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Authors: Figel, Joe J., Hambal, Muhammad, Krisna, Ivan, Putra, Rudi, and Yansyah, Dedi

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Malignant Snare Traps Threaten an Irreplaceable Megafauna Community

Joe J. Figel[1,2], Muhammad Hambal[2], Ivan Krisna[3], Rudi Putra[4], and Dedi Yansyah[4]

Abstract

Tropical forests are under severe threat from over-hunting. Subsistence harvests and poaching have decimated wildlife populations to the extent that nearly 50% of Earth's tropical forests are partially or fully devoid of large mammals. Declines are particularly acute in Southeast Asia where ongoing defaunation, largely attributable to indiscriminate snare trapping, is widespread. Using the extensively forested Aceh province in northern Sumatra as a case study, we document rampant snaring, which threatens Earth's last sympatric population of tigers, rhinoceros, elephants, and orangutans. To prevent catastrophic hunting-induced impacts already experienced in mainland Southeast Asia, we call for more comprehensive conservation planning assessments that strengthen wildlife law enforcement, promote collaborative anti-poaching, and research species-specific snaring impacts, particularly in the context of human-wildlife conflict. We conclude with a discussion of the important linkages between poaching, wildlife trade, and zoonotic disease risk.

Keywords

anti-poaching, Leuser Ecosystem, megafauna, Southeast Asia, Sumatra, tiger

More species are now threatened by human activities than at any time in history (International Union for Conservation of Nature, 2020). Habitat loss, overexploitation, climate change, pollution, invasive species, and other anthropogenic threats continue to exert unprecedented pressures on natural habitats, placing nearly 1 million plant and animal species at risk of extinction (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019). Among vertebrates, terrestrial mammalian megafauna (e.g., large herbivores and apex predators) are especially vulnerable to population declines due to their space-demanding requirements, natural occurrences at low densities, and susceptibility to overexploitation (Cardillo et al., 2005; Ripple et al., 2016). These megafauna—which we define as mammalian species with adult body masses >40 kg (Stuart, 1991)—are seriously threatened in the tropics (Wolf & Ripple, 2017), particularly in Southeast Asia (Benítez-López et al., 2019; Harrison et al., 2016; Morrison et al., 2007).

Southeast Asia is now one of the epicenters of the extinction crisis (Sodhi et al., 2004; Tilker et al., 2019). In addition to its disproportionately threatened large mammal community (Ripple et al., 2015), no other region on the planet has higher rates of vertebrate extinction risks (Davidson et al., 2017; Sodhi et al., 2010). Among tropical forest regions worldwide, Southeast Asia has the greatest rates of deforestation and, consequently, the lowest proportion of forest cover remaining (Heino et al., 2015; Miettinen et al., 2011; Wilcove et al., 2013). However, as evidenced by its remnant tracts of intact "empty forests," hunting has surpassed habitat loss as the principal driver of

[1]Department of Life, Ocean, & General Sciences, Highline College, Des Moines, WA, United States
[2]Faculty of Veterinary Medicine, Universitas Syiah Kuala, Banda Aceh, Indonesia
[3]Tropical Society, Ulee Kareng, Banda Aceh, Indonesia
[4]Leuser Conservation Forum, Ulee Kareng, Banda Aceh, Indonesia

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Corresponding Author:
Joe J. Figel, Department of Life, Ocean, & General Sciences, Highline College, Des Moines, WA 98198, United States.
Email: joe.figel@fulbrightmail.org

megafauna decline in Southeast Asia (Harrison et al., 2016; Sreekar et al., 2015; Steinmetz et al., 2013). Globally, 23 terrestrial megafauna species are threatened by extinction due to hunting in Southeast Asia, compared to 14 in Africa, 12 in the rest of Asia, and 5 in Latin America (Ripple et al., 2016).

Hunting for subsistence and traditional medicines are long-ingrained in the cultures of rural Southeast Asia (Lee et al., 2014). However, current hunting levels are unprecedented and largely attributable to insatiable international black market demand (Nijman, 2010). The highest value wildlife parts—such as elephant ivory, rhinoceros horn, and tiger bone and canines—are most frequently smuggled to East Asian markets (Shepherd et al., 2018; Shepherd and Magnus, 2004; Wasser et al., 2009). Indeed, Southeast Asia's proximity to markets of demand—primarily in China, Vietnam, and South Korea—has amplified extirpations of its large mammals (O'Kelly et al., 2018). It is of no coincidence that areas of Southeast Asia along porous Chinese borders (e.g., northern Myanmar and northern Laos) have experienced some of the region's earliest and most severe megafaunal declines (Duckworth & Hedges, 1998; Rao et al., 2011; Rasphone et al., 2019; Sreekar et al., 2015).

