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Megafauna in Laos: Historical losses, present status, and recovery prospects

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ABSTRACT

Laos has historically supported a rich megafauna assemblage, much of which has been lost in modern times. We compiled and analyzed historical and contemporary evidence (ca. 1850–2026) to reconstruct trajectories, assess current status, and identify recovery prospects for Laos's megafauna, focusing on rhinoceroses, tigers (*Panthera tigris*), and elephants (*Elephas maximus*). Javan (*Eurhinoceros sondaicus*) and Sumatran (*Dicerorhinus sumatrensis*) rhinoceroses occurred historically in Laos, with credible records continuing until approximately 1990, although the later records do not allow species-level attribution or determination of when each species disappeared. Both are now extirpated from the country. Tigers remained widespread into the early 2000s, but declined rapidly, with the last verified images from 2013; they are now considered extirpated, although limited potential for recovery may remain through recolonization or reintroduction. Asian elephants persist, but only an estimated 300–400 individuals remain across approximately 24 putative population units, 88% of which reportedly contain fewer than 20 individuals. Their demographics, connectivity, and long-term viability remain uncertain, although Nakai–Nam Theun and Nam Pouy are the two largest populations and likely have better persistence prospects than others. Reducing mortality and maintaining or restoring connectivity could improve prospects for smaller populations. Hunting for food and the wildlife trade—facilitated by widespread firearms, weak deterrence, and expanding infrastructure—have contributed to widespread faunal depletion and "empty forests." Accelerating development may increase access, trade, and demand for wildlife products, but could also create opportunities for coordinated transboundary protection and enforcement. Recovery remains possible for some of Laos's megafauna, but opportunities are rapidly narrowing.

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1. Introduction

Terrestrial megafauna—defined here as herbivores with adult body masses ≥ 500 kg and carnivores with adult body masses ≥ 15 kg (Moleón et al., 2020)—are globally imperiled, with many undergoing dramatic population declines and extensive range contractions (Ripple et al., 2016). These losses are driven primarily by anthropogenic pressures such as overexploitation, habitat conversion, and conflicts with people (Bergman et al., 2023; Bowyer et al., 2024; Greenspoon et al., 2023). Extinction risks rise sharply with body mass, reflecting a long-term, size-biased pattern of defaunation (Dirzo et al., 2014; Malhi et al., 2016). Because large-bodied animals often exert disproportionate effects on vegetation structure, seed dispersal, trophic interactions, and nutrient cycling, their loss can have cascading ecological consequences that smaller-bodied species may not fully compensate for (Malhi et al., 2016; Hyvärinen et al., 2021; Pringle et al., 2023).

Modern-era megafaunal loss has been particularly severe in Southeast Asia (Ripple et al., 2017). Asian elephants (*Elephas maximus*), Sumatran (*Dicerorhinus sumatrensis*) and Javan (*Eurhinoceros sondaicus*) rhinoceroses, tigers (*Panthera tigris*), and common leopards (*Panthera pardus*) have each lost more than 90% of their historical ranges (Mahmood et al., 2021). We follow Nardelli and Heißig (2025) in using *Eurhinoceros sondaicus* for the Javan rhinoceros, rather than the more commonly used *Rhinoceros sondaicus*. These declines extend beyond flagship species: gaur (*Bos gaurus*), banteng (*Bos javanicus*), wild water buffalo (*Bubalus arnee*), kouprey (*Bos sauveli*), and several other ungulates, as well as carnivores, have also declined sharply or disappeared from substantial parts of the region. These collapses are driven primarily by habitat conversion and unsustainable hunting, where agricultural expansion, logging, and infrastructure fragment populations, and overexploitation for bushmeat and the wildlife trade cause high mortality in large carnivores and herbivores alike (Gray et al., 2017; Struebig et al., 2025).

Laos (Lao People's Democratic Republic; Lao PDR) provides an instructive example of this regional pattern. The country retains a relatively high forest cover and has low human population density and GDP per capita compared with much of mainland Southeast Asia (World Bank, 2024a, b; Fig. 1), yet its large-vertebrate communities have been severely depleted (Harrison et al., 2016; Gray et al., 2017; WCS, 2024). High forest cover does not necessarily indicate intact habitat because hunting and snaring can create "empty forests"—forests that retain vegetation structure but have lost much of their large-vertebrate fauna and associated ecological functions (Redford, 1992; McConkey and Drake, 2006; Gray et al., 2017). Laos has experienced substantial megafaunal declines since the mid-nineteenth century, but the timing, spatial patterns, and drivers of these losses have not been consolidated into an integrated national synthesis. Reconstructing these trajectories is important for establishing appropriate historical baselines and placing conservation priorities in Laos within the wider regional context.

Here we compile and analyze historical and contemporary evidence to reconstruct the status and trajectories of Laos's terrestrial megafauna. Under our operational definition, megafauna known or presumed to persist in Laos include Asian elephants, gaur, banteng, Asiatic black bears (*Ursus thibetanus*), and sun bears (*Helarctos malayanus*). Rhinoceroses, tigers, kouprey, and wild water buffalo are extirpated or probably extirpated from the country, while the current status of common leopards (*Panthera pardus*) remains uncertain. We focus on rhinoceroses, tigers, and Asian elephants because they represent contrasting trajectories of historical extirpation, recent collapse, and persistence; other large mammals are considered more briefly to provide broader context. Specifically, we (i) compile, classify, and map historical rhinoceros records to reconstruct the timing and spatial patterns of nationwide extirpation and identify its likely drivers, (ii) synthesize site-level evidence to reconstruct tiger decline, characterize current national status, and identify conditions relevant to recovery, and (iii) consolidate available estimates of elephant abundance, spatial structure, and threats to characterize persistence prospects and identify key evidence gaps. We then compare these trajectories to identify shared drivers and conservation priorities within Laos and the wider region.

2. Laos in context: history, policy, and megafauna conservation

Following the fragmentation of the once-powerful Lan Xang Kingdom, the Lao territories were divided among the kingdoms of Luang Prabang, Vientiane, and Champasak. Throughout the nineteenth century, much of the landscape remained forested, supporting abundant wildlife, including large mammals (Stuart-Fox, 1997). Laos's modern history has strongly influenced its conservation landscape. French colonization (1893–1953) and the subsequent civil war and extensive U.S. bombing during the Indochina Conflict (1959–1975) disrupted governance and livelihoods and accelerated resource exploitation, particularly timber extraction (Stuart-Fox, 1995; Evans, 2002). After the establishment of the Lao PDR in 1975, state-led logging contributed to a sharp decline in forest cover, from ~70% in the 1940s to 41.5% by 2005 (Manivong and Sophathilath, 2007; MAF, 2024). War legacies, such as unexploded ordnance, continue to restrict access to conservation areas, raise fieldwork costs, and heighten risks for enforcement personnel (UNDP, 2009; Baird and Le Billon, 2012).

