Mitigating Disease Transmission Risk at the Wildlife–Livestock Interface to Facilitate Safe Trade

World Organisation for Animal Health

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List of abbreviations

AI	Avian Influenza
ASF	African Swine Fever
BSM	Biosecurity Measure(s)
EBP	EuroBird Portal
FAO	Food and Agriculture Organization of the United Nations
FAST	Foot and mouth disease And Similar Transboundary animal diseases
FMD	Foot and mouth disease
FsAP	Farm-specific Action Plan
GIS	Geographic Information System
GLW	Gridded Livestock of the World
GLEAM	Global Livestock Environmental Assessment Model
HACCP	Hazard Analysis and Critical Control Points
ILRI	International Livestock Research Institute
IREC	Institute for Game and Wildlife Research (Instituto de Investigación en Recursos Cinegéticos, Spain)
PCR	Polymerase Chain Reaction
TADs	Transboundary Animal Diseases
UNCITRAL	United Nations Commission on International Trade Law
USDA	United States Department of Agriculture
WLI	Wildlife–Livestock Interface
WOAH	World Organisation for Animal Health

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Summary

The **wildlife–livestock interface (WLI)** is a continuum of direct and indirect contact between free-ranging wildlife and domestic livestock. Such interactions may result in the transmission of pathogens from wildlife to livestock and vice versa. Effective interventions can reduce these interactions and, in turn, lower the risk of disease transmission. These guidelines offer Veterinary Services practical recommendations to design context-appropriate interventions to address risks at the WLI to facilitate safe trade.

The process begins with understanding the target WLI scenario. This involves defining the pathogen of concern and its epidemiology, identifying the farming systems involved, and considering the species and behaviours of both livestock and wildlife, as well as the environmental and human factors.

Understanding and mapping WLIs at large scale and high resolution improves disease risk assessment. Veterinary Services should **(1) identify key risk factors** and **(2) map WLIs and define production systems and species scenarios**.

The next step is to **assess the risks related to the WLI at the local level**, focusing on the relevant epidemiological unit (e.g. herd or farm). Once the key features of the target unit are understood, the checklist provided in these guidelines can be applied to identify potential transmission pathways. The checklist is flexible and can be adapted to different WLI contexts, supporting the development of tailored, on-farm wildlife risk mitigation protocols. The purpose of local risk assessment is to gather information on the epidemiological unit to determine the risks it faces at the WLI. This process consists of four steps: **(1) preparatory office work, (2) producer questionnaire, (3) risk point inspections and (4) recommendations**.

Communication with stakeholders is a critical transversal activity throughout the entire process. Producer participation is encouraged during the characterisation of the WLI and the epidemiological unit, in the development of the Farm-specific Action Plan, and during implementation of mitigation measures. Barriers to successful implementation should be identified, and efforts made to ensure that all stakeholders accept the proposed measures.

Risk mitigation at the WLI involves making changes to farm or herd management, or infrastructure, based on a Farm-specific Action Plan. The aim is to reduce the likelihood of interactions between relevant wildlife and target livestock, thereby preventing the transmission of pathogenic agents. These action plans consider all known and suspected transmission pathways. The guidelines present seven categories of adaptable interventions suitable for multiple diseases and host species: **(1) wildlife management, (2) grazing management, (3) building improvements, (4) water point management, (5) feed storage and deployment, (6) contact with other livestock and (7) waste management**.

Impact assessment involves monitoring and verifying the effectiveness of risk mitigation interventions through follow-up visits, disease data records, non-invasive sampling and surveillance.

WLI management alone cannot eliminate disease in subpopulations or guarantee disease-free status. In some cases, WLI management can support evidence of freedom from disease; however, more often it serves to reduce the risk of infection spillover between wildlife and livestock.

1. Introduction

Transboundary animal diseases (TADs), such as African swine fever (ASF), avian influenza (AI) and foot and mouth disease (FMD) continue to spread worldwide, with serious consequences for animal health, trade and livelihoods. In many countries where these diseases are endemic, infections can pass between wild and domestic animals, sustaining infection transmission cycles that are difficult to control because of the complex factors and risk pathways involved.

For some diseases, the World Organisation for Animal Health (WOAH) has set out standards that allow for recognition of animal health status in defined animal subpopulations (e.g. domestic *versus* wild animals, as in the case of ASF), provided these subpopulations are effectively kept separate. For other diseases, such as AI or classical swine fever, standards require Members not to impose bans on international livestock trade in response to notification of occurrence in wildlife.

To this end, WOAH is committed to providing targeted recommendations to help Members mitigate the risk of disease transmission at the wildlife–livestock interface (WLI). These guidelines offer practical approaches for reducing the risk of disease spillover between wildlife and livestock populations, applicable across a range of farming systems. They present a structured methodology to support Veterinary Services in managing any WLI scenario through customised risk mitigation programmes, with interventions tailored to local conditions.

Throughout the design and implementation of risk mitigation measures, the **'do no harm' principle** should be applied, taking into account potential negative impacts on the environment and biodiversity.

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2. Glossary of key concepts

Biosecurity
Biosecurity refers to a combination of management practices and physical measures aimed at preventing the introduction, establishment and spread of animal diseases, infections or infestations within, into or out of an animal population (WOAH, 2024).

Biosecurity plan
A biosecurity plan is a document that identifies possible pathways for disease introduction and spread within a zone or compartment, and outlines the measures in place or planned to mitigate these risks, in line with the recommendations of WOAH's *Terrestrial Animal Code* (WOAH, 2024).

Bridge host
A vertebrate species that links otherwise separate animal populations and transfers pathogens, either mechanically or as a competent host.

Direct, indirect and vector-mediated transmission
Pathogenic agents shared between wildlife and livestock can be transmitted through several routes, depending on the system. Indirect transmission – via contaminated water, feed or fomites – is the most common route. Vector-borne infections are also readily transmitted at the WLI, with wildlife often playing an important role in vector maintenance. Direct transmission through close contact is less frequent but may be the main route in certain systems.

Epidemiological unit
An epidemiological unit refers to a group of animals with a defined relationship that gives them a similar likelihood of exposure to a pathogen. This may result from sharing the same environment (e.g. animals in a pen) or being managed under the same practices. Typically, it is a herd or flock, but it can also include groups such as animals owned by residents of a village or those using a communal handling facility. The nature of the epidemiological relationship can vary depending on the disease or even the specific strain of the pathogen (WOAH, 2024).

Farm-specific Action Plan (FsAP)
A set of biosecurity measures (BSMs) applied at the level of a single epidemiological unit. Unlike a biosecurity plan, which applies to a population of epidemiological units, a Farm-specific Action Plan addresses local WLI risks specific to the unit. FsAPs are developed using a standardised On-farm Wildlife Risk Mitigation Protocol and are proposed to producers to reduce the risk of wildlife–livestock interactions (Martínez-Guijosa *et al*., 2021) .

Integrated disease control at the wildlife–livestock interface
A control strategy is considered integrated when it begins with WLI assessment and monitoring, and takes into account all available interventions. These may include biosecurity, population control, vector control (for vector-borne diseases), treatment or vaccination, as well as zoning or compartmentalisation.

Maintenance community
Also referred to as a maintenance host complex, this comprises epidemiologically connected populations or environments in which a pathogen can be permanently maintained. Any maintenance community where infection persists indefinitely is considered a reservoir. Maintenance communities may include both wild and domestic host species.

On-farm wildlife risk mitigation protocol
A science-based intervention protocol designed to (i) gather information, identify and evaluate risks for wildlife–livestock interaction and pathogen transmission in the highest detail (specific risk points), (ii) develop and implement Farm-specific Action Plans to reduce the probability of such interactions and transmissions, and (iii) monitor and verify the implementation of Farm-specific Action Plans in terms of their feasibility and acceptability by producers (Martínez-Guijosa *et al.*, 2021) .

Risk assessment
A structured evaluation of how likely a hazard is to enter, become established and spread, and of its potential biological and economic consequences. This can be either qualitative or quantitative (WOAH, 2024).

Wildlife–livestock interface (WLI)
The physical spaces where wildlife and livestock species overlap in range and may interact, creating opportunities for direct or indirect contact that could result in pathogen transmission in either direction.

3. How to use these guidelines

These guidelines provide a flexible framework for addressing WLIs, rather than prescriptive solutions. Effective risk mitigation must be tailored to specific contexts, considering local geography, production systems, wildlife species and the target disease. All efforts should align with the recommendations provided by WOAH's international standards and national regulations.

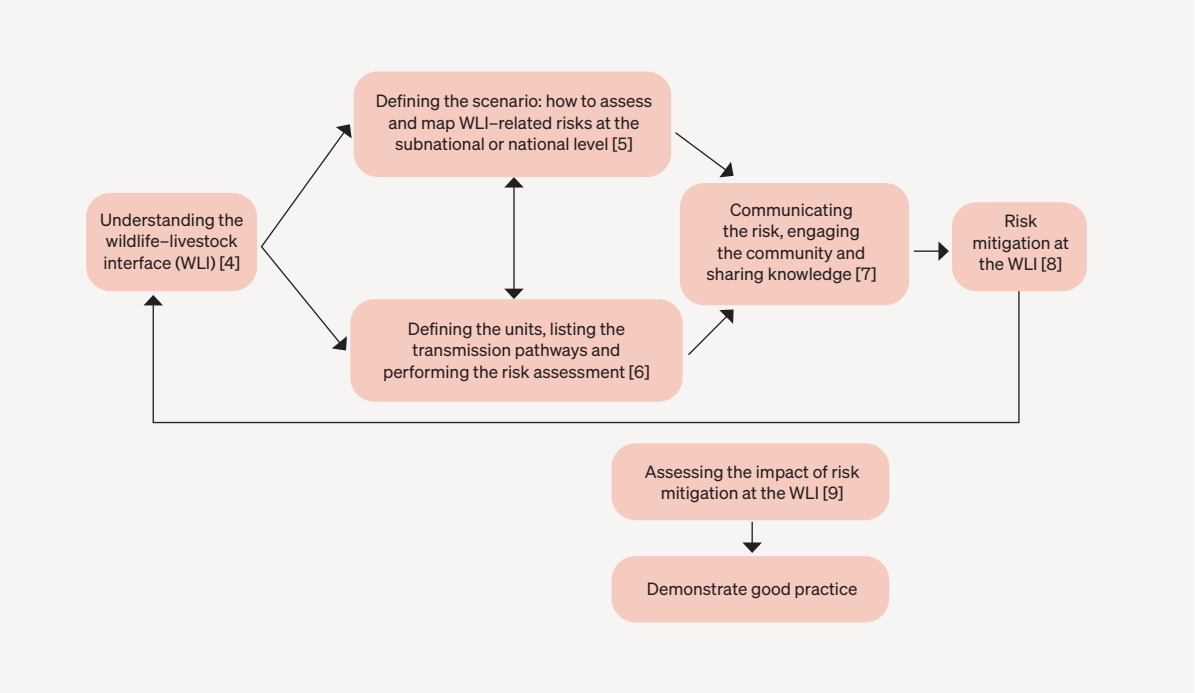


Figure 1. Risk mitigation programme flowchart

Once the background of the WLI has been characterised, relevant factors at the subnational or national level can be considered for the development of a biosecurity plan. These may include, for example, mapping farming systems and zones at greatest risk. The core section of this guide (sections 3–9) provides step-by-step instructions on how to assess risks at the epidemiological unit level, identify critical points for applying risk mitigation at the WLI and evaluate the outcomes. (Numbers in square brackets refer to section numbers in this guide)