Compounding illegal trade, habitat loss and widespread subsistence hunting are further driving the loss of megafauna (Harrison et al., 2016; Sodhi et al., 2010). These threats have culminated in pervasive defaunation such that not a single intact large mammal assemblage remains anywhere in mainland Tropical Asia (Morrison et al., 2007; Tilker et al., 2019). Concerningly, the large-bodied species generally preferred by subsistence hunters and poachers are often keystone species, responsible for disproportionate contributions to some of the most crucial services in tropical forests (Brodie et al., 2009; Ripple et al., 2015). For example, through trampling, herbivory, seed predation, and seed dispersal, large frugivores and herbivorous browsers significantly contribute to integral ecological processes such as nutrient distribution, plant regeneration, and forest succession (Campos-Arceiz & Blake, 2011; Kitamura et al., 2007). Due to their low reproductive rates, these large mammals are especially vulnerable to hunting-induced population extirpations (Cardillo et al., 2005; Ripple et al., 2015). Likewise, apex predators are particularly susceptible to declines due to their large home ranges and position at high trophic levels (Wolf & Ripple, 2017). Consequences of these megafaunal declines are not entirely understood but several long-term studies from Southeast Asia have demonstrated severe disruptions in ecological interactions in heavily hunted forests (Brodie et al., 2009; Harrison et al., 2013).

Southeast Asia has the world's highest levels of unsustainable commercial wildlife harvest, by an overwhelming margin (Di Minin et al., 2019). Nearly all of the region's large mammals have undergone extensive range collapses (Pedrono et al., 2009; Rasphone et al., 2019; Wolf & Ripple, 2017) and some, such as the kouprey (*Bos sauveli*) and several rhinoceros subspecies (e.g., *Rhinoceros sondaicus annamiticus* and *Dicerorhinus sumatrensis harrissoni*), are already extinct or functionally extinct (Brook et al., 2012; Tilker et al., 2019; Timmins et al., 2016a). In the case of tigers, breeding females have been detected in only a few scattered populations, suggesting widespread functional extinction of this apex predator (Lynam, 2010). Several areas previously recognized as priority "source sites" where tiger reproduction was documented a mere decade ago are now devoid of tigers altogether (Johnson et al., 2016; Rasphone et al., 2019) or experiencing rapid declines (Rayan & Linkie, 2015; Steinmetz et al., 2013).

Fortunately, various socio-ecological and biogeographic factors have enabled the persistence of scattered megafaunal populations in a few mountainous and inaccessible pockets of Southeast Asia. One region- the Aceh Province (hereafter Aceh) in northern Sumatra, Indonesia—has maintained a large mammal assemblage more intact than any remaining landscape in mainland Southeast Asia (Griffiths, 2019; Putra, 2014; van Schaik & Supriatna, 1996). Within its borders are two of the largest forest landscapes in Southeast Asia: the 26,500 km^2 Leuser Ecosystem (hereafter Leuser) and an adjacent 7,380 km^2 tract of forest in the Ulu Masen Ecosystem (hereafter Ulu Masen) (Figure 1). Roughly 33% of Leuser is federally protected by the 800 km^2 Lingga Isaq Reserve and the 7,927 km^2 Gunung Leuser National Park, which comprises the core of this ecosystem. Ulu Masen, in contrast, is managed at the Provincial level under the jurisdiction of forest management units.

Both ecosystems support populations of rare and endangered megafauna such as Sumatran tiger (*Panthera tigris sumatrae*), Sumatran elephant (*Elephas maximus sumatrensis*), Sumatran orangutan (*Pongo abelii*), Sumatran serow (*Capricornis sumatraensis*), sambar (*Rusa unicolor*), and sun bear (*Helarctos malayanus*) (Griffiths, 2019; Radinal et al., 2019; Wibisono et al., 2011). Notably, Leuser also provides refuge for the last in-situ population of the critically endangered Sumatran rhinoceros (*Dicerorhinus sumatrensis sumatrensis*) (Pusparini et al., 2015). In fact, if it was not for the extirpation of the Javan rhinoceros (*Rhinoceros sondaicus*) nearly one hundred years ago (Groves & Leslie, 2011), Aceh's forests would contain the only intact megafauna community in Southeast Asia (Table 1). Notwithstanding the Javan rhino, Aceh's extant megafauna span the orders Carnivora, Cetartiodactyla, Artiodactyla, Proboscidea, and Perissodactyla.

To demonstrate the severity of hunting threats in Aceh, we present results based on a descriptive dataset