Since the late 1980s, policy reforms (Table S1) have aimed to reverse these trends. The 1989 National Forestry Conference marked a shift toward sustainable forest management (MAF, 2005), and a 1993 Prime Minister's Decree established 18 National Forest Reserves. This protected-area network was subsequently expanded to include 19 National Protected Areas (NPAs) and six National Parks (NPs), which together cover 17.3% of Laos (Kukkonen and Tammi, 2019; MAF, 2024). Forest cover has reportedly rebounded to ~62% by 2020 (MAF, 2024), with estimates of ~56.5% by 2025, positioning Laos as one of the most forested countries in Southeast Asia (FAO, 2025; Fig. 1).

However, effective conservation depends not only on forest cover but also on governance. Laos is culturally and linguistically diverse, with many communities maintaining customary wildlife use (Davis and Glikman, 2020; Johnson et al., 2003; Johnson et al., 2012). As infrastructure and economic development expand, increased access and connectivity can facilitate a shift from subsistence

hunting toward commercial offtake and wildlife trade, especially where enforcement is weak (Duckworth et al., 1999; Sunderland et al., 2012; World Bank, 2020). Consequently, many protected areas face pervasive snaring and prey depletion, emphasizing the need for stronger governance to complement forest conservation efforts. At the same time, increasing regional integration may create opportunities for stronger transboundary conservation and enforcement.

3. Methods

3.1. Study design and evidence identification

We conducted a structured synthesis of historical and contemporary evidence on the occurrence, distribution, abundance, threats, and management of the focal taxa in Laos. We considered records from approximately 1850–2026 because the mid-nineteenth century is the earliest period from which written sources relevant to wildlife occurrence in Laos were identified. We also included evidence from neighboring countries where it was directly relevant to transboundary populations, movements, connectivity, or recovery prospects in Laos.

Evidence identification relied primarily on iterative citation chaining from key publications, including backward searches of their reference lists and forward searches of subsequent papers citing them. Google Scholar searches were conducted on several occasions between April and December 2025, including targeted searches on 30th April, 28th May, 12th June, and 11th July 2025. Searches were performed iteratively throughout the synthesis process, using combinations of scientific and common species names, historical taxonomic names, "Laos," "Lao PDR," and relevant geographic and conservation terms. These searches were supplemented with IUCN Red List assessments, government and NGO archives, museum catalogues, historical accounts, and documents identified through the authors' knowledge of megafaunal research and conservation in Laos. Sources in Lao and Thai languages were considered where available. To describe changes in wildlife governance over time, we conducted targeted searches for key Lao laws, decrees, and national policies related to wildlife and forest management. Searches focused primarily on official Lao government repositories, including the National Assembly legal archive and the Ministry of Agriculture and Environment's online database. For each document, we recorded the year, responsible authority, type and number, subject, and main purpose, and arranged the information chronologically in Table S1. Where possible, claims reported in secondary sources were traced to their original source.

3.2. Eligibility, data extraction, and evidence appraisal

We included sources containing information on the focal taxa in Laos between approximately 1850 and 2026, together with transboundary records directly relevant to Lao populations or recovery prospects. Regional sources were also retained where they provided comparative context for interpreting trajectories in Laos. We excluded sources that merely repeated earlier claims without identifiable provenance and records that could not be associated with an approximate locality, period, or evidential basis, except when retained explicitly as anecdotal context.

For each source, we recorded its type, provenance, and geographic and temporal scope. For each relevant record or estimate, we extracted the taxon, locality, date or period, underlying evidential basis, and information on occurrence, abundance, mortality, threats, or management, as applicable. Evidence was appraised qualitatively according to its directness, provenance, diagnostic value, methodological transparency, spatial and temporal coverage, and degree of independent corroboration. Evidential strength was evaluated in relation to the claim being assessed rather than assigned solely according to publication type. Specimens, genetic evidence, and diagnostic photographs were considered strong evidence of occurrence, whereas systematic field surveys formed the principal basis for evaluating contemporary distribution, abundance, and trends. Government and NGO reports were retained where their methods or data origin could be evaluated. Peer-reviewed reviews and conservation assessments were used primarily for synthesis and regional context and were not treated as independent confirmation when they relied on previously reported evidence.

Personal observations were included only when based on direct observation by a named author and were reported with the approximate date where relevant. Interview-based and anecdotal accounts were used only as provisional or contextual evidence and were not treated as confirmation of species occurrence or population status without independent corroboration. The principal evidence categories, appraisal criteria, and uses in the synthesis are summarized in Table S2.

Because historical rhinoceros records were frequently taxonomically ambiguous, we classified them into three categories: (i) confirmed species records, based on specimens or other unequivocal diagnostic evidence; (ii) probable species records, supported by descriptions or illustrations consistent with one species but lacking material confirmation; and (iii) non-diagnostic rhinoceros records, referring to rhinoceros occurrence but lacking evidence sufficient to distinguish Javan from Sumatran rhinoceros.

3.3. Evidence synthesis, mapping, and treatment of uncertainty

We synthesized the records thematically to reconstruct temporal trajectories and produce distribution summaries and maps. Mapping was conducted in QGIS (WGS84). Historical place names (toponyms) were geocoded, and for uncertain localities, broader administrative boundaries were used. Records were grouped into three broad regions—northern, central, and southern Laos—following commonly used geographic divisions reflecting major administrative and biogeographic patterns. Northern Laos comprised Phongsaly, Luang Namtha, Oudomxay, Bokeo, Luang Prabang, Houaphanh, and Xayabouly provinces; central Laos comprised Vientiane Capital, Vientiane, Xiengkhouang, Bolikhamxay, Khammouane, and Savannakhet provinces; and southern Laos comprised Salavan, Sekong, Champasak, and Attapeu provinces. We acknowledge potential biases due to uneven survey effort,

conflict-related reporting gaps, and rumor inflation for high-value taxa, and interpret temporal trends accordingly. We therefore did not interpret an absence of records as evidence of absence unless supported by adequate survey effort. Similarly, dates of the last credible records were treated as minimum estimates of persistence rather than exact dates of local or nationwide extirpation.