Prerequisites

These guidelines are intended for Veterinary Services to facilitate safe trade. Effective implementation requires a background in veterinary sciences, particularly in the epidemiology of relevant infections. Knowledge of wildlife ecology is also an asset. Veterinary Services must have a thorough understanding of the target WLI scenario, different farming practices, and the key risk pathways for infection introduction and spread.

To make the best use of this guide, the following prerequisites are recommended:

- Willingness of the veterinary sector and producers to act.
- Sufficient data on livestock farming systems and distribution.
- Capacity to conduct risk assessments at different geographical levels.
- Familiarity with geographic information systems.
- Basic epidemiological data on the target disease(s).
- Basic population and management data on the relevant wildlife species.
- Understanding of livestock and wildlife behaviour.

4. Understanding the wildlife–livestock interface (WLI)

An interplay of many actors, factors and scales

WLIs vary by region, farming system, wildlife species and disease context. These interactions are dynamic and shaped by climate, habitat and human activity. The diverse ecological settings where wildlife and livestock overlap create complex pathways for pathogens to transmit in both directions. Transmission events occur across a wide range of farming and ecological systems.

TAKE ACTION

When assessing risks, you must consider this variability. The probability of risk events depends on pathogen characteristics, host species and the farming systems involved (**Figure 2**).

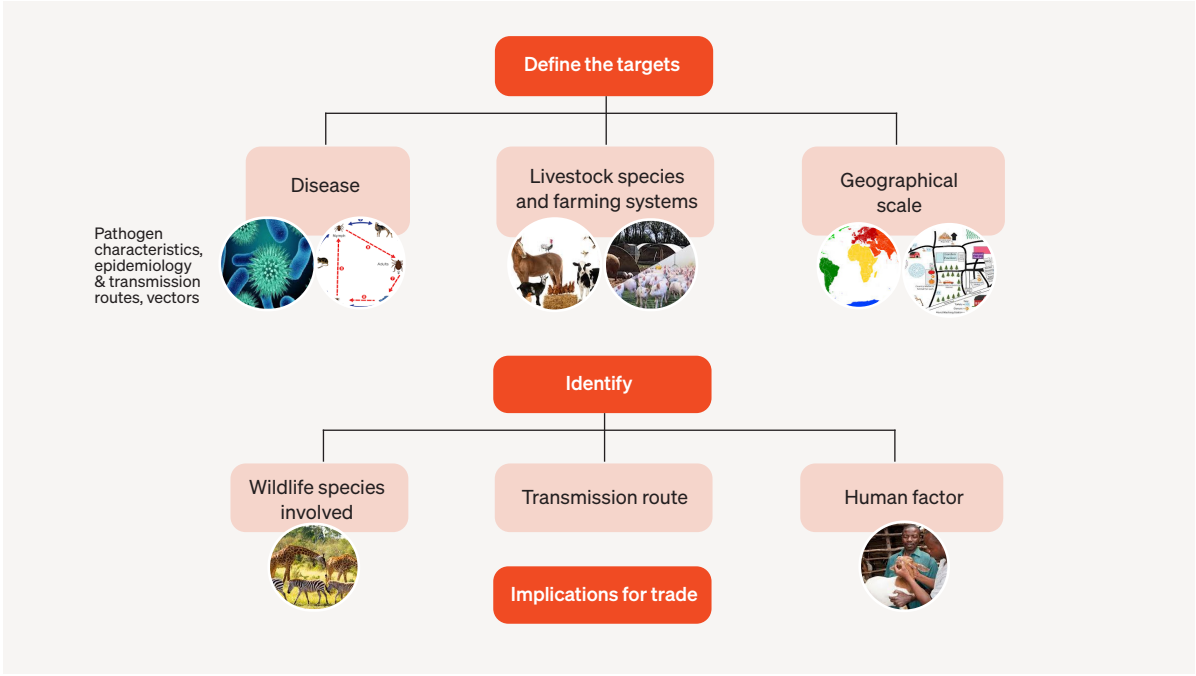


Figure 2. The wildlife–livestock interface: an interplay of many actors, factors and scales

Understanding the WLI requires consideration of livestock, wildlife and humans, as well as pathogen characteristics, transmission dynamics, farming systems and geographical scale

Wildlife and livestock share similar resource needs. When critical resources such as food and water are concentrated, these become risk hotspots for pathogen transmission. For example, in drylands most herbivores are water-dependent, and their distribution is constrained by access to water, particularly during the dry season.

TAKE ACTION

Manage key resources – such as waterholes, food-rich locations, or supplemental feed for domestic animals – at WLIs to reduce the risk of cross-species contact and pathogen transmission. Alternatively, adjusting livestock or wildlife movement and space-use patterns can help limit interactions in high-risk areas (e.g. forest-pasture ecotones) or during critical periods.

Livestock species and farming systems

The range of species relevant to a given disease may grow over time. While one species may serve as the main target host, other species can also contribute to local maintenance communities. Farming systems are central to defining the WLI, as they determine both the nature of human-mediated risks and the likelihood of interactions. Production systems such as communal pastures, extensive free-range production, open-air farming systems and small-scale holdings often present higher risks (**Figure 3**). In extensive and open-air farms, resource availability drives wildlife–livestock interactions, and resource preferences can be used to predict patterns of contact.

TAKE ACTION

To characterise the farming dimension of the WLI:

1. List all potentially relevant domestic species.
2. List all relevant farming systems and their main characteristics.
3. Pay attention to key resources (e.g. water).

Pig farm in urban habitat in Nepal
Contact with wild birds and rodents

Communal cattle in Uganda
Contact with diverse wildlife

Beef-cattle operation in Uruguay
Contact with sika deer, feral pigs, wild carnivores and birds

Backyard chicken on a mixed-species farm in Madagascar
Contact with wild birds

Figure 3. Examples of open-air farming systems

Open-air farming systems generally carry greater risk than indoor systems. Wildlife contact depends on location and the distribution of key resources such as feed and water

Geographical scale

Local, regional and global drivers shape the maintenance communities that constitute the WLI and their interaction networks, driving pathogen transmission and persistence. The WLI must therefore be assessed at multiple geographical scales, ranging from the farm to the regional or global scale.

TAKE ACTION

Clearly define the geographical scale of the risk assessment.

Wildlife species involved

Wildlife populations are dynamic and change over space and time. Susceptible wildlife can play different roles in the epidemiology of shared infections: maintenance hosts, bridge hosts, sentinels or casualties (**Figure 4**). As with domestic animals, the list of potential host species can be informed by scientific literature, though additional targeted research may be needed to fill knowledge gaps.

At the local level, risk is shaped by the combination of many factors. The probability of occurrence and subsequent impact associated with certain hosts (either domestic or wild) varies. In maintenance hosts or maintenance communities, pathogens persist even without new introductions. Identifying maintenance hosts is therefore essential for improved disease management. Attention should also be given to bridge hosts. Key characteristics of major wildlife host groups relevant to biosecurity at the WLI are summarised in Annex 2.

TAKE ACTION

Define a preliminary list of relevant wildlife species. The following data should be included for each species:

- behaviour (e.g. sociality, space use, activity rhythm, resource needs, seasonality);
- (suspected) role in epidemiology of the disease system;
- factors driving distribution and abundance status (e.g. migratory or sedentary, synanthropic or not, abundant or scarce);
- management status (e.g. protection level, hunting regulations, regulations on translocation and fencing);
- drivers of wildlife use of farm resources, or livestock use of wildlife habitats.