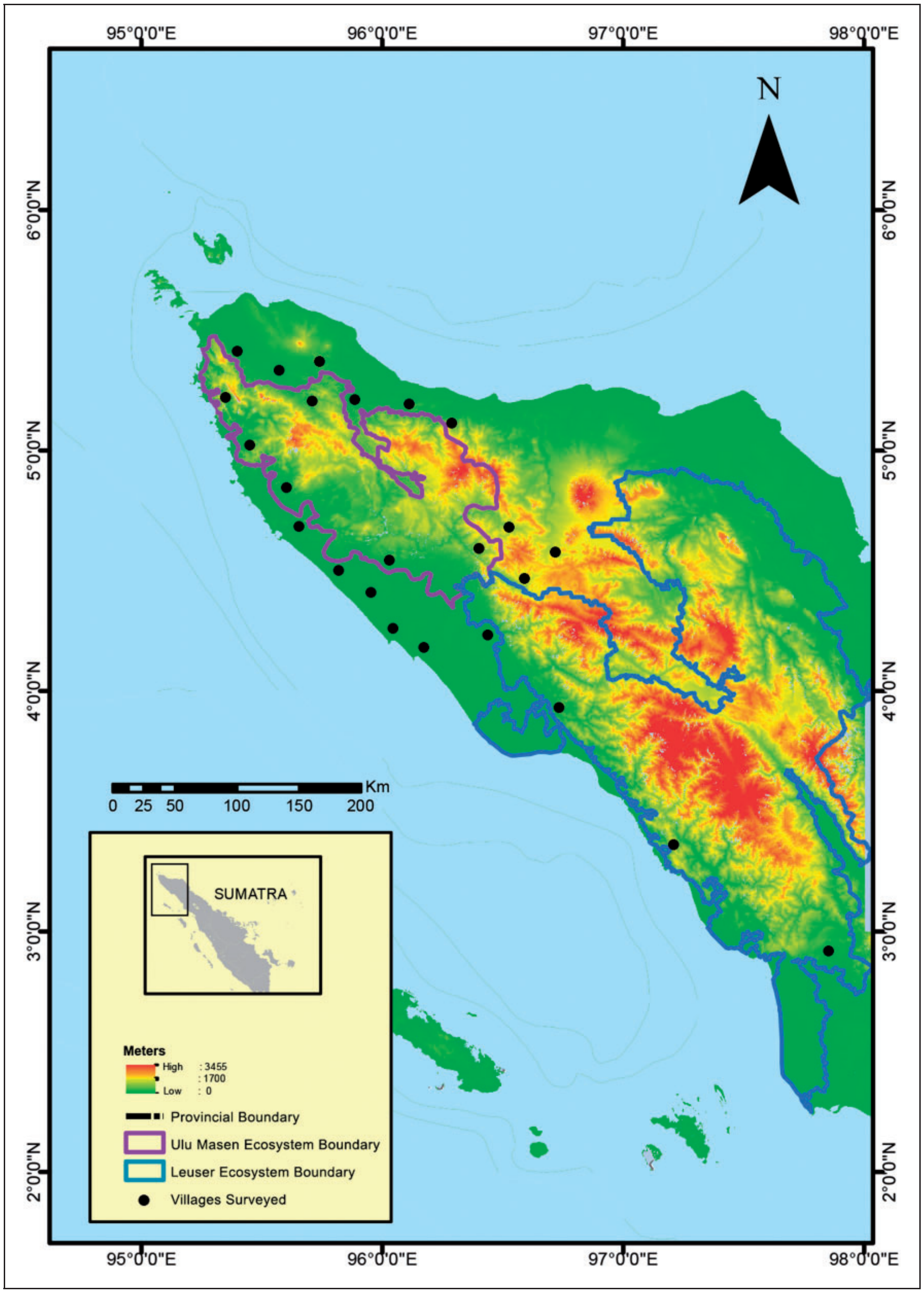

Figure 1. The Ulu Masen and Leuser Ecosystems and Locations of 2019–2020 Village Interview Surveys in Aceh, Sumatra.

from anti-poaching snare patrols conducted January–December 2018. We also briefly review results from interview surveys, completed October 2019–March 2020. Conducted in one of three languages (Acehnese, Gayo, or Bahasa Indonesia), the interviews focused on assessing the prevalence of hunting in Ulu Masen and Leuser. Interviews also included questions about human-tiger conflict, bushmeat sale and consumption, and perceptions of wildlife (Online Supplemental material). In the context of patrol and interview results, we highlight several areas in need of urgent attention for more efficient prevention and management of poaching and subsistence hunting in Aceh.

Mounting Hunting Pressures

The wave of demand emanating from East Asia has already passed mainland Southeast Asia, leaving a

Table 1 Extant and Extirpated Megafauna in Aceh and the Rest of Sumatra and Southeast Asia.[a]

	AC	SM	JV	KL	MY	TH	MM	LA	CM	VT
Pseudoryx nghetinhensis	–	–	–	–	–	–	–	+	–	+
Bos javanicus spp.	–	–	+	+	+	+	+	+	+	+
Bos gaurus spp.	–	–	–	–	+	+	+	+	+	+
Rusa unicolor	+	+	–	+	+	+	+	+	+	+
Panthera tigris spp.	+	+	X	–	+	+	+	X	X	X
Panthera pardus spp.	–	–	+	–	+	+	+	+	+	?
Muntiacus vuquangensis	–	–	–	–	–	–	–	+	+	+
Helarctos malayanus spp.	+	+	–	+	+	+	+	+	+	+
Ursus thibetanus spp.	–	–	–	–	–	+	+	+	+	+
Elephas maximus spp.	+	+	X	+	+	+	+	+	+	+
Tapirus indicus	–	+	–	–	+	+	+	–	–	–
Capricornis spp.	+	+	–	–	+	+	+	+	+	+
Rucervus eldii	–	–	–	–	–	?	+	+	+	?
Sus scrofa	+	+	+	+	+	+	+	+	+	+
Sus verrucosus	–	–	+	–	–	–	–	–	–	–
Sus barbatus	–	+	–	+	+	–	–	–	–	–
Bubalus arnee	–	–	–	–	X	+	+	X	+	X
Budorcas taxicolor spp.	–	–	–	–	–	–	+	–	–	–
Axis kuhlii	–	–	+	–	–	–	–	–	–	–
Rusa timorensis	–	–	+	–	–	–	–	–	–	–
Axis porcinus	–	–	–	–	–	–	+	?	+	?
Rhinoceros sondaicus spp.	X	X	+	–	X	X	X	X	X	X
Dicerorhinus sumatrensis spp.	+	?	–	?	X	X	X	X	X	X
Total Extant Megafauna	7	9	7	5	11	12	15	12	13	10
Total Extinct Megafauna	1	1	2	1	3	3	2	5	3	7

