Can snare removal safeguard protected areas caught in the Southeast Asian snaring crisis? Promises and perspectives

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Abstract

Unsustainable snaring is causing biodiversity declines across tropical protected areas, resulting in species extinctions and jeopardizing the health of forest ecosystems. Here, we used 11 years of ranger collected data to assess the impact of intensive snare removal in two protected areas in Viet Nam. Snare removal resulted in significant declines in snare occupancy (36.9, 95% BCI [4.6, 59.0] reduction in percent area occupied), but snaring levels nonetheless remained high (31.4, [23.6, 40.8] percent area occupied), and came with a substantial financial cost. Our results indicate that snare removal remains an important component of efforts to protect tropical protected areas, but by itself, is likely insufficient to address this threat. To achieve the target of zero snaring in protected areas, a multifaceted approach will be necessary that combines short-term reactive snare removal with long-term proactive programs that address the underlying drivers behind snaring.

Introduction

Unsustainable hunting has defaunated tropical forests around the world (Harrison et al, 2016; Benítez-López et al, 2017, 2019), and preventing further defaunation is a priority for addressing global biodiversity loss (Laurance et al 2012; Barlow et al 2018). Furthermore, because large vertebrates perform ecological functions that are integral to maintaining healthy tropical ecosystems (Lacher et al, 2019), the loss of forest fauna jeopardizes a number of ecological services linked to human well-being (Krause & Tilker et al, 2022). For example, defaunation has been linked to reduced carbon storage capacities in tropical forests (Bello et al, 2015; Osuri et al, 2016), increase in prevalence of zoonotic diseases (Young et al, 2014), and loss of ethnocultural identity for indigenous peoples (Bogoni et al, 2020).

Protected areas remain the most prominent conservation approach to safeguard pan-tropical wildlife, but the effectiveness of site-based conservation strategies varies (Watson et al, 2014; Coad et al, 2019) and has been insufficient to prevent the widespread decline of mammal and bird species in some regions (Benítez-López et al, 2017, 2019). Tropical defaunation has been particularly severe in Southeast Asia, where illegal unsustainable hunting realized through the setting of wire snares has depressed wildlife populations in many protected areas, and remains a significant and ongoing threat (Belecky & Gray, 2020; Gray et al, 2021). A recent study, for example, found that snaring is a more immediate and severe threat to Southeast Asian faunal communities than forest degradation in some areas (Tilker & Abrams et al, 2019). To prevent further defaunation in Southeast Asia, and thus maintain the ecosystem services and functions of its tropical forests, it is important to assess the effectiveness of conservation actions designed to counteract the ongoing Southeast Asian 'snaring crisis'.

Although several conservation actions have been proposed to counter snaring, snare removal remains the primary strategy employed in Southeast Asian protected areas (Belecky & Gray, 2020).

Snare removal is popular because it is straightforward and non-controversial (Belecky & Gray, 2020), and it will likely continue to prevail as the main approach to address snaring across most protected areas. Some studies have assessed the impact of snare removal on snaring levels, with both positive (Linkie et al, 2015) and equivocal (Becker et al, 2013) findings. Most of these studies, however, have been over relatively short time periods or in areas where snaring levels do not reach the high levels reported for many parts of Southeast Asia (Jachmann, 2008; Becker et al, 2013; Watson et al, 2013; Linkie et al, 2015). The extent to which snare removal reduces snaring pressure over longer time horizons remains unexplored, hindering an objective evaluation of its effectiveness. For protected areas operating under limited resources, this lack of knowledge is worrisome because employing dedicated snare removal teams is expensive, potentially limiting investment in other strategies to reduce snaring pressure.

