nature reviews biodiversity
https://doi.org/10.1038/s44358-026-00198-2

Roadmap

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Pathways to recover Asian wild pigs from African swine fever

Eva Johanna Rode-White[1,2], Ulfah Mardhiah[3], Selly Surya[3], Noviar Andayani[3], Corinne Bailey[4], Jörg Beckmann[2,5,6], Elizabeth L. Bennett[7], Sandra Blome[2,8], Simon Bruslund[9], Kathy Lene S. Cielo[10], Parag Jyoti Deka[2,11,12], Ahmad Faisal[2,3], Jens-Ove Heckel[13,14], Agus Sudibyo Jati[2], Ferran Jori[2,15,16,17], Emilia Lastica-Ternura[2,18,19], Barney Long[20], Matthew Scott Luskin[2,21], Matthias Markolf[1,2,22], Erik Meijaard[2,23,24], Ronny Putra Mokoginta[25], Hendra Dwi Purnama[25], Dini Rahmanita[25], D. Mark Rayan[26], Mikko Angelo Reyes[27], Ente Rood[28], Gono Semiadi[2,29], Andrew Tilker[18,30], Chris Walzer[7,31], Matthew Ward[2,32,33] & Matthew Linkie[2,7] ✉

Abstract

Emerging infectious diseases are an increasingly important driver of biodiversity loss. African swine fever (ASF) exemplifies this threat. Since 2018, this highly virulent virus has spread rapidly across Asia, causing near-total mortality in immunologically naive suid populations. In this Roadmap, we discuss the distribution, epidemiology and conservation impacts of ASF across Asia's 12 endemic wild pig species and formulate a plan for coordinated action to address this urgent conservation threat. Confirmed infections currently affect at least four species, with two additional species suspected to be susceptible following mass mortality events. Driven by these documented population collapses and by applying the precautionary principle, 2025 International Union for Conservation of Nature (IUCN) Red List reassessments uplisted multiple taxa, including babirusas and warty pigs, making Asian endemic suids one of the region's most threatened vertebrate groups. Addressing this multidimensional biodiversity and food security crisis requires a One Health response. Priority interventions include expanded surveillance, strengthened in situ protection, risk reduction at wildlife–livestock interfaces, strategic ex situ safeguarding, an emergency ASF fund and investment in vaccine research. These interconnected measures provide a framework to prevent ASF-driven extinctions and enable species recovery.

Sections

A full list of affiliations appears at the end of the paper. ✉e-mail: mlinkie@wcs.org

Key points

- Since late 2018, African swine fever (ASF) has caused near-total mortality in Asia's immunologically naive wild pig populations, a globally unique centre of suid diversity, with confirmed or suspected infections in at least six endemic species. For several island endemics, ASF is now a plausible driver of extinction within a single generation.
- Population collapses have already triggered severe uplistings for five species in the 2025 IUCN Red List reassessments, placing Asia's endemic suids among the region's most threatened vertebrate groups.
- We present a coordinated Roadmap of eight actions spanning in situ, ex situ and enabling domains, identifying three (early-warning surveillance, ex situ safeguarding and dedicated emergency financing) as an immediate, non-deferrable core given uneven institutional capacity across range states.
- In situ interventions must urgently prioritize rapid carcass detection, expanded epidemiological surveillance including citizen science and targeted risk reduction at high-risk wildlife–livestock interfaces.
- Ex situ programmes are a vital safeguard, but current capacity has yet to match the scale of the emerging threat: of 12 threatened Asian endemic suids, 5 are supported by established captive breeding programmes, and some are maintained on very small founder bases. As this option closes permanently once numbers fall below minimum viable thresholds, expanding strategic, biosecure, cooperative breeding and in-country assurance populations is an urgent priority.
- Coordinated implementation requires sustained investment over the next 5 years, several orders of magnitude smaller than the US $130–192 billion Asia's domestic pig industry has already lost to ASF since 2018, against costs of extinction that are ecologically, culturally and economically irreversible.

Introduction

Emerging infectious diseases are increasingly interacting with anthropogenic environmental change to amplify extinction risk across taxa[1,2]. Among these threats, African swine fever (ASF) is a highly lethal and contagious viral disease that poses an acute and underappreciated risk to non-African wild pigs. Originating in Africa, ASF has spread into Europe in two waves since the mid-twentieth century and was detected in northern China in 2018[3] before spreading rapidly to 20 countries across the Asia-Pacific region between 2018 and 2020[4,5].

African swine fever virus (ASFV) persists in African wild suids without causing clinical disease, in part owing to 1.8 million years of coevolutionary history with the pathogen (Box 1). However, extinction risk peaks when novel pathogens invade immunologically naive populations. In Europe, the introduction of ASFV triggered a major and sustained epidemic in Eurasian wild boar (*Sus scrofa*)[6–11]. In Asia, fatal disease has been documented in multiple endemic wild pig species, with some populations declining by more than 80% within months of virus emergence and at least one local population extirpated[11,12], confirming that Asia's endemic wild pigs are broadly susceptible to ASFV.

Beyond the immediate demographic collapse of suid populations, ASF has triggered cascading disruptions across food webs and human systems. Ecologically, the loss of wild pigs (important ecosystem engineers, seed dispersers and primary prey) has reduced food availability for threatened tiger populations, across the range from Sumatra to the Russian Far East[13]. Economically, the death and culling of hundreds of millions of domestic pigs across Asia since 2018 caused estimated losses of US $130–192 billion during the initial years alone[14,15]. Socially, for many Indigenous people and local communities (IPLCs) and other forest-dependent communities, wild pigs are central to food security, cultural practices, and local economies. The 2021 collapse of Sunda bearded pig (*Sus barbatus*) populations in Indonesian Borneo exemplifies this disruption, forcing dietary shifts towards smaller wildlife, such as squirrels and tree shrews[11,16]. ASF can therefore reduce food security and livelihood opportunities while exacerbating biodiversity loss, highlighting the need for conservation and disease-management strategies that recognize local priorities and participation. Despite these profound livelihood and food-system shocks, the long-term, landscape-scale ramifications of ASF remain poorly quantified[17].

Although ASF represents the most acute and immediate threat to Asia's endemic wild pigs, it operates within a broader system of interacting pressures. Unsustainable hunting and persecution, habitat loss, climate-related disturbance and the structural vulnerabilities of small, fragmented populations can amplify disease impacts and constrain recovery. Within this threat landscape, ASF exposes fundamental challenges in wildlife disease management. The virus spreads rapidly across heterogeneous landscapes and is difficult to contain once established in wild populations. Effective management therefore requires not only strengthened capacity for surveillance, but also upstream prevention measures that reduce the risk of introduction and spillover at source[18]. Despite growing recognition of these needs, the capacity to detect, monitor, prevent and respond to wildlife outbreaks remains limited[19,20]. Furthermore, wildlife conservation remains insufficiently integrated into ASF prevention, preparedness and response frameworks[21,22].

The designation of ASF as a conservation, livelihood and food-system emergency in Asia has garnered substantial international support[23,24]. The 2025 IUCN Resolution "Urgent Action to Address the Asian Wild Pig Crisis Caused by African Swine Fever" passed with overwhelming consensus (greater than 90% of votes cast). This mandate acknowledges ASF as an immediate extinction threat to Asia's endemic species and calls for integrated interventions encompassing in situ and ex situ conservation, enhanced disease surveillance, community engagement, field research and policy reform. Yet, no coordinated, science-based framework currently exists to operationalize this resolution.

To address this gap, we critically evaluate the regional distribution and multidimensional impacts of ASF, highlight core evidence gaps, and develop a Roadmap to guide priority short-term actions that halt population collapses and prevent extinctions, alongside medium-term strategies to foster in situ recovery. The interventions we recommend consider primary threats, transmission pathways, cross-cutting pressures and underlying vulnerability factors affecting the region's endemic wild pig species (Fig. 1). This Roadmap provides the scientific foundation for a comprehensive, emergency action plan to implement across the five range states that are home to Asia's endemic wild pigs.

Status of ASF in Asian wild pig species

Although evidence of ASF exposure is patchy and uneven across species and islands (Supplementary Table 1), ASF infection has been confirmed in wild populations of four species (the Sunda bearded pig, Philippine warty pig *Sus philippensis*, Sulawesi warty pig *Sus celebensis*

Box 1 | Asia's epidemiological setting differs from Africa and Europe

The epidemiological settings and transmission modes of African swine fever virus (ASFV) differ substantially across Africa, Europe and Asia and are likely to result in different consequences for wild suids.

