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Wildlife Species Recorded by Camera Traps in Reforested Lowland Rainforest and Peat Swamp Forest of Gunung Palung National Park, Indonesia

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ABSTRACT. – We quantified wildlife presence in two reforestation areas of Gunung Palung National Park (GPNP), one of the top biodiversity hotspots in Indonesian Borneo. Wildlife species were monitored using camera traps in two reforested ecosystems: lowland dipterocarp forest and peat swamp forest. The GPNP authority and the non-profit organization Alam Sehat Lestari (ASRI), in affiliation with the non-profit organization Health in Harmony (HIH), have conducted reforestation in the lowland dipterocarp forest since 2009 and the peat swamp forest since 2012. Cameras were placed at 13 locations from December 2020 to August 2022 using point and grid methods. Forty-seven wildlife species were recorded, including mammals (31 species), birds (14 species), and reptiles (2 species). Eighteen of these species are listed as Vulnerable, Endangered, or Critically Endangered by the International Union for Conservation of Nature. The wildlife documented in this study indicate that a reforestation approach emphasizing community engagement, long-term partnerships, and ecosystem functioning can support the restoration of heavily degraded lowland rainforest and peat swamp forest to viable habitat.

KEYWORDS: camera trap, presence, reforestation, wildlife species

INTRODUCTION

Borneo, an island of the Sundaland Region, is one of the world's most valuable and vulnerable biodiversity hotspots (Mackinnon et al., 1996; Myers et al., 2000; Mittermeier et al., 2011; Bellard et al., 2014). From 1973 to 2010, Borneo lost nearly a third of its primary forest (Gaveau et al., 2014; Hrdina and Romportl, 2017). The remaining forest is increasingly degraded and fragmented, driven by land use policies, commodity plantations, and timber extraction by communities with limited livelihood alternatives (Hughes, 2017; Leo et al., 2022). Within legally protected areas, degradation by selective logging is one of the main threats to wildlife habitat (Bryan et al., 2013). In addition, many Bornean wildlife species are directly harmed by hunting, capture for illegal trade, fires, and zoonotic diseases transmitted through contact with humans (Meijaard and Sheil, 2007; Ocampo-Peñuela et al., 2020).

Some of the best-preserved habitat for Bornean wildlife lies in Gunung Palung National Park (GPNP), one of eight national parks in Kalimantan (Indonesian Borneo). Flagship species include the Proboscis Monkey (*Nasalis larvatus*), Sun Bear (*Helarctos malayanus*), Sunda Clouded Leopard (*Neofelis diardi*), Helmeted Hornbill (*Rhinoplax vigil*), and Rhinoceros Hornbill (*Buceros rhinoceros*). The seven ecosystem types in GPNP are mangrove, freshwater swamp, peat swamp forest, and lowland, rheophytic, montane, and subalpine rainforests (Ministry of Forestry, 2014). Of these, the GPNP long-term strategic plan prioritizes the conservation of lowland rainforest and peat swamp forest because they provide essential habitat for the Critically Endangered southwest Bornean Orangutan (*Pongo pygmaeus* ssp. *wurmbii*) (Gunung Palung National Park, 2022). These two ecosystem types are disproportionately threatened by selective logging, fires, and rice-field encroachment (Laurance et al., 1998; Curran et al., 2004; Hiller et al., 2004).

The Indonesian non-profit organization Alam Sehat Lestari (ASRI), with support from the US non-profit organization Health in Harmony (HIH), was founded in 2007 to protect the ecosystems of GPNP by implementing solutions designed by the 60,000 people living in 44 communities around the park. The first ten years of ASRI healthcare, livelihood, and reforestation programs contributed to a 70% reduction in deforestation in GPNP and a significant improvement in human health outcomes (Jones et al., 2020). In 2009, ASRI entered a long-term partnership with communities and the GPNP authority to actively reforest the most heavily degraded areas of lowland rainforest and peat swamp forest. The reforestation sites were chosen to reconnect forest fragments with wildlife corridors and discourage the use of degraded land as an access point for loggers and hunters to enter the core forest (Hughes, 2017; Nuttall et al., 2022).