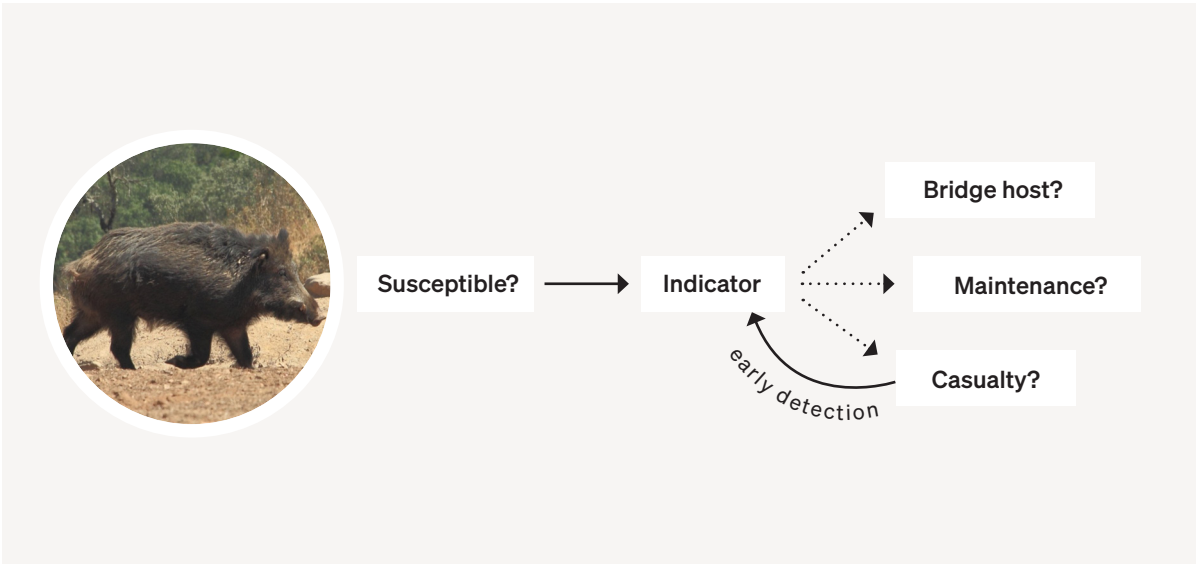


Figure 4. Role of wildlife in shared infections
Wildlife species susceptible to infection are indicators. The dashed arrows show how, over time, these can act as bridge hosts, maintenance hosts or casualties if infection causes morbidity and mortality. In such cases, the wildlife host can serve as early disease detection – for example, wild boar for African swine fever (Gortázar et al.*, 2021)*

Disease characteristics

Many infections are shared between wildlife and livestock at the WLI, but certain diseases merit special attention. This may be due to their impact on public health (zoonoses), conservation or animal production, including implications for national or international trade.

TAKE ACTION

Assess the epidemiology of the infection in wildlife based on scientific literature or through targeted research. Key aspects include:

- susceptible or suspected susceptible wildlife species, possible bridge hosts, maintenance hosts or communities (composed of host species contributing to pathogen circulation) and vectors;
- pathogen characteristics, including survival and persistence in the environment and sensitivity to temperature, aridity, sunlight and organic matter;
- main routes for intra- and cross-species transmission: direct, indirect (e.g. feed- or water-borne) and vector-mediated.

Seasonality

Seasonal variation in resource availability produces consistent patterns across ecosystems. Encounters increase when resources become scarce, forcing animals to share the remaining key resource patches, limiting their mobility. Seasonal behaviours, such as reproduction or migration, also influence wildlife–livestock interactions. Vectors are frequently linked with rainfall and temperature cycles.

TAKE ACTION

List the expected risk factors that may vary depending on the season.

The human factor

Risks at the WLI, and the success of risk mitigation efforts, depend strongly on human factors, including economic and socio-cultural aspects. Humans drive the spatial distribution and management of both wildlife populations and livestock husbandry, which has consequences for wildlife–livestock interactions and disease transmission risks.

TAKE ACTION

List and consider the main human actors, which typically include:

- Producers and farm staff.
- Field veterinarians.
- Wildlife users (e.g. hunters and nature enthusiasts).
- Authorities, including those responsible for animal health and wildlife management.
- Special interest groups or organisations with influence or ownership of the system but no formal governmental authority.
- The public.

5. Defining the scenario: how to assess and map WLI-related risks at the subnational or national level

Understanding and mapping the characteristics of the WLIs at large scales, and at the highest possible spatial resolution, strengthens the capacity to assess the spatial likelihood of disease transmission. If Veterinary Services have reliable knowledge of the epidemiological situation in the target area, two key issues must be addressed:

1. Identifying the main risk factors for the target disease and WLI in the region (see **Box 1**).
2. Mapping the WLI and characterising the main scenarios in terms of production systems and species involved (see **Box 2**).

Identifying risk factors

Levels of knowledge on WLIs vary considerably between countries, and not all host–pathogen-specific WLIs have been sufficiently investigated. As a first step, a literature review and information exchange with neighbouring countries facing similar challenges can help identify relevant information. Where knowledge is limited, simple cross-sectional or case-control surveys (where farm outbreaks are treated as cases) may provide valuable insights (see example in **Box 1**). Findings should be shared with other countries to enrich collective understanding of the WLI.

BOX 1. CASE STUDY EXAMPLE – AFRICAN SWINE FEVER RISK ASSESSMENT IN ROMANIA

ROMANIA

Goal: identify the main risk factors for the target livestock, wildlife and disease under different production systems.

Case-control study on 655 Romanian pig farms (2014 to 2018)

Cases: all domestic pig farms diagnosed with ASF if no direct link with another outbeak farm had been registered

Data available:

- Questionnaire (in person, by the Veterinary Services [VS])
- Georeferenced outbreak data in pig farms and case data in wild boar (VS)
- Pig farm distribution & pig density (VS)
- Wild boar relative abundance (hunting bag; source: Water & Forests)
- Water bodies and forest cover (CORINE land cover)

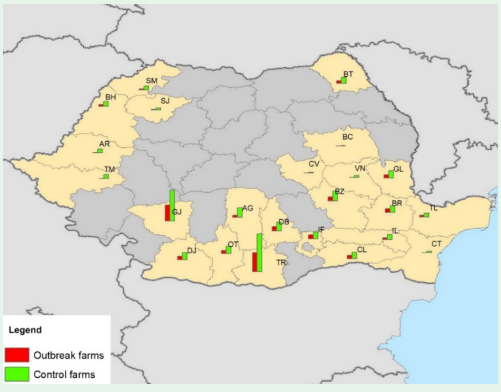
Risk factors identified:

Commercial pig farms:

- Proximity to outbreaks in pig farms

Small scale (backyard) pig farms:

- Proximity to outbreaks in pig farms
- Herd size
- Visits of professionals working on farms
- Wild boar abundance around the farm
- Proximity to wild boar ASF cases
- Growing crops around the farm which could potentially attract wild boar
- Feeding forage from ASF-affected areas to the pigs



Source: Boklund *et al.* (2020)

Figure 5. Map of Romania with counties included in the case-control study in yellow. The size of the bar reflects the numbers of case or control farms in each county.

Mapping the WLI

Mapping the WLIs by zone, farming system, and distribution and abundance of relevant wildlife presents several challenges, notably, limited access to high-resolution data on wildlife and livestock abundance (by typologies) from authoritative sources. The accuracy of the Geographic Information System (GIS) depends on the quality and spatial resolution of input data. For livestock, official census data are the primary source of information.

KEY DATA SOURCES

- **Official livestock census data**: Main source for domestic livestock information.
- **Gridded Livestock of the World (GLW)**: Modelled global livestock densities. Data available at FAO Livestock Systems. The Gridded Livestock of the World dataset (GLW), initially developed in 2007, with the most recent iteration (GLW-4) in 2022, produced global maps of cattle, buffaloes, horses, sheep, goats, pigs, chickens and ducks for 2015 at a spatial resolution of 5 arcminutes (~10 km at the equator). https://dataverse.harvard.edu/dataverse/glw_4
- **Global Livestock Environmental Assessment Model (GLEAM, by FAO)**: Uses GLW data to model the interactions between livestock production activities and the environment, quantifying production and the use of natural resources in the livestock sector. New animal distribution maps: GLEAM 3.0 uses a customised edition from Version 4 of the Gridded Livestock of the World (Gilbert *et al*., 2018), which is adjusted to 2015 animal numbers from the FAO Corporate Statistical Database (FAOSTAT). https://www.fao.org/gleam/en/
- **eBird and EuroBird Portal (EBP)**: Provides detailed data on avian species' relative abundance and migratory routes. eBird: https://ebird.org/home; EBP: https://www.eurobirdportal.org/ebp/en/#home/HIRRUS/r52weeks/CUCCAN/r52weeks/

CONSIDERATIONS FOR EFFECTIVE MAPPING

- **Socio-cultural aspects:** Consider spatial variation in farming systems and stakeholder structures.
- **Data harmonisation:** Develop frameworks for high-resolution, harmonised data collection.
- **Wildlife data collection:** Standardise methods for collecting wildlife distribution and abundance data.
- **Analytical approaches:** Combine overlapping spatial information and cluster analyses to map livestock and wildlife interactions.
- **Movement of domestic animals:** Consider long-distance movements by livestock under different production systems.

EXAMPLE FRAMEWORK

- **Pasture-based farming systems:** Define high-risk areas based on wildlife habitat proximity (e.g. wetlands for waterbirds).

BOX 2. CASE STUDY EXAMPLE: MAPPING THE PIG–WILD BOAR WLIs IN SPAIN

SPAIN

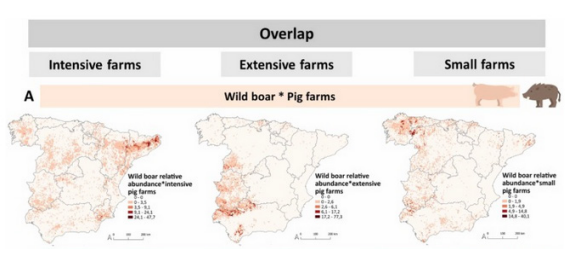
Goal: mapping the WLIs and characterising the main scenarios

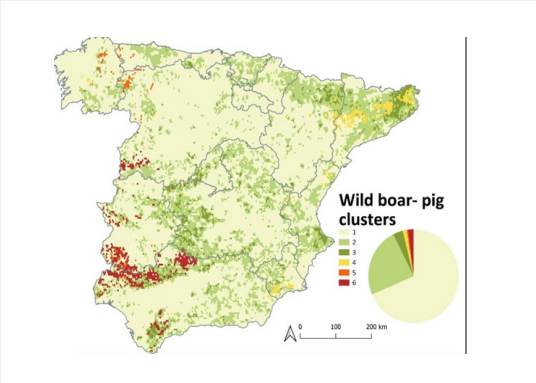
Data available (all georeferenced):

- Habitat and land use data
- Wild boar presence and hunting bag data
- Pig farm distribution, pig density & farming system

Results obtained:

- Maps of wild boar & pig farm overlap
- Clusters identified, where wild boar overlaps with
  - Commercial pig farming (A, left)
  - Extensive open-air farming (A, central)
  - Small-scale pig farming (A, right)
- This approach is applicable to other regions and interfaces





Source: Ruiz-Rodríguez *et al.* (2020)

Figure 6. Results of a cluster analysis for domestic pig farms along with wild boar relative abundance in mainland Spain

6. Defining the units, listing the transmission pathways and performing the risk assessment

Defining the epidemiological units of the relevant WLI

A livestock population is composed of epidemiological units, such as farms or herds – populations of farmed animals under a defined ownership in a defined space. Each unit has distinct characteristics that influence the risks of entry, maintenance and spread of infections shared with wildlife. Assessing risks at the unit level (farm or herd) is therefore a key step in disease control at the WLI.

