

Snaring epidemic threatens an Endangered banteng *Bos javanicus* population of global conservation significance in southwest Cambodia

Elisabeth D. GISH^{1,*}, Nicole LEROUX¹ & Nick MARX¹

¹ Wildlife Alliance, No. 86, Street 123, Toul Tompong, Chamkarmorn, Phnom Penh, Cambodia.

* Corresponding author. Email gish@wildlifealliance.org

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មូលនិយមសង្ខេប

ទន្សោង (*Bos javanicus*) គឺជាប្រភេទសត្វជិតផុតពូជ ដែលកំពុងទទួលរងការគំរាមកំហែងយ៉ាងធ្ងន់ធ្ងរ ដោយសារការរីករាលដាលនៃអន្ទាក់ នៅទូទាំងអាស៊ីអាគ្នេយ៍។ តំបន់ភាគឦសាននៃប្រទេសកម្ពុជា គឺជាទីតាំងមួយក្នុងចំណោម ទីតាំងផ្សេងទៀតក្នុងសកលលោក ដែលសម្បូរទៅដោយប្រភេទសត្វកម្រ ចំណែកភាគនិរតីនិរលោះវិញ បានក្លាយជាទីតាំងបន្ទាប់ ដ៏សំខាន់សម្រាប់ពពួកសត្វទន្សោងរស់នៅ។ អរគុណដល់ក្រុមល្បាតរបស់សហគមន៍ ដែលបាន និងកំពុងធ្វើការល្បាតនៅទូទាំង តំបន់ព្រៃសហគមន៍ប្រាំបីមុម និងចម្ការដែលនៅជុំវិញតំបន់នោះ តាំងពីឆ្នាំ២០០៣មក។ នៅដើមឆ្នាំ២០២០ ការងារល្បាតត្រូវ បានធ្វើកំណែទម្រង់ថ្មី ជាមួយនឹងវិធីសាស្ត្រល្បាតរបស់កងកម្លាំងសហគមន៍ទប់ស្កាត់ការបរបាញ់ខុសច្បាប់ ហៅកាត់ថា (CAPU) និង កិច្ចស្រាវជ្រាវតាមរយៈការបង្កប់ម៉ាស៊ីនថតស្វ័យប្រវត្តិ។ ការស្រាវជ្រាវនេះ ធ្វើឡើងក្នុងគោលបំណងកំណត់ចំនួន និងរក្សាទុកជា ឯកសារ អំពីប្រែប្រួលអន្ទាក់ រួមទាំងផលប៉ះពាល់របស់វា ក្នុងការគំរាមកំហែងដល់ជីវិតសត្វទន្សោងដែលរស់នៅក្នុងតំបន់នោះ តាមរយៈការប្រៀបធៀបទិន្នន័យដែលមាននាអំឡុងពេលដូចគ្នា ក្នុងឆ្នាំ២០២០ និងឆ្នាំ២០២១។ ដើម្បីវាស់ស្ទង់ប្រែប្រួលនៃកិច្ច ខិតខំល្បាតនេះ អាត្រានៃម៉ោងល្បាត/ការដោះអន្ទាក់ប្រចាំខែ ត្រូវបានគណនាដោយប្រើប្រាស់នូវទិន្នន័យរបស់ (CAPU) ចាប់ពីខែ កុម្ភៈ ដល់ កក្កដា ក្នុងឆ្នាំ២០២០ និង ២០២១។ នៅចន្លោះពេលនេះ អាត្រានៃការដោះអន្ទាក់បានកើនឡើង៥៥% ពោលគឺកើនពី ០.៥អន្ទាក់ ដល់ ១.១អន្ទាក់ ក្នុងរយៈពេលល្បាតមួយម៉ោង។ និន្នន័យចាស់អំពីការស្លាប់ និងរបួសរបស់ទន្សោងដោយសារអន្ទាក់ ចេញពីម៉ាស៊ីនថតស្វ័យប្រវត្តិ ធៀបនឹងទិន្នន័យថ្មី ក៏បង្ហាញការកើនឡើងផងដែរ។ កំណើននៃអន្ទាក់នេះ កើតឡើងស្របពេល ជាមួយគ្នានឹងកំណើននៃជម្ងឺកូវីដ១៩ ហើយវាកាន់តែដុះឡើងលើកម្រិត និងសង្គម ដែលបណ្តាលមកពីការឆ្លង រីករាលដាល ក្នុងប្រទេសកម្ពុជា។ ប្រសិនបើកំណើននេះនៅតែបន្ត ចំនួនសត្វទន្សោងនៅក្នុងតំបន់ប្រាំបីមុមអាចនឹងត្រូវបាត់បង់ ទាំងស្រុង លុះត្រាតែរដ្ឋបាលព្រៃឈើជំរុញបន្ថែមដល់ការអនុវត្តច្បាប់របស់ខ្លួនសម្រាប់សហគមន៍ល្បាត។

Abstract

Banteng *Bos javanicus* is an Endangered wild cattle species that is highly threatened by the Southeast Asian snaring epidemic. While northeast Cambodia is one of the species' global strongholds, an important banteng subpopulation has survived in southwest Cambodia thanks to a group of community rangers who have patrolled the Prambei Mom Community Forest and surrounding plantations since 2003. In early 2020, the patrols were formalized using the Community Anti-Poaching Unit (CAPU) approach and a camera trap survey was initiated. The aim of our study was to quantify and document changes in snaring intensity and its impacts on the local banteng population by comparing

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available data for 2020 with the same period in 2021. To account for variations in ranger patrol efforts, monthly rates of snare removal/patrol-hour were calculated over time using CAPU data for February–July 2020 and 2021. Between these periods, the rate of snare removal increased 55% from 0.5 snares/patrol-hour to 1.1 snares/patrol-hour. Camera trap data for bantengs with old versus new snare wounds and documented deaths also showed upward trends. This surge in snaring coincides with significant growth in COVID-19 cases and worsening socio-economic impacts from the pandemic in Cambodia. If these trends continue, the banteng population at Prambei Mom will likely be extirpated unless the Forestry Administration can increase its law enforcement support for community ranger patrols.