Holistic metrics of ecosystem health, rather than simply the number of hectares planted, are necessary to evaluate reforestation programs. ASRI defines

successful reforestation by the presence of diverse and threatened wildlife species; the complexity of the food web, measured by the number of trophic levels represented; and the extent to which the reconnection of forest fragments is achieved (Edwards et al., 2014; Fawzi et al., 2020). After over a decade of reforestation, ASRI evaluated its program using camera traps. Camera traps are a cost-effective alternative to direct observation for measuring animals' relative abundance, behavior, and population and demographic data (Silveira et al., 2003; Foster and Harmsen, 2012; Wayne et al., 2013; Stojanovic et al., 2014; Molloy, 2018). In recent years, camera traps have been used to monitor a range of species, including birds (Suwanrat et al., 2015), elephants (Smit et al., 2017), and even invertebrates (Hobbs and Brehme, 2017). In addition to evaluating reforestation success, this study provides information about wildlife species distribution in Kalimantan. It will help ASRI and the GPNP authority to design conservation action plans for threatened species.

MATERIALS AND METHODS

Study sites

The forest currently encompassed by GPNP was first designated as a wildlife reserve in 1981 (Ministry of Agriculture, 1981). The national park status was established for 90,000 ha in 1990 and expanded to 108,044 ha in 2014 (Ministry of Forestry, 1990). Lowland rainforest covers more than half of the park area (61,163 ha or 57%) and provides the ecosystem services of fresh water and forest products to surrounding communities. The Dipterocarp trees that dominate this ecosystem, such as meranti (*Shorea* spp.) and ironwood (*Eusideroxylon zwageri*), are targeted by selective loggers for their valuable hardwood timber (Webb, 1997; Curran et al., 2004; Soehartono and Mardiastuti, 2014). Of all the ecosystems in GPNP, lowland rainforest is particularly vulnerable to timber extraction due to the lack of barrier mountains and the presence of navigable rivers (Hiller et al., 2004). Selective loggers degraded 38% of the GPNP lowland rainforest between 1988 and 2002 (Curran et al., 2004). The second largest ecosystem in GPNP is peat swamp forest (36,400 ha or 34% of the park area), characterized by wet, carbon-rich peat soil with an average depth of 1.3 m (Ruwaimana et al., 2020). This ecosystem buffers neighboring communities from flooding and provides a preferred habitat for southwest Bornean orangutans. It is vulnerable to wildfires and conversion to irrigated rice agriculture.

This study was conducted in two reforestation sites in GPNP: the Laman Satong lowland rainforest and the Sedahan peat swamp forest. ASRI has worked with local communities and the GPNP authority to reforest 79 ha at Laman Satong since 2009 and 30 ha at Sedahan since 2012. Reforestation is ongoing at both sites. Camera traps were installed to determine whether these severely degraded lands had been restored to habitat for diverse species (Fig. 1). Laman Satong sits on the southern edge of GPNP, bordered by the Trans Kalimantan road, community agricultural land, and a 1990s clear-cut from a timber concession which crossed into the park (Fawzi et al., 2020). Before ASRI began reforestation, Laman Satong was a sunny meadow dominated by cogongrass (*Imperata cylindrica*) and common bracken fern (*Pteridium aquilinum*), both of which burned annually and prevented the germination of the natural tree seed bank. Sedahan, on the western edge of GPNP, is bordered by rice paddies, abandoned farmland, and swidden cultivation of banana and other fruit trees outside the park. In 2010, neighboring community members converted the Sedahan peat swamp forest into rice paddies and cultivated them for one year. Then, the abandoned fields became dominated by fast-growing mahang shrubs (*Macaranga* spp.) (Helms IV et al., 2018). The replacement of the Sedahan peat swamp forest with first rice fields and then shrubs eliminated a corridor that previously connected two disjunct sections of lowland rainforest.

Materials

We deployed eight Bushnell CORE Series camera traps (7 units of DS No Glow, 30MP [Model: 119977C]; 1 unit of Core Low Glow, 24MP [Model: 119936C]) at 13 locations from December 2020 to August 2022. The cameras were set to hybrid mode (photo and video), 24-hour activation time, 3-photo capture number, 30-second video length, and 5-second interval. The cameras were placed in areas expected to be animal hotspots: next to water sources, in sparse underbrush, and near observed tracks, trails, and scat. Cameras were protected with metal casing and python locks and mounted on trees 30 to 40 cm aboveground (Mohd-Azlan and Engkamat, 2013). Cameras were checked or moved every two to three months. The coordinates of each camera were marked using the global positioning system (Fig. 1).