Here, we used 11 years of patrol data from two contiguous protected areas in central Viet Nam to assess the impact of snare removal on snaring levels over time. Like many protected areas in Southeast Asia, the reserves are under high levels of snaring pressure, and snare removal has been the main strategy to counteract this threat. Within this context, we seek to understand how snare removal fits within a larger framework to counter snaring, including measures that prevent snares from being set; we refer to these approaches as “reactive” and “proactive”, respectively, even though we acknowledge that these two categories are not always clear cut, and reactive patrolling may also have proactive effects discouraging setting of snares (Moore et al, 2018; Dancer et al, 2022; results of this study). To understand the financial investment needed for snare removal, we also investigated the cost needed to implement these efforts, and possible sustainable opportunities to support this undertaking. We discuss our findings within the wider context of a holistic framework for achieving the long-term objective of zero snaring.

Methods

Collecting and processing patrol data

Ranger patrols were conducted in the contiguous Hue and Quang Nam Saola Nature Reserves by Forest Guard teams, coordinated by World Wide Fund for Nature (WWF), together with local Forest Protection Department staff. Threat data was input into Management Information System (MIST) and Spatial Management and Reporting Tool (SMART) systems. MIST and SMART data were curated and cleaned to create a database for analyses. We used patrol tracklog data to calculate monthly patrol effort in a grid of 200 x 200 meter cells. Data for traps were converted into detection/non detection matrices using monthly occasions using the same grid for analysis with occupancy models (MacKenzie et al, 2017). See Supporting Information.

Description of the covariates

We considered the effect of five site covariates, which we assumed could influence snare site selection by hunters, on snare occupancy: village density, remoteness, elevation, terrain ruggedness (topographic ruggedness index), and topographic position index (TPI) (Figure S1). All covariates were calculated in QGIS 2.18.9 (QGIS Development Team, 2016) and R version v4.1.3 (R Core Team, 2022). See Supporting Information.

Model description

We used a multi-season occupancy model (Mackenzie et al, 2017) to assess the distribution of snares across both reserves. We implemented the model in a Bayesian framework in R using the *ubms* package v1.1.9005 (Kellner et al, 2022). Monthly survey effort was calculated as the percentage of each cell's area surveyed within a month. We divided the survey period into semesters (the first and second half of each year) and used these as primary occasions. The second semester of 2012 and the first semester of 2013 were removed due to missing data.

The final model included the effect of survey effort as a covariate on detection probability and the five covariates on occupancy probability; a random effect of year on the coefficients of all occupancy covariates and the occupancy intercept (allowing covariate coefficients and baseline occupancy to vary between years); and a random effect of year-semester on detection probability (allowing variation in detection probabilities, e.g. due to changes in staff). We found no evidence of spatial autocorrelation. All models converged, and showed adequate fit (see Supporting Information).

We used parameter estimates to predict occupancy probabilities for each year and raster cell. From these, we calculated the percentage of area occupied (PAO) as the percentage of cells predicted to be occupied in each year for each posterior sample. The resulting distributions of PAO values were summarized to obtain mean and 95% Bayesian credible intervals (BCIs) of PAO.

We also used occupancy models to assess the influence of past patrolling effort on snare occupancy. Specifically, we fit separate single-season occupancy models to data from the second semester of 2016 and 2021, using the same covariate structure as described before, and adding as a covariate on occupancy the total snare patrolling effort summed over the preceding six semesters, calculated for each cell. We picked these two semesters as the approximate mid and endpoint of our time series.

Financial investment

We estimated the costs to remove a single snare by the Forest Guards, with data provided by WWF (WWF internal and unpublished data), and the cost to set a snare by a local hunter, with cost estimates provided by consultation with experts familiar with the study area (see Supporting Information).

Results

Patrolling effort and snares removed

Between 2011 and 2021, the snare removal teams patrolled 3,040 days, covering 253,048 ha (Figure 1A). Patrol effort varied among and within years (Figure 1A; Figure S2). Overall, 99.2% of all 200 x 200 m cells received some level of effort within the study period (Figure S2). Patrols removed 118,151 snares from the two reserves (Figure 1A), with more snares removed from the Hue Saola Nature Reserve compared to Quang Nam Saola Nature Reserve (Figure S3).