Keywords Banteng, Cambodia, community anti-poaching, COVID-19 impacts, patrolling, snaring epidemic.

Introduction

Southeast Asian wildlife faces an unprecedented snaring epidemic that is driving defaunation of forest habitats (Belecky & Gray, 2020) and studies have shown that “near total loss of certain groups of taxa, particularly large mammals” is increasing, even in remaining areas of good quality forest (Gray *et al.*, 2021). Snares made of affordable and easily available materials such as cord or wire are widely used for hunting (O’Kelly *et al.*, 2018). These are almost indiscriminate and when heavily distributed in large numbers throughout the forest floor pose an especially high threat to ground-dwelling mammals such as bantengs *Bos javanicus* (Dobson *et al.*, 2019b; Gray *et al.*, 2021). Snares are one of the cruelest forms of hunting, as animals can be held for days before eventually perishing from dehydration or starvation. They are also extremely wasteful, with one study finding up to 60% of animals found in snares were decomposed (Gray *et al.*, 2021). Even animals that manage to escape often die afterwards from infections or injuries. This is particularly the case for larger mammals that break free, as the snare noose can remain around the leg, constricting the flow of blood. This causes infection, usually the loss of the lower part of the snared limb, and ultimately the death of the animal. Rescues of snared animals brought for treatment to Phnom Tamao Wildlife Rescue Centre, Takeo Province, Cambodia, often die if the injury is long-standing because appropriate treatment has not been administered soon enough (N. Marx, pers. obs.).

Cambodia is a global stronghold for bantengs, an Endangered species of wild cattle which is rapidly declining due to extensive habitat loss and hunting. Gardener *et al.* (2016) estimated the remaining global population of bantengs at 8,000 individuals, around 60% of which occur in northeastern Cambodia. While the latter authors confirmed bantengs as Endangered, they also stated “Declines in the Indochinese population are likely to approach the threshold (80% ongoing decline) rate for listing as Critically Endangered”. In addition, following a multi-year survey of ground-dwelling mammals in

southwestern Cambodia, it was concluded bantengs had been extirpated (Gray *et al.*, 2017). However, Wildlife Alliance (WA) staff learned from Facebook posts in 2018 that a substantial banteng population still existed at the edge of this region in Prambei Mom (Kampong Speu Province), thanks to the vigilant protection of several herds by a group of local community rangers since 2003 (Fig. 1).

Long-term dedication to voluntary patrolling is rare in Indochina, or indeed anywhere. The community rangers at Prambei Mom persevere because they genuinely value ‘their’ bantengs and because, like the bantengs and other wildlife present, they also depend on the remaining forests. Local people harvest non-timber forest products (NTFP) from the area, although these are a diminishing resource as surrounding forests have been converted into sugarcane plantations by wealthy outsiders. Despite their best efforts, local villagers estimate approximately 14 bantengs were killed by hunters between 2003 and early 2018 (Sassoon & Phak, 2018). Additionally, the banteng population in Prambei Mom is now severely threatened by sudden and significant increases in snaring which began in 2021.

The 16 community rangers at Prambei Mom protect its banteng population from hunting parties and snares set by poachers in the forest and adjacent plantations. With support from the Forestry Administration (FA), the rangers created the Prambei Mom Community Forest (PMCF) in 2003 to gain management rights over a patch of forest used by the bantengs. An official agreement was signed in March 2018 which designated 937 ha as belonging to the PMCF and an additional 253 ha were added in September 2018 (Fig. 1). Wildlife Alliance began providing technical and financial support in early 2018 when the community requested help to capture an adult bull banteng that had been injured by a snare and broken free. In addition to poaching and snaring by locals, the banteng herds in Prambei Mom were targeted by safari-style hunting expeditions arranged by powerful outsiders until professional rangers apprehended an individual in

