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The Wildlife–Livestock Boundary Is a Moving Epidemiological System: A Cross-Sector Veterinary Governance Architecture for Shared Pathogens, Surveillance Gaps, Farm Biosecurity, Landscape Change, Conservation Constraints, and Coordinated Intervention

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ABSTRACT

Wildlife–livestock disease interfaces are often managed as geographically stable boundaries between wildlife populations and production systems, yet the epidemiological conditions that generate cross-species risk are mobile, seasonal, environmentally mediated, and institutionally fragmented. This article develops an original non-empirical cross-sector governance architecture for interpreting the wildlife–livestock boundary as a moving epidemiological system. Evidence from wildlife ecology, livestock production, host movement, landscape epidemiology, environmental persistence, farm biosecurity, conservation, intervention science, surveillance, and One Health governance is integrated without assuming that contact establishes transmission, environmental detection establishes infectious persistence, or modelled intervention performance establishes field effectiveness. The analysis distinguishes biological interface conditions from observation processes and administrative responsibility, emphasizing that host distribution, farm permeability, resource sharing, carcass ecology, surveillance intensity, and management activity can shift the practical location and meaning of the boundary. The proposed architecture subsequently links heterogeneous signals to cross-sector interpretation, responsibility allocation, intervention choice, and adaptive reassessment while preserving conservation and social constraints. Its contribution is therefore organizational rather than predictive: it structures how evidence of different strength and origin could be translated into coordinated veterinary decisions. Applicability remains conditional on pathogen biology, species assemblage, production system, landscape, surveillance capacity, legal authority, and stakeholder objectives. Prospective multisite evaluation and external validation would be required before the architecture could be considered operationally effective.

Keywords: Wildlife–livestock interface, One health governance, Disease surveillance, Farm biosecurity, Landscape epidemiology, Adaptive management

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Introduction

Wildlife and livestock are connected through shared pathogens, landscapes, resources, movement routes, environmental reservoirs, and human management. These connections generate epidemiological consequences that can extend simultaneously into animal production, wildlife conservation, trade, and public health, but their importance varies markedly among host species, pathogens, production systems, and landscapes [1–3]. Treating the interface as a fixed edge between “wild” and “domestic” populations therefore risks obscuring the processes that actually create or remove transmission opportunity.

The central argument developed here is that the wildlife–livestock boundary is better understood as a moving epidemiological system whose position and importance change with host distribution, movement, land use, environmental contamination, farm permeability, surveillance effort, and intervention. Operational wildlife-health frameworks already emphasize that effective One Health activity depends on coordinated functions distributed across institutions rather than on a single professional sector [4]. Building on that premise, this article proposes a cross-sector governance architecture that separates evidence generation, interpretation, responsibility, intervention, and reassessment. The architecture is not presented as a validated control mechanism; rather, it is an evidence-bounded way of organizing decisions where biological interfaces and administrative jurisdictions do not align neatly.

The boundary as a dynamic epidemiological interface

A wildlife–livestock boundary can exist without a fence, and a fence can exist without constituting the epidemiologically important boundary. The relevant interface is produced by conditions that permit hosts, pathogens, contaminated material, or human-mediated movements to connect otherwise separated populations. This interpretation is consistent with the broader characterization of wildlife–livestock interfaces as heterogeneous systems rather than uniform points of contact [1].

The boundary may therefore shift at several scales simultaneously. Seasonal wildlife movement can alter local farm exposure; livestock management can change access to pasture or water; landscape modification can redistribute host use; and surveillance intensity can change what appears to be the spatial extent of infection. A further distinction is proposed here between the epidemiological boundary, where exposure opportunity changes, and the governance boundary, where responsibility, information access, or authority changes. Operational One Health frameworks support the need to define coordinated functions across sectors [4], but they do not establish that a particular administrative configuration will control disease. Keeping these boundaries analytically separate prevents institutional borders from being mistaken for biological ones.

Wildlife population dynamics

Wildlife population dynamics influence disease interfaces through abundance, spatial organization, movement, social structure, and community composition. Evidence does not support reducing these processes to a universal proposition that more wildlife necessarily means more livestock infection. In traditionally managed grazing landscapes, mammalian biodiversity and selected pathogen-exposure patterns in wild boar varied with livestock presence; local badger infectious neighbourhoods were associated with *Mycobacterium bovis* infection; and simulated African swine fever dynamics changed with habitat fragmentation and hunting pressure [5–7]. Together, these findings support heterogeneity rather than a single density rule.