4. Results

4.1. Historical occurrence and extirpation of rhinoceroses in Laos

4.1.1. Historical records

Both Javan and Sumatran rhinoceroses occurred historically in Laos, but their distributions and population trajectories are poorly documented (Duckworth et al., 1999). Our compilation comprises 34 records dating from 1861 to approximately 1990 and spanning 11 of Laos's 17 provinces (Table S3). Of these, one was a confirmed *D. sumatrensis* record from Nong Het, Xiengkhouang; one was a confirmed *E. sondaicus* record based on a specimen in the Siamese Museum from an unspecified locality in Laos; three were probable *E. sondaicus* records; and 29 were non-diagnostic rhinoceros records (Table S3).

Thirteen records were from northern Laos, six from central Laos, and 14 from southern Laos; the remaining confirmed Javan rhinoceros specimen was attributed to Laos but lacked a precise locality (Fig. 2). Northern records include a probable Javan rhinoceros record near Luang Prabang in 1861, the confirmed Sumatran rhinoceros specimen from Nong Het dating to approximately 1905–1910, and the latest credible indications of rhinoceros persistence in the country: a sighting in 1988 and tracks reported around 1990 near Ban Samnyot, Luang Namtha, close to the Chinese border. Historical sources also indicate Sumatran rhinoceroses persisted in adjacent Xishuangbanna (Yunnan, China) into the mid-twentieth century (e.g., He, 1994; Xu, 2000). Together, the Luang Prabang and Nong Het records indicate that both rhinoceros species occurred historically in northern Laos, although the available evidence does not establish spatial or temporal overlap.

In central Laos, records from Bolikhamxay and the Phou Khao Khouay area consist mainly of tracks and footprints reported between

Fig. 1. Comparison of Laos with selected Southeast Asian countries and Yunnan, China, across four indicators: forest cover, population density, biodiversity & habitat, and GDP per capita. Values are standardized as z-scores separately for each indicator; positive values indicate values above the mean across the compared territories, whereas negative values indicate values below the mean. Biodiversity & habitat data were unavailable for Yunnan, China. *Sources:* Block et al. (2024); FAO, (2025); Yunnan Provincial Forestry and Grassland Bureau, (2025); *and* World Bank, (2024a), b). Country abbreviations are: Laos (LAO), Yunnan, China (YUN), Malaysia (MAL), Indonesia (IND), Vietnam (VIE), Cambodia (CAM), Myanmar (MYA), Thailand (THA), and Philippines (PHI).

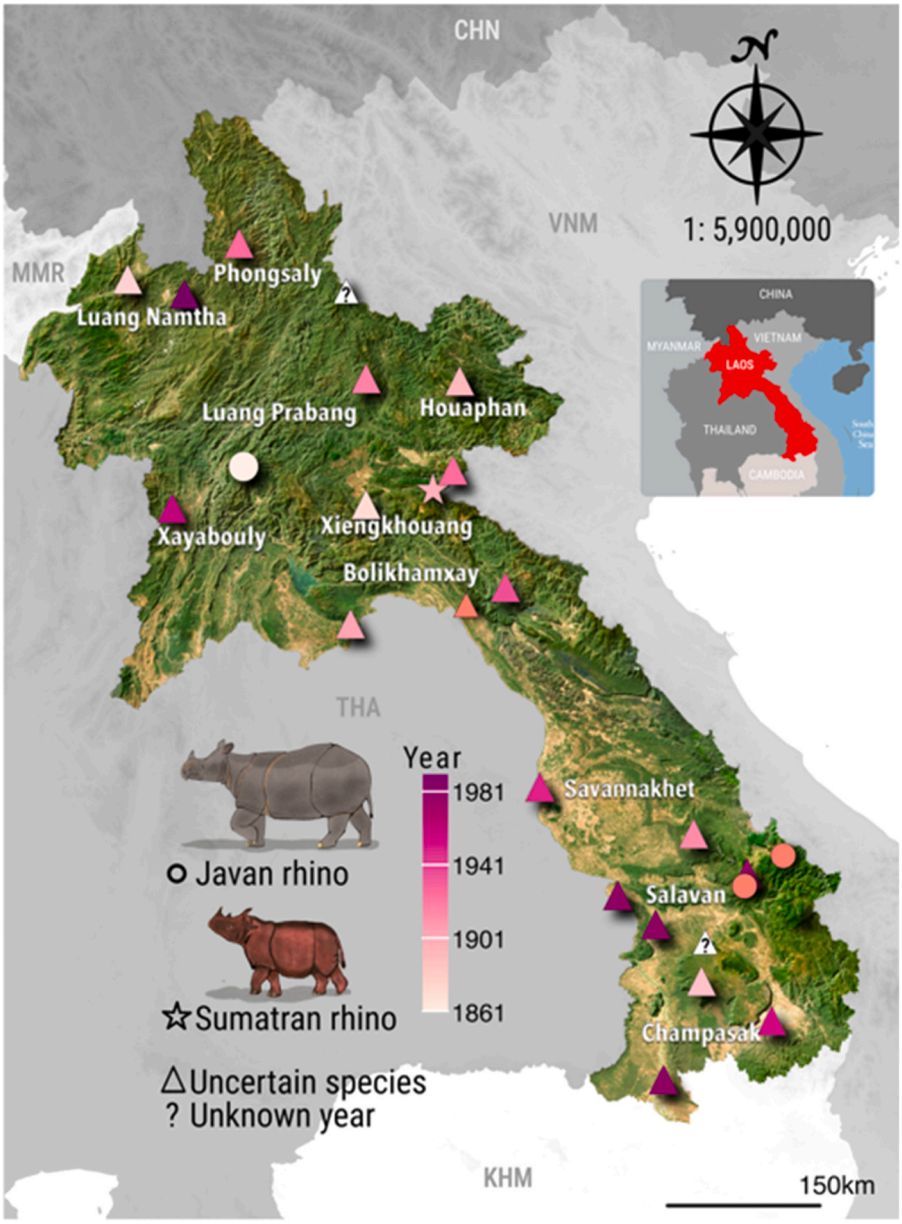

Fig. 2. Reported historical rhinoceros records in Laos from 1861 to approximately 1990. Uncertain species refers to records for which the available evidence was insufficient to distinguish Javan (*Eurhinoceros sondaicus*) from Sumatran rhinoceros (*Dicerorhinus sumatrensis*). Full details and sources for individual records are provided in Table S3. CHN = China, MMR = Myanmar, VNM = Viet Nam, THA = Thailand, KHM = Cambodia.

the 1920s and 1950s. These were attributed to rhinoceroses but did not permit species-level identification. In southern Laos, reports are concentrated between 1959 and 1974 and originate from Salavan, Champasak, Attapeu, and Savannakhet. They include reports of 'one-horned' rhinoceroses (indicative of *E. sondaicus*) in Salavan during 1959–1961 and several records from the Boloven Plateau in 1973–1974, including an account of two rhinoceroses encircled during an elephant round-up in June 1974 (Table S3). Although most southern reports are non-diagnostic, Neese (1975) and Rookmaaker (1988) considered them more likely to represent Javan rhinoceroses, consistent with the species' historical occurrence in neighboring Viet Nam and Cambodia; however, their species-level attribution remains uncertain.