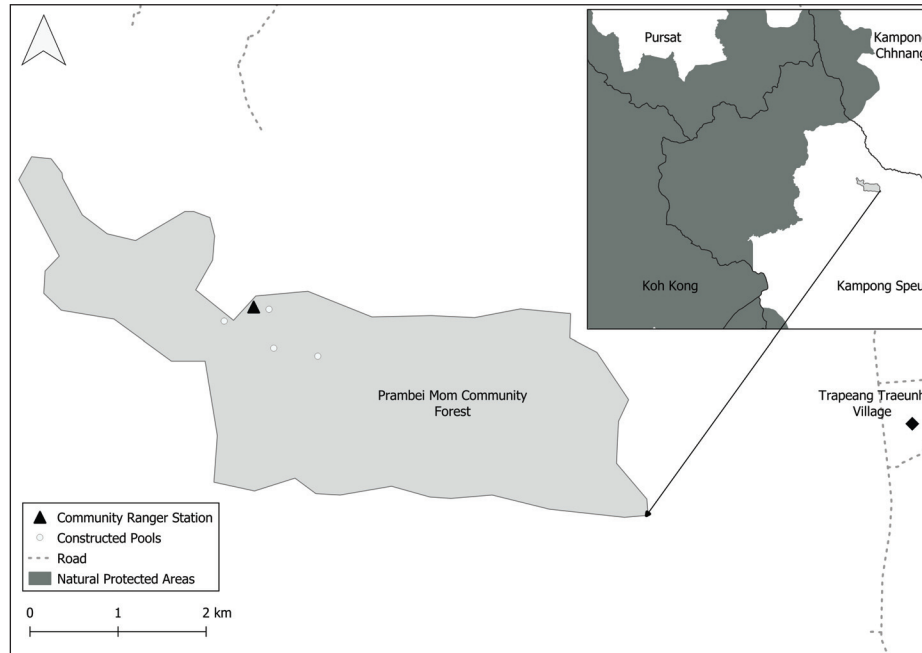


Fig. 1 Location of Prambei Mom Community Forest and nearby protected areas in southwest Cambodia.

2018 who eventually served jail-time for his crime. While this case effectively ended large-scale shooting incidents at the site, snares remain a grave threat.

The banteng population in Prambei Mom moves between a patch of dry deciduous dipterocarp forest in Thboung District and surrounding areas which have been converted into sugarcane plantations. Initial estimates based on interviews with community members in 2019–2020 suggest the population numbers approximately 50 individuals across at least three herds, and an ongoing camera trap survey is being conducted to provide a robust estimate (Marx, 2021). Given the threat posed by snares, WA support has focused on strengthening patrols by providing the rangers with professional patrol equipment, introducing new patrol techniques and strategies, and training them to systematically collect data on their results following the Community Anti-Poaching Unit (CAPU) approach developed by WA to safeguard its release sites for rescued animals.

The PMCF is the only CAPU site supported by WA that does not form part of a larger protected area managed by the FA or Ministry of Environment (MoE) and WA does not directly manage the site. The FA is the governing authority responsible for protecting wildlife within the PMCF and the surrounding sugarcane plantations used by the bantengs. Most snares removed by rangers are located in the latter area and increasing numbers of snares were detected and removed in 2021

compared to 2020, suggesting that banteng populations at the PMCF now face a greater risk of extirpation.

Few studies have been published on the impacts and reach of snaring in Southeast Asia, despite the significant threat this poses to the region's biodiversity (Gray *et al.*, 2018). Bantengs are highly susceptible to snaring and more research is needed on the species-specific impacts of snaring (Groenenberg *et al.*, 2020; Figel *et al.*, 2021), especially studies based on patrols and analyses that account for imperfect detection rates, such as Linkie *et al.* (2015) who assessed the impact of snare removal on a population of tiger *Panthera tigris* in Sumatra. Although the available patrol data for the PMCF does not include variables that would allow us to control for snare detection rates or evaluate the effectiveness of patrols, our work contributes to a growing body of research on the impact of snaring on a specific large mammal species.

This study documents a rapid increase in snaring in and around the PMCF and estimates its immediate impacts on the local banteng population. To this end, we compare monthly CAPU patrol data for February–July 2021 to data for the same period in 2020 to quantify the changes in snaring that have occurred. These data are supplemented by evidence from camera trap photos taken between March 2020 and August 2021 to illustrate the impact of increased snaring on banteng herds by providing a rough estimate of the numbers of animals with snare wounds, specifically individuals with wounds

newly identified in March–August 2020 versus the same period in 2021.

The surge in snaring described in this article coincides with the COVID-19 pandemic, which originated from a novel virus that emerged in late 2019 in Wuhan, China and spread to 100 countries by early 2020 (Shereen *et al.*, 2020). While many countries experienced rapid increases in cases and implemented severe domestic measures to curb the spread of the virus in 2020, Cambodia opted to essentially seal its borders by severely limiting international arrivals and introducing strict quarantine protocols for entrance. This devastated the international tourism sector, but largely spared Cambodia from the health crisis and measures designed to prevent the spread of COVID-19 that disrupted life elsewhere in 2020. Following the first severe community outbreak in February 2021 and rapid growth in COVID-19 cases however, the government introduced lockdowns in the capital and major cities, inter-provincial travel restrictions and widespread closures of local markets where outbreaks were identified (Tatum, 2021). As the timing of our work coincides with worsening socio-economic impacts experienced in Cambodia due to the pandemic in 2021, we discuss our findings in the context of the COVID-19 pandemic, thus responding to the recent call for “ground truthing efforts to assess whether the reported impacts of COVID-19 have resulted in heightened poaching” (Waithaka, 2020).

Methods

Community anti-poaching unit patrols

Members of the CAPU at Prambei Mom are paid a small monthly stipend to patrol each week and ensure the bantengs are protected. The team patrols on foot and on motorcycles to remove snares and prevent further forest encroachment. They also ensure that natural resource use within the PMCF accords with its management plan (e.g., that people harvest NTFPs in the correct season and respect permitted quantities, etc.). Patrol data are collected in the field by CAPU members using a basic worksheet in Khmer language and submitted each month to a WA staff member who checks the data, translates it into English and tabulates this in Excel. Variables recorded include: date, number of calendar days patrolled, number of patroller-days (patrollers x calendar days), start and end times, locations, number of snares removed, length of snares (if applicable), and relevant notes (e.g., if an animal was removed from a snare or time was spent on other activities). The data are then reviewed periodically by a different staff member, who checks for

errors, clarifies as needed, finalizes the data and analyses results. The CAPU patrol reports include all time spent on the project, including activities such as fighting wildfires, constructing pools to provide water for bantengs and meetings with FA officials to resolve conflicts with neighbouring sugarcane plantations. As these are essential to conserve the banteng herds but do not involve patrolling the forest to detect and remove snares, all time spent on such activities were excluded from our analysis.