Camera trap installations

In Sedahan, camera traps were placed with a point method. In Laman Satong, cameras were placed in a grid with 500 m between cameras. Camera effort was measured by the total camera-days, defined as the

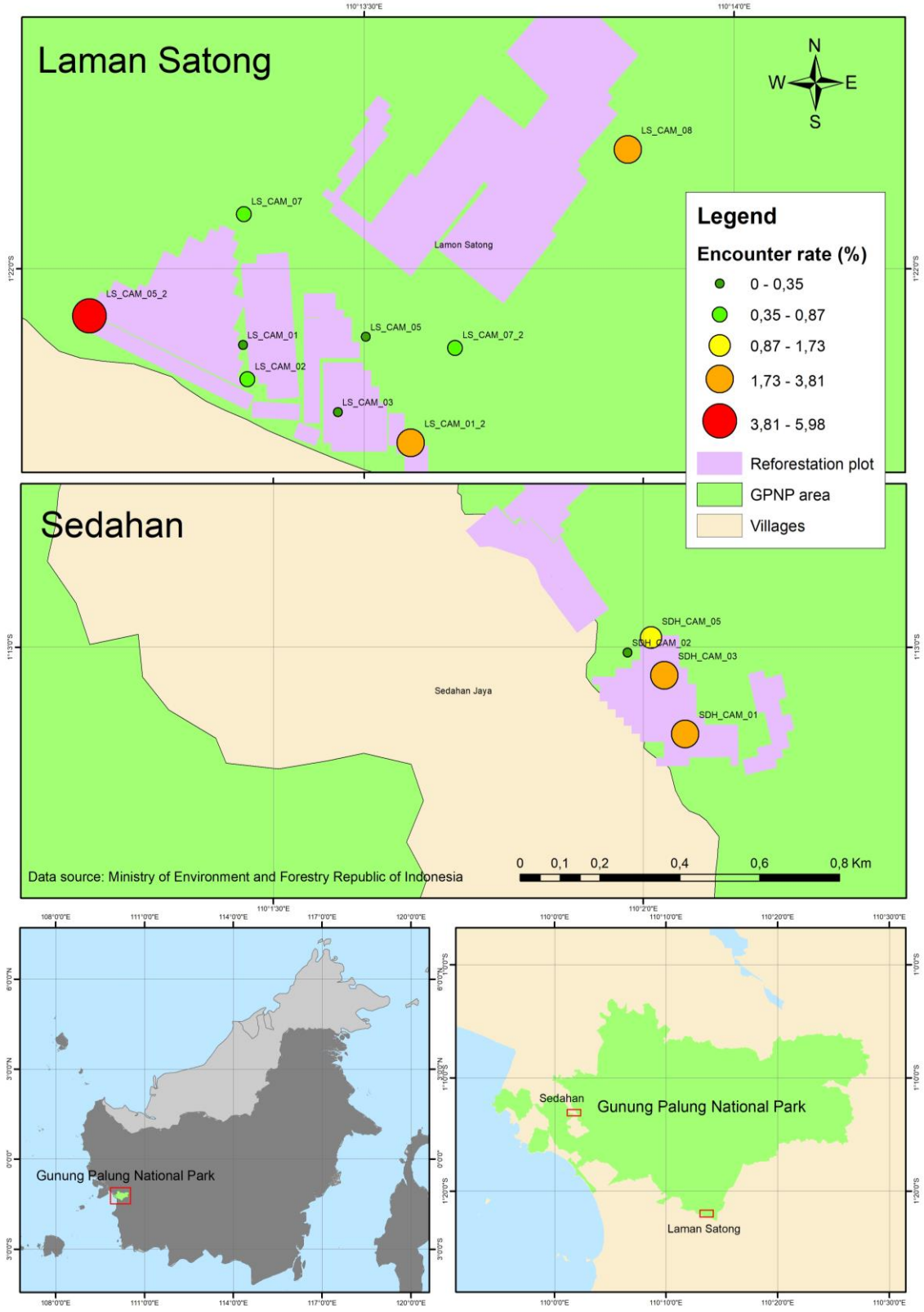

FIGURE 1. Camera trap locations and encounter rates in the Laman Satong and Sedahan reforestation sites of GPNP.

number of camera traps multiplied by the number of active days (Mohd-Azlan and Engkamat, 2013; Palmer et al., 2018). In total, we collected 1,155 camera-days of data across all locations.

Data analysis

Wildlife species recorded in photographs and videos were identified by visual comparison with field guides. Conservation statuses follow the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (https://www.iucnredlist.org/). We defined an independent detection as a photograph or video of a given species by a given camera within one hour; more frequent detections were considered non-independent (Mohd-Azlan and Engkamat, 2013; Mohd-Azlan et al., 2018). Encounter rate was calculated by the proportion of independent detections to camera-days for a given camera and visualized in ArcMap 10.4 (Fig. 1).

