but they overlapped with the same answers provided for solid fences built in parallel with electric ones, therefore, those effects are not only (if at all) the consequence of electric fence effectiveness.

It is evident that the use of electric fences for ASF controlling has some potential, as in 60% of areas where electric fences have been used respondents assessed them to be very or completely effective for virus control (Table 23). However, only in one case (out of 6 relevant; 17%) ASF has not spread beyond the fenced area, and in other 5 cases (83%) it has spread out, but with the important or moderate delay (Table 24). Importantly, in the case of reducing wildlife-livestock interactions, electric fences have proven to be very efficient: in all 4 four, they were reported as very or even completely effective (Table 23).

**Table 23:** Assessment of the effectiveness of the electric fences in relation to ASF control and reducing interactions with livestock as their primary aims (1 = completely ineffective, 2 = somewhat effective, 3 = reasonably effective, 4 = very effective, 5 = completely effective; N/A = not relevant; number of responses and % considering all relevant answers are presented). In all cases of ASF control, electric fences were installed in parallel with solid ones.

| | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 | N/A | All relevant answers |
|---|---|---|---|---|---|---|---|
| ASF control | 0 | 1 *(20%)* | 1 *(20%)* | 1 *(20%)* | 2 *(40%)* | 1 | 5 |
| Reducing wildlife-livestock interactions | 0 | 0 | 0 | 3 *(75%)* | 1 *(25%)* | 1 | 4 |

**Table 24:** Reported effect on ASF spread beyond the fenced area after the implementation of electric fence (in all cases in parallel to solid fences).

| Effect | N | % |
|---|---|---|
| No spread of ASF outside the fenced area | 1 | 16.7% |
| Very fast spread, without any expected delay | 0 | 0% |
| Moderate delay (<3 months after implementation) | 2 | 33.3% |
| Important delay (>3 months after implementation) | 3 | 50.0% |
| All relevant answers | 6 | 100% |

Similarly, responses related to preventing the crossing of wild boar as a target species over the barrier indicated that electric fences (when installed in parallel with solid fences) have some potential to reduce crossing and, therefore, disease transmission, but in general they can not completely stop/block wild boar movement across the landscape. Indeed, in all 6 reported cases, the number of dispersing/migrating individuals was lower than before which indicates partial prevention.

### 3.2.3.1 Electric fences: crop/forest protection

For experiences with electric fences aimed at crop/forest protection, we received 21 responses from 8 countries: Italy (9), Hungary (3), Sweden (3), Spain (2), Croatia (1), Latvia (1), Romania (1), and Slovenia (1). The first of these fences was built in 1998, while others have been implemented since 2005. Data for the implementation costs of the electric fences solely (without combining them with other methods) were provided in 9 cases, and ranged from 1,000 EUR to 20,000 EUR (mean: 7,300 EUR; mean per km: 4,600 EUR/km), while the annual maintenance costs (n = 6) were in the range from 500 EUR to 15,000 EUR (mean: 3,400 EUR, mean per km: 1,000 EUR/km).

At the time of implementation, ASF was present in one of the studied areas, both in wild boar and domestic pigs (data are presented in broader landscape context, not directly related to the fenced area). Currently, ASF is present in 3 areas of interest (only in wild boar: 2 cases; in both wild boar and domestic pigs: 1 case), while in 18 areas it is not present. In almost all cases, wild boar was a target species responsible for the most damages: in 20 cases it was a primary target species, and in one case it was targeted together with other large ungulates. In cases where secondary target species were mentioned (11 cases), those were cervids (red, fallow and roe deer) or large carnivores (brown bear, grey wolf). In 3 cases (15%), electric fences were used as a linear barrier, and in 17 cases (85%) as an enclosure. The size of the area enclosed by electric fence was in a range between 1 ha and 100 ha, while in case of linear barrier the length was between 6 km and 8 km. The total height of the fence was from 0.4 m to 1.2 m (in majority of cases 0.6-0.8 m). Number of electric wires was also variable, in the range between 2 and 5 wires and the height of the lowest wire was between 5 cm and 40 cm above the ground. Distance between wires was in the range between 15 cm and 50 cm and voltage was between 12 V and 230 V, respectively. Frequency of vegetation clearance along fences was also variable, from weekly to once per year.

Predominant landscape type/land use was in all cases mixed forest-farmland (mosaic) Considering typical topographical character, dynamic/variable topography prevailed (10 cases; 59% out of 17 answers), followed by flat land (n = 5; 29%), and steep slopes (n = 2; 12%). Natural or artificial elements used as a part of the barrier system were: highway(s) (2 cases), sea (1 case), and lake (1 case). Considering harvesting of the target species, we received 17 answers for culling within the fenced area, which might in this case be understood also as a protected area on the cultivated side of the fence (intensive cull: 7 cases (41%); hunting at normal intensity: 3 cases (18%); without culling: 7 cases (41%)), and another 17 answers for culling outside the fenced area (intensive cull: 4 cases (24%); hunting at normal intensity: 11 cases (65%); without culling: 2 cases (12%)).

Construction of electric fences affected local population abundance/density of wild boar in 2 cases out of 18 responses to this question (11%), while in 16 cases (89%) no effect was reported. In the case of the change of the density, it either increased as "where there were no fences and guarding, there were more wild boar as they all went there" or decreased "where wild boar were kept from the crops" (direct citings from the responses). In general, electric fences aimed at crop/forest protection have changed the spatial behaviour of wild boar; 12 out of 18 relevant answers (67%) reported such an affect, e.g.: (i) animals avoided or renounced to visit the area; (ii) animals migrated to parts where there was no implementation of fences; (iii) animals do not cross the barrier unless they arrive quickly and the current is not felt enough; (iv) wild boar have hardly crossed the fence; (v) animals have become habituated to follow paths not crossing the field; (vi) when 3 strands of wire were used animals did not cross the fence (with 2 wires occasional crossings were seen); (vii) animals were kept away from crops; (viii) wild boar has completely and permanently avoided to enter the fenced meadows; (ix) animals try to penetrate the fenced areas and may become entangled in the electric fence and even die; (x) animals avoided the fenced areas. However, changes in animal movements were measured (with telemetry) only in 2 of these areas, where also solid fences were used.

From responses presented in Table 25, it is evident that electric fences are a very effective tool for crop protection (reasonably to completely effective: 100%). Moreover, 10 out of 11 relevant responses (90.9%) revealed that crop damage has been almost completely reduced after the electric fence construction, while in 1 case damage was importantly reduced (9.9%) (Table 26). However, responses related to preventing the crossing of a target species over the barrier indicated that electric fences aimed to reduce damage in agriculture/forestry are very rarely impermeable barriers for wild boar. Indeed, in the case of electric fences alone (without combining them with solid fences or other methods) full prevention of crossings of target species was reported only in 3 cases out of 10 relevant responses (30%), while partial prevention with lower number of dispersing/migrating individuals than before was registered in 7 cases (70%). Effectiveness of electric fences aimed at crop/forest protection (15 responses) was estimated in 2 cases only (13%) as follows: (i) by damage estimation (economically); (ii) the claim for crop damage that has been almost reduced to zero, i.e., 70–90% damage reduction was observed.

**Table 25:** Assessment of the effectiveness of the electric fences in relation to crop protection as their primary aim (1 = completely ineffective, 2 = somewhat effective, 3 = reasonably effective, 4 = very effective, 5 = completely effective; N/A = not relevant; number of responses and % considering all relevant answers are presented).

| | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 | N/A | All relevant answers |
|---|---|---|---|---|---|---|---|
| Crop protection | 0 | 0 | 3 *(27.3%)* | 6 *(54.5%)* | 2 *(18.2%)* | 0 | 11 |

**Table 26:** Reported effect on crop damage after the electric fence construction.

| Effect | N | % |
|---|---|---|
| Not relevant | 0 | 0% |
| Damage was almost completely reduced (>75%) | 10 | 90.1% |
| Damage was importantly reduced (25–75%) | 1 | 9.9% |
| Damage was moderately reduced (<25%) | 0 | 0% |
| No effect | 0 | 0% |
| All relevant answers | 11 | 100% |

Main reasons why in some cases electric fences are/were understood to be ineffective or only partially effective for reducing crop/forest damage are, according to the opinion of respondents (n = 8), the same as presenting in previous (sub)chapters, with the lack of adequate maintenance over time as the mean reason (50%); moreover, also construction faults (i.e., bad construction; inappropriate type of the method for the objective; and starting with two strands of wire which was not as effective, while after adding a third wire the effect was much better) were mentioned as reasons.

### 3.2.4 Repellents (chemical/odour, acoustic/sound, visual)

In the joint group of repellents, we combined different types of deterrents, namely: chemical/odour; acoustic/sound, and visual. For experiences with them, we received 14 responses from 7 countries: Spain (3), Croatia (2), Czech Republic (2), Hungary (2), Slovenia (2), Italy (2), and Latvia (1). We received responses for odour, sound, and visual repellents in 7, 7, and 3 cases, respectively. However, only in 5 cases repellents were considered as a stand-alone method; in all other cases, they were complemented with other methods (Table 27). The most frequent combination was odour repellents + electric fence (6 cases), followed by odour repellents + solid fence, acoustic deterrents + solid fence, and acoustic deterrents + electric fence. In Table 27, also combinations between other methods, that were used complementary across areas for which we received responses, are presented (outcomes of these combinations are in some cases described in other subchapters).

**Table 27:** Frequency of different repellents used with accompanied methods.

| | Odour | Acoustic | Visual | Solid fence | Electric fence | Gustatory method | Razor-wire fence | In person guarding |
|---|---|---|---|---|---|---|---|---|
| Odour | | 5 | 3 | 5 | 6 | 2 | 0 | 2 |
| Acoustic | | | 3 | 5 | 5 | 1 | 1 | 2 |
| Visual | | | | 3 | 2 | 1 | 0 | 1 |
| Solid fence | | | | | 5 | 1 | 1 | 2 |
| Electric fence | | | | | | 2 | 1 | 2 |
| Gustatory | | | | | | | 0 | 1 |
| Razor-wire | | | | | | | | 0 |

Aims of installing repellents as stand-alone methods and in combination with other methods are presented in Table 28. Considering all received responses, the most frequent driver was crop/forest protection (8 cases), followed by road/railway safety (4), and ASF control (3). In all areas where repellents were aimed at crop protection, wild boar was a primary target species (in 2 cases it was targeted together with cervids: red, roe, and fallow deer). In the areas where deterrents (acoustic and visual) were implemented to increase road safety, the primary target species was roe deer and "large ungulates".

**Table 28:** Frequency of aims of implementing the repellents alone* and in combination with other methods** (multiple answers).

| Aim of the implementation of repellents | n* | n** | n |
|---|---|---|---|
| Crop/forest protection | 2 | 6 | 8 (47%) |
| ASF control | 1 | 2 | 3 (18%) |
| Road/railway safety | 2 | 2 | 4 (23%) |
| Reducing wildlife-livestock interactions | 0 | 1 | 1 (6%) |
| National border security | 0 | 1 | 1 (6%) |
| All relevant answers | 5 | 12 | 17 (100%) |

Repellents aiming at crop/forest protection (i.e, the only aim with a reasonable large dataset) were mainly implemented as an additional measure parallel to the electric and/or solid fences, therefore, reported outcomes in terms of effectiveness and/or changes in wild boar spatial behaviour overlapped between both measures and cannot be commented on repellents solely. Due to this, we are briefly presenting here only cases where repellents were used as an independent method.

It seems from the summarised results (Table 29) that acoustic and visual deterrents are moderately effective for increasing road safety (in both two cases assessed as reasonably effective); similarly, odour repellents were in one case reported as reasonably effective for crop protection. However, it is very evident that in most cases deterrents were not effective tools neither for crop/forest protection (completely ineffective in 2 out of 3 cases) nor for ASF control (completely ineffective in the only relevant response) and reducing wildlife-livestock interactions (somewhat effective in the only response).

It should be noted that the number of relevant responses was very limited (for ASF control and wildlife-livestock interactions we received only one response per each), therefore, it is not possible to draw firm conclusions. Nevertheless, it seems evident that (with the exception of increasing traffic safety for which they do have some -at least short term- potential) deterrents can only be effective in combination with other methods when aimed at reducing wild boar (wild ungulates) movement and separating populations.

**Table 29:** Assessment of the effectiveness of repellents in relation to their primary aim (1 = completely ineffective, 5 = completely effective).

| | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 | N/A | All relevant answers |
|---|---|---|---|---|---|---|---|
| Crop/forest protection | 2 | 0 | 1 | 0 | 0 | 2 | 3 |
| Road/railway safety | 0 | 0 | 2 | 0 | 0 | 3 | 2 |
| AFS control | 1 | 0 | 0 | 0 | 0 | 4 | 1 |
| Wildlife-livestock interactions | 0 | 1 | 0 | 0 | 0 | 4 | 1 |

### 3.2.5 Other methods: in person guarding

For experiences with in person guarding/shepherding/patrolling, we received 5 responses from 5 countries: Bosnia and Herzegovina (1), Sweden (1), Spain (1), Serbia (1), and Romania (1). In one case, guarding was the only method used, while in other cases it was used in combination with fences (solid or electric). Aims of the in person guarding are presented in Table 30.

**Table 30:** Frequency of aims of in person guarding as a method for reducing wild boar movement/activity (multiple answers).

| Aim of in person guarding | n |
|---|---|
| Crop/forest protection | 3 |
| Reduced interaction between wildlife and livestock | 2 |
| ASF control | 1 |
| Hunting enclosure | 1 |

In all areas where guarding was used, wild boar was a primary target species. Secondary target species were cervids (fallow, red and roe deer) and in one case large carnivores (brown bear, grey wolf). In Sweden, where guarding was used as an independent method for crop protection, annual costs were 5,000 EUR (fields were guarded only during the sensitive maturation period, i.e., between 1 July and 15 August). Respondents assessed that the used method (local hunters patrolling fields at night) was reasonably effective for crop protection: damage was importantly reduced, and the number of dispersing/migrating individuals was lower than before. In 2 other cases where the primary aim of the guarding was also crop protection, respondents assessed effectiveness of the method as very effective (guarding in combination with electric fence) or completely effective (guarding in combination with solid fence). In both cases, the number of dispersing/migrating individuals was lower than before.

In 2 areas, the aim of the guarding (in both cases in combination with solid/electric fences) was to reduce interaction between wildlife and livestock. In these cases, respondents assessed the effectiveness as very effective in one case and reasonably effective in another. Unfortunately, no data on effectiveness was provided in two cases where the primary aims were ASF control and hunting enclosure, respectively.

### 3.2.6 Recent experiences in areas, where fencing has been used for ASF control

Among 69 responses in total, we also received answers from many areas, where measures aimed at reducing wild boar movements by fencing and some complementary methods have been implemented recently. All relevant responses, in which ASF control was indicated as a main aim of implementing measures, are provided in Appendix C. In 9 cases (from Belgium, France, Italy (3), Romania, Czech Republic (2), and Sweden), respondents provided comprehensive sets of answers, all of them related to fences (either solid fences alone, solid fences complemented by electric ones, or solid/electric fences accompanied by other measures such as odour repellents). To our opinion, these responses provided by different experts with in-situ experiences are very relevant for understanding feasibility of implementation as well as effectiveness of various fences and fencing methods in different scenarios. Therefore, a review of the most important answers for each response is presented in this subchapter; this collection (see Tables 31–33) represents to the best of our knowledge the first European wide set of data about fence installation details and outcomes for fencing aimed at ASF control in wild boar, and provides also insight in potential influential factors that can affect the effectiveness of wild boar separation methods.

Moreover, it also provides insight into reaction/attitudes of inhabitants, as we received several relevant answers on questions related to social effects and implications of fencing aimed at reducing wild boar movement. Since social effects/implications are very important for understanding feasibility/possibility of using different epidemiological measures, having long-lasting effect on both maintenance and effectiveness of fences/barriers, we present outcomes of this part in a separate subchapter (subchapter 3.2.7; for areas where ASF control was a main aim, responses are collected in Table 32 and Appendices C).

**Belgium** (response 32_9_BE)
Solid fence (not complemented by electric one and not dug into ground) was implemented in Etalle (south-eastern Belgium) from 31 Oct 2018 till 31 March 2021; intensive wild boar culling was practised on both sides of the barrier. According to ASF zone type, the area was located in the restricted zone I, II, and outside. The fence, which was 270 km long, was installed in a mixed forest-farmland landscape. The fences (also in combination with fenced highways) created some large enclosures (approx. 20 together with the French and Luxemburg networks), and it was possible to adapt the culling method according to the epidemiological status. Considering ASF control, the measures were assessed as very effective, and the virus stopped spreading due to the fences as well as due to drastic decrease of the population.

**France** (response 35_4_FR)
Around Metz (north-eastern France, close to Belgium border), a solid fence in combination with an electric fence was implemented; intensive culling was practised on both sides of the barrier. The area was located in the restricted zone II, and the fence was installed in a mixed forest-farmland landscape. Method affected the population abundance/density of wild boar. They observed reduction in the population inside the fenced area where intensive culling was practised, while outside the fenced area the population remained at a high level. Few animals dispersed inside the fenced area, but were quickly culled because they were not habituated to night shooting. Additionally, the fences affected the spatial behaviour of wild boar as well.

**Italy** (response 2_2_IT)
Around Pavia (Northern Italy), a solid fence (not complemented by electric one, but dug into the ground) has been implemented. The area was located in the restricted zone III and in a mixed forest-farmland landscape. It was reported that the fence did not affect the population abundance/density of wild boar; however, it affected the spatial behaviour. Measures prevented wild boar from crossing and contributed to ASF control. The effectiveness in relation to ASF control was estimated as reasonably effective, and ASF spread beyond the fenced area with moderate delay.

**Italy** (response 31_13_IT)
Around Alessandria (Northern Italy), a 150 km long solid fence (neither complemented by electric one nor dug into ground) was implemented from 1 June 2022 till 22 June 2023; hunting at normal intensity was practised at both sides of the barrier. The area was located in the infected zone and in a mixed forest-farmland landscape. The fence did not affect the

population abundance/density and the spatial behaviour of wild boar, nor was it effective considering the spread of ASF, due to the mountainous terrain and the presence of highways and roads. Moreover, they used a very low-strength metal fence which allowed very rapid passage of wild boar from one side to the other, and ASF spread very fast, without any expected delay.

**Italy** (response 40_NA_IT)
In one residential (suburban) area in Central Italy (Lazio region), solid fence (10 km; dug into ground) in combination with electric fence (200 km) was implemented in May 2022, and intensive wild boar culling has been practised at both sides of the fence. The area is located in the infected zone. It was reported that the installation of the fence has not affected the population abundance/density of wild boar; however, it has affected their spatial behaviour as the fence partly prevented wild boar from crossing, i.e., the number of dispersing/migrating individuals was lower than before. The effectiveness in relation to ASF control was estimated as reasonably effective, and ASF spread beyond the fenced area with important delay (during the first year after implementation, ASF did not spread outside the fence, but in the second year it spread outside as the fence was not completely impermeable due to the landscape features, i.e., rivers, roads and railways which cross the fences and break them).

**Romania** (response 36_1_RO)
Around Brasov (central Romania), solid fence (dug into ground) in combination with electric fence was implemented from June 2018 till March 2024; intensive wild boar culling was practised within and outside the enclosed area. The area was located in the infected zone. The fence, which was 10 km long and enclosed with the size of 12 km$^2$, was in a forest landscape. It was reported that the fence did not affect the population abundance/density of wild boar; howeveit affected their spatial behaviour as it partly prevented wild boar from crossing, i.e., the number of dispersing/migrating individuals was lower than before. The effectiveness in relation to ASF control was estimated as somewhat effective, and ASF spread beyond the fenced area with moderate delay.

**Czech Republic** (response 9_1_CZ)
Electric fence in combination with odour repellents and gustatory method was implemented in Czech Republic from August 2017 till April 2019; intensive wild boar culling was practised within and outside the enclosed area. The area of interest was located in the infected zone at the time of implementation, afterwards became zone II. The size of the area enclosed by electric fence was 58 km$^2$, and it was placed in a mixed and suburban area. The method implemented affected the population abundance of wild boar: density decreased from approx. 10 individuals/km$^2$ to zero due to ASF, culling, and fencing. They also affected the spatial behaviour of wild boar: animals looked for ways of avoiding the fence and entering suburban areas. Measures partly prevented wild boar from crossing; the number of dispersing/migrating individuals was lower than before. The effectiveness in relation to ASF control was estimated as very effective, and ASF spread beyond the fenced area with important delay (>3 months after implementation).