The number of days and time spent patrolling on a given day by the CAPU can vary greatly. For example, the number of calendar days patrolled per month ranged from 6–26 and the number of patroller-days per month ranged from 61–244 in February–July 2020 and February–July 2021. Numerous studies have pointed out the need to control for variations in ranger patrol effort (RPE) when assessing patrol results (Dong *et al.*, 2021). Because measures such as the number of days patrolled do not account for the amount of time actually spent patrolling each day (O’Kelly, 2013), we employed the number of hours patrolled as a measure for RPE (Table 1). These were calculated from the reported start and end times of the patrols and the number of snares removed were divided by the number of hours patrolled to generate the rate of snare removal per month.

Known banteng fatalities and camera trap evidence

A number of fatalities due to snaring have been documented in the PMCF since March 2018 and evidence from camera traps suggests that numbers of bantengs with visible snare wounds (e.g., swollen and infected hooves, missing feet, abrasions and scars around legs from snares) or snares still attached to their legs have increased. As sample sizes were insufficient for statistical analysis however, we employed the number of confirmed banteng deaths from March 2018 to August 2021 as a measure of the impact of increased snaring on banteng herds at the site.

Table 1 Variables selected to quantify the rate of snare removal at Prambei Mom Community Forest.

Variable	Definition	Calculation
Ranger patrol effort	Number of hours patrolled	End time - start time = total hours
Snare volume	Total number of snares removed	N/A (provided on patrol sheets)
Rate of snare removal	Number of snares removed/patrol-hour	Snare hours = snares/patrol-hour

Eight camera traps (Bushnell HD Model 119739, Illinois, USA) were installed in the PMCF in March 2020 as part of a capture-mark-recapture study to estimate the population size, herd demographics and health of bantengs in the area. To maximise detection rates, the cameras were placed at least 0.5 km apart in locations that bantengs were known by the community rangers to frequent, such as waterholes and trails with consistent sightings of dung and footprints. To photograph a greater proportion of the herd and defining features of individual animals as they moved in front of cameras (e.g., differences in horns, coat colour, rips in ears and scars), each camera was set at least 1 m above ground level and activated by heat and movement, triggering bursts of three consecutive photographs at one second intervals. Two cameras were stolen, one in July 2020 and a second in August 2020 which was later replaced at a nearby location. A third camera was retrieved after a section of forest was cleared to expand the bordering sugarcane plantation and deployed in a different location within the forest boundary in October 2020. Camera trap effort (equalling the sum of cameras x operational days) was partitioned between years and was calculated from the date a camera was set in March 2020 until 31 December 2020 (or in the case of one camera, the last date images were retrieved before it was stolen) and from 1 January 2021 to 31 August 2021. Periods that cameras were not in operation due to malfunction, theft or interference were excluded from analysis.

Photographs taken between March 2020 and August 2021 were analysed, and distinct individuals with clearly visible wounds from snares were counted the first time they appeared in a photo. Wounds included in counts were as follows: snares around legs, abrasions or scars in a single line around the leg indicating contact with a snare, swollen and infected hoofs and missing feet. Animals that could not be distinguished from a previously recorded individual with a similar wound were omitted to avoid double counts. Snare wounds were categorized as either 'old' or 'new'. 'New' wounds were defined as either the first photographs of an identifiable individual seen in previous months without a wound or a wound that had a newly visible clear cut or blood from a snare, whereas 'old' wounds were defined as distinct individuals photographed for the first time with a swollen or infected hoof, missing foot or scarring from a snare with no blood present. Wounds were then classified as 'active' or 'stable' as of August 2021, based on progression of the injury and the body condition of an individual over the study period. 'Active' wounds were defined as infections that remained open, increased swelling, loss of

hoof or limb, or where the banteng's weight decreased consistently and dramatically over the study period (as opposed to minor seasonal fluctuations in body weight seen in the population). 'Stable' wounds were defined as injuries that did not progress over the study period or reduced in severity and where the individuals' body condition appeared unaffected. Wounded bantengs only photographed on a few occasions or with new wounds in 2021 were classified as 'unknown' because progression could not be determined. Numbers of old and new snare wounds registered in each year were compared. Whereas old wounds could have been inflicted by snares laid at any time in the past, new wounds were assumed to be due to snares laid more recently because the CAPU team regularly patrols and removes any snares encountered.

Limitations

Dobson *et al.* (2019a) have pointed out the challenges of determining to the extent to which patrolling deters hunters from setting snares in the future. Measuring the degree of deterrence is beyond the scope of our analysis. However, the level of support for the CAPU team and the patrolling methods adopted did not change substantially during the study period and the same methods of data collection and analysis were applied throughout the study. As such, there is no reason to suspect significant changes occurred in the degree of deterrence or effectiveness of patrols in detecting snares. Similarly, the legal penalties applied for setting snares did not change during the study period. As such, we assumed any increase in the number of snares removed in 2021 compared to 2020 was due to greater numbers of snares being set, as opposed to improved snare detection rates in patrols or any changes in their deterrence to poachers, such as reduced penalties.