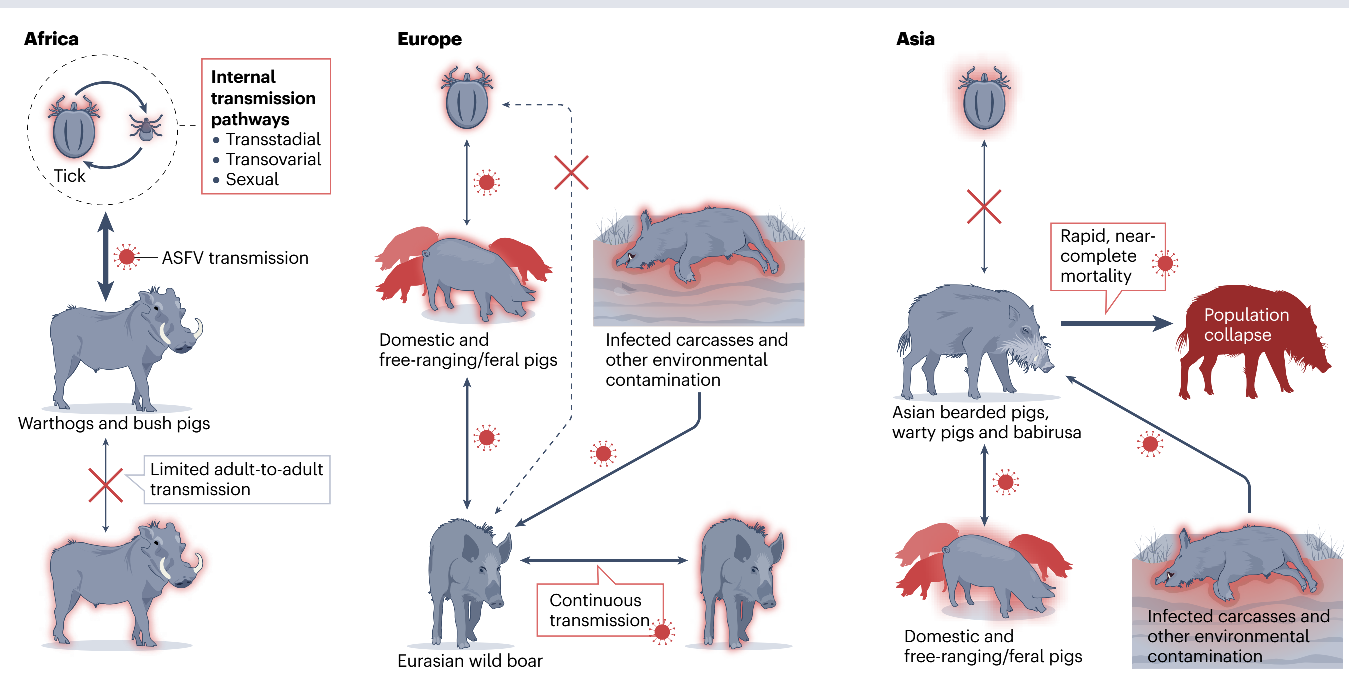
In Africa, ASFV can persist through a sylvatic cycle involving warthogs and *Ornithodoros* spp. soft ticks, but direct pig-to-pig transmission among adults is negligible[7] (see the figure). African wild suids, such as warthogs (*Phacochoerus* spp.) and bushpigs (*Potamochoerus* spp.), tolerate ASFV infection without developing clinical disease[75,76]. The repeated occurrence of fatal disease in endemic Asian pig lineages provides little evidence that similar tolerance will occur in these species.

At a global scale, transmission from Africa to other regions resulted from the human-mediated movement of infected pigs and pork products[11,28]. Following introduction, transmission can be sustained through contacts among wild pigs, between wild and domestic pigs, and through contaminated carcasses, products, vehicles, equipment and other fomites. These pathways are particularly important where smallholder production systems, free-ranging pigs and limited biosecurity create frequent connections between domestic and wild populations[17,26,27].

In Europe, outbreaks occur in wild boar following interactions with domestic pigs, feral pigs and domestic pig–wild boar hybrids. Large, high-density wild boar populations and the persistence of infectious carcasses in the environment then sustain transmission chains independently of domestic pig status, leading to self-sustaining endemicity. This endemic maintenance is unlikely to occur in Asia because the endemic pigs' population sizes and densities are generally very low, and transmission chains are expected to terminate rather than persist, often following severe mortality and local population collapse[3]. Consequently, these threatened species are more likely to experience local extirpation than function as long-term maintenance hosts for ASFV. However, the potential emergence of attenuated, non-lethal viral variants means that active virus circulation could remain undetected in cryptic or range-restricted island species[77].

In both Europe and Asia, environmental persistence is an important, ongoing source of transmission. ASFV remains highly stable in infectious carcasses. ASFV survival outside the host varies substantially with temperature, moisture, pH, substrate and the presence of organic material. Although viral DNA might persist in contaminated soil, evidence that soil consistently retains infectious virus is more limited and context dependent. For this reason, detection and safe removal of carcasses is a critical element of ASFV control.

Soft ticks are central to established sylvatic transmission cycles only in parts of Africa and have not been shown to contribute materially to ASFV transmission among wild pigs in Southeast Asia. Some *Ornithodoros* species occur in parts of Asia, including the arid-zone tick *O. savignyi* in South Asia, but their presence alone does not demonstrate competence to acquire, maintain and transmit ASFV. At present, there is no evidence that a tick-mediated cycle contributes to ASFV maintenance in Southeast Asian wild pig populations[78].



and Sulawesi babirusa *Babyrousa celebensis*), in captive Visayan warty pigs (*Sus cebifrons*), and is strongly suspected in wild Visayan pigs and Mindoro warty pigs (*Sus oliveri*). No detections have been reported from the remaining six endemic species (Javan warty pig *Sus verrucosus*, Bawean warty pig *Sus blouchi*, hairy babirusa *Babyrousa babyrussa*, Togian babirusa *Babyrousa togeanensis*, Palawan bearded pig *Sus ahoenobarbus* and pygmy hog *Porcula salvania*), although this lack of detection probably reflects limited surveillance rather than absence of infection. This section discusses the key patterns of spatial spread and aspects of different species' biology that could predispose them to ASF-related declines.

Spatial spread and mortality events across regions

Rather than advancing as a single epidemic front, ASF has spread through successive geographic and island invasions, initially affecting domestic pigs before spilling over into wild suid populations (Box 1). The chronology of spread spans Sumatra (2019), the Philippines (2019), Borneo (2020–2021), Peninsular Malaysia (2021) and Sulawesi (2023). Here, we review the evidence chronologically before discussing the islands that currently remain free of the virus.

In Sundaland, ASF was first confirmed in domestic pigs in Sumatra in September 2019, followed by wild boar in December 2019. The first confirmed infection in a Sunda bearded pig occurred in Malaysian Borneo in December 2020, followed by Sumatra in 2021[25] and Peninsular Malaysia in September 2022. Across the region, the virus spread rapidly from coastal centres into forest interiors, causing widespread mortality and localized extirpations of Sunda bearded pig[17,26,27]. Camera-trap surveys illustrate the speed of decline: at Pasoh Forest Reserve, wild boar abundance fell by 87% within 4 months of ASF detection[11], while in the Endau-Rompin landscape the relative abundance of wild boar and Sunda bearded pigs declined by 99% and 81%, respectively, between 2021 and 2023[12]. As the Sunda bearded pig is a migratory species whose movements routinely cross political boundaries, these declines are unlikely to be confined to monitored sites. Encouragingly, piglets reappeared in Endau-Rompin in 2024[12], and localized population increases were reported from parts of Borneo during 2024–2025[28,29]. However, populations in many locations remain lower than 10% of pre-ASF baseline levels (Supplementary Table 1).

In the Philippines, ASF was confirmed in the Philippine warty pig in January 2021[30] and has since been reported from all 14 administrative regions, with 141 confirmed and 134 suspected deaths and the extirpation of at least one local population (Supplementary Table 1). The species was subsequently uplisted to Critically Endangered on the Philippine Red List in 2025. Infection was confirmed in captive Visayan warty pigs in June 2023[31] and spillover into wild populations is strongly suspected. On Mindoro, ASF has been confirmed in domestic pigs since October 2023[32], whereas reports from field teams, local communities and the media indicate marked declines in the endemic Mindoro warty pig. Although laboratory confirmation is lacking, the cumulative evidence strongly suggests spillover into wild populations.