**Table 31:** Summary of experiences with implemented measures for reducing wild boar movement, aimed at ASF control in affected areas – description of areas and measures (only areas with complete responses are included; for details, see Appendix C).

| **Parameters** / **Country (code)** | Belgium (32_9_BE) | France (35_4_FR) | Italy (2_2_IT) | Italy (31_13_IT) | Italy (40_NA_IT) | Romania (36_1_RO) | Czech Republic (9_1_CZ) | Czech Republic (45_2_CZ) | Sweden (26_1_SE) |
|---|---|---|---|---|---|---|---|---|---|
| Location | Etalle | Metz | Pavia | Alessandria | Lazio | Brasov | - | Zlin | Fagersta |
| Protected area (Natura 2000 etc.) | Yes | No | Yes | No | Yes | Yes | - | - | No |
| Period of implementation | Oct 2018 – Mar 2021 | - | Dec 2022 | Jun 2022 – Jun 2023 | May 2022 – Mar 2025 | Jun 2018 – Mar 2024 | Aug 2017 – Apr 2019 | Jul 2017 – Feb 2019 | Oct 2023 onward |
| ASF currently present in the area | No | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes |
| ASF as a driver of implementation | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| ASF zone type (in time of implementation) | Restricted II, I and outside | Restricted II | Restricted III | Infected | Infected | Infected | Infected zone, after became zone II | Restricted II | Restricted II |
| Domestic pigs present within area | No | Outdoor and Indoor | Indoor | Outdoor and indoor | Outdoor and indoor | Outdoor and indoor | Outdoor and indoor | Indoor | No |
| Implementation costs (EUR) | 4,500,000 | - | 15,000 | 20,000,000 | 50,000 | - | - | - | 3,260,000 |
| Yearly maintenance costs (EUR) | 10,000 | - | - | - | 2,000 | - | 10,000 | - | 200,000 |
| **Methods that were implemented**<br><br><u>Notes for lines below</u>:<br>s. f. – solid fence<br>e. f. – electric fence | Solid fence, complementary use of fenced highway | Solid fence, electric fence | Solid fence | Solid fence | Solid fence (s.f.), electric fence (e.f.) | Solid fence (s.f.), electric fence (e.f.) | Electric fence, odour repellents, gustatory method | Electric fence, odour repellents | Solid fence, gustatory method, complementary use of lake, restrictions of access (except vehicles on roads) |
| Type of barrier | Linear | Linear | Linear | Linear | Linear | Enclosure (s. f.), linear (e. f.) | Enclosure | Enclosure | Enclosure |
| Length (km) or size (km$^2$) | 270 km | - | 2 km | 150 km | 10 km (s. f.), 200 km (e. f.) | 12 km$^2$ (s. f.), 16 km (e. f.) | 58 km$^2$ | - | 100 km$^2$ |
| Height of fence (m) | 1.2 | 1.0 (e. f.) | 1.5 | - | 1.5–2 (s. f.), 1.2 (e. f.) | 2.2 (s. f.) | 1.0 | - | 1.0 |
| Mesh size opening (cm) | 13x13 | 22x22 | 10x10 | - | - | 5x5/15x15 | - | - | 20x20 |
| Dug into ground | No | Yes | Yes | No | Yes | Yes | / | / | No |
| Complemented by electric or mesh fence | No | No | No | No | Yes | Yes | / | / | No |
| Culling of wild boar (within / outside) | Intensive / intensive | Intensive / intensive | - | Normal intensity / normal intensity | Intensive / none | Intensive / intensive | Intensive / intensive | Intensive / normal intensity | Intensive / intensive |
| Landscape type / land use | Mosaic | Mosaic | Mosaic | Mosaic | Suburban | Forest | Mixed and suburban | Mosaic | Forest |
| Typical topographic character | Flat land | Flat land | Flat land | Variable | Variable | Variable | Variable | Variable | Flat land |
| Natural/artificial elements used as a part of barrier system | Highways, villages/urban | Rivers. Highways, main roads, villages/urban | Highways | Highways, main roads | Rivers, highways, main roads, villages/urban | - | Main roads, villages/urban | Main roads | - |

**Table 32:** Summary of experiences with implemented measures for reducing wild boar movement, aimed at ASF control in affected areas – social effects, responses, effectiveness (only areas with complete responses are included; for details, see Appendix C).

| Country (code) / Question | Belgium (32_9_BE) | France (35_4_FR) | Italy (2_2_IT) | Italy (31_13_IT) | Italy (40_NA_IT) | Romania (36_1_RO) | Czech Republic (9_1_CZ) | Czech Republic (45_2_CZ) | Sweden (26_1_SE) |
|---|---|---|---|---|---|---|---|---|---|
| Was there any opposition to the fence and what motivated it? | No opposition | Opposition over: access restrictions | No opposition | Opposition over: ecological impacts, economic concerns, impacts on hunting | Opposition over: access restrictions | Opposition over: ecological impacts | Opposition over: access restrictions, economic concerns, impacts on hunting | Opposition over: access restrictions, economic concerns, impacts on hunting | Opposition over: economic concerns |
| What was the reaction of affected groups? | No opposition, full support; we did not pay attention to public responses | No opposition, full support | No opposition, full support | Moderate opposition – ignored requests, media criticism | Moderate opposition – ignored requests; severe opposition – destruction of fence | Moderate opposition – ignored requests | Moderate opposition – ignored requests | We did not pay attention to public responses | Moderate opposition – media criticism |
| Did the method implemented affect the population abundance/density of wild boar? | Yes | Yes | No | No | No | No | Yes | - | Yes |
| Did the method implemented affect the spatial behaviour of the target species? | No | Yes | Yes | No | Yes | Yes | Yes | - | Yes |
| Did you measure changes in animal movement? | No | No | No | No | No | No | No | - | Yes |
| General effectiveness of the implemented method in relation to ASF control? | Very effective | Completely effective | Reasonably effective | Completely ineffective | Reasonably effective | Somewhat effective | Very effective | Completely effective | Completely effective |
| Did the implemented method prevent wild boar from crossing? | Partially | Partially | Fully | No changes were registered | Partially | Partially | Partially | - | Fully |
| Did the disease spread beyond the fenced area? | - | No | Yes – moderate delay | Yes – very fast, without any expected delay | Yes – but important delay | Yes – moderate delay | Yes – but important delay | Yes – but important delay | No |
| Did you use any method for estimating the effectiveness? | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes |
| If yes, please briefly describe the parameters used? | Number of ASF positive detected at the other side of the fence | - | Camera trap | - | A good indicator is the spread of the infection outside the fenced area | Spreading of disease | Monitoring with thermovision on drones and helicopters | - | Trail cameras, observations at bait/feeding sites used to ensure food for remaining wild boar |

**Table 33:** Summary of experiences with implemented measures for reducing wild boar movement, aimed at ASF control in affected areas – important additional information of respondents (only areas with complete responses are included; for details, see Appendix C).

| Country (code)<br>Question | Belgium (32_9_BE) | France (35_4_FR) | Italy (2_2_IT) | Italy (31_13_IT) | Italy (40_NA_IT) | Romania (36_1_RO) | Czech Republic (9_1_CZ) | Czech Republic (45_2_CZ) | Sweden (26_1_SE) |
|---|---|---|---|---|---|---|---|---|---|
| Where methods are/were understood to be ineffective, what is/was the main reason for this? | / | Lack of adequate maintenance over time | Poor design | Badly constructed | / | Inappropriate type of method for the objective | / | / | / |
| What would make the method more effective in your opinion? | / | Prompt implementation | Prompt implementation | Should have been put in earlier and also a different type of fence | Increased monitoring of impacts and prompt adequate reaction | Better state/regional resources | Increased monitoring of impacts and prompt adequate reaction | Prompt implementation | / |

| | |
|---|---|
| **In your opinion, what makes an effective/ineffective method of control?** | |
| Belgium (32_9_BE) | • Wire fences instead of electric ones<br>• Placing fences along roads allows control and maintenance, and the road is a second barrier<br>• The landscape is also important: how many roads cross the fences, rivers are also a problem<br>• It is not possible to achieve a 100% wild boar proof fence in any case, therefore, the fence alone is not enough<br>• Enclosures allow to depopulate and to create a real brake for the virus dispersion by removing susceptible hosts in a closed area |
| France (35_4_FR) | / |
| Italy (2_2_IT) | • Implementation timeframe, appropriate initial project, political support |
| Italy (31_13_IT) | / |
| Italy (40_NA_IT) | • Openings in the fence: roads, rivers, railways crossing the barriers |
| Romania (36_1_RO) | • Distribution and dynamic of ASF in the territory |
| Czech Republic (9_1_CZ) | • Visual and mechanical effect plus possibly the electrical shock<br>• Good timing and maintenance |
| Czech Republic (45_2_CZ) | / |
| Sweden (26_1_SE) | • Minimize disturbance of wild boar (no unleashed dogs, no dog hunting, no public access), and an intact and well-maintained fence |
| **Important notes** | |
| Belgium (32_9_BE) | • The virus stopped spreading thanks to the fences and thanks to the drastic decrease of the population |
| France (35_4_FR) | • Reduction in the population inside the fenced-off area, while outside the fenced-off area the population remained at a high level |
| Italy (2_2_IT) | • The fence prevented the passage of ASF for a certain amount of time |
| Italy (31_13_IT) | • The fences used were not effective in stopping the ASF virus because of the mountainous terrain and the presence of highways and roads (at the level of which the fences were left open)<br>• Fences were very low-strength metal fences and not dug into ground, which allowed very rapid passage of wild boar from one side to the other<br>• Should have been put in earlier (the outbreak was already considerable in early 2022), and also a different type of fence should be used |
| Italy (40_NA_IT) | • There have been cases of damage to fences by farmers who could not pass with their livestock; they have torn down the fences or left the gates open<br>• Animals tried to overcome barriers, in some cases succeeding in doing so<br>• Impossible to seal all openings, in the study area there are roads, rivers, railways crossing the barriers |
| Romania (36_1_RO) | • All wild boar enclosures with metallic fence and electric wire end up with ASF or hunters were obliged to kill all the animals |
| Czech Republic (9_1_CZ) | / |
| Czech Republic (45_2_CZ) | / |
| Sweden (26_1_SE) | / |

**Czech Republic** (response 45_2_CZ)
Around Zlin (eastern Czech Republic), electric fence in combination with odour repellents was implemented from July 2017 till February 2019; intensive wild boar culling was practised within, and hunting at normal intensity outside the enclosed area. The area was located in the restricted zone III and in mixed forest-farmland (mosaic) landscape. The effectiveness of the implemented method in relation to ASF control was estimated as completely effective, and ASF spread beyond the fenced area with important delay (>3 months after implementation). Unfortunately, no other data on effectiveness of the measures implemented was provided in the response.

**Sweden** (response 26_1_SE)
In Fagersta (southern Sweden), solid fences (neither complemented by electric one nor dug into ground) in combination with gustatory methods have been implemented since October 2023; intensive wild boar culling has been practised within and outside 100 km$^2$ large enclosed area. The area is located in the restricted zone II and in forest-dominated landscape. The methods implemented have affected the population abundance/density and the spatial behaviour of wild boar, i.e., animals have not crossed the fence. The effectiveness in relation to ASF control was estimated as completely effective: no crossing of wild boar has been registered and ASF has not spread beyond the fenced area.

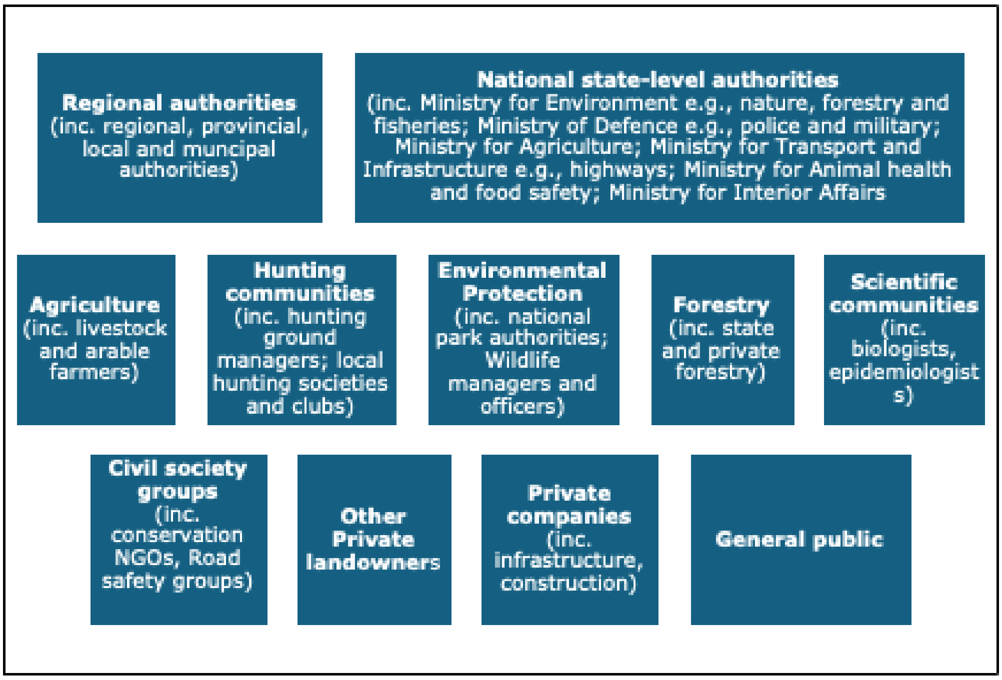
## 3.2.7 Social effects and implications of implemented measures

To understand the social effects and implications of implementing separation measures, a series of questions asked respondents to identify: (i) stakeholders involved in decisions to implement spatial separation methods; and (ii) stakeholders negatively affected by these. Questions also focused on how: (i) the general public responded to their implementation; (ii) the levels and type of opposition to fencing, and its motivation; and (iii) the social-political tensions that were present between different stakeholders. Many of these were open, rather than closed, questions. This resulted in a mix of quantitative and qualitative data.

### *3.2.7.1 Identifying key stakeholders*

In total, 35 respondents listed the key stakeholders they understood to be involved in decisions behind the implementation of all methods of separation, not just those relating to ASF and wild boar. Table 34 outlines these stakeholders, organising them into different groups according to their interests and/or social-political position. The table shows these stakeholders broadly relate to national governments; provincial, regional, and local authorities; specialist communities of practice with specific interests or expertise; private enterprise and businesses; civil society groups or NGOs; and the general public. While measures implemented by a single stakeholder often reflected their presence on land owned by a single stakeholder (e.g., implemented by a farmer on a farm, or a forestry manager on private woodland) or a singular purpose, 22 respondents identified more than one stakeholder group as being involved in a single case. This highlights the complex social-political nature and commonly collaborative processes involved in implementation. These multi-stakeholder arrangements often involved both state and non-state actors.

**Table 34:** Summary of the key stakeholders identified by respondents involved in the implementation of separation measures. This includes all measures identified in the survey. For the purposes of analysis, these stakeholders have been generalised and are not specific to national context. The table identifies: (i) authorities (top tier); (ii) specific communities of practice (middle tier); and (iii) other private and public groups (tier three).




Of 35 respondents, 12 related directly to measures implemented specifically for the control of ASF, or to reduce interactions between livestock and wildlife. In addition to national state authorities involved in measures implemented for disease control, the following stakeholders were also identified as important:

- Regional and local agricultural, environmental, food and animal health authorities;
- Scientists, including biologists and epidemiologists;
- Farmers;
- Wildlife authorities and managers;
- Forestry authorities and officers;
- National Park authorities;
- Local hunting associations, game estate and hunting ground managers;
- Private landowners;
- Transport, infrastructure, and highways agencies.

### *3.2.7.2 Identifying negative impacts and opposition to separation measures*

Respondents also identified stakeholders who were negatively affected by the implementation of separation measures. These cover a range of stakeholders already highlighted in Table 34. Of specific relevance here, Table 35 highlights the different stakeholders impacted by separation measures specifically targeting ASF control and reduced domestic-wild animal interactions. The reasons for the negative impacts vary according to stakeholder groups. For some, including hunting communities, farming communities, private enterprise and regional/local authorities, separation measures can generate economic costs and financial burden. This might be due to the movement restrictions put in place for people and animals, a moratorium on carrying out industry (such as forestry) in the fenced area and hence lost opportunity costs, or else the responsibility to maintain fencing or facilitate it on your land.

As well as economic costs, negative impacts also occurred when different stakeholders were unable to carry out practices important to their everyday practices and identity. For example, when the general public is no longer able to access land for recreation, or for foraging for natural resources. Finally, negative impacts were also identified when separation measures clashed with the objectives and agendas of communities of practice engaged with wildlife ecology, such as forestry, conservation, and wildlife protection. These results highlight that extraordinary and rapid responses carried out in the name of biosecurity can affect a range of interests and businesses beyond those specifically engaged with animal health management.

**Table 35:** Summary of the stakeholder groups negatively impacted by measures specifically implemented for managing ASF and domestic-wild animal interactions.

| Stakeholder group | Examples given for negative impacts |
|---|---|
| Hunting communities | Restrictions on hunting ground users and association members who pay concessions, but cannot use their land or shoot readily<br>Hunting grounds might suffer from reduced income |
| Farming communities | Restrictions on pig farms, and/or bans on pig keeping<br>Access to their own land can be complicated by fencing<br>Regulations or bans on arable activities such as harvesting, sowing, ploughing etc. |
| Forestry | Fences can increase the density of animals in woodland, thus impacting forest regeneration |
| General public | Restricted access to (forest) land which is commonly open for everyday activities, recreation, tourism, sports events and competitions, berry and mushroom picking etc.<br>Access to land influenced by the location or number of gates |
| Private enterprise | Restricted access affects tourism industry |
| Conservation and wildlife protection agencies | Fences hinder the movement of many species, not just those targeted for management, thus increasing ecological fragmentation |
| Regional/local authorities | Might have to bear the costs and responsibility for maintenance |

53 responses addressed whether there was opposition to any methods of separation, and the reasons for this. Table 36 highlights that out of these 53, 24 responses (45%) stated there was no opposition. Of the 29 responses (55%) stating there was opposition, several factors were highlighted. This question allowed multiple answers, reflecting the fact that opposition can often be attributed to more than one factor. Most commonly, opposition was cited in relation to: restrictions over access (11 cases); negative impacts on hunting/game management (11 cases); economic concerns (11 cases); and negative ecological impacts (9 cases). Distrust of authorities/decision-makers and the welfare impacts of target and non-target species were less significant drivers of opposition (3 cases each).

In contrast, separation measures relating to ASF and the reduction of wildlife-livestock interactions caused proportionally more opposition. Out of 17 relevant answers, only 3 (18%) did not generate some form of stakeholder opposition, compared to 14 (82%) which did, highlighting that responses to ASF can generate controversy among different stakeholders. Of these, the most notable reasons related to the restrictions on access and concerns about economic impacts (7 cases each). These were followed by the negative impacts caused to hunting and game management (4 cases), and on ecology (2 cases).

**Table 36:** Number of cases of opposition to the implementation of separation measures. This was a multiple choice, so more than one reason for opposition was possible in any given case.

| **Opposition** | **All methods of separation** | **Relating to ASF control and reduced wildlife-livestock interactions** |
|---|---|---|
| No opposition | 24 | 3 |
| Opposition over access restrictions | 11 | 7 |
| Opposition over negative impacts on hunting/game management | 11 | 4 |
| Opposition over economic concerns | 10 | 7 |
| Opposition over negative ecological impacts | 9 | 2 |
| Opposition over distrust of authorities/decision-makers | 3 | 1 |
| Welfare impacts on target and non-target species | 3 | 0 |
| Other | 7 | 3 |
| **Total number of responses** | **53** | **17** |

As well as addressing whether and why opposition might occur, 51 out of 69 respondents provided information on how opposition manifests in practice (see Table 37). Of the answers relating to forms of opposition, respondents were given 4 options which were graded by severity (moderate-severe). These answers were multiple choice, so more than one option was possible. Out of 27 responses (53%) that highlighted opposition to all measures, the most common response was that opposition was moderate in nature (18 cases), wherein actors either ignored requests or instructions (11 cases) or voiced criticism in public and the media (7 cases). There were 7 cases of severe opposition, of which the majority were incidents of damage or sabotage to fences. Significantly, in eight cases (16% of respondents) attention was not paid to public responses.