Our patrol data does not include any variables that can be used to measure the quality of patrols, as opposed to their quantity. However, while many patrol teams comprise full-time professionals who are paid to do the job and may be assigned to other areas by their employer (e.g., a government agency or NGO), all patrols in the PMCF are undertaken by local volunteers, most of whom have been continuously engaged at the site since 2003. There is no reason to suspect declines in patrol quality due to decreased motivation, although it may have increased as a result of better equipment and support since 2018 and the introduction of the CAPU approach in early 2020. Nonetheless, since the patrol methods and team composition did not change significantly during

the study period, the influence of any changes in patrol quality on our results is likely to be marginal.

Due to their movement and the limited time animals spend in front of camera traps, there are limitations in our ability to recognize and define wounds, as well as distinguishing animals that have similar wounds and no defining physical characteristics. This could potentially have led to under-counting of snared individuals in our analysis. Determining the progression of wounds from camera trap data also makes it difficult to define when animals have come into contact with snares. Categorizing wounds as 'active' or 'stable' is limited to interpretations of the progression of injuries in photographs and confined to a short period. As infections progress, more serious injuries have a higher detection likelihood, so the early stages of infections when a snare has initially broken off and constricted the end of a hoof could have been overlooked in analysis. Continued monitoring of the herd will provide a clearer understanding of individual outcomes and impact of snares on the population.

Results

By all measures examined, the number of snares threatening the PMCF banteng population was greater in February–July 2021 than the same period in 2020. It is not possible to compare numbers of snares removed from the PMCF with the surrounding sugarcane plantations over the entire study period because the CAPU team only began to track snares removed from inside vs. outside

the PMCF in January 2021. However, based on the data for 2021 and discussions with the rangers throughout 2020–2021, it is clear the majority of the snares were removed from the surrounding plantations and not from the PMCF itself. For example, of the 448 snares removed in February–July 2021, only 66 were removed from the PMCF whereas 382 were removed from the sugarcane plantations.

Community anti-poaching unit patrols

The total number of snares removed by the PMCF CAPU in February–July 2021 was almost 200% higher than the same period in 2020 (Table 2). Due to concerns in early 2021 about what appeared to be a significant increase in snaring however, the rangers increased their RPE by 37% compared to 2020. Using the rate of snare removal to control for the increased RPE, numbers of snares removed per patrol hour in 2021 were 55% greater than in 2020.

The time dedicated to patrols (and possibly also the time poachers have to set snares) in Prambei Mom varies seasonally more than at many other sites because the PMCF CAPU team consists of local volunteers who are subsistence farmers, whereas in other areas ranger teams typically receive salaries comparable to full-time employment. For example, the patrol schedule for the PMCF is affected by the rice sowing and harvesting seasons and in February–March of 2020 and 2021, the CAPU team conducted fewer patrols because more time was spent fighting wildfires. Notwithstanding this, the number

Table 2 Ranger patrol effort (RPE), snare volume and rate of snare removal at Prambei Mom Community Forest in February–July of 2020 and 2021.

Month	2020				2021				% Change		
	RPE	Snare Volume	Rate	RPE	Snare Volume	Rate	Snare Volume	Rate			
	No. of Patrol Hours	Length of Snares (m)	Total Snares Removed	Snares/Patrol-Hour	No. of Patrol Hours	Length of Snares (m)	Total Snares Removed	Snares/Patrol-Hour	Total Snare Length	Total Snares/Month	Snares/Patrol-Hour
Feb.	42.5	0	0	0	65.8	24.0	33	0.5	NA	NA	NA
Mar.	31.5	40.0	15	0.5	68.9	50.0	69	1.0	25.0	360.0	110.0
Apr.	34.7	75.0	48	1.4	57.9	220.0	100	1.7	193.3	108.3	24.8
May	18.0	0	0	0	56.4	52.0	25	0.4	NA	NA	NA
Jun.	88.5	0	0	0	74.9	90.0	85	1.1	NA	NA	NA
Jul.	68.6	220.0	87	1.3	65.9	238.0	136	2.1	8.2	56.3	62.7
Total	283.7	335.0	150		389.8	674.0	448		101.2	198.7	
Mean				0.5				1.1			54.5

of snares removed per patrol hour was higher in every month in 2021 than 2020 (Fig. 2).

Known banteng fatalities and camera trap evidence

As of August 2021, at least five bantengs have been killed in the PMCF by hunters and/or snares since early 2018 (Table 3). Following the arrest of a hunter who shot an adult male banteng in March 2018, no further safari-style shooting incidents have occurred at the site. However, local hunters with rifles were recorded by camera traps in May 2020, which resulted in their apprehension the following month.

Over a total of 2,076 camera trap nights in 2020, six distinct bantengs were photographed with wounds between March and May, with only one newly inflicted snare injury (Table 4). Of these six individuals, one has likely died from the injuries (Table 3, No.5) and two infections remained active on individuals as of August 2021. No wounds fully healed over the study period. Seven new individuals were photographed with injuries in April–August 2021, of which six appeared to be new wounds or distinct bantengs not previously identified with any injury over 1,592 camera trap nights (Table 4). Figure 3 shows examples of different animals photographed during the study period with old or new snare wounds. Four of the six individuals identified in 2020 were male, compared to two of the seven animals registered in 2021. Although calves and juveniles were photographed during the study period, including eight distinct calves, none showed evidence of injuries due to snares.