The number of reported records was low before 1950, with no more than three per decade, increased to five to seven per decade during the 1950s–1970s, and subsequently declined to the final northern reports around 1990. Because survey effort, accessibility, and reporting intensity varied among periods, these frequencies should not be interpreted as direct measures of abundance. The available evidence indicates that rhinoceroses persisted in Laos until approximately 1990, after which no credible records are known.

4.1.2. Post-extirpation context

Despite the extirpation of rhinoceroses from Laos, the country has remained implicated in the regional illegal wildlife trade, including trade in rhinoceros products (Vigne, 2013). Rhino horn carvings, powders, and shavings have been documented in Vientiane and the Golden Triangle Special Economic Zone, including in high-end commercial venues. These products have generally been reported as originating from Africa or elsewhere in Asia and sometimes processed outside Laos before being imported (EIA, 2015; Vigne, 2013, 2021).

Occasional observations of items representing rhino horn—including a horn displayed in a Luang Prabang shop in 2013 (Vigne, 2013) and our more recent observations in Luang Prabang, Oudomxay, and Luang Namtha—indicate the continued circulation or possession of such items. Some were probably counterfeit, whereas others were retained by shop owners as good-luck amulets rather than offered for sale (D. Souvansai & A. Campos-Arceiz, pers. obs., 2024–2025).

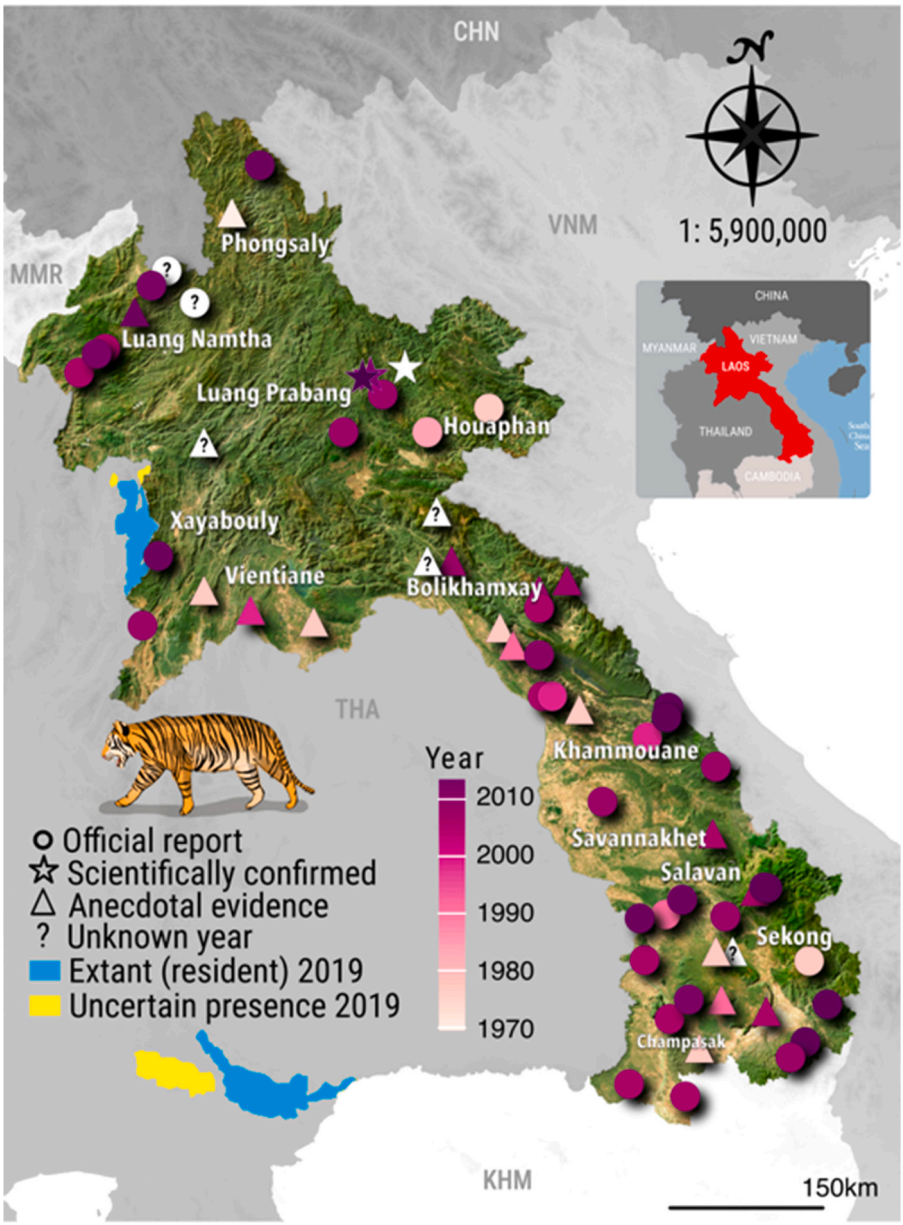

Fig. 3. Reported historical tiger records in Laos from 1970 onward, together with tiger-occupied landscapes in neighboring countries relevant to potential recovery. The last verified tiger record in Laos was obtained in Nam Et–Phou Louey in 2013. CHN = China, MMR = Myanmar, VNM = Viet Nam, THA = Thailand, KHM = Cambodia.

4.2. Tiger decline and last confirmed records

In Laos, tigers were once widespread (Fig. 3; Table S4; Salter, 1993). In the early 2000s, Nam Et–Phou Louey National Park (NEPL) was considered an important regional stronghold. Camera trapping in 2003–2004 produced an estimated density of 0.7 individuals/100 km² across a 952 km² sampling area using capture–recapture models, while genetic analyses of scats identified at least 16 distinct individuals (Johnson et al., 2006; Vongkhamheng, 2011). Subsequent monitoring indicated a steep decline in tiger abundance between 2005 and 2012, apparently associated with increasing snaring despite intensified law-enforcement efforts (Johnson et al., 2016). This study in Nam Et–Phou Louey National Park remains the only rigorous site-level assessment for Laos; elsewhere, evidence was largely anecdotal or interview-based (Department of Forestry, 2010; Duckworth and Hedges, 1998).