**Table 37:** Summary of responses to separation methods by affected actors. This was a multiple choise question: more than one form of opposition was possible for any given case.

| Response | All methods of separation | | Methods related to ASF and wildlife-livestock interactions | |
|---|---|---|---|---|
| | Frequency | Percentage | Frequency | Percentage |
| No opposition/negative reaction, full support | 24 | 47% | 5 | 29% |
| Moderate opposition - ignored requests/instructions | 11 | 22% | 6 | 35% |
| Moderate opposition - media criticism / publicly voiced criticism | 7 | 14% | 3 | 18% |
| Severe opposition - public events organised against the method (e.g. demonstrations) | 2 | 4% | 1 | 6% |
| Severe opposition – destruction of fence/sabotage | 5 | 10% | 2 | 12% |
| We did not pay attention to public responses | 8 | 16% | 2 | 12% |
| Other | 4 | 8% | 1 | 6% |
| **Total** | **51** | **/** | **17** | **/** |

Regarding responses relating to measures for ASF control and reducing wildlife-livestock interactions, 5 out of 17 respondents (29%) said there was no opposition. Reflecting the results of the overall outcomes, the most frequent forms of opposition were moderate in nature, whether defying requests and instructions (6 cases) or publicly criticising measures (3 cases). There were two cases of severe opposition materialising as damage or sabotage, and two cases where public responses were overlooked. These results highlight that opposition is, firstly, more common than not. Secondly, they also highlight how it manifests in different forms, sometimes in any given situation. While moderate opposition is most frequent, this might involve behaviours which compromise biosecurity, such as ignoring instructions and guidance.

#### *3.2.7.3 Identifying the responses of the general public, and social-political tensions among different stakeholders*

Out of 26 relevant responses, the survey shows separation measures elicit a spectrum of responses from the general public. These range from broadly to positive; neutral, ambivalent, or disinterested; to negative. Some respondents highlighted how responses vary within any single setting or situation, depending on personal experiences, ethics or values.

Regarding positive responses to measures, these are often related to positive perceptions of their purpose and effectiveness; how effectively this was communicated; and familiarity with their usage within a particular landscape. For examples, some respondents stated:

- They were generally accepted because wild boar are understood to cause damage and present the risk of traffic collisions;
- Fences are generally considered useful and, therefore, accepted across the landscape;
- Fences were positively received when local communities were engaged in their implementation as part of a conservation project.

On the other hand, examples of negative responses among the general public is related to:
- The extent to which they limited access to land, and the ability to travel;
- Concerns that they were problematic for wildlife and ecology, whether in preventing movement or in cases where animals get stuck;
- Whether they were effective and worthwhile investments.

Respondents were offered an open question to reflect on the tensions that separation methods can cause between different stakeholder groups. A total of 27 respondents addressed this question, with 13 (48%) stating there was either no, or minimal, social-political tension present in the cases they describe. On the other hand, 14 respondents (52%) stated that tensions did exist between stakeholders. Multiple tensions were highlighted by respondents regarding the different relations between authorities (national and regional), specific communities of practice (e.g., agriculture and/or hunting) and other stakeholders.

Regarding tensions around all methods of separation, respondents generally commented that tensions exist between:
- Agricultural, forestry and hunting communities over the general management of wildlife, and the uneven ways costs for fencing and management are distributed between them, e.g., game managers must pay for fencing on forestry land;
- Landowners whose fencing might inhibit their neighbours accessing their own land, or the general public from accessing public land;
- Members of the general public and hunting communities when differing values and ethics influence perceptions of wildlife management.

More specifically, respondents highlighted tensions that arise when in relation to preventative or reactionary responses to ASF and interventions that manage domestic-livestock interactions. In such incidences, they note tensions arising:
- between hunting communities and authorities, e.g., when hunters oppose bans on shooting in infected zones; when authorities encourage them to cull any wild boar they encounter, including sows and piglets; or impose the use of particular methods, such as corrals;
- when ASF regulations imposed by authorities impose the mandatory culling of livestock; ban farmers from breeding and raising pigs; or limit their capacity to farm and move livestock effectively;
- when the movement on public roads and other rights of way is restricted;
- between owners of individual enterprises and authorities, as they might suffer economically but receive no compensation;
- between ecologists/conservationists who question the extreme measures advocated by (veterinary) authorities, such as widespread culling and fencing.

# 4 Discussion

## 4.1 Fencing in relation to ASF control: previous findings

Reducing wild boar dispersion/migrations (i.e., population separation) in affected as well as at-risk areas is one of the crucial actions for decreasing the spread of ASF virus. Recently, in several areas across Europe a diversity of measures aimed at reducing wild boar movements (primarily fencing) have been used, however, with different success and attitudes towards them. For example, after discussion at the ASF-STOP COST action workshop, participating by various experts on wild boar (including several co-authors of this report), Jori et al. (2020) emphasised the need for distinguishing between different kinds of physical barriers (fences). Electric fences were mentioned as more efficient in deterring wild boar movements but requiring more maintenance and possibly having less social acceptance due to a perceived risk of electric shocks to humans and animals. The efficiency of fences was considered to be variable, depending on the goal and the temporal context: if the aim is immediate restriction of wild boar movement to mitigate disease spread and give governments and administration time to react in connection to a focal introduction, then appropriate fencing might be effective. However, if the aim is to stop the spread of ASF in the long term, fencing is likely less efficient.

Participants of this workshop highlighted that the general public's acceptability of fences could vary depending on several aspects. The decision to fence a territory has high political impact (in some cases, fences can even generate or increase diplomatic tensions between neighbouring countries or administrative units), and is often controversial because it can conflict with property, property laws, possibilities to use the land and land's products due to restrictions, as well as with international biodiversity conservation treaties (e.g., by reducing ecological connectivity and the functionality of wildlife corridors). Moreover, fences are expensive to build and maintain (thus high consideration should be given to maintenance costs and efforts when planning the construction of a fence), while their efficiency for enhancing control of ASF in wild boar population is not guaranteed (Jori et al., 2020). Indeed, fences are politically tempting in the context of an emerging disease (Mysterud and Rolandsen, 2019) because they are a highly visible measure and, in the short-term, they can efficiently reduce disease transmission by direct contact. However, when a long transboundary fence is built as a response to an emergency, plans for measuring its efficiency, calculating its maintenance costs and assessing its biological impact in terms of wildlife conservation are rarely considered (Jakeset al., 2018). Therefore, it is recommended to perform a cost-benefit analysis and seek advice on the potential environmental consequences before taking the decision to implement such a high impact and resource consuming measure (Jori et al., 2021). Due to this, the issue of fencing generated highly contrasting opinions, but there was a clear consensus that long-term fencing along national borders as well as large-scale fencing can be inefficient at preventing wild boar movements, and that these measures often are implemented for merely symbolic or political reasons (Jori et al., 2020). This is completely in accordance with previous EFSA review of at that time existing scientific evidence, concluding that no large fences have been effective for the containment of wild suids (EFSA AHAW Panel, 2018) as there had been no evidence that fencing significantly contributed to stopping the spread of ASF in wildlife because it is not possible to have a 100% proof wild boar barrier (EFSA, 2018).

In the past, the effectiveness of fencing in disease management, especially among wildlife, has not been well documented. The implementation of fencing as a tool to mitigate disease spread retains a large degree of uncertainty (Mysterud and Rolandsen, 2019). However, more recent experiences showed that using fences to reduce the risk of ASF spread through wild boar movements might be useful in case of a localised point source incursion, i.e., with the focal fencing (Jori et al., 2021) as was the case, for example, in the successful control of ASF in the Czech Republic and Belgium (Charvátová et al., 2019; Licoppe et al., 2023). In such cases, the aim should not be to completely halt wild boar movements, which might be unrealistic if the fence perimeter is long and the terrain is rough, but rather to reduce movements as much as possible. Nevertheless, since the introduction and spread of ASF in the EU, long distance transboundary fencing has been used by several countries (e.g., Bulgaria–Romania, France–Belgium, Germany–Poland) to protect their national territories from virus incursion from their neighbours, despite their questionable efficiency and negative environmental impacts. Contrary to transboundary fencing, which was in the most cases ineffective, focal fencing around affected areas should be applied as quickly as possible after an outbreak in case that the infected area can be surrounded by a physical barrier, aiming to prevent wild boar movements in and out of the infected area (Jori et al., 2021).

For example, the construction of non-buried wire fences was used in Belgium as a (obviously good) compromise between efficiency, compared to electric fences, and rapid installation, compared to buried wire fences (reviewed in Licoppe et al., 2023). Placing fences along the state roads avoided issues of ownership and also profited from the already existing barrier effect of the public roads. Fences were also used to materially demarcate some management zoning with an intended effect on public awareness. It appears that fences along urbanised zones or fenced highways offered a good barrier against the wild boar spread. The most problematic instance of crossing fences corresponded to a mosaic landscape of mixing small forests and pastures with disrupted urbanisation and many gates. On the basis of their experience authors recommended that the fenced area should not be too small (i.e., should be >50 km²) to fulfil all the requirements of wild boar population hence limiting the risk of evasion, and not too large (<200 km²) to allow intensive culling and efficient maintenance of the fences. Moreover, intensive cull of wild boar around the fenced area is the best guarantee to prevent any circulation of the virus thanks to the elimination of the virus' naïve hosts.

Apart from the published knowledge in the scientific literature, related to fencing aimed at ASF control (mainly from Belgium and the Czech Republic), which was described more into details above as well as in Chapter 3.1, several new experiences with wild boar population separation (either aimed at ASF control or several other issues, such as reducing crop/forest damages, reducing wildlife-livestock interactions, increasing road/railway safety or keeping individuals in hunting enclosures) have been obtained since 2018 throughout Europe. These experiences are fully collected and described in previous chapters of this report. Therefore, we are summarising here only main findings obtained by responses to the questionnaire. Provided experiences and knowledge enable understanding of influential factors and context-dependent effectiveness of different measures, but might also help in decision making processes.

## 4.2 New insights into effectiveness of measures for wild boar separation

The main purpose of the questionnaire was to extend our understanding of spatial separation methods used to manage wild boar movement in contemporary Europe. We were interested in what the main actors involved in their design, decision making about their implementation and actual implementation had to say about them. The motivation for undertaking the survey was to possibly uncover aspects of wildlife spatial separation measures that are not pronounced in the reviewed literature. Our reasons to suspect that such dimensions might exist were twofold. First, spatial separation measures and especially the way they are accepted by various social actors unfold in informal grey zones that are notoriously tricky to capture in scientific literature (Ledeneva, 2018). Put differently, if for example illegal sabotage of the measure by local dwellers is dealt with informally or even illegally by the authorities, it is unlikely to ever be reported in literature. Second, some part of the available literature was created in cooperation with, or even partly by, the actors involved in design, decision making about and implementation of the measures in question. Given sometimes substantial costs of such measures, its creators are not necessarily in a good position to report their failures. This likely even deepens the well-known bias of scientific literature towards underreporting failures, and, consequently, overreporting success (Duyx et al., 2017).

The present survey has its limits too. Despite guaranteed confidence, it was hardly seen by the respondents as anonymous space, something confirmed in the several parallel interviews. Hence while we partly opened informal space for communication of experiences and opinions that are otherwise self-censored in publications, there was still a clear limit to respondents' trust. Equally important, it is crucial to understand that this is not a representative survey that would in any quantitative way capture what measures are being implemented across Europe to manage wild boar or other wildlife movement. There is not an available register of all such measures from which we would be able to take either random or reasonably stratified sample, hence hoping to achieve some type of representativity. Rather, the main objective of the survey was to achieve as varied a set of answers from various stakeholders as possible to identify an array of possible scenarios that can unfold in relation to the measures in question.

Nevertheless, a large dataset (69 responses from 17 European countries) provides important insight into recent findings and experiences by using different measures for separating wild boar populations and affecting their movements, mainly in regard to ASF control and reducing crop/forest damages. Responses are analysed and fully presented (either in summarised forms per majority of questions or even individually, per the most relevant cases, i.e., for experiences with fencing aimed to ASF control) in the Chapter 3.2, therefore, in this chapter we are commenting only the most important findings about different measures, and aims. In the first part, effectiveness of different measures and influential factors affecting it is discussed, emphasising also the main differences between different scenarios. The second part of the discussion is focused on personal experiences and opinion of respondents not presented earlier (i.e., on their believes about responsibility, factors affecting effectiveness, possibilities for the improvement of implementing different measures), and the last part on social effects and implication, which has been shown to be at least as important factor affecting long-lasting efficiency/effectiveness of each measure as are techniques of implementation the measure (see also Dixon et al., 2019; Viltrop et al., 2021).

### 4.2.1 Recent experiences on effectiveness of measures for reducing wild boar movement

Across the wide range of known measures (i.e., solid (mesh) fence, electric fence, razor-wire fence, odour repellents, acoustic and visual deterrents, combination of methods) and main aims of implementing these measures (i.e., ASF control, crop/forest protection, reducing wildlife-livestock interactions, road/railway safety, enclosures built for hunting purposes) we received a broad set of individual answers, classifying the same measure–aim combination either as fully effective/feasible or not effective/feasible at all. Generally, it is evident that no single measure, neither combination of them, would fully stop wild boar movements as no barrier is 100% wild boar crossing proof (for general opinion see also: EFSA AHAW Panel, 2018; EFSA, 2018; Jori et al., 2020; for concrete findings: Dellicour et al., 2020; Jori et al., 2021; Licoppe et al., 2023). However, in several cases implemented measures were assessed to be very or even completely effective as they importantly affected spatial behaviour of wild boar. This holds true also in some cases where areas were fenced aimed at ASF control (Belgium, France,the Czech Republic, Sweden – in the last, at least so far), and where virus has not spread since the construction of the fence or the important delay of the spread was registered (Table 31). On the contrary, the same measure (in this case solid fence) was found to be completely ineffective for ASF control in the region of Alessandria in north Italy, where fences did not affect the spatial behaviour of wild boar, and the disease spread beyond the fenced area very fast, without any expected delay (*ibid.*). The answers of the Italian representatives to the survey submitted by EFSA indicated a delay in the construction of the fences as the infection had already spread beyond the fences before they were completed. This point highlights the need of preparedness coordination among different authorities and the need of rapid reaction, scaling the plan based on the local peculiarities of the area of both geographical and cultural characteristics. Probably the use of electric fences in rough hilly or mountain areas could be more efficient for a first rapid fencing in such areas. In those particularly rough areas it could be considered also not to rely solely on fences and fencing should be flanked by other intervention measures, such as culling, in order to reduce the risk that infected animals could spread from the infected area. This discrepancy in effects and effectiveness of fences for ASF control is strongly context-related, i.e., they both depend on several factors that can affect the outcomes, and, consequently, also rationality of fencing particular areas or implementing any other barriers. Indeed, while general high (but not full) effectiveness of any target measure with some contradictory cases is acceptable for some goals (e.g. crop/forest protection, hunting enclosures, wildlife/national park), non-100% effectiveness is much more problematic for other goals such as road/railway safety or disease control.

Some recent cases of national border security fencing, i.e., using longline solid fences or even walls along some borders (e.g., Hungary-Croatia, Poland-Belarus), have shown that even within EU it is possible to erect impermeable fences for large mammals, including wild boar (Safner et al., 2021); however, considering cost-effectiveness of such fences/walls and particularly their several negative impacts both in term of disrupting habitat suitability/permeability as well as causing several interactions and tensions in public (e.g., Nowak et al., 2023), such fencing would definitely not be recommended or even accepted for any veterinarian issue, including ASF control. Moreover, there is also a clear consensus among scientists that transboundary fencing (even when using more acceptable types of fences for the public) as well as other large-scale fencing can be inefficient at preventing wild boar movements, and that these measures often are implemented for merely symbolic or political reasons (Jori et al., 2020). When considering border fencing, we obtained also clear information that razor-wire fences are completely ineffective for preventing wild boar movements (Pokorny et al., 2017); moreover, they might cause additional mortality of large mammals entangled in the fence (Pokorny et al., 2017; Safner et al., 2021), therefore, they should be used as less as possible regardless the aim of implementing the barrier.

Contrary to border security fencing, solid fences regularly used for other aims than border security are of much lower quality, they are lower (between 0.8 m to 2.2 m in all cases reported), with variable techniques of wire construction, different mesh sizes, and in several cases they were not dug into ground. As they were installed across different landscape types (with mosaic as the prevailing one) and topographical characters (with dynamic/variable being predominant), it would be impossible to expect that they would be reasonably effective across all areas and scenarios. Based on answers obtained, solid fences are a very effective tool for crop/forest protection, and to a lesser extent also when aimed to increase road/railway safety or to reduce wildlife-livestock interactions, while considering ASF control, only in 35% of cases they were assessed to be very or completely effective. However, we should stress that different types of fences were used, and many of them were probably not fully adequate for wild boar as a target species. Indeed, fences can be effective against wild boar only if they are appropriately designed and regularly maintained (as summarised by Jori et al., 2021): the most effective fences against wild boar are knotted rectangular mesh fences buried to a depth of 20–25 cm into the soil; progressive density is recommended with a distance of 15 cm between vertical wires and from 5–10 cm at the bottom to 15–20 cm at the top between horizontal wires; wild boar fences must reach 140–160 cm height, and regular maintenance of fences is required.

Similar as in case of solid fences, also electric fences (mostly alone or in combination with other methods) are very effective for crop and forest protection, and to lesser extent also when aimed to reduce wildlife-livestock interactions or to increase road/railway safety. Unfortunately, assessment of their effectiveness when aimed at ASF control is more difficult because they were usually used in complement with other measures, mainly as secondary fences parallel to the solid one or accompanied by odour repellents. Nevertheless, electric fences have some potential for ASF control, as in 60% of areas where they have been used respondents assessed them to be very or completely effective for virus control, although in only one area ASF has not spread beyond the fenced area. For example, in the Czech Republic, where electric fences were used without the solid fence (but with odour repellents), they seem to be very to completely effective as they importantly reduced the number of wild boar crossings, and, consequently, also contributed to the important delay in ASF spread in the country. Effectiveness of electric fences is also very dependent of both construction techniques and maintenance: as reviewed in Jori et al. (2021), a minimum of two wires installed between 25 and 50 cm above ground level as well as appropriate energiser (providing a pulse of 4–8 J and with 12 V battery) are required to deter wild boar movements across the fence; the system needs frequent maintenance to avoid vegetation touching the wires.

Considering effectiveness of solid and electric fences for reducing wild boar movement (for different aims) as well as general issues of fencing, we received also very valuable additional information of respondent as follows:

- ASF control: (i) Metal fence is the most effective method to prevent movements but is more expensive and raises more opposition; as for the other methods, a combination of electric fence and repellents can be very effective but cannot reach the efficacy of metal fence. (ii) The fences used were not effective in containing the ASF virus because of the mountainous terrain, the presence of highways and roads (at the level of which the fences were left open); in addition, they were very low-strength metal fences and not in-ground in the soil, which allowed very rapid passage of wild boar from one side to the other. (iii) Good system, keeps running continuously since it works; putting up electric fence is a fast and reasonably cheap option, it also saves time; fence is placed at an open space of a few metres from the forest edge, giving a feeding site for wild boar. (iv) Fences require a lot of resources for construction and maintenance, and are not a solution to avoid the problem, but rather a way to delay it; if we want to reduce contacts and the risk of disease transmission, we really need to reduce the population.
- Crop protection: (i) Electrified fences are extremely effective when installation and maintenance is shared and supported by all stakeholders (farmers and public agencies). (ii) Some adult large wild boar jumped over the fence; nevertheless, it is a cost-efficient method compared to crop damage losses, it is also easy and fast to erect electric fences. (iii) Only positive effects, farmer culturing crops are very happy; however, electric fences are a danger, so limits some types of hunting. (iv) In addition to the application and maintenance of fences, meetings should be held (or through questionnaires) to learn not only what is wrong but also what works directly from the people involved (e.g., farmers).