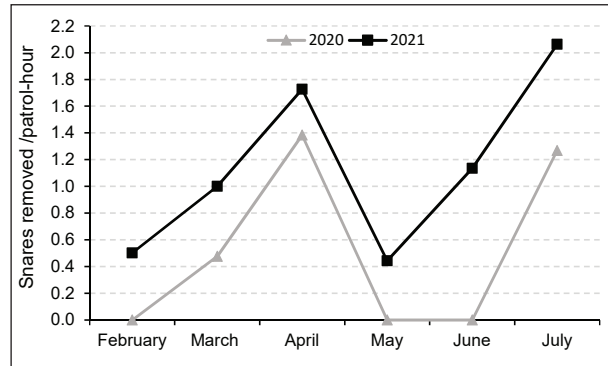


Fig. 2 Variation in snare removal rates in Prambei Mom Community Forest in February–July of 2020 and 2021.

Discussion

By every measure, threats posed by snares to the banteng population in the PMCF escalated alarmingly between February–July 2020 and the same period in 2021. The volume of snares detected within the PMCF and surrounding sugarcane plantations increased almost 200% in 2021 and despite additional patrol efforts the same year, the hourly rate at which snares were detected and removed increased almost 55%. More bantengs were also identified with snaring wounds or broken snares on their legs from camera trap images in 2021, despite greater sampling effort in 2020. In addition, two were killed by snares in 2018–2019 and one was shot, and two more have died since the CAPU approach was introduced in 2020. Furthermore, because the banteng population moves between the PMCF and surrounding

Table 3 Documented fatalities of adult bantengs in Prambei Mom Community Forest in 2018–2021.

No.	Year	Month	Sex	Cause of Death	Details
1	2018	Mar.	Male	Shot	Rangers called WA when they heard shots fired, and a law enforcement team apprehended the hunter.
2	2018	Apr.	Male	Snare injury	Banteng was snared but broke free and was wandering around injured. WA staff and rangers ultimately captured and treated the animal, but it died under sedation.
3	2019	Mar.	Female	Snare injury	Banteng was snared but broke free and was wandering around injured. WA staff and rangers ultimately captured and treated the animal, but it died under sedation.
4	2020	Feb.	Male	Snare injury	Found dead in a snare. Had also lost a leg due to a previous snare injury.
5	2021	Aug.	Male	Snare injury	A male banteng frequently captured on three cameras with a swollen front right hoof and missing front left foot was last photographed 5 July 2021. Rangers discovered an old carcass near the pool where this male was last photographed on 13 August. This was too decomposed to determine if it was the same male although this is highly likely.

Table 4 Banteng with snare injuries detected by camera traps in Prambei Mom Community Forest in March 2020–August 2021.

No.	First Record	Details of Wound	Age of Wound	Status of Injury ¹	Age of animal	Sex (M/F)	Distinguishing features of animal (if present)
1	Mar.'20	Swollen front left hoof, line of blood from snare	New	Active	Adult	M	Yellow coat, large slit in lower left ear
2	Mar.'20	Swollen and infected front left hoof	Old	Active	Adult	M	Dark brown, slit in upper left ear
3	Apr.'20	Swollen front right hoof, missing front left foot	Old	Death from injury suspected	Adult	M	Fig. 3, upper left image
4	May'20	Swollen front right hoof, scar line on leg from snare	Old	Stable	Adult	M	Dark brown, small tear on upper right ear
5	May'20	Scar line on upper front right leg, swollen front left hoof	Old	Stable	Adult	F	Long, curved horns, left horn curved under right
6	May'20	Missing front left foot	Old	Unknown	Adult	F	Short upright horns, no curve
7	Apr.'21	Swollen and infected front left hoof, open wound	Old	Active	Adult	M	Yellow coat, tear on upper and lower left ear (Fig. 3, upper right image)
8	Apr.'21	Infected lower front right leg, raw skin in line from snare	New	Unknown	Adult	F	
9	Jun.'21	Swollen front left hoof	New	Unknown	Adult	F	
10	Jun.'21	Front right leg, open bleeding wound and visible snare still attached to leg	New	Unknown	Adult	F	Broken left horn (Fig. 3, lower left image)
11	Jun.'21	Infected back right foot, open wound	New	Unknown	Adult	F	
12	Jul.'21	Straight line cut into right front leg, snare possibly still attached to leg, no visible infection	New	Unknown	Sub-adult	M	
13	Aug.'21	Left back leg, line cut from snare, blood visible	New	Unknown	Adult	F	Fig. 3, lower right image

¹ As of August 2021.

sugarcane plantations, it is also likely some deaths were not discovered by patrols such that the true number of fatalities is higher than presently documented.

Similar increases in the number of snares, hunting camps and live animals discovered in snares have been documented at other sites patrolled by CAPU's and professional ranger teams in Cambodia. For example, the Chi Phat CAPU operates in southwest Cambodia, patrolling forests that surround a wildlife release station in Tatai Wildlife Sanctuary. In February–July 2021, the rate of snare removal at Chi Phat increased >85%, while the quantity of normal (non-civet) snares detected increased almost 360% compared to the same period in 2020 (WA, unpublished data). In just 5-weeks in April–May 2021, the Chi Phat CAPU discovered two hunting camps with snare lines set nearby, evidence of hunting

dogs, and separate bands of hunters with their dogs, a rare occurrence in previous years. In addition, whereas the CAPU team in the Phnom Tamao Protected Forest did not find any live animals snared in February–July 2020, a live sambar *Rusa unicolor* stag was found snared around the neck during the same period in 2021. Similarly, professional ranger patrols undertaken by the Cardamom Forest Protection Program removed greater numbers of snares in February–July 2021 compared with the same period in 2020. In this case, the volume of snares removed increased 22% from 9,422 snares in 2020 to 11,517 snares in 2021, whereas the length of wildlife netting removed increased 55% (WA, unpublished data). Taken together, these results indicate that the number of snares set, detected and removed in sites across Cambodia increased markedly in February–July 2021 compared with the same period in 2020.