In Sulawesi, infection was confirmed in the Sulawesi warty pig in August 2023 and the Sulawesi babirusa in October 2023. As the *Babyrousa* genus is evolutionarily distinct from the *Sus* genus, conservation scientists had hoped that this evolutionary divergence might confer some degree of immunity or resistance to ASF. However, outbreaks have now been reported from all six provinces, with 37 confirmed and

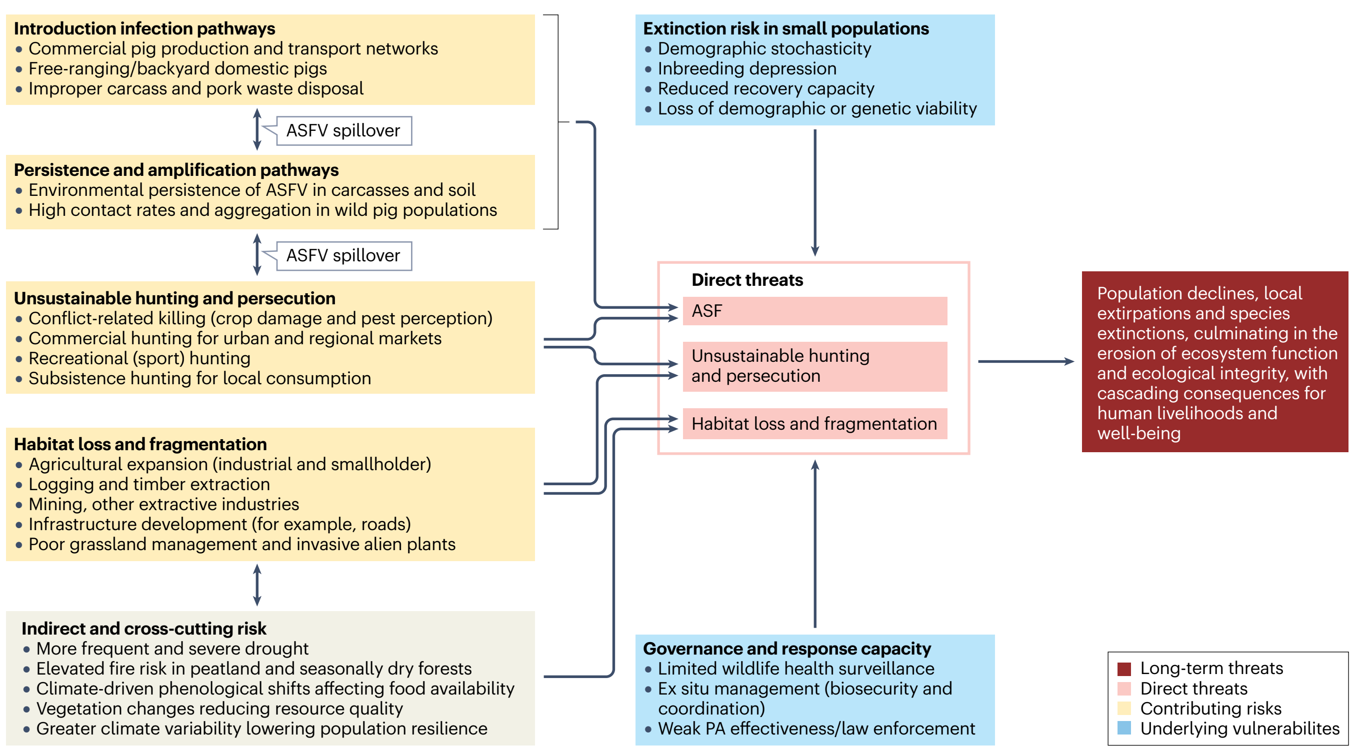


Fig. 1 | Interacting drivers of decline in Asia's endemic wild pig species. A set of contributing risks, pathways for African swine fever (ASF) virus (ASFV) introduction and persistence, drivers of unsustainable hunting and persecution, drivers of habitat loss, and indirect climate-linked pressures such as drought and fire, combine to produce three primary direct threats: ASFV transmission at wildlife–livestock interfaces; unsustainable hunting and persecution; and habitat loss, degradation and fragmentation driven by agricultural expansion and infrastructure development. The magnitude of these threats impact on populations is mediated by two underlying vulnerabilities: intrinsic extinction risk in small populations (demographic stochasticity, inbreeding depression and reduced recovery capacity) and governance and response capacity (surveillance, biosecurity, enforcement and cross-sector coordination). Together these interacting processes increase mortality and reduce recruitment and connectivity, driving the long-term consequences of population decline, local extirpation and species extinction, with cascading effects on ecosystem integrity and human livelihoods. PA, protected area.

34 suspected deaths in the Sulawesi warty pig and six confirmed and four suspected deaths in the Sulawesi babirusa (Supplementary Table 1). As both species are endemic to a single island and were uplisted during the 2025 IUCN Red List reassessment (Sulawesi warty pig uplisted from Near Threatened to Endangered; Sulawesi babirusa uplisted from Vulnerable to Critically Endangered), Sulawesi has become the epicentre of ASF-driven extinction risk, with the nearby island-endemic hairy babirusa and Togian babirusa uplisted to Critically Endangered, as a precautionary measure.

Four other endemic taxa remain free of confirmed ASF infection. Notably, Palawan remains ASF free despite infection on nearby islands. This exclusion resulted from stringent border controls, restrictions on pork imports and rapid containment of incursions. Similarly, the Javan warty pig and Bawean warty pig remain free of confirmed infection. However, ASF is established in domestic pigs across three of Java's four provinces, leaving the Javan warty pig highly exposed. By contrast, Bawean Island has no domestic pig industry and is predominantly Muslim, substantially reducing the likelihood of ASF introduction and spillover to the Bawean warty pig. Finally, the pygmy hog in India remains unaffected despite ASF occurring in sympatric wild boar, although this apparent persistence should be interpreted as reflecting limited exposure and effective biosecurity so far, rather than inherent resistance.

Taken together, these accounts show that the conservation outlook for Asia's endemic suids is defined as much by where ASF has yet to arrive as by where it has already become established. Whether populations behind these remaining barriers can be protected, and those already affected can recover, depends on species-specific demography, which we consider next.

Species-specific recovery and extinction risk

The long-term conservation impact of these ASF-driven crashes is inextricably linked to species-specific recovery potential. In areas that experienced severe declines during 2021–2023, local monitoring indicates positive population trends for the Sunda bearded pig in 2024–2025 in Borneo, with more modest increases in Sumatra and Peninsular Malaysia[28]. The Sunda bearded pig is adapted to mast-fruiting-driven boom-and-bust cycles and exhibits a comparatively high reproductive output (producing 2–12 offspring), facilitating rapid population growth after perturbations[33,34].

In stark contrast, the three babirusa species (hairy, Togian and Sulawesi) possess slow life histories, typically producing one to two offspring (occasionally three), which severely constrains population-level recovery from die offs[35,36]. Reflecting this vulnerability, the dire 2025 IUCN Red List uplistings underscore the catastrophic extinction risk now facing these taxa. Whether recent, localized population increases observed in Sunda bearded pigs can be sustained or replicated in slower-reproducing taxa and more severely affected regions remains uncertain.

Surveillance challenges and knowledge gaps

Population status, mortality rates and long-term viability are poorly quantified for most endemic pig species, particularly in remote forests lacking systematic monitoring[25]. The current evidence base relies on a patchwork of confirmed infections, suspected ASF-linked mortality events and population declines inferred heavily from community reports. For instance, suspected die offs of the Critically Endangered Visayan warty pig are reported across Negros and Panay, and unconfirmed carcasses suggest severe impacts on the Mindoro warty pig (Supplementary Table 1). However, laboratory-confirmed cases in these wild populations are absent. This lack of confirmatory diagnostics, often because carcasses are disposed of before sampling, highlights a fundamental challenge in wildlife disease detection.

Beyond logistical constraints, passive surveillance is limited by social and institutional barriers. In many endemic regions, hunters and local communities have limited incentives to report sick or dead animals, particularly where reporting is associated with fears of regulatory penalties, movement restrictions, or trade and livelihood impacts. These factors contribute to systematic under-reporting, meaning that current distributions based on confirmed detections and reported mortality events probably underestimate the true extent of ASFV circulation and impacts on wild pig populations[37].