Considering different repellents/deterrents (odour, acoustic, visual), we did not receive adequate number of responses for firm conclusions, particularly because they were mainly used as a complementing measure to either solid or electric fence (this was the case in all areas, where ASF control was the aim). Based on a few answers where each group of deterrents was solely used, it seems that acoustic and visual deterrents might be moderately effective for increasing road safety (but only on a short-term basis; see review in Langbein et al., 2011). Similarly, according to responses received, odour repellents seem to be reasonably effective for crop protection, while effectiveness of acoustic deterrents is in case of this aim a context-dependent: while they affected decrease of crop damage caused by wild boar in case of alternative food source (i.e., non-protected field), they did not stop entering wild boar into the maize field in the area without alternative food availability. In most cases, however, it was shown that deterrents were not effective tools neither for crop/forest protection nor for ASF control and reducing wildlife-livestock interactions. This is in accordance with previous opinion on efficiency of odour repellents for affecting wild boar movement: while some products show a temporary effect for several weeks, others have not proven to be effective at all, wild boar often become habituated, and their effectiveness is lost after several applications; therefore, their use is not recommended if a long-term effect is needed (*sensu* Jori et al., 2021). According to this, it is also evident from responses that (with the exception of increasing traffic safety for which they do have some –at least short term– potential) deterrents should only be applied in combination with other methods when aimed at reducing wild boar (wild ungulates) movement and separating populations, and have no potential to be used alone when spread of ASF or any other disease is the main aim of separating method.

Obviously, effectiveness of both solid and electric fences for separating wild boar populations (due to lack of data, we do not include deterrents and other methods in this part) is affected by different environmental as well as technical influential factors. Unfortunately, apart from a very few published studies (e.g., Dellicour et al., 2020; Licoppe et al., 2023) in which also some scenario-related effects were studied, there is no scientifically confirmed information on the effect of influential factors. Therefore, we tried to upgrade recent scientific findings with the questionnaire. However, due to complexity of combination of different factors, almost complete lack of scientific methods assessing their effects, as well the fact that in the most ASF affected areas fences have been installed only recently and the ultimate outcome is still unknown, these data are only partially relevant. Nevertheless, by combining both outcomes of the literature review and questionnaire, we can define the following factors/scenarios that determined effectiveness of fences (with emphasis on ASF control):

- **Aim of the fencing**: Focal fencing at smaller and concrete locations, aimed at enclosing susceptible wild boar groups and virus inside infected area or its close vicinity (i.e., restricted zones) should be implemented, while longline transboundary fencing, aimed at protection of large areas or even countries against dispersing individuals from other areas/countries should be omitted, as it is usually ineffective and only causes political and social tensions and conflicts (Jori et al., 2021).
- **Optimal size of the area enclosed**: The size should consider the spatial ecology of wild boar; fenced area should not be too small but also not too large (i.e., optimal size 50–200 km²), which fulfils all the requirements of wild boar population and hence limiting the risk of evasion, but also allows intensive culling and efficient maintenance of the fences (Licoppe et al., 2023).

- **Effect of typical topographic characteristics**: Considering responses obtained, effectiveness of solid fences is dependent on orography, being higher in flat land, where solid fence construction is a much easier task. Indeed, all favourable outcomes (i.e., fences assessed to be very to completely effective, fully prevention of wild boar crossing, no spread of ASF outside the fenced area) were from flat land, while no such outcomes were reported in areas characterised by dynamic/variable topography (Tables 15, 16).
- **Landscape type**: The forest coverage pattern should be considered and is of strategic importance to install fences and delimiting the area of containment, as the wave-front velocity is expected to be faster in forest areas and slower in non-forest areas; open land actually slows down the ASF progression throughout a non-continuous wild boar population (Dellicour et al., 2020). The most permeable fences were in a mosaic landscape of mixing small forests and pastures with disrupted urbanisation and many gates (Licoppe et al., 2023). Moreover, according to the response from Italy, mountainous terrain also negatively affects the effectiveness of the solid fence to stop the ASF spread.
- **Presence of different landscape features (water bodies, villages, longline infrastructure)**: Generally, the presence of rivers and streams as well as anthropogenic corridors increases the permeability of the fence, and, consequently, increases also wild boar crossing and virus spread (Jori et al., 2021; see also Table 32). The presence of villages, which cannot be (completely) fenced, acts in the same direction (Licoppe et al., 2023). Moreover, watercourses were identified as vulnerable points of fences, where the frequency of crossings was higher than expected by chance (Laguna et al., 2022).
- **Inclusion of other (manmade, natural) barriers in the fence network**: Roads as a longline infrastructure barrier (particularly fenced highways, although even they are not 100% impermeable barrier for wild boar; see Chapter 3.1.2) can be effectively included in the network of fences and can contribute to decrease ASF virus dispersal and wave-front velocity (Dellicour et al., 2020; Licoppe et al., 2023). Similarly, rivers (but only wide ones, with high discharge) can act as an important barrier for the spread of the ASF virus (Reiner et al., 2021). Therefore, they can be incorporated into the barrier system as well. With the questionnaire, we indeed received responses that water bodies were occasionally included as a part of fencing strategy (for example, successful use of the lake in Sweden; Tables 30–32), but we should bear in mind that wild boar has in general great ability to swim: for example, the species dispersed on many, also distant, Croatian island by swimming (personal observations). Moreover, wild boar passage over rivers is highly dependent on the season and the amount of water in the rivers (response to the questionnaire).
- **Culling of wild boar inside/outside the fence**: In case of infection, intensive cull of wild boar on both sides of the fence, strictly following biosecurity measures, is mandatory to provide an effective outcome of the fence, i.e., to stop the virus spread. Indeed, among 9 areas for which we received complete responses (Table 30), fences were assessed to be completely ineffective only in a case where wild boar was hunted at normal intensity on both sides of the fence (Italy, Alessandria). Intensive cull of wild

boar around the fenced area is the best guarantee to prevent any circulation of the virus due to the elimination of the virus naïve hosts (Licoppe et al., 2023).

- **Quality/type of the solid fence**: Height, together with maintenance, importantly affects efficiency of the solid fences for preventing wild boar crossing; for example, 2.0 m high well-maintained fences with tightened horizontal and vertical wires (15×15 cm) that were weekly maintained were on average 30% more efficient than 1.2-1.5 m high livestock fences (Laguna et al., 2022).
- **Digging the solid fence into the ground**: When comparing two scenarios (dug vs. not dug fences), responses to the questionnaire (Table 13) did not strongly confirm usual idea that buried fence would be less permeable for wild boar in comparison with non-buried ones (*sensu* Jori et al., 2021). However, it should be mentioned that in Italy (Alessandria), where solid fences were assessed as completely ineffective in relation to ASF control, the fence was not dug into the soil. On the contrary, the same holds true also in Belgium, where the fence was nevertheless very effective, although non-buried wire fences were used there as a compromise between efficacy, compared to electric fences, and rapid installation, compared to buried wire fences (reviewed in Licoppe et al., 2023).
- **Complementary use of electric fences along solid ones**: According to responses to the questionnaire, addition of electric fences did not affect general effectiveness of solid fences, i.e., no important differences considering the effect on spatial behaviour of wild boar, wild boar crossing frequency, the spread of ASF beyond the fenced area, and on general effectiveness of the method was reported (Tables 11, 12).
- **Number of wires in case of electric fences**: A minimum of two wires installed between 25 and 50 cm above ground level is required to deter wild boar movements across the fence (*sensu* Jori et al., 2021). In all cases for which we received responses, this perquisite was fulfilled; although we were not able to assess the differences between the two scenarios (two vs. three wires) because in the majority of cases electric fences were installed along solid ones, we received some responses indicating that using three instead of two wires would importantly increase the effectiveness of electric fences in specific areas where they were used.
- **Costs and cost-effectiveness**: Implementation of electric fences is much cheaper in comparison with solid fences (ratio of approx. 4:1, i.e., 10.2 euros/m vs. 2.6 euros/m for solid and electric fences, respectively, as reported in the response to the questionnaire for an area where both types of fences were used). However, costs of maintenance of electric fences are higher as they need regular checking of electricity power and cleaning of the vegetation. Considering type/quality of solid fences, the difference of costs for installation and maintenance between lower quality livestock fence and higher quality game fence is lower but still considerable (livestock fence: 6 and 8 euros/m; game fence: 10 and 12 euros/m, respectively).
- **Maintenance of the fence**: Proper maintenance of the fences (both solid and electric ones) is a key for their long-lasting effectiveness (Jori et al., 2021; Cox et al., 2022; Laguna et al. 2022). The fact that adequate and permanent maintenance of fences (and

possibility to organise it) is one of very important scenarios that should influence the decision where and what kind of fences to implement (for example, electric fences need much more maintenance in comparison with solid ones), is obvious from responses to the questionnaire. Indeed, in the case of solid and electric fences, 33% and 38% of respondents, respectively, reported lack of adequate maintenance over time as the main reason why fences were understood to be ineffective.

Comparisons in relation to different scenarios presented above provides insight into critical factors that can –either alone or in combination– affect the effectiveness of fences (mainly for controlling ASF and other diseases which are or might be in the future transmitted via wild boar movements). In our opinion, it is essential that authorities before making the decision where, how, and which measure will be implemented check all these factors (and potentially also some locally important additional ones), and on the basis of comprehensive analysis select the proper method, which will ensure desired outcomes in the most cost-effective way. However, the decision should not be partial and based only on solving veterinarian-related issues (i.e., ASF or other disease control), but has to holistically consider also all ecological effects of fencing (e.g., impact on habitat connectivity and gene flow within populations of other species) as well as attitudes of public and acceptance of selected measure by different stakeholders (which will, among others, influence up-following possibility of long-lasting maintenance of the implemented measure).

Indeed, when fences are constructed for a specific species and/or purpose this purpose is often achieved, but on the other hand there is usually a critical lack of information on other, non-target species (McInturff et al., 2020). Therefore, it is important to note that fencing can significantly affect species other than wild boar. Although we asked with the questionnaire for effects on other species as well, we received very few relevant information. Therefore, we provide here a short review of fencing-related effects on wildlife from the literature.

Fences are spatially extensive, creating vertical obstacles for wildlife to cross and are constructed with varying degrees of permeability. Direct negative effects of wildlife-fence interactions involve physical contacts between the individual and the fence which include direct mortality, injuries, and hair loss. Indirect effects of fences on wildlife manifest themselves as changes in behaviour and biology which includes heightened stress of negotiating fences, habitat loss, fragmentation, and obstructed movements (Jakes et al., 2018). Animal movements connect disparate habitats in space and time and sustain critical ecosystem functions and services (Lundberg and Moberg, 2003; Bauer and Hoye, 2014). Fences impede movements across various temporal and spatial scales – they can block the migratory paths of wildlife and inhibit the daily and seasonal migratory movements (e.g., Mackie, 1981; Flesch et al., 2010; Kowalczyk et al., 2012). Moreover, fences can hinder dispersion and cause genetic substructuring of populations (Epps et al., 2005; Daleszczyk and Bunevich, 2009; Frantz et al., 2012; Šprem et al., 2013) and may change the spatial distribution, overlap and demography of species, as well as altering the community structure (Didham et al., 1996; Kowalczyk et al., 2012). They may also reduce the carrying capacity of habitats as in the case of ungulates (Kindschy et al., 1982; Kie and Boroski, 1996; Forman et al., 2003) and can increase the energetic costs on a daily and seasonal basis, thus potentially increasing mortality risk and may result in a loss of fitness (Jones et al., 2022). Larger animals, such as ungulates, can snare their legs or be entangled when attempting to cross the fence and are consequently restrained until death occurs (Mackie 1981; Kie and Boroski, 1996; Mbaiwa and Mbaiwa, 2006), therefore increasing fence-related mortality has been sometimes reported, also in Europe (Pokorny et al., 2017; Safner et al., 2021). Apart form unguated (*ibid.*)., fences are also a major source of mortality for grouse species in Europe and North America, and may be a factor driving population declines (Baines and Andrew, 2003; Wolfe et al., 2007; Stevens et al., 2012). In North America, for example, Wolfe et al. (2007) found that 39.8% of lesser prairie-chicken (*Tympanuchus pallidicinctus*) mortality was caused by collision with fences, and in Europe collisions with fences have been observed for western capercaillie (*Tetrao urogallus*), black grouse (*Tetrao tetrix*), red grouse (*Lagopus lagopus*), and ptarmigan (*Lagopus* spp.) (Catt et al., 1994; Bevanger, 1995; Baines and Andrew, 2003). Moreover, changes in the behaviour due to the construction of the fences have also been observed, for example in pronghorn (*Antilocapra americana*) populations in Alberta, Canada (Jones et al., 2019). Pronghorn showed strong avoidance of fencing and model predictions with complete removal of fences from the landscape (i.e., natural conditions) predicted an increase in the area of high-quality habitat by 16–38%. In contrast, doubling fence density in the landscape decreased the amount of high-quality habitat by 1–11% and increased low-quality habitat by 13–21%. In Wyoming, USA, Xu et al. (2023) showed that fence density determined the correlation between barrier behaviour and space use of mule deer (*Odocoileus hemionus*), which was negatively associated with individual survival.

Due to the overlooked negative impacts of fencing on many animal species, it was pointed out that efforts need to be made to reduce these negative effects through either complete or temporary removal of fences (which is in a complete contradiction with veterinary/health issue approach) and/or widespread adoption of fence modification approaches that mitigate their negative impact on habitats and animal movements (Jakes et. al., 2018; Jones et al., 2019, 2022; Safner et al., 2021; Hering et al., 2022; Xu et al., 2023).

Moreover, with the questionnaire, we gathered several useful pieces of information indicating how effective each measure was in the concrete area where it was implemented. However, we should bear in mind that neither findings nor measures can be transferred to any given country or specific area without major adjustments based on the ecological, epidemiological, and social context (see also Dixon et al., 2019).

## 4.3 Social effects and implications

When assessing feasibility of fencing and other measures connected with it in the context of ASF control, we should also have in mind several negative contexts of fences, both in terms of negative impacts on wildlife ecology and economical consequences. Fences seriously impact biodiversity by preventing wildlife movements and migrations, thus reducing ecological connectivity (Woodroffe et al., 2014). Considering economical consequences, for example, in Belgium a non-exhaustive list of collateral damages of ASF-related fences is very long and includes among others the suspension of forestry activities, the postponement of exploitation works, complication of the bark beetle crisis management, leisure pursuits and green tourism in general, loss of value of the hunting grounds, undefined responsibility for damage to crops due to the prohibition of hunting, and increased pressure from wild herbivores (roe and red deer, mouflon) on forest regeneration after two years without hunting in some areas. Although no data is available on all these costs, there is an estimate of the measures implemented only for wild boar management, which is around 300 euros/ha. This explains the perceptible tensions locally, i.e., between the administration and the landowners, the administration and the hunters, and the local and central administrations, while the federal and international authorities held up the management of the crisis as an exemplar model. This shows that human dimension is a key element in the process that should be better taken into an account (Licoppe et al., 2023).

### 4.3.1 Stakeholder mapping

Respondents to the survey were given the opportunity to highlight the stakeholders they deemed key to the implementation of separation measures as a strategy for controlling animal movement. Mapping, categorising, and analysing the range of stakeholders embroiled in biosecurity related issues is critical to the effectiveness of interventions (Reed & Curzon, 2015). The results of this survey show how many different stakeholders are potentially involved in the erection and maintenance of separation measures, and strategic, practical responses to ASF presence or risk. As these measures often traverse different property boundaries, territories and points of responsibility, different stakeholders with varying degrees of power and authority are often required to work together. This more broadly brings attention to the numerous social-political relations that might exist in any given situation, reiterating the complexity of biosecurity and wildlife management.

Literature suggests it is important for decision-makers to identify the stakeholders who would not only be involved in the practical implementation of separation measures that preempt or respond to disease outbreaks, but, secondly, also those who would be affected by this. While authorities undergoing an emergency response to an ASF (or other notifiable disease) outbreak might be expected to act with urgency in the moment, stakeholder mapping and identification should be carried out in advance to: (i) foster trust; (ii) encourage buy in in the event of an outbreak; and (iii) help reduce the kinds of practical challenges they may face, and ward off potential opposition.

The survey made it clear that while stakeholders might react differently, the attention that professionals and authorities involved in decision-making and implementation paid to those reactions differed substantially. For example, one of the respondents honestly confirmed that the agency implementing anti-ASF fencing at the time of the outbreak simply did not care about the reaction of the public. From other respondents' answers it was nevertheless clear that such ignorance of various stakeholders' attitudes might undermine the efficiency of the implemented measure.

### 4.3.2 Understanding opposition, tension, and controversy

To this end, opposition meant going beyond mere disagreement (but with the functional result of complying or not mounting resistance) to actually voicing dissent in various pathways – by non-compliance, sabotage, protest, media coverage. There was not a clear link set up in the questionnaire for respondents to answer which different stakeholders manifested the different forms of opposition, nor the differently assessed levels of opposition, e.g., if 'mushroom pickers' and 'visitors' voiced moderate opposition compared to the forestry industry launching "severe opposition". By the stakeholders being differently situated in relation to the wild boar, fences and contagion, the nature of their opposition is necessarily manifested differently: through not complying with, e.g., fence directives or restrictions, or by actively sabotaging those that do.

We also acknowledge that opposition is a complex cultural phenomenon that manifests differently across the countries surveyed. In wildlife management in particular, so-called 'shoot, shovel and shut up' logics of resistance, where actors simply disobey and take the law into their own hands, is distinguished from outward-facing communicative efforts of, e.g., protest and demonstration (von Essen, 2016). Managers may find it easier to engage with opposition of the latter logic, as this presents opportunities for dialogue and public justification.

Social/societal factors nevertheless surfaced also in the answers to other questions of the survey. Notably, when asked what makes a method (in)effective, respondents mentioned social acceptance, political support, or continuous discussions with stakeholders. Turned around, this indicates the importance of prioritising public relations, media coverage, and transparency. In settings where there is a legacy of mistrust or a poorly handled state intervention, opposition, and pushback even to new initiatives will be more frequent. Regaining trust and legitimacy may be "a steep hill to climb" (Luke et al., 2018: p. 656).

# 5 Conclusion and recommendations

Preventive and control measures should be ‘tailor made’ in order to address every disease’s unique epidemiological profile, consequences, and distribution within the EU (Viltrop et al., 2021). However, current ASF control and prevention policies are tailored mainly to high-income countries’ eco-social conditions and are, therefore, of only limited effectiveness in low- to middle-income countries, where the level of residual accepted risk after implementation can often be higher, given the importance of other socioeconomic factors (Dixon et al., 2019). Moreover, the global dimension of the current epidemic, including the long-distance translocations and incursions, shows that human-mediated dispersal to domestic or wild boar populations can occur at any time and to any country, regardless of the distance from ongoing infections in wild boar populations (Chenais et al., 2019a). Therefore, the major challenge in achieving control of ASF in Europe now seems to be not necessarily technical (for example, finding the most effective measure for separating wild boar populations, i.e., how to effectively fence target areas), but rather relating to the specific needs and circumstances of stakeholders in affected areas. Especially in the parts of Europe where pig production is dominated by smallholder systems, low-cost control options fully adapted to the local context and highly accepted by the end users are required (Chenais et al., 2019b). In this context, understanding of local sociocultural, economic and political dimensions, as well as individual keys to effective communication is equally important as epidemiological knowledge in ASF control (Chenais et al., 2019a; Loi et al., 2019b; Jori et al., 2020). With both review of recently published papers and the questionnaire we gathered several useful pieces of information indicating how effective each measure was in the concrete area where it was implemented. However, we should bear in mind that neither findings nor measures can be transferred to any country or specific area without major adjustments based on the ecological, epidemiological, and social context (see also Dixon et al., 2019).