Snare occupancy over time

The multi-season occupancy model showed that the mean snare percent area occupied (PAO) decreased by 36.9% (95% BCI [4.6, 59.0]) from 2011 to 2021 (Figure 1E & 1F; Figure S4). The largest decline was 46.1% (95% BCI [21.8, 64.0]) between 2011 and 2016, after which PAO remained approximately stable (Figure 1F). The decline in snare PAO was slightly stronger in the Quang Nam Saola Nature Reserve (Figure 1D). The median snare occupancy across both sites during the last year was 31.4% (95% BCI [23.6, 40.8], Figure 1C). Trap detection probability increased with the amount of patrol effort (Figure 1B). Predicted snare occupancy increased with topographic position index (TPI), elevation, remoteness, and ruggedness, and decreased with village density (Figure 1C; Table S2).

Finally, snare occupancy probability decreased with increasing previous patrol effort (Figure 1G); the effect was significant (95% BCIs did not overlap 0) in 2016 (-0.48, 95% BCI [-0.77, -0.24]) and 2021 (-0.67, 95% BCI [-0.99, -0.40]), but had a larger magnitude in 2021.

Financial investment

To achieve this level of snare reduction, it was necessary to invest approximately 220,000 USD annually (WWF unpublished data), resulting in an average cost of 20.5 USD per snare removed; this is more than an order of magnitude more expensive than the cost of setting a single snare (1.13 USD; Figure 1H). During the initial years, patrol costs were covered by WWF, with financing provided through international biodiversity conservation aid funds. In 2014 patrol costs began to be

supplemented by a Payment for Forest Environmental Service (PFES) initiative by the Vietnamese government, and provided directly to the provincial management authorities. Some Forest Guard costs began to be covered by PFES funding starting in 2015, increasing to 15% in 2021 (WWF unpublished data).

Discussion

We show that, with intensive and sustained snare removal, snaring levels can be significantly reduced within tropical protected areas. Snare removal is therefore an important component of strategies to counter the widespread snaring in Southeast Asia, if employed at the appropriate spatial and temporal scales. The constant effort needed to reduce snaring and maintain depressed snaring levels may require conservation stakeholders to re-think how they approach site-based conservation, especially since most initiatives are funded by short-term projects that last at best a few years. Clearly, for protected areas facing high levels of snaring pressure, long-term engagement is needed to counter this threat. Overall snare occupancy declined steadily for the first six years of patrolling, and then appeared to plateau. This may indicate that, after an initial decline in snaring, subsequent reductions are progressively more difficult to secure. Furthermore, declines in snaring were stronger near the edges of the reserves and along access points. Such a finding highlights the importance of increasing patrol effort in remote areas, especially since these are more likely to harbor conservation-priority species (Tilker et al, 2020). In this way, robust monitoring of patrol data has the potential to offer insights into patrolling strategies that can help inform adaptive management.

Our finding that prior patrolling decreased the probability of snare occupancy suggests that patrolling acts as a deterrent to future snaring. Other studies have also indicated the deterrence value of patrolling (Moore et al, 2028; Dancer et al, 2022). One possible explanation is that, with continued snare removal, hunters experience increasingly diminishing rates of return, and thus the cost-benefit

ratio shifted so that it was less profitable to set snares in the study areas. In other parts of the world, the threat of arrest or fines might also serve as a deterrent; in our sites in central Vietnam, however, arrests for snaring are rare, due in part to legal loopholes that do not penalize people for having wire materials inside protected areas (Belecky & Gray 2020; Gray et al, 2021), and in part because snaring is seldom treated as a serious forest crime. We note that it is possible that local reductions in snaring in our sites caused poaching to spill over to other protected areas which did not receive intensive patrol effort; similar patterns of displacement have been documented for illegal logging in tropical protected areas (Ford et al, 2020). Additional studies are needed to assess potential leakage and, if present, ways to counteract it.