Population management can also modify the interface it is intended to control. Removal, hunting pressure, altered resource availability, or landscape fragmentation may affect where animals aggregate or move, with epidemiological consequences that depend on the pathogen and host system. The modelling evidence for African swine fever is therefore informative about conditional mechanisms but cannot be generalized automatically to other reservoirs or landscapes [7]. In the proposed architecture, wildlife population state is treated as a changing input that must be interpreted jointly with movement, environmental conditions, and surveillance rather than as an isolated control target.

Livestock production systems

Livestock production systems determine how domestic animals occupy space, how feed and water are provided, whether animals range outdoors, and how farms can exclude or attract wildlife. These characteristics alter the meaning of wildlife presence around livestock. Evidence from traditional grazing systems illustrates that livestock occurrence can coexist with higher mammalian diversity and lower selected wildlife pathogen-exposure indicators rather than functioning uniformly as an amplification pressure [5]. Such observations argue against assigning extensive, traditional, or intensive systems an inherent epidemiological rank.

Production architecture instead modifies the pathways through which exposure can occur. Housing, fencing, pasture rotation, feed storage, water provision, carcass management, manure handling, stocking patterns, and human movement can each change interface permeability. Global wildlife–livestock evidence likewise shows that conflict and mitigation strategies vary greatly among systems [3]. The governance implication is that production type should not be used as a surrogate for risk. It should be treated as a set of operational conditions that constrain which surveillance and biosecurity measures are plausible and which exposure pathways require specific evidence.

Livestock and wildlife movement

Movement converts spatial proximity into changing opportunity for interaction. Multicountry tracking of wild boar around European pig farms showed that contact events were unevenly distributed among animals, farms, locations, and periods [8]. This supports targeted interpretation of movement signals but does not establish that recorded proximity produced pathogen transmission. Movement data become more epidemiologically meaningful when interpreted alongside livestock management: integrating elk telemetry with cattle-management information demonstrated how spatial overlap can be refined into context-dependent exposure assessment [9]. Such risk indices remain proxies rather than infection probabilities.

The interface can also be displaced by humans. Retrospective analysis of wild-boar shipments showed how managed animal movement could create a long-distance route for African swine fever introduction beyond immediately adjacent wildlife populations [10]. Consequently, local wildlife mobility and anthropogenic translocation should remain separate analytical categories.

Table 1 presents movement mechanisms that create wildlife–livestock contact opportunities at different scales.

Table 1. Movement mechanisms that create wildlife–livestock contact opportunities at different scales

Movement mechanism	Livestock-space configuration	Wildlife expression	Joint evidence stream	Intervention locus	Scale or time limit
Local farm visitation	Farm edge, housing, feed or water access	Repeated approach to livestock premises	**Conditions:** Season, farm attraction, barriers, individual behaviour **Observed:** GPS proximity, camera detections, tracks or sightings	Prioritize verification of the specific access pathway	**Limit:** Presence or proximity does not establish infectious contact **Refresh:** Reassess after farm practice, season, or wildlife-use pattern changes **Basis:** Evidence-supported distinction
Concentrated contact opportunity	Only a subset of farms or animals contributes disproportionately	Uneven use of farm-adjacent space	**Conditions:** Host identity, time of day, farm type, resource availability **Observed:** Recurrent animal–farm co-location	Target surveillance or mitigation where opportunity is concentrated	**Limit:** Sampling may miss infrequent animals or short contacts **Refresh:** Repeat movement assessment rather than extrapolating from a single period **Basis:** Evidence-supported distinction
Management-conditioned overlap	Livestock location changes with husbandry	Wildlife range intersects managed livestock space	**Conditions:** Grazing schedule, pasture rotation, feed placement, fencing **Observed:** Telemetry interpreted with management records	Modify the specific husbandry pathway where feasible	**Limit:** Risk index remains a proxy for exposure **Refresh:** Reassess when management configuration changes **Basis:** Evidence-supported distinction
Anthropogenic relocation	Interface is created beyond the local landscape	Wildlife transported between territories	**Conditions:** Trade rules, source status, destination ecology, containment **Observed:** Shipment or translocation records	Evaluate release and onward-interface risk separately from local movement	**Limit:** Historical movement patterns may not represent current regulation **Refresh:** Reassess after regulatory or trade-network change **Basis:** Evidence-supported; cross-scale synthesis proposed

Shared grazing and water resources

Shared grazing areas, water points, feed resources, mineral sites, and other attractants can concentrate wildlife and livestock in the same landscape, but co-use is not equivalent to transmission. Their epidemiological importance depends on timing, species behaviour, pathogen route, environmental survival, production practice, and whether direct or indirect exposure is biologically plausible. Evidence from traditionally grazed systems demonstrates that livestock presence can coexist with ecological configurations not consistent with a simple amplification assumption [5].