Critical knowledge gaps persist regarding: (1) baseline exposure, as several taxa (the Javan warty pig, Togian babirusa, hairy babirusa and Mindoro warty pig) currently have no confirmed detections, or reside on islands presumed ASF free (the Bawean warty pig and Palawan bearded pig); (2) age-specific survival and mortality in wild populations; (3) species-specific susceptibility and recovery potential; and (4) the role of wild pigs in landscape-scale ASF maintenance. Furthermore, epidemiological uncertainties surrounding domestic and backyard pig production further obscure understanding of spillover dynamics and wild population exposure (Box 1). In turn, these limitations constrain precise demographic estimates and underscore the urgent need for strengthened, field-based disease surveillance to improve future assessments.

Despite these data gaps, spatial overlap between documented ASF outbreaks and endemic wild pig ranges indicates that exposure is probably widespread across the region (Fig. 2). Even where population-level impacts remain unquantified, this geographic coincidence indicates that multiple taxa currently inhabit landscapes where ASF is circulating in domestic and/or wild pig populations. Furthermore, epidemiological uncertainties surrounding domestic and backyard pig production obscure understanding of spillover dynamics and wild population exposure (Box 1). Domestic pigs (*S. scrofa*, the same species as wild boar) are likely to represent the principal source of exposure for most endemic suids, whereas sympatric wild boar might contribute to transmission in a subset of species (including the Sunda bearded pig, Javan warty pig and pygmy hog) and landscapes. In turn, these limitations constrain precise demographic estimates and underscore the urgent need for strengthened, field-based surveillance to improve future assessments.

A Roadmap for ASF management and policy

We outline a Roadmap (Fig. 3) consisting of eight actions supporting two overarching goals: preventing ASF-driven extinctions (short-term goal) and enabling species recovery (medium-term goal) through coordinated in situ and ex situ measures. No single intervention can eliminate ASF, but a coordinated portfolio can reduce transmission and spillover to levels compatible with species persistence, operationalizing the commitments established by the 2025 IUCN Resolution. As safe and effective ASF vaccines for free-ranging wildlife populations remain unavailable (Box 2), immediate management must rely on surveillance-led, non-pharmaceutical interventions. Underpinning all eight actions, the emergency fund (Action 8) provides the financial mechanism required to deliver the remaining interventions at scale, and is therefore treated as a cross-cutting prerequisite throughout this framework. Effective implementation will require coordinated action across conservation, veterinary, agricultural, and research sectors (Fig. 3b).

Action 1: update Red List and Green List assessments

Seven of the 12 endemic Asian wild pig species were last assessed for the IUCN Red List in 2015–2016, pre-dating the regional emergence of ASF. Consequently, these listings fail to capture recent ASF-driven mortality, population collapses and escalating extinction risks. The profound impact of the virus is evident in the 2025 reassessments[38–41], which uplisted all three babirusa species (Sulawesi, Togian and hairy) to Critically Endangered, and the Sulawesi warty pig from Near Threatened to Endangered. A coordinated reassessment of all remaining species is urgently needed to align global extinction risk categories with contemporary disease pressures and justify emergency international interventions.

Crucially, global updates must align with and inform national-level assessments. As demonstrated by the Philippine warty pig's recent uplisting to Critically Endangered on the national Red List of the Philippines[42], national classifications are indispensable. In many range states across mainland Southeast Asia (such as Vietnam), national red data books and wildlife decrees carry far more legal weight than global IUCN guidelines[43,44]. Updating these legislative frameworks is essential to mobilize state funding, enforce strict biosecurity and penalize poaching. Prioritizing these national evaluations for highly threatened species is a critical bottleneck that must be resolved.

In parallel, IUCN Green Status of Species assessments are vital for framing recovery potential alongside extinction risk. Although the pygmy hog's historical decline to Critically Depleted status was driven by habitat loss rather than ASF, its ongoing recovery through sustained protection, habitat restoration and reintroductions[45] is precisely the type of conservation success now jeopardized by the virus's spread[46] (Box 3). By clarifying conservation dependence and realistic recovery trajectories, Green Status metrics can effectively benchmark what stands to be lost to ASF, informing the prioritization of in situ protection, disease mitigation and ex situ safeguarding.

Action 2: strengthen in situ conservation of wild pig species

In situ conservation is indispensable to prevent the extinction of highly threatened wild pigs. Restricted-range island endemics in the Philippines and Indonesia are particularly vulnerable to the compounding

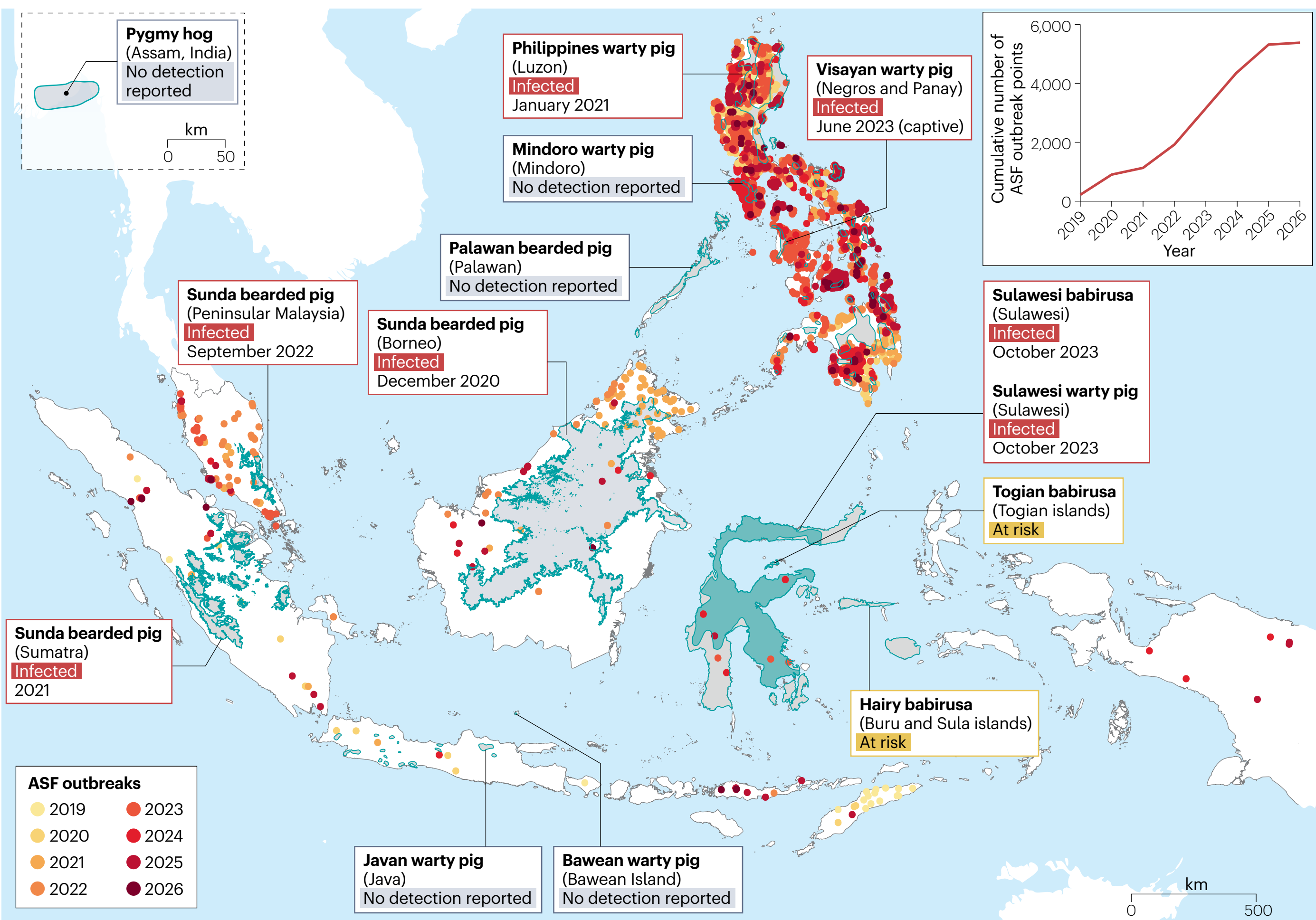
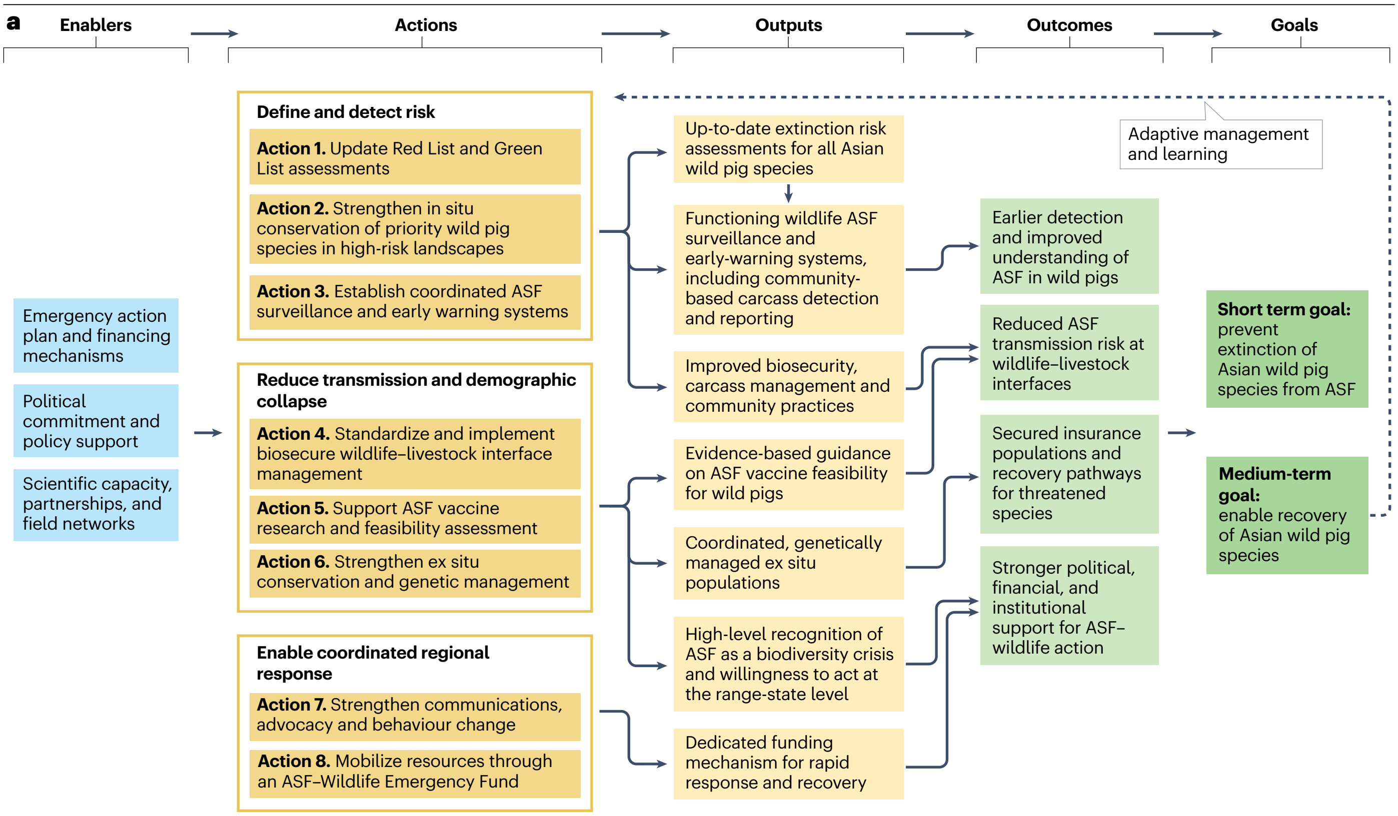