The first task is to define the typology of epidemiological units where external biosecurity at the WLI will be assessed, with emphasis on territorial basis and risk elements. Defining the typical 'model' unit at the WLI in the geographical area of interest is essential, as such features determine where Hazard Analysis and Critical Control Points (HACCP) principles will be applied and guide the design of an adapted On-farm Wildlife Risk Mitigation Protocol.

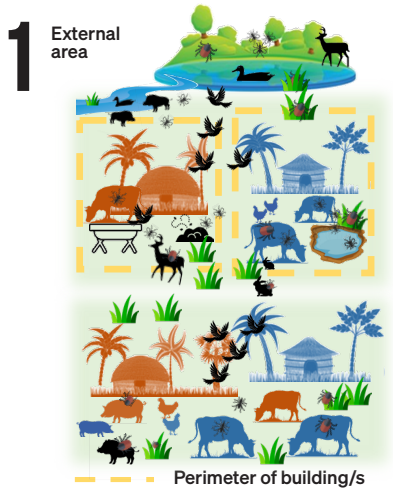
TAKE ACTION

Describe the key characteristics of the epidemiological unit, focusing on risk points (e.g. feeders or water points) across the entire area, with special attention to:

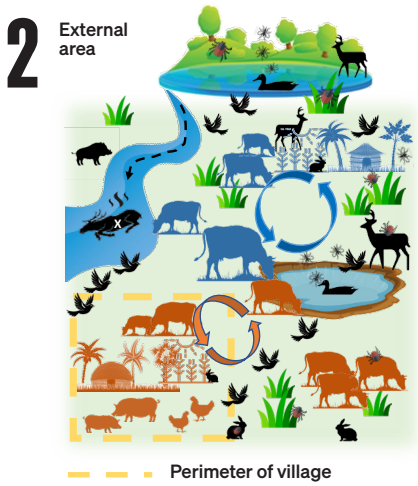
- Risk points for wildlife–livestock interaction.
- Animal access to areas around buildings, pastures, forests and runs/yards, including open-air structures or buildings that allow contact with open air or the external environment.
- Fences/barriers around and across these outdoor elements, which may constrain the movements of livestock and wildlife.

Figure 7 illustrates simplified examples of epidemiological unit typologies, based on their production system and territorial basis. These represent a continuum, as farms vary greatly, often combining elements of different scenarios (potentially combined or absent). Overall, two features are important: (i) aggregation points or areas for wildlife–livestock interactions, and (ii) physical barriers at two levels: inner barriers immediately surrounding main farm facilities/buildings, and outer barriers separating the epidemiological unit from other land uses.

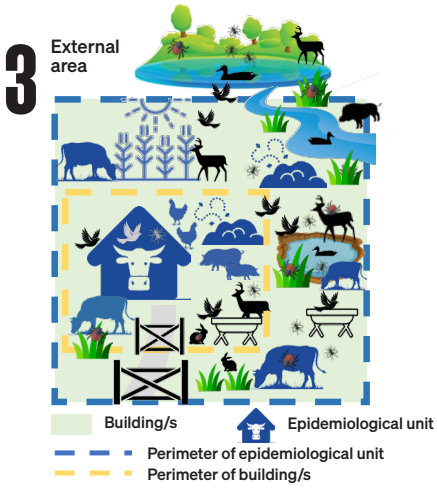
To further understand the target farming system and WLI, discussions with several (4–6) local producers and the wildlife sector can offer valuable insights into production systems and perceptions of the local WLI.



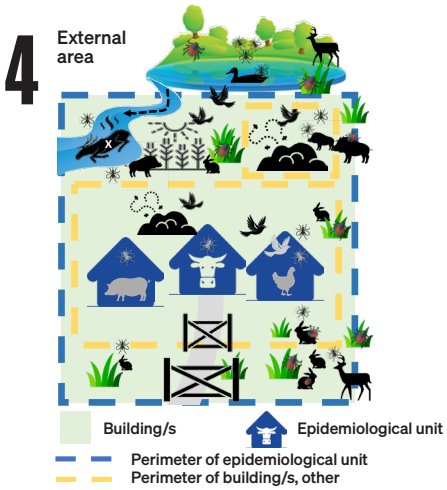
Example 1: Two epidemiological units, backyards/small holdings. Top: independently in separated family units (indoor and/or outdoor). Bottom: Communal use of space, fenced or not.



Example 2: Two epidemiological units/ farms/herds, in this case, from different villages, share use of extensive resources. Village can be fenced.



Example 3: One single epidemiological unit, presence of buildings and two fenced perimeters, for building and complete epidemiological unit, delimiting the main farm area, where extensive practices may apply.



Example 4: One single intensive indoor epidemiological unit with several buildings, two fenced perimeters (for buildings, some facilities, such as slurry pools, and the complete epidemiological unit).

Figure 7. Examples of epidemiological units
Defining the epidemiological unit's main characteristics and territorial basis for subsequent on-farm biosecurity assessment

Listing transmission pathways: developing an adapted On-farm Wildlife Risk Mitigation Protocol

Once the main characteristics of the target epidemiological units are defined, the possible risks and transmission pathways (in both directions) must be considered (see the checklist in Annex 1 for help). These include the following:

- Farmed animal species and management
- Location and distance to other epidemiological units
- Domestic animal movements
- Building and fencing characteristics
- Habitats and land uses (within and surrounding the unit)
- Rodents
- Interaction with wildlife
- Aerosols
- Arthropods
- Vehicles entering or crossing the premises
- People
- Equipment and fomites
- Feed
- Bedding and enrichment
- Water
- Waste

This checklist is adaptable to different WLIs and provides a flexible framework to develop WLI-specific On-farm Wildlife Risk Mitigation Protocols.

TAKE ACTION

Adapt this non-exhaustive list, considering the specificities of the target WLI.

Performing the risk assessment at the epidemiological unit level

Risk assessments involve collecting information on unit-specific risks at the defined WLI. The key questions focus on potential contact with wildlife and the critical risk points where such contact may occur (e.g. feeders or water sources). The flowchart in **Figure 8** outlines the steps of the process. For an example of how to estimate the cost of conducting a risk assessment per epidemiological unit (in terms of personnel hours) see the case study in this article based on the application of the protocol to extensive beef cattle farms.

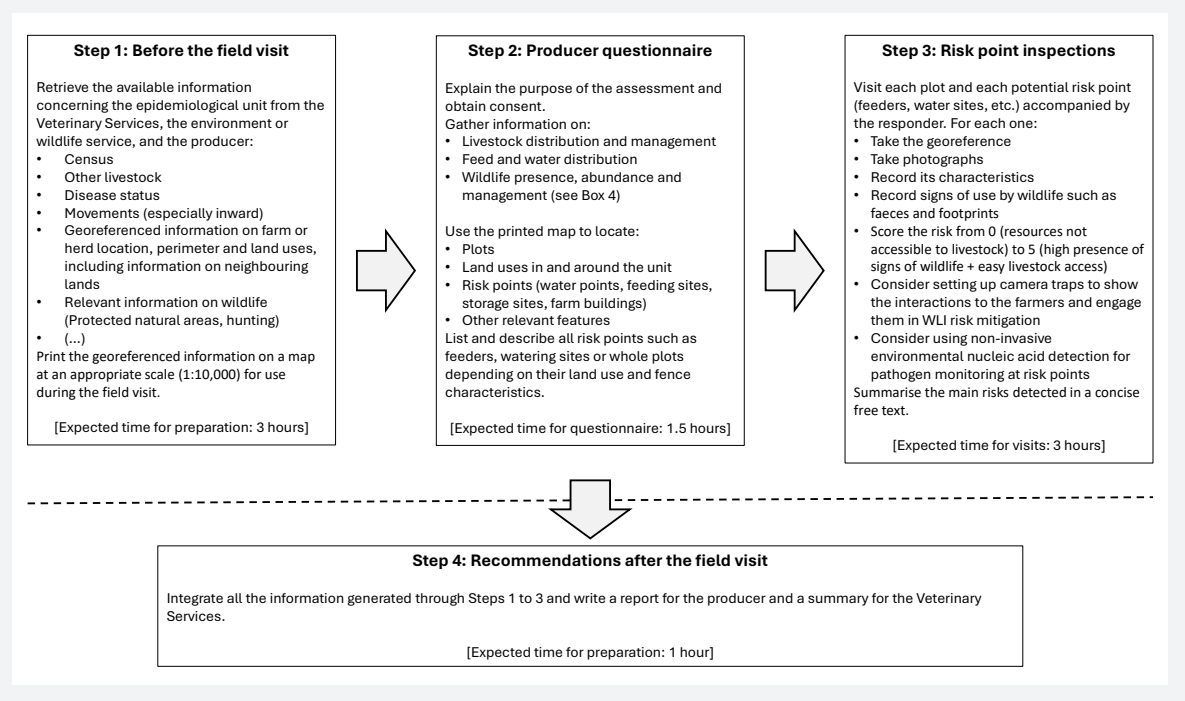


Figure 8. Main steps of a risk assessment at the epidemiological unit level

TAKE ACTION

Step 1: Before the field visit

Compile available information on the epidemiological unit and its surroundings. Generate a map for use in the participatory GIS in Step 2 (see **Figure 9**).

Step 2: Producer questionnaire

To identify potential risks, conduct an interview using a standardised questionnaire (see the basic list in **Table 1**; example in **Box 3**; further examples in **Figure 10**) to collect information on livestock, wildlife, as well as feed and water distribution and management. Producers are valuable sources of local knowledge, supplemented by other means of estimating wildlife abundance (see **Box 4**). Printed farm maps are particularly useful to locate plots, land uses, risk points and any other management issues of relevance (participatory GIS).