Movement studies further show why shared resources require temporal interpretation. Wild-boar contact with farms is uneven rather than uniformly distributed [8], while integrated telemetry and livestock-management data demonstrate that the same spatial overlap can have different implications depending on how livestock use the landscape [9]. A shared resource should therefore be treated as a conditional exposure field, not a preclassified hotspot. This is a proposed analytical distinction. Surveillance or intervention should be intensified when host use, management, and pathogen biology converge to make exposure plausible, while non-concurrent or biologically incompatible resource sharing should not be assigned equivalent importance merely because both sectors occupy the same mapped location.

Landscape and habitat change

Landscape is an active epidemiological variable because it shapes host distribution, movement corridors, farm exposure, vectors, environmental persistence, and detectability. Empirical and review evidence shows that these relationships are neither uniform nor necessarily monotonic: wild-boar exposure to *Coxiella burnetii* varied with environmental correlates, poultry spillover risk reflected both environmental conditions and farm-level protection, and climate effects on livestock disease can increase, decrease, or redistribute suitability depending on the pathogen and vector system [11–13]. Landscape change therefore cannot be represented as a generic directional "risk increase."

The proposed architecture treats land-use and climatic change as modifiers of several pathways at once. Habitat fragmentation may alter wildlife movement; agricultural intensification may change attraction and exclusion mechanisms; drought may redistribute animals around water; and changing vegetation or weather can influence where carcasses or environmental contamination are detected. These cross-domain links should remain hypotheses unless directly measured. Their governance importance lies in forcing reassessment: a surveillance design, farm barrier, or wildlife intervention calibrated to one landscape state may become poorly matched when host use or environmental conditions shift.

Pathogen maintenance

Shared-pathogen persistence should not be assigned automatically to a single wildlife reservoir. Maintenance may result from within-species transmission, spatially structured neighbourhoods, recurrent cross-species exposure, environmental contamination, anthropogenic reintroduction, or combinations of these processes. Badger data show that local intra- and interspecific neighbourhood structure can be associated with *M. bovis* infection [6], whereas African swine fever modelling indicates that population and landscape configuration can alter persistence and control dynamics [7]. These findings support mechanism-specific interpretation rather than a generic reservoir label.

Long-distance movement introduces another possibility: a local system that appears self-maintaining may also be repeatedly reseeded by animal movement or trade [10]. Distinguishing maintenance from reintroduction matters because the appropriate intervention differs. The article therefore proposes that pathogen maintenance be adjudicated across three questions: whether infection can persist within hosts, whether environmental material can remain epidemiologically relevant, and whether repeated external introduction is plausible. Failure to distinguish them can lead to prolonged wildlife control when the important pathway lies elsewhere, or to premature relaxation of controls where environmental or networked pathways remain unresolved.

Environmental persistence

Environmental evidence is particularly vulnerable to inferential overreach. An integrated highly pathogenic avian influenza investigation demonstrated the value of combining wildlife, poultry, and environmental observations when reconstructing an interface event [14]. However, detecting pathogen material in water, soil, premises, or other environmental matrices does not by itself establish viable persistence, infectivity, or direction of transmission. Environmental detection should therefore be interpreted as a signal requiring biological and temporal context.

Carcass-mediated systems illustrate a stronger persistence mechanism. Delayed detection of African swine fever-positive wild-boar carcasses has been associated with conditions favouring sustained transmission opportunity [15], while carcass-location studies indicate that habitat can structure where infected animals die and consequently where carcasses are likely to be found [16]. The observation process is therefore partly ecological: surveillance may appear weak because contamination is absent, or because relevant material is difficult to detect.

Table 2 presents environmental-pathway hypotheses separated by detection, persistence, carcass delay, and habitat observability.