Photo trap rate index (PTRI) and relative abundance index (RAI) were selected as analysis metrics to calculate the presence rate and relative abundance of wildlife species and estimate the total number of wildlife species occurring in the area (Magurran, 2004). PTRI values were calculated by the proportion of independent detections containing a given species per total camera-days:

$$PTRI = N_i \times 100 / \sum cd$$

Where N_i is the number of independent detections for species and $\sum cd$ is the sum of camera-days (Mohd-Azlan and Engkamat, 2013). RAI values were calculated by the number of independent detections compared to the naive occupancy (the proportion of cameras that recorded at least one detection of a given species); RAI assumes that detection rates are related to community abundance (Jenks et al., 2011) and was generated using software R 4.2.1 (Mandujano, 2022). The species accumulation curve indicates the number of unique detected species as a function of sampling effort, allowing us to assess the benefits of additional sampling (Kolowski and Forrester, 2017).

RESULTS

A total of 47 wildlife species (33 in Laman Satong and 22 in Sedahan) were recorded, grouped into mammals (31), birds (14), and reptiles (2). The camera traps recorded 18 species of conservation concern, all of which are at risk across their whole range, including five primates (*Cephalopachus bancanus*, *Hylobates albibarbis*, *Macaca fascicularis*, *Macaca nemestrina*, *Pongo pygmaeus*), two carnivores (*Cynogale bennetti*, *Pardofelis marmorata*), one pangolin (*Manis javanica*), and two hornbills (*Anorrhinus galeritus*, *Buceros rhinoceros*). A complete species list is provided in Table 1. Camera-trap photographs of selected species of conservation concern are provided in Figure 2.

Most species were detected only once or twice, but a few were detected multiple times. PTRI results (Table 1) show that the most frequently detected species were *C. notatus* (PTRI 4.9), *M. fascicularis* (PTRI 3.11), and *H. brachyura* (PTRI 2.63) in Laman Satong, and *E. gymnura* (PTRI 5.33), *M. fascicularis* (PTRI 4.7), and *L. ignita* (PTRI 4.39) in Sedahan. RAI results show that *M. fascicularis* and *C. notatus* (both RAI 3.55) were the most abundant species across both sites combined. Because the camera traps were placed low to the ground, the most commonly detected birds were terrestrial species, such as *L. ignita*. Two hornbills and a raptor were also recorded foraging on the forest floor.

The camera traps recorded 260 independent detections in 1,155 camera-days, resulting in an overall encounter rate of 22.5% (Fig. 1, Table 2). In general, the cameras with the highest encounter rates were those installed in the older reforestation plots where the planted trees had matured into secondary forest (see red and orange points in Fig. 1).

A given species' RAI was highly correlated with that species' distribution across the 13 sampling locations ($r^2 > 0.5$; $r^2 = 0.76$) (Fig. 3). *M. fascicularis* was the most evenly distributed species (recorded in 7 of 13 locations), followed by *R. tiomanicus* and *L. ignita* (each recorded in 6 of 13 locations) and *M. nemestrina* (recorded in 5 of 13 locations). Despite *C. notatus* being an abundant species, it was recorded in only 3 of 13 locations, all in Laman Satong, indicating a strong preference for lowland rainforest habitat. *M. fascicularis* was the most abundant and widely distributed species in Laman Satong and Sedahan despite being classified as Endangered. The species accumulation curve was still ascending at the end of the study period, suggesting that additional species would be recorded if camera trapping efforts were extended (Fig. 4).

DISCUSSION

The presence of threatened wildlife species in the Laman Satong and Sedahan reforestation areas indicates that heavily degraded lowland rainforest and peat swamp forest can be restored to habitat. Since the initiation of reforestation, both sites have become dominated by a combination of slow-growing Dipterocarp hardwoods and fast-growing native fruit trees, such as *Parkia* spp., *Archidendron* spp., *Syzygium* spp., *Palaquium* spp., *Nephelium* spp., *Litsea* spp., and *Artocarpus* spp., which provide food and habitat for wildlife including the southwest Bornean

TABLE 1. List of species, photo trap rate index (PTRI), relative abundance index (RAI), and IUCN conservation status: Not Evaluated (NE); Data Deficient (DD); Least Concern (LC); Near Threatened (NT); Vulnerable (VU); Endangered (EN); Critically Endangered (CR); Extinct in The Wild (EW); Extinct (EX), or Not Available (N/A).