Table 1 presents the basic points that should be included in all producer questionnaires. These questions are specifically targeting the WLI. For a broader epidemiological investigation (e.g. outbreak investigation) please refer to other sources.

Table 1. Basic points that should be included in all producer questionnaires

Farmed species data	Record the number and demographics (population structure) of farmed species within the epidemiological unit.
Participatory mapping	Draw the perimeter of the epidemiological unit, including plots or sub-units, habitats (woodland, pasture, wetland, urban), buildings, and main risk points such as water points or feeding sites.
Land use description	Describe the surrounding land uses (farming systems, main crops, protected areas, hunting zones, urban areas) of the epidemiological unit.
Barrier description	Detail geographical features, fences, buildings, and their permeability to mammals, birds and vectors. Include information on public roads crossing the unit, doors and access points.
Wildlife questions	Ask about relevant wildlife, their relative abundance and wildlife management practices (e.g. hunting, nearby protected areas).
Wildlife contact questions	Inquire about direct and indirect contact with wildlife, such as sightings of species together, wildlife presence at water or feed points, and observed wildlife mortality.
Water management	Document the number and type of water points, water quality and accessibility for livestock and relevant wildlife.
Feed management	Describe feed types, distribution and management. Include details on feeding site characteristics, pasture seasonality, feeder types and accessibility for wildlife. Note feed storage sites and wildlife access.
Disease situation	Gather producers' views and perceptions of the disease situation on the farm, including mortality, diseased individuals, clinical signs, seasonality of disease, and records of disease events, mortality or treatments.
Commingling of units	Describe the interaction between different epidemiological units with varying WLIs (e.g. common pastures for cattle, rice paddies for ducks) and inward animal movements from other WLIs.

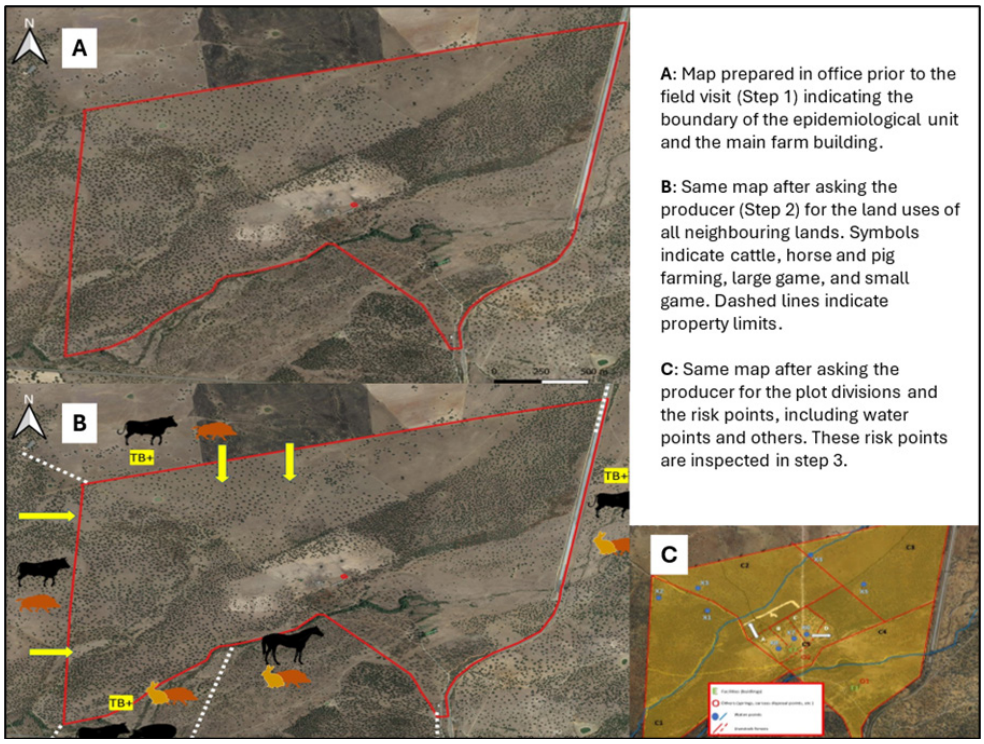


Figure 9. Example epidemiological unit map (pig and cattle farm) used for participatory GIS in field assessments

Step 3: Risk point inspections

This step involves inspecting all major risk points and carrying out a risk scoring exercise. Each plot and potential risk point should be visited, ideally with the respondent present. Every potential risk point must be geo-referenced, photographed and described in detail, including any signs of wildlife use. These may include footprints, rootings, faeces, feathers or other traces depending on the local wildlife of concern. Camera traps can be used to confirm interactions between species and to demonstrate these to producers, encouraging them to implement mitigation actions. Where feasible, risk points can then be sampled for environmental nucleic acids and tested for wildlife DNA as indicators of pathogen presence in the environment.

In this step, the farm map and questionnaire results are supplemented by tables listing and describing each risk point (e.g. feeders, watering sites or entire plots and buildings) according to their land use and fencing characteristics (see **Figure 10**). This step requires sufficient time for site visits.

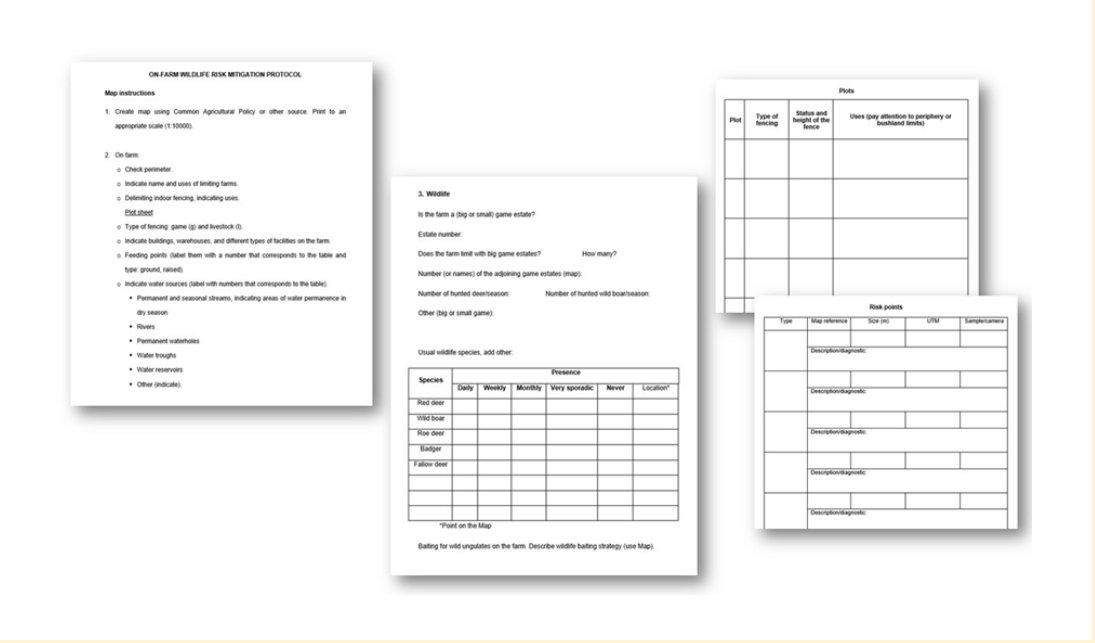


Figure 10. Example of a risk assessment questionnaire for producers

The images illustrate sections of a 14-page interview, including the instructions for using the map in participatory GIS (left), questions on wildlife presence (centre) and specific tables to list the plots (upper right) and the risk points (lower right). (Source: Martínez-Guijosa et al.*, 2021)*

Risk point scoring ranks sites according to the likelihood of wildlife–livestock interactions, ensuring that mitigation actions are applied in proportion to risk, cost and efficacy. This semi-quantitative method of risk assessment assigns a subjective value (typically from 0 to 5) to each risk point identified in Step 2. In some cases, where risks are qualitative rather than quantitative (e.g. the presence or absence of a perimeter fence in indoor production systems), scoring can use binary (presence/absence) or ordinal categories. Because scoring is influenced by observer bias, proper training of veterinarians involved in on-farm risk assessments is essential. Scoring criteria should be tailored to each WLI, considering the target farming system, livestock species, wildlife species and disease.

A score of 0 indicates no risk – for example, a fenced plot that prevents external access for livestock. The maximum score reflects a high-risk point, such as a waterhole accessible to livestock and heavily used by relevant wildlife. Hence, risk scoring produces a value per risk point. The sum of all scores, including risks due to processes (e.g. bringing meat from hunted wildlife onto the farm) and not due to physical elements (e.g. waterhole) provides a total risk score for the epidemiological unit. Veterinary Services can use these totals for risk monitoring and risk mapping, comparing epidemiological units and tracking changes over time. This also allows evaluation of risk reduction after implementing an action plan, and assessing the efficacy of different actions. **Box 3** presents an example scoring table.

BOX 3 HOW TO SCORE RISK POINTS

Example based on Martinez-Guijosa *et al*. (2021) for domestic and wild ungulates in seasonally dry pastureland-based systems.

This scoring system estimates the interaction risk between wildlife (mainly ungulates) and extensive cattle at aggregation points. Risk are scored on a scale from **0 (no risk)** to **5 (highest risk)**. The scoring method is flexible and can be adapted to different WLIs.

A score of 0 is applied when there is no possibility of interaction (e.g. potential risk points not accessible to livestock). Because wildlife access cannot always be ruled out, even seemingly secure sites (e.g. feed stored in closed buildings), may receive a minimum score of 1 if wildlife are present nearby. This ensures continued attention to biosecurity.

In some cases, other species such as wild birds may act as bridge vectors, even if terrestrial wild vertebrates cannot access the site. In seasonally dry areas, scores are assigned to water points depending on their characteristics and accessibility to wildlife. Thus, a higher score is given to low waterers (e.g. easily accessible to wild boar) and to smaller water bodies, where animal interaction and pathogen accumulation are more likely. Feed storage and feeding points accessible to wildlife also receive higher scores.

When scoring, consider: (i) signs of wildlife activity at the site and (ii) the specific characteristic of water points, which may increase or decrease risk. A maximum score of 5 can be reached.

