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Transboundary Livestock Disease Control: Insights from the PRC and other GMS Countries

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NOTES

The views expressed are those of the authors and do not necessarily reflect the views and policies of the ADB, UNFAO or the governments they represent.
In this publication, the symbol “$” refers to US dollars.

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Abbreviations

ADB – Asian Development Bank
AGP - Antimicrobial Growth Promoters
AMA – Antimicrobial Agent
AMR – Antimicrobial Resistance
AMU – Antimicrobial Use
APVAX – Asia-Pacific Vaccine Access Facility
ASEAN – Association of Southeast Asian Nations
CDDEP - Center for Disease, Dynamics Economics & Policy
COVAX - COVID-19 Vaccines Global Access (Facility)
CPI – Consumer Price Index
EFSA - European Food Safety Authority
ENI – The Economist Normalcy Index
ESCAP – (United Nations) Economic and Social Commission for Asia and the Pacific
FAO – United Nations Food and Agriculture Organization
FTA – Free Trade Agreement
GDP – gross domestic product
GLEAM - Global Livestock Environmental Assessment Model
GMS – Greater Mekong Sub-region
HPAI – Highly Pathogenic Avian Influenza
ICT – information and communication technology
ILO – International Labor Organization
LMIC - Livestock Marketing Information Center
LPL - Livestock Policy Lab
MAFF – Ministry of Agriculture, Forestry and Fisheries (Cambodia)
MARA – Ministry of Agriculture and Rural Affairs (The People's Republic of China)
MOC – Ministry of Commerce (Cambodia)
OECD – Organisation for Economic Co-operation and Development
PRC – The People's Republic of China
SDGs – Sustainable Development Goals
SMEs – small and medium-sized enterprises
SPS – sanitary and phytosanitary
TA – Technical Assistance
UNCTAD – United Nations Conference on Trade and Development
UNDP – United Nations Development Program
UNICEF – United Nations Children's Fund
WGA – Working Group on Agriculture
WHO – World Health Organization

Executive Summary

This paper examines how the Greater Mekong Subregion (GMS) can manage the risk of transboundary animal diseases (TADs) in a predictable and affordable way. Regional integration has increased both individual country livestock disease risk exposure and interdependence. Livestock production is denser, cross-border movements more frequent, and expanding value chains are linking farms, processors, and cold chains across more jurisdictions. Wildlife–livestock interfaces are also more dynamic than a decade ago. Country systems have improved, but four dimensions of the TAD challenge still decide outcomes: early warning, data exchange, zoning and compartmentalization, and mutual recognition of animal-health standards. When outbreaks occur, linkages across and between these dimensions raise the total cost of control and can shake confidence in domestic and transboundary markets.

It must also be borne in mind that livestock disease risk presents direct threats to human health. Over 200 zoonotic (animal originating human) diseases have been identified in the medical literature. Recent evidence makes it clear that over 60% of new infectious diseases in humans have animal origins.[1] Changes in animal husbandry (e.g., agricultural intensification, global trade) facilitate the emergence and cross-over of pathogens. Increased animal mobility via transboundary livestock trade thuspresents both a challenge and opportunity, the risk of more extensive transmission but also a framework for more determined health surveillance and veterinary intervention.

The epidemiology of TADs is familiar. Top priority diseases continue to circulate across the GMS: Highly Pathogenic Avian Influenza (HPAI), African Swine Fever (ASF), Foot-and-Mouth Disease (FMD), Classical Swine Fever (CSF), Newcastle Disease (ND), Hemorrhagic septicaemia, Brucellosis, Lumpy Skin Disease (LSD), and Bluetongue (BT). Patterns differ by country and by value chain, but the logic is the same. Direct losses come from mortality and culling. Indirect losses come from transport delays, price swings, and fiscal pressure. Prevention pays when systems move fast from suspicion to action and when clear rules keep low-risk trade moving.

After biogenesis of an outbreak, the main sources of risk are institutional, not technical. Information is often delayed, or it is in a format that cannot be shared. The level that pays for routine prevention does not always capture the wider benefits. At borders, thresholds, laboratory standards, and certificates differ, so coordination stops. Technology helps, but it does not replace agreements on what to collect, when to act, and how to recognize each other's procedures. This report proposes a practical framework that identifies and stratifies risk, makes systems interoperable, and finances outcomes that are relevant for disease control and trade continuity.

Regional Approach

Risk differentiation focuses attention where infection probability and consequences are largest, such as specific corridors, commodities, seasons, and wildlife–livestock interfaces. Regional coordination makes systems talk to each other. A minimum case and laboratory data set lets provinces talk to capitals, and capitals talk to neighbors, without weeks of translation. Triggers for notification are aligned. Roles across veterinary, customs, and border agencies are clear. Joint responses are rehearsed before the next emergency. Results-based financing links public outlays to a short list of performance indicators that people can verify: time from detection to reporting, laboratory turnaround, traceback

[1] Nguyen, Thanh Trung, Thi Ngan Mai, Sinh Dang-Xuan, Hung Nguyen-Viet, Fred Unger, and Hu Suk Lee. "Emerging zoonotic diseases in Southeast Asia in the period 2011–2022: a systematic literature review." *Veterinary Quarterly* 44, no. 1 (2024): 1-15.

accuracy, the share of production under certified zones, clearance times for compliant consignments, and adherence to antimicrobial rules.

Priority Order

This report orders diseases by the scale and immediacy of the shocks they have already produced in the subregion and nearby markets. Highly pathogenic avian influenza comes first. Viet Nam culled about 60 million birds, Thailand lost its position as the world's fourth-largest exporter, and egg prices in the United States surged. African swine fever virus follows. China lost 27.9 million tons of pork between 2018 and 2021, roughly 18 percent of normal output, and Viet Nam went through nationwide disruption in 2019. Foot-and-mouth disease comes next because of its direct effect on market access and border rules across livestock. Classical swine fever follows with single episodes large enough to matter on their own: during the 1997–1998 epidemic in the Netherlands, pre-emptive culling on uninfected farms alone reached about 1.1 million pigs and pushed total losses above US$2.3 billion, while in 2000 the United Kingdom paid more than £4.3 million in compensation. Newcastle disease comes next, with documented poultry costs in Australia of A$26.4 million in direct losses and about A$200 million in indirect losses. Hemorrhagic septicaemia follows with estimated annual losses of about US$792 million in Asia. Brucellosis remains a persistent zoonotic threat that affects both public health and livestock production, although the short-run trade spillovers in the material used here are smaller. Lumpy skin disease virus appears smaller and more localised in this evidence base, with producer losses of about US$3.5 million in Lao PDR in 2021–2022 and local herd-level impacts in Thailand. Bluetongue virus closes the list, with quantified losses concentrated in Europe, where the Netherlands alone absorbed net costs of €32.4 million in 2006 and a further €117–128 million in 2007, and the direct link to the Greater Mekong Subregion is weaker. The ordering is meant to guide near-term focus. The accompanying table shows what that means in practice.

Table 1: Cross-disease comparison for the GMS Countries

Disease	Priority	Risk & Significance	Epidemiological Pattern	Key Interventions
Highly Pathogenic Avian Influenza (HPAI)	Highest	Poultry exposure is largest, and shocks spill quickly into trade and prices. Recent waves show that once HPAI escapes, culling and market disruption are on a different scale from other diseases.	Recurrent global waves rather than one-off events; H5 viruses now behave like a permanent background risk with occasional sharp spikes.	Keep HPAI at the centre of regional early warning, link wild-bird, poultry and dairy surveillance, and use zoning and compartmentalization so safe flows can continue while high-risk areas are contained.
African Swine Fever (ASF)	High	Swine remain central in diets and rural incomes in China and Viet Nam, and the first ASF wave left very large losses. Recovery is incomplete and producers still price in the risk.	After the initial crisis, outbreaks became less explosive but more chronic, with flare-ups along wild-boar and smallholder corridors and visible effects on prices.	Invest in fencing and carcass management where wild and domestic pigs meet, standardize traceback and notification, and keep restocking rules clear enough that farmers feel it is safe to re-enter.
Foot-and-Mouth Disease (FMD),	High	FMD does not always kill many animals, but it still decides who can trade where. Even small events close export doors and trigger long negotiations with trading partners.	Endemic pressure in parts of the GMS, with clean and infected zones operating side by side and vaccination quality uneven across provinces.	Focus vaccination and surveillance on high-value zones, upgrade certification and zoning rules that neighbours recognise, and keep predictable channels open for compliant consignments.
Classical Swine Fever (CSF),	Medium–High	CSF episodes are rarer than ASF but when they do break out, the combination of culling, welfare losses and trade reactions is still material.	Control is highly program-driven: where vaccination and movement rules are enforced, CSF stays quiet; where coverage slips, occasional epidemics re-appear.	Maintain vaccination where it is already policy, treat new clusters as early warning of coverage gaps, and pair movement control with rapid confirmation and transparent compensation.
Newcastle Disease (ND)	Medium	Newcastle disease keeps poultry systems uneasy even when vaccines are cheap and available. Coverage gaps and confusion with HPAI still create volatility.	Cyclical within poultry chains, with more issues in backyard and market-oriented flocks than in large integrated operations.	Use ND to strengthen basic poultry biosecurity and vaccination practice, and ensure provincial labs can reliably distinguish ND from HPAI on a predictable timetable.
Hemorrhagic Septicemia	Medium	HS remains a notable killer of cattle and buffalo in Asia but, in the current evidence base, its cross-border spillovers and trade effects look smaller than those of ASF or HPAI.	Seasonal hotspots along known trading and grazing corridors, overlaid on very patchy routine reporting.	Bundle HS vaccination and outbreak clean-up into routine large-ruminant services in hotspot districts, and improve case and lab recording so programme managers can see where the disease persists.
Brucellosis	Medium	Brucellosis is a classic One Health problem: it quietly damages public health and livestock productivity over long periods, even when short-run market reactions are muted.	Chronic, location-specific clusters that move slowly with changes in dairy, small-ruminant and occupational exposure patterns.	Align animal and human surveillance, tighten testing in dairy and breeding chains, and invest in worker protection and prescription compliance where incidence is known or suspected.
Lumpy Skin Disease (LSD)	Medium–Low	LSD is now established in parts of the region but, so far, with a smaller documented economic footprint than HPAI or ASF, and clearer control tools.	First a rapid spread phase, then more localized outbreaks as vaccination and movement rules start to bite; information quality differs widely by country.	Secure vaccine supply and protocols for cattle, target surveillance along trading and grazing routes, and coordinate movement documentation with neighbours to avoid gaps in the control belt.
Bluetongue (BT)	Low	Most quantified losses come from European outbreaks; inside the GMS the bigger concern is how little we know about BTV rather than evidence of large shocks to date.	High seroprevalence and competent vectors documented just across the border in southern China, contrasted with almost no recent national-level reporting from GMS countries.	Treat BTV as a priority data-gap disease: start low-cost serosurveys in goats and sheep, basic vector trapping and simple cross-country reporting templates, so future policy rests on more than an evidence vacuum.

For each disease and country pair, this report cross-checked WOAH/WAHIS, recent FAO situation updates, and national official reports up to 2025. When older figures were still the newest official data that could be found, the text notes that they represent the latest available information. When no recent official data were found at all, the disease and country pair is treated as a data gap and flagged in the synthesis table on data availability and gaps.

Table 2： Disease data gaps for the GMS Countries

Disease	China	Cambodia	Lao PDR	Thailand	Vietnam	Myanmar
Highly Pathogenic Avian Influenza (HPAI)	No gap	Gap	Gap	No gap	No gap	Gap
African Swine Fever (ASF)	No gap	No gap	No gap	No gap	No gap	Gap
Foot-and-Mouth Disease (FMD),	No gap	Gap	Gap	Minor gap	Gap	Gap
Classical Swine Fever (CSF),	No gap	Gap	Gap	No gap	No gap	Gap
Newcastle Disease (ND)	No gap	Gap	Gap	No gap	No gap	Gap
Hemorrhagic Septicemia	No gap	Gap	Gap	No gap	Minor gap	Gap
Brucellosis	Minor gap	Gap	Gap	Minor gap	Gap	Gap
Lumpy Skin Disease (LSD)	No gap	No gap	Gap	Minor gap	Minor gap	Gap
Bluetongue (BT)	No gap	Gap	Gap	Minor gap	Gap	Gap

In this table, “Gap” indicates that no recent official data were identified for that disease and country pair. “No gap” means the country section already draws on the latest accessible data from WOAH/WHO or national sources. “Minor gap” refers to partial coverage. For example, series that stop a few years early, or cases where numerical detail is missing but the qualitative story remains correct.

Core Functions

Early warning is the first place to invest. Use one standard data spine: the case, the lab result, the epidemiological links, and the action taken. Interoperability cuts the time from suspicion to confirmation. Proficiency testing and regular publication of time-to-result show where support is needed. Zoning and compartmentalization make control proportional. Scientifically defined zones and differentiated movement rules keep flows open where risk is low and focus restrictions where risk is high. Mutual recognition of certificates, lab protocols, and animal-ID systems reduces duplication and uncertainty. For compliant operators, recognition should show up as lower transaction costs in visible ways. At the farm level, biosecurity is still the lowest-cost defense. Use clear, tiered standards, such as physical separation, vehicle and personnel hygiene, feed and water controls, stocking density, vaccination plans, and booster schedules. Pair audits with practical training and realistic upgrade timelines. Where wild boar and domestic pigs overlap, use fencing, habitat management, and better waste handling to reduce contact and cumulative risk. Antimicrobial resistance (AMR) is part of the main plan. Enforce prescription rules. Use alternatives to routine antibiotics. Test at slaughter and along the cold chain. Align animal-health and public-health surveillance so indicators and messages are coherent.

Financing, Monitoring, and Communication

RBF gives ministries and partners a common yardstick and rewards steady work, timely reporting, reliable lab throughput, and consistent farm audits, rather than campaigns that fade after a crisis. Keep indicators few, measurable, and independently verified. Tie disbursements to milestones and publish progress in a format the public can read. Blend national budgets, regional facilities, and private contributions where social returns are high but private capture is low. Communication is not a side task. Regular, plain-language updates on cases, response times, and market conditions stabilize expectations. Clear compensation rules reduce underreporting and disorderly sales. Aligned terminology across countries lowers the chance of avoidable trade frictions.

Country Perspectives

Differences in the GMS reflect production structures, border-trade intensity, laboratory capacity, and alignment with neighboring standards. The regional frame applies; emphasis and pace differ.

In the People's Republic of China, surveillance from the national to the county level is extensive. Standards for zoning, compartmentalization, slaughter hygiene, and cold-chain management are mature. Along southern corridors, the task is to make existing tools legible in cross-border settings. Certificates, lab results, and animal-ID codes should match shared templates and be exchanged on time. In areas where wild boar and domestic pigs overlap, routine habitat management and farm biosecurity keep risk down at a reasonable cost. AMR stewardship, strong on the public-health side, should be fully integrated into animal health through prescription compliance and slaughter-chain testing.

In Viet Nam, value chains have grown fast. Small and medium producers remain important. Long-distance domestic movements intersect with porous borders. Priorities are to make compliance visible and worthwhile through audited, tiered biosecurity standards; to bring laboratory turnaround to predictable levels across provinces; and to recognize documentation and test protocols with neighbors in common trade categories. Clear rules and timely compensation reduce distress sales and support early reporting.

In Thailand, the livestock sector and cold-chain system operate from a strong institutional base. The next step is predictability that the market can feel: consistent recognition of compliant consignments, documentation pathways that are understood and used, and laboratory proficiency accepted by partners without reopening methods. Where wildlife–domestic interfaces persist, targeted habitat management complements farm biosecurity. Large integrated enterprises can accelerate AMR stewardship by embedding prescription compliance, vaccination alternatives, and slaughter-stage testing into supplier contracts, along with annual transparency reports.

In the Lao People's Democratic Republic, small ruminants and cross-border trade are central to livelihoods. Rules are straightforward, but local execution and laboratory capacity face resource constraints. A reliable, simple data backbone, such as cases, locations, dates, and actions, should be recorded in formats neighbors can read. Field-appropriate testing at key crossings helps. Recognition of basic documentation in common trade categories reduces friction without unaffordable demands. Communication should stress the direct benefits of compliance and the real costs of non-compliance.

In Cambodia, backyard production and dispersed market nodes create overlaps between formal and informal flows. Data continuity is uneven. Two visible gains are within reach: predictable provincial laboratory turnaround backed by standardized sampling and referral, and basic market-level biosecurity that reduces cross-contamination. Recognition with neighbors can start in common, lower-risk categories and expand as systems mature. Publishing a small, stable set of indicators, detection intervals, laboratory turnaround, and clearance times for compliant consignments signals steady progress.

In Myanmar, security constraints and data gaps limit the pace of system development. A pragmatic route is to place accessible sentinel and rapid-testing capacity at border and corridor nodes to capture signals that matter for cross-border risk, to rely on neighbor notifications and simplified domestic procedures for local containment, and, where supply allows, to phase targeted immunization and producer education to avoid campaign fatigue. Financing can draw on regional facilities with disbursements tied to verifiable milestones along the detection–reporting–action chain. Continuous training and basic inputs keep frontline capacity viable.

Outlook

The economic case is strong for early action and targeted controls to reduce direct losses from major TAD events and attenuate the fiscal risk of emergency relief and intensive health interventions. Exact magnitudes vary by disease ecology and market structure, but the argument applies in all cases. The primary benefit is risk reduction and predictability for investments in livestock quality and food safety. Processors and distributors face less value chain disruption, and border agencies rely less on discretionary measures because rules fit more stable risk profiles. AMR controls add a longer-term dividend by protecting treatment efficacy and food-safety credibility in domestic and export markets. In the near term, increased surveillance can chill reporting, adapting fragmented standards can cause frictions, compliance and new skills take time to diffuse, but a more coherent institutional design aligns responsibility with more positive longer term outcomes. The region's exposure to mobile risks will persist. What can change is how those risks are managed. Alignment, not uniformity, is the goal. China and Thailand can align mature practices into cross-border standards others can adopt. Viet Nam and Cambodia can make core functions predictable and visible so compliance lowers cost. Lao PDR and Myanmar can focus on the most expedient risk-reduction measures: reliable signals at key crossings, documentation neighbors can recognize, and procedures that frontline staff can execute within or with moderately enhanced capacity. Anchored in a concise indicator set and financed on a results-oriented basis, this architecture keeps disease risks within bounds that farmers, consumers, and treasuries can absorb, while buttressing the credibility of the regional trading system. That is a realistic definition of resilience for this sector, and it is achievable.

1 Introduction

Highly Pathogenic Avian Influenza (HPAI, H5N1) is the most recent example of a legacy of Transboundary Animal Diseases (TADs) that have challenged the agro-food economy and public health for millennia. As the world economy becomes more highly integrated, and as the aggregate economic value of both the agro-food economy and human life continue to rise, so does the economic risk posed by TADs. These risks are especially acute in the case of TADs with mutagenic potential for animal to human (zoonotic) and human to human transmission. Estimates from the SARS epidemic (World Bank:2006) suggest that economic damages from a serious future pandemic could be measured in trillions of dollars, and some biologists see the emergence of such diseases as relatively inevitable, much like seismic risk in earthquake prone regions.

Antimicrobial resistance operates within the same animal-health system and conditions the outcomes of transboundary events. Recent global evidence indicates a rising mortality burden among older populations, alongside large avoidable losses where diagnosis is confirmed earlier, effective treatment is available, and antimicrobial use follows clear rules. For the GMS, these functions are not adjuncts but core defences: predictable laboratory turnaround, prescription compliance aligned with farm and slaughter practice, and routine checks along the cold chain support disease control while preserving the credibility of trade (GBD 2021 Antimicrobial Resistance Collaborators, 2024).

For policy makers to devise effective defences against TADs risks, it is important that economic vulnerabilities be clearly understood. Particularly when society must commit significant resources to public defensive measures, these commitments can be more easily justified and better targeted if we understand the costs of inaction or he economic consequences of alternative responsive policies. This report seeks to strengthen the basis of such evidence by reviewing recent TADs history, examining available data on the economic impacts of a wide variety of disease types and locations where outbreaks occurred. We make no attempt to be exhaustive, and in some cases reliable data are very scarce and/or uncertain. Only by improving our perceptions of the economic impact of TADs, however, can we expect to make the most appropriate future commitments to disease risk management and coping.

2 Highly Pathogenic Avian Influenza

1.1 Overview

Highly pathogenic avian influenza (HPAI) is an acute, often lethal infection of domestic and wild birds caused mainly by H5- or H7-subtype influenza A viruses; today the global epizootic is driven almost entirely by the H5N1 subgroup known as clade 2.3.4.4b. In the current nomenclature, "H5" designates the hemagglutinin antigen, and "N1" the neuraminidase, while the clade number traces the virus back to its ancestral A/Goose/Guangdong/1/1996 (Gs/GD) lineage and maps its subsequent branching into at least ten primary H5 clades. Of those, 2.3.4.4b shows exceptional ecological fitness, infecting more than 300 avian species and, to date, over fifty mammalian hosts, including mink, sea lions, and cattle, thus erasing the traditional boundary between an avian virus and a broader multi-host pathogen (Charostad et al., 2023; WOAH, n.d.).

Epidemiologically, the virus has moved from seasonal flare-ups to year-round, transcontinental circulation. Between 2005 and 2024 more than 633 million poultry either died of HPAI or were culled, a cumulative toll unmatched by any other animal disease in modern records (Charostad et al., 2023). Migratory waterfowl now act as both victims and vectors: Mass die-offs in Arctic breeding colonies reseed wintering grounds on every populated continent, while spillover into dairy herds in the United States (first confirmed in March 2024) demonstrates that mammal-to-mammal transmission is no longer hypothetical (WOAH, n.d.). Zoonotic infection remains rare, with 878 laboratory-confirmed human H5N1 cases since 2003 with an overall case-fatality ratio near 52 percent.

The economic shadow tracks the biology. Countries free of HPAI follow WOAH's recommended "stamping-out" policy to preserve trade status, whereas enzootic regions lean increasingly on preventive vaccination coupled with DIVA (differentiating infected from vaccinated animals) testing. Both strategies carry heavy price tags: high-income exporters fund perimeter fencing, truck-wash stations, and real-time genomic surveillance, while low- and middle-income producers face the prospect of losing their primary protein source overnight without reliable compensation. Trade partners impose swift embargoes on live birds and raw products, so a single national outbreak can wipe billions from agrifood revenue and ripple through grain, logistics, and tourism sectors. For these reasons, WOAH now ranks HPAI alongside foot-and-mouth disease as a priority transboundary hazard and urges members to integrate wildlife monitoring, targeted vaccination, and transparent farmer compensation into a One-Health defense that keeps pace with the virus's expanding host range (WOAH, n.d.).

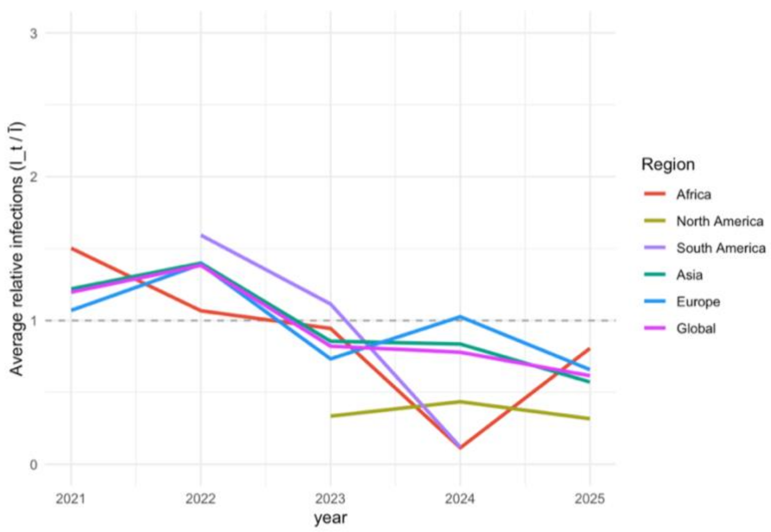
1.2 Global Trends

Highly pathogenic avian influenza (HPAI) first emerged from the Gs/GD lineage in Asia in the mid-2000s and has since transitioned from a series of regional flare-ups to a structurally embedded, transboundary threat. The pivotal year was 2022: eighty-four countries and territories reported outbreaks, and 146 million birds were lost, which was a spike that redrew the epidemiological and economic map of HPAI. Europe and North America drove that peak, recording explosive poultry die-offs alongside unprecedented wildlife mortality, while Asia maintained a consistently high baseline without the same acute surge. Africa's notifications, by contrast, swung sharply: reports briefly dropped to near zero in 2024 (WOAH, 2025). Importantly, Figure 2.1 shows that global infection rates have never returned to their pre-2022 baseline, signalling that HPAI has moved from periodic outbreaks into an endemic global presence.

Genetic evolution has mirrored that geographic spread. Since its first escape from poultry, the virus, especially clade 2.3.4.4b of H5N1, has undergone extensive reassortment, producing multiple genotypes now entrenched in diverse wildlife hosts. By early 2025 H5N1 had been confirmed in more than fifty mammalian species, including mustelids, felids, pinnipeds, and, most recently, cattle. The March 2024 confirmation of HPAI A(H5N1) in U.S. dairy cows marked the first recognized outbreak in bovines: initial cases were traced to the B3.13 genotype, likely introduced via wild birds; subsequent incursions of the D1.1 genotype soon dominated detections in North American poultry and wildlife (Krammer et al., 2025). Crucially, field investigations documented cow-to-cow transmission and recovered high viral loads from bulk milk and milking equipment, indicating that mammals are no longer mere terminal hosts. Instead, cattle appear to provide the virus with a new ecological niche, broadening its evolutionary runway and raising fresh public-health and trade concerns.

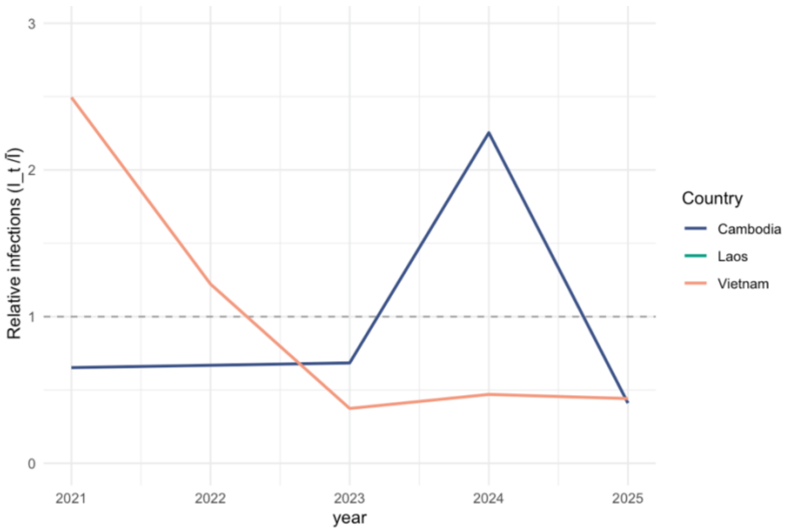
Economic fallout has kept pace with these biological shifts. Direct poultry losses remain the most visible metric, yet the ripple effects now span agriculture, wildlife conservation, international trade, and human-health budgets. In the European Union, successive outbreaks between 2022 and 2024 triggered immediate import bans by key partners, notably China, crippling export revenues for Germany's pork-and-poultry complex and prolonging market restrictions for France and Poland (WOAH, 2025). In the United States, the dairy sector has joined poultry producers in absorbing production losses and compliance costs linked to federal testing mandates and interstate movement controls. High-income countries have responded with large-scale biosecurity investments, perimeter fencing for outdoor flocks, truck-wash stations at processing plants, and real-time genomic surveillance, while lower-income regions, still epidemiologically exposed, remain fiscally constrained. Underfunded veterinary systems in parts of Asia and Africa struggle to detect and control outbreaks promptly, allowing viral evolution and export risk to continue unchecked and perpetuating a costly global cycle.

Figure 2.1 Average annual Highly Pathogenic Avian Influenza virus infections by continent and global total, 2021–2025



Note: Y-axis shows the Relative Infection Index $I_t/\bar{I}$. For each region, $\bar{I}$ is the 2021–2025 mean (baseline = 1.0; dashed line marks the baseline). Values above 1.0 are above the period average; values below 1.0 are below it. Lines are annual averages. Cross-region levels are not directly comparable; read within-series change and timing. World Animal Health Information System (WAHIS), accessed May 2025

Figure 2.2 Trends in Highly Pathogenic Avian Influenza virus infections in GMS region, 2021-2025



Note: Relative Infection Index $I_t/\bar{I}$. Cambodia and Vietnam are scaled to their 2021–2025 mean (baseline = 1.0); both series run through 2025. No country-level series for Laos in this period. Values above 1.0 are above the period average. Levels are not directly comparable across countries; focus on each series' own pattern. World Animal Health Information System (WAHIS), accessed May 2025

1.3 OECD Background and Economic Impact

The latest clade 2.3.4.4b wave of highly pathogenic avian influenza (HPAI) has turned what was once an episodic threat into a systemic challenge for the OECD. Since an H5N1-positive wigeon was sampled in South Carolina in January 2022, the virus has torn through the poultry heartlands of North America and Europe, ultimately affecting 1,689 flocks and 168.62 million birds across the United States alone by 23 April 2025 (Biondo, 2025). Because OECD members collectively supply about two-thirds of the world's shell-egg exports, even this three-percent biological hit to the bloc's layer inventory has echoed through global commodity markets, lifting price indices for eggs, further-processed poultry, and substitute proteins.

Nowhere are the economic reverberations clearer than in the United States. Layers account for three-quarters of all domestic poultry losses, cutting the national flock from a 2020–2021 monthly average of 310 million hens to 296 million in 2022–2024 and throttling table-egg output (Biondo, 2025). Retail prices duly broke records at US $6.23 per dozen in March 2025, surpassing the previous peaks of the 2014-2015 crisis and doubling pre-outbreak norms (Biondo, 2025). Federal outlays have kept pace with the biological toll: from February 2022 to February 2025, the Animal and Plant Health Inspection Service committed US $ 1.811 billion to HPAI response, of which US $ 1.195 billion went directly to producer indemnities and a further US $ 353 million to depopulation and virus-elimination logistics (Biondo, 2025). These sums rival the hurricane-relief budgets of some U.S. states and underline how a comparatively modest livestock die-off can generate outsized fiscal drag when the commodity in question is a dietary staple with few substitutes.

Across the Atlantic the pattern is thinner in absolute numbers but similar in economic mechanics. During the four-month surveillance window from 7 December 2024 to 7 March 2025, the European Food Safety Authority logged 743 new HPAI detections in 31 countries, 239 of them in poultry holdings, triggering the culling of almost ten million birds (EFSA et al., 2025). Although that loss shaved only 1.1 percent from EU-27 poultry-meat output, a sharper 2.6 percent contraction in shell-egg supply drove the bloc's Harmonized Index of Consumer Prices for eggs up 18 percent year-on-year, a steeper proportional rise than in the United States because European household demand for eggs is even less elastic (EFSA et al., 2025). Member states have opened sizeable compensation lines, and Brussels is fast-tracking dossiers on antigen-matched vaccines for ducks and geese, which is remarkable in a policy arena long wedded to stamping-out alone.

The biological map widened again in March 2024, when clade 2.3.4.4b spilled into U.S. dairy cattle. The joint FAO/WHO/WOAH risk update of 17 April 2025 documents three independent bird-to-bovine transmission events, each linked to a unique genotype and together involving almost 1 000 herds in 17 states (FAO et al., 2025). While pasteurization neutralizes the virus, farm-gate milk yields in affected counties have dropped by ten to twenty percent during acute illness, forcing processors to pay spot premiums that ripple through butter and skim-milk-powder quotations. The assessment warns that continued mammalian spillover enlarges the ecological space in which human-adapted variants might evolve, layering a risk premium onto already-volatile protein markets.

Market dislocation has not respected borders. East Asian import suspensions on fresh poultry from both the United States and the European Union have redirected product toward lower-priced destinations in Africa, suppressing cost-insurance-freight values by as much as twelve percent relative to 2021 averages. Domestically, scarcity has triggered regulatory improvisation: Nevada temporarily lifted its cage-free mandate in February 2025, and a federal "Lowering Egg Prices" bill is now seeking to repurpose surplus broiler hatching eggs for table use (Biondo, 2025). Such measures reveal how quickly disease economics can override long-standing policy norms when consumer staples become scarce.

Three structural drivers explain why the fiscal bill keeps rising. First, staple proteins such as eggs and pasteurized milk exhibit low price elasticity; small biological shocks therefore generate large retail swings. Second, the OECD's continued reliance on rapid depopulation embeds a high fixed cost in every new outbreak cycle, costs that scale non-linearly as wildlife reservoirs keep reseeding infections (Biondo, 2025). Third, wild-bird genomics show persistent circulation of a single goose- and gull-adapted genotype across Europe, meaning that even exemplary farm biosecurity cannot guarantee freedom from reintroduction (EFSA et al., 2025).

Against this backdrop, OECD agriculture ministers are converging on a cautious pivot. France, Hungary, and Italy have launched targeted vaccination pilots in high-density duck and turkey zones; portable multiplex PCR kits now bring confirmation times below eight hours in several U.S. states; and wildlife-bait immunization is being financed through biodiversity budgets under the One-Health umbrella (FAO et al., 2025). Whether such measures will tame the economic bleed remains uncertain. What is clear is that without integrated vaccination, wildlife management, and shared risk-insurance instruments, treasuries across the OECD could face a recurring liability of 0.02-0.05 percent of agricultural GDP each year.