Table 2. Environmental-pathway hypotheses separated by detection, persistence, carcass delay, and habitat observability

Environmental observation	Persistence hypothesis	Detectability structure	Control lever	Evidence that would establish or weaken the pathway
Configuration: Detection without demonstrated persistence **Observed:** Positive environmental detection or linked host/environment observations	Environmental material may document contamination or interface connectivity	Sampling timing, matrix, assay, host activity	Investigate source, timing, and biological plausibility before escalating causal claims	**Unresolved:** Detection does not prove viability, infectious dose, persistence, or transmission direction **Test:** Repeat sampling or pair environmental results with host epidemiology **Basis:** Evidence boundary
Configuration: Repeated contamination in a biologically plausible interface **Observed:** Recurrent compatible detections with host or premise context	Environmental pathway becomes more credible but remains pathway-specific	Pathogen stability, temperature, moisture, host access	Consider environmental pathway in control design	**Unresolved:** Repetition still may not demonstrate effective transmission **Test:** Reassess after environmental management or seasonal change **Basis:** Proposed interpretive state
Configuration: Carcass-associated persistence with delayed discovery **Observed:** Positive carcasses and delayed detection/removal	Infected carcasses may extend exposure opportunity after host death	Carcass longevity, scavenging, removal capacity, access	Prioritize timely search and removal where biologically justified	**Unresolved:** Strength and duration are pathogen- and setting-dependent **Test:** Track detection delay and revise search effort **Basis:** Evidence-supported distinction
Configuration: Habitat-structured observability **Observed:** Non-random carcass locations or search yield	Apparent absence may reflect where carcasses or contamination can be detected	Vegetation, terrain, water, search accessibility	Design surveillance around detectability, not uniform spatial effort	**Unresolved:** Search bias can distort apparent disease geography **Test:** Reallocate search effort as habitat and season change **Basis:** Evidence-supported; surveillance synthesis proposed

Surveillance asymmetry

Surveillance is not evenly distributed across wildlife, livestock, farms, landscapes, or environmental matrices. Some compartments are routinely sampled; others are observed mainly during outbreaks, carcass searches, or targeted studies. The resulting asymmetry can distort the apparent location of the interface: low detection may represent low infection, weak access to the relevant host or habitat, or insufficient surveillance. Environmental and carcass evidence therefore requires interpretation alongside how and where observation occurs.

This article proposes surveillance asymmetry as a governance variable rather than merely a technical limitation. If one sector has substantially better observability than another, decisions should record which population is directly measured and which is inferred. Later evidence supports operational maturity, sentinel information, and changing risk, without assuming that one host can always proxy another.

Farm-level biosecurity

Farm biosecurity converts broad interface risk into controllable premises-level conditions. A wildlife-focused external biosecurity protocol for intensive pig farms demonstrates that perimeter integrity, wildlife access, attractants, and other external vulnerabilities can be assessed systematically [17]. Such assessment structures risk identification but does not establish a validated incursion probability.

Farm practices also differ in their association with infection signals. In Bangladeshi commercial chicken farms, avian influenza circulation varied with reported biosecurity practices [18]. Because the evidence is observational, those associations should not be reframed as guaranteed preventive effects. In Mediterranean cattle systems, an on-farm wildlife-risk mitigation protocol showed that wildlife-related tuberculosis risks can be translated into farm-specific mitigation actions [19]. Together, these studies support identifying interface permeability, matching feasible controls to pathways, and reassessing after conditions change.

Wildlife management

Wildlife management can modify abundance, movement, carcass availability, habitat use, and surveillance access at the same time. Consequently, an action aimed at reducing one epidemiological pathway may alter another. African swine fever modelling shows that hunting effects depend on landscape and population configuration [7], while carcass ecology demonstrates that surveillance and removal opportunities are habitat structured [16]. These findings do not support a universal "more removal equals less risk" rule.

The proposed principle is objective–intervention matching. Population reduction, carcass removal, exclusion, vaccination, habitat modification, or intensified surveillance should be selected according to the mechanism being targeted and the evidence available for that host–pathogen setting. Farm-focused mitigation evidence also shows that intervention feasibility can be localized rather than assumed at system level [19]. The following register separates management states from permissible claims. **Table 3** presents wildlife interventions matched to the transmission or exposure mechanism they are intended to alter.