Although there had been no universal agreement with respect to the epidemiological suitability and cost-effectiveness of fences for ASF control in wild boar, it seemed plausible that fencing could limit their movements and, therefore, present a barrier for spread of the virus (Dixon et al., 2019). This is confirmed by our exercise: several examples from recently published scientific papers as well as responses received from different European countries confirm that –although fences do not act as absolutely nonpermeable structures– both solid and electric fences can be effectively used for ASF control, i.e., for reducing or even annulling the virus spread. The positive examples from the Czech Republic and Belgium show that control and eradication of ASF can be achieved, but to reach this goal a multifactorial approach is needed, and all stakeholders need to be involved, engaged, and understood (Viltrop et al., 2021). Indeed, field experiences clearly show that successful ASF control requires collaboration of different stakeholders, including animal health authorities, local authorities, hunting associations, wildlife managers, farmers, landowners, general public, etc. (Gavier-Widén et al., 2021). It is, therefore, crucial to consider and understand the social dimension behind that may affect effectiveness of any measure (including implementation of fences and other barriers) aimed at ASF control across the whole process of taking decision, implementing the measure (e.g., construct the fence), and maintaining it.

Following the emphasis on maintenance expressed by many respondents of the survey we suggest generalising ‘maintenance’ as a productive metaphor of practical thinking about spatial separation measures, namely fences. Our proposition is to see fences as structures that require not only physical maintenance but also **social maintenance**. It has long been established that implementing the measure should ideally be done upon consensus of local stakeholders, including the general public. However, such consensus should not be seen as something static but rather as a process that requires constant, even if not always equally intense, attention. Thus, in the decision-making processes and calculation of costs it should be taken into account what it means to attend to implemented measures both in terms of material care and social care.

Paying attention to social maintenance has an additional advantage. In the follow up interviews it turned out that in some contexts implemented measures that lost their purpose are simply forgotten, becoming no one’s interest and possibly no one’s responsibility. Hence the practice of social maintenance in which the implementing party has to continually/periodically communicate the purpose of the measure would effectively uncover that it outlived the purpose and naturally start the decision-making process regarding its future fate.

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# Appendix A – Extra figures and tables from systematic literature review

**Table A.1:** Summarised outcomes of literature review on wild boar population separation methods.

| | | | | Method | | | | | | | | | Effects | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reference** | **Location** | **ASF** | **Landscape** | **Electric fence** | **Solid fence** | **Gustatory** | **Natural barrier** | **Infrastructures** | **Others** | **Species** | **Period** | **Method estimation effectiveness** | **Behaviour** | **Genetic differentiation** |
| Laguna et al., 2022 | Spain - Cabañeros National Park | N | Forest, agricultural and livestock | | x | | | | | *Sus scrofa* | 2009-2010 | GPS tracking – crossing events | Passage | |
| Negus et al., 2019 | Australia - Archer River catchment | N | Wetlands | | x | | | | | *Sus scrofa* | 2017-2018 | Observation of feral pig damage | No damage (with good maintenance) | |
| Pascual-Rico et al., 2018 | Spain - Sierra Espuña regional park | N | Mountain range | | | x | | | | *Ammotragus lervia - Sus scrofa* | 2015-2015 | GPS tracking – core home ranges | Increases animal concentration - disease transmission risk; no change in core home range | |
| Cox et al., 2022 | New Zealand - Falla Peninsula | N | Forest and grassland | x | | | | | | *Sus scrofa* | 2019-2019 | Visual inspection, field cameras – pigs presence and behaviour | Passage | |
| Gerald Reiner et al., 2021 | Germany - Rhineland-Palatinate | N | Low mountain, broadleaf forest | | | | x | x | | *Sus scrofa* | 2018-2019 | Genetic analysis | | YES |
| Honda et al., 2020 | Japan - Hokuto and Kai city | N | Forest and roads | | | | | | Grates | Ungulates | 2012-2018 | Camera traps – passed individuals in control and treated | No passage | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gross et al., 2019 | Zambia, Nepal, India, Tanzania - South Luangwa National Park, Tarangire National Park, Bardia National Park, Manas National Park | Y | | x | x | | x | | Guarding, trenches | Herbivorous | 2009-2014 | Damage events collection | Damage (ineffective) | |
| Mihalik et al., 2018 | Hungary - North east of Hungary | N | | | | | | x | | *Sus scrofa* | 2017-2017 | Genetic analysis | | YES (low) |
| Griciuviene et al., 2021 | Lithuania | Y | Forest, agricultural and livestock | | x | | | x | | *Sus scrofa* | 2009-2013 | Genetic analysis | | NO |
| Ryan et al., 2023 | Australia - Herbert region | N | Lowland coastal area, agricultural and livestock | | | | x | x | | *Sus scrofa* | 2012-2013 | Genetic analysis | | YES (only for distance) |
| Saito et al., 2022 | Japan - Fukushima and Kumamoto Prefecture | N | Forest, agricultural, livestock, urbanized area | | | | x | x | | *Sus scrofa* | 2013-2018 | Genetic analysis | | YES |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tajchman et al., 2018 | Poland – regions of Lublin, Warmia and Mazury, Wielkopolska | Y | | | | | x | *Sus scrofa* | | Genetic analysis | | YES (only between regions) |
| Methner et al., 2018 | Germany - District of Arnsberg | | | | | x | x | *Sus scrofa - Vulpes vulpes, Meles meles, Capreolus capreolus,* domestic pig | 2017-2017 | | | YES |
| Bollen et al., 2021 | Belgium | both | Forest, agricultural, livestock | | x | | | *Sus scrofa* | 2018-2020 | Camera traps – field occupancy | No passage | |
| Safner et al., 2021 | Croatia - border with Hungary | | Forest, agricultural | | x | | | *wildlife, especially ungulates* | 2015-2017 | Roadkills counts | Mortality | |
| Davoli et al., 2022 | Italy - northern Apennines | N | Forest, agricultural, livestock, urbanized area | x | x | | x | *Canis lupus - Sus scrofa* | 2011-2016 | Wolf occurrence, depredation events, crop damage | Limited passage (with good fences); avoidance behaviour of wild boar due to wolf presence | |
| Ważna et al., 2020 | western Poland (Lubuskie province). - | N | Agricultural, livestock, urbanized area, water | | x | | x | *Species of medium- and large-sized mammals* | 2012-2013 | Animal traces – openness index and index of use | Passage (through underpasses) | |
| Bhardwaj et al., 2022 | Sweden - Skåne County | N | Agricultural, scattered forests and large urban/suburban developments | | x | | x | *Sus scrofa, Capreolus capreolus, Cervus elaphus* | 2020-2021 | Number of collisions | Limited passage | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sawai et al., 2023 | Japan | N | Forest, mountains, residential | | x | | | *Sus scrofa* | 2014-2020 | Genetic analysis | | YES |
| Cozzi et al., 2019 | Italy - Basilicata | Y | Forest, agricultural | | x | | | *Sus scrofa* | | Spatial-based risk classification of damages | Damage (higher risk for agriculture areas) | |
| Castillo-Contreras et al., 2018 | Spain - Barcelona | N | Urban, green spaces | | | | Vegetation clearing - food availability | *Sus scrofa - Vulpes vulpes* | 2010-2014 | Wild boar movement | Passage (through corridors) | |
| Lecis et al., 2022 | Italy - Sardinia | | Forest, agricurtural, urbanized areas | | | x | | *Sus scrofa* | 2001-2019 | Genetic analysis | | YES |
| Iwiński et al., 2019. | Poland - Poland | | | | | x | | wildlife | 2018-2019 | Field cameras | Passage (different pattern) | |
| Botting et al., 2023 | Spain - Doñana Biosphere Reserve | | Forest, agrucurtutal, urban | x | | x | | *Sus scrofa, Cervus elaphus* | | Presence data – spatial analysis | Affects wildlife movement | YES |
| Colomer et al., 2021 | Spain - Montseny natural park | | Forest | | | | Hunting pressure | *Sus scrofa* | 2014-2016 | Camera traps – animal monitoring | Reserve effect (concentration in protected areas) | |
| Dellicour et al., 2020 | Belgium-Wallonia | Y | Agricultural, forest patches. | x | | x | | *Sus scrofa* | 2018-2019 | Comparison over null dispersal model | Reduced dispersal and the ASF wavefront dispersal velocity | |
| Licoppe et al., 2023 | Belgium-Wallonia | Y | Agricultural, forest patches. | x | | | Zoning, carcass recovery, depopulati on | *Sus scrofa* | 2018-2021 | Distance ASF positive cases from fence | ASF outbreak extinction | |

# Appendix B – Questionnaire

## Questionnaire about experiences in effectiveness of methods for controlling wild boar movement (wild boar separation)

Dear colleagues,

Beyond the project/network *Wildlife and One Health: wildlife ecology, health surveillance and interaction with livestock, human population and environment* (ENETWILD 2.0) funded by EFSA, one of the important tasks of the consortium is to assess the effectiveness of different methods aiming to control/limit wild boar movement in different scenarios and settings where these methods have been implemented. Along with a comprehensive review of published scientific literature, a very important part of this task is to collect and analyse unpublished field experiences of different end-users/stakeholders (e.g. authorities responsible for stopping the spread of ASF, landowners and agricultural companies, population / hunting ground managers, agencies responsible for road safety, police or other authorities responsible for border fences etc.) across Europe. This will be achieved through this questionnaire which aims to bring an insight into unpublished first-hand experiences and provide valuable case studies on the effectiveness of methods, the role of different environmental/landscape features, as well as the scenarios enabling the science-based implementation of feasible and effective methods in the future.

In line with this, we are kindly asking all members of ENETWILD consortium to distribute the following questionnaire to wildlife professionals and/or other relevant stakeholders that might help to fill our knowledge gaps by sharing their experiences. To simplify the whole process, we hope that it is possible to use the English version of the questionnaire; in the case that some relevant respondents are likely to have problems with this, we kindly ask ENETWILD members to translate the questionnaire in their own language.

**Disclaimer**: To collect as much information as possible on the effectiveness of different methods aiming to control/limit wild boar movements from different sources and when goals differ, several questions/question groups are optional or specific to context. In such cases, please only answer the relevant questions. Moreover, since we are interested in all types of separation methods, we generally avoid referring directly to 'fences'/'fenced areas' etc. However, in questions where we use these terms for clarity, we refer to any type of manmade barriers potentially acting as "fence" (rather than solely solid fences).

**Motivation for collaboration**: All Enetwild partners providing at least one response from relevant stakeholders/end-users will – as active partners in this working task– become co-authors in the final report. They will also be invited to join an online workshop in March 2024, where we will try to further establish our knowledge on the effectiveness of methods for controlling wild boar movement. Moreover, all active partners will be invited to collaborate and contribute to scientific manuscripts generated from the data collected in this working task and will, accordingly, become co-authors of such papers.

**Management of personal data in the research**: This questionnaire is in line with the project/network *Wildlife and One Health: wildlife ecology, health surveillance and interaction with livestock, human population and environment* (ENETWILD 2.0), the European Code of Conduct for Research Integrity issued by ALLEA – Association of European Academies and the General Data Protection Regulation of the European Union (https://gdpr.eu/). Only personal data that is necessary for the research will be collected. These will include your affiliation to a scientific institution and the countries where you operate. No other information will be collected. Personal data will be stored securely and the identity of participants in the research will not be disclosed under any circumstances.

**Conscious and free consent to participate in the research**: I understand the purpose, objectives, and course of the research. Regarding the research, I can ask for further information ENETWILD 2.0 members responsible for the work task related to the questionnaire (please, contact Zarja Platovšek or Boštjan Pokorny, Faculty of Environmental Protection – zarja.platovsek@fvo.si; bostjan.pokorny@fvo.si).

PLEASE FILL THIS QUESTIONNAIRE ONLY IF YOU ARE AWARE OF ANY METHODS AIMING TO CONTROL/LIMIT WILD BOAR MOVEMENT IN YOUR COUNTRY.

**Responsible authority/end-user (please, indicate your principle position related to the topic):**

- Veterinary authority/veterinarian
  - state agency
  - regional authority
  - private
- Hunting ground manager
- Landowner
  - agriculture
  - forestry
- Wildlife officer in protected area/wildlife park
  - manager
  - ranger
- Wildlife scientist
  - ecologist
  - epidemiologist
  - other (specify): ___________________________
- Police officer
- Other (specify): _________________________________

## I. General background information

Country: _____________________________

Locality (name): _____________________________

Locality (coordinates, EPSG): _____________________________

Is the area where the measure was implemented a NATURA 2000 site, or have another form of protection? (Y/N): _____________

When did the implementation of method for control start? (month, year): _________________________

When did the barrier implementation of method for control end? (month, year): _____________________

If applicable, what time gaps were there in barrier implementation? (duration, days/weeks/months): ___

Is ASF currently present in the area?

- Yes – wild boar
- Yes – domestic pig
- Yes – in both
- No

Was ASF present when the method of control was implemented?

- Yes – wild boar
- Yes – domestic pig
- Yes – in both
- No

Was ASF the driver behind the method of control?

- Yes
- No

If ASF is present, please specify the zone type at the time of implementation (according to the EU zoning policy):

- Infected zone
- Restricted zone I
- Restricted zone II
- Restricted zone III
- Other (specify): _____________

Are domestic pigs present within area?

- No
- Indoor
- Outdoor
- Outdoor and indoor

If outdoor pigs are present, what is the kind of breeding system?

- N/A
- Back-yard
- Free-ranging

If known, what are the implementation costs of the method of control (in EUR)? _____________________

If known, what are the annual maintenance costs (in EUR)? _____________________

## II. Information on separation method

1. *What is the aim of the method of control?*
    - ASF control
    - Crop/forest protection
    - Reduced interaction between wildlife and livestock
    - Road/railway safety
    - National border security
    - Hunting enclosure
    - Wildlife/National park
    - Multiple aims (please specify): __________________
    - Other: ____________________

2. *Was wild boar the target species?*
    - Yes
    - No
    - If not, which species was the primary target: ________________________
    - Secondary target species (if any): ________________________

3. *What type(s) of method are/were implemented (multiple choice):*
   - Solid (mesh) fence
   - Electric fence
   - Razor-wired / barbed wire fence
   - Chemical/odour repellents
   - Acoustic/sound deterrents
   - Artificial light deterrents
   - Visual repellents (e.g., fladry/flags)
   - Gustatory/food methods
   - In person guarding/shepherding/patrolling
   - Complementary use of natural barriers (specify): ____________________________
   - Combination of methods (specify): _______________________________________
   - Other: ______________________________________________________________

4. *Technical info on solid (mesh) fences if used:*
   - Linear barrier or enclosure: _______________________________________
   - Size of area enclosed ($km^2$): _____________________________
   - Length (km): _________________________________________
   - Height (m): _________________________________________
   - Size of mesh openings (cm): _____________________________
   - Distance from bottom of fence to ground (cm): ______________________________
   - Dug into ground (Y/N): ___________________________________
   - Fence material (plastic, metal, concrete, etc.): __________________________
   - Complemented by electric fence (Y/N): __________________________

5. *Technical info on electric fences if used:*
   - Linear barrier or enclosure: _______________________________________
   - Size of area enclosed ($km^2$): ________________________________
   - Length (km): _________________________________________
   - Total height (cm): _________________________________________
   - Number of electric wires (one/two/three/more): ________________________
   - Height of the lowest wire (cm): _________________________________________
   - Distance between wires (cm): ______________________________
   - Voltage (V): ______________________________
   - Frequency of vegetation clearance along fence (weekly, monthly, never): ______________
   - Type of vegetation clearance (mechanical, chemical, combination, other): _____________

6. *Technical info in the case of razor-wired / barbed wire fence:*
   - Linear barrier or enclosure: _______________________________________
   - Size of area enclosed ($km^2$): __________________________________
   - Length (km): _________________________________________
   - Total height (m): ______________________________________
   - Number of razor reels (in parallel): _______________________
   - Razor-wired / barbed wire fence combined with solid fence (Y/N): _______________________

7. *Technical info in the case of odour repellents:*
   - Length (km): ________________________________________
   - Height of the position of repellents (m): ______________________________
   - Distance between poles (m): ___________________________
   - Active substance used (if known): ___________________________
   - Frequency of maintenance (days between maintaining episodes): ____________________

8. *Technical info in the case of acoustic repellents:*
   - Linear barrier or point source: ________________________________________
   - Size of area covered (km$^2$): __________________________________
   - Length (km): ______________________________________
   - Source of acoustic noise (radio, cracking sound, gas cannon, etc.): ______________________
   - Loudness (mild/severe/very loud): _____________________________
   - Frequency of sound emission (s/min between intervals): _______________________

9. *In cases of enclosure, is the culling of a target species practiced on either side of the barrier?*
   - Within the enclosed area:
     - Yes – intensive cull
     - Yes – hunting at normal intensity
     - Not at all
   - Outside the enclosed area:
     - Yes – intensive cull
     - Yes –hunting at normal intensity
     - Not al all

**III. Information on the area where the measures are implemented**

10. *Landscape type / land use:*
    - Farmland
    - Forest
    - Mixed forest-farmland (mosaic)
    - Residential (suburban)
    - Wetland
    - Other (specify): ________________________________________

11. *Typical topographical character:*
    - Flat land
    - Steep slopes
    - Dynamic, variable topography
    - Other (specify): ________________________________________

12. *Are the following natural/artificial elements used as part of the barrier system (multiple choice):*
    - River(s)
    - Streams
    - Highway(s)
    - Main roads
    - Villages/urban areas
    - Mountains
    - Sea (coast)
    - Other (specify): ________________________________________

## IV. Social effects and implications

13. *Please list the key stakeholders involved in the decision to implementation the stated method(s):*

    ____________________________________________________________

    ____________________________________________________________

    ____________________________________________________________

14. *Please list the stakeholders who were negatively affected by the implementation?*

    ____________________________________________________________

    ____________________________________________________________

    ____________________________________________________________

15. *What was the response of the general public?*

    ____________________________________________________________

    ____________________________________________________________

    ____________________________________________________________

16. *Was there any opposition to the fence and what motivated it? (multiple choice)*
    - No opposition
    - Opposition over:
      - o access restrictions
      - o negative ecological impacts
      - o distrust of authorities/decision-makers
      - o welfare impacts on target and non-target species
      - o economic concerns
      - o negative impacts on hunting /game management
    - Other (please list): ____________________________________________

17. *What was the reaction of affected groups? (multiple choice)*
    - No opposition/negative reaction, full support
    - Moderate opposition
      - o ignored requests/instructions
      - o media criticism / publicly voiced criticism
    - Severe opposition
      - o public events organised against the method (e.g., demonstrations)
      - o destruction of fence/sabotage
    - We did not pay attention to public responses
    - Other (specify): ________________________________

18. What social and/or political tensions did the methods of control cause among different stakeholders?

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

## V. Responses of target species

19. *Did the method implemented affect the population abundance/density of the target species (Y/N):* ___
    - If yes, please provide concrete data and its source, and/or briefly describe the change:
      ______________________________________________________________________________
      ______________________________________________________________________________
      __________________________________________________________________

20. *Did the method implemented affect the spatial behaviour of the target species (Y/N):* _____________
    - If yes, please describe how animals reacted:
      ______________________________________________________________________________
      ______________________________________________________________________________
      __________________________________________________________________
    - *Did you measure changes in animal movement (e.g., with telemetry, GPS, etc.) (Y/N):* _______
    - If yes, please briefly describe the method used for determining this change:
      ______________________________________________________________________________
      ______________________________________________________________________________
      __________________________________________________________________

21. *What other scientifically confirmed effects were there on wild boar?*
    - Population separation
    - Genetic differentiation of population
    - Hindered migration/dispersion
    - Other (specify): _________________________________________________________

22. *What other registered effects were there on target species other than wild boar (please, specify species?*
    - N/A, no other species
    - Population separation
    - Genetic differentiation of population
    - Hindered migration/dispersion
    - Other (specify): _________________________________________________________

## VI. Effectiveness

23. *On a scale of 1-5, please assess the general effectiveness of the implemented method in relation to its primary aim (1 = completely effective, 3 = reasonably effective, 5 = completely ineffective; N/A = not relevant):*
    - ASF control: ______________________
    - Crop protection ______________________
    - Forest protection: __________________________
    - Reducing wildlife-livestock interactions: ______________________
    - Road/railway safety: __________________________
    - National border security: ____________________________