In addition, some specific risks are classified as 'killer factors'. These are evident risks that, on their own, result in a negative score of the epidemiological unit by the Veterinary Services, regardless of the overall risk score. For example, if a pig farmer hunts and brings wild boar meat onto the farm premises (risk of ASF), or if a poultry farm is located in a wetland area (risk of AI).

Table 2. Example scoring table for risk assessments

Site typology and characteristics	**Risk Score (0–5)**
Not accessible to livestock	0
Not accessible to wildlife	1
Waterer/feeder	
Low waterer/feeder[1] (≤ 90 cm height)	3
High waterer/feeder[2] (>90 cm height)	2
Water body[3]	
Small waterhole (≤ 25 m Ø), spring or waterlogged river/stream	4
Large waterhole (>25 m Ø) or flowing river/stream	3
Feed storage	
Closed building	0
Open air/accessible to wildlife	2
Score modifiers	
Signs of wildlife[5]	+2
Waterer with mud presence in its base[4]	+1
Water point totally dry in summer	-1
Water point with rocky or stony shore (no mud)	-1

[1] Not wild boar-proof. [2] Wild boar-proof. [3] For reservoirs, the type of banks determines the score, equating them to the corresponding waterhole. In rivers or streams, the riskiest points along the banks should be scored as separate water bodies. Where no waterlogging occurs (e.g. well-defined banks with constant flow), this should be scored as a large waterhole. [4] Where waterlogging is present, classify as a waterhole

BOX 4. ASSESSING WILDLIFE USE OF FARM RESOURCES AND RISKS DURING FIELDWORK

This box outlines how to assess wildlife use of farm resources and associated risks during fieldwork. Before processing the information back in the office, complete Step 3 by preparing a short summary of the main risks involved, along with any observations that may inform the Farm-specific Action Plan (FsAP). The duration of field visits will vary according to the size of the epidemiological unit and the number of plots.

At the epidemiological unit level

- **Questionnaire**: Ask the producer for semiquantitative information on how often they detect the presence of a certain wildlife species or on the size of the largest group of that species ever seen.
- **Signs of wildlife presence**: Signs such as footprints or faeces can be quantified based on how frequently they are detected on transects or surfaces.
- **Hunting bags**: If the epidemiological unit is (part of) a hunting area, game bags inform on wildlife abundance and population trends.
- **Camera-traps**: Can be deployed at risk points such as feeders or waterholes and at random points to quantify wildlife visits and wildlife–livestock interactions and to characterise the local vertebrate community. This is one of the best means of characterising the local WLI.

At the risk unit level

- **Visit and characterise each risk point:**
  - Take the georeference
  - Take photographs
  - Record its characteristics
  - Record and if possible, quantify signs of use by wildlife
  - Consider deploying camera traps to confirmcross-species interactions and to engage farmers in mitigation actions
- **Score each risk point:**
  - Based on the information collected during the visit, score each risk point and rank the risk of different points. The mitigation actions, in terms of cost and efficacy, should be proportional to the risks. Scores also help in comparing risks among farms and over time.

Annex 5 provides photographs of potential risk points, their assessed risk scores, proposed mitigation measures and actions implemented by producers. It also lists the materials and labour required for mitigation, along with estimated costs per unit.

For biosecurity evaluation, observer scores can be complemented by expert scoring of specific WLI factors. Experts assess the local relevance of different pathogen transmission pathways within a defined WLI (see Annex 1) using a structured questionnaire. These expert scores can then be used to generate weighted final risk scores for individual farms, integrating local expertise into the broader framework. This approach allows comparison of values across units and biosecurity programmes over time (e.g. before and after implementation). A good level of agreement among experts is generally expected.

Step 4: Recommendations after the field visit

This step involves consolidating all information from Steps 1–3 into a WLI risk report with tailored recommendations for the producer. The report also serves as feedback to Veterinary Services, supporting improvements in future large-scale risk assessments.

7. Communicating the risk, engaging the stakeholders and sharing knowledge

Although communication is a transversal activity throughout the entire process, this section describes how Veterinary Services can communicate the results to producers, gather their feedback, share information with relevant stakeholders and engage with the public. This section also includes guidance on training.

The information generated at the epidemiological unit level on WLI-related risks is relevant not only for producers, but also for private veterinarians, Veterinary Services and other administrative departments responsible for domestic and wildlife health. Public awareness is equally important, especially when the target disease has the potential to create conflict. There is increasing recognition of the need for integrated, cross-sectoral management of animal health – bringing together environmental and wildlife conservation agencies.

Communicating the risk assessment results to producers, field veterinarians and the wildlife sector

A detailed WLI risk report and FsAP should be prepared for each epidemiological unit. These should include:

- General contents (common to all reports)
  - Background on the target disease, including its epidemiology and relevance to the WLI.
  - A concise summary of the main risk factors typical of the target WLI.
  - Risk questions, applied methodology and proposed risk mitigation interventions.
- Specific contents (tailored to each epidemiological unit)
  - A ranked (prioritised) list of identified risks and proposed mitigation measures (see Section 8).
  - A comparison of the farm or herd's risk ranking with that of other (similar) epidemiological units in the region.

A draft report should be discussed with the producer and, where possible, the farm veterinarian and the wildlife sector, to allow for feedback and clarification.

Aggregated or anonymised data from multiple farms or herds in the same region should also be analysed, with results shared back to producers, their veterinarians and the wildlife sector. This exchange can be organised through meetings, providing an opportunity for stakeholders to comment on and strengthen the risk mitigation programme. The key message should be clear: everyone working with or in contact with livestock or wildlife plays a vital role in maintaining biosecurity.

Annex 6 contains examples of FsAPs for extensive cattle, intensive pig and poultry systems, as well as follow-up templates.

TAKE ACTION

Communicate the WLI risk assessment results through a detailed, farm-specific report and action plan, discussed directly with producers, veterinarians and the wildlife sector, and reinforced with feedback and training to strengthen biosecurity awareness and engagement.

Communicating risk assessment results to the Veterinary Authority and other relevant authorities

Risk assessments are typically coordinated by regional or national Veterinary Authorities. The information generated, including main risk types, risk scores per farm or herd, and proposed intervention measures, should be shared with the Veterinary Authority. They should also have access to a database containing detailed information at the epidemiological unit level. In addition, this information should be communicated to other relevant departments, such as those responsible for wildlife conservation or hunting.

TAKE ACTION

Share farm-level risk assessment results with the Veterinary Authority and relevant departments via a centralised database to support coordinated disease control and cross-sectoral collaboration.

Training on the assessment and implementation of biosecurity at the WLI

Training is recommended for all the mentioned stakeholders (producers, farm veterinarians, Veterinary Authorities and other relevant departments). Training should include at least one day of theory and one day of fieldwork. The structure of the training contents may follow the flowchart presented in **Figure 2**.

Understanding how pathogens spread across complex multi-host systems through WLI barriers, across time and space, and identifying the drivers of wild and domestic host movements and contacts requires an interdisciplinary approach. A combination of ecology, epidemiology and social sciences is therefore most effective.

As a final exercise, participants may develop a real FsAP during a field visit, followed by presentation and discussion of findings. Alternatively, this exercise can be replaced by classroom-based group case studies. Annex 4 provides examples of training materials.

TAKE ACTION

Provide targeted training for relevant audiences, combining theory and fieldwork, to build interdisciplinary understanding of WLI-related risks and support the development of FsAPs.

Communicating WLI-related activities to the public

To raise public awareness and prevent misinformation, communications should cover key elements, similar to those included in the general section of an individual farm report:

- The aims of the risk assessment and the proposed risk mitigation measures.
- An outreach version of the background on the target disease, its epidemiology and relevance to the WLI.
- A concise overview of the main risk factors typical of the target WLI.
- A list of the main mitigation options.

This information is especially important in cases where interventions, such as fencing, may lead to conflict. Media content should be tailored to each WLI and presented in local languages.

TAKE ACTION

Deliver clear, locally adapted public communication on WLI-related risks and mitigation measures to raise awareness, prevent misinformation and build stakeholder understanding – particularly in situations where interventions may lead to conflict.

Engaging stakeholders

Effective risk mitigation at the WLI requires a multi-sectoral approach built on interdisciplinary collaboration and adaptive management. Livestock producers need training on disease characteristics, transmission pathways, risks and farm biosecurity. They should also be consulted about their views on the target disease, the WLI and available control options. Producers play a key role in implementing biosecurity plans and sharing data with field veterinarians and Veterinary Services. These services, in turn, can compile and share infection prevalence and incidence data, and develop maps to identify high-risk areas or changes in transmission risk over time (e.g. flu radar for AI). They should also coordinate with conservation officers to monitor relevant wildlife populations. Conservationists and hunters contribute through participatory monitoring programmes, reporting unusual morbidity events or demographic changes.

To be effective, engagement must clearly demonstrate the benefits for each community and ensure regular information exchange.

TAKE ACTION

Engage stakeholders from all sectors in WLI-risk mitigation by providing training, facilitating data sharing, promoting participatory monitoring, and clearly communicating the benefits of collaboration to strengthen coordinated biosecurity efforts.

8. Risk mitigation at the WLI

WLIs are complex and dynamic systems where pathogen spillover and spillback are central challenges. Mitigating the risk of spread is especially difficult when taxonomically related species depend on the same resources. The systematic implementation of FsAPs can help manage and reduce the risk of disease transmission to livestock.

This section focuses on the implementation of the FsAP, which serves as the foundation for risk mitigation. These plans are applied at the local, epidemiological unit level and rely primarily on the producer and their veterinarian, while broader disease control at the regional or national level is the responsibility of the Veterinary Services. Risk mitigation at the WLI involves adjustments to farm or herd management, infrastructure and, in some cases, wildlife management. The goal is to reduce and eventually prevent interactions between relevant wildlife and target livestock by addressing all known and suspected transmission pathways of the target pathogen (see Annex 1).

TAKE ACTION

Implement these measures as part of an FsAP:

- Modify pasture use and plot rotation.
- Upgrade facilities, such as perimeter fencing and isolation areas.
- Adjust water points or feeders.
- Make farm resources less attractive to wildlife.
- Modify wildlife habitats to divert them away from livestock aggregation sites.