Fig. 2 | Spatial overlap of African swine fever and endemic wild pig distributions in Southeast Asia. Geographic ranges (with boundaries shown in teal) of 12 endemic wild pig species overlaid with officially reported African swine fever (ASF) cases in domestic and wild pigs since 2019 (ASF outbreak data from FAO (Food and Agriculture Organization) EMPRES-i[73], 2007–2025, and World Animal Health Information System (WAHIS)[74], 2017–2025). The inset shows the cumulative number of ASF outbreaks over time.

Roadmap

a



b

Action	Lead institutions	Supporting partners
1	IUCN SSC Wild Pig Specialist Group, national Red List authorities	Government wildlife agencies, NGOs, researchers, zoos
2	PA agencies, national and/or subnational wildlife authorities	NGOs, IPLCs, law enforcement, agribusinesses
3	National veterinary and wildlife authorities	PA agencies (including rangers), NGOs, IPLCs, research institutions, diagnostic laboratories, technology companies
4	Veterinary authorities, agriculture and environment ministries	Smallholder farmers, local government, conservation NGOs, PA managers
5	Research institutions, veterinary authorities	Universities, vaccine developers, zoos
6	Conservation breeding institutions and programmes, zoos	Veterinary and wildlife agencies, Species360, IUCN SSC, researchers
7	Wildlife and environment agencies, agriculture and veterinary extension services, conservation NGOs	IPLCs, customary, village and religious leaders, communication experts, media
8	Range state governments, conservation NGOs	Multilateral donors, philanthropic organizations, private sector (agribusinesses, commercial pork industry)

Fig. 3 | Roadmap of eight key actions, pathways and goals for averting African swine fever-driven extinction risk in Asian wild pig species. a, Enablers – policy support, scientific capacity and field partnerships, and emergency financing – underpin eight actions, grouped into three clusters: defining and detecting risk (Actions 1–3), reducing transmission and demographic collapse (Actions 4–6) and enabling coordinated regional response (Actions 7–8). These drive outputs and four outcomes: earlier African swine fever (ASF) detection, reduced transmission risk at wildlife–livestock interfaces, secured insurance and recovery pathways for threatened species, and stronger political, financial and institutional support. Outcomes converge on a short-term goal of preventing extinction and a medium-term goal of enabling species recovery. The dashed feedback arrow reflects the Roadmap's adaptive management basis, whereby progress towards these goals informs ongoing refinement of actions. **b**, Principal actors responsible for implementing the ASF Roadmap. IPLCs, Indigenous peoples and local communities; IUCN SSC, International Union for Conservation of Nature Species Survival Commission; NGO, non-governmental organization; PA, protected area.

threats of overexploitation, habitat loss and disease. Range-wide, unsustainable hunting remains the principal threat, requiring mitigation through strengthened law enforcement, ranger patrols and enhanced habitat protection. In ASF-vulnerable landscapes, preventing spillover from domestic pig populations requires strict biosecurity measures, movement controls and strengthened surveillance. Rapid carcass detection and safe disposal are also critical to reducing environmental transmission and limiting further spread.

Box 2 | Scientific progress and conservation constraints for ASFV vaccines

Advances in African swine fever (ASF) vaccine development over 2022–2025, particularly the first gene-deleted live-attenuated vaccines to receive regulatory approval for commercial use, represent a major scientific achievement and offer a pathway to control ASF in domestic pigs under strict, high-biosecurity conditions[79]. Several candidates have demonstrated strong protective efficacy against virulent genotype II ASF virus (ASFV) in experimental and limited field settings[61]. Moreover, multiple live-attenuated strains have been assessed for oral immunization of domestic pigs and Eurasian wild boar, with accompanying bait studies optimizing delivery, indicating overall suitability and supporting proof-of-concept for oral vaccine delivery, although practical application in free-ranging wildlife remains unproven[80].

However, a growing body of evidence highlights important limitations and risks, particularly with respect to safety, including residual virulence, impacts on reproductive performance, virus persistence, shedding and uncertainties regarding long-term genetic stability[81–83]. Consequently, although these vaccines offer promising features, their application in wildlife, free-ranging pigs or at landscape scale in Asia raises substantial safety and ecological concerns. Their use should therefore be guided by context-specific benefit–risk assessments that account for local epidemiological, ecological and management conditions[84].

These constraints delineate a limited but strategically relevant opportunity. If restricted to well-controlled settings and informed by rigorous benefit–risk assessment, live-attenuated ASF vaccines could provide one of the few immediately available disease-management tools to support ex situ assurance colonies and conservation breeding programmes for threatened wild pig species. Such applications could be particularly relevant within range countries, as well as in coordinated international zoological programmes maintaining genetically important populations[85]. For Critically Endangered island endemics such as the Sulawesi babirusa, carefully managed vaccination within conservation breeding programmes could help to preserve irreplaceable genetic diversity while reducing the immediate risk of extinction.