HPAI has outgrown its status as a poultry disease and now casts a supply-chain shadow across the whole OECD. The virus's biological footprint may still be patchy, but its economic imprint, through price inflation, public-expenditure pressures, and cross-species uncertainty, has become a common denominator that binds the bloc's food economies together.

1.4 Data Availability and Gaps in the GMS

Across the GMS, official information on HPAI follows two distinct patterns. China, Thailand and Viet Nam continue to submit regular notifications to WOAH and WHO, and the country narratives already reflect this recent record, with China and Viet Nam characterised by low-level endemic circulation and Thailand reporting no poultry outbreaks since 2008. For Cambodia and the Lao PDR, most of the detailed case-study evidence predates 2010. More recent WAHIS notifications confirm continued circulation, but they do not provide economic detail, so this chapter treats 2010–2025 as a significant data gap rather than a period of true disease absence. Myanmar appears only intermittently in international databases. For these countries, the poultry outbreak counts cited in this chapter should therefore be read as the last confirmed events in the official record, rather than a complete time series, and the more important signal is the wide surveillance gap that opens up after the first epidemic wave.

1.5 People's Republic of China

China's highly pathogenic avian influenza (HPAI) landscape has shifted markedly since the nationwide adoption of compulsory bivalent H5/H7 vaccination in September 2017. Extensive post-vaccination surveillance (160,359 poultry samples collected between January 2020 and June 2023) yielded only 16 H7N9 isolates, all belonging to a single residual G2 genotype that has lost human-type (α2,6-linked) receptor affinity and exhibits reduced virulence in both mice and chickens (Hou et al., 2024). Parallel monitoring of H5Nx viruses shows continuing incursions of clade 2.3.4.4b derivatives, yet antigenic matching studies indicate that the current trivalent formulation (Re-13/Re-14/H7-Re4) retains high protective efficacy (Huang et al., 2023). No laboratory-confirmed human H7N9 infection has been recorded since the first vaccination round; poultry outbreaks are now sporadic, localized, and managed through ring culling, short-term movement bans, and intensified live-bird-market disinfection. Molecular data from both H5 and H7 lineages suggest that sustained immunization is steering viral evolution toward lower zoonotic risk while preventing large-scale farm-level epidemics (Hou et al., 2024; Huang et al., 2023).

Economically, the vaccination-led strategy has reduced the magnitude and variability of direct production losses compared with neighboring countries that rely primarily on stamping-out. Hou et al. (2024) estimate that the post-2017 fall in clinical H7N9 outbreaks averted the culling of tens of millions of birds and eliminated the public-health costs associated with more than 1,560 pre-vaccination human cases. Although China now budgets several billion doses per year, modelling cited by Huang et al. (2023) shows that vaccine procurement and administration remain cost-effective when contrasted with the revenue shocks that would follow widespread culling, trade embargos, and consumer boycotts. The steady internal demand of the 14-billion-bird commercial sector has therefore been maintained, protecting smallholder incomes and limiting feed-industry volatility. In short, the Chinese model demonstrates that continuous antigenic surveillance combined with adaptive vaccination can contain HPAI, stabilize domestic poultry markets, and minimize macroeconomic disruption.

1.6 Cambodia

By mid-2025, Cambodia again faced a rising risk of zoonotic H5N1. After nearly a decade without reported human infections, laboratory-confirmed A(H5N1) cases "re-emerged" in 2023. By 1 July 2025, WHO had been notified of 27 human infections and 12 deaths, including 11 cases and six deaths in 2025 alone, almost all with reported exposure to sick backyard poultry. These recent events show that H5N1 remains endemic in poultry and capable of spilling over into humans, even though detailed economic assessments are still only available for earlier waves(WHO, 2025).

Cambodia only experienced a mild HPAI epidemic compared to neighbouring Thailand and Viet Nam during the first wave of outbreaks. Cambodia's first reported HPAI poultry outbreak occurred in late January 2004 in a 7,500-bird commercial layer unit near Phnom Penh. During 2004–2008, the country confirmed 21 poultry outbreaks with around 20,000 bird deaths and culls, concentrated along the Mekong–Tonle Sap–Bassac river system (OIE). Thirteen of the twenty-one outbreaks occurred in March–April and six between July and September, coinciding with the release of ducklings into newly planted rice fields in the Mekong River Valley in Southern Cambodia. Four outbreaks occurred in large industrial units, which represent less than 0.1% of registered poultry operations, suggesting substantial under-detection or under-reporting in backyard systems (Burgos et al. 2008c). These 2004–2008 outbreaks remain the only episode for which national-level economic impacts have been quantified in detail. During this early wave, eight human H5N1 cases were confirmed in Cambodia and seven were fatal, mostly clustered in Kampot province adjacent to Viet Nam's high-duck-density areas. Since then, cumulative human infections have increased substantially: by mid-2025, WHO reports 27 laboratory-confirmed A(H5N1) cases and 12 deaths.

After the confirmation of HPAI the Cambodian government implemented poultry movement restrictions and the culled infected flocks. Approximately 10,000 birds were culled and no compensation was provided for the animals. Additionally, 3-kilometer protection and 10-kilometer surveillance zones were established around outbreaks. Temporary suspension of sales and purchases of birds were also established, but given weak law enforcement, compliance was essentially optional to farmers. Furthermore, it is reported that various poultry sector stakeholders have remained silent fearing government retaliation leading to underreporting and lack of debate on the effectiveness of the implemented disease migration measures. Other measures employed by the government include campaigns to encourage chicken raisers to erect fences and housing to improve biosecurity as well community hotlines to obtain feedback and reports on HPAI outbreaks. Cambodia also receives support from numerous international governments and non-governmental organizations to help control HPAI (Burgos et al. 2008c).

The direct economic impacts of the HPAI outbreaks were quite minimal that only 0.2% of the national flock in 2003, and is a far cry from the near 20% stock losses of neighboring Thailand and Viet Nam. Furthermore, the risk of infection was extremely low at only 0.001%. Most economic damages hit medium- and large-scale duck and industrial-integrated layer and broiler farms, because poultry represent the main source of income for these operations. These farms were forced to lay off workers and temporarily reduced the salaries of the remaining ones (from $47 USD to $28 USD per month). Regardless, with such low numbers of affected animals any damages must still be considered very minimal. Small-scale traditional backyard producers had comparatively much lower losses during the outbreak (Seng 2007)

Farmers who borrowed from micro-finance and banking institutions to help their poultry businesses were especially hit hard. Flock losses from disease outbreaks matched with uncompensated culling, resulted in many farmers having to sell household assets to pay back loans or receive support from relatives living in urban centers or abroad. In some cases, assistance was provided to farmers by local institutions, but this was not official compensation, as law did not mandate it. For example in the Kamakor village, provincial government officials provided 300,000 Riel to large-scale and 30,000 Riel to small-scale farmers during HPAI culling operations (Burgos et al. 2008c).

Market shocks existed in Cambodia just like other parts of the region. The confirmation of HPAI led to a decreased demand causing poultry prices to fall in urban markets (from 4,000 to 1,500 Riels per kilo of broiler). Additionally, the drop in consumption of poultry meat led to an increase in substitutes such as other meats, fruits, vegetables, and nuts causing prices to rise. This added stress to poor households as the prices of some inexpensive staple goods rose during the epidemic. Again, semi-intensive and intensive producers were most affected as their market-oriented production systems were put under stress due to price reductions. Conversely, small-scale traditional backyard producers reported that market shocks had minimal impacts on their livelihoods and those that could not sell their birds are reasonable prices would either postpone sale or slaughter the birds for food consumption. In traditional backyard systems chickens scavenge for food and thus do not require large amounts of commercial feed. Therefore keeping chickens for longer does not led to increased production costs as it does for industrial chickens Regardless, reduced bird stocks and lowered market prices led to a decrease in poultry trading in general. Middlemen and traders were hit the hardest as transactions in villages and city markets decreased. However by March 2004, prices for poultry products had recovered to pre-HPAI levels and even increased by 25% at the end of the year due to supply shortages caused by import bans from Viet Nam and Thailand ("Review of the Poultry Production and Assessment of the Socio-economic Impact of the Highly Pathogenic Avian Influenza Epidemic in Cambodia").

Again looking at up- and downstream market affects, similar trends occur. One survey found that HPAI outbreaks caused a reduction in bird stocks of up to 40%, as producers were reluctant to restock due to uncertainty. Lower bird stocks led to a reduction in feed purchases affecting feedstuff purveyors and grain sellers ("Review of the Poultry Production and Assessment of the Socio-economic Impact of the Highly Pathogenic Avian Influenza Epidemic in Cambodia."). Looking at other indirect flows, the Cambodian government notes that quarantine zones were often maintained for too long making it difficult for producers stay in business ("Kingdom of Cambodia National Strategy on Highly Pathogenic Avian Influenza"). Restocking also proved to be difficult as import bans on DOCs from neighboring countries left only the CP hatchery in Cambodia to supply the commercial sector. As a result, DOC prices increased from $0.25 USD in December 2003 to $0.33 USD in May 2005. Due to these hardships the number of commercial layer farms fell from 74 in 2003 to 52 in November 2004, and the number of broiler farms fell from 108 to 92 over the same period (Burgos et al. 2008c). Finally one potentially overlooked indirect impact is the lower nutritional profiles of villagers from reduced consumption of eggs and poultry meat during outbreaks. Although purchases of substitutes do increase, the consumption of other meats may not replace lost poultry intakes because of the higher prices for pigs and beef ("Review of the Poultry Production and Assessment of the Socio-economic Impact of the Highly Pathogenic Avian Influenza Epidemic in Cambodia" and Seng 2007).

1.7 Lao PDR

Lao PDR has experienced only a few documented human H5N1 infections, but the virus has not disappeared. WHO reports three laboratory-confirmed human A(H5N1) cases since 2005: two fatal cases in 2007 and a non-fatal infection in a one-year-old child detected through sentinel surveillance in 2020. From an animal health perspective, HPAI outbreaks have recurred beyond the 2004–2009 wave, including detections in Sekong province in 2018, underscoring that the virus continues to circulate in poultry and wild birds even as surveillance remains patchy. Lao PDR's officially confirmed HPAI data run through 2009; the next confirmed poultry outbreak occurred in 2018, indicating persistence of the virus despite limited routine reporting.

Lao PDR confirmed its first case of HPAI in January 27, 2004 in a commercial chicken layer farm in the village of Nonsavang near Vientiane. In total there have been 19 outbreaks, with the vast majority (84%) occurring in only 2 months in 2007 and 2008. Eight outbreaks were recorded in February and March of 2007, followed by 5 outbreaks in February 2008 and 3 outbreaks in September 2008. Most reported outbreaks occurred in 2007–2008, and earlier OIE/WAHID summaries described February 2009 as the end of this first wave. Subsequent investigations, however, have documented additional HPAI detections in poultry, including events in Sekong province in 2018, suggesting that low-level circulation has continued. The 2004 HPAI virus isolates were genetically different from later isolates (Inui 2008), and given that no reported outbreaks occurred in 2005 it appears duck trade with Cambodia and Thailand may have reintroduced HPAI to Lao PDR. Outbreaks have been most common in the Vientiane capital region and found predominantly in commercial farms. Although only 19 outbreaks have been recorded, commercial producers lost as much as 20% of the national layer flock and almost 40% of the layer flock in Vientiane province during outbreaks. Commercial quail production was also hit hard, losing just over a third of the national flock ("FAO-ECTAD Duck

Study: Terms of Reference"). One study found that at least 156,000 birds died approximately 105,000 of which were culled in commercial farms in the Vientiane, Champasak, and Savannakhet provinces (Boltz et al. 2006). Unfortunately the national veterinary institutions are very week and matched with the high acceptance of seasonal poultry deaths, the real number of cases has surely been underreported.

Until 2008, only two confirmed human H5N1 cases had been reported from Lao PDR, both fatal and linked to direct contact with sick poultry. More recent WHO data indicate a third laboratory-confirmed case detected in 2020 in a one-year-old child who recovered, bringing the total to three human infections and two deaths. Both cases occurred in February and March of 2007 and both were found in woman who had likely had direct contact with sick birds ("Avian influenza – situation in Lao People's Democratic Republic – update 2").

After HPAI confirmation the Laotian government imposed a series of control measures including poultry movement restrictions, poultry import bans from Thailand, enhanced border trade inspections, media campaigns to raise public awareness, protection and surveillance zones around outbreaks, and a 3-kilometer culling zone for all birds around infected premises. Although a compensation plan for culled birds was originally considered, the costs were too high and had to be abandoned (Nicely 2005). Additionally an emergency task force was established and was responsible for coordinating and implementing control measures, rehabilitating laboratory facilities for confirmatory testing, and organizing the training of animal health officials in disease detection, biosecuirty enhancements, disinfection, surveillance, culling, and disposal techniques (Burgos et al. 2008d).

Much like Cambodia, weak governmental oversight has severely limited the effectiveness of these measures. For example, the five boader checkpoints with Thailand have had large difficulties policing border trade along the Mekong, despite firm instructions to be vigilant about poultry imports from Thailand. Despite these bans farmers in Champasak proudly announced they had restocked their farms with DOCs from Thailand (Nicely 2005). To its credit however, Lao PDR faces an immense challenge in policing its borders, as it is landlocked and shares large borders with Viet Nam and Thailand, both of which have struggled to contain the spread of their epidemics. Additionally the limited capacity and under-funding of national veterinary services imposes severe constraints for efficient disease prevention, early detection, and effective control. Thus the role of village surveillance networks through the training of village veterinary workers (VVW) has been critical as they are able provide reliable grassroots disease information. Additionally, a disease awareness and training program was launched nationwide that provides livestock officials with training in epidemiology, surveillance strategies, immediate outbreak control measures, and disinfection and follow-ups after outbreaks. These strategies helped achieve significant increases in reporting of high poultry mortality after an incentive-based passive surveillance network was created (Mondry 2008).

The most immediate and direct impact of HPAI in Lao PDR comes form the stock loss of poultry, either from the disease itself or government-mandated culling. In total, 156,365 birds have died between 2004 and 2008. Assuming an average value of $1.50 USD per bird this represent an approximately $235,000 USD direct loss to poultry producers. For an average broiler farm of 500 birds, this corresponds to an income loss of approximately $1,100 USD per month. These income shocks make it extremely difficult for many farmers to repay loans or access new credit to finance animal stocks, feed, and medications ("Socio-Economic Impact Assessment of HPAI on the Poultry Sector in Lao PDR"). Since outbreaks were concentrated in commercial broiler and layer operations, commercial producers bore the majority of the costs. Furthermore, restocking delays due to market uncertainty after outbreaks lasted between two to eight months on commercial farms.

Other direct impacts hit traders, intermediaries, and market sellers as large stock losses led to income reductions ranging from 20-40% during the four weeks following an outbreak. Semi-commercial poultry producers were also hurt as those with stock losses had to fire workers to cope with lost income. These layoffs led to reduced expenditures from fired employees affecting the overall economy. Even traditional backyard systems in affected locations were hurt as poultry-related income fell from 63% to 43% of total income in female-headed households ("Socio-Economic Impact Assessment of HPAI on the Poultry Sector in Lao PDR").

Just as in other Southeast Asian countries, HPAI outbreaks led to market shocks in Lao PDR. After HPAI was confirmed, Laotian consumers purchased less poultry meat and eggs in fear of contracting the disease, which led to decreased demand for poultry products. As consumers moved away from poultry they began to purchase more substitute meats such as fish and pork. As a result, poultry meat and egg prices fell by about 5 to 10% while prices for alternative meats increased by 10 to 20% ("Socio-Economic Impact Assessment of HPAI on the Poultry Sector in Lao PDR"). Although Vientiane poultry producers lost nearly 40% of their total stock, local market prices or availability of poultry products were not drastically affected as smallholder production outputs were able to met demand (Burgos et al. 2008d).

As previously discussed, poultry producers that kept low production profiles due to uncertainty in the poultry market corresponded to lower amounts of feeds purchased, thus also harming feedstuff purveyors and grain sellers. Additionally, aggregators and middleman undoubtedly saw a reduction in income form lower production profiles, but the exact costs on either of these associated impacts are very difficult to quantify. Poultry producers saw the price of DOCs increase form $0.35 USD to $0.59 USD, while the price for ducklings remained constant at $0.47 USD. Due to the price increase in DOCs, many smallholders decided to switch new stock purchases from chickens to ducks or to delay restocking altogether ("Socio-Economic Impact Assessment of HPAI on the Poultry Sector in Lao PDR"). Although some producers have switched away from poultry into fish, cattle, and/or hog production, it is not known if this was done in response to HPAI outbreaks or if they were already engaged in mixed farming as a risk reduction strategy through diversification.

Lao PDR has not enacted severe measures to curb the disease, and thus long-term changes in the entire poultry sector are unlikely. This is likely due to the fact that the commercial poultry sector in Lao PDR is still very small, localized, loosely organized, and without any strong lobbying power creating pressure to impose a centrally planned restructured sector (Burgos et al. 2008d).

1.8 Thailand

Suspected outbreaks of HPAI began to appear in Thailand in late 2003 when high death rates were reported in commercial chicken farms. The first official confirmation of the disease was on January 23, 2004, and since then Thailand has had an ongoing battle with HPAI. Four separate endemic waves have been identified, totaling 1,929 outbreaks as of January 2007 according to the Thai department of livestock development (DLD). The OIE presents more recent data, but there is a discrepancy in the numbers as it reports only 1,141 outbreaks as of April 19, 2009.

The first epidemic wave started in January 2004 and lasted until May 2004. However, this wave was smaller to the second and largest wave that struck in July 2004 and lasted until April 2005. The second wave had a total of 1,655 outbreaks (according to DLD) reaching a peak of 39 outbreaks per day in November 2004. The following waves all became progressively smaller, and the third waves lasted from July to November 2005. In 2006, only two outbreaks were reported for the entire year occurring in July. January 2007 also had two outbreaks and there was one in March 2007 as well. Sporadic outbreaks have continued all the way until November 2008 when two outbreaks were confirmed by the OIE. The vast majority of HPAI affected districts were located in the center of the country and occurred most commonly in backyard flocks (73, 58, and 77% over the first three waves) (Burgos et al 2008b).

HPAI has infected 25 humans resulting in 17 deaths in Thailand to date. The majority of cases (17 to 68%) occurred in 2004, which corresponds with the two major outbreaks during this year. The following cases in 2005 and 2006 also coincide with the outbreaks in those years (Burgos et al. 2008b).

The Thai government has implemented a variety of control measures over the course of the outbreaks. Upon discovery of the first outbreaks standard measures were put into place such as culling of infected flocks and restriction of poultry movements. The Thai government also made considerable efforts to improve hygiene during production and handling. During the fist wave the Thai government was very heavy-handed and created a 5-kilometer zone for pre-emptive culling around infected farms, as well as a 50-kilometer movement ban zone (Burgos et al 2008b).

By the time of the second wave in July 2004 the Thai government changed their policy due to the large losses of mostly healthy birds. Pre-emptive culling was reduced to a 1-kilometer radius, while movement bans were reduced to a 5-kilometer radius. Additionally at this time the DLD changed their classifications to be able to act more swiftly once outbreaks were reported. New cases were defined as a flock having more than 10% of mortality in one day. Upon discovery of new cases all birds, their products and other potential contaminated material would be destroyed immediately. Furthermore, birds were required to be sampled before any movements and were only allowed to move upon negative sample results (Burgos et al. 2008b).

In July 2005, the case definition was further updated in order to increase response time and improve detection. New cases were now classified as higher than 1% mortality rate on commercial farms and higher than 5% for backyard poultry. Pre-emptive culling was still limited to a 1-kilometer radius, but movement bans increased to a 10-kilometer radius. Additionally, poultry restocking had to wait minimum of 90 days given no new cases were discovered. Controls were also placed on ducks during this time, as free-grazing ducks were thought to be a large risk factor in the spread of the virus. The Thai government attempted to make farmers move ducks into a house farming system, but too little time was allocated for the change, and free-grazing ducks were instead forced into 3-provincial approved areas. By 2006 however, all free-grazing ducks were banned and farmers were forced to house their birds (Burgos et al 2008b).

In terms of compensation, all farmers are entitled to 75% of the value of the asset destroyed under the Thai governments Animal Epidemic Act. During initial outbreaks however, complete compensation was provided due to the widespread and devastating nature of the early epidemic waves. As the scale of outbreaks fell and the culling levels were reduced, payments lowered back to 75%. Compensation levels ranged from \$0.38 USD to \$65 USD depending on the type of animal culled. The government also provided soft-loans with 2% interest rate for free-range duck raisers to both help recover asset losses and relocate animals (Burgos et al. 2008b). The overall budget for animal compensation was set at \$132.5 million USD (Tiensin et al. 2005).

The HPAI outbreaks have affected the Thai economy in a variety of ways. Much like other epidemic diseases, the impacts are often difficult to quantify due to the variety of factors involved. The most basic quantification comes from asset losses from either the disease itself or the culling of animals. In total, approximately 64 million birds were culled to help eradicate the disease, which cost the Thai government approximately \$46.5 million USD (Dolberg et al). Additionally, the DLD calculated that it spent \$12.5 million USD and \$26 million USD during the first and second outbreaks respectively on control measures such as cleaning and disinfection, surveillance, movement control, and public awareness ("Cost of Avian Influenza Control: DLD Perspectives"). The government also spent \$18.5 million USD on compensation for the culling of 41.3 million birds

Much like in Viet Nam, domestic markets faced shocks as consumers reduced poultry consumption in fear of contracting the disease. This decreased demand led to sharp price drops in poultry meats and eggs, and conversely the sales and prices of alternative meat substitutes increased. Additionally demand for other protein sources such as legumes and nuts rose. Furthermore as people shied away from live poultry markets, sales of non-agricultural goods in these markets took a hit due to the reduced traffic flows (Burgos et al. 2008b).

Before the HPAI outbreak Thailand was the world's fourth largest poultry meat exporter. Immediately after HPAI was confirmed, Thailand's two largest poultry export markets, Japan and the EU, imposed bans on fresh-frozen poultry. As a result, Thailand saw exports plummet. In 2003, Thailand exported 485,000 tons of poultry meat of which approximately two-thirds was frozen and the rest pre-cooked. Following bans, poultry exports fell by 45% to 218,000 tons in 2004 (NaRanong 2007 and Otte et al. 2008). Frozen meat exports were hit especially hard. In 2001, raw and frozen chicken exports to the EU reached a high of 98,686 tons, but fell to 11,027 tons in 2004 after outbreaks. Frozen meat exports to other countries reached 8,927 tons in 2003 before falling to 457 tons in 2004 (Burgos et al. 2008b). However, Thailand was able to compensate its massive decline in frozen meat by exporting more pre-cooked meat. By increasing pre-cooked meat exports by 25% from 2003 to 2004, Thai exporters reduced the damage from the 90% drop in frozen meat during this same period (Otte et al. 2008). Regardless, these shifts in the export market resulted in large financial losses. In 2003, Thailand earned $597.2 million USD from frozen chicken meat exports. After the HPAI outbreaks, export profits fell to $44.4 million USD in 2004, $13.7 million USD in 2005 and $15.8 million USD in 2006 (Burgos et al 2008b). Due to these significant losses, Thailand saw many chicken export companies go out of business. Before the HPAI outbreaks there were 22 chicken exporters and by 2005 less than 10 remained in business (Poapongsakorn 2005)

There were also significant affects on both the up- and downstream sectors of the poultry market, although these are often difficult to estimate. One study conducted by the Thai Broiler Processing Exporters Association estimates the total cost to the poultry sector to be approximately 100 billion baht ($3 billion USD) in 2004. These estimates cover both up- and downstream industries including hatchery farms (4.4 million baht), feed mills (12.4 million baht), broiler farms (28 million baht), slaughterhouses (28.4 million baht), and exporting entities (23.7 million baht). Unfortunately these estimates do not take into account any horizontal linkages to other sectors (NaRanong 2007 and Table 4).

Table 2.1: Estimated HPAI-related losses to the poultry industry, Thailand, 2004

Description	Losses (in million Baht)
Hatchery Farms	4,420
Feed Mills	12,430
Broiler Farms	27,950
Slaughterhouses	28,400
Exporting entities	23,700
Total	**96,900**

Source: Thai Broiler Processing Exporters Association, 2005.

Source: Burgos et al. 2005b

Thailand has put considerable effort into the complete eradication of the disease and as a result long-term structural changes can be expected. Free-grazing duck farming has been eliminated and as a consequence the approximately 3,000 duck farmers were required to register and covert to a housed production system. Chicken farmers with open poultry houses are no longer allowed to restock with DOCs unless they upgrade to a closed housing system requiring a large upfront investment. Large poultry companies are also changing. Before HPAI outbreaks, many large commercial companies contracted out poultry production to individual farmers. However now commercial farms are becoming increasingly vertically integrated further adding to the concentration of poultry production. In terms of exports, the bans on frozen poultry has encouraged many producers to begin food processing as cooked exports are still allowed. Thus it is likely that many large commercial poultry firms will begin adding food processing capacitates in their operations as well (Burgos et al. 2008b).

1.9 Vietnam

Viet Nam has had three major outbreaks of HPAI H5N1, which have caused considerable amounts of economic damage to an already poor country. Although present in the country since mid-2003, the first major epidemic began in early 2004 and officially lasted from January 10 to February 28, although this is likely underreported by at least 14 days due to a lack of data before January 10. The disease spread to 57 of Viet Nam's 64 provinces causing 2,506 separate outbreaks resulting in the culling of 38.8-44 million birds depending on estimates. The second wave struck almost a full year later on December 4 and lasted 118 days until April 1, 2005. There were 1,511 reported outbreaks in 17 provinces, which lead to the culling of 2.2 million birds. The third major outbreak started on October 20, 2005 and lasted until December 17, and had 457 outbreaks with 0.9 million birds culled (Burgos et al. 2008 and "The Impact of Avian Influenza on Poultry Sector Restructuring and its Socio-economic Effects").

Viet Nam has continued to have HPAI outbreaks, but since the first three all have been significantly smaller. There was a fourth outbreak in December 2006 with only 122 reported cases. Following this, there were 8 sporadic cases between February and April 2007, until a fifth wave struck in May resulting in 216 cases. After the fifth have there have been continuing intermittent cases, and the OIE still considers this outbreak to be continuing (Burgos et al. 2008).

HPAI in Viet Nam has caused a substantial human disease burden. From 2003 to 25 March 2024, WHO reports 129 laboratory-confirmed human A(H5N1) infections and 65 deaths, with most cases occurring during the large 2004–2005 waves but sporadic infections continuing thereafter. In March 2024, a 21-year-old man from Khanh Hoa province developed severe pneumonia and died from H5N1 infection, illustrating that zoonotic transmission remains possible despite improved control in poultry. Most human cases have reported direct contact with sick or dead birds, although a minority had no clear history of poultry exposure.

The Vietnamese government created a series of control measures similar to those observed by other countries with animal disease outbreaks. These include: large-scale culling, movement restrictions, the closure of live poultry markets, campaigns to educated the public about preventative measures, and a vaccination program starting in 2005. The Vietnamese culling policy has undergone a series of transformations due to the high costs involved. The initial policy was based on geographical criteria such as culling all animals within a 1-kilometer zone around an infected area. However, after the first outbreak and the eventual culling of 38.8 million, it became clear that the costs were much too high and farmers were unwilling to give up healthy birds. In the following waves a new approach was implemented where only high-risk birds immediately adjacent to infected farms were culled, which brought culling levels down significantly. Eventually a voluntary culling scheme with compensation was created in late 2005. Viet Nam is somewhat unique in the sense it has implemented a large-scale vaccination program. Starting in September/November 2005, approximately 85 million chickens, 39 million ducks, and 79 million domestic water birds were vaccinated in the high-risk areas of the Mekong and Red River deltas. The vaccination campaign was continued in 2006 and over 180 million birds were vaccinated. In 2007, a third campaign was launched covering 63 provinces and vaccinating 165 million birds. In 2008, the vaccination program was further increased due to booster vaccinations needed for previously vaccinated birds and the higher acceptance by farmers that vaccination is successful preventative measure. Although exact numbers are not yet available, it is estimated that 250 to 500 million vaccine doses were used (Burgos et al. 2008).

Although it is unclear as to how HPAI H5N1 became introduced into Viet Nam, the two leading hypotheses are either from infected wild birds or the illegal imports of infected poultry from neighboring countries. Given that several of the outbreaks have occurred during the festival time of Tet, it appears that the large-scale movement of people and poultry prior to this event has certaintly played a part.

In total, approximately 60 million poultry died or were culled in Viet Nam throughout the HPAI outbreaks. The vast majority of culling took place during the first outbreak, where approximately 20% of the entire poultry population was eradicated. The Vietnamese government estimates that the direct loss from culling during the first outbreak equates to roughly $75 million USD and a further $112.5 million USD was lost due to production and marketing bans. The Department of Agriculture makes a similar estimate claiming that the costs of the first wave were approximately $200 million USD. World Bank estimates place the total cost of the first outbreak between .3 and 1.2% of GDP ("Technical Annex for a Proposal Credit of SDR 3.5 million (US$ 5 million equivalent) to the Socialist Republic of Vietnam for an Avian Influenza Emergency Recovery Project."). The second outbreaks cost were estimated to be much smaller at .12% of GDP. This lower impact was due to reduced culling and the limited spread of the outbreak ("Assessment on Strategy, Responses and Preparedness to the Threat of a Potential Pandemic").

However, these costs represent just a portion of the total costs, as they do not capture the associated up- and downstream costs throughout the entire poultry sector. Culling, market bans, movement restrictions and decreased poultry prices have affects throughout the entire sector, and are especially damaging to those living on the margins and people who receive their main source of income from poultry. One study analyzed a 5,000 broiler family farm that lost poultry from HPAI and found the total loss equal to $11,748 USD, of which $1,270 was due to production downtime (VSF 2004). Movement restrictions can be especially damaging, as found in an FAO study on a Northern Vietnamese semi-industrial poultry farm. The study found that even though the farm did not loose any animals due to HPAI, movement restrictions causing delayed sales resulted in losses of approximately $2,000 USD ("FAO Workshop On Social and Economic Impacts of Avian Influenza Control"). Losses to smallholders can be particularly destructive as many have such minimal profit margins. One study found that smallholders in the Northern Viet Nam highlands with an average flock size of 60 birds lost $90 USD from culled birds and two months of forgone production. Considering the average income for poultry farmers in this area is $165 USD per year, it can be seen that HPAI poultry controls can be extremely damaging (Delquigny et al. 2004). However for 99% of surveyed farms, poultry is not the most important source of income but rather a security measure for times of hardship. Based on survey data from Vietnamese household living standards, Roland-Holst et al. (2007) found that a total stock loss only represents a 10% income loss for the majority of poor poultry-keeping households. Another study based on the same data found that traditional smallholder farmers would lose approximately 2.1% of total income from a stock loss and 0.8% from a sales ban (Phan Van Luc et al 2007).

After the first major outbreak wave, the Vietnamese government began their compensation policy for culled birds. Original compensation levels were priced at 5,000 VND per culled bird, with an additional 2,000 VND eligible for the purchase of DOCs for restocking. These compensation levels only covered approximately 10-15% of the market price of the birds, but still resulted in the large cost of $18.5 million USD for 41.3 million birds (Riviere-Cinnamond, 2005). Thus, in June 2005 the compensation scheme was revised to 15,000 VND per culled bird with an additional 3,000 VND eligible for replacement DOCs. When the eventual voluntary culling scheme was introduced in November 2005, farmers received 10,000 VND per bird. The vaccination scheme also adds considerable costs at approximately $20 million USD per year ("Future of Poultry Farmers in Vietnam After HPAI."). There are also costs associated with pre and post vaccination surveillance, and were estimated at $1.125 million USD for the first two years of the vaccination program (Hinrichs et al).

HPAI also impacted consumer markets for poultry even though the disease is not transmissible through properly prepared food. During the first outbreak, poultry prices sell sharply from 15,300 VND to 8,000 VND per kg live weight. Egg prices were also adversely affected, falling from 900 VND to 500 VND ("FAO Workshop On Social and Economic Impacts of Avian Influenza Control"). Similar trends occurred during the second outbreak, and poultry prices fell by 50-60% due to decreased demand ("The Economic Impact of Highly Pathogenic Avian Influenza – Related Biosecurity Policies of the Vietnamese Poultry Sector."). As consumers shifted away from poultry they substituted other meats and fish into their diets causing prices to rise (pork prices alone rose by 21% from 2004 to 2005) ("Vietnam Livestock and Products Annual 2006").

Both up- and downstream impacts, as well as horizontal linkages to other industries, also imposed significant costs on the Vietnamese economy. The sharp decrease in Viet Nam's poultry stock produced a negative outcome for the feed industry as some individual producers faced an almost 90% decrease in demand ("The Economic Impact of Highly Pathogenic Avian Influenza – Related Biosecurity Policies of the Vietnamese Poultry Sector"). As poultry operations were shut down, the demand for DOCs fell as a result prices dropped from $0.25 USD to $0.10 USD in Northern Viet Nam ("FAO Workshop On Social and Economic Impacts of Avian Influenza Control"). Rice farmers also saw a reduction in their incomes due to the decrease in ducks, which are a natural pest controller. As duck numbers dwindled, pests such as golden snails increased, creating crop damage (Men 2007). Tourism is another sector that traditionally is adversely affected during an animal disease outbreak capable of spreading to humans. However, there were no signs that the tourism industry faced any serious damage in 2004 when the first human cases of HPAI were reported.