24. *Did the implemented method prevent the target species from crossing?*
    - Fully, no crossing was registered
    - Partially, the number of dispersing/migrating individuals was lower than before
    - No changes were registered
    - Unknown, not possible to monitor
25. *If the method was aimed at limiting ASF spread, did the disease spread beyond the fenced area (Y/N)?*
    - If yes, what was the time scale of spread beyond the separating measure:
        - Very fast, without any expected delay
        - Moderate delay (<3 months after implementation)
        - Important delay (>3 months after implementation)
26. *In the case of crop protection, did the method have any effect on damage?*
    - Yes, damage was almost completely reduced (>75%)
    - Yes, damage was importantly reduced (25–75%)
    - Yes, damage was moderately reduced (<25%)
    - No effect
27. *In the case of road fencing, did the method have any effect on roadkill?*
    - Yes, roadkill was almost completely reduced (>75%)
    - Yes, roadkill was importantly reduced (25–75%)
    - Yes, roadkill was moderately reduced (<25%)
    - No effect
28. *In the case of hunting enclosures or wildlife parks, did the target species escape beyond the fenced area?*
    - No, never
    - Yes, but only sporadically (<3 cases annually)
    - Yes, with moderate frequency
    - Yes, very frequently (almost on a monthly basis)
    - Unknown, not possible to monitor
29. Where methods are/were understood to be ineffective, *what is/was the main reason for this?*
    - Poor design
    - Badly constructed
    - Inappropriate type of method for the objective
    - Bad timing of the original implementation
    - Lack of adequate maintenance over time
    - Sabotage
    - Other (specify): ____________________________
30. *What would make the method more effective in your opinion:*
    - Better state/regional resources
    - Increased monitoring of impacts
    - Prompt implementation
    - Increased maintenance
    - Better guidance
    - Other (specify): ____________________________

31. Whose responsibility is/was it to fund/install/check/maintain the methods of control?

___________________________________________________________________________________________

_____________________________________________________________________________________

32. *Did you use any method to estimate the effectiveness of the methods of control on wild boar (Y/N)?* _

- If yes, please briefly describe the parameters used:

  _________________________________________________________________________________

  _________________________________________________________________________________

  _____________________________________________________________________

- If yes, please briefly present the results (quantitative data or qualitative remarks):

  _________________________________________________________________________________

  _________________________________________________________________________________

  _____________________________________________________________________

*33. In your opinion, what makes an effective/ineffective method of control?*

___________________________________________________________________________________________

___________________________________________________________________________________________

_______________________________________________________________________________

## VII. Additional notes

34. Any other comments/suggestions/criticisms?

___________________________________________________________________________________________

___________________________________________________________________________________________

_______________________________________________________________________________

35. Can you provide us a link to any published data or research on the topic from your country?

___________________________________________________________________________________________

___________________________________________________________________________________________

__________________________________________________________________________________

## VIII. Further contact

Would you be interested in a follow up conversation about this topic (Y/N)? ___________________

Would you like to be informed about the results (Y/N)? ___________________

If yes for either of the questions above, please leave your contact details below:

___________________________________________________________________________________________

_____________________________________________________________________________________

# Appendices C – Responses to the questionnaire, related to ASF control measures

## Appendix C.1 – Response 32_9_BE

GENERAL / BACKGROUND INFORMATION

**Responsible authority/end-user:** Wildlife scientist - ecologist

**Country:** Belgium

**Locality (name):** Etalle

**Locality:** 49.673892, 5.600236 (Étalle, Belgique)

**Locality (coordinates, WGS 84)?** 5.593527°E 49.672639°N

**Is the area where the measure was implemented a NATURA 2000 site, or have another form of protection?** Yes

**When did the implementation of method for control start:** 31 Oct 2018

**When did the barrier implementation of method for control end?** 31 Mar 2021

**Is ASF currently present in the area:** No

**Was ASF present when the method of control was implemented:** Yes – wild boar

**Was ASF the driver behind the method of control:** Yes

**If ASF is present, please specify the zone type at the time of implementation (according to the EU zoning policy):** Other (specify): Restricted II, I and outside

**Are domestic pigs present within area:** No

**If known, what are the implementation costs of the method of control (in EUR)?** 4,500,000 EUR

**If known, what are the annual maintenance costs (in EUR)?** 10,000 EUR

INFORMATION ON SEPARATION METHOD

**What is the aim of the method of control:** ASF control

**Was wild boar the target species:** Yes

**What type(s) of method are/were implemented:** Solid (mesh) fence, Complementary use of natural barriers (specify): fenced highway

**Solid (mesh) fence:**

**Linear barrier or enclosure:** Linear barrier

- Size of area enclosed (km²): /
- Length (km): 270
- Height (m): 1.2
- Size of mesh openings (cm): 13
- Distance from bottom of fence to ground (cm): 120
- Dug into ground (Y/N): No
- Fence material (plastic, metal, concrete, etc.): Metal
- Complemented by electric fence (Y/N): No

**In cases of enclosure, is the culling of a target species practiced on either side of the barrier?**

- Within the enclosed area: Yes - intensive cull
- Outside the enclosed area: Yes - intensive cull

INFORMATION ON THE AREA WHERE THE MEASURES WERE IMPLEMENTED

**Landscape type / land use:** Mixed forest-farmland (mosaic)

**Typical topographical character:** Flat land

**Are the following natural/artificial elements used as part of the barrier system?** Highway(s), Villages/urban areas

SOCIAL EFFECTS AND IMPLICATIONS

**Please list the key stakeholders involved in the decision to implement the stated method(s):** Regional administration of Agriculture and Environment (Nature and Forest) and scientists (biologists and epidemiologists)

**Please list the stakeholders who were negatively affected by the implementation:** Municipalities, hunters, farmers, Regional Administration of roads

**What was the response of the general public?** The restriction of the access to the forest was perceived as a necessary measure, even if not always respected (at least after some months). There was no bad perception of the fences to my knowledge.

**Was there any opposition to the fence and what motivated it:** No opposition

**What was the reaction of affected groups:** No opposition/negative reaction, full support, we did not pay attention to public responses

**What social and/or political tensions did the methods of control cause among different stakeholders?** No tension about fences

RESPONSES OF TARGET SPECIES

**Did the method implemented affect the population abundance/density of the target species:** Yes

**If yes, please provide concrete data and its source, and/or briefly describe the change:** Limited migration combined with intensive culling : the fences created some large enclosures (+-20 together with the French and Luxemburg networks). So it was possible to adapt the culling method according to the epidemiological status. The virus stopped spreading thanks the fences and thanks the drastic decrease of the population. Thanks to a camera trap survey it has been shown that the culling strategy worked.

**Did the method implemented affect the spatial behaviour of the target species:** No

**Did you measure changes in animal movement (e.g., with telemetry, GPS, etc.):** No

**What other scientifically confirmed effects were there on wild boar?** Hindered migration/dispersion

EFFECTIVENESS

**On a scale of 1-5, please assess the general effectiveness of the implemented method in relation to its primary aim:**

- ASF control: 4 – very effective
- Crop protection: 4 - very effective
- Forest protection: not relevant
- Reducing wildlife-livestock interactions: not relevant
- Road/railway safety: 4 - very effective
- National border security: not relevant

**Did the implemented method prevent the target species from crossing:** Partially, the number of dispersing/migrating individuals was lower than before

**Whose responsibility is/was it to fund/install/check/maintain the methods of control:** Regional Administration

**Did you use any method for estimating the effectiveness of separation measures for wild boar:** Yes

**If yes, please briefly describe the parameters used:** Number of ASF positive detected at the other side of the fence

**If yes, please briefly present the results (quantitative data or qualitative remarks):** https://www.mdpi.com/2076-0817/12/2/152

**In your opinion, what makes an effective/ineffective method of control?** Wire fences instead of electric ones, the place where it is used = placing fences along roads allows control and maintenance and the road is a second barrier, a double fence along a road could be ideal, the landscape is also important : how many roads cross the fences ? the best is to reduce the number of gates into the fence, rivers are also a problem. But it is not possible to achieve a 100% wild boar proof fence in any case. Finally, the fence alone is not enough. Enclosures allow to depopulate and to create a real brake for the virus dispersion by removing susceptible hosts in a closed area.

ADDITIONAL NOTES

**Can you provide us link to any published source/study on the topic from your country?** https://www.mdpi.com/2076-0817/12/2/152

**Would you be interested in a follow up conversation about this topic:** Yes

**Would you like to be informed about the results:** Yes

**If yes for either of the questions above, please leave your contact details below:** alain.licoppe@spw.wallonie.be

# Appendix C.2 – Response 35_4_FR

GENERAL / BACKGROUND INFORMATION

**Responsible authority/end-user:** Hunting ground manager

**Country:** France

**Locality (name):** Metz

**Is the area where the measure was implemented a NATURA 2000 site, or have another form of protection?** No

**Is ASF currently present in the area:** Yes – wild boar

**Was ASF present when the method of control was implemented:** Yes – wild boar

**Was ASF the driver behind the method of control:** Yes

**If ASF is present, please specify the zone type at the time of implementation (according to the EU zoning policy):** Restricted zone II

**Are domestic pigs present within area:** Outdoor and indoor

**If outdoor pigs are present, what is the kind of breeding system?** N/A

INFORMATION ON SEPARATION METHOD

**What is the aim of the method of control:** ASF control

**Was wild boar the target species:** Yes

**What type(s) of method are/were implemented:** Solid (mesh) fence, Electric fence

**Solid (mesh) fence:**

**Linear barrier or enclosure:** Linear barrier

- Size of area enclosed (km²): /
- Length (km): /
- Height (m): /
- Size of mesh openings (cm): 220
- Distance from bottom of fence to ground (cm): 0
- Dug into ground (Y/N): Yes
- Fence material (plastic, metal, concrete, etc.): metal
- Complemented by electric fence (Y/N): No

**Electric fence:**

**Linear barrier or enclosure:** Linear barrier

- Size of area enclosed (km²): /
- Length (km): /
- Total height (cm): 100
- Number of electric wires (one/two/three/more): /
- Height of the lowest wire (cm): / 30
- Distance between wires (cm): / /
- Voltage (V): / /
- Frequency of vegetation clearance along fence (weekly, monthly, never): Weekly
- Type of vegetation cleaning (mechanical, chemical, combination, other): / /

**In cases of enclosure, is the culling of a target species practiced on either side of the barrier?**

- Within the enclosed area: Yes - intensive cull
- Outside the enclosed area: Yes - intensive cull

INFORMATION ON THE AREA WHERE THE MEASURES WERE IMPLEMENTED

**Landscape type / land use:** Mixed forest-farmland (mosaic)

**Typical topographical character:** Flat land

**Are the following natural/artificial elements used as part of the barrier system?** River(s), Highway(s), Main roads, Villages/urban areas

SOCIAL EFFECTS AND IMPLICATIONS

**Was there any opposition to the fence and what motivated it:** Opposition over access restrictions

**What was the reaction of affected groups:** No opposition/negative reaction, full support

**RESPONSES OF TARGET SPECIES**

**Did the method implemented affect the population abundance/density of the target species:** Yes

**If yes, please provide concrete data and its source, and/or briefly describe the change:** Reduction in the population inside the fenced-off area, where destruction operations were carried out, while outside the fenced-off area the population remained at a high level. Populations were maintained at a high level. Few animals were transferred from outside to inside the fenced area. Animals were quickly killed because they were not used to night shooting.

**Did the method implemented affect the spatial behaviour of the target species:** Yes

**If yes, please describe how animals reacted**: Looking for passages in the fence, then avoiding the area that was uncovered (and which became a danger zone at night with night shooting).

**Did you measure changes in animal movement (e.g., with telemetry, GPS, etc.):** No

**What other scientifically confirmed effects were there on wild boar?** Other (specify): population reduction

**EFFECTIVENESS**

**On a scale of 1-5, please assess the general effectiveness of the implemented method in relation to its primary aim:**

- ASF control: 5 – completely effective
- Crop protection: not relevant
- Forest protection: not relevant
- Reducing wildlife-livestock interactions: 5 – completely effective
- Road/railway safety: 5 – completely effective
- National border security: 3 – reasonably effective

**Did the implemented method prevent the target species from crossing:** Partially, the number of dispersing/migrating individuals was lower than before.

**If the method was aimed at limiting ASF spread, did the disease spread beyond the fenced area?** No

**In the case of crop protection, did the method have any effect on damage?** N/A

**In the case of road fencing, did the method have any effect on roadkill?** N/A

**In the case of hunting enclosures or wildlife parks, did the target species escape beyond the fenced area?** N/A

**Where methods are/were understood to be ineffective, what is/was the main reason for this?** Lack of adequate maintenance over time

**What would make the method more effective in your opinion?** Prompt implementation

**Did you use any method for estimating the effectiveness of separation measures for wild boar:** No

**ADDITIONAL NOTES**

**Would you be interested in a follow up conversation about this topic:** Yes

**Would you like to be informed about the results:** Yes

**If yes for either of the questions above, please leave your contact details below:** thibault.petit@onf.fr

# Appendix C.3 – Response 2_2_IT

GENERAL / BACKGROUND INFORMATION

**Responsible authority/end-user:** Veterinary authority/veterinarian – regional authority

**Country:** Italy

**Locality (name):** Milan

**Locality:** 45.453853, 9.192249

**Is the area where the measure was implemented a NATURA 2000 site, or have another form of protection?** Yes

**When did the implementation of method for control start:** 11 Dec 2024

**If applicable, what time gaps were there in barrier implementation:** 10 days

**Is ASF currently present in the area:** Yes – wild boar

**Was ASF present when the method of control was implemented:** Yes – wild boar

**Was ASF the driver behind the method of control:** Yes

**If ASF is present, please specify the zone type at the time of implementation (according to the EU zoning policy):** Restricted zone III

**Are domestic pigs present within area:** Indoor

**If outdoor pigs are present, what is the kind of breeding system:** N/A

**If known, what are the implementation costs of the method of control (in EUR)?** 15,000 EUR

INFORMATION ON SEPARATION METHOD

**What is the aim of the method of control:** ASF control

**Was wild boar the target species:** Yes

**What type(s) of method are/were implemented:** Solid (mesh) fence

**Solid (mesh) fence:**

**Linear barrier or enclosure:** Linear barrier

- Size of area enclosed (km²): /
- Length (km): 2
- Height (m): 1.5
- Size of mesh openings (cm): 10
- Distance from bottom of fence to ground (cm): 0
- Dug into ground (Y/N): Yes
- Fence material (plastic, metal, concrete, etc.): Metal
- Complemented by electric fence (Y/N): No

INFORMATION ON THE AREA WHERE THE MEASURES WERE IMPLEMENTED

**Landscape type / land use:** Mixed forest-farmland (mosaic)

**Typical topographical character:** Flat land

**Are the following natural/artificial elements used as part of the barrier system:** Highway(s)

SOCIAL EFFECTS AND IMPLICATIONS

**Please list the key stakeholders involved in the decision to implement the stated method(s):** Highway owners/managers

**Please list the stakeholders who were negatively affected by the implementation:** No. The fence was provided with gates to allow passage.

**What was the response of the general public:** Neutral

**Was there any opposition to the fence and what motivated it:** No opposition

**What was the reaction of affected groups:** No opposition/negative reaction, full support

**What social and/or political tensions did the methods of control cause among different stakeholders:** Nobody

RESPONSES OF TARGET SPECIES

**Did the method implemented affect the population abundance/density of the target species:** No

**Did the method implemented affect the spatial behaviour of the target species:** Yes

**If yes, please describe how animals reacted:** The fence prevented the passage of ASF for a certain amount of time.

**Did you measure changes in animal movement (e.g., with telemetry, GPS, etc.):** No

**What other scientifically confirmed effects were there on wild boar?** Population separation

**What other registered effects were there on target species other than wild boar?** N/A, no other species

EFFECTIVENESS

**On a scale of 1-5, please assess the general effectiveness of the implemented method in relation to its primary aim:**

- ASF control: 3 - reasonably effective
- Crop protection: not relevant
- Forest protection: not relevant
- Reducing wildlife-livestock interactions: not relevant
- Road/railway safety: not relevant
- National border security: not relevant

**Did the implemented method prevent the target species from crossing:** Fully, no crossing was registered

**If the method was aimed at limiting ASF spread, did the disease spread beyond the fenced area:** Yes - moderate delay

**In the case of crop protection, did the method have any effect on damage?** N/A

**In the case of road fencing, did the method have any effect on roadkill?** N/A

**In the case of hunting enclosures or wildlife parks, did the target species escape beyond the fenced area?** N/A

**Where methods are/were understood to be ineffective, what is/was the main reason for this?** Poor design

**What would make the method more effective in your opinion:** Prompt implementation

**Whose responsibility is/was it to fund/install/check/maintain the methods of control:** Ministry of Health

**Did you use any method for estimating the effectiveness of separation measures for wild boar:** Yes

**If yes, please briefly describe the parameters used:** Camera trap

**If yes, please briefly present the results (quantitative data or qualitative remarks):** No movements of wild boar over the barrier were registered

**In your opinion, what makes an effective/ineffective method of control:** Implementation timeframe, appropriate initial project, political support

ADDITIONAL NOTES

**Would you be interested in a follow up conversation about this topic:** Yes

**Would you like to be informed about the results:** Yes

**If yes for either of the questions above, please leave your contact details below:** mario_chiari@regione.lombardia.it

# Appendix C.4 – Response 31_13_IT

GENERAL / BACKGROUND INFORMATION

**Responsible authority/end-user:** Other (specify): Confagricoltura member

**Country:** Italy

**Locality (name):** Alessandria

**Locality:** 44.907272, 8.611680 (Alessandria AL, Italia)

**Is the area where the measure was implemented a NATURA 2000 site, or have another form of protection?** No

**When did the implementation of method for control start:** 1 Jun 2022

**When did the barrier implementation of method for control end?** 22 Jun 2023

**Is ASF currently present in the area:** Yes – wild boar

**Was ASF present when the method of control was implemented:** Yes – wild boar

**Was ASF the driver behind the method of control:** Yes

**If ASF is present, please specify the zone type at the time of implementation (according to the EU zoning policy):** Infected zone

**Are domestic pigs present within area:** Outdoor and indoor

**If outdoor pigs are present, what is the kind of breeding system:** Back-yard

**If known, what are the implementation costs of the method of control (in EUR)?** 20,000,000 EUR

INFORMATION ON SEPARATION METHOD

**What is the aim of the method of control:** ASF control

**Was wild boar the target species:** Yes

**What type(s) of method are/were implemented:** Solid (mesh) fence

**Solid (mesh) fence:**

**Linear barrier or enclosure:** Linear barrier

- Size of area enclosed (km²): /
- Length (km): 150
- Height (m): /
- Size of mesh openings (cm): /
- Distance from bottom of fence to ground (cm): 0
- Dug into ground (Y/N): No
- Fence material (plastic, metal, concrete, etc.): Metal
- Complemented by electric fence (Y/N): No

**In cases of enclosure, is the culling of a target species practiced on either side of the barrier?**

- Within the enclosed area: Yes – hunting at normal intensity
- Outside the enclosed area: Yes – hunting at normal intensity

INFORMATION ON THE AREA WHERE THE MEASURES WERE IMPLEMENTED

**Landscape type / land use:** Mixed forest-farmland (mosaic)

**Typical topographical character:** Dynamic, variable topography

**Are the following natural/artificial elements used as part of the barrier system?** Highway(s), Main roads

SOCIAL EFFECTS AND IMPLICATIONS

**Please list the key stakeholders involved in the decision to implement the stated method(s):** Ministry of health, liguria and piedmont regions

**Please list the stakeholders who were negatively affected by the implementation:** Hunters, residents, tourists

**Was there any opposition to the fence and what motivated it:** Opposition over negative ecological impacts, opposition over economic concerns, opposition over negative impacts on hunting/game management

**What was the reaction of affected groups:** Moderate opposition - ignored requests/instructions, Moderate opposition - media criticism / publicly voiced criticism

RESPONSES OF TARGET SPECIES

**Did the method implemented affect the population abundance/density of the target species:** No

**Did the method implemented affect the spatial behaviour of the target species:** No

**Did you measure changes in animal movement (e.g., with telemetry, GPS, etc.):** No

EFFECTIVENESS

**On a scale of 1-5, please assess the general effectiveness of the implemented method in relation to its primary aim:**

- ASF control: 1 - completely ineffective

**Did the implemented method prevent the target species from crossing:** No changes were registered

**If the method was aimed at limiting ASF spread, did the disease spread beyond the fenced area:** Yes - very fast, without any expected delay

**In the case of crop protection, did the method have any effect on damage?** N/A

**In the case of road fencing, did the method have any effect on roadkill?** N/A

**In the case of hunting enclosures or wildlife parks, did the target species escape beyond the fenced area?** N/A

**Where methods are/were understood to be ineffective, what is/was the main reason for this?** Badly constructed

**What would make the method more effective in your opinion?** Other (specify): should have been put in earlier and also a different type of fence

**Whose responsibility is/was it to fund/install/check/maintain the methods of control:** Ministry of Health, Liguria and Piedmont regions

**Did you use any method for estimating the effectiveness of separation measures for wild boar:** No

ADDITIONAL NOTES

**Any other comments/suggestions/criticism?** The fences used were not effective in containing the ASF virus because of the mountainous terrain, the presence of highways and roads (at the level of which the fences were left open). In addition, they were very low-strength metal fences and not in-ground in the soil, which allowed very rapid passage of wild boars from one side to the other. Based on these aspects and considering the size of the outbreak already considerable in early 2022, alternative methods of African Swine Fever management should have been considered.