Fig. 3 Camera trap photos of wounded banteng detailed in Table 4: (upper left) No. 3, male with missing left front foot—old wound, dead; (upper right) No. 7, male with swollen, infected left front foot—old wound, active; (lower left) No. 10, female with bloody right front foot—new wound; (lower right) No. 13, female with bleeding wound on back left leg—new wound.

Studies around the world have found that measures to contain the pandemic have resulted in devastating socio-economic impacts (Park *et al.*, 2020; Shrestha *et al.*, 2020; Usui *et al.*, 2020). The timing of the surge in snaring we document coincides with the period when COVID-19 cases in Cambodia increased significantly due to the country's first major community outbreak and as the socio-economic impacts of the pandemic worsened. Largely spared from the effects of the pandemic in 2020 and austerity measures taken in other countries to prevent its spread, Cambodia began to experience these in early 2021 when case numbers suddenly rose from fewer than 500 on 1 February to over 77,000 on 31 July (Worldometer, 2021). The tourism, export manufacturing and construction sectors that have been hit hardest employ 40% of the workforce (Kuntear, 2021). Disaggregated data on socio-economic measures in Cambodia is sparse, particularly for our study period. However, findings from quarterly household surveys undertaken by the World Bank since early 2020 indicate the socio-economic impacts of COVID-19 were greater in 2021 than 2020. For example, almost half of respondents reported

their economic status was worse in March 2021 than the previous year and “moderate-or-severe food insecurity” increased from 34% in December 2020 to 55% among poor households (Karamba *et al.*, 2021).

Our study adds to a growing body of research examining the links between the socio-economic impacts of the pandemic and increased exploitation of wildlife and forests in Africa and Asia (Brancaion *et al.*, 2020; Waithaka, 2020; Koju *et al.*, 2021). Several studies have found that after lockdowns and travel restrictions were introduced at specific sites, livelihoods were impacted and illegal exploitation of nearby wildlife and forest resources increased (Cherkaoui *et al.*, 2020; Aditya *et al.*, 2021; Koju *et al.*, 2021; Rahman *et al.*, 2021). We posit that the same has occurred in the PMCF after strict prevention measures were introduced in Cambodia in 2021.

Given the large numbers of Khmer who migrate domestically or internationally for jobs in sectors that have been heavily impacted by COVID-19 containment measures (e.g., hospitality, construction and manufacturing), pressure on natural resources has likely increased

at sites across Cambodia as unemployed workers return to rural communities. Approximately 200,000 migrant workers have returned to Cambodia since the pandemic began and a recent United Nations survey found over 50% are indebted and nearly 30% have no household income (Anon, 2021). Remittances from people who migrate to urban centres or abroad for work are essential to the Cambodian rural economy (Hutt, 2021) and in disrupting work migrations, COVID-19 created a surplus of domestic labour as people returned from abroad, making it more difficult for families to service household debts (Res, 2021). In this context, decreasing household income may be a driver for increased wildlife snaring as rural people return to natural resource exploitation to make ends meet. In the face of this growing pressure, more must be done to safeguard Cambodia's remaining wildlife, especially important populations such as the bantengs at the PMCF, both within and outside of protected areas.

The banteng population at the PMCF is currently the only known population of the species remaining in the entire Cardamom Mountains rainforest eco-region. The ongoing camera trap survey at the PMCF may show this population exceeds 50 individuals, which would make it one of 6–8 remaining subpopulations of this size outside of northeastern Cambodia (Gardener *et al.*, 2016). Although deaths of adult bantengs have been recorded at the PMCF, one hopeful sign is that newborns continue to be identified, none of which show evidence of snaring injuries. Given the location of the PMCF, hundreds of kilometres from the banteng stronghold in northeast Cambodia and its isolation from other subpopulations, its banteng population may be genetically distinct as well. Bottlenecking effects have been found in populations of non-native bantengs and it has been suggested that this may occur in isolated wild populations (Bradshaw *et al.*, 2007). Eld's deer *Cervus eldi* represents another Endangered species at risk of inbreeding due to isolation, and geneticists have recommended transferring individuals between populations where possible to reduce the degree of inbreeding (Balakrishnan *et al.*, 2003). Should bantengs need to be translocated in the future for such purposes, the population at the PMCF could represent an important reservoir of genetic diversity for species conservation efforts.