No	Species name	Common name	Photo trap rate index		Relative abundance index (RAI)	Total independent detections	Conservation status (IUCN)
			Laman Satong (lowland rainforest)	Sedahan (peat swamp forest)			
Mammals							
1	*Arctictis binturong*	Binturong	0.12	0	0.09	1	VU
2	*Arctogalidia stigmatica*	Small-toothed Palm Civet	0	0.31	0.09	1	LC
3	*Callosciurus notatus*	Plantain Squirrel	4.90	0	3.55	41	LC
4	*Cephalopachus bancanus*	Horsfield's Tarsier	0.36	0	0.26	3	VU
5	*Cynogale bennettii*	Otter Civet	0.12	0	0.09	1	EN
6	*Echinosorex gymnura*	Moonrat	0	5.33	1.47	17	LC
7	*Helarctos malayanus*	Sun Bear	0.12	0	0.09	1	VU
8	*Hylobates albibarbis*	Bornean White-Bearded Gibbon	0.12	0	0.09	1	EN
9	*Hystrix brachyura*	Malayan Porcupine	2.63	0	1.90	22	LC
10	*Macaca fascicularis*	Long-Tailed Macaque	3.11	4.70	3.55	41	EN
11	*Macaca nemestrina*	Southern Pig-Tailed Macaque	0.72	0.31	0.61	7	EN
12	*Manis javanica*	Sunda Pangolin	0.12	0	0.09	1	CR
13	*Martes flavigula*	Yellow-Throated Marten	0.48	0	0.35	4	LC
14	*Muntiacus muntjak*	Southern Red Muntjac	0.24	0	0.17	2	LC
15	*Mydaus javanensis*	Sunda Stink-Badger	0.60	0	0.43	5	LC
16	*Paradoxurus philippinensis*	Common Palm Civet	0.36	0.31	0.35	4	LC
17	*Pardofelis marmorata*	Marbled Cat	0.12	0.31	0.17	2	NT
18	*Pongo pygmaeus*	Bornean Orangutan	0	0.63	0.17	2	CR
19	*Presbytis rubicunda*	Red Langur	0.12	0	0.09	1	VU
20	*Prionailurus bengalensis*	Mainland Leopard Cat	0.12	0	0.09	1	LC
21	*Rattus tiomanicus*	Malayan Field Rat	1.91	0.94	1.65	19	LC
22	*Rusa unicolor*	Sambar Deer	0.12	0	0.09	1	VU
23	*Sundamys muelleri*	Müller's Sundamys	0	0.31	0.09	1	LC
24	*Sundasciurus lowii*	Low's Squirrel	0	0.31	0.09	1	LC
25	*Sus barbatus*	Bearded Pig	1.32	0	0.95	11	VU
26	*Tragulus napu*	Greater Oriental Chevrotain	0.24	2.19	0.78	9	LC
27	*Trichys fasciculata*	Long-Tailed Porcupine	0.24	0	0.17	2	LC
28	*Tupaia splendidula*	Ruddy Treeshrew	0	0.31	0.09	1	LC
29	*Urva brachyurus*	Short-Tailed Mongoose	0	0.94	0.26	3	NT
30	*Urva semitorquata*	Collared Mongoose	0.12	0.31	0.17	2	NT
31	*Viverra tangalunga*	Malay Civet	0.12	0	0.09	1	LC
32	Unidentified mammal species	N/A	1.20	0.63	0	12	N/A
Birds							
33	*Anorrhinus galeritus*	Bushy-crested Hornbill	0.12	0	0.09	1	NT
34	*Arborophila hyperythra*	Bornean Partridge	0	0.31	0.09	1	LC
35	*Buceros rhinoceros*	Rhinoceros Hornbill	0	0.31	0.09	1	VU
36	*Caprimulgus indicus*	Jungle Nightjar	0.12	0	0.09	1	LC
37	*Caprimulgus sp.*	Nightjar	0.12	0	0.09	1	LC
38	*Centropus sinensis*	Greater Coucal	0.24	0	0.17	2	LC
39	*Chalcophaps indica*	Grey-capped Emerald Dove	0	0.63	0.17	2	LC
40	*Gerygone sulphurea*	Golden-bellied Gerygone	0.12	0	0.09	1	LC