Tiger killings were reported from several protected areas during the mid-2000s, including Nam Ha, Nam Kan, Phou Daen Din, Xe Bang Nouan, Xe Sap, and Nam Pouy. Records from NEPL documented at least 17 tigers reportedly poached between 2003 and 2009, a

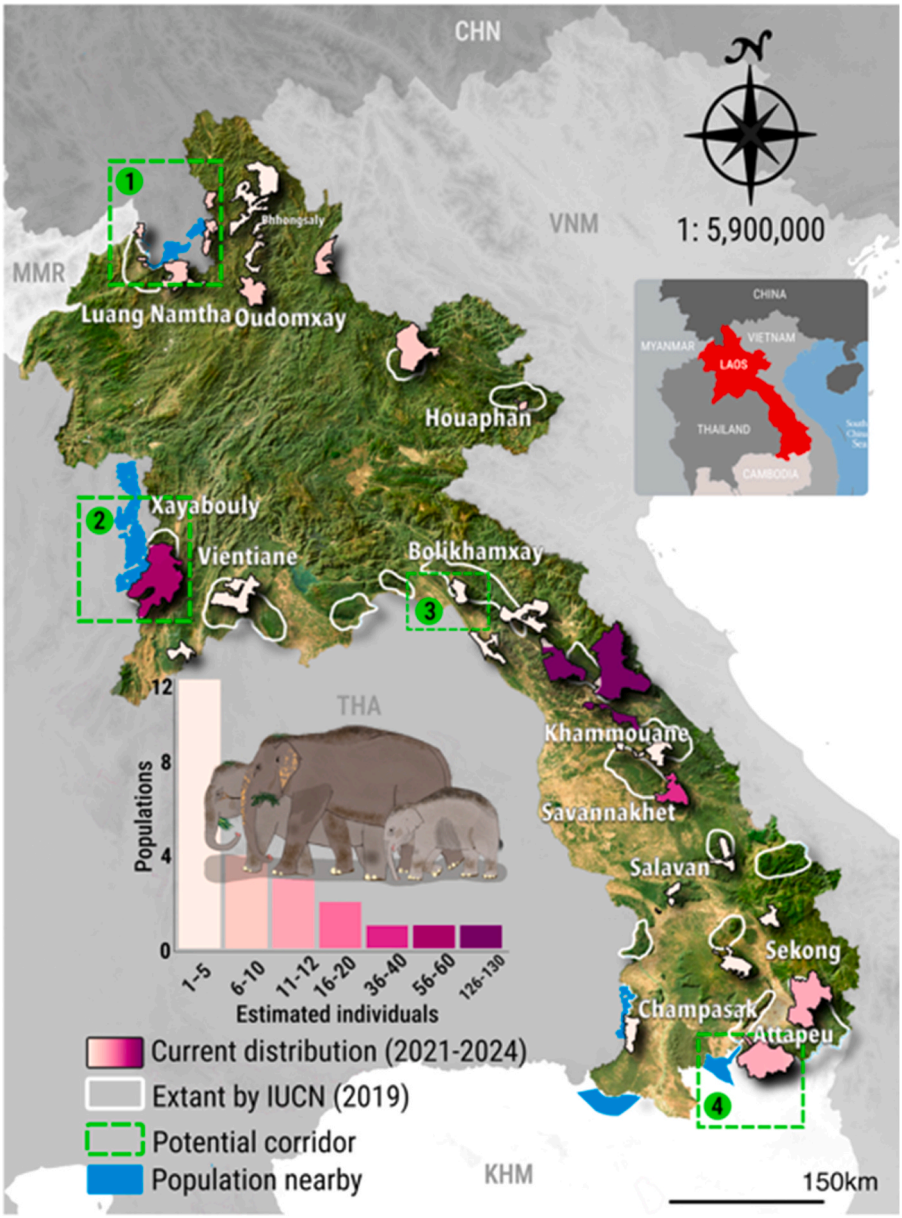

Fig. 4. Historical and recent occurrence of Asian elephants in Laos, showing the approximately 24 putative population units reported in recent national assessments and potential transboundary connections with elephant populations in China, Thailand, and Cambodia. Potential corridors indicate areas where cross-border movement is documented or considered plausible and should not be interpreted as evidence of continuous habitat or established demographic connectivity. CHN = China, MMR = Myanmar, VNM = Viet Nam, THA = Thailand, KHM = Cambodia.

figure that probably underestimates true mortality (Vongkhamheng and Johnson, 2009). Across the border in China, a female tiger was photographed in 2007 at Shangyong, Xishuangbanna—very likely after crossing from Laos—indicating northern persistence into the late 2000s (Feng et al., 2008). Subsequent local reports suggested the animal may have been killed around 2009, though this report was not independently verified (China Daily, 2009). Comparable evidence of persistence is lacking from central and southern Laos after the mid-2000s, where tiger records ceased earlier and subsequent surveys and patrol data failed to confirm continued presence.

Laos adopted its National Tiger Action Plan in 2010, during the final period of verified tiger persistence, with NEPL as the principal site with confirmed tigers (Department of Forestry, 2010). Initiatives by government agencies, the Wildlife Conservation Society (WCS), and local partners implemented wildlife monitoring, core protection zones, strengthened patrols, and ecotourism activities (Johnson et al., 2006; Johnson, 2012). Community outreach emphasized the Wildlife and Aquatic Law (NA, 2007), which lists tigers as Category I (no hunting or trade). Nevertheless, intensive snaring and illegal trade eroded remaining wildlife communities, undermining tiger persistence.

The last verified tiger photographs in Laos were taken at NEPL in 2013. Intensive camera trapping (32,027 camera-trap nights) through 2017 produced no further detections at NEPL, and no subsequent verified records are known elsewhere in Laos; the species is now considered extirpated from the country (Rasphone et al., 2019).

Two tiger-occupied landscapes in Thailand are relevant when considering prospects for tiger recovery in Laos (Fig. 3). Doi Phu Kha National Park (Nan Province) lies contiguous with the Nam Pouy border landscape in Xayabouly. By contrast, the Thap Lan–Pang Sida complex, in the Dong Phayayen–Khao Yai landscape, while important for Thailand's tiger recovery, lacks direct ecological connectivity to Laos (Ash et al., 2021).