Some interventions, such as modifying feeders, are within the producers' control, while others, like installing perimeter fencing or undertaking wildlife management, may require permits from relevant administrative bodies.

Producers can provide valuable insights into risk mitigation options and implementation methods. Adopting a collaborative approach helps build trust between producers, field veterinarians and Veterinary Services.

Types of risk mitigation interventions

A detailed, prioritised list of the specific risks and proposed mitigation measures should be prepared and shared with the producer. Each measure should be classified as either a *priority action* or an *alternative action* for a specific risk:

- **Priority actions** are those with the greatest potential effectiveness to reduce risk at the WLI.
- **Alternative actions** are less effective in theory but can still help manage risks. They should be considered when priority actions are not feasible for the producer. For example, while installing perimeter fencing may be the priority action to prevent wildlife entry, an alternative action could be avoiding the use of pastures near wildlife habitats during high-risk seasons.

Mitigation actions can also be classified as either *general* or *specific*:

- **General actions** are comprehensive management measures that affect farm resources or livestock as a whole, such as prohibiting wildlife feeding on the premises.
- **Specific actions** address specific risk points, such as plots, water points or feeders.

The knowledge and experience gained from developing and implementing FsAPs will help build a catalogue of biosecurity measures tailored to each WLI. **Box 5** shows a summary of typical risk mitigation actions at the WLI.

BOX 5. TYPICAL RISK MITIGATION ACTIONS AT THE WLI

1. Wildlife management

- Install perimeter fencing designed to exclude relevant risk species.
- Prohibit wildlife feeding and baiting within the premises/interface.
- Considering the potential impact on wildlife, modify habitats within the epidemiological unit to make them less attractive to risk wildlife (e.g. reduce roosting and nesting opportunities for birds on roofs, trees, fences or similar structures).
- Enhance habitats away from domestic animal areas to attract wildlife away from the premises/interface.
- Hunting or culling of relevant wildlife, following a thorough assessment of potential impacts on wildlife populations and in close collaboration with wildlife sectors.

2. Grazing management

- Avoid grazing, or limit it to low risk seasons or specific times of day.
- Graze with alternative livestock species that are less susceptible to the target disease.
- Avoid communal pastures.
- Set up or repair livestock fencing.
- Set up electric fencing to restrict access to high-risk pastures within plots.

3. Building improvements

- Install bird-proof nets.
- Adapt farm buildings to be wildlife-proof, considering the main risk species.
- Control peridomestic vertebrates in farm buildings.
- Apply insect control and other vector-proofing measures.
- Construct new farm buildings away from high-risk wildlife habitats.

4. Water point management

- Install or modify waterers: repair leaks, prevent spills, adjust position (e.g. height) to restrict access by certain wildlife species, and add additional waterers to reduce aggregation at a single point. Use waterers only at certain times. For poultry, place waterers indoors or in areas inaccessible to wild birds.
- Create or modify ponds or waterholes. Larger and deeper waterholes are generally less risky. Establish new, larger waterholes to reduce aggregation at a single point and improve farm biodiversity.
- Fence off water points.
- Cover water deposits and wells that supply barns with roofing or bird-proof netting.

5. Feed storage and deployment (including mineral supplementation)

- Improve feed storage to prevent wildlife access.
- Prevent and clean up spills from silos.
- Set up or modify feeders: avoid ground feeding, schedule concentrated feeding in the morning to reduce nocturnal mammal access, install species-specific feeders and restrict access to set times. Place feeders indoors where possible or cover them to prevent bird access.
- Limit wildlife access to mineral blocks by placing them in fenced plots, elevating them to restrict smaller wildlife, or replace blocks with mineral premix incorporated into feed.

6. Contact with other livestock that may be in contact with risk wildlife

- Segregate livestock species.
- Avoid close contact with other herds.
- Restrict animal movements between farms or herds.
- Test external livestock for the target disease, where relevant.

7. Waste management

- Improve carcass disposal practices.
- Fence off slurry or manure storage sites.

Annex 5 contains photographs of potential risk points along with their assessed risk scores. It also outlines the proposed mitigation actions for each case, the actions implemented by producers, and the materials and labour required for implementation, including their unit costs.

Barriers to risk mitigation implementation

The main barriers to effective risk mitigation at the WLI are often linked to the producer's willingness to adopt biosecurity measures, the financial cost of implementing the proposed mitigation actions, and regulatory or other restrictions.

Biosecurity is an investment

Biosecurity should be regarded as a long-term investment rather than an additional production cost. However, its implementation can be hindered by the involvement of multiple stakeholders with overlapping economic interests. For example, supplementary wildlife feeding is a recognised risk factor for disease transmission, yet producers and hunters may be reluctant to abandon this practice because of its perceived economic and social benefits, which may outweigh concerns over biosecurity.

Even when action plans are provided free of charge or fully subsidised, some producers may still decline to adopt them or fail to commit to ongoing maintenance. Persuading producers to invest in animal health is challenging, as decisions are shaped not only by financial considerations but also by subjective factors. For example, perceptions of 'good farming status' – the way a farmer's management practices are perceived by peers – can be more influential than economic incentives in shaping biosecurity-related decisions.

It is essential to communicate that effective livestock health management requires integrated disease control. This includes combining all available tools – biosecurity, testing, culling, medication and vaccination – tailored to the disease in question and the circumstances of the epidemiological unit. Promoting farm biosecurity should emphasise that it complements, rather than replaces, other interventions. Importantly, profit maximisation and disease minimisation are not fully compatible goals. Striking the right balance is key to sustainable livestock management.

Restrictions imposed by regulation

Policy-makers should support producers, veterinarians and take into account the importance of protecting endangered wildlife, by promoting compliance with biosecurity measures and legislation, particularly regarding sanitary interventions for game and wildlife species that act as disease reservoirs. However, veterinary, environmental and conservation regulations may sometimes result in poorly coordinated policies. For example, biosecurity measures such as fencing or population control may be prohibited in extensive natural areas as they may hinder natural movement/migration of wildlife and are often strictly regulated in peri-urban and farm habitats. In some cases, WLIs even arise from grazing within protected areas.

Small-scale production can also present challenges when it involves substandard husbandry practices, creating risks for commercialisation at or beyond the WLI. Such production systems may further be linked to wider networks through the movement of animals, products and waste. Coordination among various administrative bodies is essential.

9. Assessing the impact of risk mitigation at the WLI

Evaluation of risk mitigation interventions

After discussing the FsAP with the producer, Veterinary Services should maintain regular communication (e.g. by phone, email or other means) to allow producers to report incidents, raise questions and share concerns. All feedback should be recorded for further evaluation.

One year after delivering the report, producers should be asked which proposed actions were implemented (noting whether they were priority or alternative actions, and their motivations), the difficulties encountered and the estimated costs. This process not only improves the effectiveness of the FsAP but also provides valuable insights for veterinarians, as producers' experiences and alternative approaches can inform future biosecurity strategies.

TAKE ACTION

Methods for monitoring and verification:

1. **Follow-up visits:** Farms or herds should be revisited to confirm the implementation of biosecurity actions and to interview producers about their perceptions of the programme. Follow-up inspections serve two main purposes:

   a) **Verification** confirms that the recommended physical barriers are in place and properly maintained. Conduct a new interview to assess whether the recommended mitigation actions have been implemented.

   b) **Feedback collection** gathers the producer's views on the feasibility and efficacy of the risk mitigation actions.

2. **Disease data records:** Veterinary Services may have data on the annual incidence of the target disease or related disease indicators at farm or regional level. This information can shed light on the success of interventions.

3. **Non-invasive sampling:** If camera traps or other non-invasive sampling methods (see **Box 6**) were deployed during the initial risk assessment, redeployments in subsequent visits can track changes in the presence of risk wildlife species, the target pathogen or other indicators of pathogen circulation.

4. **Surveillance:** Biosecurity plans must be paired with effective, integrated disease surveillance and early detection systems at the WLI. This generates objective evidence of the effectiveness of implemented measures.
   In cases where freedom of disease is claimed in domestic subpopulations, in line with WOAH international standards, the surveillance system should aim to:

   a) **Rapidly detect** the pathogenic agent of concern if it enters domestic populations, reducing the risk of infected animals or animal products leaving the epidemiological unit, and enabling the swift recovery of disease-free status.

   b) **Substantiate disease** freedom within the epidemiological unit to support safe national and international trade, even if the disease remains present in wildlife populations.

BOX 6. NON-INVASIVE MONITORING OF RISK MITIGATION EFFECTS

The graph shows an example of the impact of a FsAP, showing a reduction in wild mammal farm visits (notably wild boar, red fox and badger) and a decrease in pathogen marker detection (specifically the *Salmonella* marker *invA*).

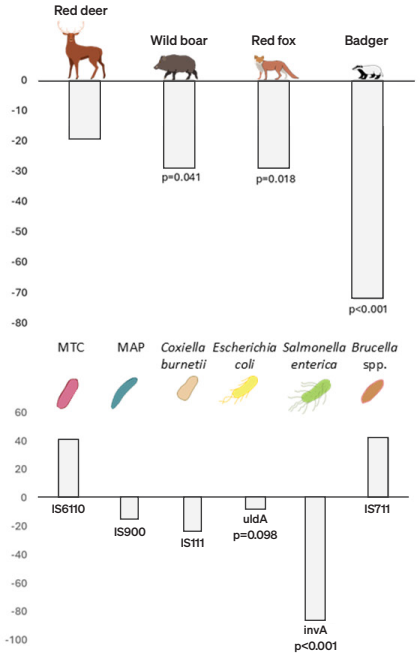


Figure 11. Reduction in wildlife farm visits and pathogen marker detection following implementation of Farm-specific Action Plans

Wild mammal farm visits were monitored using 30 camera traps per epidemiological unit (ten at water points, ten at feeders and ten at random locations) both before and after risk mitigation. Each deployment lasted 48 hours. Pathogen markers were identified by polymerase chain reaction testing on sponge swabs collected from ten animals, ten water points and ten feeders per epidemiological unit. Source: modified from Marín-Rojo et al. *(2025)*

Timeframe and documentation

Ideally, all participating epidemiological units should be assessed within a short timeframe: one to a few months for areas with fewer than 100 units, and up to one year for larger populations, such as subnational or national surveys. After delivering the FsAPs to each participating epidemiological unit, a one-year period is generally appropriate for implementing the recommended mitigation measures and evaluating their impact. Nonetheless, as in all biological fields, continuous monitoring of trends over time is preferable whenever feasible.