**Would you be interested in a follow up conversation about this topic:** No

**Would you like to be informed about the results:** No

## Appendix C.5 – Response 40_NA_IT

**GENERAL / BACKGROUND INFORMATION**

**Country:** Italy

**Locality?** 41.981704, 12.459534

**Is the area where the measure was implemented a NATURA 2000 site, or have another form of protection?** Yes

**When did the implementation of method for control start?** 5 May 2022

**When did the barrier implementation of method for control end?** 6 Mar 2025

**Is ASF currently present in the area:** Yes – wild boar

**Was ASF present when the method of control was implemented:** Yes – wild boar

**Was ASF the driver behind the method of control:** Yes

**If ASF is present, please specify the zone type at the time of implementation (according to the EU zoning policy):** Infected zone

**Are domestic pigs present within area:** Outdoor and indoor

**If outdoor pigs are present, what is the kind of breeding system?** Free-ranging

**If known, what are the implementation costs of the method of control (in EUR)?** 50,000 EUR

**If known, what are the annual maintenance costs (in EUR)?** 2,000 EUR

**INFORMATION ON SEPARATION METHOD**

**What is the aim of the method of control:** ASF control

**Was wild boar the target species:** Yes

**What type(s) of method are/were implemented:** Solid (mesh) fence, Electric fence

**Solid (mesh) fence:**

**Linear barrier or enclosure:** Linear barrier

- Size of area enclosed (km²): /
- Length (km): 10
- Height (m): 1.5-2
- Size of mesh openings (cm): /
- Distance from bottom of fence to ground (cm): /
- Dug into ground (Y/N): Yes
- Fence material (plastic, metal, concrete, etc.): /
- Complemented by electric fence (Y/N): Yes

**Electric fence:**

**Linear barrier or enclosure:** Linear barrier

- Size of area enclosed (km²): /
- Length (km): 200
- Total height (cm): 120
- Number of electric wires (one/two/three/more): 3
- Height of the lowest wire (cm): / 20
- Distance between wires (cm): / 50
- Voltage (V): / 230
- Frequency of vegetation clearance along fence (weekly, monthly, never): Monthly
- Type of vegetation cleaning (mechanical, chemical, combination, other): / Mechanical

**In cases of enclosure, is the culling of a target species practiced on either side of the barrier?**

- Within the enclosed area: Yes – intensive cull

**INFORMATION ON THE AREA WHERE THE MEASURES WERE IMPLEMENTED**

**Landscape type / land use:** Residential (suburban)

**Typical topographical character:** Dynamic, variable topography

**Are the following natural/artificial elements used as part of the barrier system?** River(s), Highway(s), Main roads, Villages/urban areas

SOCIAL EFFECTS AND IMPLICATIONS

**Please list the key stakeholders involved in the decision to implement the stated method(s):** Hunters, farmers, people involved in road maintainance, veterinaries, regional authorities, city managers

**Please list the stakeholders who were negatively affected by the implementation:** Farmers

**What was the response of the general public?** Favourable, no problem reported

**Was there any opposition to the fence and what motivated it:** Opposition over access restrictions

**What was the reaction of affected groups:** Moderate opposition - ignored requests/instructions, Severe opposition - destruction of fence/sabotage

**What social and/or political tensions did the methods of control cause among different stakeholders?** There have been cases of damage to fences by farmers who could not pass with their livestock; they have torn down the fences or left the gates open.

RESPONSES OF TARGET SPECIES

**Did the method implemented affect the population abundance/density of the target species:** No

**Did the method implemented affect the spatial behaviour of the target species:** Yes

**If yes, please describe how animals reacted:** They tried to overcome barriers, in some cases succeeding in doing so.

**Did you measure changes in animal movement (e.g., with telemetry, GPS, etc.):** No

**What other registered effects were there on target species other than wild boar?** N/A, no other species

EFFECTIVENESS

**On a scale of 1-5, please assess the general effectiveness of the implemented method in relation to its primary aim:**

- ASF control: 3 – reasonably effective
- Crop protection: 2 – somewhat effective
- Road/railway safety: 3 – reasonably effective

**Did the implemented method prevent the target species from crossing:** Partially, the number of dispersing/migrating individuals was lower than before.

**If the method was aimed at limiting ASF spread, did the disease spread beyond the fenced area?** Yes - important delay (>3 months after implementation)

**In the case of crop protection, did the method have any effect on damage?** N/A

**In the case of road fencing, did the method have any effect on roadkill?** N/A

**In the case of hunting enclosures or wildlife parks, did the target species escape beyond the fenced area?** N/A

**Where methods are/were understood to be ineffective, what is/was the main reason for this?** Other (specify):

**What would make the method more effective in your opinion?** Increased monitoring of impacts and prompt adequate reaction

**Whose responsibility is/was it to fund/install/check/maintain the methods of control?** Motorway management company

**Did you use any method for estimating the effectiveness of separation measures for wild boar:** Yes

**If yes, please briefly describe the parameters used:** A good indicator is the spread of the infection outside the fenced area

**If yes, please briefly present the results (quantitative data or qualitative remarks):** the infected animals were immediately close, inside the fence, the first year the infection did not spread outside the fence, the second year it spread to areas outside the fence.

**In your opinion, what makes an effective/ineffective method of control?** Impossible to seal all openings, in the study area there are roads, rivers, railways crossing the barriers.

ADDITIONAL NOTES

**Would you be interested in a follow up conversation about this topic:** Yes

**Would you like to be informed about the results:** Yes

**If yes for either of the questions above, please leave your contact details below:** dcapizzi@regione.lazio.it

## Appendix C.6 – Response 4_6_HR

GENERAL / BACKGROUND INFORMATION

**Responsible authority/end-user:** Landowner - forestry

**Country:** Croatia

**Is the area where the measure was implemented a NATURA 2000 site, or have another form of protection?** Yes

**Is ASF currently present in the area:** Yes – wild boar

**Was ASF present when the method of control was implemented:** Yes – wild boar

**Was ASF the driver behind the method of control:** Yes

**If ASF is present, please specify the zone type at the time of implementation (according to the EU zoning policy):** Restricted zone III

**Are domestic pigs present within area:** Outdoor and indoor

**If outdoor pigs are present, what is the kind of breeding system:** Back-yard

INFORMATION ON SEPARATION METHOD

**What is the aim of the method of control:** ASF control

**Was wild boar the target species:** Yes

**What type(s) of method are/were implemented:** Combination of methods

INFORMATION ON THE AREA WHERE THE MEASURES WERE IMPLEMENTED

**Landscape type / land use:** Mixed forest-farmland (mosaic)

**Typical topographical character:** Dynamic, variable topography

**Are the following natural/artificial elements used as part of the barrier system:** Other (specify)

SOCIAL EFFECTS AND IMPLICATIONS

**Was there any opposition to the fence and what motivated it:** Opposition over access restrictions

**What was the reaction of affected groups:** Severe opposition - public events organised against the method (e.g., demonstrations)

RESPONSES OF TARGET SPECIES

**Did the method implemented affect the population abundance/density of the target species:** No

**Did the method implemented affect the spatial behaviour of the target species:** No

**Did you measure changes in animal movement (e.g., with telemetry, GPS, etc.):** No

**What other registered effects were there on target species other than wild boar?** N/A, no other species

EFFECTIVENESS

**Did the implemented method prevent the target species from crossing:** Partially, the number of dispersing/migrating individuals was lower than before

**If the method was aimed at limiting ASF spread, did the disease spread beyond the fenced area:** N/A

**In the case of crop protection, did the method have any effect on damage?** N/A

**In the case of road fencing, did the method have any effect on roadkill?** N/A

**In the case of hunting enclosures or wildlife parks, did the target species escape beyond the fenced area?** N/A

**Where methods are/were understood to be ineffective, what is/was the main reason for this?** Badly constructed

**What would make the method more effective in your opinion:** Better state/regional resources

**Did you use any method for estimating the effectiveness of separation measures for wild boar:** No

ADDITIONAL NOTES

**Would you be interested in a follow up conversation about this topic:** No

**Would you like to be informed about the results:** No

## Appendix C.7 – Response 38_1_BA

**GENERAL / BACKGROUND INFORMATION**

**Responsible authority/end-user:** Veterinary authority/veterinarian - state agency

**Country: Bosnia and Herzegovina**

**Locality (name):** Sarajevo

**Locality?** 43.855045, 18.406518

**Locality (coordinates, WGS 84)?** 43.5337 18.2258

**Is the area where the measure was implemented a NATURA 2000 site, or have another form of protection?** No

**When did the implementation of method for control start?** 1 Jan 2023

**If applicable, what time gaps were there in barrier implementation:** Everything is done spontaneously, only the findings are reported after the veterinary analysis.

**Is ASF currently present in the area:** Yes – in both

**Was ASF present when the method of control was implemented:** Yes – in both

**Was ASF the driver behind the method of control:** Yes

**If ASF is present, please specify the zone type at the time of implementation (according to the EU zoning policy):** Other (specify): Zones were not divided, only the places of occurrence of the disease were registered.

**Are domestic pigs present within area:** Outdoor and indoor

**If outdoor pigs are present, what is the kind of breeding system?** Back-yard

**If known, what are the implementation costs of the method of control (in EUR)?** No, a certain sum, approximating the market value, was paid only for the euthanized pigs

**INFORMATION ON SEPARATION METHOD**

**What is the aim of the method of control:** ASF control, Reduced interaction between wildlife and livestock

**Was wild boar the target species:** No

**If not, which species was the primary target:** Domestic pig

**What type(s) of method are/were implemented:** Other: Unfortunately, when it comes to the movement of wild boars, no barriers have been made for their movement.

**In cases of enclosure, is the culling of a target species practiced on either side of the barrier?**

- Within the enclosed area: Yes – hunting at normal intensity
- Outside the enclosed area: Yes - hunting at normal intensity

**INFORMATION ON THE AREA WHERE THE MEASURES WERE IMPLEMENTED**

**Landscape type / land use:** Mixed forest-farmland (mosaic)

**Typical topographical character:** Flat land

**Are the following natural/artificial elements used as part of the barrier system?** Other (specify) We did not use any natural barriers, and there was an opportunity to stop the disease on the Drina River.

**SOCIAL EFFECTS AND IMPLICATIONS**

**Please list the key stakeholders involved in the decision to implement the stated method(s):** The ministries did not undertake any activities, and when the disease appeared, everything was left to the hunters to find the dead animals, report them and analyse the samples, and bury the corpses.

**Please list the stakeholders who were negatively affected by the implementation:** The biggest losers are the users of the hunting grounds who pay the concession, and due to less shooting, they will have a smaller inflow of funds, considering the importance of wild boar hunting.

**What was the response of the general public?** The general public was uninterested except for the farmers who lost their domestic pigs.

**Was there any opposition to the fence and what motivated it:** Other (please list): No fences were raised so there was no opposition. If it had gone in that direction, there would certainly have been protests from NGOs dealing with ecology.

**What was the reaction of affected groups:** Moderate opposition - ignored requests/instructions.

**What social and/or political tensions did the methods of control cause among different stakeholders?** There were no tensions, because the euthanized domestic pigs were paid, and nothing was paid for the wild ones, because they are the concern of hunting associations and state hunting.

RESPONSES OF TARGET SPECIES

**Did the method implemented affect the population abundance/density of the target species:** No

**Did the method implemented affect the spatial behaviour of the target species:** No

**Did you measure changes in animal movement (e.g., with telemetry, GPS, etc.):** No

**What other scientifically confirmed effects were there on wild boar?** Genetic differentiation of population, Hindered migration/dispersion, Other (specify): This answer is not based on the experience of other countries, it was not investigated in our country.

**What other registered effects were there on target species other than wild boar?** N/A, no other species

EFFECTIVENESS

**On a scale of 1-5, please assess the general effectiveness of the implemented method in relation to its primary aim:**

- ASF control: /
- Crop protection: /
- Forest protection: /
- Reducing wildlife-livestock interactions: /
- Road/railway safety: /
- National border security: /

**Did the implemented method prevent the target species from crossing:** No changes were registered

**If the method was aimed at limiting ASF spread, did the disease spread beyond the fenced area?** Yes – very fast, without any expected delay

**In the case of crop protection, did the method have any effect on damage?** No effect

**In the case of road fencing, did the method have any effect on roadkill?** No effect

**In the case of hunting enclosures or wildlife parks, did the target species escape beyond the fenced area?** No, never

**Where methods are/were understood to be ineffective, what is/was the main reason for this?** Inappropriate type of method for the objective

**What would make the method more effective in your opinion?** Increased monitoring of impacts and prompt adequate reaction

**Whose responsibility is/was it to fund/install/check/maintain the methods of control?** Entity ministries, cantonal ministries and municipalities should have created a crisis management plan, but they did not take any action in time.

**Did you use any method for estimating the effectiveness of separation measures for wild boar:** No

**In your opinion, what makes an effective/ineffective method of control?** Everything came down to monitoring, unfortunately nothing was done when it comes to wild pigs. In the case of domestic pigs, the ministries of agriculture reacted quickly.

ADDITIONAL NOTES

**Any other comments/suggestions/criticism?** Although there was a warning 2 years before the appearance of APC, nothing was done, and when they appeared, the reactions were lukewarm, and the hunters also showed disinterest.

**Can you provide us link to any published source/study on the topic from your country?** Only for wild boars there appeared a couple of articles and some information that the disease was registered in individuals shot in wild boar hunting. I can make pictures of those texts if needed.

**Would you be interested in a follow up conversation about this topic:** Yes

**Would you like to be informed about the results:** Yes

**If yes for either of the questions above, please leave your contact details below:** Dalibor Ballian, University of Sarajevo, Faulty of Forestry, Zagrebačka 20, 71000 Sarajevo, Bosnia and Herzegovina

# Appendix C.8 – Response 36_1_RO

GENERAL / BACKGROUND INFORMATION

**Responsible authority/end-user:** Veterinary authority/veterinarian - state agency

**Country:** Romania

**Locality (name):** Brasov

**Locality?** 45.639911, 25.585718

**Is the area where the measure was implemented a NATURA 2000 site, or have another form of protection?** Yes

**When did the implementation of method for control start?** 1 Jun 2018

**When did the barrier implementation of method for control end?** 31 Mar 2024

**Is ASF currently present in the area:** Yes – wild boar

**Was ASF present when the method of control was implemented:** Yes – wild boar

**Was ASF the driver behind the method of control:** Yes

**If ASF is present, please specify the zone type at the time of implementation (according to the EU zoning policy):** Infected zone

**Are domestic pigs present within area:** Outdoor and indoor

**If outdoor pigs are present, what is the kind of breeding system?** Back-yard

INFORMATION ON SEPARATION METHOD

**What is the aim of the method of control:** ASF control, Reduced interaction between wildlife and livestock

**Was wild boar the target species:** Yes

**What type(s) of method are/were implemented:** Solid (mesh) fence, Electric fence

**Solid (mesh) fence:**

**Linear barrier or enclosure:** Enclosure

- Size of area enclosed (km²): 12
- Length (km): /
- Height (m): 2.20
- Size of mesh openings (cm): 5 cm to 15 cm
- Distance from bottom of fence to ground (cm): 0
- Dug into ground (Y/N): Yes
- Fence material (plastic, metal, concrete, etc.): metal
- Complemented by electric fence (Y/N): Yes

**Electric fence:**

**Linear barrier or enclosure:** Linear barrier

- Size of area enclosed (km²): /
- Length (km): 16
- Total height (cm): /
- Number of electric wires (one/two/three/more): 3+1
- Height of the lowest wire (cm): / 30 cm
- Distance between wires (cm): / 30 cm
- Voltage (V): / /
- Frequency of vegetation clearance along fence (weekly, monthly, never): Weekly
- Type of vegetation cleaning (mechanical, chemical, combination, other): / Mechanical, chemical, combination

**In cases of enclosure, is the culling of a target species practiced on either side of the barrier?**

- Within the enclosed area: Yes - intensive cull
- Outside the enclosed area: Yes - intensive cull

INFORMATION ON THE AREA WHERE THE MEASURES WERE IMPLEMENTED

**Landscape type / land use:** Forest

**Typical topographical character:** Dynamic, variable topography

SOCIAL EFFECTS AND IMPLICATIONS

**Please list the key stakeholders involved in the decision to implement the stated method(s):** Encloser owners

**Was there any opposition to the fence and what motivated it:** Opposition over negative ecological impacts

**What was the reaction of affected groups:** Moderate opposition - ignored requests/instructions

**What social and/or political tensions did the methods of control cause among different stakeholders?** Generally was supported

RESPONSES OF TARGET SPECIES

**Did the method implemented affect the population abundance/density of the target species:** No

**Did the method implemented affect the spatial behaviour of the target species:** Yes

**Did you measure changes in animal movement (e.g., with telemetry, GPS, etc.):** No

**What other scientifically confirmed effects were there on wild boar?** Population separation, Genetic differentiation of population, Hindered migration/dispersion

**What other registered effects were there on target species other than wild boar?** Population separation, Genetic differentiation of population, Hindered migration/dispersion

EFFECTIVENESS

**On a scale of 1-5, please assess the general effectiveness of the implemented method in relation to its primary aim:**

- ASF control: 2 – somewhat effective
- Crop protection: 3 – reasonably effective
- Forest protection: 3 – reasonably effective
- Reducing wildlife-livestock interactions: 4 – very effective
- Road/railway safety: 3 – reasonably effective
- National border security: not relevant

**Did the implemented method prevent the target species from crossing:** Partially, the number of dispersing/migrating individuals was lower than before

**If the method was aimed at limiting ASF spread, did the disease spread beyond the fenced area?** Yes – moderate delay

**In the case of crop protection, did the method have any effect on damage?** Yes, damage was importantly reduced (25–75%)

**In the case of road fencing, did the method have any effect on roadkill?** Yes, roadkill was importantly reduced (25–75%)

**In the case of hunting enclosures or wildlife parks, did the target species escape beyond the fenced area?** Yes, but only sporadically

**Where methods are/were understood to be ineffective, what is/was the main reason for this?** Inappropriate type of method for the objective

**What would make the method more effective in your opinion?** Better state/regional resources

**Whose responsibility is/was it to fund/install/check/maintain the methods of control?** Land owners with the help of the state (Ministry of Environment)

**Did you use any method for estimating the effectiveness of separation measures for wild boar:** Yes

**If yes, please briefly describe the parameters used:** Spreading of disease

**If yes, please briefly present the results (quantitative data or qualitative remarks):** ASF was present in the encloser

**In your opinion, what makes an effective/ineffective method of control?** Distribution and dynamic of ASF in the territory

ADDITIONAL NOTES

**Any other comments/suggestions/criticism?** All wild boar enclosed with metallic fence and electric wire end up with ASF or were oblige to kill all the animals.