4.3. Asian elephants: status, spatial structure, and threats

4.3.1. Wild population estimates and spatial structure

Laos, historically the "Kingdom of a Million Elephants" (Santiapillai, 1993), has never conducted a standardized nationwide census of wild elephants. Available national estimates derive largely from provincial reports, interviews, and *ad hoc* assessments and are therefore not strictly comparable across periods. Early twentieth-century accounts suggested fewer than 4000 wild elephants (Santiapillai, 1993). Estimates declined to 2000–3000 by the late 1980s (Venevongphet 1992, in Khounboline, 2011) and approximately 600–800 by 2009 (Khounboline, 2011). The most recent government estimate, from 2021, suggests that approximately 300–400 wild elephants remain (MAF, 2022; Fig. 4). Although these estimates indicate a substantial long-term decline, differences in survey coverage, data sources, and estimation methods preclude precise assessment of its magnitude or timing.

The remaining elephants are reportedly partitioned into 24 spatially distinct population units (MAF, 2022; Khounboline et al., in press; Fig. 4). These units are derived from available occurrence records and local population estimates. We therefore refer to them as putative population units. Their reported sizes are highly right-skewed: approximately 54% (13 out of 24) are reported to contain fewer than five elephants, 88% (21 out of 24) fewer than 20, and only one more than 100.

The putative population units are unevenly distributed across Laos (Fig. 4). Northern Laos supports 7–9 units totaling approximately 50–90 elephants, many near the China and Viet Nam borders. Central Laos supports 5–6 units totaling 200–240 elephants, including the two largest—Nakai–Nam Theun (110–130) and Nam Pouy (50–60)—plus a population of 35–40 elephants in Savannakhet and several very small populations (with no more than five individuals). Southern Laos contains 8–10 units totaling 40–70 elephants, mostly with ten or fewer individuals. Connectivity among these population units has not been formally assessed (MAF, 2022; Khounboline et al., in press).

4.3.2. Transboundary occurrence and connectivity

In northern Laos, elephants from Nam Ha NPA and Phongsaly move into Shangyong and Mengla sub-reserves in Xishuangbanna, China (Wang et al., 2021; Manyvong, 2021). In the west, Nam Pouy elephants regularly cross into Thailand, and a very small group ($\leq$3 individuals) in Bolikhamxay has crossed the Mekong into Thailand as recently as 2026 (Manyvong, 2021; Thailand's Department of National Parks, Wildlife and Plant Conservation, 2026). In the southeast (Attapeu), a small group regularly crosses the border into Virachey NP, Cambodia (GDANCP, 2020). Eastward movements into Viet Nam are uncertain, with the Annamites as a partial barrier. No transboundary movements between Laos and Myanmar are known.

4.3.3. Captive population

Laos also supports a captive population, concentrated largely in Xayabouly Province and managed under private ownership within village-based and tourism systems. Captive elephants are often tethered at night and free-foraging by day, creating occasional opportunities for mating with wild bulls from Nam Pouy. Captive elephants are required to be registered by the Department of Livestock and Fisheries.

Available estimates indicate that the captive elephant population in Laos declined from approximately 1000 elephants in the 1990s to about 530–540 by 2012 (Suter et al., 2014; Maurer et al., 2017). However, earlier estimates were based on less complete records than the later national registration system, and the figures should be interpreted as evidence of a broad decline rather than as directly comparable standardized censuses. The population is aging and has low reproductive output, with annual births equivalent to approximately 2–3% of breeding females (Maurer et al., 2017). Legal exports have also contributed to the decline.

4.3.4. Threats and demographic uncertainty

Poaching appears to have been the leading proximate cause of elephant mortality in Laos. As many as 50 elephants were reportedly

killed during 1990–1992 (Santiapillai, 1993), and up to 15 were reportedly killed in the Nam Theun region in 1996 (K. Khounboline, pers. obs.). A national compilation recorded 67 elephants poached during 2000–2020, compared with 27 deaths associated with human-elephant conflict (HEC; Manyvong, 2021), with additional incidents reported since 2021 (B. Manyvong, pers. obs.). The accessibility of firearms since the Indochina War, cross-border incursions by organized hunters, and demand for ivory, skin, and meat have driven illegal offtake (AsERSM, 2017; Riddle et al., 2010; Santiapillai, 1993).

Habitat conversion associated with agriculture, logging, and infrastructure has reduced and fragmented elephant habitat in some landscapes. Increasing overlap between elephants, agriculture, and settlements contributes to recurrent HEC, as elephants enter human-dominated landscapes in search of food. Crop raiding, particularly of rice, banana, and sugarcane, leads to recurring economic losses and sometimes fatalities of both people and elephants (Khounboline et al., 2004; Khounboline, 2011; Khotpathoom et al., 2022).

Although demographic and genetic studies have been conducted on selected elephant populations in Laos (e.g., (Ahlering et al., 2011; Maurer et al., 2017), their geographic coverage remains limited. Information on population trends, vital rates, connectivity, and genetic structure is therefore incomplete across much of the country, and population viability analyses have not been conducted for individual wild populations. Consequently, the long-term viability of most elephant populations in Laos remains uncertain.

4.4. Comparative trajectories across focal taxa

The focal taxa showed contrasting trajectories of decline and persistence (Table 1). Rhinoceroses represent the earliest and least precisely documented collapse, with both species historically present but extirpated from Laos by the late twentieth century. Tigers persisted into the early twenty-first century, with systematic monitoring documenting a rapid decline before the last verified record in 2013. Asian elephants remain extant across approximately 24 putative population units, but most reported units are small and their connectivity and long-term viability remain uncertain. Thus, the three focal groups span a gradient from historical extirpation, through recent collapse, to persistence in fragmented and numerically reduced populations.

4.5. Other imperiled large mammals in Laos

Beyond rhinoceroses, tigers, and elephants, many other large mammals in Laos have undergone substantial declines, and several are extirpated or close to it (Duckworth et al., 1999; WCS, 2024). See Table S5 for a general summary of other large mammals.

4.5.1. Wild bovids

The kouprey is almost certainly globally extinct, with no confirmed record since the early 1980s. Subsequent reports from 1988 to 1993 were not substantiated by intensive surveys during the 1990s, suggesting that the species disappeared from Laos by the late twentieth century (Duckworth et al., 1999; Hassanin and Ropiquet, 2007; Timmins et al., 2016). No individuals are known in captivity.