TABLE 1. Continue

No	Species name	Common name	Photo trap rate index		Relative abundance index (RAI)	Total independent detections	Conservation status (IUCN)
			Laman Satong (lowland rainforest)	Sedahan (peat swamp forest)			
41	*Lophura ignita*	Bornean Crested Fireback	0.60	4.39	1.65	19	VU
42	*Malacocincla abbotti*	Abbott's Babbler	0.12	0	0.09	1	LC
43	*Prinia flaviventris*	Yellow-bellied Prinia	0	0.31	0.09	1	LC
44	*Pycnonotus melanicterus*	Black-capped Bulbul	0.12	0	0.09	1	LC
45	*Rhipidura javanica*	Sunda Pied Fantail	0.12	0	0.09	1	LC
46	*Spilornis cheela*	Crested Serpent-eagle	0	0.31	0.09	1	LC
47	Unidentified bird species	N/A	0	0.31	0	1	N/A
Reptiles							
48	*Eutropis multifasciata*	Common Mabuya	0	0.31	0.09	1	LC
49	*Varanus salvator*	Common Water Monitor	0	0.94	0.26	3	LC
Std. Error			0.92	1.18	0.80		
Species found			33	22		47	
Independent detections			178	82		260	
Camera-days			836	319		1155	

orangutan. The multiple trophic levels of wildlife detected indicate successful reforestation. Observed seed-dispersing species, such as civets, hornbills, and some primates, may accelerate forest regeneration and enrich plant diversity (Corlett and Hau, 2000). Observed predator species, including cats, martens, and mongooses, contribute to resilient food webs and sustainable prey populations (Berlyn and Ashton, 1997; Hilty and Merenlender, 2000).

Results suggest that particular species, such as *M. fascicularis* and *L. ignita*, were habitat generalists, detected in both ecosystems. Others were habitat specialists, occurring in only one of the two ecosystems. For example, *C. notatus* and *H. brachyura* were detected only in lowland rainforest, and *E. gymnura* appeared only in peat swamp forest. Each species showed high presence and abundance in its respective ecosystem, evidenced by PTRI and RAI values. Typically, generalist species are thought to have higher occupancy of disturbed areas than specialists (Matthews et al., 2014). However, the high PTRI and RAI values of the specialist species in this study indicate that specialists can be abundant in recently reforested areas despite ecological disturbance, proximity to edges, and anthropogenic pressures (Matthews and Whittaker, 2015; Semper-Pascual et al., 2022).

The camera traps photographed two hornbills and a raptor foraging on the forest floor, even though hornbills and raptors are known as upper-canopy species. These birds possibly descended to forage for fallen figs and small terrestrial animals such as snails, arthropods, reptiles, and mammals (Kitamura et al., 2009). This study adds evidence that many wildlife species, including threatened orangutans and macaques, often live and travel through edge habitats and recently reforested areas adjacent to human communities, potentially due to a lack of other suitable habitats or food sources (Knott et al., 2021).

The high abundance and diversity of wildlife recorded in this study may be attributable to several ecological and programmatic factors. First, the reforestation areas were surrounded by intact primary forest from which wildlife could colonise regrown habitat (Hanski, 2002; Ruiz-Jaén & Aide, 2005). Second, the reforestation protocols mandated a mix of native fruit trees and hardwoods to support specific wildlife species (Chazdon, 2013; Rachmat, et al., 2021). Third, communities were meaningfully engaged in reforestation, from site selection and program design to planting, maintenance, and monitoring. Communities have committed to preventing future logging and hunting in the park through reciprocity agreements with ASRI, and community members continuously build and maintain fire breaks to protect the reforestation sites from wildfires during the dry season.

FIGURE 2. Species of conservation concern were recorded by camera traps in the reforestation areas; A. *Macaca nemestrina*, B. *Cephalopachus bancanus*, C. *Anorrhinus galeritus*, D. *Buceros rhinoceros*, E. *Cynogale bennettii*, F. *Manis javanica*, G. *Helarctos malayanus*, H. *Pardofelis marmorata*, I. *Pongo pygmaeus*, J. *Presbytis rubicunda*.

TABLE 2. Encounter rate for each camera, determined by the number of independent detections by a single camera divided by the total number of camera-days from all cameras.