1.10 Recommendations for GMS Policy Makers

Sustained control of highly pathogenic avian influenza across the GMS region will depend first on strengthening the surveillance architecture that links national laboratories to real-time field intelligence. China's post-2017 experience demonstrates that systematic virological sampling, which is carried out at scale in live-bird markets, commercial farms, and wild-bird habitats, can pinpoint residual virus lineages and guide timely antigenic updates to vaccines. Replicating this model will require each Mekong country to expand routine sampling beyond current outbreak investigations, harmonize reporting formats, and share sequence data through a regional platform so that antigenic drift, transboundary virus incursions, and changes in zoonotic potential are detected before they seed new epidemic waves. Parallel investment in rapid diagnostic capacity at the provincial level would shorten the lag between suspicion and laboratory confirmation, thereby allowing ring culling or market closures to be imposed while outbreaks are still geographically contained.

The second priority is to coordinate risk-based vaccination and movement management. Where China relies on compulsory bivalent H5/H7 immunization, Cambodia and Lao PDR have largely pursued stamping-out without indemnification, and Thailand and Viet Nam apply mixed strategies that vary by province and production system. Convergence on a GMS vaccination calendar, targeting peak trading periods and migratory-bird seasons, would raise herd immunity simultaneously on both sides of porous borders and reduce the need for disruptive trade bans. To sustain farmer compliance, compensation frameworks should be recalibrated so that payments for officially culled flocks reflect a transparent share of market value and are disbursed rapidly; otherwise, producers will remain tempted to move birds clandestinely. Complementary regulations that require pre-movement testing of high-risk species (especially ducks) and enforce market-rest days can further dampen virus amplification along trade corridors that link smallholder catchment areas with urban consumption hubs.

Finally, longer-term resilience rests on re-engineering production and marketing channels that still concentrate the virus in high-density settings. Thailand's transition from free-grazing to housed duck systems and Vietnam's phased conversion of wet markets illustrate that structural change is feasible when accompanied by credit lines, technical training, and clear biosecurity standards. Policymakers could accelerate similar transformations elsewhere by earmarking low-interest loans for market renovations, creating incentives for medium-scale farmers to adopt closed housing with controlled access, and integrating animal-health safeguards into rural-development projects. Embedding these measures within a regional framework, under ASEAN or WOAH auspices, would spread costs, align standards, and give producers a credible pathway to retain export market access while protecting public health.

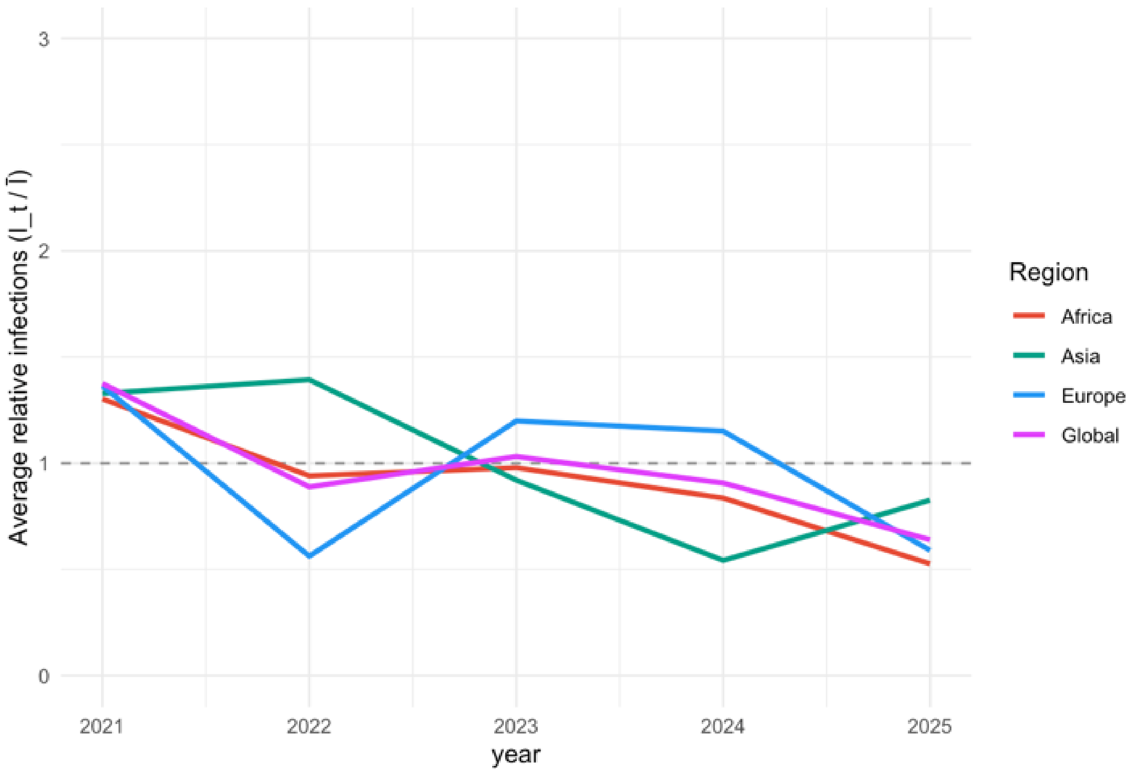
3 African swine fever virus (Inf. with)

1.11 Overview

African swine fever (ASF) is an acute, highly contagious disease of domestic and wild pigs caused by *the African swine fever virus*, a large double-stranded DNA virus in the family Asfarviridae (World Organisation for Animal Health [WOAH], n.d.). Mortality can approach 100%, earning the nickname *"Ebola of pigs."* Typical clinical signs include sudden high fever, widespread hemorrhages in skin and internal organs, loss of appetite, and, in peracute cases, death within days. Even low-virulence strains can establish subacute or chronic infections that keep carriers infectious for months. The virus is notoriously resilient: it survives for weeks in chilled meat and for months in cured hams and sausages. Swill feeding and the movement of contaminated pork products therefore remain powerful drivers of long-distance spread. ASF is not zoonotic, but its economic and social footprint is vast. Because no widely available vaccine or treatment exists, control depends on rapid reporting, movement bans, extensive culling, and thorough disinfection.

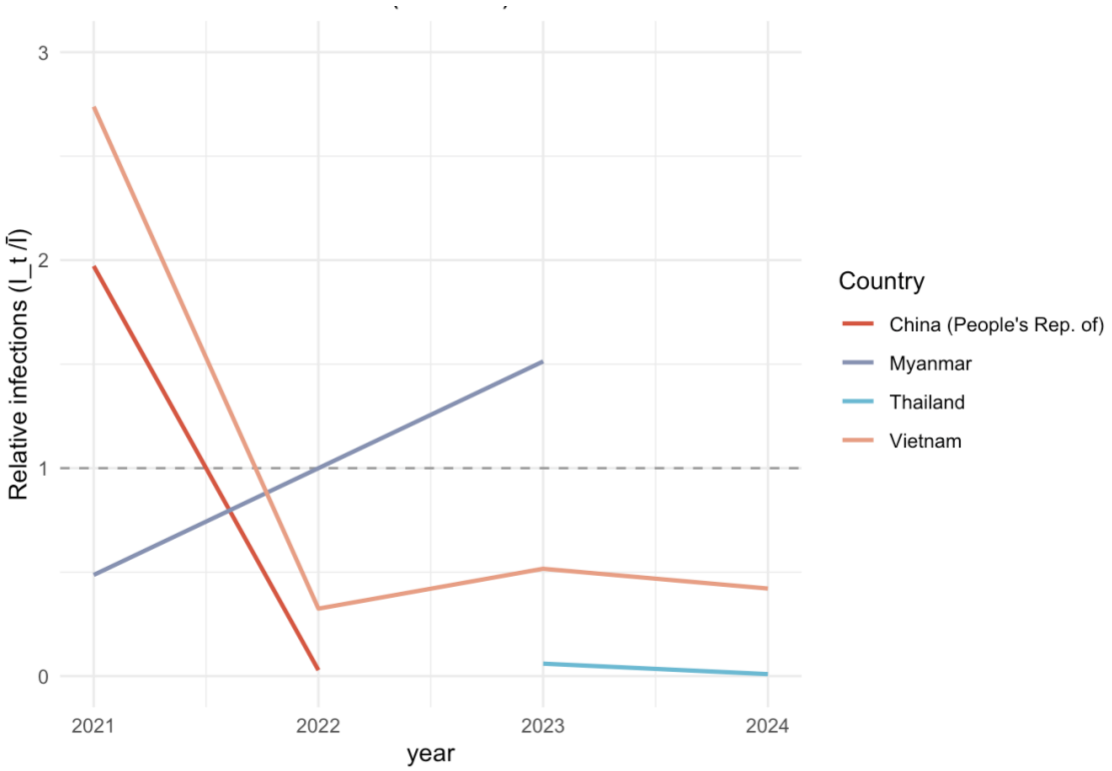
1.12 Global Trends

Figure 3.1 Average annual African swine fever virus infections by continent and global total, 2021–2025



Note: Y-axis shows the Relative Infection Index $I_t/\bar{I}$. For each region, $\bar{I}$ is the 2021–2025 mean (baseline = 1.0; dashed line marks the baseline). Values above 1.0 are above the period average; values below 1.0 are below it. Lines are annual averages. Cross-region levels are not directly comparable; read within-series change and timing. Data source: World Animal Health Information System (WAHIS), accessed May 2025.

Figure 3.2 Trends in African swine fever virus infections in GMS region, 2021–2025



Note: Relative Infection Index $I_t/\bar{I}$. Each country is scaled to the mean over its available years (baseline = 1.0). Coverage: China 2021–2022; Myanmar 2021–2023; Thailand 2023–2024; Vietnam 2021–2024. Values above 1.0 are above the period average. Levels are not directly comparable across countries; focus on each series' own pattern. Data source: World Animal Health Information System (WAHIS), accessed May 2025.

For decades, ASF circulated almost exclusively in the warthog–soft-tick sylvatic cycle of sub-Saharan Africa, yet after its 2007 leap to Georgia, the virus expanded into a truly global panzootic. By 2025, more than fifty countries across Africa, Europe, Asia, and, since 2021, parts of the Caribbean and South America, reported outbreaks or endemic infection (OECD, 2023). The Asian wave that began in 2018 wiped out an estimated half of China's herd and drove pork prices to double (Gale, Kee, & Huang, 2023), while Vietnam lost roughly one-fifth of its stock, underscoring the disproportionate toll on smallholders (Nguyen-Thi et al., 2021).

With no effective, broad-spectrum vaccine, many countries are locked into long-term wildlife management; FAO and WOAH regional programs on early warning, compensation, and biosecurity are crucial but will take time to show full effect. Against this backdrop, the accompanying figure charts average relative infections (I_t / $\bar{I}$), where $\bar{I}$ represents the 2021–2025 mean outbreak level. The global trajectory falls steadily from above baseline to well below 1.0, signaling a moderation in outbreak intensity, yet regional paths diverge. Asia peaked early and then dipped with an uneven recovery. Europe saw a turning point in 2024, when the number of affected EU member states dropped for the first time since 2014, and domestic pig outbreaks declined by 83% (European Food Safety Authority [EFSA], 2024), though wild boar infections remained entrenched in Poland, Italy, and Germany. Africa, by contrast, follows a gentler but steady decline. Crucially, these gains owe as much to drastic culling and trade bans as to genuine epidemiological progress. Wherever infected wild boar or feral pigs persist, resurgence remains likely, so sustaining the sub-baseline trend will hinge on continued investment in rapid detection, transparent reporting, and tightly coordinated regional action.

2023–2025 genotype shift and vaccine gap. Genotype II remains dominant region-wide, but a Genotype I/II recombinant first seen in China (2021–2023) and then in Viet Nam (2023–2024) has been confirmed with 100% identity to China's strain. Current vaccines perform poorly against this recombinant, posing a program risk as Viet Nam expands vaccination.

1.13 OECD Background and Economic Impact

ASF now constitutes a structural threat to the OECD pig industry. According to the Animal Disease Information System (ADIS), 7442 wild-boar outbreaks were reported in 2022 across nineteen European countries, thirteen of which are both EU and OECD members (European Parliamentary Research Service [EPRS], 2023). Poland remains the Union's epidemiological center: detections in wild boar peaked at 4152 in 2020 and, despite a 33% decline, still reached 2152 cases in 2022. Germany followed with 1628 detections. The first positive carcass found in Brandenburg in 2020 provoked what an EU briefing described as "an immediate and very dramatic" trade shock, as China and other partners closed their markets within forty-eight hours, removing export sales worth almost one billion euro in 2019 and flooding an already saturated EU market.

Member responses vary with outbreak status and risk exposure. Poland combines extensive perimeter fencing with targeted culling along its western frontier, yet high caseloads persist. Germany erected similar barriers, but incursions beyond containment lines continue, demonstrating the limits of physical infrastructure alone (Kruszyński et al., 2023). Italy confirmed its first mainland cases in wild boar in 2022 after decades of freedom outside Sardinia, highlighting the virus's unpredictability. Belgium, by contrast, recovered ASF-free status in 2020 following strict forest closures, intensive carcass removal, and two consecutive years of negative surveillance (United States Department of Agriculture [USDA], 2020). These cases show that eradication from wildlife is feasible but costly and operationally demanding.

In Asia, South Korea has faced a prolonged epidemic since 2019. By early 2023 more than 4,200 infected wild boar had been identified, with infection fronts moving south despite extensive fencing and military culling (Ko et al., 2024). For ASF-free OECD members such as the United States and Canada, the priority is prevention. After ASF emerged in the Caribbean in 2021, both countries expanded border inspection and surveillance; the United States committed several hundred million dollars to customs checks, detector-dog teams, and a federal response plan.

Market effects are mixed. China's pork shortage in 2019–2020 lifted global prices, benefiting exporters such as the United States, but China's herd recovery in 2021–2022 reversed the trend and pushed prices down. Within the EU, Germany's export suspension created short-term opportunities for Spain and Denmark, yet these gains are outweighed by systemic risk: as long as ASF persists in Europe, all producers face potential trade disruption. To limit this exposure, the EU applies a regionalization regime that allows certified ASF-free zones to export; in 2021, it allocated twenty-eight million euro to surveillance and buffer-zone work in seven eastern Member States (EPRS, 2023).

ASF is accelerating structural change across the OECD. Germany is diversifying sales toward Southeast Asia and intra-EU markets to reduce reliance on China. Spain, although ASF-free, ships nearly forty-five percent of its pork to China and now moderates herd growth to limit price volatility. Heightened biosecurity that includes stricter farm access, routine disinfection, and reinforced fencing has become a standard investment throughout the OECD, reflecting a new baseline for disease-risk management.

1.14 Data Availability and Gaps in the GMS

For ASF, the regional evidence is comparatively coherent. China, Cambodia, the Lao PDR, Thailand and Viet Nam all experienced incursions after 2018, and the country sections already draw on recent WOAH notifications and FAO updates that extend into the early- to mid-2020s. On this disease there is little discrepancy between the outbreak timelines presented here and those in international sources. The main blind spot concerns Myanmar: although ASF has reached neighbouring areas, publicly accessible, country-level information remains extremely limited. While WAHIS data covers 2021-2023, it lacks detailed narrative context, and Myanmar therefore does not have a substantive ASF section in this report, leaving a visible gap in the regional picture.

1.15 People's Republic of China

ASF reached China on 3 August 2018, when Liaoning veterinarians confirmed the country's first case (Gale et al., 2023; Food and Agriculture Organization [FAO], 2025). Barely eight months later the virus had touched every mainland province (including Xinjiang, Tibet, and Hainan), exposing the ease of long-haul spread and the weaknesses in even the most sophisticated biosecurity systems. By May 2025 official reports listed infections in thirty-two provincial-level jurisdictions, Hong Kong included.

The economic fallout proved just as swift. Between 2018 Q3 and 2021 Q1, China produced an estimated 27.9 million tons less pork, which is eighteen percent of the volume a normal cycle would have delivered (Gale et al., 2023). In the crisis year of 2019 alone, output fell twenty-one percent; some metrics put the shortfall a touch higher (Frezal et al., 2021). Surge imports cushioned the hit but covered barely a fifth of the lost tonnage. With supplies tight, wholesale prices breached RMB 51 per kg in November 2019 (more than twice the pre-outbreak norm) and stayed elevated for over a year. Households adapted: average pork purchases slipped from 22.8 kg to 18.2 kg, while poultry, eggs, and aquaculture products filled part of the gap.

Central authorities responded with a suite of emergency measures: stamping out in infected zones, tightened movement controls, subsidies for commercial-scale farms, and large-scale upgrades to on-farm biosecurity (Wang, 2023). By November 2019, 1.193 million pigs had been culled. In April 2021, the Ministry of Agriculture and Rural Affairs issued a zoned-control framework that divided the country into five regions; apart from certified ASF-free compartments, breeding stock and piglets, live pigs must remain within their designated zones. These interventions, coupled with aggressive restocking, lifted the national herd to roughly 416 million head by the end of Q1 2021, near its pre-ASF level, and eased price pressure.

But the recovery was deceptive. The virus never left. Sporadic flare-ups, most recently in Hong Kong in 2021-2023, confirm that ASF now circulates endemically. China's experience remains a cautionary tale: even with intense surveillance and heavy investment, the country must maintain strict biosecurity and transparent reporting or risk a fresh market shock.

1.16 Cambodia

Cambodia has reported renewed African swine fever activity after several quiet years, indicating re-emergence rather than elimination. Given porous borders and smallholder-dominant production, recent detections warrant heightened active surveillance and movement controls. Recent global swine-disease surveillance shows persistent ASF activity across Asia, with repeated domestic-pig outbreaks in neighbouring Viet Nam, China and other producers, implying sustained re-introduction risk for Cambodia's smallholder pig sector and reinforcing the need for basic farm-level biosecurity and movement control (Swine Health Information Center, 2025). Cambodia detected its index ASF event in backyard herds in Ratanakiri Province on 22 March 2019; laboratory confirmation followed on 29 March (Ministry of Agriculture, Forestry and Fisheries [MAFF], 2019). Over the next four months the virus advanced southwest to Tboung Khmum, Svay Rieng, Takeo, and Kandal, bringing the total to five affected provinces (FAO & MAFF, 2020). Field reports attribute roughly 5000 pig deaths and culls to these first-wave outbreaks. Epidemiological tracing points to informal movements of live pigs and pork products from Viet Nam or China as the introduction route. The structural context is high vulnerability: in 2018 Cambodia's pig inventory stood at about three million head, 86 % of which were kept in low-biosecurity, family-run units (Agronomes et Vétérinaires Sans Frontières [AVSF], 2024).

Authorities mounted a standard response, combining stamping-out and ring disinfection with intensified surveillance that included mobile PCR platforms for on-site diagnostics. But the campaign was stymied by a constellation of persistent challenges: free-ranging husbandry, limited producer compliance, language barriers in minority areas, and chronic constraints on veterinary manpower and financing. To strengthen community-level biosecurity, Cambodia joined the FAO/AVSF's CABI pilot in two provinces in 2023, with a broader scale-up planned for 2024.

1.17 Lao PDR

Lao PDR confirmed its first African swine fever (ASF) outbreak on 20 June 2019 in Samakkhixay District, Salavan Province; by December that year, officially recorded outbreaks had been reported in every one of the country's 18 provinces, with 150 affected villages over a 190-day period (Hui et al., 2023). Case investigations showed that transmission was concentrated in smallholder systems: in Oudomxay Province, individual households lost a mean of 3–23 pigs and village-level mortality reached 71 %, translating to an average economic loss of USD 349 per herd (Matsumoto et al., 2023). Spatial modelling linked early outbreak clusters to dense road networks, proximity to the Viet Nam border, and higher village pig densities, conditions that facilitated long-range virus introduction via informal trade and local movement of pigs or pork products.

Government response combined stamping-out, village quarantine, carcass disposal, and border disinfection checkpoints, supported by passive and active surveillance led by district veterinary officers (DLF, 2020). Despite these measures, sporadic flare-ups continue: the most recent laboratory-confirmed outbreak was reported on 19 February 2025 in Xaysomboun Province, underscoring the virus's persistence in backyard herds and the ongoing challenge of enforcing biosecurity in free-range settings (FAO, 2025). Key constraints include limited laboratory capacity, uneven farmer reporting, and the cost of sustained compensation; current national plans therefore prioritise village-level biosecurity training, contingency fund mobilisation, and strengthened cross-border coordination with neighbouring Vietnam and China.

1.18 Thailand

Thailand's first laboratory-confirmed ASF outbreak in domestic pigs was reported by the Department of Livestock Development (DLD) in January 2022, following several years during which the virus had only been detected in confiscated pork products at airports and border posts (Boonpornprasert, 2023). Between 2022 and mid-2024, the country recorded 114 farm-level outbreaks across 35 of 77 provinces, with the most recent event documented in Luang Nuea village, Chiang Mai Province, in June 2024 (FAO, 2025). The DLD response has centered on culling of affected herds, movement control, carcass disposal, and intensified molecular surveillance; national laboratory networks now apply both OIE-recommended real-time PCR and in-house LAMP assays for rapid field diagnosis.

Concurrently, concern about viral maintenance in wildlife has prompted spatial risk work. A 2025 Random-Forest model estimated ≈ 307 000 free-ranging wild boar nationwide, with high-density clusters along the northwestern frontier bordering Myanmar and Lao PDR (Thanapongtharm et al., 2025). The model highlighted forest cover and elevation as key predictors and identified fifty-five sub-districts where abundant wild boar overlap with intensive pig farming; those areas are now prioritized for biosecurity outreach and fencing initiatives. Although Thailand's outbreak count remains modest relative to some neighbors, these wildlife–livestock interfaces, coupled with the country's active informal trade in live pigs and pork, keep ASF a standing structural threat that demands sustained surveillance and cross-border coordination (FAO, 2025).

1.19 Vietnam

Vietnam has lived with ASF since its first commune-level outbreak was confirmed on 19 February 2019 in Hưng Yên Province. The initial epidemic phase was explosive: by December 2019 the virus had spread to 8,553 of the country's 10,614 communes, forcing the death or culling of roughly six million pigs, about one-quarter of the national herd (Chuong et al., 2025). Outbreaks fell to 1808 in 2020 but resurged to 3029 in 2021 before trending downward again (1407 in 2022 and 952 in 2023), signaling the transition from an acute epidemic to an endemic situation.

Official figures show renewed pressure in 2024: the Department of Animal Health recorded 1 609 commune outbreaks across forty-eight provinces (mostly small clusters that were rapidly contained) resulting in 89 580 pigs dead and 81 030 culled, 2.6 times the 2023 losses (Department for Environment, Food and Rural Affairs [DEFRA], 2025). Complicating control efforts, a recombinant ASFV strain carrying genotype I and II signatures (previously reported in China) was detected in northern provinces and is not neutralized by Viet Nam's genotype II live-attenuated vaccines. Moreover, field investigations have revealed vaccine-like deletion variants causing reproductive failure in naïve breeding herds, highlighting biosecurity gaps and the risk of inadvertent viral dissemination (Nguyen et al., 2025).

Vietnam's national control plan couples ring culling with stepped-up surveillance, compartmentalization, and the commercial deployment of domestic live attenuated vaccines (Chuong et al., 2025). While these measures have stabilized the industry and encouraged a shift toward larger, more biosecure farms, persistent challenges, smallholder biosecurity deficits, the emergence of recombinant strains, and uneven vaccine uptake underscore the need for sustained monitoring, targeted producer education, and careful evaluation of vaccination strategies.

1.20 Recommendations for GMS Policy Makers

The epidemiology of ASF in the Greater Subregion(GMS) is now characterized by persistent, low-level endemicity rather than a unified epidemic wave. The subregion's key challenge is a shared corridor of high transmission risk, defined by porous borders, integrated pork value chains, and the movement of infected wild boar populations. Against this backdrop, an effective regional strategy requires shared early-warning systems and harmonized movement controls, though specific national control strategies must be adapted to local conditions.

China, as the northernmost country in the GMS, functions as a key location for both monitoring and potential disease introduction. Implementing regular serotype surveillance at border inspection posts, along with province-level data platforms that report real-time PCR results within forty-eight hours, would provide crucial early warning to neighboring countries about emerging viral lineages. Furthermore, subsidizing bio-secure transit hubs in Yunnan for the testing and batching of feeder pigs would reduce the risk of subclinically infected animals entering cross-border trade.

The kingdom’s challenge in Thailand is sustaining expensive vigilance in the face of modest case numbers. A ring-fence strategy that limits heavy investment to the fifty-five high-risk sub-districts mapped by the 2025 Random-Forest model would yield the highest return per baht. Bangkok could further stretch its budget by formalizing a “co-maintenance pact” with adjoining districts in Myanmar and Lao PDR, sharing the cost of fence repairs, carcass removal, and ranger patrols that keep wild boar from breaching the perimeter.

For Cambodia, the priority is knowledge before capital. A national serotype baseline, collected via twice-yearly cluster sampling in each agro-ecological zone, would turn anecdotal risk into quantifiable threat. Pairing that dataset with micro-grants would fund a toolkit of practical defenses (footbaths, slaked-lime pits, and basic perimeter fencing), converting awareness into action without waiting for large donor tranches.

In Lao PDR, most ASF outbreaks are concentrated in backyard farms, but laboratory confirmation is often significantly delayed. The diagnostic timeline could be reduced to within the five-day window critical for effective quarantine by upgrading the district veterinary network with solar-powered PCR units and a mobile-based reporting system. A modest, ring-fenced compensation fund, automatically triggered by a positive PCR result, would incentivize prompt reporting from farmers.

Following the rollout of a live-attenuated vaccine, Vietnam's primary challenge is managing the emergence and spread of recombinant strains. This requires mandatory post-vaccination sero-surveillance to monitor vaccine efficacy and the sequencing of any field strains that cause vaccine-breakthrough infections. Such data would allow regulators to adjust vaccination protocols proactively. Concurrently, a QR-code-based transport permit system would improve traceability of live animals, mitigating the spread of new viral variants.

Technological advances, however, are toothless without a modernized data infrastructure to support them. Effective disease control hinges on the capacity to fuse disparate datasets (farm censuses, movement logs, laboratory results, and genomic information) into a single, real-time operational picture. Only such integrated platforms can power the predictive analytics and machine learning models needed to identify high-risk areas, forecast outbreak trajectories, and allocate resources with tactical precision. This shift toward a data-centric approach is what fundamentally separates reactive containment from proactive, long-term disease management.

4 Foot and Mouth Disease

1.21 Overview

Foot-and-mouth disease is a highly contagious viral infection of cloven-hoofed animals and ranks among the most disruptive transboundary livestock diseases. The causative agent, an Aphthovirus in the family Picornaviridae, occurs in seven immunologically distinct serotypes (O, A, C, SAT 1, SAT 2, SAT 3, and Asia 1), and immunity to one does not protect against another danger (WOAH, n.d.). Serotype C has not been detected since 2004 and is regarded as potentially extinct.

Clinical signs include fever and vesicles on the feet, oral mucosa, and mammary glands. Morbidity in naive herds approaches one hundred percent, but adult mortality seldom exceeds five percent, whereas young stock can suffer losses above twenty percent due to fatal myocarditis.

The virus is shed in all secretions and excretions of acutely infected animals and spreads efficiently by direct contact, aerosols, and contaminated fomites such as vehicles, equipment, and uncooked animal products (WOAH, n.d.). Some ruminants become long-term carriers, retaining the virus in the oropharynx for months or even years and sustaining the risk of new outbreaks. Human infection is rare and mild, so the disease poses little public-health danger (WOAH, n.d.).

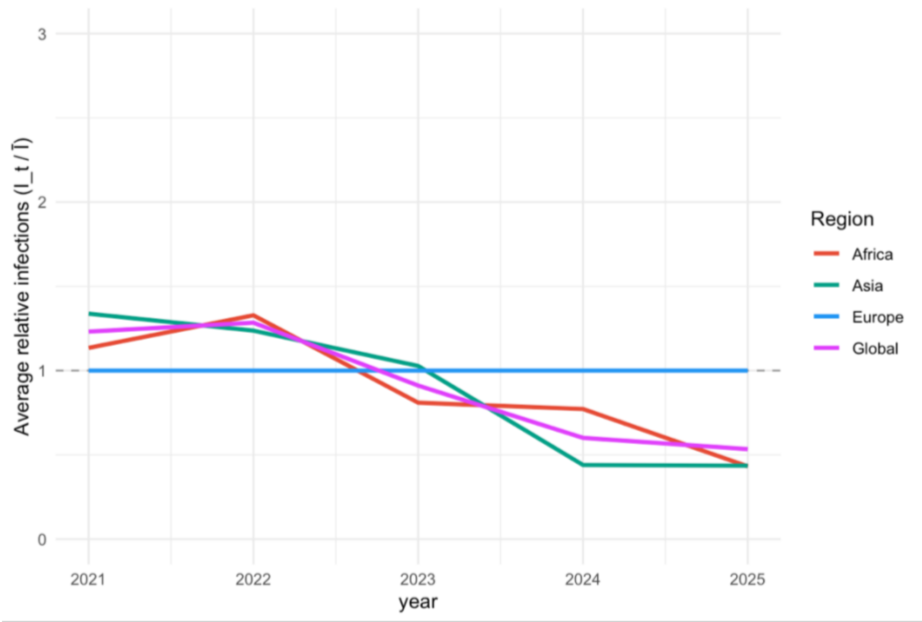
1.22 Global Trends

Foot-and-mouth disease remains entrenched across large parts of Africa, the Middle East, and Asia, with residual pockets in South America. This wide endemic zone imposes heavy costs on global livestock production. Direct production losses and routine vaccination in affected regions are valued at 6.5–21 billion USD each year, while incursions into previously free countries add a further 1.5 billion USD in eradication expenses and trade disruption (FAO, 2023).

Average relative-infection data for 2021–2025 (Figure 4.1) show that Africa and Asia begin just above the baseline in 2021, peak modestly in 2022, and then decline below one by 2024, reflecting intensified vaccination and movement control. Europe holds a flat line at unity until 2025, when the first outbreaks in Germany since 1988 and in Hungary since 1973, followed by spread to the Slovak Republic, break a long period of freedom (FAO, 2023). The global trend, illustrated by the magenta line, mirrors these events: a mild rise in 2022 followed by a steady fall, yet still finishing above the pre-2021 benchmark, underscoring the disease's resilience.

In 2012 more than one hundred countries endorsed the joint FAO–WOAH Global FMD Control Strategy, placing the Progressive Control Pathway (PCP-FMD) at its core (Global Framework for the Progressive Control of Transboundary Animal Diseases [GF-TADs], n.d.). The pathway guides endemic states through risk-based stages toward improved control and, ultimately, eradication. Regional roadmap platforms review progress, harmonize vaccination schedules, and share information on circulating strains, a process identified as the single most effective way to lower the global infection curve over the next decade. Full implementation of this stepped approach, combined with rapid diagnosis and strict biosecurity in free zones, remains essential to protect international trade and to push the downward trajectory seen after 2023 even lower in the years ahead (Knight-Jones et al., 2016).

Figure 4.1 Average annual foot and mouth disease virus infections by continent and global total, 2021–2025



Note: Y-axis shows the Relative Infection Index $I_t/\bar{I}$. Each region is scaled to its 2021–2025 mean (baseline = 1.0; dashed line marks the baseline). Values above 1.0 are above the period average; values below 1.0 are below it. Lines are annual averages. Cross-region levels are not directly comparable; read within-series change and timing. Data source: World Animal Health Information System (WAHIS), accessed May 2025.

Figure 4.2 Trends in Foot and mouth disease virus infections in GMS region, 2021–2025

Note: Relative Infection Index $I_t/\bar{I}$. Cambodia and China are scaled to their 2021–2025 mean with data through 2025. Thailand and Vietnam are scaled to their 2021–2024 mean; series end in 2024. Values above 1.0 are above the period average. Levels are not directly comparable across countries; focus on each series' own pattern.Data source: World Animal Health Information System (WAHIS), accessed May 2025. Cross-region magnitudes are not directly comparable

1.23 OECD Background and Economic Impacts

FMD is distributed along the world's economic gradient: industrialized nations are almost universally free of the virus, whereas it persists as an endemic infection in many developing regions (Rweyemamu & Astudillo, 2002). Recent incursions into several members of the OECD show, however, that long periods of freedom confer no permanent immunity and that eradication is both financially and socially expensive (Junker et al., 2009). These events underscore the vulnerability of high-income livestock systems and the need to control FMD at its source in endemic countries to safeguard global trade and food security.

The United Kingdom's 2001 epidemic remains the canonical OECD example. Between February and September, authorities confirmed 2030 infected premises after the virus emerged at a pig-finishing unit in Northumberland, almost certainly through the feeding of infected meat waste (Scott et al., 2004; DEFRA, 2002). Infected pigs moved to a slaughterhouse in Essex initiated one line of spread, while airborne transmission from the index farm infected nearby sheep that were then sold through markets, disseminating the virus nationwide (DEFRA, 2002). A nationwide movement ban was imposed three days late, a delay later judged pivotal in the scale of the outbreak (Inquiry, 2002). Control required the destruction of about 6.5 million animals and the closure of public footpaths and waterways, creating the impression that the countryside was "closed" (Blake et al., 2001; Scott et al., 2004). Direct agricultural losses reached £3.1 billion, and tourism lost a further £2.7–3.2 billion (DEFRA/DCMS, 2002). The United Kingdom regained FMD-free status in January 2002, three and a half months after the final case (Junker et al., 2009).