Table 1
Broad historical trajectories of the four focal taxa in South and Southeast Asia and Laos. Note: Period boundaries are approximate. Regional and Lao trajectories represent qualitative syntheses derived from heterogeneous historical and contemporary evidence. Population estimates are not directly comparable across periods, and species-level attribution remains uncertain for many historical rhinoceros records.

Taxon	Period	Wider regional trajectory	Evidence and inferred trajectory in Laos
Javan rhinoceros	19th–early 20th century	Widespread but declining across mainland and insular Southeast Asia	Confirmed and probable evidence indicates historical occurrence; abundance unknown
	Mid–late 20th century	Increasingly restricted and extirpated from most of mainland Southeast Asia	Sparse probable and non-diagnostic records indicate continued decline; last potential records around 1990
	21st century	Extirpated from mainland Southeast Asia and restricted to one remaining population in Indonesia	Extirpated from Laos; no credible records since the late 20th century
Sumatran rhinoceros	19th–early 20th century	Widespread but declining across parts of mainland and insular Southeast Asia	One confirmed Lao specimen; broader distribution uncertain
	Mid–late 20th century	Extirpated from most of its mainland range	Unclear whether they were present in Laos; late 20th century Lao records were largely non-diagnostic
	21st century	Restricted to a few small populations in Indonesia	Extirpated from Laos
Tiger	19th–early 20th century	Widespread across Asia	Recorded widely in Laos, although abundance was poorly documented
	Mid–late 20th century	Major range contraction across Asia, particularly in Indochina	Continued national occurrence followed by substantial decline
	21st century	Persists in several Asian range states but has disappeared from much of Indochina	Rapid decline after the early 2000s; last verified Lao record in 2013; considered extirpated from Laos
Asian elephant	19th–early 20th century	Widespread across South and Southeast Asia	Widespread in Laos; abundance uncertain
	Mid–late 20th century	Substantial regional decline and range contraction	Substantial decline in abundance and contraction of distribution
	21st century	Persists in increasingly restricted and fragmented ranges across Asia	Approximately 300–400 elephants reported across about 24 putative population units; population estimates and connectivity remain uncertain

The saola (*Pseudoryx nghetinhensis*) is an endemic of the Annamite region. The last confirmed records were obtained in Laos in 2010 and Viet Nam in 2013. Expert assessments suggest that any surviving global population is extremely small, possibly comprising fewer than 100 individuals (Van Dung et al., 1993; Timmins et al., 2020; WCS, 2024). No saola are known to be held in captivity.

Among the other wild bovids, wild water buffalo is considered extirpated from Laos (WCS, 2024). Banteng persists in at least one confirmed relict population in Phou Xieng Thong NPA, in southwest Laos (WCS, 2024). Recent camera-trap records indicate that gaur remains more widespread, particularly in central and southern Laos (T. Khotpathoom, unpublished data), although its distribution and abundance continue to decline and it is considered vulnerable to extirpation (WCS, 2024).

4.5.2. Large and medium-sized carnivores

The common leopard is probably extirpated or close to extirpation in Laos and the rest of Indochina (Rostro-García et al., 2016). A small leopard population persists in Xishuangbanna, on the Chinese side of the China-Laos border (Cao et al., 2024). In contrast, clouded leopards (*Neofelis nebulosa*) remain in several NPAs and non-protected areas, though they exist at low densities (WCS, 2024).

Two wild canids are native to Laos: the dhole (*Cuon alpinus*) and the golden jackal (*Canis aureus*; WCS, 2024). Dholes have been recorded in Nam Kan, Nam Ha, and NEPL, but recent surveys have reported low occupancy and detection rates (Rasphone et al., 2019; Tananantayot et al., 2022). The current national status of the golden jackal remains poorly known, although recent camera-trap surveys have confirmed its continued presence in Nam Ha National Protected Area (Bleisch et al., 2026). Laos's native bears, the Asiatic black bear and the sun bear, also persist in small populations (Scotson et al., 2021; WCS, 2024).

5. Discussion

The trajectories reconstructed here broadly parallel the regional pattern of megafaunal defaunation across Southeast Asia (Ripple et al., 2017; Goodrich et al., 2022; WCS, 2024; Table 1). Laos is notable, however, for the severity of these losses despite its relatively extensive forest cover and low human population density. This contrast illustrates that forest extent alone is a poor indicator of faunal integrity. Hunting, snaring, wildlife trade, and prey depletion can remove large vertebrates while leaving much of the vegetation structure intact, producing "empty forests" in which important ecological interactions are diminished or lost (Redford, 1992). Limited institutional capacity, uneven enforcement, transboundary wildlife trade, and expanding infrastructure may have contributed to this disparity. At the same time, the country's remaining forests and transboundary landscapes retain value for conserving elephants, recovering prey communities, and assessing longer-term possibilities for carnivore recovery.

5.1. Cross-species lessons and challenges

The rhinoceros record documents historical occurrence followed by progressive loss, although heterogeneous reporting and the predominance of non-diagnostic records prevent precise reconstruction of population trends or the timing of the extirpation in Laos. This history illustrates the difficulty of detecting declines in rare, low-density species from sporadic and taxonomically uncertain evidence, and the importance of systematically verifying credible indications of persistence. The failure to act on early signals of their persistence allowed populations to disappear (Duckworth et al., 1994; Evans et al., 2000; Vigne, 2013). An entrenched "single-site" narrative, which confined Javan rhinos to Indonesia's Ujung Kulon, Java (Ellis, 2005, after Hoogerwerf, 1970), discouraged systematic mainland surveys. The failure to verify presence claims, expand protection measures, and suppress the trade at the appropriate scale ultimately sealed the fate of rhinos in the region. Given the lack of credible evidence of wild rhinos persisting in continental Southeast Asia, their recovery in Laos is implausible in the foreseeable future.

The tiger trajectory represents a more recent collapse documented partly through systematic monitoring. Tigers persisted in Nam Et–Phou Louey into the early twenty-first century, but abundance declined sharply while snaring and prey depletion remained widespread despite conservation efforts (Johnson et al., 2016; Rasphone et al., 2019). Tiger persistence in neighboring Thailand means that regional source populations still exist (Goodrich et al., 2022). Nam Pouy, which adjoins the tiger-occupied Doi Phu Kha landscape in Thailand, therefore represents the clearest potential setting for natural recolonization. Elsewhere, recovery would probably require reintroduction, but neither pathway can currently be assumed feasible in Laos. Natural recolonization would require functional connectivity with an occupied source landscape, whereas reintroduction would additionally require sustained threat reduction, prey recovery, secure habitat, suitable source animals, institutional and financial capacity, local support, conflict preparedness, and long-term monitoring. Under current conditions, the evidence is insufficient to recommend reintroduction at any specific site in Laos.