Note. + = species is extant, X = extinct, ? = possibly extinct or functionally extinct, – = species not present in the region during the Holocene epoch. Abbreviations: AC=Aceh; SM=Sumatra; JV=Java; KL=Kalimantan; MY=Malaysia; TH=Thailand; MM=Myanmar; LA=Laos; CM=Cambodia; VT=Vietnam.
[a]For the purposes of this review, we define Southeast Asia as the area between 91° West, 130° East, –15° South and 33° North. This range encompasses two biodiversity hotspots (Indo-Burma and Sundaland) and includes Myanmar, Thailand, Cambodia, Laos, Vietnam, Singapore, Malaysia, Brunei, and the western Indonesian islands of Sumatra, Java, and Kalimantan.

destructive wake of defaunation in all but the most inviolate protected areas (Benítez-López et al., 2019; Morrison et al., 2007). Aceh, separated >2,000 km from major East Asian markets and buffered by the Malacca Strait and Andaman Sea, is now experiencing intensifying poaching pressures (Hanafiah, 2020; Lubis et al., 2020). Whereas Aceh's rural communities have traditionally practiced subsistence hunting (e.g., deer for consumption) and pest control (e.g., removal of wild boar *Sus scrofa* in agricultural areas), poachers pursue species with high-commercial value for sale (e.g., elephants and tigers, Figure 2) (Hanafiah, 2018; Hilton, 2014). Despite variation in quarry, both hunters and poachers generally employ the same method for animal capture: snares.

Typically consisting of a wire or cable noose designed to close and tighten around a body part once it has been triggered by a passing animal, snares have been deployed in Southeast Asia for centuries (Izikowitz, 1939; Macpherson et al., 1897). However, insatiable demand and rising wealth in East Asia along with rapidly expanding agricultural frontiers and new, existing, and upgraded road networks in previously remote areas have led to intensive snaring and devastating defaunation (Clements et al., 2014; Gray et al., 2018; Hance, 2018; Tilker et al., 2019). Snares were responsible for the recent extirpation of tigers from Laos (Johnson et al., 2016) and they now represent the greatest existential threat to critically endangered large mammal endemics such as saola (*Pseudoryx nghetinhensis*) and giant muntjac (*Muntiacus vuquangensis*) (Tilker et al., 2017; Timmins et al., 2016b).

Snares are cost-efficient and, unlike firearms, easy for poachers to conceal and transport. Despite their basic design, snares regularly cause severe injuries and long-term distress to captured animals even in controlled scientific studies abiding by animal welfare guidelines (Gese et al., 2019; Mowat et al., 1994; Powell, 2005), much less in remote areas where hunters leave traps unattended for weeks or even months at a time. Animals captured in such conditions will usually experience prolonged suffering before death. In some cases, an animal may manage

Figure 2. Skeleton of an endangered Sumatran elephant caught in a cable snare trap in the southern Leuser Ecosystem. Photograph © P. Hilton.

to escape, sometimes by self-mutilation (i.e., chewing through an ensnared limb to free itself) (Noss, 1998). These crippled individuals face considerable hardships if they survive (Figure 3).

Led by the *Forum Konservasi Leuser* (FKL; Leuser Conservation Forum) a grass-roots NGO dedicated to the protection of biodiversity in Aceh, 26 anti-poaching teams documented 843 snares in the Leuser and Ulu Masen Ecosystems in 2018. The 2-week patrol operations, typically comprised of 5 community rangers per team, resulted in ~20,000 km patrolled, investigations of 613 poaching incidents, and arrests of 38 poachers in 2018. Additional ranger patrols in Aceh are regularly conducted by the Wildlife Conservation Society and periodically conducted by Fauna & Flora International, Leuser International Foundation, and *Balai Konservasi Sumber Daya Alam* (BKSDA-Aceh; Natural Resources Conservation Center) (FFI, 2014; Hafiz, 2019; Lubis et al., 2020). Thus, snares documented by FKL should be considered lower-end estimates of snaring in Aceh.

Once FKL patrol teams discover snares installed in the forest, the species-or taxa - targeted by the hunter is ascertained by several characteristics such as snare material, diameter of the snare's noose, habitat type, and snare positioning. Whereas wire and nylon rope are typically used to ensnare ungulates, heavy-duty metal cables (e.g., 5–8 mm in diameter) are a tell-tale sign of traps set for tigers and bears. These large carnivores can chew through rope or sever such materials with sheer force; hence the use of thicker cables—usually constructed from steel—for their capture. Snare noose diameters for smaller animals such as birds and porcupines (*Hystrix sumatrae*) are generally 13–18 cm and—for large carnivores and ungulates—approximately 25–30 cm. Snares for montane species such as

Figure 3. Camera-trap image of a wild, 3-legged Sumatran tiger taken on November 13, 2019 in an area frequented by poachers in the Ulu Masen Ecosystem. Eight days prior, on November 5, 2019, a community ranger patrol team dismantled 28 wire and steel snare traps in a 1 km^2 area of forest surrounding the location of this photograph. Also on November 5, 2019, we observed carcasses of one sun bear and one dhole, both killed by snare entrapment. Subsequently, a live 3-legged sun bear was photographed at the same location in January 2020. Severed limbs are a common indication of an animal's escape from snare entrapment; thus, both the tiger and bear were most likely crippled by these malignant traps. Photograph © J. J. Figel, A. Atarli, Hermansyah, and Sariman.