Two other British outbreaks illustrate how speed of response shapes impact. The 1967 epidemic produced more confirmed cases (2228), but 94% occurred in the Northwest Midlands and North Wales, where an immediate movement ban and lower animal density limited spread. Only 442,285 animals were culled, and the estimated economic loss (scaled from 2001 DEFRA/DCMS ratios) was about £212 million (DEFRA, 2009; DEFRA/DCMS, 2002). By contrast, the 2007 episode, managed under a well-rehearsed contingency plan, was confined to two farms and 183 culled animals. Prompt nationwide movement restrictions contained the virus, and costs to the Scottish livestock sector were about £32 million, with allied businesses losing an additional £4.5 million (Anderson, 2008; Moxey, 2008).

The 2001 crisis also spilled onto the European continent. France, free of FMD for two decades, confirmed infection on 13 March in Mayenne. Preemptive movement bans and strict zoning limited the toll to two outbreaks and 390 culled animals (Junker et al., 2009). The Netherlands, despite early precautions, detected its first case on 21 March, probably seeded by calves infected in France. Twenty-seven outbreaks followed. When culling capacity was stretched, authorities adopted a "suppressive-vaccination" (vaccinate-to-die) strategy and eventually destroyed more than 247 500 animals (Bouma et al., 2003; Bouma et al., 2002; Junker et al., 2009). The Netherlands regained FMD-free status in September 2001, four months after the last vaccinated herd was culled (Junker et al., 2009).

Across these OECD experiences, three economic constants emerge. Routine prevention, such as border inspection, surveillance, and vaccine banking, is far cheaper than eradication once the virus is established. Moreover, indirect losses can rival or exceed farm-sector costs; in the United Kingdom, tourism bore almost half the total quantified damage. Lastly, the modern concentration of farms, markets, and abattoirs accelerates dissemination when infection enters the network, magnifying the penalty for any delay in movement controls. The record therefore confirms that the true price of FMD in high-income economies lies not in viral pathogenicity but in the wide economic reverberations that accompany any lapse in FMD-free status.

1.24 Data Availability and Gaps in the GMS

For FMD, China's situation is broadly consistent with a controlled system following the major epidemic in 2013, and the description in this chapter aligns with that pattern. In Cambodia, much of the discussion rests on village-level information from around 2010; in the Lao PDR it relies on a 2020 serological survey; in Viet Nam most figures stop around 2017–2018; and Thailand's account does not yet incorporate post-2019 trends, despite ongoing control programmes. These snapshots are still the latest national series that can be traced in official and published sources, but they leave recent years largely undocumented. Myanmar is absent altogether, making FMD one of the clearest examples where an important disease is present in the broader region but poorly described for several GMS countries.

1.25 People's Republic of China

FMD is a highly contagious infection that continues to constrain the growth of China's livestock sector, and the country, as one of the world's largest producers and consumers of animal protein, remains among those most seriously affected. The virus was first reported in 1958, with serotypes O and A detected in the Xinjiang Uyghur Autonomous Region and serotype Asia 1 in Yunnan Province (Chen et al., 2020; Wang et al., 2021). A large-scale epidemic of serotype Asia 1 unfolded between 2005 and 2009, yet that serotype has not been identified on the mainland since. From 2010 onward, the disease profile has shifted to endemic, sporadic outbreaks of serotypes O and A, concentrated mainly in northwestern and southeastern provinces (Wang et al., 2021). During 2010–2020, authorities recorded 140 outbreaks; cattle accounted for 54.76 percent of cases, and pigs for 32.74 percent.

Clear spatiotemporal patterns characterize these events. Outbreaks cluster in the first half of each calendar year, with March to May emerging as the principal risk period (Chen et al., 2020; Wang et al., 2021). Warm, rainy spring weather favors virus transmission, although winter incidents still occur in southern coastal provinces where temperatures remain mild and in northern districts where cold stress may depress immunity. Spatially, the main foci lie in the northwest and the southeast, and statistical analyses show a prevailing transmission axis running from the northwest toward the southeast (Chen et al., 2020). Multi-criteria risk mapping identifies four persistent high-risk zones: (i) a western belt spanning parts of Xinjiang and Tibet; (ii) a southern belt covering sections of Yunnan, Guizhou, Guangxi, and Guangdong; (iii) a northern belt that includes portions of Gansu, Ningxia, and Inner Mongolia; and (iv) an eastern belt that extends through parts of Hebei, Henan, and Shandong (Wang et al., 2021). Of these, Xinjiang and Tibet report the most frequent outbreaks, a pattern linked to high densities of susceptible livestock and the continued use of traditional, extensive husbandry systems.

Several factors dominate the national risk landscape. Proximity to previous outbreak sites, the presence of communal grazing land, and high cattle density rank as the strongest predictors of new cases (Wang et al., 2021). Border districts face additional danger because illegal cross-border livestock movements can introduce fresh virus. Husbandry practice is critical: small household units, free-range grazing, and the mixed rearing of multiple susceptible species all elevate risk (Wang et al., 2021). Moreover, dense transport networks, together with the location of livestock markets and slaughterhouses, facilitate mechanical spread.

China has responded with a compulsory immunization strategy. After significant serotype O outbreaks in Tibet in 2013, authorities intensified disinfection, culling, and full-coverage vaccination, while vaccine-quality standards were upgraded. Since then, the number and geographic spread of hotspots have declined (Chen et al., 2020). These combined insights into temporal peaks, spatial clusters, and key drivers now underpin targeted surveillance and control, enabling more efficient allocation of veterinary resources and strengthening national FMD preparedness.

1.26 Cambodia

Foot-and-mouth disease remains endemic in Cambodia, but its true incidence is difficult to quantify because routine surveillance captures only a small fraction of events (Bellet et al., 2012; Vergne et al., 2012). Participatory interviews conducted in 51 cattle–buffalo villages in Svay Rieng Province indicated that 84 percent of communities had experienced vesicular disease compatible with FMD between January 2009 and June 2010 (Bellet et al., 2012). A parallel capture-recapture study compared these village-level reports with provincial notification records and estimated that approximately 315 villages (around 46 percent of the province) were affected in 2009, whereas the official system registered only fifteen outbreaks, yielding an estimated reporting sensitivity of about five percent (Vergne et al., 2012).

Clinical impact at the herd level is moderate: farmers report transient losses in draft power, reduced fertility, and treatment costs, but adult mortality is low, and sick animals often recover after basic care (Bellet et al., 2012). Because outbreaks seldom cause large die-offs, village animal-health workers tend to alert district offices only when simultaneous cases appear in several neighboring villages, reinforcing chronic under-notification. Serotype information during the study period was sparse, but laboratory confirmation of a subset of cases pointed to the continued circulation of serotype O (Vergne et al., 2012).

Epidemiological risk is closely linked to animal movement. Villages that purchased young cattle or buffalo from markets reported higher odds of infection, indicating that trade remains the primary pathway for virus introduction and spread (Vergne et al., 2012). Communal grazing and mixed-species husbandry further elevate risk in rural lowland districts. Vaccines are available through public channels, yet uptake is inconsistent because producers perceive FMD as less economically damaging than hemorrhagic septicemia and other priority diseases (Bellet et al., 2012).

Current surveillance relies on passive reporting and ad hoc laboratory support, leaving significant gaps in incidence data and antigenic characterization. Establishing a modest, province-rotating NSP sero-survey program and linking village alerts to a digital reporting platform would provide the baseline evidence necessary for targeted vaccination and movement control. Until such measures are in place, Cambodia is likely to continue experiencing undetected low-level transmission that limits livestock productivity and complicates regional trade negotiations.

1.27 Lao PDR

FMD in Lao PDR illustrates a classic pattern of “managed endemicity” punctuated by periodic flare-ups. Encouragingly, zero outbreaks have been reported for 2–3 consecutive years, though regional risk remains due to serotype circulation in neighboring countries. Historical surveillance shows that between 1998 and 2007 the country recorded at least 142 confirmed outbreaks, with serotype O reported every year from 1998 to 2005 and smaller waves of serotypes A and Asia 1 (Khounsy et al., 2008). Outbreaks focused on the trade corridors radiating from Vientiane Capital and the central provinces, a distribution that mirrors both animal-movement routes and areas of highest cattle density. These spatial patterns, coupled with the porous borders Laos shares with five FMD-endemic neighbors, underscore how transboundary movements rather than local husbandry alone continue to seed new incursions (Khounsy et al., 2008).

More recent data confirm that the virus is still circulating widely at subclinical levels. A 2019–2020 cross-sectional survey of nine northern provinces found a true non-structural-protein (NSP) seroprevalence of 43.7% in large ruminants, with at least one seropositive animal detected in 90% of sampled villages (MacPhillamy et al., 2022). Antibody profiles suggested co-circulation of serotypes O and A, and seroconversion was significantly higher in cattle and buffalo aged two to eight years, implying regular exposure rather than isolated spill-overs. Critically, only two of ten post-vaccination herds reached the >80% immunity threshold recommended for effective herd protection, highlighting gaps in vaccine coverage that leave ample room for silent virus maintenance (MacPhillamy et al., 2022; Khounsy et al., 2008).

Institutionally, Laos remains at Stage 1 of the Progressive Control Pathway for FMD: risks are recognized, but routine surveillance, high-potency vaccination, and computerized reporting are still evolving (MacPhillamy et al., 2022). Field interviews reveal an informal, phone-based reporting chain in which village veterinary workers decide whether to escalate cases; this discretion, combined with limited laboratory capacity, leads to “information leakage” that obscures the true burden and delays response. The practical consequence is a surveillance system good at confirming large clinical outbreaks yet largely blind to the low-level transmission documented serologically.

1.28 Thailand

FMD persists in Thailand as a state of managed endemicity. National records show 826 confirmed outbreaks between 2011 and 2018, with cases climbing steadily to a peak of 284 in 2016 before tapering (Chanchaidechachai et al., 2022). Incidence follows a marked annual rhythm: reports are scarcest in the hot, dry months of March to May, then rise through the cooler, wetter period from October to December, a seasonality that reflects both enhanced viral survival in humid weather and possible lags in vaccine delivery during the monsoon (Chanchaidechachai et al., 2022).

Spatial analyses converge on the same high-risk corridors. A GIS-based multi-criteria model validated against the 2016 data pinpoints persistent hot spots in the western, central, and upper-northern regions, with smaller pockets in the lower northeast and deep south (Sangrat et al., 2020). Empirical cluster detection corroborates this picture, showing that most outbreaks form small, self-limiting foci inside those belts; in 2016 alone, 51 significant clusters were recorded, many confined to just a few sub-districts (Chanchaidechachai et al., 2022). Risk rises in step with animal density: a ten-fold increase in dairy cattle, beef cattle, or pigs multiplies the odds of an outbreak by 2.06, 1.43, and 1.22, respectively, while a sub-district lying within 10 km of a recent case faces nearly triple the risk. Proximity to livestock markets, slaughterhouses, dense road networks, and international borders, especially the trade corridor with Malaysia, further amplifies exposure (Sangrat et al., 2020).

Thailand’s compulsory trivalent cattle vaccine and bivalent pig vaccine underpin the current equilibrium, yet the persistence of small clusters reveals immunity gaps in backyard ruminants and unvaccinated pig holdings. The evidence suggests that strengthening pre-rainy-season vaccination in dairy and beef belts, intensifying post-outbreak surveillance within 10 km buffers, and tightening border biosecurity along transboundary trade routes are vital steps if Thailand is to progress from containment toward sustained reduction of FMD incidence.

1.29 Vietnam

FMD remains enzootic throughout Viet Nam, with serotypes O and A circulating continuously and serotype Asia 1 detected intermittently (Do et al., 2018). An analysis of official outbreak data from 2007 to 2017 documented more than 1600 confirmed outbreaks, most linked to the O/ME-SA/PanAsia and O/SEA/Mya-98 lineages; incidence peaked in 2011, declined after 2013, yet has never fallen to zero. Seasonality is pronounced: cases rise from December to March, when cooler, drier weather and heightened livestock movements around the Lunar New Year favor virus transmission (Do et al., 2018). Spatial clustering is equally clear. High-risk foci persist in the Red River Delta, the coastal central provinces, and the Mekong Delta, regions that combine dense cattle or pig populations with major live-animal trade corridors (Do et al., 2018).

Control policy relies on compulsory biannual vaccination of cattle and buffalo in officially designated high-risk provinces, supplemented by risk-based vaccination of pigs. Field surveys show that implementation is uneven. In a 2017 cross-section of dairy and beef farms in the southeastern region, mean vaccination coverage exceeded 90% in commercial dairy herds but fell below 70% in smallholder beef systems (Truong et al., 2018). A partial budgeting exercise on the same farms found that two-dose annual vaccination yielded a benefit-cost ratio of 11.6 for large dairy units and 9.9 for medium dairy units, whereas the figure for small beef herds was just 3.0, reflecting lower animal values and liquidity constraints (Truong et al., 2018). These economic results help explain farmers' differing compliance: commercial dairies perceive vaccination as profitable risk insurance, while smallholders tend to postpone or skip doses when cash flow is tight.

Several structural factors continue to undermine eradication efforts. First, cold-chain breaks and on-farm handling errors reduce effective seroconversion, leaving immunity gaps even in nominally vaccinated herds. Second, informal trans-provincial movement of pigs and cattle, especially into urban slaughterhouses, bypasses inspection points and disseminates virus from endemic centers to low-incidence zones. Third, antigenic drift within serotype O (most recently the emergence of O/ME-SA/Ind2001e in neighboring countries) poses an ever-present threat that existing bivalent vaccines could lose potency before field formulations are updated (Do et al., 2018). Finally, current surveillance remains heavily outbreak-driven; routine non-structural-protein serology is limited, so silent transmission chains are often detected only after clinical clusters appear.

Taken together, these findings portray a country that has pushed FMD incidence down through mass vaccination but still faces persistent, low-level transmission sustained by smallholder immunity gaps, porous market chains, and the continual evolution of the virus. Strengthening cold-chain logistics, widening NSP serological monitoring, and accelerating the rollout of updated trivalent vaccines are now central to moving Vietnam from chronic endemicity toward sustained reduction in FMD burden.

1.30 Recommendations for GMS Policy Makers

Progress toward lasting foot-and-mouth disease control in the Greater Mekong Subregion will hinge on closing a specific set of technical and institutional gaps that vary markedly from one member state to the next. The region already shares vaccine strains, diagnostic protocols, and market linkages, yet the epidemiological picture reveals five distinct challenges that cannot be solved by a single blueprint. Sustained regional momentum will come from tailoring resources (vaccines, surveillance budgets, training, and border controls) to the stage that each country has now reached on the Progressive Control Pathway.

China has squeezed the virus into four lingering corridors that run through Xinjiang and Tibet, parts of Yunnan and Guangxi, grazing districts in Gansu and Ningxia, and finishing belts in Hebei and Shandong. Vaccine coverage in commercial feedlots is approaching saturation, but traditional transhumance and live-animal exchanges along county roads still give the virus seasonal footholds. National planners can obtain the greatest marginal gain by synchronizing the spring vaccination round with livestock movements out of winter grazing areas while expanding electronic permits that tag every shipment leaving a border prefecture. Portable PCR units at informal crossings would shorten the time between detection and movement restriction, limiting the need for large-scale culls in downstream production zones.

Cambodia remains the blind spot in the regional surveillance network. Participatory interviews and small antibody surveys show that more than half of high-density cattle villages experience clinical disease every two to three years, yet only a handful of outbreaks reach the national database. The country is unlikely to mobilize annual blanket vaccination in the near term, so the immediate priority is evidence generation. A rolling, district-level NSP sero-survey (designed to sample each province once every eighteen months) and automatic text alerts that push suspected case reports up the chain of command would give authorities the information needed to justify targeted vaccine banks and emergency movement bans.

Lao PDR sits at the first formal step of the Progressive Control Pathway. Serology across nine northern provinces indicates widespread subclinical infection, but audits of vaccine cold rooms reveal temperature excursions that degrade potency before doses reach village cattle. A modest investment in solar refrigeration for district stores, allied to refresher courses that demonstrate proper dose preparation, would raise seroconversion rates in herds that are already nominally covered. Coupling those improvements with a tablet-based dashboard that displays real-time vaccination gaps would let district officers redeploy vaccinators before the December marketing peak, when traders move cattle south toward Vientiane.

Thailand offers the most comprehensive outbreak dataset in the sub-region and illustrates the limits of vaccination when backyard immunity lags behind commercial coverage. Risk maps place the western and central dairy belts, the pig-dense lower northeast, and the southern highway to Malaysia at the heart of residual transmission. Renewing cattle boosters six weeks before the October rainfall surge, together with systematic post-outbreak surveillance extending ten kilometers in every direction from the index farm, would preempt many of the small clusters that have characterized recent years. Joint patrols with Malaysian inspectors at secondary crossings would further reduce the chance that infected goats or cattle undermine progress.

Vietnam has lowered outbreak counts through twice-yearly vaccination of cattle and buffalo, yet household beef producers, who often hold only two or three animals, continue to delay injections when cash is scarce. Strengthening the cold chain will raise vaccine efficacy, but the program will only sustain momentum if smallholders perceive clear economic value. Matching grants that cover half the cost of each primary course, redeemable at local veterinary pharmacies, would ease the liquidity bottleneck, while integrated NSP testing at abattoirs would flag silent hotspots that occasionally seed outbreaks in commercial farms.

When vaccination systems already reach most livestock, incremental gains will come from precise risk mapping, fast diagnostics, and tighter control of animal movements. Where basic surveillance capacity is still maturing, the first dividend lies in making true incidence visible through low-cost serology and digital reporting. Aligning external support with each country’s current position on that spectrum, rather than applying a uniform regional template, is the surest path to push foot-and-mouth disease toward sustained decline across the Greater Mekong Subregion.

5 Classical Swine Fever

1.31 Overview

Classical swine fever (CSF), historically called hog cholera, remains one of the most consequential transboundary animal diseases of pigs and wild boar (Sus scrofa) worldwide (Merck & Co., Inc. [Merck], n.d.). The aetiological agent, Pestivirus suis, is an enveloped, positive-sense RNA virus in the family Flaviviridae whose close antigenic relationship with bovine viral diarrhoea and border disease viruses can confound serological diagnosis (WOAH, n.d.). Because CSF produces high mortality, disrupts trade, and persists in wildlife reservoirs, the World Organisation for Animal Health (WOAH) classifies it as notifiable, obliging member states to report outbreaks promptly (CAB International [CABI], n.d.). Although eradicated from North America, Australasia, and much of western Europe, the virus remains endemic across large swathes of Asia, Central and South America, and parts of eastern Europe and Africa (CABI, n.d.).

Since the regional ASF surge, routine CSF surveillance data have become more fragmented in official reporting streams after 2018. The apparent 'silence' likely reflects monitoring gaps rather than true absence. Pathogenesis is determined chiefly by viral virulence and host immunity. Highly virulent strains precipitate an acute syndrome marked by pyrexia above 41°C, widespread hemorrhages, neurological signs, and death within three weeks (Merck, n.d.). Moderately or low-virulent strains are now more common; they cause chronic or subclinical infection, poor growth, reproductive failure, and the birth of persistently infected "carrier" piglets that silently perpetuate the virus (CABI, n.d.). Definitive diagnosis therefore relies on WOAH-prescribed laboratory assays: RT-PCR or virus isolation for agent detection and ELISA or virus-neutralization tests for antibody surveillance (WOAH, n.d.).

CSF spreads most efficiently by direct contact, with infectious virus present in high titers in saliva, nasal exudate, urine, and feces (WOAH, 2025). Environmental tenacity is noteworthy; the agent survives for months in chilled pork and years when frozen, making the feeding of untreated swill a major pathway for transcontinental introduction. Fomites and transport vehicles contribute to farm-to-farm spread, while free-ranging wild boar maintain self-sustaining cycles in many European ecosystems. Crucially, although CSF and African swine fever (ASF) share similar clinical pictures, they are virologically distinct. CSF can be prevented with potent live-attenuated vaccines, whereas no commercial vaccine exists for ASF, obliging reliance on biosecurity and stamping-out alone (UP FVS, n.d.).

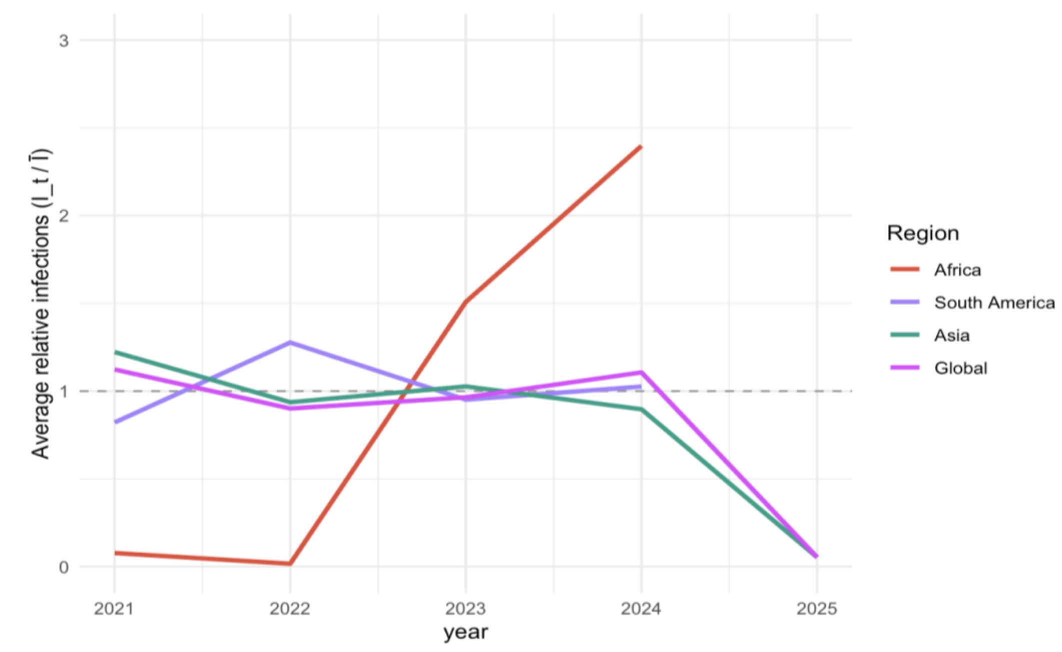
1.2 Global Trends

The evolution of CSF between 2021 and 2025 paints a mixed global picture. When the average relative-infection index ($I_t / \bar{I}$) is plotted for all regions together (Figure 5.1, purple line), the curve drifts modestly below the baseline in 2022 before edging upward through 2023 and 2024, then tapering again in early 2025. In statistical terms the virus is neither exploding nor receding worldwide; rather, the global average conceals a series of region-specific surges and retreats that cancel one another out at the macro level. For international organizations and donors, this apparent stability is misleading because it can disguise acute crises that demand rapid, localized support.

Disaggregation exposes sharply divergent trajectories. In Asia the green line remains above the baseline for most of the period, with pronounced oscillations that typify endemic circulation in large, densely populated pig sectors where routine vaccination and subclinical infection keep the virus in constant play (CABI, n.d.). Africa, represented by the red line, is comparatively quiet until a sudden leap in 2024 lifts the index well past two, signaling one or more major epizootics that have redrawn the continental risk map. A similar spike appears in South America (light purple line) during the same year; this mirrors official reports of fresh foci in the region, including a confirmed outbreak in Brazil outside its long-standing disease-free zone (WOAH, 2025). North America and most of Europe remain officially CSF-free (Merck, n.d.), yet the continued presence of the virus in European wild boar populations obliges constant surveillance to guard against reintroduction to commercial herds.

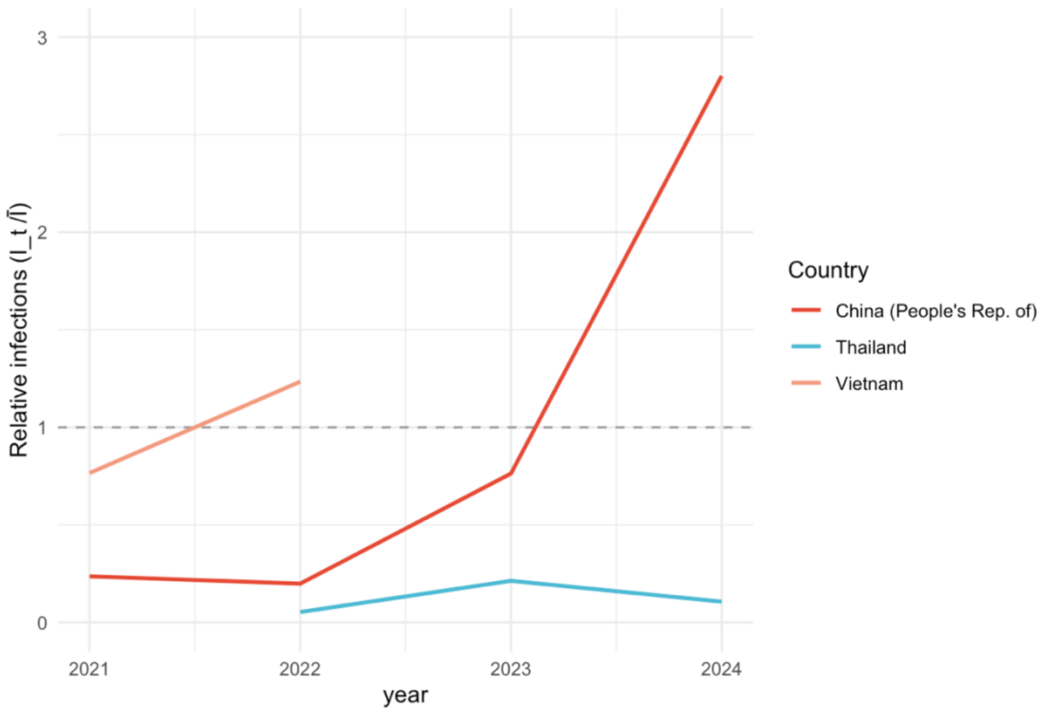
Within Asia, two contrasting national stories underline both the promise and the peril of CSF control. Taiwan has executed a decade-long program of vaccination, movement control, and intensive monitoring that positions it to receive WOAH confirmation of CSF-free status in May 2025 (Taipei Times, 2025). This achievement demonstrates that eradication is possible even in high-density production systems and will likely shift regional trade patterns as Taiwanese exporters regain premium market access. Japan, by contrast, has battled re-emergence since 2018 after twenty-six years of freedom. The virus has entrenched itself in wild boar, forcing a costly change from a strict stamping-out policy to widespread emergency vaccination of both domestic pigs and wildlife (Fournié et al., 2020). Between 2018 and 2023 Japan logged eighty-nine farm outbreaks and culled roughly 368 000 pigs (Shih & Lee, 2024), and in June 2024 a single incident on a farm of 17 500 animals underscored the scale of the continuing threat. The economic repercussions include the loss of WOAH CSF-free status and associated export privileges (Rossi & Le Potier, 2021), a cautionary reminder that even highly resourced veterinary systems remain vulnerable when wildlife reservoirs are in play.

Figure 5.1 Average annual Classic swine fever virus infections by continent and global total, 2021–2025



Note: Y-axis shows the Relative Infection Index $I_t/\bar{I}$. For each region, $\bar{I}$ is the 2021–2025 mean (baseline = 1.0; dashed line marks the baseline). Values above 1.0 are above the period average; values below 1.0 are below it. Lines are annual averages. Cross-region levels are not directly comparable; read within-series change and timing. Data source: World Animal Health Information System (WAHIS), accessed May 2025. Cross-region magnitudes are not directly comparable

Figure 5.2 Trends in Classic swine fever virus infections in GMS region, 2021–2025



Note: Relative Infection Index $I_t/\bar{I}$. China, Thailand, and Vietnam are each scaled to their 2021–2024 mean (baseline = 1.0). Values above 1.0 are above the period average. Country series run through 2024; 2025 not available at this level. Levels are not directly comparable across countries; focus on each series' own pattern.. Data source: World Animal Health Information System (WAHIS), accessed May 2025. Cross-region magnitudes are not directly comparable

1.3 OECD Background and Economic Impacts

Across the high-income economies of the OECD, Classical Swine Fever exerts its heaviest toll not through routine herd losses but through the financial architecture required to prevent and detect and, when defenses fail, eradicate the virus. The imperative is to preserve WOAH-certified CSF-free status, a credential that secures access to premium export markets and underwrites the profitability of highly globalized pork industries. Maintaining that credential demands continuous investment in surveillance networks, high-specification biosecurity, and contingency funds for emergency depopulation; the balance sheet is therefore dominated by fixed and preparedness costs rather than by the direct value of pigs lost to infection.

When control does break down, the economic shock is swift and severe. The 1997-1998 Dutch epidemic remains the benchmark: a five-to-seven-week diagnostic delay in Europe's most pig-dense corridor allowed the virus to outrun traditional stamping-out measures, forcing the preemptive culling of 1.1 million pigs on uninfected farms and pushing total losses above US $2.3 billion (Meuwissen et al., 1999). The Netherlands accepted this extraordinary outlay because the alternative, adopting vaccination and forfeiting export credentials that cover more than 70 percent of national production, was judged even more costly. Germany's experience in the 1990s illustrates a different economic hazard: when wild boar become an endemic reservoir, the battle extends beyond farm fences to the landscape itself. Repeated spillover drove 424 domestic-herd outbreaks, the culling of roughly two million pigs, and control costs of about €1 billion; more than half of primary cases were traced to direct or indirect contact with infected boar, highlighting the expense of wildlife surveillance, fencing, and targeted depopulation (Fritzemeier et al. 2000).

Even isolated flare-ups can carry a hefty price tag. The United Kingdom's 2000 incident, limited to sixteen farms and seventy-five thousand pigs, still generated compensation payouts exceeding £4.3 million, a figure that captures only direct indemnities and omits wider business disruption. For Chile and Mexico, both OECD members that now hold official CSF-free recognition, the historical record shows that outbreaks shifted industry policy towards strict zoning, border controls, and, ultimately, nationwide vaccination bans once freedom was established. These measures impose continuing compliance costs on producers, yet they are deemed preferable to the trade penalties that would follow any lapse in disease status.

Structural consequences are already visible. The capital required for state-of-the-art filtration, controlled-access housing, and dedicated transport fleets encourages consolidation into larger, vertically integrated enterprises better able to amortize these investments (Cerutib et al., 2025). At the same time, multinational processors diversify sourcing to hedge against sudden trade embargoes, a strategy reinforced by the US $111 billion shock China sustained from African swine fever in 2019 and by a European ASF control program whose indirect business losses amounted to forty percent of its €28 million total cost (Juszkiewicz et al., 2023; Gren et al., 2024). In short, CSF functions as both a direct threat and a structural market force, shaping the geography, ownership patterns, and risk-management calculus of the modern OECD pork sector.

1.4 Data Availability and Gaps in the GMS

For CSF, the material again splits along similar lines. China, Thailand and Viet Nam are portrayed using relatively recent information: China is described as endemic but controlled with data extending into the early 2020s, Thailand's infection index is followed through 2024, and Viet Nam's section traces genotype changes and vaccination trials up to about 2020. Cambodia and the Lao PDR, in contrast, are represented mainly by abattoir and serosurvey work around 2011–2012, with no newer national surveillance outputs available in the public domain. In these two countries, the figures presented here are simultaneously the first and last national snapshots on record, pointing more to longstanding weaknesses in surveillance and reporting than to an absence of CSF. Myanmar has limited CSF reporting in international databases and no dedicated CSF section in this report, with the epidemiological situation remaining largely undocumented.

1.5 People's Republic of China

CSF has been recognized in China since the 1950s, and the national control strategy has centered on compulsory, herd-wide vaccination with the lapinized C-strain ever since. Official data chart a long descent in reported outbreaks: surveillance tallied more than six hundred incidents in the mid-1990s, fell below one hundred by 2005, and reached just twenty-one cases in 2017. On paper these numbers point to steady progress, yet the relative-infection curve in Figure 5.2 tells a different story. After hovering near baseline in 2022, the index rises sharply to almost three by 2024, indicating that virus circulation is intensifying even as clinical alarms remain muted.

The apparent contradiction is explained by the changing viral landscape. Molecular studies show that subgenotype 2.1 viruses (distant relatives of the original vaccine strain) now dominate on commercial farms and in backyard herds (Zhou, 2019). These contemporary variants tend to cause chronic or subclinical infection rather than fulminant disease, allowing them to move unnoticed through large-scale production systems. Continuous vaccination suppresses classical, highly virulent outbreaks but also exerts selection pressure that favors immune-escape strains (Ganges et al., 2020). The result is a vast, low-mortality reservoir that does not trigger mass culling yet keeps the infection base high, which is an epidemiological pattern consistent with the steep trajectory observed after 2022.

China's experience illustrates a central dilemma for export-oriented, high-density pig industries: mass vaccination can drive recorded outbreaks towards zero while viral prevalence drifts upward in a clinically silent form. Without marker vaccines or routine post-vaccination serology, official monitoring underestimates this hidden burden, leaving producers vulnerable to sudden flare-ups and neighboring markets exposed to inadvertent spread.