Despite the success of demonstrably reducing snaring levels in these protected areas, the snaring levels that persist suggests that wildlife populations are still threatened by unsustainable offtake. Snaring has already contributed to the loss or functional extinction of many larger vertebrates from these areas (Tilker et al, 2019) – including the saola (*Pseudoryx nghetinhensis*), a Critically Endangered bovid that these reserves were established to protect – and it seems likely that remaining conservation-priority and snaring-sensitive species will continue to decline unless snaring pressure is reduced further. However, we note that because species show different abilities to recover from unsustainable harvest, largely due to life history characteristics (Cardillo et al, 2008), it is possible that populations of some mammals and ground-dwelling birds will stabilize or increase with this level of snare reduction. Long-term wildlife monitoring is needed to assess population dynamics and potential recovery for individual species.

The financial investment necessary to attain such a level of snare reduction was substantial. With an estimated 13 million snares in the protected areas of Viet Nam, Laos, and Cambodia alone (Belecky & Gray, 2020), the cost to remove existing snares in Southeast Asian protected areas would likely sum to hundreds of millions of dollars. Moreover, the high cost of snare removal prompts questions about the long-term sustainability and scalability of this approach. It was only with a substantial and

continual investment from an external NGO that such intensive levels of snare removal were possible in the two sites. Given the general lack of financial and personnel resources, capacity, and government support that characterizes most protected areas in the region (Graham et al, 2021), similar snare removal projects can likely only be implemented if NGO stakeholders work in collaboration with government protected area staff. One option to increase the financial sustainability of snare removal is to access sustainable financing schemes, such as Payment for Ecosystem Services (PES, PFES in Viet Nam), Reducing Emissions from Deforestation and forest Degradation (REDD+), or Carbon and Biodiversity offsets. The use of such incentive programs seems to be increasing: In 2020, more than 80% of protected areas in Viet Nam obtained PFES funds at an average of 323 USD per km^2 (Emerton et al, 2021), which based on Decree No. 156/2018/ND-CP can be used for forest and biodiversity protection activities. However, these sustainable financing schemes are unlikely to be a shortcut to complete financing of snare removal operations; in the two reserves in our study, only 15% of the total costs could be covered by PFES in 2020 and 2021. Furthermore, funding alone will not guarantee effective replication of intensive snare removal in Southeast Asian protected areas. To guarantee transparency and accountability, protected area managers should set clear targets for threat reduction, and these metrics should be monitored. Our analytical workflow provides a streamlined approach to facilitate such robust analyses of patrol data in the future.

Our results indicate that snare removal alone is likely insufficient to protect wildlife in Southeast Asian protected areas. Although this is not unexpected, since snare removal does not address the fundamental drivers behind snaring, our results provide strong empirical evidence that a multifaceted approach is needed that combines short-term immediate responses within protected areas, such as snare removal, with long-term approaches in rural and urban areas (Figure 2). Such long-term responses could include demand reduction for illegal wildlife products (Shairp et al, 2016), strengthened legislation that penalizes the possession of wire material inside protected areas

255 (Belecky & Gray, 2020), community engagement that promotes local guardianship (Viollaz et al,
256 2022), improved law enforcement coordination and capacity (Dudley et al, 2013), and engagement
257 with local judicial authorities to ensure appropriate prosecution and sentencing (Nurse & Nurse,
258 2015). Simultaneously, actions which support inclusive governance of protected areas and nature-
259 based and nature-positive development opportunities for buffer zone communities are required to
260 offset potential losses of income, ensure equitable benefit sharing, and harmonize both economic
261 advancement and biodiversity management and protection (Borrini et al, 2004; Andrade & Rhodes,
262 2012). Together, the activities needed for such a holistic approach will involve coordination among
263 multiple government and non-governmental stakeholders and will require considerable financial
264 investment.