Sumatran serow are usually set at higher elevations (>1,200 meters a.s.l.) while boar are most commonly targeted around agricultural areas, usually in an attempt to reduce crop raiding (Lubis et al., 2020). Due to their high sensitivity to hunting and other forms of human disturbance (Guharajan et al., 2018; Lynam et al., 2012, Sunarto et al., 2012), tigers, bears, and sambar are most often targeted by snare-setting poachers in the interior of intact forest. Finally, snares set for larger animals require more strength during capture and greater resistance during the animal's subsequent struggle as it attempts to free itself. Therefore, live saplings with a diameter at breast height of roughly 7–10 cm are selected to spring traps set for large carnivores and ungulates whereas smaller saplings are used for smaller animals.

The main snare type used in Aceh are foot snares, which are generally set on animal trails in the forest. Hunters dig a small hole, cover it with small sticks, and set the snare encircling the edge of the hole. One end of the snare is attached to a bent sapling, positioned 2–4 m from the trail, at a 90-degree angle from the snare. When an animal steps in the snare and through the hole, the sapling violently springs, triggering the noose to instantaneously tighten around the animal's leg. Once captured, animals typically suffer a tortuous death caused by a . combination of shock, blood loss, infection, fatigue, dehydration, and starvation (Noss, 1998).

Despite their species-specific designs, snares engender substantial bycatch, routinely capturing non-target animals (Campbell et al., 2019; Linkie et al., 2003). Also, large carnivores—including occasional scavengers such as tigers and dholes (*Cuon alpinus*)—may be especially vulnerable to snare entrapment due to their wide ranging movements and attraction to carcasses of other animals captured in these destructive traps (Knopff et al., 2010). In rural Aceh, it is not uncommon for an agricultural worker setting wire snares for wild boar to inadvertently catch threatened megafauna, such as a sun bear or tiger (J.J. Figel, pers observ.). The chance of bycatch can also complicate the process of apprehending perpetrators because putative farmers can falsely claim they were hunting boar when, in reality, they were after critically endangered megafauna.

Based on snare data collected by FKL in 2018, subsistence hunting and pest control were approximately 1/3 the level of commercial poaching (Table 2). Whereas ungulates are targeted for their meat and pest control (boar), large carnivores, porcupines, and birds are targeted by poachers for sale (Heinrich et al., 2020; Nijman, 2010; Shepherd & Magnus, 2004). Sunda pangolins (*Manis javanica*) are also in high demand but, in Aceh, these critically endangered mammals are generally captured by poachers using hunting dogs, not snares. FKL patrol teams did not encounter ensnared elephants in 2018; however, in September 2018, upon notification from another agency, teams confirmed that a female elephant was killed by a snare in northeast Leuser. Likewise, no orangutans were rescued by FKL teams in 2018 but these apes are also susceptible to snare entrapment (Sherman et al., 2020).

Table 2. The Number of Snares Encountered by FKL teams and the Proportion of Species Targeted by Poachers in Aceh in 2018.

Taxonomic order of species targeted	Number (%)
Artiodactyla: **Sumatran serow**, **sambar**, **boar**, muntjac	278 (33)
Carnivora: **Sumatran tiger**, **sun bear**	233 (27.6)
Rodentia: Porcupine	192 (22.8)
Passeriformes,[a] Galliformes[a]	140 (16.6)

Species in bold denote megafauna.
[a]These orders are combined because snares set for different bird species are often indistinguishable.

Besides poaching of high-value species, illicit subsistence hunting by local people is widespread. From our interview sample spanning 24 villages in Aceh, 14% of respondents claimed to have set snares for deer (sambar or muntjac *Muntiacus muntjak*). Furthermore, 50% of rural inhabitants were documented to have recently (i.e., within the past two years) consumed meat of sambar, which is one of the most important tiger prey species (Simcharoen et al., 2018). As an additional indicator of hunting pressure, 47% of respondents claimed sambar meat was occasionally sold in their home village. Given the reproductive biology of sambar (e.g., gestation period of 8–9 months and average litter size of 1.05 fawns) and their naturally low densities in rainforest habitats (Leslie Jr., 2011), intensive hunting seriously threatens the persistence of this tropical cervid in Aceh. Sambar population status has important implications for tiger conservation (Simcharoen et al., 2018).