Asian elephants differ because they remain distributed across multiple Lao landscapes. Nakai–Nam Theun and Nam Pouy are the two largest reported population units and may have better relative persistence prospects than smaller populations. Most reported population units contain fewer than 20 elephants and, where such populations are also isolated, demographic stochasticity and loss of genetic diversity are likely to become increasingly important (Armbruster et al., 1999; Vidya et al., 2004; Maurer et al., 2024). However, census size alone cannot establish persistence prospects, and their demographic boundaries, genetic structure, and degree of interchange remain poorly understood. Smaller population units may identify occupied habitats and potential movement linkages, although their contribution to demographic or genetic connectivity should be evaluated rather than assumed.

Experience from neighboring Yunnan indicates that strengthened protection and broader socioecological change can permit elephant populations and ranges to expand, but such recovery can also intensify interactions with people and associated costs (Chen et al., 2022; Campos-Arceiz et al., 2021). Elephant conservation in Laos therefore requires concurrent attention to human safety, livelihood losses, and public support. Near-term priorities are to reduce human-caused mortality, protect the principal remaining population units, clarify population structure and connectivity, maintain movement routes where feasible, and develop locally

appropriate mechanisms for human–elephant coexistence. Population reinforcement through translocation should remain a separate, long-term option considered only after site-specific demographic, genetic, habitat, governance, and conflict assessments.

5.2. From policy to practice: necessary conditions for recovery

Laos has established policy frameworks relevant to megafaunal conservation, including the National Tiger Action Plan 2010–2020 and the National Elephant Action Plan 2022–2032, but outcomes depend on sustained financing, institutional capacity, interagency coordination, and effective implementation. Prevention and enforcement should operate together: community engagement, livelihood measures, and demand reduction can reduce incentives for illegal hunting, while targeted patrols, investigations, and prosecution remain necessary where organized hunting and wildlife trade persist (Challender and MacMillan, 2014; Biggs et al., 2017). Performance should be evaluated through changes in illegal activity, wildlife mortality, prey abundance, and judicial outcomes rather than patrol effort or snare removal alone (Walston et al., 2010; EIA, 2015; Goodrich et al., 2022).

Monitoring should be linked directly to management decisions. In potential tiger-recovery landscapes, standardized camera-trap surveys are needed to assess prey recovery and threat reduction before any formal feasibility assessment (O'Connell et al., 2011; De Oliveira et al., 2025). For elephants, priorities include comparable population estimates, demographic and genetic assessment, individual identification, mortality monitoring, and evaluation of connectivity among population units (Archie and Chiyo, 2012).

Expanding roads, railways, hydropower facilities, settlements, and plantations may further increase habitat fragmentation, hunting access, and wildlife trade (Ng et al., 2020). Transboundary coordination should therefore focus on compatible monitoring, information exchange, and operational protocols for priority landscapes shared with Thailand, China, Viet Nam, and Cambodia. Such cooperation is particularly relevant to elephant movements and to assessing potential connectivity with tiger-occupied landscapes in Thailand (WWF, 2025). Regional cooperation could also strengthen conservation capacity in Laos through joint training and technical exchange in wildlife monitoring, genetic assessment, law enforcement, and human–wildlife conflict management, with China in particular offering substantial technical expertise and institutional experience.

5.3. Regional implications and research priorities

Laos is not unique; mega-defaunation across Indochina shares common drivers—hunting, trade, and weak enforcement—affecting large, forested landscapes (Ripple et al., 2017; WCS, 2024). As infrastructure, trade, and tourism expand, future research should focus on: (i) standardizing monitoring methods (e.g., camera grids, genetic capture-recapture; Hedges et al., 2013), (ii) quantifying market dynamics and enforcement performance, including tourism-driven demand (Challender et al., 2015), and (iii) testing scalable coexistence models that align with protection gains (Campos-Arceiz et al., 2022). For elephants, studies on connectivity and gene flow should inform a managed-metapopulation plan, integrated with transboundary initiatives in Yunnan, Thailand, and Cambodia. Research should also examine the ecological consequences of defaunation, including effects on seed dispersal, herbivory, and forest regeneration. Given the rise of Belt & Road Initiative (BRI) projects, priority should be given to evaluating the impacts of linear infrastructure—such as access and mortality risk—and the effectiveness of mitigation strategies like crossing structures and patrol redeployment (Lechner et al., 2018; Carter et al., 2020; Ng et al., 2020). Additionally, policy measures should include sustained support for transboundary protected areas and no-net-loss requirements from BRI-related project revenues (Lechner et al., 2018).

5.4. Limitations

Historical records are uneven, many rhino reports are non-diagnostic, elephant numbers come from heterogeneous methods, and survey effort varies spatially and temporally; grey literature and personal communications, while vetted, introduce potential biases. Despite these limitations, our study provides a novel, comprehensive, and action-relevant overview of the status of megafauna conservation in Laos.

6. Conclusions

Both rhinoceros species have been extirpated from Laos, tigers are also considered extirpated from Laos, and Asian elephants persist in approximately 24 putative population units, most of them small and of uncertain connectivity. These trajectories were not necessarily inevitable. Delayed recognition and response, insufficient control of hunting, and limited enforcement capacity likely contributed to these declines, suggesting that earlier and more sustained intervention might have reduced at least some losses. As development and access expand, conserving Laos's remaining megafauna will require reducing human-caused mortality, securing priority landscapes, restoring prey communities, assessing and maintaining connectivity, preparing for human–elephant conflict, and strengthening transboundary coordination. Forest cover alone will not ensure faunal recovery; effective conservation will depend on sustained implementation, monitoring, and adaptation. These measures could improve the persistence prospects of elephants and other remaining large mammals while establishing the conditions needed to evaluate longer-term recovery options.

Author contributions

DS and ACA conceived the idea and designed methodology; DS collected the data; BM, WVB, KK, TK, TSH, and ACA contributed to the investigation; DS, NR, and ACA led the writing of the manuscript. All authors contributed critically to the drafts and gave final

approval for publication.

Declaration of Competing Interest

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Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT (model 5.2 and 5.6) in order to improve language and readability. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2026.e04399.

Data availability

Data will be made available on request.

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