Table 3. Wildlife interventions matched to the transmission or exposure mechanism they are intended to alter

Wildlife action	Targeted pathway	Conditions for mechanistic fit	Process indicator	Livestock-side decision	Failure test
Population reduction	May alter host abundance and encounter structure	Landscape connectivity, compensatory movement, host demography	Removal effort, abundance indices, movement response	Use only when the targeted mechanism plausibly depends on population state	**Limit:** Reduced abundance does not prove reduced transmission **Reassess:** Reassess host redistribution and disease indicators **Basis:** Evidence-bounded interpretation
Carcass search and removal	Targets post-mortem exposure for relevant pathogens	Habitat, detectability, removal delay, scavenging	Search yield, detection delay, carcass location	Prioritize where carcass-mediated exposure is biologically credible	**Limit:** Search success may reflect detectability rather than carcass density **Reassess:** Adapt search allocation to habitat and season **Basis:** Evidence-supported distinction
Farm-interface mitigation	Reduces selected opportunities for wildlife access or contamination	Farm design, attractants, fencing, husbandry	On-farm vulnerability assessment and corrective action	Match measures to identified access pathways	**Limit:** Feasibility does not establish disease effectiveness **Reassess:** Reaudit after operational or environmental change **Basis:** Evidence-supported distinction
Multi-action wildlife strategy	Combines measures acting on different pathways	Pathogen biology, conservation limits, resources, stakeholder acceptance	Component-specific process and surveillance indicators	Preserve separate objectives and evaluate components individually	**Limit:** Package success cannot validate every component **Reassess:** Revise or discontinue unsupported components **Basis:** Proposed synthesis

Conservation constraints

Disease governance can become distorted when wildlife is represented only as a reservoir or hazard. Conservation scholarship argues that zoonotic and wildlife-health research should also generate biodiversity value and avoid treating spillover reduction as the sole legitimate endpoint [20]. This matters where protected species, habitats, or ecosystem functions constrain otherwise plausible interventions.

Wildlife-trade guidance similarly shows that disease risk may need to be considered alongside welfare and conservation consequences rather than through a single-objective rule [21]. These constraints may limit culling, fencing, habitat manipulation, translocation, or disturbance even when epidemiologically attractive. Stakeholder work on foot-and-mouth disease control in South Africa further demonstrates that preferences for control options differ among groups [22]. Conservation constraint is therefore not evidence against intervention; it is a decision condition requiring explicit consideration of ecological obligations, welfare, legal authority, and social legitimacy.

Economic and social trade-offs

Interface interventions redistribute costs and benefits. Farmers, wildlife agencies, conservation actors, and public authorities can bear different costs and prioritize production, ecology, trade, or outbreak containment differently. Wildlife-trade guidance makes these competing objectives explicit [21], while stakeholder analysis shows that preferred disease-control options can vary across affected groups [22].

The architecture therefore rejects a single composite "best intervention" when evidence cannot justify common weighting. Epidemiological plausibility, operational feasibility, conservation compatibility, distribution of costs, and legitimacy should remain visible as separate decision dimensions. No numerical utility is assigned here. Where one objective is prioritized, the choice should be documented rather than disguised as a purely technical conclusion. This preserves the distinction between what evidence suggests about disease processes and what institutions decide under competing social and ecological obligations.

A proposed wildlife–livestock governance architecture

The proposed architecture organizes the moving interface through five functions: signal acquisition, cross-sector interpretation, responsibility assignment, intervention selection, and adaptive reassessment. Governance evidence supports distinguishing coordination, engagement, policy, and financing functions rather than treating collaboration as a single activity [23]. Communication-network research further indicates that practical information pathways may differ from formal institutional hierarchies [24]. Accordingly, the architecture assigns responsibility according to function, access to evidence, and authority to act, not simply agency identity.

Cross-sector coordination is treated as conditional. Dynamic modelling of SARS-CoV-2 in deer found coordinated One Health actions more effective than isolated sectoral actions in that specific system [25], while a broad review of One Health surveillance systems shows that nominal integration does not necessarily translate into operational integration [26]. The proposed escalation rule intensifies coordination when evidence, authority, or intervention dependencies cross administrative boundaries, and limits it when one competent sector can act without unmanaged external effects.

The figure below compresses how heterogeneous interface signals become decisions without erasing uncertainty or sectoral boundaries.