265 Overall, our results are encouraging in that they show that sustained snare removal can be an
266 effective method for reducing snaring. Therefore, intensive snare removal schemes should be
267 expanded to other protected areas as a first and immediate response to safeguard highly threatened
268 wildlife populations. For these populations, snare removal could buy crucial time needed to
269 implement more proactive and long-term approaches, many of which could take time to become
270 effective. Ideally, these efforts should be funded through sustainable financing mechanisms to allow
271 for the long-term continuity necessary to suppress snaring. We acknowledge that, because the
272 drivers behind snaring are so complex, the impact of sustained and intensive snare removal in other
273 areas may differ from the results that we present here, nonetheless, the high demand for wild meat
274 in urban centers fueling snaring in central Vietnam is present across Southeast Asia (Lee et al, 2014;
275 Belecky & Gray, 2020), and we therefore believe that the situation in our sites is representative of the
276 larger snaring problem in the region. Perhaps most importantly, our findings illustrate the
277 importance of viewing snare removal as one component of a wider and multi-faceted conservation
278 response that addresses these underlying drivers; to rely solely on snare removal to safeguard
279 protected areas is unlikely to sufficiently address the threat. If we want to prevent the extinction of

many of the region's iconic megafaunal species, as well as to preserve the health of the tropical ecosystems that Southeast Asian societies depend upon, snare removal operations will need to be embedded within a more holistic and proactive framework that prevents snares from being set in the first place.