**Can you provide us link to any published source/study on the topic from your country?** There are no published study.

**Would you be interested in a follow up conversation about this topic:** Yes

**Would you like to be informed about the results:** Yes

**If yes for either of the questions above, please leave your contact details below:** Ovidiu Ionescu

## Appendix C.9 – Response 9_1_CZ

GENERAL / BACKGROUND INFORMATION

**Responsible authority/end-user:** Veterinary authority/veterinarian - state agency

**Country:** Czech Republic

**Locality (name):** Whole country

**Locality:** 49.849185, 14.958528

**When did the implementation of method for control start:** 16 Aug 2017

**When did the barrier implementation of method for control end:** 22 Apr 2019

**If applicable, what time gaps were there in barrier implementation:** Approx. 2 months

**Is ASF currently present in the area:** Yes – wild boar

**Was ASF present when the method of control was implemented:** Yes – wild boar

**Was ASF the driver behind the method of control:** Yes

**If ASF is present, please specify the zone type at the time of implementation (according to the EU zoning policy):** Other (specify): first infected zone and during the implementation became zone II

**Are domestic pigs present within area:** Outdoor and indoor

**If outdoor pigs are present, what is the kind of breeding system:** Back-yard

**If known, what are the implementation costs (in EUR):** /

**If known, what are the annual maintenance costs (in EUR):** 10,000 EUR

INFORMATION ON SEPARATION METHOD

**What is the aim of the method of control:** ASF control

**Was wild boar the target species:** Yes

**What type(s) of method are/were implemented:** Electric fence, Chemical/odour repellents, Gustatory/food method

**Electric fence:**

**Linear barrier or enclosure:** Enclosure

- Size of area enclosed (km²): 58
- Length (km): /
- Total height (cm): 100
- Number of electric wires (one/two/three/more): Net
- Height of the lowest wire (cm): /
- Distance between wires (cm): /
- Voltage (V): /
- Frequency of vegetation clearance along fence (weekly, monthly, never): /
- Type of vegetation cleaning (mechanical, chemical, combination, other): /

**Chemical repellents:**

**Linear barrier or enclosure:** Point source

- Size of area enclosed (km²): 58
- Length (km): /
- Height of the position of repellents (m): 0 cm (summer) / 100 cm (winter)
- Distance between poles (m): 5 m
- Active substance used (if known): Produced by company Pacholek
- Frequency of maintenance (days between maintaining episodes): Once every two months

**In cases of enclosure, is the culling of a target species practiced on either side of the barrier?**

- Within the enclosed area: Yes – intensive cull
- Outside the enclosed area: Yes – intensive cull

INFORMATION ON THE AREA WHERE THE MEASURES WERE IMPLEMENTED

**Landscape type / land use:** Other (specify): mixed and suburban

**Typical topographical character:** Dynamic, variable topography

**Are the following natural/artificial elements used as part of the barrier system:** Main roads, Villages/urban areas

SOCIAL EFFECTS AND IMPLICATIONS

**Please list the key stakeholders involved in the decision to implement the stated method(s):** State veterinary administration, county representatives

**Please list the stakeholders who were negatively affected by the implementation:** Farmers (access to land, ban on harvest), hunters (maintenance, limitations of hunting rights), general public (access), county administration (responsibility of maintenance etc.)

**What was the response of the general public:** Disliked the limited access

**Was there any opposition to the fence and what motivated it:** Opposition over access restrictions, Opposition over economic concerns, Opposition over negative impacts on hunting/game management

**What was the reaction of affected groups:** Moderate opposition - ignored requests/instructions

**What social and/or political tensions did the methods of control cause among different stakeholders:** Hunters opposed ban on hunting in the infected zone and then the incentive to cull all wild boar including saws. Uncertain competences rather than tensions per se

RESPONSES OF TARGET SPECIES

**Did the method implemented affect the population abundance/density of the target species:** Yes

**If yes, please provide concrete data and its source, and/or briefly describe the change:** From original density (approx. 10 per $km^2$) to zero density due to AFS, culling and indeed fencing. Thermovision monitoring from drones, plus photo traps

**Did the method implemented affect the spatial behaviour of the target species:** Yes

**If yes, please describe how animals reacted:** Wild boar looked for ways of avoiding the fence, entering suburban area. Other effects were in synergy with other measures, e.g. no harvest of crops...

**Did you measure changes in animal movement (e.g., with telemetry, GPS, etc.):** No

EFFECTIVENESS

**On a scale of 1-5, please assess the general effectiveness of the implemented method in relation to its primary aim:**

- ASF control: 4 – very effective
- Crop protection: not relevant
- Forest protection: not relevant
- Reducing wildlife-livestock interactions: not relevant
- Road/railway safety: not relevant
- National border security: not relevant

**Did the implemented method prevent the target species from crossing:** Partially, the number of dispersing/migrating individuals was lower than before

**If the method was aimed at limiting ASF spread, did the disease spread beyond the fenced area:** Yes - important delay (>3 months after implementation)

**What would make the method more effective in your opinion:** Increased monitoring of impacts and prompt adequate reaction

**Whose responsibility is/was it to fund/install/check/maintain the methods of control:** Hunters (users of hunting ground) and county administration

**Did you use any method for estimating the effectiveness of separation measures for wild boar:** Yes

**If yes, please briefly describe the parameters used:** Ongoing monitoring with thermovision on drones and helicopters

**If yes, please briefly present the results (quantitative data or qualitative remarks):** Population density from 10 per $km^2$ to virtually zero

**In your opinion, what makes an effective/ineffective method of control:** Visual and mechanical effect plus possibly the electrical shock; good timing; maintenance.

ADDITIONAL NOTES

**Any other comments/suggestions/criticism:** Some questions are not completely clear: for example, this one – is it criticism of the questionnaire or the measure?

**Can you provide us link to any published source/study on the topic from your country:** Havranek et al., Jezek et al., Cukor are the authors of several studies available in English and some in Czech (e.g. ASF measures report)

**Would you be interested in a follow up conversation about this topic:** Yes

**Would you like to be informed about the results:** Yes

**If yes for either of the questions above, please leave your contact details below:** t.jarosil@svscr.cz

# Appendix C.10 – Response 45_2_CZ

GENERAL / BACKGROUND INFORMATION

**Responsible authority/end-user:** Veterinary authority/veterinarian - regional authority

**Country:** **Czech Republic**

**Locality (name):** Zlín

**Locality:** 62F2682M+F2

**Locality (coordinates, WGS 84)?** 49°13'9.918" N, 17°40'48.959" E

**When did the implementation of method for control start?** 21 Jul 2017

**When did the barrier implementation of method for control end?** 22 Feb 2019

**Is ASF currently present in the area:** No

**Was ASF present when the method of control was implemented:** Yes – wild boar

**Was ASF the driver behind the method of control:** Yes

**If ASF is present, please specify the zone type at the time of implementation (according to the EU zoning policy):** Restricted zone II

**Are domestic pigs present within area:** Indoor

INFORMATION ON SEPARATION METHOD

**What is the aim of the method of control:** ASF control

**Was wild boar the target species:** Yes

**What type(s) of method are/were implemented:** Electric fence, Chemical/odour repellents

**Electric fence:**

**Linear barrier or enclosure:** Enclosure

**Chemical repellents:**

**Linear barrier or enclosure:** Point source

**In cases of enclosure, is the culling of a target species practiced on either side of the barrier?**

- Within the enclosed area: Yes – intensive cull
- Outside the enclosed area: Yes – hunting at normal intensity

INFORMATION ON THE AREA WHERE THE MEASURES WERE IMPLEMENTED

**Landscape type / land use:** Mixed forest-farmland (mosaic)

**Typical topographical character:** Dynamic, variable topography

**Are the following natural/artificial elements used as part of the barrier system?** Main roads

SOCIAL EFFECTS AND IMPLICATIONS

**Was there any opposition to the fence and what motivated it:** Opposition over access restrictions, Opposition over economic concerns, Opposition over negative impacts on hunting/game management

**What was the reaction of affected groups:** We did not pay attention to public responses.

EFFECTIVENESS

**On a scale of 1-5, please assess the general effectiveness of the implemented method in relation to its primary aim:**

- ASF control: 5 – completely effective
- Reducing wildlife-livestock interactions: 5 – completely effective

**If the method was aimed at limiting ASF spread, did the disease spread beyond the fenced area?** Yes - important delay (>3 months after implementation)

**In the case of hunting enclosures or wildlife parks, did the target species escape beyond the fenced area?** Yes, with moderate frequency

**What would make the method more effective in your opinion?** Prompt implementation

**Did you use any method for estimating the effectiveness of separation measures for wild boar:** No

ADDITIONAL NOTES

**Would you be interested in a follow up conversation about this topic:** No

**Would you like to be informed about the results:** No

# Appendix C.11 – Response 41_9_LT

GENERAL / BACKGROUND INFORMATION

**Responsible authority/end-user:** Wildlife scientist - ecologist

**Country:** Lithuania

**Locality (name):** Plateliai

**Locality?** 56.033691, 21.851806

**Locality (coordinates, WGS 84)?** 56.02331, 21.91205

**Is the area where the measure was implemented a NATURA 2000 site, or have another form of protection?** Yes

**When did the implementation of method for control start?** 30 Mar 2015

**When did the barrier implementation of method for control end?** 8 Sep 2021

**If applicable, what time gaps were there in barrier implementation?** Continued depending on the changeable frequency of outbreaks and in corresponded zoning (most territory of Lithuania attributed to the restricted zone II)

**Is ASF currently present in the area:** Yes – wild boar

**Was ASF present when the method of control was implemented:** Yes – wild boar

**Was ASF the driver behind the method of control:** Yes

**If ASF is present, please specify the zone type at the time of implementation (according to the EU zoning policy):** Other (specify): All territory of country is attributed to the zone II

**Are domestic pigs present within area:** Indoor

INFORMATION ON SEPARATION METHOD

**What is the aim of the method of control:** ASF control

**Was wild boar the target species:** Yes

**What type(s) of method are/were implemented:** Combination of methods (specify): Sampling of wild boar (obligated); voluntary survey of the territory (carcasses); individual control measures (hunters, farmers, other visitors) and increased biosecurity measures (incl. disinfection measures, processing and ban to use production until response from Laboratory of the National Food and Veterinary Risk Assessment Institute, etc. considering EC C/2024/1758

INFORMATION ON THE AREA WHERE THE MEASURES WERE IMPLEMENTED

**Landscape type / land use:** Forest

**Typical topographical character:** Dynamic, variable topography

**Are the following natural/artificial elements used as part of the barrier system?** Other (specify): No any artificial barriers

SOCIAL EFFECTS AND IMPLICATIONS

**Please list the key stakeholders involved in the decision to implement the stated method(s):** Foresters, administration of national park, territorial branch of the regional department of the State Food and Veterinary service; local municipality; local Society of Hunters (NGO), hunter clubs/groups

**Please list the stakeholders who were negatively affected by the implementation:** Farmers (partly) due to restrictions and bans on domestic pig farms

**What was the response of the general public?** Positive

**Was there any opposition to the fence and what motivated it:** Other (please list): Territory was not fenced

**What was the reaction of affected groups:** No opposition/negative reaction, full support

**What social and/or political tensions did the methods of control cause among different stakeholders?** As the restrictions and bans press farmers and intentions to raise pigs, there were some discontent but public understand situation of ASF jeopardy and resign to measures against ASF.

RESPONSES OF TARGET SPECIES

**Did the method implemented affect the population abundance/density of the target species:** Yes

**If yes, please provide concrete data and its source, and/or briefly describe the change:** Thanks to biocontrol and monitoring measures, the local population of wild boar has started recovering. The population density increased from 5.1 / 1 000 ha (in 2020, year of local ASF outbreak) to 11.9/1000 ha (2024).

**Did the method implemented affect the spatial behaviour of the target species:** No

**Did you measure changes in animal movement (e.g., with telemetry, GPS, etc.):** Yes

**If yes, please briefly describe the method used for determining this change:** Camera trapping method was used

**What other scientifically confirmed effects were there on wild boar?** Other (specify): Local herds have recovered themselves after ASF outbreak and non-intensive hunting (excluding drive hunting.

**What other registered effects were there on target species other than wild boar?** Other (specify): Simultaneously, the COVID 19 lockdown and ASF outbreak have multiple effect on wolf population growth as well as roe deer.

EFFECTIVENESS

**On a scale of 1-5, please assess the general effectiveness of the implemented method in relation to its primary aim:**

- ASF control: 5 – completely effective
- Crop protection: 3 – reasonably effective
- Forest protection: 3 – reasonably effective
- Reducing wildlife-livestock interactions: 1 – completely ineffective
- Road/railway safety: 2 – somewhat effective
- National border security: not relevant

**Did the implemented method prevent the target species from crossing:** No changes were registered

**If the method was aimed at limiting ASF spread, did the disease spread beyond the fenced area?** N/A

**In the case of crop protection, did the method have any effect on damage?** N/A

**In the case of road fencing, did the method have any effect on roadkill?** No effect

**In the case of hunting enclosures or wildlife parks, did the target species escape beyond the fenced area?** N/A

**Where methods are/were understood to be ineffective, what is/was the main reason for this?** Other (specify): N/A

**What would make the method more effective in your opinion?** Other (specify): N/A

**Whose responsibility is/was it to fund/install/check/maintain the methods of control?** At the governmental level

**Did you use any method for estimating the effectiveness of separation measures for wild boar:** Yes

**If yes, please briefly describe the parameters used:** Outcomes from camera trapping, FPG

**If yes, please briefly present the results (quantitative data or qualitative remarks):** Assessment of the recovery of the local population (change in the density was already indicated above)

**In your opinion, what makes an effective/ineffective method of control?** Understanding on ASF danger and hunter awareness and wish of recovered and healthy population

ADDITIONAL NOTES

**Any other comments/suggestions/criticism?** The ASF control and management measures on wild boar (and domestic pigs) should be continued considering the risk of repeated outbreaks in the absence of vaccine.

**Can you provide us link to any published source/study on the topic from your country?** Anon. 2024. Order of the Director of the State Food and Veterinary Service of 2024 Feb 9 No. B1-208 on the amendment of the Order of 2016 30 March No. B1-265 "Concerning ASF monitoring and control measures in the wild boar population and pig keeping places". TAR,2024-02-09, No.2467. Gervasi, V.; Masiulis, M.; Bušauskas, P.; Bellini, S.; Guberti, V. Optimizing Vaccination Strategies against African Swine Fever Using Spatial Data from Wild Boars in Lithuania. Viruses 2024, 16, 153. https://doi.org/10.3390/v16010153 Stonciute, E.; Schulz, K.; Malakauskas, A.; Conraths, F.J.; Masiulis, M.; Sauter-Louis, C. What Do Lithuanian Hunters Think of African Swine Fever and Its Control—Perceptions. Animals 2021, 11, 525. https://doi.org/10.3390/ani11020525

**Would you be interested in a follow up conversation about this topic:** Yes

**Would you like to be informed about the results:** Yes

**If yes for either of the questions above, please leave your contact details below:** olgirda.belova@lammc.lt

# Appendix C.12 – Response 26_1_SE

GENERAL / BACKGROUND INFORMATION

**Responsible authority/end-user:** Veterinary authority/veterinarian – state agency

**Country:** **Sweden**

**Locality (name):** Fagersta

**Locality (coordinates, WGS 84)?** 59°59'48.3"N, 15°53'25.3"E

**Is the area where the measure was implemented a NATURA 2000 site, or have another form of protection?** No

**When did the implementation of method for control start:** 1 Oct 2023

**Is ASF currently present in the area:** Yes – wild boar

**Was ASF present when the method of control was implemented:** Yes – wild boar

**Was ASF the driver behind the method of control:** Yes

**If ASF is present, please specify the zone type at the time of implementation (according to the EU zoning policy):** Restricted zone II

**Are domestic pigs present within area:** No

**If outdoor pigs are present, what is the kind of breeding system:** N/A

**If known, what are the implementation costs of the method of control (in EUR)?** 3,260,000 EUR

**If known, what are the annual maintenance costs (in EUR)?** 200,000 EUR

INFORMATION ON SEPARATION METHOD

**What is the aim of the method of control:** ASF control

**Was wild boar the target species:** Yes

**What type(s) of method are/were implemented:** Solid (mesh) fence, Gustatory/food method, Complementary use of natural barriers (specify): lake, Other: restrictions of access on forest or land, other than road for vehicles

**Solid (mesh) fence:**

**Linear barrier or enclosure:** Enclosure

- Size of area enclosed (km²): 100
- Length (km): /
- Height (m): 1.0
- Size of mesh openings (cm): 20
- Distance from bottom of fence to ground (cm): 0
- Dug into ground (Y/N): No
- Fence material (plastic, metal, concrete, etc.): Metal wire, with "skirt" of 6 cm mesh metal wire fence added angling into enclosure, laid on ground, not buried, to avoid WB lifting fence bottom. Poles of wood 2 m high to be able to add electric wire higher up if deep snow cover in winter.
- Complemented by electric fence (Y/N): No

**In cases of enclosure, is the culling of a target species practiced on either side of the barrier?**

- Within the enclosed area: Yes – intensive cull
- Outside the enclosed area: Yes – intensive cull

INFORMATION ON THE AREA WHERE THE MEASURES WERE IMPLEMENTED

**Landscape type / land use:** Forest

**Typical topographical character:** Flat land

SOCIAL EFFECTS AND IMPLICATIONS

**Please list the key stakeholders involved in the decision to implement the stated method(s):** Competent national authorities regarding combatting ASF outbreak: Swedish Board of Agriculture, Swedish Veterinary Agency

**Please list the stakeholders who were negatively affected by the implementation:** Forestry industry, landowners, general public (due to restrictions to access to forest land - normally open access to all land, even private land), hunters, berry picking companies, tourist companies, farmers, sport event associations.

**What was the response of the general public:** A generally good acceptance for the restrictions, and good compliance.

**Was there any opposition to the fence and what motivated it:** Opposition over economic concerns

**What was the reaction of affected groups:** Moderate opposition - media criticism / publicly voiced criticism

**What social and/or political tensions did the methods of control cause among different stakeholders:** No tensions in general, some individual enterprise owner complained publicly.

RESPONSES OF TARGET SPECIES

**Did the method implemented affect the population abundance/density of the target species:** Yes

**If yes, please provide concrete data and its source, and/or briefly describe the change:** See: https://www.sva.se/en/what-we-do/contagion-status/surveillance-of-african-swine-fever-asf/monitoring-of-african-swine-fever-asf/ Fencing and culling eliminated all wild boar within enclosure.

**Did the method implemented affect the spatial behaviour of the target species:** Yes

**If yes, please describe how animals reacted:** Did not pass the fence

**Did you measure changes in animal movement (e.g., with telemetry, GPS, etc.):** Yes

**If yes, please briefly describe the method used for determining this change:** Tracking with game trail cameras and tracking manually when snow cover.

**What other scientifically confirmed effects were there on wild boar?** Hindered migration/dispersion

**What other registered effects were there on target species other than wild boar?** Other (specify): cervids could jump fence, badger and fox could probably dig under at some places.

EFFECTIVENESS

**On a scale of 1-5, please assess the general effectiveness of the implemented method in relation to its primary aim:**

- ASF control: 5 - completely effective
- Crop protection: not relevant
- Forest protection: not relevant
- Reducing wildlife-livestock interactions: not relevant
- Road/railway safety: not relevant
- National border security: not relevant

**Did the implemented method prevent the target species from crossing:** Fully, no crossing was registered

**If the method was aimed at limiting ASF spread, did the disease spread beyond the fenced area:** No

**In the case of crop protection, did the method have any effect on damage?** N/A

**In the case of road fencing, did the method have any effect on roadkill?** N/A

**In the case of hunting enclosures or wildlife parks, did the target species escape beyond the fenced area?** N/A

**Whose responsibility is/was it to fund/install/check/maintain the methods of control:** Contracted staff

**Did you use any method for estimating the effectiveness of separation measures for wild boar:** Yes

**If yes, please briefly describe the parameters used:** Trail cameras, observations at bait stations and feeding sites used to ensure plenty of feed for remaining wild boar.

**If yes, please briefly present the results (quantitative data or qualitative remarks):** No observed break-out through fence, no entrance of WB either. Systematic searches of enclosure and surrounding areas (RZ I): no further corpses found.

**In your opinion, what makes an effective/ineffective method of control:** Minimize disturbance of wild boar (no unleashed dogs, no dog hunting, no public access), and an intact and well maintained fence.

ADDITIONAL NOTES

**Can you provide us link to any published source/study on the topic from your country?** https://www.sva.se/en/what-we-do/contagion-status/surveillance-of-african-swine-fever-asf/monitoring-of-african -swine-fever-asf/

**Would you be interested in a follow up conversation about this topic:** Yes

**Would you like to be informed about the results:** Yes

**If yes for either of the questions above, please leave your contact details below:** erik.agren@sva.se