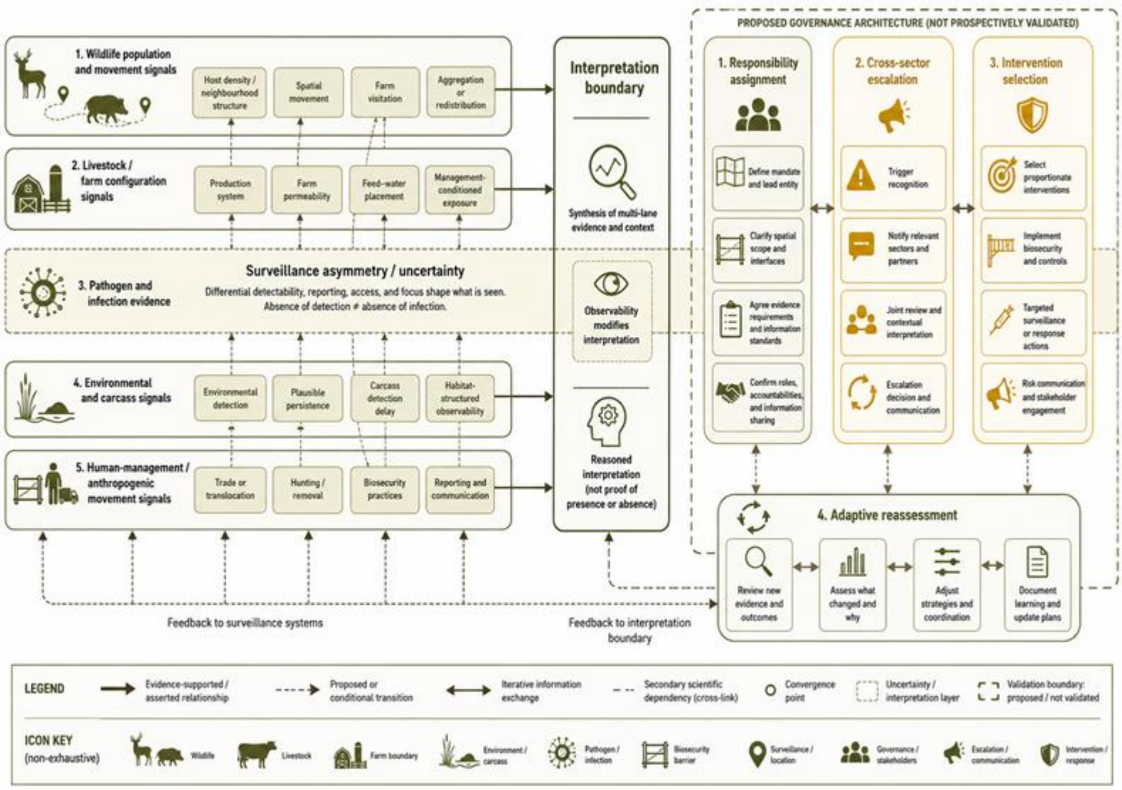

Figure 1. Signal convergence at a moving wildlife–livestock boundary: evidence translation, escalation, and reassessment

Cross-sector decision responsibilities

Decision responsibility should follow the function required at each boundary state. Wildlife agencies may possess host-distribution information, veterinary services may control livestock surveillance and farm measures, environmental bodies may govern habitat or water, and public-health or local authorities may hold additional data or legal powers. Operational One Health frameworks support explicit functional coordination [4], while governance research indicates that these functions are institutionally separable [23].

Formal authority is insufficient if actionable information travels elsewhere. Smallholder communication networks demonstrate that trusted and frequently used animal-health pathways can differ from institutional assumptions [24]. The proposed rule pairs each decision with an evidence holder, an accountable action authority, and a defined handoff when these roles diverge. Cross-sector governance should be triggered by dependency, not symbolism.

Table 4 presents governance arrangements required when evidence ownership, legal authority, and external consequences diverge.