1.6 Cambodia

CSF in Cambodia is best described as an information-gap disease. The Department of Animal Health and Production lacks a routine, nationwide surveillance system, and laboratory resources remain limited; most data still come from externally funded, time-bound projects (Tokash, 2019). As a result, officials cannot say with confidence whether CSF is genuinely scarce or simply escaping detection.

The one substantial snapshot is an abattoir survey conducted in Phnom Penh between October 2019 and January 2020. Among 655 slaughter pigs, investigators found a CSF antibody seroprevalence of 55.4 percent (Siengsanan-Lamont et al., 2022). They concluded that such a high figure almost certainly reflects widespread, farmer-driven vaccination, since commercial vaccines are easily purchased and used ad hoc to suppress clinical signs (Tokash, 2019).

This creates a strategic dilemma. Vaccine-induced antibodies shield herds but simultaneously obscure any underlying virus circulation. Without DIVA testing and structured monitoring, Cambodia cannot determine whether high seroprevalence marks success or masks endemic infection. The uncertainty hampers risk assessment, stalls policy design, and blocks access to disease-free trade status. Closing this gap will require sustained investment in field surveillance, improved diagnostics, and eventually a marker-vaccine program that distinguishes infection from immunization.

1.7 Lao PDR

CSF is recognized as one of the most important pig diseases in Lao PDR, yet accurate epidemiological intelligence remains sparse. The best nationwide snapshot comes from a two-province serological survey carried out in 2011 that sampled 647 pigs from 59 villages. Overall, 11.2 percent of animals carried CSF antibodies, with exposure highest in the southern province of Savannakhet (16.2 percent) and markedly lower in the northern uplands of Luang Prabang (4.8 percent) (Holt et al., 2019). When vaccinated animals were excluded from the analysis, the pattern persisted, suggesting genuine geographical variation in viral circulation.

Low-input, smallholder systems dominate the national herd, with about four pigs per household on average, and most pigs still roam or are tethered for parts of the year. Management factors strongly influence infection risk: pigs kept in pens had roughly one quarter the odds of seropositivity compared with scavenging animals (odds ratio 0.28), while those managed in communal "sanaam" enclosures faced elevated exposure to multiple transboundary diseases (Holt et al., 2019). Despite this, vaccination coverage for CSF was patchy (fewer than ten percent of herds reported any immunization), and national funding for livestock disease control was described as "lacking" at the time of the study.

Cross-border movement of live pigs complicates matters further. Lao PDR acts as a transit route within the Mekong region, and informal trade with neighboring Thailand and Vietnam has been repeatedly linked to the spread of CSF and other viral diseases. In an environment where routine surveillance is scarce and veterinary services are thinly resourced, these porous frontiers magnify the risk of periodic outbreaks that can wipe out up to 70 percent of village herds when the virus gains a foothold.

The picture in Lao PDR is one of endemic CSF maintained by extensive, low-biosecurity husbandry and constrained public-sector capacity. Serology confirms that the virus is widespread but uneven, vaccination remains opportunistic, and informal trade continually refreshes the threat landscape. Until sustained investment is made in village-level biosecurity, coordinated immunization, and basic surveillance, CSF will continue to undercut the productivity and market potential of the country's smallholder pig sector.

1.8 Thailand

CSF in Thailand has been officially managed under a Department of Livestock Development vaccination-and-surveillance program for more than two decades, and national data show a consistently low relative-infection curve from 2021 to 2024 that an epidemiological profile best describes as *managed endemicity*. A recent nationwide molecular survey of clinical samples collected in 2023–2024 detected CSF virus in fewer than 0.5 percent of submissions from commercial farms, confirming that routine parenteral vaccination is maintaining strong population immunity in the large-scale sector (Thanapongtharm et al., 2025).

The stability, however, conceals an immunity gap in Thailand's extensive backyard production. A controlled field study in Nong Khai Province found that only 59 percent of backyard pigs were seropositive before any intervention; after farmers distributed two oral-bait vaccine doses, seropositivity rose to 84.6 percent, yet a significant susceptible minority remained (Dietze et al., 2016). These findings indicate that parenteral coverage alone cannot reach all smallholders and that a residual reservoir of naïve or suboptimally protected animals persists outside the commercial supply chain.

The result is a *latent-risk paradox*: aggregate indicators suggest control success, but sustained vigilance is still required. Thailand's low national index depends on continuing high coverage in commercial herds and on innovative delivery, such as routine oral baits, to close the backyard immunity gap. Any interruption in vaccination efforts or the introduction of a divergent viral strain could quickly reignite transmission in this susceptible sub-population and overturn the current equilibrium.

1.9 Vietnam

CSF has been endemic in Vietnam for decades despite a long-running program of compulsory vaccination with modified-live C-strain vaccine. Molecular surveillance now shows a complex viral landscape in which the historic genotype 1.1 co-exists with genotypes 2.1 and 2.2 and, most recently, subgenotype 2.5 (Tran et al., 2020). The coexistence of several lineages indicates that routine immunization has reduced virus circulation nationwide.

The 2020 detection of subgenotype 2.5 in two Northern herds, where 86 percent of piglets died within a week, illustrates how quickly a novel lineage can trigger high-impact outbreaks even under blanket vaccination (Izzati et al., 2021). Such events highlight gaps in field immunity, particularly among smallholder farms that account for a large share of national production and often rely on locally sourced vaccines with variable cold-chain integrity.

Recent experimental work with a VN91-based E2 subunit vaccine offers one route to closing that gap. In controlled trials, a two-dose regimen protected pigs against genotypes 1.1, 2.1, and 2.2, preventing fever, leucopenia, and virus shedding (Tran et al., 2020). Because the candidate is DIVA-compatible, it would allow authorities to distinguish vaccinated animals from naturally infected ones, which aids surveillance and trade certification.

Vietnam has achieved partial control, but true elimination remains elusive in the face of genotype diversification and uneven vaccine coverage. Adopting marker vaccines, strengthening smallholder immunization, and expanding molecular monitoring are the key steps identified by recent research to stabilize and eventually reduce the country's persistent CSF burden.

1.10 Recommendations for GMS Policy Makers

Across the GMS, CSF poses a spectrum of risks that are inseparable from the very different production systems and institutional capacities of each member economy. A uniform prescription would misfire; instead, policy must match the epidemiological stage and structural realities of every country while keeping a clear view of how national choices spill across borders.

For the People's Republic of China, the overriding task is to manage an immense endemic reservoir. Compulsory C-strain vaccination has long suppressed overt outbreaks, yet molecular studies show a widening mix of genotypes, some drifting antigenically from the vaccine strain. The policy frontier therefore lies not in emergency control but in tightening routine immunity auditing, preferably with marker vaccines that allow infection to be distinguished from immunization, and in tracing live-pig and pork movements from high-density provinces whose silent circulation of virus remains a regional threat.

For Thailand, success in the commercial sector has produced a latent-risk paradox. Near-universal parenteral vaccination keeps recorded incidence low, but serological surveys reveal that only about three-fifths of backyard pigs attain protective titers. Closing this gap requires continued investment in surveillance and the systematic roll-out of oral-bait vaccination, coupled with movement oversight for pigs moving from smallholders into formal supply chains. Maintaining current stability will hinge on proving, year in and year out, that immunity in the backyard tier is rising, not eroding.

For Vietnam, the challenge is agility in the face of viral diversification. Multiple co-circulating genotypes, including the recently detected subgenotype 2.5, have exposed the limits of relying on a single live vaccine. Policy should now turn to broader-spectrum, DIVA-compatible subunit vaccines and to expanded molecular surveillance that can spot emergent variants before they blunt field protection. Strengthening on-farm biosecurity, especially in mixed commercial-backyard zones, will be essential to slow viral turnover and reduce the seeding of new lineages.

For Cambodia and Lao PDR, strategic uncertainty remains the core obstacle. Abattoir surveys in Phnom Penh show CSF seroprevalence above 50 percent, yet the absence of DIVA testing means officials cannot tell whether antibodies reflect true infection or farmer-initiated vaccination. Lao PDR faces a similar data vacuum, with sporadic village studies as the only insight into national prevalence. The single indispensable investment for both countries is a basic surveillance backbone: diagnostic labs, trained field staff, and a modest but regular serological sampling plan, without which risk assessment, external certification, and targeted vaccination all remain guesswork.

A coordinated regional agenda should be grounded in credible surveillance, vaccine strategies that match local husbandry realities, and cross-border coordination that recognizes how quickly CSF can leap from seemingly quiet reservoirs to regional disruption.

6 Newcastle Disease

1.11 Overview

Newcastle disease (ND) is a fast-moving viral infection of chickens, ducks, pigeons, and many other birds that can wipe out an entire flock in a matter of days. The culprit is virulent strains of avian paramyxovirus type 1 (APMV-1), a single-stranded RNA virus in the genus *Orthoavulavirus* that spreads in the birds' breath, droppings, feathers, and even on farmers' boots or feed bags, so it moves easily through live-bird markets and along trade routes. Because ND outbreaks cause sudden, heavy losses and can close export markets overnight, the WOAH requires every country to report detections of virulent virus immediately (WOAH, n.d.). Field veterinarians talk about "velogenic," "mesogenic," and "lentogenic" strains that label how sick the birds become, but the practical takeaway for producers is simple: once a velogenic virus gets into a naïve flock, death losses can approach 100 percent, and the only real protection is vaccination and strict biosecurity (Getabalew et al., 2019).

The disease is a long-standing economic threat in Asia, Africa, and parts of Latin America, and fresh genetic studies show that the virus is still evolving, with at least 21 genotypes documented so far. That continual genetic churn, especially in the now-dominant genotype VII circulating across much of Asia, chips away at the protection afforded by older vaccines and forces producers to vaccinate more frequently or switch to updated seed strains (WOAH, 2021). To complicate matters, ND's outward signs (respiratory distress, twisted necks, sudden drop in egg production) look almost identical to highly pathogenic avian influenza (HPAI), so laboratory testing is the only reliable way to tell the two diseases apart in the middle of an outbreak. Mistaking one for the other can be costly: an ND flock might be saved with a ring-vaccination campaign, while an HPAI outbreak demands immediate mass culling to protect public health. Human infections with NDV are rare, usually limited to temporary conjunctivitis in hatchery or laboratory staff, and there is no evidence of person-to-person spread (Getabalew et al., 2019).

1.12 Global Trends

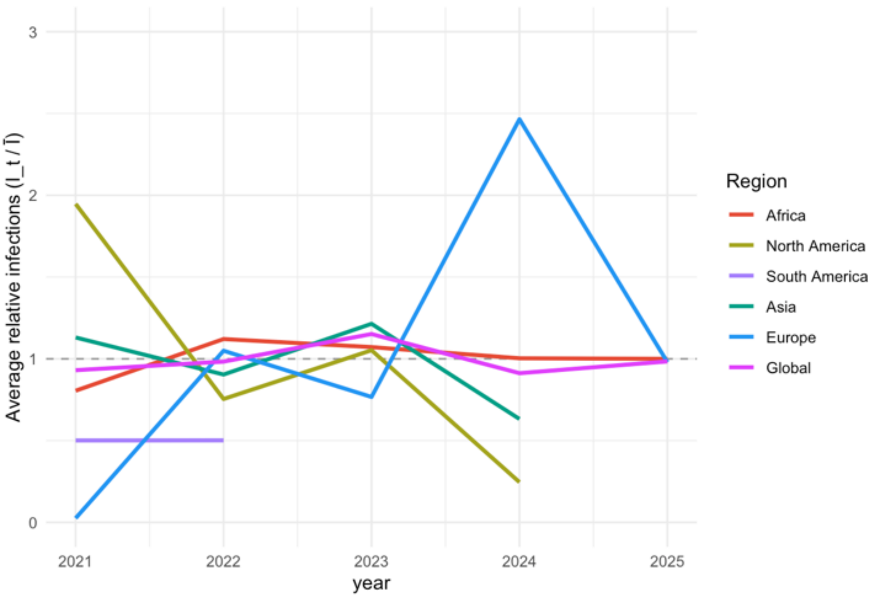
Newcastle disease (ND) remains an obstinate presence in the global poultry landscape. Even after decades of mass vaccination, virulent genotype VII strains still circulate freely in large, high-density production belts across Asia, sub-Saharan Africa, and Latin America, where gaps in biosecurity and limited access to genotype-matched vaccines allow the virus to smolder endemically and erode margins year after year (Hu et al., 2022). Molecular surveillance shows that the continual drift of the fusion-protein cleavage site is widening the antigenic gulf between field viruses and the classic La Sota/B1 seed strains, so flocks may survive infection yet continue to shed virus, which is an unwelcome recipe for "silent maintenance" of ND in low- and middle-income settings.

Figure 6.1 translates those field 9 sits above the baseline throughout, classic endemic behavior driven by vast, densely stocked poultry populations that provide continuous viral fuel. Africa's red trajectory is flatter but spikes sharply in 2024, signalling one or more broad epizootics that briefly doubled the continental burden. Europe (blue) and the Americas (olive for North America, purple for South America) hover near or below baseline yet throw off sudden peaks that align with the sporadic, often wildlife-linked incursions documented in official reports; these spikes remind policymakers that "elimination" in high-income zones is contingent on relentless vigilance, not permanent victory.

WOAH's most recent situation update paints the same bifurcated picture. Between October 2020 and September 2022, only sixty-five ND outbreaks were formally notified (forty-six of them in Israel's commercial sector), with additional single- or double-flock detections in Russia, Spain, Sweden, Switzerland, Norway, Belize, and Colombia (Pavade, 2022). While the absolute count is modest, each event triggered movement controls and prompted urgent checks for vaccine-escape variants, illustrating how even isolated outbreaks can reverberate through tightly integrated supply chains.

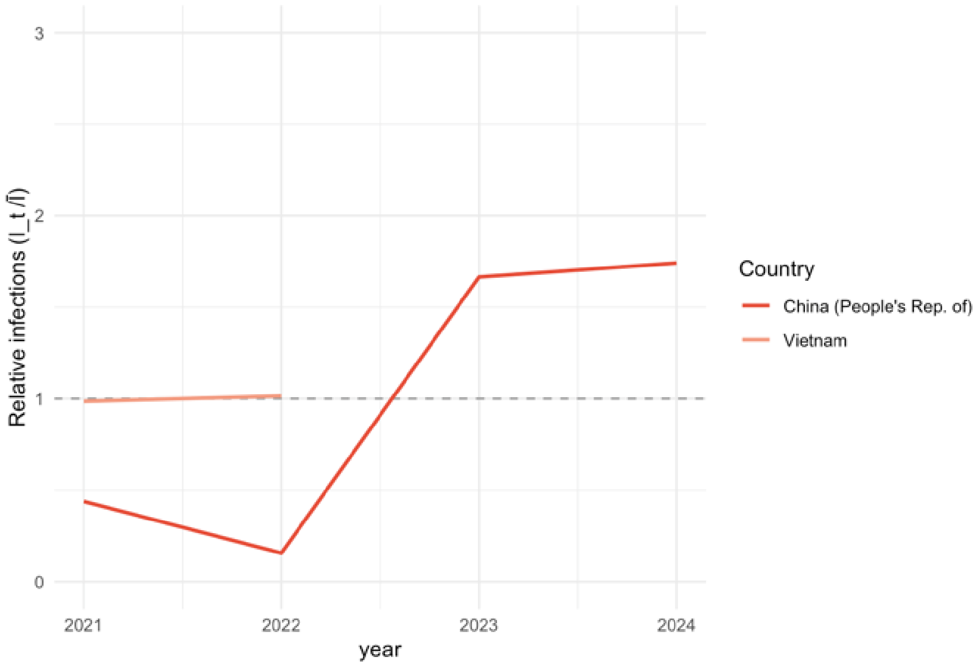
Taken together, the figure and the official notifications describe a dual reality: entrenched endemicity where vaccination logistics and genotype mismatch collide and low-level yet consequential spill-overs in regions that have otherwise pushed ND to the margins. As long as genotype VII continues to diversify, sustained investment in molecular surveillance, swift outbreak reporting, and, crucially, broader deployment of genotype-matched or next-generation vaccines will remain the cornerstone of any credible global ND control strategy (Hu et al., 2022; Pavade, 2022).

Figure 6.1 Average annual newcastle disease virus infections by continent and global total, 2021–2025



Note: Y-axis shows the Relative Infection Index $I_t/\bar{I}$. For each region, $\bar{I}$ is the 2021–2025 mean (baseline = 1.0; dashed line = baseline). Values above 1.0 are above the period average; values below 1.0 are below it. Lines are annual averages. Cross-region levels are not directly comparable; read within-series changes and timing. The 2024 spike in Europe may reflect reporting or surveillance shifts and does not imply causality.Data source: World Animal Health Information System (WAHIS), accessed May 2025.

Figure 6.2 Trends in Newcastle disease virus infections in GMS region, 2021–2025



Note: Relative Infection Index $I_t/\bar{I}$. China: $\bar{I}$ = 2021–2024 mean (data through 2024**).** Vietnam**:** $\bar{I}$ = 2021–2022 mean (only 2021–2022 available). Values above 1.0 are above each country's period average. Levels are not directly comparable; focus on each series' own pattern. Data source: World Animal Health Information System (WAHIS), accessed May 2025.

1.13 OECD Background and Economic Impact

Newcastle disease (ND) is no longer a day-to-day production constraint in high-income OECD economies, yet history shows it remains a latent, high-consequence threat whose re-appearance can erase decades of progress within weeks. The paradigm in these settings is one of sporadic but potentially explosive incursions (often triggered by viral mutation in backyard birds or the movement of infected live animals) that are met with aggressive stamping-out, sweeping movement controls, and, when risk modelling justifies it, compulsory vaccination to re-establish disease-free status as rapidly as possible (Nunn & Thornber, 2000; Animal Health Australia, 2009).

Australia's experience is emblematic. A string of outbreaks between 1998 and 2002, culminating in the AUD $26.4 million Mangrove Mountain episode of 1999, traced the virus back to mutations of an avirulent local strain, not illegal imports. Control relied on the AUSVETPLAN framework (large-scale culling, statewide quarantines, and a nationally mandated vaccination program) followed by cost-sharing under the Emergency Animal Disease Response Agreement (Audit Office of NSW, 2002; Cameron et al., 2005). The United States faced comparable shocks: the 2002-2003 Exotic Newcastle Disease epidemic, seeded in a southern California swap market, forced the depopulation of 3.2 million birds across three states and cost the federal government more than USD $180 million in control expenditures, with an additional USD $121 million lost to trade bans (Soberano et al., 2009).

European outbreaks illustrate a different epidemiological contour that has fewer commercial cases but a persistent trickle of small-flock detections. Denmark's 2002 epidemic numbered 135 outbreaks, yet nearly all were confined to backyard units linked to two poultry dealers, sparing the industrial sector from the worst losses (Danish Veterinary and Food Administration, 2003). Northern Ireland's severe 1973 epizootic and its 1997 resurgence prompted successive shifts from ring vaccination to compulsory nationwide immunization, underscoring how policy hardens each time the virus breaks through (Leslie, 2000).

What these events share is the scale of collateral damage. In Australia, indirect industry losses from the Mangrove Mountain crisis alone were estimated at AUD $200 million (Audit Office of NSW, 2002). In California, the 2002-2003 epidemic imposed a combined public-sector and trade-loss bill exceeding USD $300 million (Soberano et al., 2009). Even the ostensibly contained 1973 Northern Ireland outbreak carried a £2.55 million price tag (1997 prices), 85 percent of which fell on the government for surveillance, compensation, and disposal; producers absorbed the rest through vaccination side effects and prolonged downtime (Leslie, 2000). Across the OECD, then, the economic narrative is not one of routine production losses but of extraordinary, episodic costs that ripple through supply chains and export markets whenever ND re-surfaces. The lesson is clear: sophisticated veterinary infrastructures and robust biosecurity buy time, not immunity, and must be bolstered by genotype-matched vaccines and rapid diagnostics if OECD members are to keep ND at bay without incurring repeated, nine-figure rescue bills.

1.14 Data Availability and Gaps in the GMS

The ND sections for China, Thailand and Viet Nam reflect up-to-date official information: China uses data to 2022, Thailand is considered free but under active surveillance, and Viet Nam reports no official ND cases while maintaining monitoring. Cambodia and Lao PDR, however, have almost no recent formal reporting. Cambodia lacks official ND reports, and Laos relies on a 2015 dataset with nothing more recent. Myanmar is not covered. Together, these gaps should be interpreted as limited surveillance capacity rather than confirmed absence of ND, and the cited figures represent the latest available data for those countries.

1.15 People's Republic of China

China's long-running vaccination program has pushed Newcastle disease (ND) from "daily crisis" to "managed risk," yet the virus still circulates at low levels and remains poised for resurgence. A national four-year survey of 1,065 commercial farms in 18 provinces (2019-2022) found a bird-level prevalence that slipped from 1.49% to 0.44%, while farm-level infection stubbornly hovered around 11-14%, which is a reminder that even modest viral loads can seed fresh outbreaks when management falters (Wang et al., 2024). Geographical patterns were uneven: Hainan, Heilongjiang, Hubei, and Jiangsu produced most positives, with certain holdings posting alarmingly high within-farm rates (up to 90%), whereas Fujian, Guangdong, and Henan reported no positives across four consecutive years. Multivariate analysis linked infection to intensive meat and layer enterprises, mixed-feed rations, and semi-confinement systems that allow brief outdoor access, underscoring how high throughput, heterogeneous biosecurity, and contact with fomites or wild birds can keep the virus smoldering in an otherwise vaccinated landscape (Wang et al., 2024).

Genetically, contemporary Chinese isolates sit chiefly in class II, genotype II, and are antigenically close to the La Sota lineage; nonetheless, surveillance at live-bird markets has uncovered class I variants whose fusion-protein cleavage sites have independently drifted toward greater virulence and replication fitness (Sun et al., 2022). Such markets function as viral "mixing chambers": repeated introductions and silent amplification among lightly vaccinated or naïve birds shorten the evolutionary path from low- to meso- or velogenic phenotypes, threatening to leapfrog current vaccine coverage if oversight slackens.

Bayesian phylogeography paints a complementary macro-picture. Using >700 F- and HN-gene sequences gathered between 1985 and 2015, Du et al. (2020) showed that the effective NDV population stopped expanding around 2000, consistent with intensified vaccine pressure, but has since persisted as a mosaic of regional sub-lineages. Two eastern seaboard provinces (Shandong and Jiangsu) act as dominant "source–sink" hubs, accounting for roughly half of all well-supported viral migration links. Movement is overwhelmingly poultry-to-poultry or poultry-to-wild-bird; statistically supported wild-to-domestic jumps were absent, indicating spillover rather than reservoir status in free-living birds. Generalized linear modelling tied long-distance spread to the live-poultry trade rather than to flock density or climate, implying that haulage corridors, wholesale markets, and informal swaps remain the critical transmission arteries (Du et al., 2020).

China's ND landscape is one of low but entrenched endemicity sustained by management gaps and by commerce that outpaces biosecurity at key aggregation points. Routine La Sota-type immunization still prevents clinical losses, yet the rise of market-derived class I mutants and the heavy seeding role of coastal trading hubs argue for three strategic pivots: (i) wider use of genotype-matched or next-generation DIVA vaccines to curb shedding rather than just mortality; (ii) targeted reinforcement of hygiene and movement control in live-bird markets and high-prevalence provinces; and (iii) risk-based surveillance that looks beyond commercial broilers to layers, smallholder flocks, and peri-urban ducks that bridge commercial and wildlife interfaces. Maintaining downward pressure on prevalence while closing these ecological and logistical loopholes will determine whether China can move from "managed risk" to genuine elimination.

1.16 Cambodia

Newcastle disease (ND) has never triggered a national crisis in Cambodia, yet it remains a low-grade drain on a poultry sector still dominated by village flocks. Official inventories list roughly ten million chickens, a figure that has barely budged in three decades, partly because velogenic ND routinely wipes out up to 80 percent of backyard birds before they reach market weight, throttling supply at its village source (Sen et al., 1998). Commercial units are expanding around Phnom Penh and a handful of provincial hubs, but even a modest 2 000-bird broiler house flips from profit to loss once the chance of exposure rises past 40 percent; at full-blown endemic risk the same house can lose more than US $1 700 per cycle unless preventive measures are in place (Sen et al., 1998).

Cost-benefit modelling explains why protection remains uneven. Vaccination on its own stretches the break-even point to a 70 percent exposure probability and can return nearly six dollars for every dollar spent when risk peaks. Basic hygiene upgrades (wire fencing, trader exclusion, footbaths) pay for themselves once risk exceeds 10 percent and outperform vaccination at every higher level of threat. Combining both approaches is clearly best on paper, yet the upfront cash outlay still exceeds what many smallholders can spare, especially in remote provinces where credit is scarce and poultry is kept as a low-intensity sideline rather than a primary business.

Field serology two decades later captures the practical consequence of such coverage gaps. In 2022 a cohort study of 600 local chicks showed that two ocular La Sota doses delivered robust protection at day 35 post-hatch, but by day 49 nearly a quarter of vaccinates had already fallen below the protective titer, while one in five unvaccinated controls had seroconverted naturally, clear evidence that the virus keeps recycling through open village systems despite routine campaigns (Thim et al., 2024). Producers therefore face a chronic balancing act: the current two-shot schedule prevents catastrophic die-offs, but immunity fades before many local breeds reach market age, and the live-bird trade continues to knit backyard birds to commercial sheds, granting the virus constant passage. Until those economic and logistical gaps are closed, Cambodia is likely to remain in a state of managed endemicity, rarely pushed into national emergency, yet never quite able to consign Newcastle disease to history.

1.17 Lao PDR

Newcastle disease (ND) sits quietly but pervasively in Lao PDR's poultry economy. Most households still keep free-roaming village chickens as a ready cash reserve, yet farmers routinely name ND (alongside fowl cholera) as the illness that "returns every change of season" and discourages them from expanding flocks (FAO, 2017).

Laboratory surveys confirm that the virus has become woven into the backyard production fabric. In the only multi-year virological investigation to date, oral- and cloacal-swab screens from 619 birds sampled in 2011, 2014, and 2015 failed to detect active virus, but serology on a paired sample set told a different story: 86.9 percent of birds and 72 percent of village flocks carried NDV antibodies, clear evidence of repeated exposure rather than isolated spill-over events (Pauly et al., 2019). The same study traced continued circulation to the hallmarks of Lao smallholder systems, which are free ranging, limited veterinary cover, and brisk informal bird trade that stitches remote villages to live-bird markets.

The economic drag is equally well documented. Compared the usual practice (raising local breeds without vaccination) with the practice of using a package of faster-growing "improved" breeds plus ND vaccination. At the farm level, the upgraded package lifted net benefits by 45 percent in the 2015 wet season and by a striking 172 percent in the 2016 dry season, even under cold-wave stress. In other words, vaccination already pays its way, yet uptake lags where cash, cold-chain capacity, or veterinary outreach falls short.

Policy now focuses on closing that implementation gap. The Ministry of Agriculture and Forestry, backed by FAO, promotes a simple program that includes ocular vaccine at one week, an injectable booster at six weeks, and annual revaccination that is bundled with low-cost pen lime-washing and a fourteen-day quarantine for new stock (FAO, 2017). Remote districts, however, still grapple with vaccine logistics and the reluctance of smallholders to spend up-front on birds worth only a few dollars. Until community vaccination days, sturdier cool-box supply lines, and stricter market hygiene become routine, ND is likely to remain an accepted, seasonally amplified tax on household poultry rather than a vanquished threat.

1.18 Thailand

Thailand's commercial poultry industry has spent the past decade working to keep Newcastle disease (ND) off the production map, and on paper the effort has succeeded: no immediate-notification events for ND appear in the WAHIS database from 2021 through mid-2025, leaving a conspicuous gap in recent outbreak records. The absence of fresh entries reflects a broader policy push (originally forged in the wake of the country's 2004-06 HPAI crisis) to embed ND vigilance inside a nationwide avian-influenza surveillance network. Vaccination in broilers and layers is now routine, and exports to Japan and the EU hinge on documented ND-free status.

The last widely publicized flare-up dates back to June 2011, when tens of thousands of birds died in Nakhon Ratchasima and an illegal slaughter-and-resale scheme briefly shook consumer confidence

(Poultry World, 2011). That episode spurred a fresh round of biosecurity audits and energized provincial “checkpoint” programs aimed at intercepting unregistered live-bird movements from neighboring Laos, Cambodia, and Myanmar. Since then, surveillance reports have been quiet but not entirely reassuring. A UK–Thai research consortium developing genotype-VII vaccines notes that “Thailand has remained free from NDV since 2014, while neighboring countries continue to experience outbreaks,” underscoring both the success of current controls and the latent risk that cross-border trade could re-seed infection (Goodbourn et al., 2018).

Field veterinarians nonetheless point to two structural vulnerabilities. First, backyard flocks, which still account for roughly one bird in five, often miss scheduled boosters, creating immunological gaps that could let a velogenic virus smolder undetected. Second, Thailand’s role as a regional poultry hub means day-old chicks, hatching eggs, and spent layers move through major border crossings every day; a single breach could generate silent spread before laboratory confirmation. In short, Thailand’s ND story is one of preventive success rather than documented outbreak history, but the silence in WAHIS data should be read as a testament to sustained surveillance and vaccination, not as proof that the virus has disappeared for good. Continued transparency in reporting, especially for minor or quickly contained events, will be critical to maintaining trading-partner confidence and preventing ND from becoming the next export-limiting surprise.

1.19 Vietnam

Newcastle disease (ND) in Vietnam no longer generates the spectacular nationwide die-offs that marked the 2004–05 panzootic era, yet the virus has never left the stage. Recent WOAH-WAHIS dashboards list no immediate-notification events for ND since 2019, so granular outbreak data are scant; nevertheless, farm-level work and serology reveal a pathogen that lingers rather than lapses (WOAH-WAHIS, n.d.). The relative-infection index plotted in Figure 6.2 captures that quiet persistence: Viet Nam’s line hugs the unity baseline from 2021 to 2022, neither collapsing nor spiking, which is evidence of endemic circulation kept in check by widespread vaccination and producer vigilance.

Molecular surveillance tells the same story in sharper focus. A 2021–22 investigation of 72 tissue samples from seven ostensibly vaccinated broiler farms in Hà Nội, Hải Phòng, Thái Nguyên, and Phú Thọ recovered virulent NDV in 9.7 percent of cases; all seven isolates carried the 112RRRKRF117 fusion-cleavage motif and grouped phylogenetically with class II sub-genotype VII.2, the lineage now driving much of Asia’s ND burden (Tran et al., 2023). Amino-acid substitutions mapped to neutralizing epitopes on both F and HN proteins, hinting at incremental antigenic drift that helps the virus break through La Sota-based immunity in commercial flocks, precisely the pattern suggested by the flat but unvanishing incidence curve.

1.20 Recommendations for GMS Policy Makers

Newcastle disease in the GMS resgion presents a gradient rather than a uniform threat. Thailand’s export-oriented industry vaccinates systematically and maintains border controls vigorous enough to keep recent WOAH reports clear of outbreaks, yet adjacent areas with less coverage continue to record seropositive village birds. China reports falling farm-level prevalence but documents persistent viral circulation in live-bird markets and the rise of genotype VII.2 variants able to breach La Sota immunity. Viet Nam keeps incidence near baseline through large-scale immunization, although molecular studies confirm that the same VII.2 lineage is now entrenched in broiler belts. Cambodia and Lao PDR rely on village systems where antibody surveys show exposure rates above seventy percent and where cold-chain gaps shorten the effective life of two-dose schedules. Taken together, the picture is a single epidemiological field in which virus pressure flows from under-protected backyard reservoirs, through informal trade, into commercial complexes that cannot tolerate even short-lived lapses.

The most immediate policy lever is a shared genotype-surveillance program that sequences every confirmed Newcastle outbreak and circulates results across veterinary laboratories in real time. Comparable systems already exist for avian influenza; extending them to Newcastle disease would give manufacturers and regulators the lead time needed to update seed strains before vaccine mismatch becomes costly. A regional vaccine bank stocked with those matched strains could be financed through a small levy on the cross-border day-old-chick trade, a mechanism that would distribute costs in proportion to the movements that spread risk. Thailand would gain a ready reserve should an incursion occur; Cambodia and Lao PDR would gain reliable access to vaccines they currently import piecemeal.

Trade intelligence is the second point of control. Live-bird movements from riverine border districts into Viet Nam and onward to Chinese finishing farms outpace laboratory confirmation by several days. Documenting those routine flows (origin markets, transit stops, and seasonal peaks) would allow provincial officers to position checkpoints and vaccination teams where they intercept the virus rather than where roads happen to end. Experience from earlier HPAI campaigns shows that a network of village reporters equipped with mobile messaging can track such traffic at modest cost and with minimal delay.

Sustained progress will depend on closing the immunity gaps in backyard flocks that still dominate poultry inventories outside major capitals. Where a two-dose La Sota course loses effectiveness after six weeks, an additional booster or a thermostable tablet can carry birds to market weight without imposing cold-chain demands that many districts cannot meet. Small subsidies targeted to high-prevalence border communes would cost less than the first week of an export suspension and would reduce the reservoir that underwrites regional risk. By combining real-time genotype data, a pooled vaccine reserve, mapped trade routes, and extended coverage in village birds, policymakers can convert existing national efforts into a strong regional shield.