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Figures

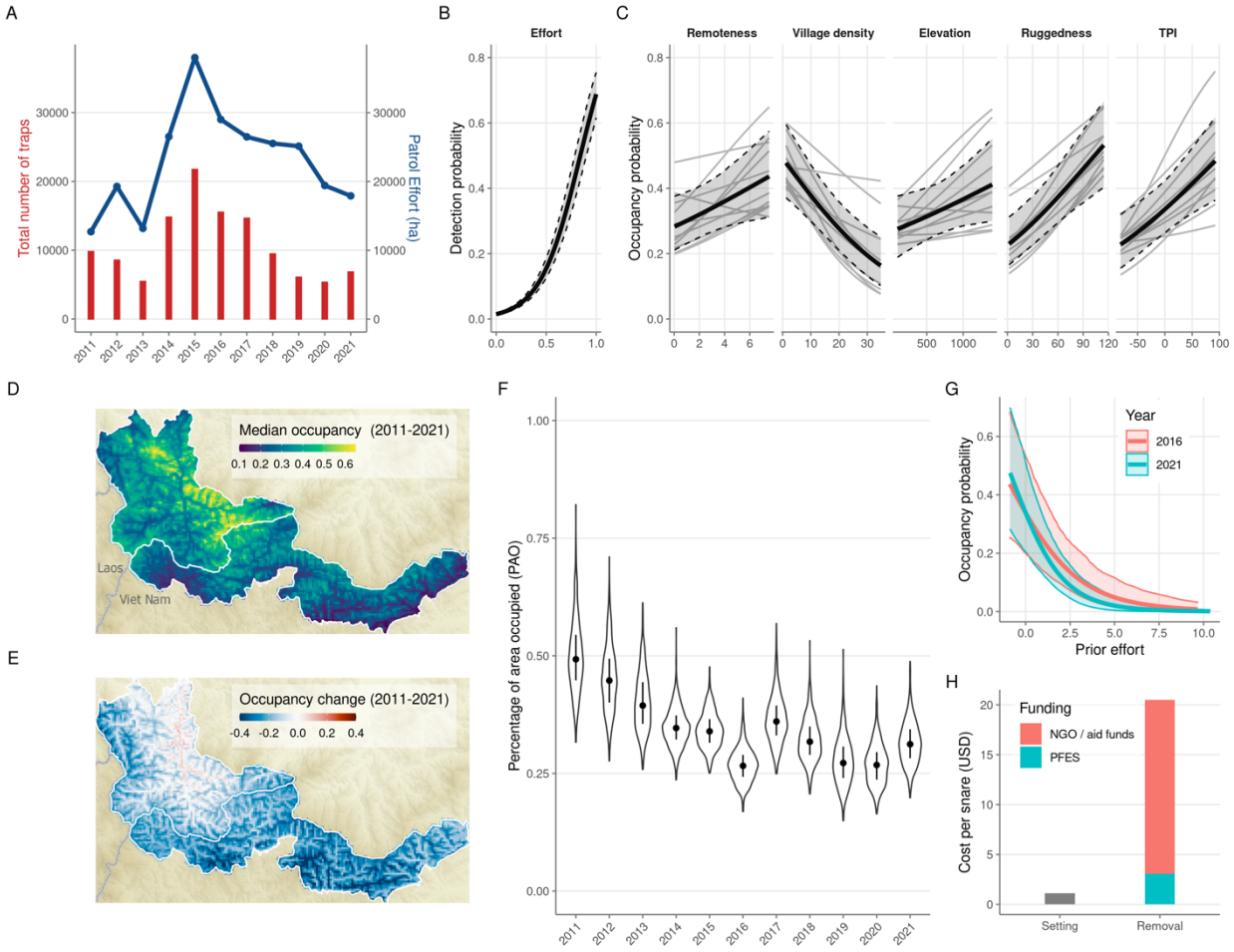

Figure 1: (A) Total number of snares and patrol effort (ha); (B) response of snare detection probability to survey effort; (C) response of snare occupancy probability to covariates; thick black line shows mean effect for all years, gray shaded area show 95% confidence intervals (B and C), and light gray lines show mean effect for individual years (C only); (D) median snare occupancy probability for survey period (2011-2021); (E) median change in snare occupancy probability across the survey period; (F) Percentage of area occupied (PAO) values for individual years; black dot indicates median and line indicates 50% posterior mass; based on predictions from multi-season occupancy model (D - F); (G) response of snare occupancy to prior patrol effort for two time periods,

2016 and 2021; and (H) cost of setting and removing an individual snare in the study areas, with removal cost divided by Payment for Forest Ecosystem Services and NGO aid funds.

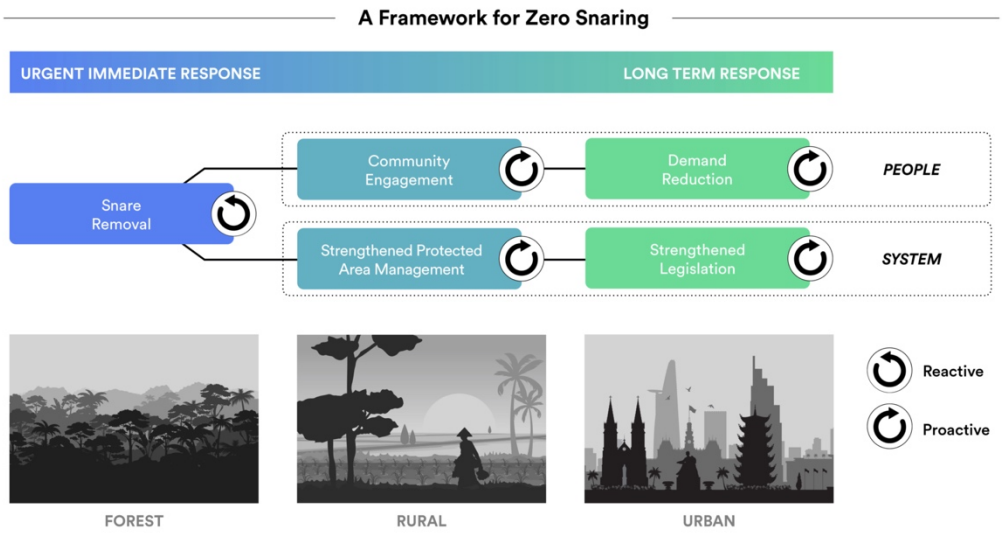

Figure 2: Conceptual framework for achieving the target of zero snaring using a combination of reactive and proactive approaches across different environments and time scales.