To see more detailed case studies, please refer to Annex 6. For further resources, please refer to Section 11.

TAKE ACTION

For documentation purposes, a basic file for each epidemiological unit should include the following items:

- FsAP.
- Checklist of the recommended mitigation actions, noting their implementation status and the producer's feedback.
- Monitoring records, including wildlife presence, pathogen circulation or disease incidence.

All records should be accessible to the Veterinary Authority to facilitate the evaluation of the FsAP's progress, the level of risk at the farm and any emerging critical situations.

10. Annexes

The following annexes provide detailed supporting materials and practical tools essential for comprehensively assessing and mitigating disease risk at the wildlife–livestock interface.

Annex 1. **Potential pathways for pathogen transmission and spread in a defined WLI and the relevance of wildlife**

https://zenodo.org/records/17826863

Annex 2. **Characteristics of the main wildlife host groups' relevance for assessing biosecurity at the WLI**

https://zenodo.org/records/17826863

Annex 3. **Photographs illustrating the variability of WLI interfaces across continents**

https://zenodo.org/records/17826863

Annex 4. **Additional materials – Videos, online courses and other resources**

https://zenodo.org/records/17826863

Annex 5. **Photographs illustrating potential risk points with assessed scores, proposed and implemented mitigation actions, and a list of required materials, work and costs.**

https://zenodo.org/records/17826863

Annex 6. **Case studies – Examples of real Farm-specific Action Plans for extensive cattle and intensive pigs and poultry, including follow-up templates**

https://zenodo.org/records/17826863

11. References

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12. Further Resources

The symbol 🔒 refers to a paywall, while 🔓 refers to open access. Wherever possible, open access resources have been provided. EN indicates an English-language publication, ES indicates a Spanish-language publication.

General resources on wildlife–livestock interactions

🔒 EN Diseases at the Wildlife–Livestock Interface

Vicente J, Vercauteren K, Gortázar C (Eds.). 2021. Diseases at the Wildlife–Livestock Interface: Research and Perspectives in a Changing World. Cham (Switzerland): Springer. https://link.springer.com/book/10.1007/978-3-030-65365-1

🔓 EN Global trends in infectious diseases at the wildlife–livestock interface

Wiethoelter AK, Bletrán-Alcrudo D, Kock R, Mor SM. 2015. Global trends in infectious diseases at the wildlife–livestock interface. PNAS, 112, 9662-7. https://doi.org/10.1073/pnas.1422741112

🔓 EN The coexistence of wildlife and livestock

Barroso P, Gortázar C. 2024. The coexistence of wildlife and livestock. Animal Frontiers, 14(1):5-12. https://doi.org/10.1093/af/vfad064

🔓 EN Cross-species transmission potential between wild pigs, livestock, poultry, wildlife, and humans

Miller RS, Sweeney SJ, Slootmaker C, *et al*. 2017. Cross-species transmission potential between wild pigs, livestock, poultry, wildlife, and humans: implications for disease risk management in North America. Sci Rep 7, 7821. https://doi.org/10.1038/s41598-017-07336-z

EN What is this infamous "wildlife-livestock disease interface?" A review of current knowledge for the African continent

Kock, RA. 2005. Conservation and Development Interventions at the Wildlife–Livestock Interface: Implications for Wildlife, Livestock, and Human Health. Osofsky, S. A. (Ed.). 'Chapter 1: What is this infamous "wildlife-livestock disease interface?" A review of current knowledge for the African continent.' Gland (Switzerland): International Union for Conservation of Nature (IUCN). https://wcs-ahead.org/book/chapter01.pdf

EN General guidelines for surveillance of diseases, pathogens and toxic agents in free-ranging wildlife

WOAH, IUCN. 2024. General guidelines for surveillance of diseases, pathogens and toxic agents in free-ranging wildlife: An overview for wildlife authorities and others working with wildlife. Paris, Gland, 56 pp. https://doi.org/10.20506/woah.3509

EN Bridge hosts, a missing link for disease ecology in multi-host systems

Caron A, Cappelle J, Cumming GS, de Garine-Wichatitsky M, Gaidet N. Bridge hosts, a missing link for disease ecology in multi-host systems. Vet Res. 2015 Jul 21;46(1):83. https://doi.10.1186/s13567-015-0217-9. PMID: 26198845; PMCID: PMC4509689.

References on risk assessment and mitigation at the WLI for specific production systems

EN A methodological framework to characterize the wildlife-livestock interface: The case of wild boar in mainland Spain

Ruiz-Rodríguez C, Blanco-Aguiar JA, Fernández-López J, Acevedo P, Montoro V, Illanas S, *et al*. 2024. A methodological framework to characterize the wildlife-livestock interface: The case of wild boar in mainland Spain. Prev. Vet. Med. 230:106280. https://doi.org/10.1016/j.prevetmed.2024.106280

EN Characterization and management of interaction risks between livestock and wild ungulates on outdoor pig farms in Spain

Jiménez-Ruiz S, Laguna E, Vicente J, *et al*. 2022. Characterization and management of interaction risks between livestock and wild ungulates on outdoor pig farms in Spain. Porc. Health. Manag. 8(2). https://doi.org/10.1186/s40813-021-00246-7

ES Manual para la actuación frente a la tuberculosis en fauna silvestre

Martínez-Guijosa J, Acevedo P, Balseiro A, García-Bocanegra I, Sáez-Llorente JL, Vicente J, *et al*. 2021. Manual para la actuación frente a la tuberculosis en fauna silvestre: Medidas de bioseguridad en explotaciones extensivas de ganado bovino. Ciudad Real (Spain): IREC. https://www.irec.es/wp-content/uploads/2021/07/Manual-Tuberculosis-explotaciones-ganaderas-ganado_compressed.pdf

EN Analysis of wild boar-domestic pig interface in Europe: spatial overlapping and fine resolution approach in several countries

ENETWILD-consortium, Illanas S, Fernández-López J, Acevedo P, Apollonio M, Blanco-Aguiar JA, *et al*. 2021. Analysis of wild boar-domestic pig interface in Europe: spatial overlapping and fine resolution approach in several countries. EFSA Supporting Publications. EN-1995, pp. 23 https://doi.org/10.2903/sp.efsa.2021.EN-1995

EN Tools and opportunities for African swine fever control in wild boar and feral pigs

Palencia P, Blome S, Brook RK, *et al*. Tools and opportunities for African swine fever control in wild boar and feral pigs: a review. Eur. J. Wildl. Res. 69(69). https://doi.org/10.1007/s10344-023-01696-w

EN Assessment of the factors that determine the presence of wild boars near outdoor and extensive pig farms in Eastern Europe

ENETWILD-consortium, Sebastián-Pardo M, Laguna E, Csányi S, Gacic D, Katona K, Mirceta J, *et al*. 2023. Assessment of the factors that determine the presence of wild boars near outdoor and extensive pig farms in Eastern Europe. EFSA Supporting Publications, 20(5)EN-8015, pp. 87. https://doi.org/10.2903/sp.efsa.2023.EN-8015

EN The Wild Side of Disease Control at the Wildlife-Livestock-Human Interface: A Review

Gortazar C, Diez-Delgado I, Barasona JA, Vicente J, De La Fuente J, Boadella M. 2015. The Wild Side of Disease Control at the Wildlife-Livestock-Human Interface: A Review. Front. Vet. Sci. 1:27. https://doi.org/10.3389/fvets.2014.00027

EN Wildlife–livestock interactions in animal production systems: what are the biosecurity and health implications?

Jori F, Hernandez-Jover M, Magouras I, Dürr S, Brookes VJ. 2021. Wildlife–livestock interactions in animal production systems: what are the biosecurity and health implications? Animal Frontiers, 11(5):8-19. https://doi.org/10.1093/af/vfab045

EN Balancing livestock production and wildlife conservation in and around southern Africa's trans-boundary conservation areas.

Thomson GR, Penrith M-L, Atkinson MW, Atkinson SJ, Cassidy D, Osofsky SA. 2013. Balancing Livestock Production and Wildlife Conservation in and around Southern Africa's Transfrontier Conservation Areas. Transbound. Emerg. Dis. 60:492-506. https://doi.org/10.1111/tbed.12175

EN Identifying reservoirs of infection: a conceptual and practical challenge

Identifying Reservoirs of Infection: A Conceptual and Practical Challenge. Emerg. Infect. Dis. 2002;8(12):1468-73. https://doi.org/10.3201/eid0812.010317

EN Effectiveness of cattle operated bump gates and exclusion fences in preventing ungulate multi-host sanitary interaction

Barasona JA, VerCauteren KC, Saklou N, Gortazar C, Vicente J. 2013. Effectiveness of cattle operated bump gates and exclusion fences in preventing ungulate multi-host sanitary interaction. Prev. Vet. Med. 111(1-2): 42-50. http://doi.org/10.1016/j.prevetmed.2013.03.009

EN One Health Farming: Noninvasive monitoring reveals links between farm vertebrate richness and pathogen markers in outdoor hoofstock.

Herrero-García G, Pérez-Sancho M, Barroso P, Herranz-Benito C, Relimpio D, García-Seco T, *et al*. 2024. One Health Farming: Noninvasive monitoring reveals links between farm vertebrate richness and pathogen markers in outdoor hoofstock. One Health, 19:100924. https://doi.org/10.1016/j.onehlt.2024.100924

EN Let's meet at the interface: modeling the spatial interaction between wild boar and domestic pigs in Argentina.

La Sala LF, Caruso N, Capobianco G, *et al*. Let's meet at the interface: modeling the spatial interaction between wild boar and domestic pigs in Argentina. Eur. J. Wildl. Res. 71(81). https://doi.org/10.1007/s10344-025-01955-y

EN Waterhole Characteristics in Tuberculosis Positive and Negative Beef Cattle Farms from Endemic Regions in Spain.

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