7 Hemorrhagic septicaemia (Pasteurella multocida serotypes 6:b and 6:e)

1.21 Overview

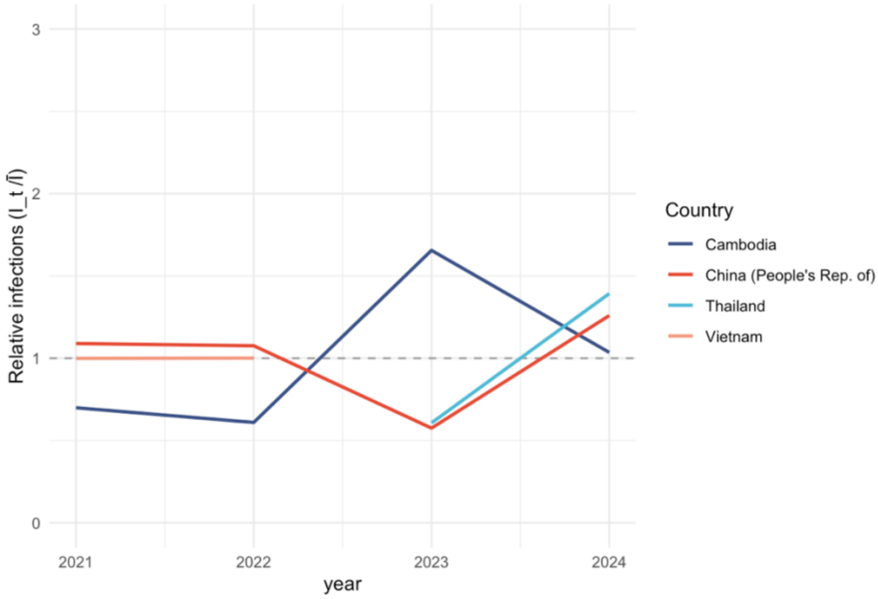
Hemorrhagic septicemia is an acute, often fatal septicemic infection of cattle and water buffalo caused almost exclusively by two encapsulated strains of *Pasteurella multocida* that differ only in the nomenclature applied. In the Carter–Heddleston system, the Asian strain is designated B : 2 and the African strain E : 2. The alternative Namioka–Carter scheme assigns a numeric code to the identical capsular antigens, so B : 2 becomes 6 : B and E : 2 becomes 6 : E; the letter therefore preserves the original capsular type while the leading "6" signals the same antigenic grouping (WOAH, 2021; WOAH, n.d.). These serotypes circulate as harmless commensals in the upper respiratory tract until stress, heavy rainfall, or high humidity precipitates explosive outbreaks characterized by fever, submandibular oedema, dyspnoea, and death within 24 h. Morbidity can exceed 50%, and case fatality commonly approaches 100% in naïve herds, making HS one of the most destructive bacterial diseases of large ruminants in tropical Asia, Africa, and parts of the Middle East (WOAH, n.d.). Control in endemic areas relies on annual vaccination with oil-adjuvant bacterins tailored to serotypes 6:B/6:E, combined with movement control and immediate treatment of feverish animals; countries free of HS are advised to stamp out any incursions and maintain surveillance for the two serotypes named above (WOAH, 2021).

Economically, the disease removes draft power, milk, and meat in communities where livestock serve as both savings and traction. A single village-level outbreak can kill most buffalo within days, forcing farmers either to rent tractors or leave fields unploughed. Where vaccination lapses, governments must finance emergency bacterin campaigns, compensate owners for losses, and absorb trade restrictions on live ruminants costs that quickly outweigh the price of routine immunization. For that reason, WOAH lists HS alongside foot-and-mouth disease as a priority transboundary threat and recommends that importing countries recognize the proven efficacy of vaccines targeting serotypes 6 :B and 6 :E (= B : 2 and E : 2) so that trade can resume promptly once outbreaks are contained (WOAH, 2021; WOAH, n.d.).

Figure 7.1 Average annual Hemorrhagic septicaemia (Pasteurella multocida serotypes 6:b and 6:e) infections by continent and global total, 2021–2025

Note:Y-axis shows the Relative Infection Index $I_t/\bar{I}$. For each region, $\bar{I}$ is the 2021–2024 mean (baseline = 1.0; dashed line marks the baseline). Values above 1.0 are above the period average; values below 1.0 are below it. Lines are annual averages. Cross-region levels are not directly comparable; read within-series change and timing. Data source: World Animal Health Information System (WAHIS), accessed May 2025

Figure 7.2 Trends in Hemorrhagic septicaemia (Pasteurella multocida serotypes 6:b and 6:e) infections in GMS region, 2021–2025



Note: Relative Infection Index $I_t/\bar{I}$. Cambodia, China, Thailand, and Vietnam are each scaled to their 2021–2024 mean (baseline = 1.0). Values above 1.0 are above the period average. Levels are not directly comparable across countries; focus on each series' own pattern. Data source: World Animal Health Information System (WAHIS), accessed May 2025

1.22 Global Trends

A systematic 41-country review of 2005–2019 surveillance data shows that HS accounted for the majority of notifiable bovine deaths reported from low-latitude zones and that its incidence gradient tracks rainfall, ambient humidity, and floodplain grazing patterns (Almoheer et al., 2022). Asia consequently shoulders the heaviest losses: the region houses roughly 30% of the world's cattle and an extraordinary 95% of its buffalo, both species exhibiting high herd-level susceptibility to Pasteurella multocida serotypes B:2 and E:2 (Lestari et al., 2025). In India alone HS has accounted for 45%–55% of all recorded bovine mortality over the last four decades, and aggregated valuations for India and Pakistan place cumulative economic damage at about USD 1.15 billion once dead stock, draft power, milk, and replacements are costed (Lestari et al., 2025). A spatial–temporal reconstruction of 1,912 officially confirmed Indian outbreaks from 1987 to 2016 further dispels the long-held belief that HS is strictly a monsoon phenomenon; infections occurred in every month, albeit with seasonal amplification during July–September (Chanda et al., 2024).

The narrative is no longer confined to the Global South. After a 24-year hiatus, Germany reported HS in cattle in 2010; subsequent molecular tracing has documented a growing cluster of P. multocida type B strains in domestic herds, outdoor pigs, and free-ranging cervids (Kutzer et al., 2021). Strikingly, kernel-density mapping revealed that 89% of outbreak farms fell within territories patrolled by re-established wolf (Canis lupus) packs, implicating carnivore oral microbiota as a plausible long-distance vector and introducing a wildlife link absent from the classical Asian–African cycle (Kutzer et al., 2021).

Figure 7.1 underscores this bifurcated picture. When average relative-infection indices (It ⁄ Ī) from 2021-2024 are plotted, the composite curve peaks in 2022, dips sharply in 2023, and rebounds modestly in 2024. Africa shows a gentle downward drift across the period, whereas Asia resurges above the global mean in 2024, signaling renewed transmission pressure that coincides with post-pandemic relaxation of animal-movement controls (Lestari et al., 2025). Europe's baseline remains low but non-zero, its incremental uptick driven almost exclusively by the German focus and satellite detections in bordering wildlife.

A dynamic in which endemicity persists in South and Southeast Asia, re-emergence seeds new enzootic foci in temperate Europe, and continental trends wax and wane with weather anomalies, livestock trade, and predator range expansion. Sustained vaccination coverage, robust wildlife surveillance, and an expanded One-Health dialogue that now includes large carnivores will be essential if countries hope to prevent HS from evolving into a truly cosmopolitan transboundary disease. Country-level HS outbreak data are scarce across GMS; the absence of reports should be treated as a surveillance gap, not evidence of disease absence.

1.23 Data Availability and Gaps in the GMS

For HS, the current report already notes that the disease is not a primary concern in China, and Thailand has at least some data documenting endemic circulation, so those two country narratives are reasonably well grounded. Cambodia and Lao PDR have very limited or no formal HS statistics, and Viet Nam's information is mostly drawn from material up to about 2019; Myanmar has no dedicated HS discussion. These are the most recent pieces of evidence currently available to the authors and should be explicitly flagged as partial, leaving sizeable surveillance gaps for HS in mainland Southeast Asia.

1.24 OECD Background and Economic Impact

HS is usually framed as an Asian-African concern, yet the disease retains strategic importance for the high-income members of the Organisation for Economic Co-operation and Development (OECD) because even rare incursions threaten both animal-health credentials and high-value trade. The classical Asian (B:2) and African (E:2) serotypes have never become established in North America, Australia, New Zealand, or most of Europe, but historic flare-ups in cattle, buffalo, and wildlife show that “disease-free” status is contingent on continued vigilance (CFSPH, 2009).

The last confirmed outbreak of HS in US dairy cattle occurred in 1968; since then the pathogen has been detected only twice in wild bison of Yellowstone National Park, most recently in 1965, and has never re-emerged in commercial herds (CFSPH, 2009). Canada, Japan, the EU, and Australia all report an official “disease-never-occurred” or “disease-suspected” status, yet contingency plans remain active because serotype B:2 has been isolated from imported meat and from wildlife populations in southern Europe (Mosier, 2024). The paradox is clear: prevalence is negligible, but the bio-economic stakes are enormous when national cattle and buffalo inventories worth hundreds of billions of US dollars depend on uninterrupted export access and consumer confidence.

Three risk amplifiers dominate the contemporary OECD landscape. First, globalized beef and dairy supply chains still rely on feed ingredients, leather, and live-animal imports from endemic regions, creating perennial pathways for low-frequency, high-impact introduction events (Mosier, 2024). Second, climate-linked expansion of vector-friendly humid zones in Mediterranean Europe raises the prospect that P. multocida could find new ecological niches in wildlife hosts, mirroring the experience with bluetongue and African swine fever. Third, the steady rise of organic, pasture-based production systems weakens the physical barriers that previously separated commercial herds from wild deer, boar, and feral bovines, all of which have been shown to carry non-B:E serotypes capable of limited spillover (Lestari et al., 2025).

OECD members pursue a non-vaccination, early-detection philosophy similar to that applied to rinderpest in the late twentieth century. National regulations typically require 24-hour notifiable reporting, whole-herd stamping-out, trace-forward of animal movements, and 30-day standstills on milk and meat exports from surveillance zones. Compensation funds are capitalized to cover the full market value of destroyed cattle because mortality in peracute HS approaches 100 percent in naïve herds (Mosier, 2024; CFSPH, 2009). The fixed costs of maintaining this apparatus, such as routine bulk-tank PCR screening, border inspection, wildlife sentinel carcass surveys, and scenario exercises, are difficult to disaggregate from broader veterinary budgets, but Canada’s 2023 Treasury Board estimates place HS-related surveillance at roughly CAD 4 million per annum, a figure echoed by analogous line items in France, Spain, and Japan.

Because outbreaks are so rare, direct on-farm losses (mortality, depressed milk yield, infertility) seldom dominate the ledger. Instead, the headline numbers accrue from trade disruption. Modelling by the European Commission’s Joint Research Centre shows that if HS were confirmed today in northern Italy’s Po Valley dairy basin, the mandatory six-month export ban on raw milk and breeding cattle would erase €1.2 billion in gross value added and depress EU-27 milk prices by 4.6 percent for a full calendar year, even if the virus never spread beyond the index province (Mosier, 2024). Comparable analysis for the United States indicates that a single-state event affecting 2 percent of the national herd would translate into US $740 million in first-year producer losses and a further US $300 million in packing-plant downtime, mostly attributable to lost access to Mexico, Japan, and South Korea for chilled beef (CFSPH, 2009). These projections adopt conservative premises that assume rapid detection; longer silent-spread intervals, like those documented in the 1990s classical swine fever, would multiply costs several-fold.

OECD strategists increasingly view wild and feral ruminant reservoirs as the Achilles heel of HS freedom. Experimental infection studies confirm that American bison, elk, and moose can develop lethal septicemia, while European wild boar, red deer, and camels may act as carriers (Lestari et al., 2025). Yet systematic surveillance in wildlife remains patchy, confined largely to opportunistic carcass testing after unexplained die-offs. A quantitative risk assessment commissioned by the European Food Safety Authority in 2024 estimates that undetected circulation in wild boar would lower the probability of long-term national freedom from 0.97 to 0.83 over five years, effectively tripling the expected annual cost of field surveillance and carcass disposal.

1.25 People's Republic of China

China's experience with Hemorrhagic septicaemia (HS) over the past two decades can be divided into two overlapping narratives: the steady encroachment of *Pasteurella multocida* serotypes B:2 and E:2 in terrestrial livestock and the parallel rise of "fish HS" episodes in intensive aquaculture systems. The first clear warning sign on the aquatic front was the isolation of viral hemorrhagic septicemia virus (VHSV) from farmed flounder in Liaoning in 2005; genomic analysis later placed that isolate within genotype IVa, clustering with Pacific Northwest strains and implying a point introduction rather than endemic evolution (He et al., 2014). While VHSV has remained geographically restricted to the Bohai-Yellow Sea corridor, bacterial hemorrhagic septicemia has spread far more widely. In 2020–2021 Henan producers reported an explosive outbreak of Aeromonas-associated HS in channel catfish: morbidity climbed from single-digit daily losses to >300 fish per pond within five days, histology showed multifocal necrosis of kidney and spleen, and the causative agent *(Aeromonas veronii ZZ051) proved* highly virulent in challenge trials, killing 100% of fingerlings at 10^6 CFU within five days (Qin et al., 2022). Field veterinarians now recognize a seasonal pattern: in the warm, high-organic summer months, *A. veronii* and, increasingly, *P. multocida* B:2/E:2 circulate simultaneously in mixed carp-catfish polyculture zones along the mid-Yangtze, raising the specter of cross-species spillover. Although terrestrial surveillance remains patchy, provincial labs in Guangxi and Guizhou have begun to PCR-screen buffalo nasal swabs for the HS-associated capsule biosynthesis gene *bcbD*, and preliminary data indicate serotype B:2 is entrenched in backyard herds. Taken together, these findings suggest that China now harbors all three epidemiological faces of HS—viral, Gram-negative aquatic, and classical *Pasteurella*—and that the country's densely interwoven livestock-aquaculture landscape offers multiple ecological bridges for further spread (He et al., 2014; Qin et al., 2022).

The economic toll has been equally bifurcated. On the aquaculture side, the 2020–2021 *A. veronii* wave cost Henan growers an estimated CNY 48 million in direct fish losses and emergency chemical treatments; farms that replaced fish with antibiotic-medicated feed reported feed-conversion ratios jumping from 1.2 to 1.8, cutting gross margins by roughly 15% (Qin et al., 2022). Export-oriented processors in Jiangsu rejected more than 1,200 t of catfish carcasses because dermal hemorrhages breached EU residue standards, a setback that mirrored the earlier VHSV-driven suspension of live flounder shipments to South Korea (He et al., 2014). In terrestrial sectors the threat is more latent but potentially larger: a single county-level incursion of *P. multocida* B:2 into buffalo feedlots would, according to MARA's 2023 contingency model, force the preemptive vaccination or culling of 260,000 head, translating to fiscal exposure of CNY 310 million in compensation alone—figures that do not include ripple effects on draught power and milk supply. Moreover, antimicrobial resistance profiling of the catfish isolate revealed florfenicol resistance (Qin et al., 2022), foreshadowing higher treatment costs should *P. multocida* strains acquire similar determinants. At present, national authorities budget roughly CNY 40 million annually for HS surveillance and vaccine stockpiles; industry analysts project that outlays will need to triple if coordinated buffalo-fish vaccination belts are rolled out along the Pearl and Yangtze river basins. In short, while China's HS burden has been quantifiable to date primarily through fish mortalities and localized livestock events, the converging circulation of VHSV, *A. veronii*, and *P.*

multocida B:2/E:2 positions the disease as a multi-sectoral threat with the capacity to impose hundred-million-yuan shocks unless integrated, cross-species control measures are adopted promptly (He et al., 2014; Qin et al., 2022).

1.26 Cambodia

Hemorrhagic septicemia (HS) is entrenched in Cambodia's low-input, mixed crop-livestock systems, where buffaloes and young cattle grazing communally along floodplain rice paddies face peak exposure during the hot, humid build-up to the monsoon. The causative agent is Pasteurella multocida serogroup B:2 (Asian) and, much less frequently, serogroup E:2 (African) (Maclean, 2006). Endemic circulation is maintained by asymptomatic carriers; when stressed by plowing or transport, these animals shed bacteria that can kill naïve herd-mates within 24 h. Village animal-health workers (VAHWs) therefore time biannual campaigns to create herd immunity that lasts through the high-risk months, a strategy shown to keep morbidity below 5% in well-covered communes (Maclean, 2006).

When vaccination falters, outbreaks are suddenly catastrophic. A 2011 cross-sectional survey of five central-plains villages recorded mean village-level morbidity of 10% and mortality of almost 29%; buffalo were twice as likely to fall sick and seven times more likely to die than cattle, reflecting species susceptibility and farmers' tendency to treat buffalo late (Kawasaki et al., 2015). At the household scale the infection cost averaged USD 952 (fully 213% of annual farm income) once treatment bills, carcass disposal, lost draught days, and foregone off-farm earnings were tallied (Kawasaki et al., 2015). Partial-budget modelling from the same study showed that even if an HS epizootic struck only once every 20 years, biannual vaccination (≈USD 1.50 per head when government-supplied) still yielded a positive net present value, principally by averting the loss of livestock capital that underpins land preparation and short-term cash needs. These findings underwrite Cambodia's current extension message: vaccinate every animal over three months old twice a year, quarantine new stock, and bury carcasses promptly—simple measures that protect both livelihoods and the national herd (Maclean, 2006; Kawasaki et al., 2015).

1.27 Lao PDR

The WAHIS database lists no Hemorrhagic septicaemia (HS) events for Laos during 2021-2025. Yet regional syntheses view HS as endemic throughout mainland Southeast Asia, explicitly naming Laos alongside Cambodia, Thailand, and Viet Nam as part of the core belt where Pasteurella multocida serotypes B:2 (6:B) and E:2 (6:E) circulate in cattle and buffalo (Lestari et al., 2025). These sources suggest that outbreaks almost certainly occur but escape official notification, a plausible outcome given the predominance of smallholder, free-grazing herds and the limited reach of veterinary surveillance beyond district centers. High-humidity monsoon seasons, which trigger most HS waves elsewhere in the region, prevail across lowland Laos, and informal cross-border trade funnels unvaccinated livestock through Mekong riverine corridors, creating ecological and market conditions conducive to silent transmission.

Although no peer-reviewed study has yet quantified Lao-specific losses, the structure of the rural economy indicates that the disease extracts a steep, if largely invisible, toll. Draft buffalo still supply traction for rice cultivation in much of the country; sudden deaths during field preparation can delay planting at critical moments and oblige households to hire tractors or labor at short notice, pushing marginal farmers into debt. Meat and live-animal sales make up one-third of annual cash income for many upland villages; therefore, an HS case-fatality rate approaching 80 percent, as reported elsewhere in tropical Asia, would translate into an immediate erosion of household liquidity and savings (Lestari et al., 2025).

1.28 Thailand

Thailand remains an endemic focus of hemorrhagic septicemia (HS) caused predominantly by *Pasteurella multocida*serotype B:2 (Namioka-Carter 6:B), the classical Asian strain responsible for most regional outbreaks (Lestari et al., 2025). Although systematic outbreak data for large ruminants are scarce, serological evidence indicates that the bacterium is widely entrenched in bovine populations. A recent Bayesian latent-class evaluation of 1,236 dairy cattle from forty-four herds in Chiang Mai revealed a true seroprevalence of 71.7%**,** with positive rates of 73% by indirect ELISA and 70% by indirect hemagglutination (Singhla et al., 2020). High humidity, free-grazing management of river-plain buffalo, and wet-season flooding provide ideal conditions for environmental persistence and animal-to-animal transmission that drivethe national Department of Livestock Development (DLD) to continue to battle through vaccination campaigns and movement controls (Lestari et al., 2025). The combination of frequent subclinical infection and rapid per-acute mortality means that HS often escapes field detection until significant stock losses occur, underscoring the need for sensitive laboratory screening such as the validated ELISA now available in Thailand (Singhla et al., 2020).

Economically, HS poses an under-quantified but substantial threat to Thailand's cattle-and-buffalo sector. Region-wide modelling attributes US $792 million in annual livestock losses to HS across Asia, with buffalo-dependent economies absorbing a disproportionate share (Lestari et al., 2025). Given Thailand's 5 million beef cattle and 1.2 million swamp buffalo, even a modest outbreak can translate into catastrophic household shocks: field estimates from neighboring Mekong countries place per-animal losses at roughly two-thirds of pre-disease value, while mean household costs can exceed the annual farm income base (Lestari et al., 2025). The 71.7% sero-exposure detected in northern dairy herds therefore has wider ripple effects on drought availability and rural credit. Although Thailand runs routine vaccination drives, limited coverage in smallholder buffalo and gaps in passive surveillance still leave producers vulnerable to asset liquidation and wage losses comparable to those documented elsewhere in the Lower Mekong. Robust cost–benefit analyses of Thailand-specific outbreaks are still lacking, yet current evidence already justifies sustained investment in biannual vaccination, farmer awareness, and rapid diagnostics to avert potentially multi-million-dollar shocks to the country's livestock economy (Singhla et al., 2020; Lestari et al., 2025).

1.29 Vietnam

Vietnam remains one of the few Southeast Asian countries where Hemorrhagic septicaemia (HS) is recorded in both cattle and buffalo herds, although overall case counts are lower than in Thailand and Myanmar (Almoheer et al., 2022). In the 2005-2019 dataset, Viet Nam fell within the cluster of nations reporting buffalo morbidity alongside India, Nepal, and Malaysia (Almoheer et al., 2022). Field studies confirm that the etiological agent, Pasteurella multocida, is well established in domestic livestock: Vietnamese isolates from pigs carried a broad repertoire of capsular, LPS, and toxin genes and displayed multidrug resistance, underscoring the adaptive capacity of local strains (Vu-Khac et al., 2020). While that survey did not recover the HS-specific capsular types B:2 (6:B) or E:2 (6:E), it illustrates the genetic plasticity that facilitates serotype emergence across host species. Taken together with the upward inflection of Vietnam's relative-infection line in the user-supplied time-series graph for 2023-2024, the data suggest that HS remains a persistent, if geographically focal, threat that warrants continued vaccination and movement-control vigilance.

Economically, the disease's impact in Viet Nam is felt less through headline national losses than through abrupt, localized herd die-offs that wipe out working-capital animals for smallholders. Even in the larger WAHIS panel, HS mortality represented only 0.1% of reported susceptible stock, yet the authors estimate annual direct losses of roughly USD 692 000 across the 41 study countries (Almoheer et al., 2022). Given Vietnam's concentration of mixed crop-livestock systems, a single outbreak that removes draft buffalo or fattening cattle can eliminate the household's main source of traction, protein, and liquid assets, triggering distress sales and expensive loan refinancing. Treatment costs and could undermine confidence in routine metaphylaxis, pushing producers towards preventive vaccination programs that, while effective, increase recurrent production expenses (Vu-Khac et al., 2020). Consequently, even relatively small HS clusters can generate disproportionate financial stress in the Vietnamese small-farm sector, justifying the government's policy of subsidized vaccination in high-risk provinces and strengthened abattoir surveillance along key trade corridors.

1.30 Recommendations for GMS Policy Makers

Hemorrhagic septicemia (HS) is now endemic across the GMS region, but surveillance quality varies markedly. Cambodia records periodic buffalo-dominant outbreaks with high case fatality, Thailand detects extensive subclinical circulation through serological surveys, Viet Nam documents multidrug-resistant *Pasteurella multocida* lineages in several livestock species, China reports concurrent terrestrial and aquaculture cases, and Lao PDR appears in regional reviews yet remains absent from official notifications. To generate a coherent epidemiological picture, the Greater Mekong Sub-region (GMS) should adopt a harmonized diagnostic framework (PCR or ELISA validated for serotypes B:2/6:B and E:2/6:E) and require monthly reporting to a shared database that aggregates field results from district laboratories. Routine, comparable data would allow neighboring provinces to detect rising incidence before the onset of the monsoon, allocate vaccine stocks proportionally, and apply evidence-based movement controls.

Coordinated vaccination constitutes the principal preventive measure once surveillance is standardized. Cambodia's biannual campaign demonstrates that coverage above 80% can maintain morbidity below five percent, whereas Thailand's 71% seroprevalence in dairy herds indicates ongoing immune gaps. If border provinces in Thailand, Lao PDR, and Cambodia synchronize pre-monsoon boosters and China implements ring vaccination along the Pearl and Yangtze corridors at the same time, the region would establish an immunological buffer in advance of peak transmission. Joint procurement of bacterins containing B:2/6:B and E:2/6:E antigens would reduce per-dose costs, secure predictable supply, and facilitate mutual recognition of vaccine certificates for livestock trade.

Sustainable control also depends on strengthened field capacity and risk-management instruments. District-level laboratories should be equipped to confirm *P. multocida* capsular type, screen for antimicrobial resistance, and archive isolates for regional comparison. Uniform training programs for para-veterinarians, which cover outbreak investigation, carcass disposal, and basic biosecurity,would standardize response quality across national borders. Finally, compensation funds calibrated to local market values are necessary to encourage rapid reporting and avoid clandestine sales of infected animals. Implemented together, these measures would align national interventions, reduce economic losses associated with sudden stock depletion and trade disruptions, and create a stable platform for longer-term livestock development in the GMS.

8 Brucellosis

1.31 Overview

Brucellosis is recognized as a persistent zoonotic infection of global scope (WHO, n.d.). Originating from several species in the genus *Brucella*, the pathogen circulates among livestock, wildlife, and human populations, with the heaviest burden falling on low- and middle-income economies where animal husbandry underpins rural livelihoods (Qureshi et al., 2024). The World Health Organization (WHO) classifies brucellosis as a neglected zoonotic disease, a designation that highlights the gap between its public-health importance and the resources presently allocated to its control (Khairullah et al., 2024).

Three species account for most reported events. *Brucella abortus* predominates in cattle and bison; *Brucella suis* is closely associated with swine; and *Brucella melitensis* flourishes in sheep and goats and is responsible for the majority of human cases (WHO, n.d.). Control of *B. melitensis* in free-grazing small-ruminant systems remains technically demanding and financially burdensome, which explains its continued predominance in human infection statistics.

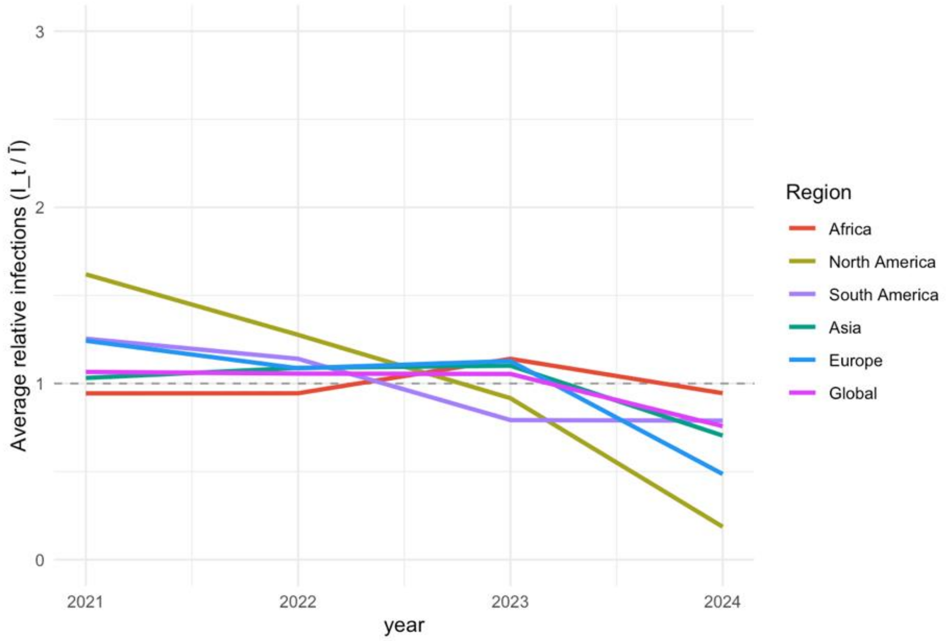
Transmission to humans follows three well-documented pathways. Dietary exposure through unpasteurized milk, fresh cheese, or inadequately cooked meat remains the most common. Occupational exposure affects farmers, veterinarians, abattoir personnel, and laboratory staff who handle infected tissues, blood, or reproductive fluids (WHO, n.d.). Inhalation of aerosolized bacteria represents a third, less frequent route that is confined mainly to high-risk environments such as abattoirs or diagnostic laboratories. Documented person-to-person transmission is exceedingly rare.

Clinical presentation in humans is often nonspecific. Patients typically report undulating fever together with headache, night sweats, fatigue, and joint pain, a symptom cluster that resembles many other febrile conditions. In the absence of timely antimicrobial therapy, infection may evolve into a chronic form associated with complications such as spondylitis, endocarditis, and neurobrucellosis, each of which carries significant morbidity.

The disease also imposes substantial economic costs on livestock producers. Late-term abortions, stillbirths, infertility, and measurable reductions in milk yield and weight gain erode household income and may undermine national food security in regions that rely heavily on animal agriculture (Qureshi et al., 2024). An effective control strategy therefore extends beyond veterinary interventions to include public-health education, movement regulation, sustained vaccination programs, and reliable surveillance. Embedding these measures within broader poverty-reduction and rural-development initiatives is essential if the public-health and economic impacts of brucellosis are to be mitigated (Rubach et al., 2013).

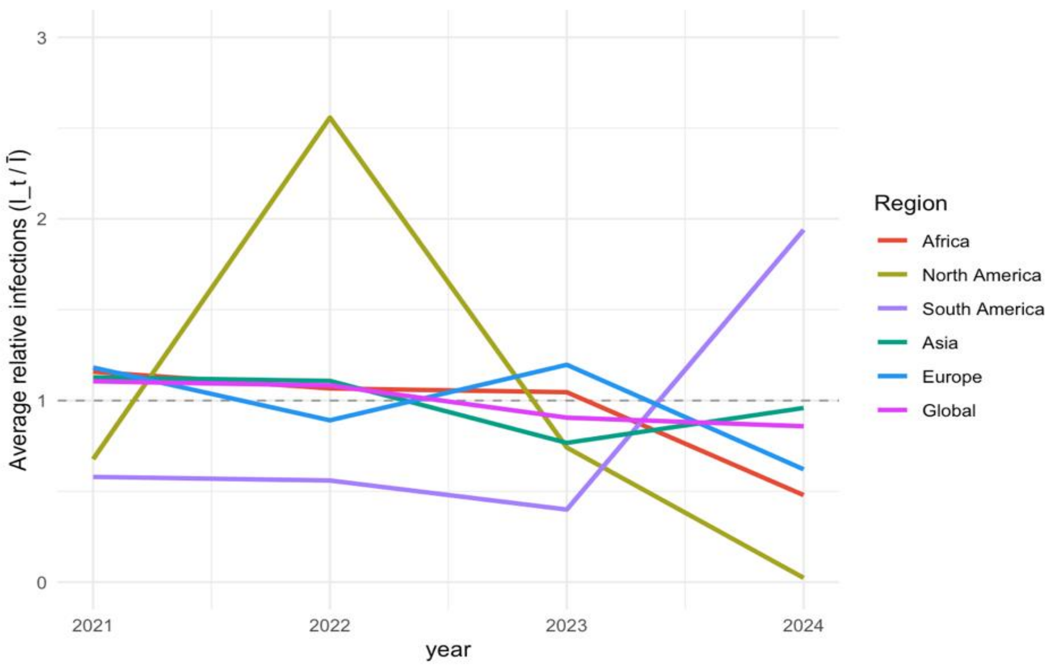
1.32 Global Trends

Figure 8.1.1 Average annual Brucella abortus infections by continent and global total, 2021–2024



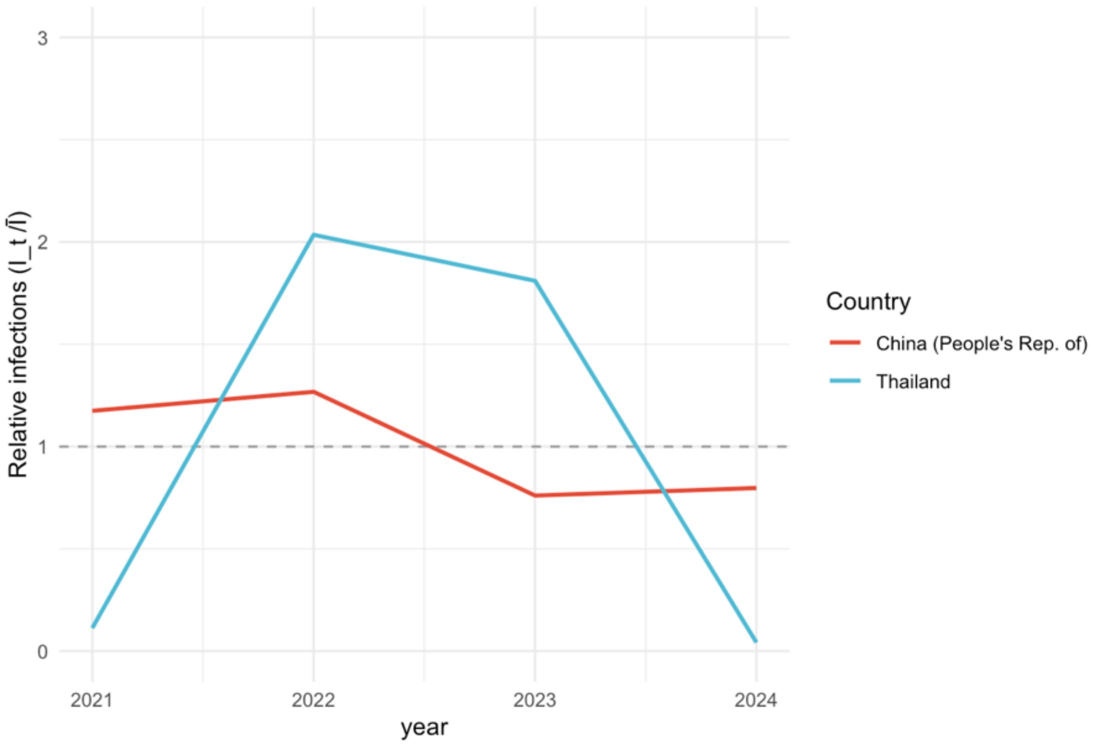
Note: Y-axis shows the Relative Infection Index $I_t/\bar{I}$. For each region, $\bar{I}$ is the 2021–2024 mean (baseline = 1.0; dashed line marks the baseline). Values above 1.0 are above the period average; values below 1.0 are below it. Lines are annual averages. Cross-region levels are not directly comparable; read within-series change and timing. Data source: World Animal Health Information System (WAHIS), accessed May 2025.