Clearly, different forms and scales of hunting—e.g., poaching for sale vs. deer harvests for consumption—will require nuanced enforcement and management approaches. Strategies to monitor and regulate subsistence hunting, for example, will require more community-based approaches than the commercial poaching of high-value species for illegal trade (Lewis & Wilkie, 2020). Emphasizing the supply-side, we highlight three pathways for addressing Aceh's snaring crisis: 1) Strengthened enforcement of existing laws, 2) Expansion of community outreach and collaborative anti-poaching, and 3) Research species-specific snaring impacts, particularly in the context of human-wildlife conflict. In the case of Ulu Masen, which is under Provincial jurisdiction, two agencies are primarily responsible for law enforcement: *Dinas Lingkungan Hidup dan Kehutanan* (DLHK; Environment and Forestry Service of Aceh) and BKSDA-Aceh. In contrast, the governing body of Gunung Leuser National Park, which is under national government jurisdiction, is the *Kementerian Lingkungan Hidup dan Kehutanan* (Indonesian Ministry of Environment and Forestry).

Strengthened Enforcement of Existing Laws

Ultimately, we acknowledge that significant reduction in local and international demand is the principal solution to the snaring crisis. Until that evasive, long-term goal is achieved, steadfast enforcement of existing laws must remain a top priority. In October 2019, the government of Aceh province made important strides toward this end when it enacted new legislation for wildlife protection (Aceh Qanun Register Number: 16-325/2019). The government, in Article 32 of Aceh's regional regulations known as *Qanun*, explicitly prohibits the construction and use of snares capable of harming wildlife (DLHK Aceh, 2019).

At the national level, Indonesia has included all its megafauna, besides non-threatened wild boar, on the list of protected species according to Government Regulation No. 7 year 1999 on Preserving Flora and Fauna. Similarly, at the international level, all Indonesian megafauna besides wild boar are listed on Appendix I of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), a multilateral environmental treaty established in 1975 to regulate the international trade of wild species. In accordance with Indonesia's Law No. 5 (1990) on the Conservation of Biological Resources and Ecosystems, the maximum fine and sentence for killing (or illegally transporting) a protected species is five years and/or IDR 100 million (approximately USD $6755). Unfortunately, many perpetrators are not apprehended and, given the fact that the value of the fine is usually less than the value of the profit, there is very little deterrent to poach (McClenachan et al., 2016; Nijman, 2017).

Enforcement of wildlife laws is one of the single greatest determinants of megafauna persistence and recovery at numerous sites in Asia and Africa (Aryal et al., 2017; Gonedelé Bi et al., 2020; Hilborn et al., 2006; Linkie et al., 2015; Martin, 2010). Ranger patrols, which generally rely on deterrence to motivate compliance, have been the major focus of anti-poaching strategies in Southeast Asia (Duangchantrasiri et al., 2016; Linkie et al., 2015; Risdianto et al., 2016). In Thailand, for example, intensive patrolling from 2005 to 2012 significantly reduced poaching, thereby enabling population increases of tigers in Huai Kha Khaeng Wildlife Sanctuary, a globally important source site (Duangchantrasiri et al., 2016). In Kerinci Seblat National Park, Sumatra, patrol teams operating from 2000 to 2010 found and destroyed nearly 4,000 snares (an average of 388 snares removed/year) and arrested and prosecuted 37 tiger poachers and traders (Risdianto et al., 2016). Thus, experienced and well-equipped anti-poaching teams should remain at the forefront of preventative law enforcement for wildlife protection.

Sustained efforts are needed to further facilitate community collaboration with law enforcement agencies. Consistent enforcement increases the perceived risk of arrest and, consequently, temporarily alters behavior (e.g., fewer trips to the forest to poach in response to greater perceived risk) (Duangchantrasiri et al., 2016). However, without change in underlying social norms, poaching often persists during lapses in enforcement (Hanafiah, 2020; Johnson et al., 2016; Semyonov, 2009). Thus, as part of a larger and more strategic approach, efforts to establish additional informant networks at the community and district (locally known as *bupati*) level will help make wildlife crime a more punishable offense.

Community Outreach for Collaborative Anti-Poaching

Compared to top-down enforcement, community-based anti-poaching programs have received far less attention and funding (International Union for Conservation of Nature–Sustainable Use and Livelihoods Specialist Group, 2015). This oversight is unfortunate because collaboration with remote and rural communities is often the most logistically feasible option for protecting high-value megafauna (Linkie et al., 2015; Steinmetz et al., 2014). In fact, top-down enforcement as a stand-alone intervention can seriously undermine approaches for participatory management of natural resources, particularly in ethnic communities far removed from state control (Dongol & Heinen, 2012; MacMillan & Nguyen, 2014; Scott, 2009).

The importance of collaborative anti-poaching strategies is supported by the consistently documented inverse relationship between hunting pressures and proximities to human settlement (Mudumba et al., 2020; Tilker et al., 2019). Thus, complementary approaches that promote trust and engage community members as active participants in anti-poaching efforts can build local capacity and create a sense of pride in management, ultimately strengthening preventative measures (Gonedelé Bi et al., 2019; Steinmetz et al., 2014). Engaging rural communities and using local intel to guide the location and timing of patrols can increase responses to snare removal by up to 41% (Linkie et al., 2015). Notably, employment opportunities as rangers or local informants offer an alternative source of income for people who are otherwise likely to participate in some form of poaching and/or wildlife trade (Lewis & Wilkie, 2020). These local anti-poaching teams, such as the FKL rangers, can also serve as direct links between the broader local community and enforcement personnel (Linkie et al., 2015).