Although developing an effective ASF vaccine is critical, vaccines inherently do not confer protection across generations, necessitating sustained and logistically challenging delivery in the wild, as observed in interventions for plague in black-footed ferrets and amphibian chytridiomycosis[86,87]. A longer-term perspective lies in understanding the basis of resilience to ASFV, including its genetic and host–pathogen determinants. Understanding the basis of resilience or disease tolerance to ASFV, particularly in warthogs, have yielded insights into potential mechanisms of disease tolerance, although their functional basis and transferability remain uncertain[88,89]. Such knowledge could inform the design of improved vaccines and, more speculatively, the exploration of heritable resistance strategies for threatened Asian suids. Although technically challenging and uncertain, this line of research warrants continued investment in foundational studies[90] and should be pursued in parallel with, rather than as a substitute for, immediate non-pharmaceutical interventions.

Where ASF is present or emerging, management must prioritize rapid carcass detection and safe disposal given the virus's high stability in carcasses and its role in sustaining environmental transmission. Given the logistical challenges of monitoring vast tropical forests, community engagement in carcass detection, supported by modest financial incentives, is probably key to cost-effective coverage[47]. In tandem, local observations of sudden declines in pig activity should immediately trigger targeted official searches. Disposal methods require strict oversight: discarding carcasses in rivers facilitates downstream viral spread and must be avoided in favour of safe on-site burial, where feasible. Rapid carcass management could yield disproportionately high disease-control benefits in tropical systems, although this hypothesis requires empirical testing. Faster decomposition under tropical conditions is likely to shorten the period during which carcasses remain infectious compared with temperate regions, thereby reducing opportunities for ASFV transmission. This risk period could be further minimized through the rapid detection and safe disposal of carcasses.

ASF-driven population collapses have prompted temporary hunting bans in parts of Borneo[27] and similar adaptive moratoria are urgently recommended in other severely affected regions, such as the Philippines, until populations stabilize. During extreme declines, short-term livelihood support can prevent displacing hunting pressure onto other threatened wildlife[16]. Such support could include temporary employment in community-based conservation activities, food-security assistance for affected households or alternative income-generating opportunities during periods of hunting restrictions.

Action 3: establish coordinated ASF surveillance and early-warning systems

Coordinated surveillance of wild pig mortality is resource intensive and efforts must, therefore, be strategically concentrated in high-risk areas at the wildlife–domestic pig interface[48]. Currently, the impacts of ASF on Asian wild pigs remain severely under-represented in conventional animal health reporting and surveillance frameworks. Rapid carcass decomposition in tropical forests, limited wildlife diagnostic capacity and delayed outbreak recognition often mean infections are only identified after a substantial population declines have already occurred. These constraints highlight the need for integrated surveillance systems that combine conventional diagnostic sampling with complementary non-invasive approaches, including environmental DNA and extra-organismal DNA sources such as faeces and hair. Encouragingly, participatory, risk-based surveillance at livestock–wildlife interfaces in Lao PDR, Vietnam and Cambodia has successfully detected ASF in free-ranging wild boar, demonstrating that wildlife can be effectively integrated into national response strategies[49].

Effective surveillance must operate across scales. National veterinary and wildlife authorities should establish centralized reporting systems that integrate wildlife mortality with domestic pig surveillance. At landscape scales, protected area staff, local governments and IPLCs should undertake structured carcass searches, passive reporting and rapid field investigations, with suspected cases reported through national ASF surveillance systems for confirmation and response. Community-based surveillance should form a core component of early-warning systems, particularly in remote landscapes where local knowledge can substantially improve the timely detection and reporting of unusual mortality events. Experiences from Belgium and Sweden demonstrate that surveillance, coupled with rapid response measures including carcass removal and movement controls, can progressively reduce and even eradicate ASF circulation[50,51]. Detection dogs can further improve carcass detection in difficult terrain[52].

Implementation should follow a phased approach. Initial priorities include integrating wildlife into existing national ASF surveillance systems, training protected area staff and community partners, and establishing surveillance in high-risk landscapes. As capacity develops, programmes can incorporate non-invasive diagnostics and broader landscape-scale monitoring. Building on existing veterinary services, protected area networks and community monitoring programmes will also be substantially more cost-effective than establishing dedicated surveillance systems.

In tropical forest landscapes, integrating ranger patrols, camera trapping, community reporting, non-invasive sampling and rapid field diagnostics provides a practical pathway for the early detection of ASF in Asian wild pig populations, enabling timely management responses[53]. Commercial lateral-flow tests can provide field confirmation of ASFV in wild pig carcasses within 10–15 min[54] and have already been used in Sulawesi to support rapid management decisions, including carcass disposal and local biosecurity measures, ahead of laboratory PCR confirmation[55]. In parallel, non-invasive approaches, including faecal sampling, extra-organismal DNA and environmental DNA, offer considerable potential for landscape-scale surveillance of cryptic populations, despite important biological limitations. The effectiveness of these approaches is constrained by patchy and variable ASFV shedding into the environment, but they could nevertheless complement early detection efforts when integrated with other surveillance methods[56]. Further validation of these methods, together with collaboration with conservation technology developers such as Conservation X Labs, could substantially improve point-of-care diagnostics and early outbreak detection across the ranges of Asia's endemic wild pigs[57].

Action 4: standardize biosecure wildlife–livestock interface management

Mitigating transmission at wildlife–livestock interfaces is critical to prevent repeated ASF spillover. Across much of Asia, smallholder and free-ranging pig production systems facilitate direct and indirect contact between domestic and wild pigs, driving viral persistence and reinfection cycles[49]. Although the epidemiological landscape in Europe differs substantially from Asia, successful European approaches to controlling ASF in wild boar populations provide valuable frameworks that can be adapted to local Asian contexts[58,59]. Consequently, range states must adopt standardized, context-appropriate biosecurity protocols for high-risk interface zones.

Key interventions include biosecure carcass disposal, controlled access to forest-edge production systems, targeted fencing or other physical barriers, routine disinfection, restrictions on live-pig transport, and the strict regulation of swill feeding and the informal pork trade[22,30]. Carcass disposal here refers to two distinct practices: biosecure disposal (such as deep burial or incineration) of domestic pigs that die during outbreaks, replacing current practices (informal burial or open dumping near production sites); and systematic search-and-removal of wild pig carcasses to reduce environmental persistence of the virus, following European wild boar protocols[58,59]. Regulating the movement of people between domestic pig-producing communities and high-risk interface zones further reduces the risk of human-mediated (fomite) transmission[4].

Where physical barriers are used, they should be targeted to high-risk interface zones rather than deployed as large-scale landscape barriers and designed to minimize habitat fragmentation and unintended impacts on other wildlife. To ensure local compliance, these measures must be adapted to rural production realities and supported by targeted technical and financial assistance.

Interface management should be prioritized around the core habitats of highly threatened endemic species and aligned with early-warning surveillance alerts (Action 3). By reducing spillover risk in these targeted landscapes, standardized biosecurity provides an immediately deployable safeguard for vulnerable wild pig populations while longer-term tools, such as wildlife-safe vaccines, are developed and scaled.

Action 5: support ASF vaccine research and feasibility assessment

Continued investment in ASF vaccine research is essential, alongside careful evaluation of the feasibility, risks and ethical considerations of deploying vaccines in wild pig populations, both in situ and ex situ (Box 2). Although no such vaccines are currently available, early assessment of delivery mechanisms, safety and population-level effectiveness is needed to determine whether vaccination could reduce mortality in highly threatened species or safeguard assurance populations.

Box 3 | Downgrading from Critically Endangered: the recovery of the pygmy hog

The monotypic genus pygmy hog stands out as an example of successful recovery due to the existence of a dedicated conservation breeding and reintroduction programme. Formerly listed as Critically Endangered on the International Union for Conservation of Nature (IUCN) Red List until its downlisting to Endangered in 2019, the species' recovery reflects sustained, long-term intervention. Established in 1995 through collaboration between the Durrell Wildlife Conservation Trust and the IUCN SSC Wild Pig Specialist Group and the Assam Forest Department, the Government of India Pygmy Hog Conservation Programme began with founders captured from the wild in 1996[91]. Later, the non-governmental organizations Ecosystems-India and Aaranyak joined as delivery partners and, since then, the programme has expanded this founder population. It presently maintains some 80 individuals in captivity for conservation breeding and research, and as of 2025, has released 179 captive-bred pygmy hogs into protected grassland habitats[92] and has established a population from reintroduction[93]. The programme currently maintains a demographically well-structured captive population across two breeding facilities and continues to produce offspring under strict conservation breeding protocols designed to preserve genetic diversity. Stringent biosecurity measures, originally established before the emergence of ASF to protect the population from other disease threats, were subsequently strengthened to reduce the risk of ASF introduction. The two facilities are managed as separate epidemiological units, with fenced perimeters, controlled personnel access and quarantine procedures, to safeguard this insurance population[46].