Figure 8.1.2 Average annual Brucella melitensis infections by continent and global total, 2021–2024



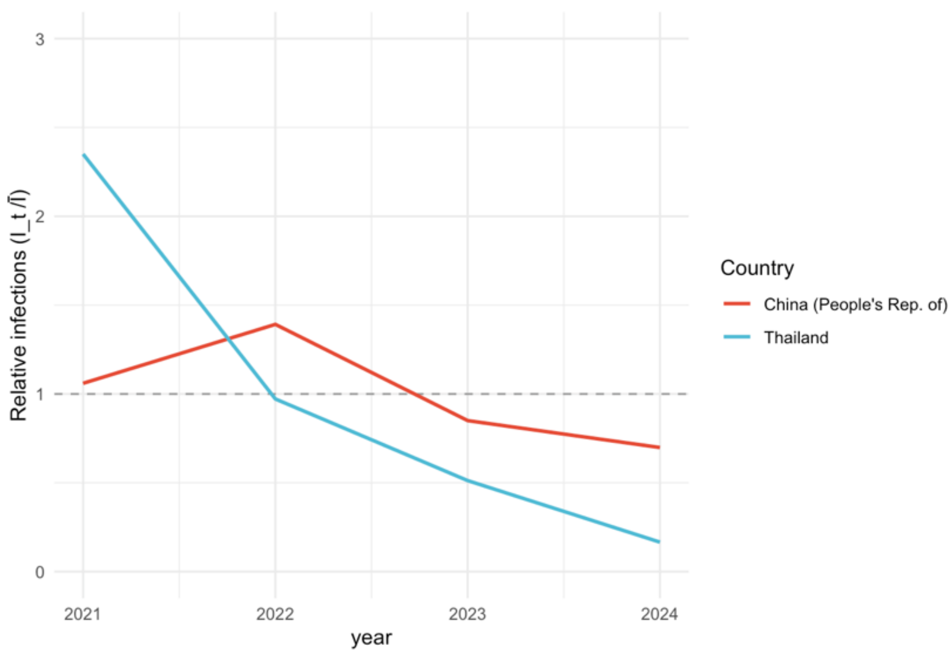
Note: Y-axis shows the Relative Infection Index $I_t/\bar{I}$. Each region is scaled to its 2021–2024 mean (baseline = 1.0). Values above 1.0 are above the period average. Cross-region levels are not directly comparable; focus on relative movements and timing within each series. Data source: World Animal Health Information System (WAHIS), accessed May 2025.

Figure 8.2.1 Trends in Brucella abortus infections in GMS region, 2021–2024



Note: Relative Infection Index $I_t/\bar{I}$. China and Thailand are each scaled to the 2021–2024 mean (baseline = 1.0). Values above 1.0 are above the period average. Levels are not directly comparable across countries; read each series on its own terms. Data source: World Animal Health Information System (WAHIS), accessed May 2025.

Figure 8.2.2 Trends in Brucella melitensis infections in GMS region, 2021–2024



Note: Relative Infection Index $I_t/\bar{I}$. China and Thailand are normalized to their 2021–2024 mean (baseline = 1.0). Values above 1.0 indicate above-average activity for the period. Cross-country levels are not directly comparable; interpret within-series patterns and timing.Data source: World Animal Health Information System (WAHIS), accessed May 2025.

Global patterns of brucellosis display pronounced regional differences and distinct trajectories for the principal pathogens *Brucella abortus* and *Brucella melitensis*. Recent estimates place the annual incidence of human brucellosis at a minimum of 2.1 million cases, a figure considerably higher than earlier assumptions, with most cases occurring in Africa and Asia (Laine et al., 2023). The disease remains endemic throughout the Middle East, the Mediterranean basin, Central and South America, and extensive parts of Asia, with the sharpest increases reported in Central and Southwest Asia (Qureshi et al. 2024).

An assessment of average relative infections from 2021 to 2024 (Figure 8.1.1& 8.1.2) reveals contrasting global narratives. For *B. abortus,* the $It/\bar{I}$ metric indicates a modest yet steady decline, shifting from just above the baseline in 2021 to below it by 2025. Beneath this global average lie notable regional gains: Asia and Africa begin from higher baselines but register marked reductions, whereas North America and Europe show relatively stable trends near the baseline, reflecting the longstanding impact of well-funded control programs. This pattern underscores the success of systematic state-backed eradication initiatives in the formal cattle industries of many high-income economies (USDA, 2025).

The epidemiological landscape for *B. melitensis* tells a more concerning story. The global trend is volatile, dipping in 2023 and rising sharply in 2024. This variability stems from pronounced regional events. Africa and Europe both record substantial increases in 2024, while Asia remains consistently above the baseline, signaling persistent transmission. South America exhibits an extreme spike in 2022, followed by a collapse, a pattern consistent with a large outbreak followed by either effective intervention or depletion of susceptibles. Compared with *B. abortus*, *B. melitensis* remains difficult to control because it circulates primarily in sheep and goats managed in extensive, nomadic, or smallholder systems where surveillance, vaccination, and biosecurity are hard to sustain (WHO, n.d.). Consequently, the expanding global burden of brucellosis is increasingly centered on *B. melitensis* in resource-limited settings, a finding with direct relevance to the GMS.

1.33 OECD Background and Economic Impact

Within the high-income economies of the OECD, the economic calculus of brucellosis has shifted from managing direct production losses to financing the surveillance, control, and certification systems needed to safeguard disease-free status (USDA, 2025). This status is crucial for international trade, and the resources required to maintain it dominate policy considerations. The economic burden in these countries is measured less by clinical losses and more by the public expenditure necessary to prevent re-establishment and to satisfy trading-partner requirements (McDermott et al., 2013).

The Cooperative State–Federal Brucellosis Eradication Program in the United States illustrates this shift. When launched in the mid-twentieth century, the disease was widespread, but decades of sustained efforts have reduced affected cattle herds from 124 000 in 1956 to single digits today (USDA, 2025). Annual losses from reduced milk yields and abortions have fallen from an estimated 400 million USD in 1952 to less than 1 million USD. Total benefits to producers and consumers exceed 18.3 billion USD, and projections show that abandoning the program would add an estimated 80 million USD to annual beef and milk production costs within a decade (ERS, n.d.).

A comparable scenario exists in the European Union, where most member states now hold officially brucellosis-free status in cattle, sheep, and goats after prolonged eradication campaigns (EFSA, 2024). These efforts involve considerable expenditure; the overall EU budget for food safety, which includes animal health, runs into the billions of euros (European Commission [EC], 2013). In spite of substantial progress, residual pockets of disease persist in southern Europe, especially parts of

Greece, Italy, and Portugal, requiring continued, co-financed eradication activities (EFSA, 2024). Economic analyses confirm the value of these programs. In one Italian province, the combined cost of eliminating brucellosis and two other diseases approached 19 million EUR, yet benefit–cost ratios remained comfortably above unity and averted far larger economic damage (Caminiti et al., 2017).

Experience across the OECD demonstrates that brucellosis control constitutes a long-term public good that demands sustained government investment. The principal driver is not the mitigation of on-farm losses but the protection of national market access. This reality creates significant financial and institutional barriers for developing economies, including those in the Greater Mekong Subregion. Although the OECD model offers a proof-of-concept for successful eradication, its dependence on prolonged, high expenditure for test-and-slaughter, strong veterinary services, and producer compensation may be unrealistic in resource-constrained settings. More pragmatic and context-specific strategies are therefore required for countries in the region.

1.34 Data Availability and Gaps in the GMS

Brucellosis data are particularly uneven. China and Thailand both operate national surveillance systems, and verification suggests that reasonably current information exists, even if only part of it is reflected in the country sections. By contrast, Cambodia and Viet Nam have almost no official brucellosis data in the public domain, Lao PDR is represented by a single recent survey, and Myanmar is again missing. In practice, this means that the figures cited here are the few solid points available, but they offer only a fragmentary view of how brucellosis affects smallholders and pastoral systems in mainland Southeast Asia.

1.35 People's Republic of China

China remains the principal epicenter of brucellosis in the GMS. A recent systematic review that pooled more than three million bovine samples collected between 2014 and 2024 places the national seroprevalence in cattle at 1.5 percent overall; dairy herds show the greatest burden at 3.1 percent, more than double the 1.3 percent recorded in beef cattle, highlighting the particular vulnerability of intensive dairy systems in the northern rangelands (Tian et al., 2024). Human incidence mirrors this trajectory: interpretability analysis of surveillance data records an average annual increase of 8.2 percent from 2004 to 2021 and documents a gradual geographic shift south- and westward from the historic strongholds of Inner Mongolia, Shanxi, and Xinjiang (Wang et al., 2024).

The two principal pathogens display contrasting recent dynamics. Figure 8.2.2 shows that the relative-infection index for *Brucella melitensis* rose modestly in 2022 before trending downward, yet it still lies above the one-to-one baseline in 2024, reflecting sustained transmission in small-ruminant systems that are difficult to vaccinate comprehensively. By contrast, the *B. abortus* curve in Figure 8.2.1 peaks in 2022 and falls slightly below baseline thereafter, suggesting that integrated vaccination, test-and-slaughter, and movement-control programs in the formal cattle industry are beginning to take hold. These early gains accord with the objectives of the national "Five-Year Action Plan for Brucellosis Prevention and Control in Livestock, 2022–2026," which targets high-incidence counties for intensified surveillance and progressive establishment of officially recognized brucellosis-free zones (Wang et al., 2024).

New vulnerabilities nevertheless continue to emerge. An occupational outbreak at a biologics plant in Chongqing in 2020 infected 43 percent of employees when aerosols of live *B. abortus* A19 and S2 vaccine strains escaped containment, illustrating how lapses in biosafety outside the northern pastoral belt can seed infection in naïve populations (Zhou et al., 2022). Socio-economic drivers compound the challenge: machine-learning models attribute the recent geographic spread of human cases less to livestock-density metrics than to variables such as railway mileage, hospital-bed availability, and GDP, all of which facilitate long-distance movement of animals and of consumers who trade and eat their products (Wen et al., 2024).

China therefore stands at an inflection point. Control measures in the commercial cattle sector are delivering measurable progress against *B. abortus*, yet rising demand for mutton, continued expansion of goat and sheep production in the south-central provinces, and the logistical reach of national transport networks still favor *B. melitensis* transmission. Sustained success will require closing biosecurity gaps along live-animal value chains, tightening occupational-health safeguards in vaccine and meat-processing facilities, and extending veterinary-public-health capacity to the rapidly growing small-ruminant industries beyond the traditional pastoral heartland.

1.36 Cambodia

Brucellosis in Cambodia is best described as a domain of strategic uncertainty, a condition driven by the absence of comprehensive national surveillance and limited institutional capacity (Siengsanan-Lamont & Blacksell, 2021). The disease is considered neglected and remains outside formal reporting structures, leaving its prevalence and impact largely unknown. Current knowledge derives almost entirely from recent pilot studies supported by international partners.

An abattoir-based surveillance project in Phnom Penh during 2019 and 2020 detected Brucella antibodies in only 0.2 percent of cattle and swine (Siengsanan-Lamont et al., 2022). A broader survey of large ruminants in seven provinces recorded similarly low seroprevalence (Siengsanan-Lamont & Blacksell, 2021). In 2023, the first focused investigation of goats, a primary host for highly pathogenic *B. melitensis*, yielded an apparent seroprevalence of 0.4 percent, with positive animals found only in Kampot and Tboung Khmum provinces (Siengsanan-Lamont et al., 2023).

These low figures should not be interpreted as evidence of freedom from disease. Investigators emphasize that limited diagnostic capacity at the National Animal Health and Production Research Institute, combined with low awareness among veterinarians and public-health officials, constrains case detection. Abattoir-based surveys capture mainly animals sent for slaughter and seldom reach remote smallholder systems, where surveillance gaps are largest (Siengsanan-Lamont & Blacksell, 2021). Moreover, the reliance on externally funded, project-based initiatives raises questions about the sustainability of monitoring efforts once donor support ends.

Cambodia shares porous borders with Thailand and Viet Nam, both of which report endemic brucellosis, and informal cross-border livestock movement is common. It is therefore plausible that the pathogen circulates undetected within the country. For Cambodian decision-makers, the central challenge is less about managing a known epidemic than about creating the veterinary and public-health infrastructure needed to establish an accurate epidemiological baseline. Until such foundational investments are made, this strategic uncertainty will remain a non-tariff barrier to trade and a latent risk to public health.

1.37 Lao PDR

In Lao PDR, the epidemiological landscape of brucellosis remains largely conjectural because routine reporting is sparse and researchers must rely on ad hoc surveys to gauge infection levels. Even so, a 2024 review that incorporated a nationwide goat-serology campaign detected antibodies in only 1.4 percent of samples, while an abattoir study of cattle and buffalo in 2020 recorded a prevalence of 0.7 percent (Jayasekara et al., 2024; Siengsanan-Lamont et al., 2022). These findings confirm that *Brucella* is present but circulating at what appear to be low levels.

Disease risk in Lao PDR is closely bound to the rapid growth of the goat industry, which is almost entirely driven by sustained demand for live animals from Viet Nam (Jayasekara et al., 2024). The trade itself is informal and only loosely regulated, creating an obvious conduit for transboundary spread. Producers therefore face a tension between the immediate gains of continued sales and the longer-term threat that a single outbreak, once traced to Lao herds, could prompt Viet Nam to close the market overnight.

Institutional factors magnify this vulnerability. Farmers routinely cite disease as a major constraint on production, yet veterinary and extension services remain thin on the ground outside major towns. Surveillance capacity likewise depends heavily on donor-funded projects, a model that offers limited sustainability (Siengsanan-Lamont & Blacksell, 2021). Because no one trader has an incentive to pay for diagnostic testing or certification, the system as a whole under-invests in risk reduction; that's a classic collective-action problem. The logical policy response is a formal bilateral framework with Vietnam that establishes harmonized rules for surveillance, testing, and certification so that trade can continue without compromising regional biosecurity.

1.38 Thailand

Thailand presents a more intricate picture, reflecting the capabilities of a comparatively advanced veterinary system that nevertheless contends with diverse risks. The Department of Livestock Development operates a national Brucellosis-Free program that combines active serological screening with the compulsory culling of positive animals (Jiemtaweeboon et al., 2023).

Despite these efforts, brucellosis persists. Human cases still emerge, most often linked to the goat sector and to the consumption of unpasteurized milk, indicating that *B. melitensis* in small ruminants remains a priority concern. 51 Recent surveys underscore the point: farm-level seropositivity reached 13.33 percent in Chainat Province and 26.4 percent in Sing Buri Province in studies published in 2023 (Jiemtaweeboon et al., 2023).

Time-series data for 2021–2024 draw a sharp contrast between *B. melitensis* and *B. abortus*. In goats the relative infection rate for *B. melitensis* falls steeply from a very high baseline in 2021 to almost zero by 2024, testament to a targeted intervention that has achieved measurable success. By contrast, *B. abortus* shows a sudden spike in 2022; its relative infection index reaches two, followed by a swift return to baseline. Such a pattern suggests a short-lived but intense outbreak that was rapidly contained. Although the precise source remains uncertain, recent work notes that several bovine pathogens, including brucellosis, have spilled into Thailand's wildlife populations, notably gaur, raising the possibility of wildlife-to-livestock transmission (USDA, 2025; Horpiencharoen et al., 2024).

1.39 Vietnam

Vietnam has reached a pivotal moment in its approach to brucellosis, moving from an initial recognition of a largely hidden threat toward the systematic design of a national control program. For many years the disease drew little attention, but that changed after investigators documented ten human cases of *Brucella melitensis* in the south in 2017 (Franco et al., 2017). All patients had regular contact with goats, confirming that an endemic cycle exists in small-ruminant herds and that undetected transmission can spill into the wider community. The cases were first misclassified as sepsis, dengue, or tuberculosis, a finding that illustrates both the low level of clinical awareness and the extent to which routine surveillance had underestimated the burden.

The government, led by the Ministry of Agriculture and Rural Development, has since adopted a proactive stance framed within a One Health agenda. A draft roadmap now under preparation places brucellosis alongside avian influenza and rabies in the portfolio of high-priority animal diseases (FAO, 2024). This signals a commitment to embedding zoonoses control in an integrated public health and veterinary strategy. The central challenge, however, lies in translating national policy into local action. Studies show that expertise in surveillance, outbreak investigation, and data management is concentrated at provincial and national headquarters, whereas the district and commune officers who form the front line possess limited training and resources (Khan et al., 2024). Weaknesses in food-safety oversight and the regulation of animal products further complicate control by allowing contaminated milk and meat to reach consumers (USDA FAS, 2024).

1.40 Recommendations for GMS Policy Makers

Brucellosis presents a patchwork of risks and responses rather than a uniform epidemic in the GMS. China faces a large and deeply entrenched problem that has grown in parallel with rapid livestock expansion and changing dietary preferences. Thailand must manage distinct threats in cattle, goats, and wildlife, each requiring tailored interventions. Viet Nam is working to align progressive national policies with the practical realities of field implementation. Cambodia and the Lao People’s Democratic Republic contend with the greatest uncertainty, as gaps in surveillance and diagnostics obscure the true scale of infection and complicate participation in regional trade.

Unstructured and often informal livestock movements bind these national situations together. High-volume goat shipments from the Lao People’s Democratic Republic to Viet Nam exemplify a trade that delivers essential income to smallholders while opening efficient channels for disease spread. The tension between short-term economic gain and long-term biosecurity is a classic collective-action dilemma that no single country can resolve in isolation.

Regional policy therefore needs to balance three broad priorities. First, surveillance systems should be risk-based rather than uniform, concentrating intensive monitoring where incidence is highest and investing in baseline studies where data are scarce. Second, key trade corridors would benefit from formal agreements that align testing, certification, and animal-identification requirements, thereby safeguarding commerce while reducing the threat of transboundary transmission. Third, durable progress depends on strengthening district-level human resources in both veterinary and public-health services and on creating economic incentives that reward farmers for adopting good biosecurity and participating in vaccination and testing campaigns.

These actions, pursued in concert, can transform brucellosis control from a series of isolated national efforts into a coherent regional strategy that protects public health, supports trade, and promotes sustainable rural livelihoods across the GMS.

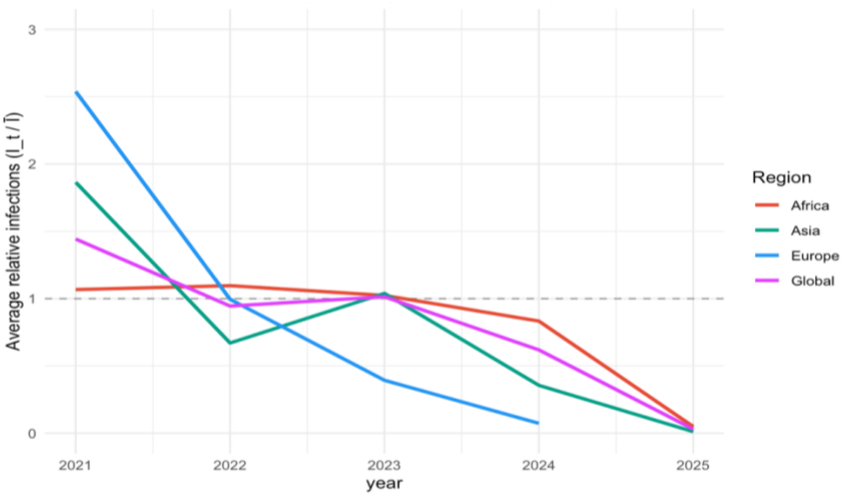
9 Lumpy skin disease virus (Inf. with)

1.41 Overview

Lumpy skin disease (LSD) is an acute, vector-borne infection of cattle and water buffalo caused by lumpy skin disease virus (LSDV), a Capripoxvirus closely related to sheep- and goat-pox viruses. Although it produces relatively low mortality (typically 1–5%), morbidity can exceed 50%, with fever, characteristic nodular dermatitis, lymphadenitis, and prolonged debilitation that slash milk yield, fertility, and hide quality. Because the virus is mechanically transmitted by biting insects (notably mosquitoes, Stomoxys, and certain ticks) and survives for weeks in desiccated scabs or chilled hides, it spreads readily through vector movement and trade in live animals or animal products. Consequently, the WOAH lists LSD as a notifiable disease that triggers immediate trade restrictions once detected (WOAH, n.d.).

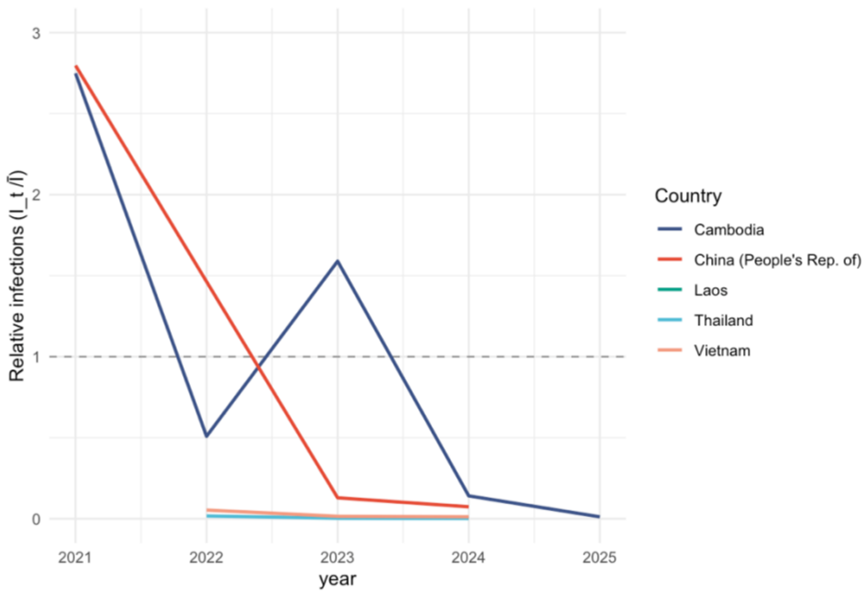
Since its first description in Zambia in 1929, LSD has expanded dramatically beyond its African cradle. After becoming entrenched throughout sub-Saharan Africa, the virus leapt to Egypt and Israel in the late 1980s and, over the past decade, has swept through the Middle East, the Caucasus, and large swathes of Asia, reaching India, China, Southeast Asia, and, most recently, the Korean Peninsula (Moudgil et al., 2024). This epidemiological shift reflects a potent mix of abundant insect vectors in tropical climates, porous borders that facilitate informal cattle movements, and, in some areas, the emergence of recombinant vaccine-derived strains that may display heightened virulence or altered transmissibility (Moudgil et al., 2024). WOAH recommends a triad of measures, such as early detection, mass vaccination with homologous live-attenuated vaccines, and rigorous movement control, to arrest outbreaks, and experience in southeastern Europe shows that region-wide, synchronized vaccination can eliminate the virus locally. Yet endemic circulation in Africa and much of Asia means that countries remaining free of LSD must maintain vigilant surveillance and emergency vaccine stocks to protect their livestock economies and preserve export markets (WOAH, n.d.).

Figure 9.1 Average annual lumpy skin disease virus infections by continent and global total, 2021–2025



Note: Y-axis shows the Relative Infection Index $I_t/\bar{I}$. For each region, $\bar{I}$ is the 2021–2025 mean (baseline = 1.0; dashed line marks the baseline). Values above 1.0 are above the period average; values below 1.0 are below it. Lines are annual averages. Cross-region levels are not directly comparable; read within-series change and timing. World Animal Health Information System (WAHIS), accessed May 2025

Figure 9.2 Trends in lumpy skin disease virus infections in GMS region, 2021–2025



Note: Relative Infection Index $I_t/\bar{I}$. Each country is scaled to its 2021–2025 mean (baseline = 1.0). Values above 1.0 are above the period average. Coverage runs through 2025 for the series shown. Some countries report very low or zero values in parts of the period, which plot near zero. Levels are not directly comparable across countries; focus on each series' own pattern. World Animal Health Information System (WAHIS), accessed May 2025

1.42 Global Trends

Originally detected in Zambia in 1929, lumpy skin disease (LSD) lurked inside sub-Saharan Africa for more than six decades, surfacing only in scattered clusters across southern and eastern Africa, where humid seasons fuel *Stomoxys*flies and *Aedes* mosquitoes (Nugroho et al., 2025). North African expansion began in the late 1980s (Egypt confirmed cases in 1988), and the virus broke its continental leash the very next year when Israel reported the first extra-African outbreak (Nugroho et al., 2025). From that moment, LSD advanced in pulses through the Levant and Arabian Peninsula, propelled by informal cattle movements and the steady traffic of live-animal trade.

Momentum accelerated after 2012. A West Eurasian wave rolled across Turkey, the Caucasus, and the wider Middle East between 2012 and 2015 (Nugroho et al., 2025). In 2015 the virus crossed into the European Union via Greece; within fourteen months it ignited more than 7 400 farm outbreaks across Greece, Bulgaria, North Macedonia, Serbia, Kosovo, Albania, and Montenegro (EFSA, 2017). The EU's response was unprecedented: 1.8 million cattle were immunized in 2016–2017, driving outbreak numbers down by 95% in a single calendar year and eliminating new reports in the Balkans by 2018 (EFSA, 2017). Member States then pivoted from blanket vaccination to high-resolution surveillance, retaining emergency stockpiles but trusting ring vaccination to smother any fresh spark (Olvera Porcel, 2022). Europe's trajectory proves a region can expel LSD, yet also underscores the need for permanent border vigilance.

Africa, by contrast, never left the endemic stage. Virtually every sub-Saharan country still registers annual outbreaks, and southern African hot spots such as Zimbabwe record the highest herd-level incidence anywhere in the world (Anwar et al., 2022). Only Algeria, Morocco, and Tunisia remain officially free as of 2023, and even they reported high-risk introductions at their southern frontiers after Libya's first cases that year (Anwar et al., 2022). Persistent circulation is blamed on wet-season vector blooms, porous borders, and underfunded vaccination programs.

The most dramatic expansion since 2021 has unfolded in Asia. Before 2019 the continent was LSD-free, but that changed abruptly when India, Bangladesh, Nepal, Pakistan, Kazakhstan, and China recorded first detections in the same season (Wilhelm & Ward, 2023). A second leap followed in late 2020 (Viet Nam diagnosed LSD in October, Myanmar in November (Wilhelm & Ward, 2023)), and by July 2021, Thailand, Laos, Cambodia, and peninsular Malaysia were battling simultaneous epidemics. Figure 9.1 captures the shock: Asia's average relative infection index ($I_t/\bar{I}$) rockets from virtually zero in 2021 to several-fold above baseline by 2023, dwarfing the steadier African curve and the flat-line European profile. In the same graphic, the global composite climbs in lockstep with the Asian spike, peaks in 2023, and then flattens as vaccination and natural immunity begin to bite (Olvera Porcel, 2022).

Recombinant vaccine-derived strains complicate the Eastern Hemisphere map. Live-vaccine lineages detected in Russia and Kazakhstan around 2017 re-emerged during outbreaks in South and Southeast Asia; whole-genome sequencing shows vaccine-like fragments interwoven with field strains, a consequence of extensive prophylactic use in zones without tight cold-chain oversight (Li et al., 2022). These mosaics raise fresh questions about long-term control tools and reinforce the argument that modern inactivated or vector-free platforms may be needed for sustained Asian eradication.

By 2025 LSD has been confirmed in more than 80 sovereign states, with at least 25 of those experiencing their inaugural outbreaks as recently as 2023–2024 (Roche et al., 2020). New frontiers include Bhutan (first cases 2022), Indonesia's Sumatra (early 2022), and, most alarmingly, the Korean Peninsula in October 2023, where South Korea's detection proved no high-income cattle nation is automatically safe (Roche et al., 2020). India's 2022 nationwide wave killed tens of thousands of cattle and infected millions, demonstrating the sheer scale of loss possible in mega-herds. Informal trade corridors and shared river basins aided the synchronized May-to-July 2021 explosion across Viet Nam, Laos, Cambodia, and eastern Thailand; outbreak-cluster analysis pinpoints the Mekong borderlands as the epidemic's radiating core (Wilhelm & Ward, 2023). In Figure 9.1 the Asian line spikes exactly during that window and only decays once emergency vaccination saturates the most-affected provinces.

1.43 OECD Background and Economic Impact

LSD's emergence has had significant repercussions even in OECD countries, primarily via its impact on trade and the costs of control measures. While many OECD members (e.g. in North America, Western Europe, and Oceania) have thus far remained free of LSD, the disease's incursions in parts of Europe and its rapid spread in Asia have prompted substantial economic and policy responses.

In 1989, when Israel confirmed an outbreak linked to livestock imports from Africa (Nugroho et al., 2025). Sporadic incursions continued in the Middle East during the 1990s and early 2000s, but the critical shock to OECD trade arrived in Southeast Europe in 2015. Greece reported the first European Union (EU) cases in August 2015; within fourteen months, 7 483 outbreaks were confirmed in Greece, Bulgaria, North Macedonia, Serbia, Kosovo, Albania, and Montenegro (EFSA, 2017). Emergency measures included movement bans, vector control, and testing of cattle within 3 km zones (EFSA, 2017).

In response, the European Commission implemented a mass-vaccination program that delivered 1.8 million homologous live-attenuated doses between May 2016 and April 2017 (EFSA, 2017). Outbreaks fell by 95% in 2017, from 7 483 in 2016 to 385, and by 2018 no further cases were reported in the Balkans (EFSA, 2017). Direct control costs reached approximately €1.5 billion, covering vaccine purchase, veterinary labor, disinfection, and producer compensation (EFSA, n.d.). Economic assessments concluded that vaccination was the most cost-effective option; a stamping-out-only strategy would have required larger culls and prolonged export bans (EFSA, n.d.).

Most EU member states ceased routine LSD vaccination in 2020 after the disease was eliminated from their territories, retaining emergency stockpiles and strengthening passive surveillance at external borders (Olvera Porcel, 2022). Greece and Bulgaria continued targeted prophylactic vaccination through 2021 as a buffer against reintroduction from Turkey, which remains endemic (Olvera Porcel, 2022).

Beyond Europe, OECD members in Asia–Pacific have adopted preventive measures in light of LSD's eastward expansion. Japan built an emergency stockpile of 800 000 doses in 2023, while South Korea pre-positioned 500 000 doses before reporting its first outbreak in October 2023 (Tran et al., 2024). Australia, currently LSD-free, estimates potential first-year losses of AUD 7–8 billion if the virus were introduced, primarily through export suspensions (Roche et al., 2020). As a precaution, Canberra has increased border disinsection of vessels and aircraft and allocated AUD 134 million for regional vaccine banks (Roche et al., 2020).

Insurance and finance sectors have adjusted to the new risk environment. European dairy lenders now require evidence of LSD vaccination before approving capital expenditure loans, and reinsurers provide premium discounts to feedlots demonstrating documented vaccination and vector-control protocols (Anwar et al., 2022). During the 2016 Balkan epidemic, social media images of ulcerated hides depressed consumer confidence; processors consequently developed rapid-response communication plans to mitigate future demand shocks (EFSA, 2017).

Data from endemic developing countries illustrate the scale of losses the OECD seeks to avoid. In Ethiopia, median herd-level economic loss per outbreak was US $1 176, and a national vaccination program showed a benefit-cost ratio exceeding six (Wilhelm & Ward, 2023). Across South and Southeast Asia, FAO projects direct production losses of up to US $1.45 billion over five years without sustained vaccination (Roche et al., 2020). These figures support OECD funding for international surveillance and vaccination, viewed as cost-effective insurance against trade disruption.

LSD imposes direct costs through productivity declines, mortality, culling expenses, and indirect costs through trade restrictions. OECD members have prioritized early vaccination, compensation frameworks, and continuous surveillance to protect high-value export industries. The European experience confirms that coordinated vaccination can suppress LSD in naïve regions, but maintaining freedom requires ongoing vigilance and contingency funding (EFSA, n.d.).