To promote more collaborative law enforcement, strategies that support anonymous reporting by local people were shown to expedite the reporting of poaching incidents while also generating social pressure against poaching (Steinmetz et al., 2014). Indeed, community alliances and local informants are especially crucial in cases when outside poachers—reporting and selling to middlemen in distant localities—infiltrate community lands. In such cases, local residents can be better positioned to intervene because, compared to external personnel, they usually have greater intel about on-the-ground movements (Linkie et al., 2015).

In Aceh there is considerable potential to develop anti-poaching initiatives based on local cultures and beliefs. Ethnic groups in this province have significant cultural reverence for tigers, generally exhibiting high tolerance of the big cat, even after cases of livestock depredation (Lubis et al., 2020). Many Acehnese communities also have customary laws about tigers and, in some cases, believe tigers enforce moral rules in villages, a phenomenon also documented elsewhere in Sumatra (McKay et al., 2018). In response to our survey's open-ended question about perceptions of tigers, 22% of respondents referenced the predator as a beneficial ally whose presence helps reduce agricultural damage caused by wild boar. Indeed, tigers and other apex predators have widespread effects on prey populations beyond predation (Brown et al., 1999). These effects, which are often unrecognized and underappreciated even among ecologists, include the altering of prey habitat use and foraging behavior in accordance with perceived risk of predation (Thinley et al., 2018). Thus, as a complement to government regulation, we recommend efforts to expand strategies that promote the cultural and ecological value of live tigers and sympatric megafauna.

Research Species-Specific Snaring Impacts, Particularly in the Context of Human-Wildlife Conflict

Many of the species most susceptible to snaring—such as Asiatic black bear (*Ursus thibetanus*), saola, and giant muntjac—are among the least studied large mammals in Southeast Asia (Figure 4). This discrepancy is significant because cost-efficient conservation is dependent upon accurate assessments of populations and threats (Johnson et al., 2016; Risdianto et al., 2016). Yet, with some noteworthy exceptions (e.g., Gray et al., 2018), the snaring crisis in this region has been largely overlooked. For example, a recent prioritization exercise did not explicitly include snaring in a comprehensive list of the

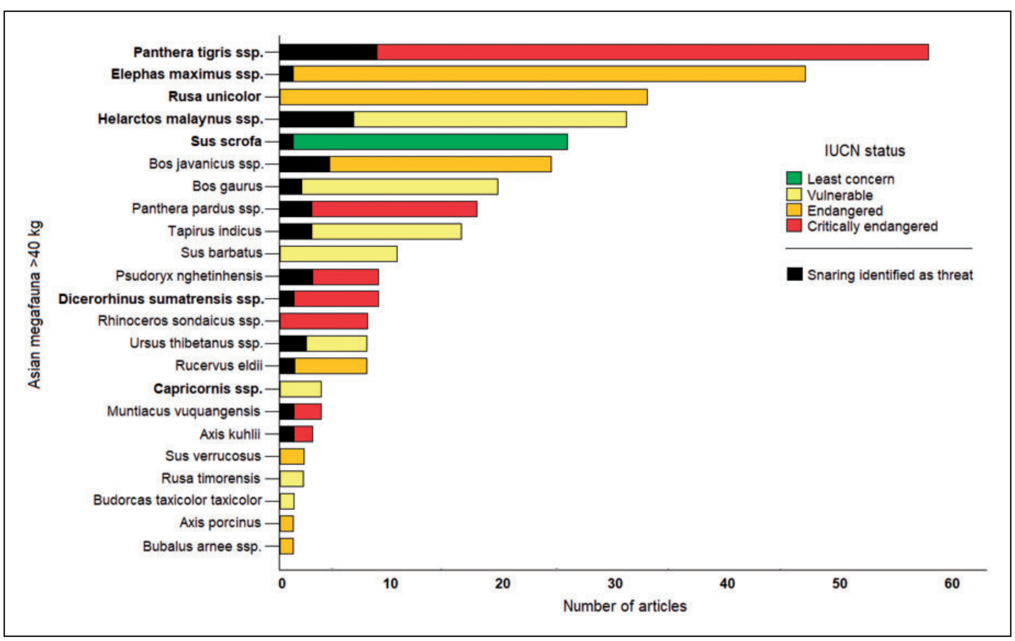

Figure 4. Using ISI Web of Science and Google Scholar, we conducted a literature review for articles published 1980–2020 on 23 extant megafauna species in Southeast Asia. We tabulated studies and recorded articles where snaring was explicitly reported as a threat. Species in bold occur in Aceh. We only considered in-situ studies for which the given large mammal was a focal species of the study. Ex-situ studies (e.g., observations on animals in captivity or modelling exercises that analyzed secondary data) were not included. We further excluded book chapters, technical reports, dissertations, and theses.

"top 100 research questions for biodiversity conservation in Southeast Asia" (Coleman et al., 2019). Given the ubiquity of snares and their highly indiscriminate impacts, we urge greater recognition of the severe and cryptic threats of these malignant traps.

Unlike gun-hunting, snares remain a threat long after the hunter has departed the forest and they consistently evade detection by even the most experienced anti-poaching teams (Gray et al., 2018; Moore et al., 2018). Among Cambodian patrol teams, for example, snare detection probabilities were 0.28–0.36, which suggests that the magnitude of this problem is considerably greater than observed (O'Kelly et al., 2018). Thus, we further recommend implementing patrols and subsequent analyses that account for imperfect detection to avoid the risk of biased interpretations resulting from sites where snares were present, but undetected.