Table 1 | Summary of ex situ facilities with established breeding programmes for the Asian wild pig species in 2026

Species	Ex situ individuals (by sex)			Number of facilities holding species (% by region)			Individuals per facility			Facilities with breeding (past 12 months)	Sex ratio in facilities	
	Female (F)	Male (M)	Unsexed	Asia	Europe	North America	Average	Min	Max		Number of facilities with F and M	Average ratio F:M
Sunda bearded pig (*Sus barbatus*)	8	11	0	1 (100%)	0	0	19.0	19	19	0	1 (100%)	1.4:1
Javan warty pig (*Sus verrucosus*)	56	57	16	7 (100%)	0	0	18.4	2	51	2 (30.0%)	7 (100%)	1.0:1
Sulawesi babirusa (*Babyrousa celebensis*)	49	71	0	1 (3.0%)	13 (39.4%)	19 (57.6%)	3.5	1	8	9 (27.3%)	25 (75.8%)	1.4:1
Hairy babirusa (*Babyrousa babyrussa*)	29	29	0	4 (100%)	0	0	14.5	10	18	0	4 (100%)	1.0:1
Bawean warty pig (*Sus blouchi*)	1	2	0	1 (100%)	0	0	3.0	3	3	1 (100%)	1 (100%)	2.0:1
Visayan warty pig (*Sus cebifrons*)	127	155	22	3 (5.4%)	42 (75.0%)	11 (19.6%)	5.4	1	73	6 (10.7%)	34 (60.7%)	1.2:1
Pygmy hog (*Porcula salvania*)	39	57	0	3 (100%)	0	0	32.0	1	51	2 (66.7%)	2 (66.7%)	1.5:1

Breeding records reflect data from reporting institutions only; range-country facilities that breed without submitting records to regional studbooks are probably under-represented. Data source: Species360 Zoological Information Management System database (https://species360.org/zims/; downloaded on 24 January 2026).

The government-led development of ASF vaccines for domestic pigs in Vietnam in 2023 represents an important scientific milestone[60]. However, vaccine deployment remains limited, and the safety, efficacy and feasibility of applying these approaches to free-ranging wild pig conservation remain unverified. Approvals and emergency use of ASF vaccines in domestic pigs, including the Indonesian approval of the AVAC ASF live vaccine in 2025, highlight rapid advances in livestock vaccination but do not yet address the substantially different challenges of immunizing free-ranging wildlife populations[61]. Embedding conservation-focused research questions into ongoing vaccine trials is therefore critical. These questions include whether vaccines are safe and immunogenic in threatened wild pig species, whether practical delivery strategies are feasible for free-ranging populations, the duration of protection, and whether vaccination can reduce mortality sufficiently to support long-term population persistence and recovery.

Action 6: strengthen ex situ conservation and genetic management

Ex situ conservation breeding is an essential conservation tool and must be rapidly expanded and strategically coordinated as a credible emergency safeguard for all threatened endemic wild pigs. Immediate support must prioritize the Bawean warty pig, Mindoro warty pig and Palawan bearded pig, species facing extreme vulnerability owing to their highly restricted island ranges and imminent ASF incursion risk, alongside the three babirusa species, all now Critically Endangered, where active national and global management planning is underway but critical genetic questions about population structure and admixture remain unresolved and must inform future breeding decisions. Scaling to other species should follow as resources permit, as has already begun for the Mindoro warty pig.

Among the 88 global facilities holding a reported 729 living individuals across seven species, there is a substantial deficit in population viability (defined as maintaining ≥95% of extant genetic diversity over 100 years, a standard benchmark used in studbooks and long-term management plans) (Table 1 and Supplementary Fig. 1). Breeding success is concentrated in a minority of facilities (22.7%) maintaining larger, mixed-sex groups, whereas most facilities (56.8%) hold small groups (fewer than four individuals); although for some taxa this reflects species-appropriate husbandry rather than inadequate capacity.

We acknowledge several constraints driving these data: not all individuals are reproductively viable[62], and ex situ breeding is strictly guided by conservation breeding programmes (such as the European Association of Zoos and Aquaria Ex-situ Programme and the Association of Zoos and Aquariums Species Survival Plan) that define target population sizes through regional collection plans, regional species plans and long-term management plans developed collaboratively with species committees, population biologists and in situ experts. Historically, studbooks have restricted breeding to prevent steep population increases that facilities lack the space and logistics to accommodate. Maintaining small intentionally non-breeding populations, a standard tool within studbook management to control population size and preserve genetic representation, is nevertheless insufficient in the context of the ASF emergency, where the priority must shift to actively building assurance population numbers. Compounding these demographic challenges is the ever-present threat of ASF infiltrating captive facilities. The critical need for stringent biosecurity was starkly illustrated in June 2023, when an ASF outbreak at the Kabankalan breeding centre in the Philippines led to the death of 16 Visayan warty pigs (100% of the population)[63].

To transform ex situ holdings into viable assurance populations, two priorities must be addressed. First, cooperative breeding must be expanded. Regional zoo associations coordinate conservation breeding through their appropriate taxon advisory groups, regional collection plans and long-term management plans, frameworks that have already produced strong formal programmes for the Sulawesi babirusa, Visayan warty pig and pygmy hog, with a programme for the Javan warty pig currently under development. Existing programmes should be reviewed in light of ASF risk, and new programmes established for taxa currently lacking formal coordination. The principal bottleneck is not institutional willingness but capacity: wild pigs are frequently deprioritized as exhibit species, and European institutions face additional constraints under ASF-related biosecurity regulations. Expanding participation will require targeted outreach, standardized husbandry guidelines, and biosecurity protocols to attract new holding institutions and increase space allocations. Range-country facilities holding pigs outside formal reporting structures represent an important, untapped resource that strategic coordination could mobilize towards conservation goals. Sustaining long-term captive viability also requires regular production of surplus animals; where management euthanasia is legally or culturally restricted, breeding capacity is constrained. Broader acceptance of managed culling among conservation stakeholders is therefore essential.

Second, metapopulation management and enhanced data sharing are required. Zoos already share detailed animal and programme data through platforms such as Species360, providing a robust foundation for coordinated demographic management. The priority now is extending equivalent frameworks to in situ populations, integrating field and captive data on population structure, age composition and reproductive status, to support a formal IUCN One Plan Approach and unify all conservation efforts into a single, cohesive strategy[64,65].

Action 7: strengthen communications, advocacy and behaviour change

Clear messaging is urgently needed to reposition ASF as a multidimensional biodiversity and food security crisis, rather than solely a livestock disease. Strategic advocacy targeting governments, multilateral agencies and donors is required to elevate political priority and mobilize sustained, cross-sectoral investment across conservation, veterinary services and rural development. Furthermore, promoting direct exchanges between ASF management teams in Asia and Europe offers high potential to translate past successful experiences into actionable, cross-regional strategies.

At the community level, social and behaviour change communication must be embedded within mitigation strategies to reduce transmission at wildlife–livestock interfaces. As established in Action 4, low-biosecurity and free-ranging pig systems heavily amplify spillover risk. However, these biosecurity gaps are rarely driven by knowledge deficits alone. Financial constraints, limited access to infrastructure (such as fencing or disinfectants), fear of culling and income loss, and entrenched husbandry norms within informal value chains severely limit the adoption of safer practices. Context-specific diagnostic research is therefore required to identify and navigate these locally salient barriers.

Communication strategies should be co-designed with IPLCs to ensure they are culturally appropriate, build trust and recognize local knowledge, livelihoods and food security needs[66]. These strategies must also recognize that motivations and barriers to engagement vary among communities. In parts of Southeast Asia, many Christian communities rely heavily on wild pigs for food security and cultural practices, potentially complicating hunting restrictions and biosecurity measures, whereas religious sensitivities surrounding pigs might influence the prioritization of pig-related interventions in predominantly Muslim communities. Tailoring engagement approaches to these differing sociocultural contexts will be essential for sustained local participation and compliance.