Bantengs belong to the class of Southeast Asian megafauna described by Figel *et al.* (2021) for which hunting has surpassed habitat loss as the primary driver of species decline. With over 100,000 snares removed from the Southern Cardamom National Park alone in 2010–2015 (Gray *et al.*, 2018) and no records of bantengs generated by a multi-year survey of ground-dwelling mammals

in seven protected areas in southwest Cambodia (Gray *et al.*, 2017), it had been assumed these were extirpated in the region until the community rangers at the PMCF requested outside help. Our analysis of camera trap data from the PMCF to date suggests increasing numbers of bantengs are wounded by snares, with a larger number of injured animals declining in condition over time. Combined with at least four snare-related deaths since 2018, this suggests a large portion of snared bantengs ultimately die from their injuries. In such a relatively small and isolated subpopulation, even a small number of deaths each year could devastate the herds within a few generations. Indeed, studies have shown that mortalities from snaring have significantly affected lion *Panthera leo* and spotted hyena *Crocuta crocuta* populations in southern Africa, with “evidence for population declines and extirpation of large carnivores in the most heavily affected areas” (Loveridge *et al.*, 2020). Where industrial-scale snaring has occurred in Laos and Vietnam, species once reasonably common have become barely detectable by camera traps within just a few years (W. Duckworth, pers. comm.).

It is not a stretch to conclude that unless further action is taken immediately to address the problem, snaring could extirpate the banteng subpopulation in the PMCF. Between 2010 and 2020, populations of bantengs declined by 81% and 60% in the Srepok and Phnom Prich Wildlife Sanctuaries respectively in eastern Cambodia, whereas the rate patrols encountered and removed snares increased more than a hundredfold from 0.04 to 6.46 per 100 km (Groenenberg *et al.*, 2020). This massive increase in snaring is believed to be a significant driver in the rapid decline of this population (Gray *et al.*, 2021). If the world's largest population can be so reduced across several massive protected areas patrolled by professional rangers within a decade, the impact of a >50% increase in snaring on the small and highly vulnerable subpopulation in the PMCF is likely to be catastrophic.

Loss of bantengs from the PMCF would be extremely painful for the local rangers who have worked for almost two decades to ensure the survival of this socially and culturally unique subpopulation. Though the rangers continue to do everything they can to protect the remaining animals, increased patrol efforts do not necessarily result in higher detection of snares (Ibbett *et al.*, 2020). With additional pressures generated by the pandemic and related measures to limit the spread of the virus, the community rangers cannot compete with the increasing volumes of snares set in the forest and surrounding area without further support. As concluded by Brunner *et al.* (1999): “Communities are best at preventing and detecting forest crimes, but once

detected, it is the responsibility of the state's law enforcement agencies to suppress them.”.

Cambodia has two main laws which govern the use of snares. These are the 2002 Forestry Law which is applied by the FA in community forests such as the PMCF and unprotected state forests (FA, 2003), and the 2008 Protected Areas Law which is applied by the MoE on state-protected lands (MoE, 2008). Article 49 of the former law strictly prohibits hunting, harming or harassing wildlife, with particular mention that it is prohibited to “hunt, net, trap or poison” rare and Endangered species such as bantengs. Article 97 of the same law states that the penalty for Class I offences (which include hunting, killing, trading or exporting Endangered species) is 5–10 years in prison and confiscation of all evidence. Article 98 states penalties for Class II offences against wildlife (such as hunting in protected zones, hunting rare species and hunting wildlife by dangerous means) include a prison term of 1–5 years and a fine of 10,000,000–100,000,000 riel (FA, 2003) (equivalent to \$2,500–25,000 USD). The Protected Areas Law similarly prohibits wildlife hunting. For instance, article 61 of the law stipulates that it is an offence to “Catch, trap, hunt, cause injury, poison, kill, take out, collect eggs and offsprings from their original habitats of any Vulnerable, rare, or Critically Endangered wildlife species” and article 58 sets a penalty of 100,000 to 1,000,000 for these acts (MoE, 2008). These provisions should be sufficient to guard against snares in theory.

Yet despite this legal framework, Cambodian laws, like those in neighbouring countries, do not “include provisions that clearly prohibit the possession of materials (like metal wires or nylon ropes) that can be quickly fashioned into snares” (Gray *et al.*, 2021). Snares are made from commonplace materials such as nylon, wire or cord and are usually attached to natural anchors in the forest or countryside, such as small trees. Patrol teams seldom meet hunters while they are setting the snares and unless they possess wildlife at the time of apprehension, prosecutions and penalties are generally not applied (N. Marx, pers. obs.). This makes it difficult even for professional ranger teams to punish hunters effectively unless they are caught in the act of snare setting or holding wildlife. Fines for hunters apprehended while setting snares also do not appear to be an effective deterrent, although prison sentences are (B. Davis, pers. comm.). Unfortunately, these options are not available to the PMCF CAPU team however, since this comprises a group of community volunteers without law enforcement authority. Only with greater government support can the likelihood of apprehending offenders be increased, existing laws be more strictly applied, and courts encouraged to prosecute offenders and apply maximum penalties.

In the longer term, policy and legislative reforms that increase legal penalties and prohibitions on snaring and improve enforcement of existing laws are key to solving the snaring epidemic in Southeast Asia (Gray *et al.*, 2018, 2021; Figel *et al.*, 2021). The kouprey *Bos sauveli*, a species closely related to bantengs, is likely extinct (Hassanin & Ropiquet, 2007), whereas tigers have now been extirpated from the country and snaring has proven to be a major cause of declines of such megafauna species (Figel *et al.*, 2021). If authorities do not act swiftly to counter the current increase in snaring, banteng populations in the PMCF and northeast Cambodia may follow the same path. If the banteng population in the PMCF is to survive, the rangers need greater government support, increased law enforcement presence and stronger penalties for offenders who set snares in the PMCF and neighbouring plantations.

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