Of the few published studies documenting animal injuries from snaring, rates of escape (as measured by signs such as severed cables and chewed locks) can be as high as 67% for non-target species (Phillips, 1996). Upon escape from entrapment, common injuries include compound fractures or compression fractures of front and hind feet, tendon or ligament lacerations, avulsed claws, loss of digits or entire limbs, and permanent tooth fracture (Mowat et al., 1994; Phillips, 1996). Animals experiencing such injuries are likely to have smaller home ranges, suffer from malnourishment, and occupy degraded habitats due to difficulties defending territories from healthy animals (Obanda et al., 2008; Sunquist, 1981). Physical ailments can alter behavior and predispose animals to greater likelihood of conflict (Becker et al., 2013). In Nepal, for example, physical impairments were the most common factor associated with human-killing tigers (Gurung et al., 2008). Also, elephants wounded by snares pose serious dangers to rural villagers, thereby exacerbating conflict with a species already prone to antagonistic encounters with humans (Abdullah et al., 2019; Becker et al., 2013; Obanda et al., 2008; Othman et al., 2019).

Thus, in-depth analyses on correlations between snare abundance and human-wildlife conflict would help inform site-specific conservation and management. Recent research in Leuser documented greater likelihoods of human-tiger conflict in areas with lower occurrences of prey, presumably attributable, in part, to greater snaring (Lubis et al., 2020). Similarly, the probability of livestock depredation by Amur tigers (*Panthera tigris altaica*) increased in areas closer to deer snares (Soh et al., 2014). In Aceh, however, correlations between snare traps and conflict have not been adequately investigated and the effects of snare injury on propensity for conflict remain unknown.

Conclusions and Implications for Conservation

Snaring is one of the most urgent threats to numerous large mammal communities in Southeast Asia, including Aceh's sympatric population of tiger, rhinoceros, elephant, and orangutan, which is the last such assemblage remaining on Earth. While numerous protected areas in Southeast Asia have already experienced widespread snaring-induced defaunation (Rasphone et al., 2019; Tilker et al., 2019), Sumatra's Aceh province has maintained the most intact megafauna assemblage remaining in the region. Yet, the clandestine nature of illegal snaring has undermined efforts to control the complex consequences of the poaching crisis. Beneath its extensive canopy cover, Aceh's megafauna are relentlessly pursued by poachers seeking profits on the black market. To avoid further declines and extinctions, we urge greater prioritization for more comprehensive conservation assessments—beyond remotely-sensed estimates of forest intactness and protected area coverage—that consider faunal intactness and explicitly distinguish impacts of snaring from other, less destructive, forms of wildlife harvest.

In the devastating wake of COVID-19, significant attention has been directed toward wildlife harvests and trade (United Nations Environment Programme and International Livestock Research Institute [UNEP], 2020). As a preventative measure to reduce risks of future pandemics, insistent and widespread campaigns have called for bans of wet markets (Congress of the United States, 2020; Yang et al., 2020) where live domestic and wild species are openly kept, often in unsanitary conditions with appalling disregard for animal welfare (Broad, 2020; UNEP, 2020). After the World Health Organization (WHO) declared COVID-19 a global pandemic in March 2020, thousands of early cases of COVID-19 were traced to vendors at a wet market in Wuhan, China (Hao et al., 2020). Indeed, COVID-19 has prompted valid concerns about the role of poaching and wildlife trade in the emergence of future pandemics (UNEP, 2020).

Zoonotic viruses are frequently associated with illegally imported wildlife products (Greatorex et al., 2016) and there is mounting evidence supporting Sunda pangolins as probable hosts of novel coronaviruses, including COVID-19 (Zhang et al., 2020). Pangolins, which are still extant in Aceh, are now considered the "most heavily trafficked mammals in the world" (Challender et al., 2020). This critically endangered species is smuggled through the same trafficking routes as Southeast Asian megafauna (Zhang et al., 2017), highlighting the complex linkages between poaching, wildlife trade, and disease-transmission risk.

Despite the gravity of illegal wildlife trade, the inconvenient reality is that prevention of pandemics and extinctions is not as straightforward as simply shutting down markets (Zhu & Zhu, 2020). Beyond a singular focus on wildlife trade bans, which can also have undesirable impacts on conservation efforts by triggering the emergence of underground black markets, it is important to recognize the contribution of intact habitats to reducing pathways of zoonotic pathogen spillover (UNEP, 2020). The Leuser and Ulu Masen Ecosystems, core habitats of Aceh's megafauna, provide a valuable buffer against the emergence of future zoonotic diseases, which are driven by land-use change and agricultural expansion (Allen et al., 2017; Han et al., 2016). Hunting and the subsequent handling and consumption of bushmeat contributes to the emergence and spread of infectious diseases, particularly in deforested or otherwise disturbed landscapes (Karesh & Noble, 2009). Therefore, trained rangers—such as those guarding Aceh's megafauna—can be one of the first lines of defense against not only snare-setting poachers but also wildlife trade and disease spillover.

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ORCID iD

Joe J. Figel https://orcid.org/0000-0002-9536-2834

Supplemental Material

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