Table 4. Governance arrangements required when evidence ownership, legal authority, and external consequences diverge

Governance mismatch	Evidence and authority co-located	Evidence held outside action authority	Shared causal uncertainty	Cross-sector external effects
Epidemiological meaning	One competent sector can interpret and act on the relevant pathway	Signal cannot become action without transfer	Several sectors hold partial, non-equivalent evidence	A sector can act, but costs or ecological consequences fall elsewhere
Authority or capacity condition	Legal mandate, technical capacity, local scope	Data access, interoperability, trust, reporting delay	Surveillance asymmetry, environmental ambiguity, species uncertainty	Conservation law, farm burden, welfare, trade implications
Evidence distribution	Direct sector-owned surveillance plus actionable control option	Verified signal plus identified external authority	Discordant host, farm, or environmental signals	Actionable pathway plus documented external consequence
Governance form required	Sector-led action with transparent notification to affected partners	Formal handoff and receipt confirmation	Joint interpretation before irreversible intervention	Escalate to multi-objective decision process
What coordination cannot solve	External effects may still emerge	Information loss or delay can alter relevance	Coordination cannot eliminate evidential uncertainty	No evidence-based universal weighting exists
Condition for transfer or reopening	Escalate if consequences cross sectors	Track whether transfer changes action timing	Reassess as new evidence changes plausibility	Reopen decision if objectives or constraints change
Basis	Proposed governance rule	Proposed governance rule	Proposed governance rule	Proposed governance rule

Intervention choices

Wildlife-interface interventions should be treated as conditional portfolios rather than as a fixed hierarchy. Field comparison of wild-pig population-control methods demonstrates that operational efficiency, logistics, and resource demands differ by method and setting [27]. Those differences justify component-level selection, not universal ranking.

Modelled African swine fever control indicates that hunting and intensive carcass removal can be complementary under specified conditions [28]. Oral vaccination against classical swine fever in wild boar likewise has a spatially bounded operational footprint [29], reinforcing that interventions should be matched to the scale of the pathway being targeted. Raccoon-rabies contingency evaluation further shows why deployed components should not be presumed equally effective: some contributions can remain uncertain even within an overall response [30]. The proposed architecture requires each intervention to state its mechanism, reach, constraints, and reassessment criterion. Combined actions should remain decomposable so ineffective or unnecessary components can be revised without abandoning the entire response.

Conflict and competing objectives

Conflict is not merely an implementation defect. It can be intrinsic to interface governance because stakeholders experience different disease risks, costs, legal obligations, welfare concerns, and conservation consequences.

Differences in foot-and-mouth disease control preferences illustrate that legitimate groups may rank options differently even when responding to the same disease problem [22]. Operational evidence also shows that wildlife-control methods differ in resource demands [27].

The proposed architecture therefore preserves unresolved disagreement rather than converting it into an unsupported numerical score. A technically plausible action may remain unacceptable, unlawful, unaffordable, or ecologically disproportionate. Conversely, a socially preferred action may provide weak epidemiological leverage. Component-level uncertainty also matters: rabies contingency evaluation demonstrates that intervention packages can contain measures whose independent contribution is unclear [30]. Governance should document these conflicts explicitly, identify which objective is being prioritized, and specify conditions under which the decision will be revisited.

Evaluation and adaptive governance

Evaluation must address both epidemiological signals and governance performance. A recent scoping review of animal-health syndromic surveillance found substantial variation between proof-of-concept systems and sustained operational implementation [31]. Technical detection capability therefore is not equivalent to durable surveillance capacity.

Where wildlife observation is difficult, cross-species information may sometimes reduce asymmetry. Modelling of bovine tuberculosis surveillance showed that livestock can, under defined spatial conditions, provide sentinel information about infection in a wildlife reservoir [32]. This is a conditional strategy, not a general substitute for wildlife surveillance. Adaptive risk-based surveillance further supports reallocating effort as risk changes rather than maintaining static targeting [33]. Participatory modelling for African swine fever preparedness identified coordination, legal clarity, leadership, and operational resources as salient governance constraints [34]. The proposed architecture evaluates whether signals were detected, interpreted, transferred, acted upon, and reassessed, while leaving effectiveness to prospective testing across host–pathogen and institutional systems.

Conclusion

The wildlife–livestock boundary is best treated as a changing epidemiological and governance problem rather than a fixed spatial line. Host dynamics, movement, production practice, shared resources, landscape conditions, environmental persistence, surveillance effort, conservation constraints, and institutional authority can each shift where risk becomes actionable. The architecture proposed here separates observation from interpretation, epidemiological boundaries from administrative ones, and technical plausibility from governance choice. Its purpose is to make cross-sector decisions more explicit and auditable, not to claim a universally effective control system. Applicability remains pathogen-, species-, landscape-, production-, and jurisdiction-dependent. Prospective comparative evaluation, external validation, and repeated testing under changing surveillance and ecological conditions are required before operational effectiveness can be inferred.

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