Social and behaviour change communication frameworks grounded in behavioural theory and participatory risk communication have proven effective during infectious disease emergencies, such as Ebola and COVID-19 (refs. 66,67). Similar participatory approaches have also improved ASF biosecurity in resource-limited communities in Uganda, where co-created community contracts strengthened the adoption and implementation of locally feasible biosecurity measures[68,69]. Applied to ASF conservation, these approaches can strengthen community participation in surveillance and reporting, facilitate the co-design of feasible biosecurity adaptations, improve risk perception and build local implementation capacity. Integrating behavioural science into ASF response plans is therefore essential to sustain transmission reduction and protect vulnerable wild pig populations.

Action 8: mobilize resources through an ASF–Wildlife Emergency Fund

A dedicated ASF–Wildlife Emergency Fund must be established to enable rapid outbreak response, support ex situ safeguarding and finance applied field interventions. Current biodiversity and animal health funding mechanisms are frequently fragmented, slow to disburse or strictly siloed by sector, limiting their effectiveness during fast-moving disease events. An effective emergency fund must therefore provide flexible, rapidly deployable resources accessible to conservation agencies, veterinary authorities and research institutions, governed by clear activation triggers linked to surveillance alerts. Initial investments should prioritize surveillance and early-warning systems, rapid outbreak response (including carcass detection and safe disposal), targeted wildlife–livestock biosecurity measures and emergency ex situ safeguarding of the most threatened species.

Design principles should draw on existing rapid-response models, such as the Re:wild Rapid RESCUE Fund and IUCN Save Our Species Rapid Action Grants, prioritizing speed, accountability and cross-sectoral coordination[70,71]. Crucially, reaching the necessary scale of funding requires expanding beyond traditional conservation philanthropy. The commercial pork industry must be engaged as a primary financial partner; their contribution would serve as a strategic investment in safeguarding wild suids, which harbour invaluable genetic resources and resilient traits essential for the future security of domestic breeds. Ultimately, timely and predictable financing is critical to translate surveillance and early warning data into rapid management action and ensure that priority interventions are deployed before irreversible population declines occur.

Conclusion

Nearly a decade after its emergence in Asia, ASF has become a chronic, region-wide crisis, a plausible extinction driver for several island endemics within a single generation. Yet this trajectory is not inevitable. The scientific, technical and institutional tools required to prevent species loss exist. However, they must be deployed in a highly coordinated, time-bound manner. Although all eight actions are necessary components of a coherent regional response, not all can be implemented simultaneously in range states with varying institutional capacity and resources. Triage is therefore required.

Three actions – actions 3, 6 and 8 – constitute the immediate strategic core and should be treated as non-deferrable. Action 3 (surveillance and early warning) provides the situational intelligence on which all other interventions depend. However, surveillance systems must not rely solely on visible mortality events, as the emergence of gene-deleted or naturally attenuated ASFV variants could result in chronic, subclinical or less conspicuous infections that remain undetected in both domestic and wild pig populations[66,72]. Expanding surveillance approaches beyond carcass-based detection, including molecular and risk-based monitoring, will therefore be critical to identify cryptic transmission and prevent silent spread. Action 6 (ex situ safeguarding) has the narrowest time window, as the option to establish viable assurance populations closes permanently once captive numbers fall below minimum viable thresholds. Without Action 8 (the emergency fund) neither surveillance systems nor ex situ programmes can be scaled or sustained.

In parallel, Action 2 (in situ protection including rapid carcass management) and Action 4 (interface biosecurity) form an operational detect-and-respond package that should be initiated immediately in confirmed outbreak zones, particularly for the most restricted-range endemics in the Philippines and Sulawesi. The remaining actions (1, 5 and 7) are enabling and medium-term in character: essential to achieving durable recovery, but not dependent on resolution of the immediate emergency to begin.

Although no single intervention can eliminate ASF from Asia's wild pig populations, an integrated portfolio, combining strengthened in situ protection, surveillance-led rapid response, behaviour change at wildlife–livestock interfaces, strategic vaccine research and biosecure assurance populations, can reduce transmission and demographic collapse to levels compatible with species persistence and recovery. The critical challenge now is operational alignment across the conservation, veterinary and rural development sectors. The principal institutions responsible for leading and supporting each action are summarized in Fig. 3b, highlighting the cross-sectoral partnerships required to translate the Roadmap into implementation. Achieving this alignment will also require supportive national policy and regulatory frameworks that enable coordinated action, allocate institutional responsibilities, support sustainable financing, strengthen farm-level biosecurity requirements, and provide effective enforcement mechanisms against illegal wildlife and pork product movements.

Catalysing a coordinated regional response will require sustained, dedicated investment over the next 5 years. Although formal cost–benefit analyses remain to be developed, and we encourage their urgent commissioning, the comparative scale is instructive: the domestic pig industry across Asia has already sustained estimated losses of US $130–192 billion since 2018[14,15], against which the cost of preventing wild suid extinctions is likely to be several orders of magnitude smaller. More fundamentally, the costs of extinction, ecological, cultural and food security are not recoverable by any investment after the fact. The case for preventive action does not ultimately rest on a cost–effectiveness ratio; it rests on irreversibility.

Published online: 15 September 2026

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Acknowledgements
We are grateful to contributions from 'African Swine Fever in South-East Asia' Working Group, funded by the Science for Nature and People Partnership, and the International Union for Conservation of Nature Species Survival Commission Wild Pig Specialist Group.

Author contributions
All authors contributed to the literature research, data collection and analysis, and the formulation of the proposed conservation actions. Furthermore, all authors actively participated in discussing the content and extensively reviewed and edited the manuscript before submission.

Competing interests
The authors declare no competing interests.

Additional information
Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s44358-026-00198-2.

Peer review information *Nature Reviews Biodiversity* thanks John Humphreys, Serge Morand and Mary-Louise Penrith for their contribution to the peer review of this work.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

[1]Zoo Cologne, Cologne, Germany. [2]IUCN SSC Wild Pig Specialist Group, Gland, Switzerland. [3]Wildlife Conservation Society, Indonesia Program, Bogor, Indonesia. [4]Chester Zoo, Chester, UK. [5]Bremerhaven Zoo, Bremerhaven, Germany. [6]Nuremberg Zoo, Nuremberg, Germany. [7]Wildlife Conservation Society, New York, NY, USA. [8]Institute of Diagnostic Virology, Friedrich-Loeffler-Institut, Greifswald, Germany. [9]Copenhagen Zoo, Frederiksberg, Denmark. [10]Mindoro Biodiversity Conservation Foundation Inc, Calapan City, Philippines. [11]Durrell Wildlife Conservation Trust, Pygmy Hog Conservation Programme, Guwahati, India. [12]Aaranyak, Guwahati, India. [13]Zoological Society for the Conservation of Species and Populations, Landau in der Pfalz, Germany. [14]Zoo Landau in der Pfalz, Landau in der Pfalz, Germany. [15]CIRAD, UMR ASTRE, Montpellier, France. [16]ASTRE, Univ de Montpellier, CIRAD, INRAE, Montpellier, France. [17]Department of Zoology and Entomology, University of Pretoria, Pretoria, South Africa. [18]College of Veterinary Medicine, University of the Philippines Los Banos, Los Baños, Philippines. [19]Discipline of Veterinary Sciences, James Cook University, Townsville, Queensland, Australia. [20]Re:wild, Austin, TX, USA. [21]School of the Environment, University of Queensland, Brisbane, Queensland, Australia. [22]IUCN SSC Centre for Species Survival Cologne Zoo, Cologne, Germany. [23]Borneo Futures, Bandar Seri Begawan, Brunei Darussalam. [24]Durrell Institute of Conservation and Ecology, University of Kent, Canterbury, UK. [25]Bogani Nani Wartabone National Park, Kotamobagu, Indonesia. [26]Wildlife Conservation Society, Malaysia Program, Kuching, Malaysia. [27]Department of Environment and Natural Resources, Tamaraw Conservation Program, San Jose, Philippines. [28]KIT Royal Tropical Institute, Center for Applied Spatial Epidemiology, Amsterdam, The Netherlands. [29]Research Centre for Biosystematics & Evolution, National Research and Innovation Agency, Jakarta, Indonesia. [30]Leibniz Institute for Zoo and Wildlife Research, Berlin, Germany. [31]Research Institute of Wildlife Ecology, University of Veterinary Medicine, Vienna, Austria. [32]Talarak Foundation Inc., Bacolod City, Philippines. [33]Faculty of Tropical Agrisciences, Czech University of Life Sciences, Prague, Czech Republic.