No.	Location	Camera code	Camera- days	Independent detections	Encounter rate (%)
1	Sedahan	SDH_CAM_01	61	32	2.77
2	Sedahan	SDH_CAM_02	15	0	0.00
3	Sedahan	SDH_CAM_03	209	30	2.60
4	Sedahan	SDH_CAM_05	35	20	1.73
5	Laman Satong	LS_CAM_01	22	4	0.35
6	Laman Satong	LS_CAM_05	22	1	0.09
7	Laman Satong	LS_CAM_03	1	1	0.09
8	Laman Satong	LS_CAM_01_2	130	44	3.81
9	Laman Satong	LS_CAM_07	98	10	0.87
10	Laman Satong	LS_CAM_08	171	32	2.77
11	Laman Satong	LS_CAM_02	143	7	0.61
12	Laman Satong	LS_CAM_05_2	171	69	5.97
13	Laman Satong	LS_CAM_07_2	77	10	0.87
		Total	1,155	260	22.51

Limitations

This study quantifies wildlife presence in active reforestation areas; it does not assess naturally regenerated or primary forests. Data analyses were limited because we used two different sampling methods. The study period was too short to establish saturation of the species accumulation curve. Because individual animals could not be identified, we could not quantify population sizes or individual ranges. All cameras were prepared with the same settings but varied in battery life, resulting in varying effort days for different cameras. Short battery life required frequent manual checking, occasionally resulting in lost data (Hughson et al., 2010; Cusack et al., 2015; Kolowski and Forrester, 2017).

Threats and opportunities

When ASRI was founded in 2007, most community members surrounding GPNP lived in poverty, and the extraction of timber from the park was a major source of income (Onda et al., 2008; Yoshikura et al., 2016; Fawzi et al., 2020). Primary drivers of lowland rainforest and peat swamp forest degradation were selective logging and small-scale agriculture by community members to pay for basic needs, especially healthcare (Webb et al., 2018). These pressures have decreased significantly since healthcare and livelihood programs were designed by communities and implemented by ASRI (Jones et al., 2020). However, despite community support for reforestation and the national park, hunting activity has been reported within the reforestation areas and detected by camera traps, potentially reducing the populations of bushmeat species such as bearded pig (*Sus barbatus*), chevrotain (*Tragulus* spp.), Sambar deer (*Rusa unicolor*), squirrels (Sciuridae), and macaques (*Macaca* spp.) (O'Brien et al., 2003; Fawzi et al., 2020; Knott et al., 2021). Some communities continue to practice swidden agriculture and collect non-timber forest products within the park (Sudrajat et al., 2018). These challenges are opportunities for ASRI to continue working closely with communities and the GPNP authority to design programs that simultaneously improve human and ecosystem wellbeing. Threats to the reforested areas include anthropogenic wildfires exacerbated by climate change and the smothering of tree seedlings by fast-growing and fire-tolerant weeds, such as cogongrass and common bracken fern. ASRI works with community members to address these challenges through fire prevention, rapid fire fighting, and frequent weeding. Developing long-term strategic plans that adapt to the changing climate and community needs is an ongoing priority (Fawzi et al., 2020).

Recommendations

Reforestation in biodiversity hotspots such as GPNP is crucial to reconnect fragmented forests with wildlife corridors, buffer edges against anthropogenic encroachment, and increase habitat for threatened species. Future studies should leave cameras in place for a longer period until the species accumulation curve indicates saturation (Burton et al., 2015; Cusack et al., 2015). An expanded study of both reforestation sites and surrounding intact forests would be useful for understanding wildlife species distribution and colonisation dynamics.