1.44 Data Availability and Gaps in the GMS

LSD is better documented than some other cattle diseases, but the coverage is still incomplete. China and Cambodia are described using recent introduction and spread data, with outbreaks reported around 2020–2022. For Lao PDR, Thailand and Viet Nam, the chapter notes incursions in 2020–2021 and early control efforts, yet there is little publicly available information on what has happened since. These country stories therefore capture the first impact of LSD but not the longer-term pattern. Myanmar appears only in passing and lacks a full country-level account, leaving another gap in the regional picture.

1.45 People's Republic of China

China confirmed its first LSD outbreak on 3 August 2019 in Ili, Xinjiang, near the Kazakhstan border (Li et al., 2022). Within the same month, genetically identical viruses were detected in Jiangxi, Fujian, Anhui, Zhejiang, and Guangdong, indicating rapid long-distance spread or multiple introductions (Li et al., 2022). Laboratory sequencing showed a recombinant vaccine-like strain, similar to viruses reported in Central Asia (Li et al., 2022).

The Ministry of Agriculture and Rural Affairs (MARA) imposed a 21-day standstill on cattle movements from affected counties, established disinfection checkpoints on major highways, and procured 12 million vaccine doses by September 2019 (Lu et al., 2021). Compensation for culled dairy cattle was set at approximately RMB 8 000 per head to encourage early reporting.

A second wave began in June 2020 when Fujian confirmed new cases (Li et al., 2022). In October 2020, 1 700 feeder cattle imported from Chile arrived in Xilingol, Inner Mongolia, with clinical LSD; MARA suspended imports from the source facility and tightened maritime quarantine (Zan et al., 2022). By December 2020, at least seven provincial-level jurisdictions, including Kinmen Island (Taiwan), had reported outbreaks (Zan et al., 2022).

Control efforts intensified in 2021. Xinjiang completed mass vaccination of its cattle population; Yunnan and Guangxi mandated annual boosters in border districts. Abattoirs nationwide installed lesion-detection cameras linked to a central database. Dairy farms in hotspot counties reported milk-yield reductions of approximately 15% during acute infection periods, and beef prices in Fujian fell by 20% during movement restrictions, but national supply chains prevented major consumer impact.

By late 2022, China's official LSD notifications to WOAH declined sharply, suggesting a successful transition to limited endemic status. Sporadic cases continued in Qinghai in 2021, likely linked to livestock movements from Xinjiang, but ring vaccination prevented wider spread. MARA maintains an annual reserve of 5 million doses and authorizes immediate vaccination of cattle in any prefecture reporting more than five outbreaks (Olvera Porcel, 2022).

China has integrated its LSD response into regional cooperation. Diagnostic reagents and training have been provided to Lao PDR and Cambodia, and a shared surveillance platform exchanges genomic data among Greater Mekong Subregion laboratories (Olvera Porcel, 2022). Internally, electronic movement permits are now mandatory for inter-provincial cattle transport, and online livestock platforms must display verified vaccination records.

China's experience demonstrates that early mass vaccination, strict movement control, and transparent reporting can contain LSD in a large cattle population. However, MARA's risk assessment highlights two vulnerabilities: limited cold-chain capacity among yak herders on the Qinghai–Tibet Plateau and informal trade across the Myanmar and Laos borders (Zan et al., 2022). Sustained vaccination and border surveillance therefore remain priorities in the 14th Five-Year Animal-Health Plan.

1.46 Cambodia

Cambodia detected its first LSD cases in June 2021 in Ratanakiri Province, adjacent to Viet Nam (Porco et al., 2023). The virus spread rapidly: by September 2021, all provinces had reported outbreaks. Cumulative data indicated approximately 73 000 clinical cases (≈ 2.5% of the national herd) and about 1 000 deaths, predominantly among calves (Porco et al., 2023).

The Ministry of Agriculture, Forestry and Fisheries (MAFF) established movement restrictions and promoted insecticide application, but compliance was inconsistent because many cattle free-graze and move through informal markets (Wilhelm & Ward, 2023). Large-scale culling was not implemented owing to limited compensation funds. Consequently, farmers sold sick or exposed cattle at reduced prices, and Thailand suspended informal cattle imports during the outbreak peak.

Cambodia lacked an LSD vaccine stockpile. FAO secured supplies of the South African Lumpyvax in late 2021, and MAFF initiated a targeted campaign in July 2022, prioritizing cattle near wildlife reserves after an endangered banteng tested positive for LSD (Porco et al., 2023). By October 2022, approximately 20 000 cattle and buffalo had been vaccinated in buffer districts; national coverage remained below 10%.

Economic impacts were concentrated in 2021–2022. Household surveys recorded a 30% decline in livestock income in border districts, and some farmers refinanced microloans at higher interest rates (Porco et al., 2023). Draft cattle shortages delayed rice planting, and informal traders saw monthly volumes fall by two-thirds. MAFF estimates sectoral GDP losses at US $42 million over two years, which is a significant figure for rural livelihoods.

Since 2023, LSD incidence has fallen to sporadic levels, attributed to partial herd immunity and limited vaccination. MAFF plans to incorporate LSD boosters into its routine Hemorrhagic-septicaemia and foot-and-mouth-disease campaigns, targeting 200 000 doses per year once funding is secured. Surveillance capacity has improved: village animal-health workers now upload geo-tagged lesion photographs to an ASEAN dashboard, and portable PCR units donated by international partners reduce confirmation times to 48 hours (Wilhelm & Ward, 2023).

Cambodia's experience underscores three operational points. First, LSD can spread nationwide within months in free-grazing systems lacking movement control. Second, absence of compensation encourages distress sales that propagate the virus. Third, integrating wildlife-protection objectives can attract additional resources for vaccination. Continued donor support for vaccines and surveillance is essential to prevent resurgence during the rainy season, when vector populations rise and new calf cohorts are naïve to infection (Porco et al., 2023).

1.47 Lao PDR

Laboratory confirmation of lumpy skin disease in Lao PDR was obtained in the final week of May 2021, when real-time PCR testing of samples from nine villages in Vientiane Capital and Savannakhet Provinces identified LSDV in 369 of 2,018 cattle examined (≈ 19% morbidity); buffalo in the same villages showed no clinical signs (Souriya, 2021). The Department of Livestock and Fisheries enacted emergency movement bans, instructed district staff to apply topical insecticides, and initiated active case finding, but vaccine was unavailable and no culling was ordered. Passive reports collected during the following four months documented spread to at least twelve provinces, yet incidence remained low in absolute terms, a pattern illustrated by the Laos trace in Figure 9.2, which rises only marginally above the baseline before trending downwards after 2022 (Mazloum et al., 2023). A first shipment of 200 000 Neethling-strain doses arrived in early 2023 and was deployed as ring vaccination in border districts; nationwide coverage is still incomplete, and annual boosters for high-density cattle zones have been recommended to prevent recrudescence (Souriya, 2021).

Direct producer losses during 2021-2022 were estimated at US $3.5 million, derived from morbidity-related weight loss, milk decline, and veterinary treatment; because more than four-fifths of cattle owners keep five or fewer head, these costs were borne chiefly by smallholders (Mazloum et al., 2023). Disease-related debility of draught animals delayed rice transplanting on approximately 4700 ha in the central plain, contributing to a national paddy shortfall of about 12000 t valued at US $2.4 million, while the three-month standstill on cattle movements cut formal exports to Viet Nam by 42% (Souriya, 2021). Public expenditure on insecticides, surveillance fuel, and laboratory reagents reached LAK 23 billion (≈ US $2 million) in 2021-2022, and the 2023 vaccine purchase added a further US $0.36 million; for the medium term, the finance ministry has flagged the need to fund 200,000 annual booster doses and to maintain mobile teams for vector monitoring, noting that any lapse could shift the Lao infection curve back above the unity threshold shown in Figure 9。2 (Mazloum et al., 2023).

1.48 Thailand

Originally free of lumpy skin disease (LSD), Thailand confirmed its index cases in March 2021, with the first laboratory-positive herds clustered in the northeastern beef-cattle belt and, days later, in several central provinces (Modethed et al., 2023). An official investigation recorded 283,213 affected herds and 628,089 clinical cases within fifteen months, yet spatio-temporal modelling of the initial wave shows how transmission remained highly focal: in Lamphun’s dairy basin, a herd-attack rate of 72% was generated by clusters whose radii rarely exceeded one kilometer (Modethed et al., 2023). Monte-Carlo scan statistics dated the primary cluster to 6–8 June 2021, when 35 clinically infected cattle on a single farm seeded local spread; subsequent Poisson windows captured the epidemic peak of 14–20 July, by which time 159 cases had accumulated across 58 farms inside a 1.05 km radius (Modethed et al., 2023). These dimensions corroborate entomological evidence that short-range vector flight, rather than long-haul cattle movements, drove the early Thai outbreaks. A national case-control survey later quantified this entomological signal: herds lacking insect-vector control were twice as likely to be hit by LSD, whereas mere proximity to communal water points, shared grazing, or informal trading showed no significant effect (Arjkumpa et al., 2024). The same study highlighted husbandry inertia as an independent risk factor, suggesting that long-established holdings may be slower to upgrade sheds, drainage, or screening (Arjkumpa et al., 2024). Concerted control measures followed swiftly. The Department of Livestock Development (DLD) imposed 50 km movement bans, closed cattle markets, and, in the absence of immediate vaccine stocks, issued insecticide guidelines focused on the one-kilometer buffer implied by the outbreak clusters (Modethed et al., 2023). Homologous vaccination became widely available only in late 2021; nevertheless, by early 2023 the national relative-infection index plotted in Figure 9.2 sits just above baseline, far below the peaks registered in Cambodia or Vietnam, attesting to the combined effect of emergency insect control, ring vaccination, and improved on-farm biosecurity. Thailand therefore illustrates a key regional lesson: even after explosive seeding, LSD can be throttled if spatial analytics translate rapidly into operational radii for vector control and immunization.

The economic footprint of Thailand’s 2021–2022 epizootic was material but contained. Field surveys across three outbreak provinces report that only 34% of farmers applied any insecticidal protocol before the crisis, yet once LSD struck, nearly all herds purchased pour-on pyrethroids or organized communal fogging, expenditures that were unbudgeted and rose with fuel prices (Arjkumpa et al., 2024). Because Thai beef herds are small (median five head) and milk production is concentrated in peri-urban dairies, direct productivity losses (fever, nodules, milk drop, or hide downgrading) were dispersed over tens of thousands of households; Modethed et al. (2023) calculate a morbidity of 11.3% and a mortality of 0.34% in Lamphun’s dairy enclave, figures that translate nationally into an estimated 70–80 million baht in lost carcass and milk value. Far costlier, however, were the control operations: insecticides, disinfectants, and improvisation of vector-proof night stalls averaged 2,500 baht per herd in the risk-factor survey, exceeding the book value of many local calves (Arjkumpa et al., 2024). Government outlays added another layer, yet these investments forestalled harsher macroeconomic shocks. Unlike neighboring exporters, Thailand avoided long-term bans on live-cattle shipments because outbreaks never infiltrated its feedlot supply chain, and dairy processors restored normal raw-milk volumes within one quarter of the peak (Modethed et al., 2023). Importantly, the mixed-effect models show no association between legitimate cattle purchases and herd-level infection, implying that the national movement standstill, though disruptive, shielded Thailand's formal trade routes from stigma-driven closures (Arjkumpa et al., 2024). Looking forward, the Thai experience suggests that the marginal cost of sustained vector suppression and annual booster vaccination is outweighed by the avoided burden of another nationwide epidemic, particularly given the demonstrated vulnerability of long-established herds. Policymakers therefore frame LSD as a chronic biosecurity cost rather than a transient disaster, budgeting recurring insect-control subsidies and maintaining emergency antigen banks, which is an economic recalibration grounded in the empirical attack rates, cluster sizes, and risk ratios documented during the first national encounter with the disease.

1.49 Vietnam

Vietnam confirmed its first lumpy skin disease (LSD) outbreaks in October 2020 and by December 2021 had recorded 207 687 infected cattle and buffalo with 29 182 animals culled, the bulk of cases occurring in the northern and north-central provinces where communal grazing and high vector densities coincide (Tran et al., 2021). Sequencing of viruses collected in Ha Tinh in 2021 showed 100% identity with the national reference strain in the P32 and RPO30 genes but revealed a distinct branch in the GPCR gene, indicating that at least two variants were already circulating (Tran et al., 2024). Live-attenuated Neethling-based and goat-pox vaccines were introduced under a government program that authorized three commercial products; coverage expanded rapidly during 2022, and official reports fell to 2,274 infections and 455 culls that year, a decline mirrored by the Vietnam line in the comparative infection chart, which drops from the region's highest relative index in 2021 to near-baseline by 2023. Molecular monitoring continues because the 2024 study detected a 12-bp insertion in the GPCR of the CX01 field isolate, underscoring the need to track genetic drift as vaccination pressure increases (Tran et al., 2024).

Economic impact peaked in 2021. Direct losses stemmed from mortality, weight loss, and milk reduction in the 200 000-plus clinical cases, while compulsory culling removed an additional 14% of confirmed animals (Tran et al., 2021). Producers faced uncompensated disposal costs until provincial funds were mobilized; herd owners also purchased insecticides and improvised screening to satisfy movement controls. National expenditure focused on vaccine procurement, cold-chain distribution, and emergency diagnostics; three approved vaccines accounted for the largest single outlay, but their deployment reduced incident cases fifteen-fold within one year, limiting further producer losses (Tran et al., 2024). Trade disruption was transient: live-animal exports to China and Cambodia were suspended during the 2021 peak but resumed after vaccination certificates became mandatory. The rapid decline in Vietnam's relative infection index after 2022, visible in Figure 9.2, indicates that the combined cost of vaccination and surveillance averted a potentially larger, long-term economic burden.

1.50 Recommendations for GMS Policy Makers

The recent trajectory of LSD across the GMS region underscores how quickly a single transboundary virus can test national systems, yet the initial responses also show the value of treating surveillance as a shared asset rather than a sovereign chore. After sweeping Southeast Asia in 2020–2021, LSD has been brought under control across GMS via coordinated vaccination campaigns; current priorities are maintaining coverage in border districts and sustaining post-outbreak immunity. Cambodia's early alerts in 2021 helped Thailand tighten its insect-control cordon, and Lao PDR used Vietnamese sequence data to confirm that its first detections belonged to the same regional lineage. A standing mechanism that circulates outbreak maps, genomic characterization, and field-investigation summaries in real time would formalize this informal exchange and allow veterinary teams on both sides of a river or highway to act in parallel. Embedding that mechanism in the broader transboundary-disease agenda, alongside foot-and-mouth disease or African swine fever, would avoid creating yet another vertical program and make it easier to fund the routine sequencing, field sampling, and dashboard maintenance that have already proved decisive for LSD.

Vaccination has clearly been the pivot from emergency to containment, but its impact has been uneven because supply and timing have varied from province to province. A regionally coordinated calendar, one that lines up booster campaigns in border districts before the main vector season, would create an immunological buffer spanning national frontiers and reduce the stop-start movement bans that disrupt trade. Advance purchase agreements or a pooled reserve managed through an existing ASEAN or WOAH facility could stabilize supply without adding new bureaucracy, while mutual recognition of vaccination status would let cattle move from certified compartments even when sporadic cases persist elsewhere. The practical benefit is twofold: fewer price shocks for farmers and traders and less temptation to move animals covertly when formal channels close.

Finally, the region's experience shows that controlling LSD cannot stop at vaccine vials and checkpoints. The disease has exposed gaps in laboratory diagnostics, field staffing, and vector management, particularly in areas where cattle share landscapes with wildlife and cross-border grazing is common. Upgrading one reference laboratory in each country to full PCR and gene-sequencing capability and pairing it with joint training programs for district para-veterinarians would create a lattice that can serve all priority diseases, not just LSD. Integrating wildlife surveillance, especially in parks where banteng or gaur range near village cattle, into routine livestock monitoring would extend that lattice into the forest edge and provide early warning of viral persistence outside domestic herds. These investments in people, laboratories, and ecological intelligence may feel unspectacular next to a headline vaccination drive, but they are what turn an emergency campaign into sustained regional resilience.

10 Bluetongue virus (Inf. with)

1.51 Overview

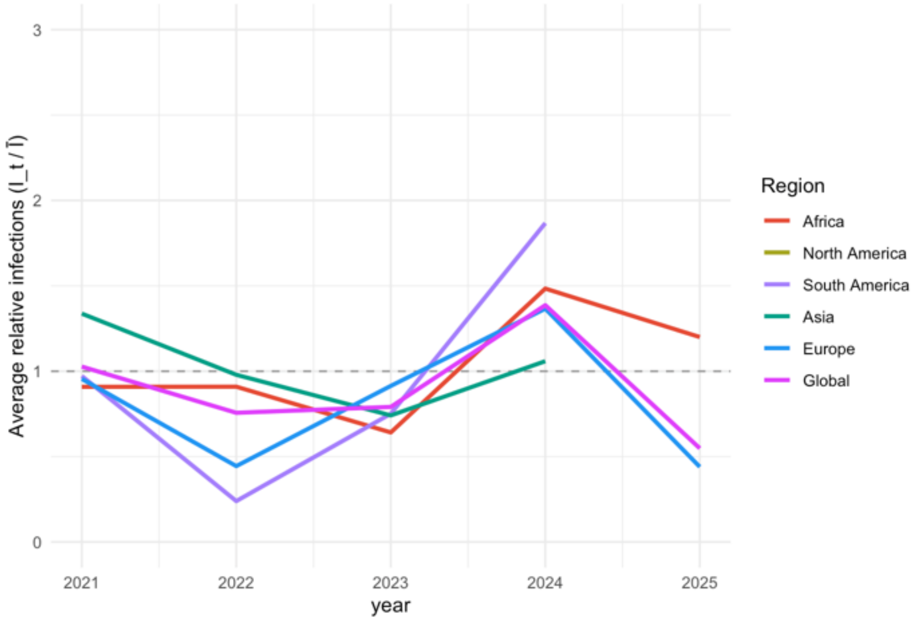
Bluetongue virus (BTV) is an infectious, non-contagious, vector-borne viral disease affecting wild and domestic ruminants. The virus is transmitted between susceptible ruminants almost exclusively by biting midges of a few species within the genus Culicoides after feeding on a viremic animal (WOAH, n.d.). At least 26 distinct BTV serotypes have been identified, with variable pathogenicity. BTV poses no significant public-health risk. Vaccination, alongside vector control, remains the most practical tool to reduce losses and interrupt the animal-to-vector cycle.

Publicly available BTV data in the GMS are extremely sparse. A review of WOAH/WAHIS notifications, national veterinary portals, and regional review papers found no national-level BTV reports from Cambodia, Lao PDR, Viet Nam, or Myanmar between 2020 and 2025. By contrast, southern China (including Yunnan and neighbouring provinces) repeatedly documents high seroprevalence in cattle/goats and a diverse Culicoides fauna capable of transmitting multiple orbiviruses, with recent entomological surveys detecting/isolating BTV and EHDV in Yunnan border areas. Taken together, “no reports” in several GMS countries more likely reflects under-detection and limited active surveillance than true absence, and underscores the need for baseline serosurveys, vector-infection monitoring, and trade-chain sentinels along shared borders. As of May 2025, these notifications and published studies are the most recent publicly available evidence we were able to identify for GMS member countries.

1.52 Global Trends

Throughout much of the twentieth century, BTV remained largely confined to tropical and subtropical latitudes. In the late 1990s, however, climate variability, intensified trade, and adaptation to local midge species facilitated the establishment of multiple serotypes in temperate Europe (FAO, n.d.).

Figure 10.1 Average annual Bluetongue virus infections by continent and global total, 2021–2025



Note: Y-axis shows the Relative Infection Index $I_t/\bar{I}$. For each region, $\bar{I}$ is the 2021–2025 mean (baseline = 1.0; dashed line marks the baseline). Values above 1.0 are above the period average; values below 1.0 are below it. Lines are annual averages. Cross-region levels are not directly comparable; read within-series change and timing. Data source: World Animal Health Information System (WAHIS), accessed May 2025.

Figure 10.1 summarizes recent dynamics: the global trend remains close to baseline in early 2021, declines in 2022, ascends sharply in 2024, and is projected to fall in 2025. Africa follows a similar trajectory but attains a higher peak in 2024. South America undergoes the most pronounced increase, moving from below baseline in 2022 to the highest regional peak in 2024, which indicates a substantial epizootic. Asia displays persistent fluctuations that typify endemic circulation. Europe declines in 2022 and subsequently rises to its own 2024 peak, corresponding with the BTV-3 and BTV-8 episodes reported by the (BAB, 2024). The synchronized peaks observed in 2024 suggest the influence of a common driver, possibly an El Niño-associated climate anomaly that augments vector abundance on several continents simultaneously (The Cattle Site, 2022).

According to the World Organisation for Animal Health, bluetongue ranked among the most frequently reported vector-borne diseases in 2024. During that calendar year, twenty-four countries documented 3,626 outbreaks, and Europe alone recorded 3,481 outbreaks between January 2024 and February 2025, the majority linked to BTV-3 (WOAH, 2024; WOAH, 2025).

1.53 OECD Background and Economic Impact

In the OECD region, bluetongue generates a profound and asymmetric economic impact. The direct losses from animal mortality, reproductive failure, and lost production are significant, yet they are consistently eclipsed by the far greater indirect costs of control, surveillance, and, most critically, trade disruption. This dynamic disproportionately affects nations with significant livestock export markets, where national BTV policy is often driven more by the import requirements of trading partners than by the domestic clinical burden of the disease (Sperlova & Zendulkova, 2011).

This reality is clearly illustrated by the varied strategic postures of OECD members. In the United States, where several serotypes circulate endemically with largely subclinical effects in cattle, the economic losses, estimated at USD 125 million to USD 144 million annually, stem almost entirely from export testing and movement restrictions (USDA, 1999). Similarly, Australia manages endemic BTV in its northern regions through a comprehensive National Arbovirus Monitoring Program (NAMP) designed explicitly to sustain the country's lucrative live-export markets. By contrast, New Zealand has maintained a hard-won BTV-free status, a valuable trade asset preserved through costly and stringent biosecurity and surveillance.

The northwest European BTV-8 epizootic of 2006–2008 demonstrates the speed at which economic losses can escalate when the virus establishes itself in a new region. The Netherlands recorded losses of EUR 157 million to EUR 164 million in 2007, while France incurred costs of approximately USD 1.4 billion in the same year (Ben Salem et al., 2024). The emergence of a new, highly pathogenic serotype like BTV-3 in 2023 immediately altered this economic calculus. It not only inflicted severe direct losses, such as high sheep mortality and significant drops in milk yield in cattle, but also triggered immediate trade repercussions, including China's 2024 suspension of animal products from 14 EU member states.

The costs of living with BTV are therefore structural and recurrent. Control programs represent a major, ongoing financial commitment, as illustrated by Austria and Switzerland spending a combined total of over EUR 40 million on surveillance and vaccination between 2007 and 2016 (Pinior, B. et al., 2018). Timely diagnosis can yield a significant return on investment; the Pirbright Institute estimates that its early confirmation of BTV in the UK in 2007 saved the national economy approximately GBP 485 million by preventing a wider disaster. Nevertheless, with the European Food Safety Authority (EFSA) concluding that BTV eradication is exceptionally difficult and would require at least five years of intensive, high-coverage vaccination, these costs represent a new, long-term baseline for the agricultural sector in affected regions (EFSA, 2017).

Vaccination remains fundamental to bluetongue control. Even though live attenuated vaccines offer strong protection, worries about them becoming harmful again or mixing genes lead many OECD countries to choose inactivated vaccines instead. Because immunity is serotype-specific, veterinary authorities must adapt rapidly when novel serotypes emerge. Reflecting this necessity, the European Medicines Agency recommended emergency BTV-3 vaccines for approval in January 2025. Vector management represents a complementary measure rather than a standalone solution. Field evidence for insecticidal efficacy is limited, and chemical control alone does not reliably reduce transmission. Consequently, most programs integrate vaccination with movement zoning that is informed by real-time entomological data. Using different types of monitoring, like health checks and insect studies, helps with early warnings and setting movement limits, but keeping these movement restrictions for a long time can be very costly. England's decision to extend the BTV-3 restricted zone to encompass the entire country from July 2025, coupled with reliance on mass vaccination, illustrates a pragmatic policy shift from containment to mitigation.

1.54 Data Availability and Gaps in the GMS

Bluetongue stands out as one of the most data-poor diseases in the GMS region. Official WAHIS database listings treat most GMS provinces of China as free of BT, and there are no routine national-level notifications from Cambodia, Lao PDR, Thailand, Viet Nam, or Myanmar during 2020–2025. However, subnational studies in southern China, including Yunnan, consistently report high seroprevalence in small-ruminant herds and active Culicoides vector populations, indicating likely endemic circulation at least along the Mekong border areas. These signals suggest that BT has been circulating quietly in parts of the GMS while escaping formal notification, so in this report the BT section relies on the best currently available subnational evidence rather than assuming true disease absence.

1.55 People's Republic of China

Although recent outbreak data for China is not detailed in the World Animal Health Information System (WAHIS), a significant body of scientific research confirms that BTV remains a persistent and complex challenge within the country. The virus has been a known entity since its first isolation in Yunnan Province in 1979 and is classified as a Category A disease of concern, posing a serious economic threat to China's substantial ruminant industries (Zhong et al., 2024).

The epidemiological landscape of BTV in China is defined by a distinct geographical divide. Analysis of data spanning from 2010 to 2020 reveals a "south-high, north-low" prevalence pattern, with southern provinces, such as Yunnan and Guangdong, consistently identified as hotspots with high rates of seropositivity in both cattle and sheep. This empirical data is reinforced by predictive risk modeling, which identifies southern, central, and eastern China as durable high-risk zones for future outbreaks. Critically, this heightened risk is attributed to a significant geographical overlap between climates suitable for the virus itself and habitats suitable for its Culicoides insect vector. The situation is further complicated by the considerable genetic diversity of the virus within China, where at least 16 different BTV serotypes have been isolated, making national-level control and vaccination strategies exceptionally challenging.

Therefore, based on the available scientific literature, the fundamental drivers of the disease (a suitable climate, the presence of vectors, a large population of susceptible host animals, and a wide variety of viral serotypes) are all firmly established in China. These factors combine to ensure that Bluetongue remains a significant and ongoing animal health issue requiring robust domestic surveillance and targeted control strategies, particularly in the country's high-risk southern and central regions (Zhong et al., 2024; Yang et al., 2022).

1.56 Cambodia

The 1995 symposium proceedings characterize Cambodia as a significant gap in the regional epidemiological map of the BTV. At the time, as no formal reports or surveillance data were available through international channels, Cambodia was among several Southeast Asian nations whose official bluetongue status was unknown (Hawkes, 1996).

Despite the absence of specific surveillance data, expert analysis within the proceedings suggested it was probable that bluetongue viruses circulated subclinically within Cambodia's animal populations (Gard, 1996). These mid-1990s proceedings still represent the latest country-specific evidence available for this assessment. It assessment was based on the broader understanding of BTV as an endemic disease throughout most tropical regions. Given Cambodia's geographical location and climate, conditions were considered suitable for sustaining both the virus and its

Culicoides vectors, making the presence of the virus highly likely even without direct in-country confirmation.

1.57 Lao PDR

The historical record on BTV in Lao PDR, as captured in the 1995 ACIAR proceedings, is notably complex. While several expert assessments at the time characterized the country's official BTV status as unknown due to a lack of detailed surveillance data, it was also widely hypothesized that the virus probably circulated subclinically, consistent with its endemicity in the broader tropical region (Gard, 1996; Alexander et al., 1996). Compounding this picture, another report within the same volume indicated that Laos had, by 1993, already formally reported the presence of the disease or group-specific antibodies to the OIE, the World Organisation for Animal Health (Hawkes, 1996). This suggests that even by the early 1990s, the virus was officially recognized as being present in the country.

While the more recent 2018 study on other zoonotic diseases in Laotian goats does not present new data on BTV, it provides a critical, modern-day footnote to this history (Burns et al., 2018). The paper's bibliography explicitly references a 2016 seroprevalence study that specifically investigated Bluetongue in selected Lao provinces. The existence of this modern scientific inquiry confirms that BTV has remained a subject of veterinary surveillance in the country well beyond the initial historical reports. The 2016 seroprevalence work referenced above is also the most recent BTV-specific investigation we were able to trace, highlighting the lack of routine national reporting in the past decade.

Therefore, synthesizing the available information from these specific documents leads to a clear conclusion. The historical record confirms that BTV was officially recognized in Lao PDR by the early 1990s, and modern academic literature indicates that scientific surveillance for the virus has continued into the last decade. Although detailed, contemporary outbreak statistics are not available in the provided literature, the evidence affirms that BTV is a recognized and persistent animal health issue in Laos, rather than an unknown or absent pathogen.

1.58 Thailand

Thailand now has clear evidence of entrenched BTV circulation in small-ruminant systems, especially goats. A 2025 sero-epidemiological survey of 583 goats on 56 farms in central and western Thailand found an individual seroprevalence of 74.4% and a herd-level seroprevalence of 94.6% (Homat et al., 2025). Infection odds were higher in the western region, on farms located near other ruminant holdings, and in older goats, while goats in more intensive systems had lower odds of infection (Homat et al., 2025). Conventional RT-PCR used in the study showed high diagnostic performance, and seven BTV serotypes (2, 3, 4, 7, 12, 16 and 21) were detected. BTV-2, 12 and 21 were most common, and BTV-4 was reported for the first time in Southeast Asia, which is more consistent with long-standing, multi-serotype circulation than with one-off incursions.

These findings, together with existing Culicoides surveillance showing BTV-positive midge species in Thailand, place much of central and western Thailand towards the "endemic with seasonal flare-ups" end of the spectrum. In practical terms, risk is likely to cluster along trading and border corridors where goat movements and vector activity overlap. Because routine outbreak notifications are still limited, BTV programme design should start from these baselines: periodic ELISA serosurveys in goats, seasonal vector trapping with infection testing, and diagnostic planning that can type at least the seven serotypes already detected. This keeps surveillance proportional to demonstrated risk, supports trade-related risk assessment, and avoids over-promising rapid elimination.

1.59 Vietnam

The historical record on Bluetongue virus (BTV) in Vietnam, as captured in the 1995 ACIAR proceedings, is defined by a notable divergence between official reporting and expert scientific assessment. According to official data submitted to the OIE (World Organisation for Animal Health) at the time, Vietnam had never reported the presence of bluetongue disease or positive serology (Hawkes, 1996).

However, multiple expert analyses within the same proceedings characterized Vietnam's true epidemiological status as "unknown" (Gard, 1996; Alexander et al., 1996). The prevailing scientific hypothesis was that BTV likely circulated subclinically within Vietnam's ruminant populations. This view was based on the virus's known endemicity throughout the broader Southeast Asian tropical region, which provides a suitable climate and habitat for its *Culicoides* vectors (Gard, 1996).

Therefore, the available literature from the period positions Vietnam not as a confirmed BTV-free country, but as a nation where the risk of endemic viral activity was considered high, even in the absence of specific surveillance data or clinical outbreaks. The active participation of delegates from Vietnam's national veterinary institutes in the 1995 symposium further underscores that the disease was a recognized issue of national concern at the time (St. George & Peng, 1996). Country-level BTV analyses for Viet Nam, these mid-1990s assessments still effectively define the current evidence base and underline the scale of the data gap.

1.60 Recommendations for GMS Policy Makers

For policymakers in the GMS, the available data on BTV presents not a uniform crisis but a complex tapestry of varied risks and information gaps. The nature of BTV (a multi-serotype, vector-borne virus with often subclinical reservoir hosts) means that a "one-size-fits-all" policy approach is unviable. The key policy challenge for the GMS as a whole is managing a shared, persistent threat where each member country faces a fundamentally different stage of the problem, from foundational data gathering to managing a complex, high-diversity viral landscape.

For China, particularly its GMS province of Yunnan, the policy implication is one of regional responsibility. The confirmation of high viral diversity and entrenched endemicity positions this area as a potential "source nursery" for BTV serotypes that could directly threaten downstream GMS neighbors. Chinese domestic policy on surveillance and biosecurity in its southern regions, therefore, has direct, unavoidable consequences for the entire subregion's animal health security.

The Thai policy perspective is necessarily one of managing the paradox of latent risk. The country faces the difficult task of justifying sustained, costly investment in surveillance and biosecurity for a disease that, while confirmed to be present with at least 12 serotypes, is not currently causing widespread clinical outbreaks. For policymakers, the challenge is maintaining vigilance and preparedness against a silent threat that could destabilize its advanced and valuable livestock economy with little warning.

For Cambodia, Lao PDR, and Vietnam, the challenge is more foundational, centered on overcoming strategic uncertainty. Historical data suggests the probable presence of the virus, but without a clear, modern baseline of which serotypes are circulating and where, the actual scale of the domestic threat remains unquantified. For policymakers in these nations, this information gap is a primary obstacle. It impedes their ability to conduct accurate economic risk assessments, prioritize veterinary resources, and confidently negotiate science-based regional protocols for livestock trade and health.

Taken together, these patterns define a clear BTV data-gap matrix across the GMS: up-to-date incidence and serotype data are missing for Cambodia, Lao PDR, and Viet Nam; high-resolution economic impact estimates are limited even in better-studied systems such as China and Thailand; and cross-border surveillance along shared trade and vector corridors remains fragmentary.

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