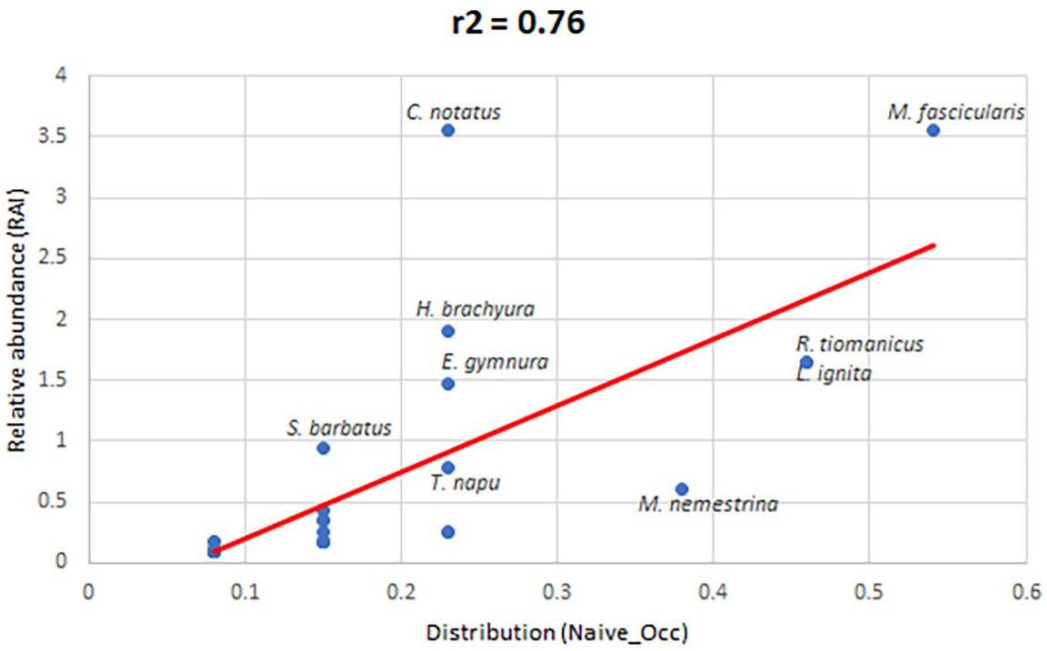

FIGURE 3. The relative abundance index (RAI) of wildlife species was correlated with the species' distribution across 13 camera locations in the Laman Satong and Sedahan reforestation sites.

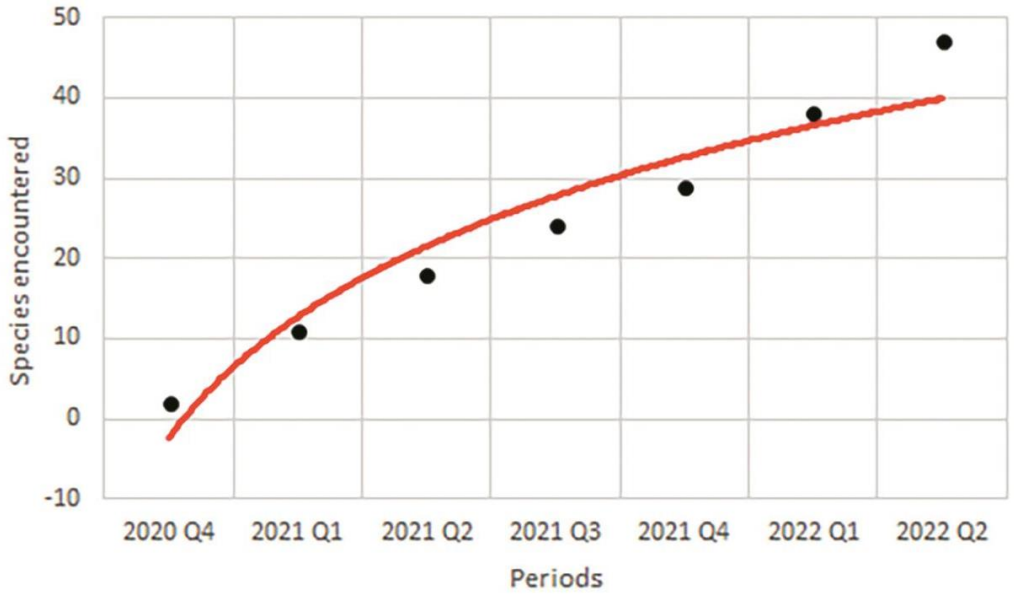

FIGURE 4. The species accumulation curve visualizes the additional species recorded daily during 1,155 camera-days from December 2020 to August 2022.

Meaningful collaboration between communities, government authorities, and non-profit organizations is essential for successful reforestation and wildlife protection. In this program, ASRI and the GPNP authority synchronized their reforestation plans and co-monitored forest use with GPNP officials and ASRI forest guardians (community members who record forest use indicators in and around the park). ASRI forest guardians share resources with their communities about minimizing human-wildlife conflict and accessing livelihood and healthcare services through ASRI. We strongly recommend community co-design of reforestation plans and focusing on long-term ecological monitoring.

CONCLUSION

This study detected the presence of wildlife in a reforested lowland rainforest and peat swamp forest ecosystems to measure the success of a collaborative, community-engaged reforestation program in Indonesian Borneo. Camera traps detected 47 species, including the southwest Bornean orangutan, a priority species in the GPNP strategic plan. Eighteen of the observed species are of conservation concern, and nearly all observed species are known to fill an ecosystem function such as dispersing seeds or maintaining prey populations. The presence of diverse native wildlife accelerates forest regeneration and indicates the success of reforestation efforts by communities, ASRI, and the GPNP authority. The leadership of communities in design and implementation has been essential. We recommend community co-design of reforestation programs to ensure justice in decision-making, protection from hunting, logging, and wildfires, and the long-term health of the regenerating forest and its wildlife inhabitants.

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