Research Article

The Increase of Sumatran Tiger's Prey Following Eradication of *Melastoma malabatrichum* in Way Kambas National Park, Indonesia

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ABSTRACT

The invasion of the planter's rhododendron (*Melastoma malabatrichum*) in Way Kambas National Park caused the loss of the sumatran tiger preys feeding ground, therefore efforts were made to eradicate the plant. This study aimed to compare the presence of sumatran tiger preys between *M. malabatrichum*-invaded location and eradicated location. Eradication was carried out by removing *M. malabatrichum* on a plot measuring 80 x 60 m². To record the animal visit, the camera traps were placed at the eradicated and invaded location of *M. malabatrichum* for comparison. The results showed that the *M. malabatrichum* eradicated location was more frequently visited by sumatran tiger preys. At the *M. malabatrichum* eradicated location, camera traps recorded 19 species of wild boar having the highest encounter rate (55.23) followed by sambar deer (33.24), and long-tailed macaque (17.43). Meanwhile, at the *M. malabatrichum* invaded location, camera traps recorded 13 species with wild boar having the highest encounter rate (30.56), followed by sambar deer (14.75), and long-tailed macaque (14.48). Thus, the eradication of *M. malabatrichum* had a good impact on increasing the number of sumatran tiger preys due to the availability of feed after being free from *M. malabatrichum* invasion.

Keywords: feeding ground, invasive species, Melastoma malabatrichum, sumatran tiger, tiger preys

INTRODUCTION

The sumatran tiger (*Panthera tigris sumatrae*) is a highly endangered carnivore whose distribution is limited on the Sumatra island, Indonesia. These animal conditions are threatened by poaching, both tigers and their prey animals. Other threats are caused by habitat fragmentation and degradation, as well as being killed due to conflicts that frequently occur between humans and tigers in border areas of tiger habitat and human settlements (Wibisono & Pusparini 2010; Linkie et al. 2018). Sumatran tiger population continues to decline, in its natural habitat only about 500 animals remain and some occupy

fragmented forests (Kenney et al. 2014; Goodrich et al. 2015; Joshi et al. 2016; Harihar et al. 2017). This condition becomes a considerable challenge for the conservation efforts of these animals.

Nowadays, the remaining population of sumatran tiger is partly in conservation areas, for example, Way Kambas National Park (WKNP), Lampung Province, Indonesia (Wibisono et al. 2011). Like other national parks, WKNP is also not immune to a variety of threats. One of the threats that recently happening is *Melastoma malabatrichum* invasion. This problem causes the loss of feeding grounds for sumatran tiger preys, such as sambar deer (*Cervus unicolor*), barking deer (*Muntiacus muntjak*), and java mouse-deer (*Tragulus javanicus*) (Master et al. 2020). One of the locations that invaded quite badly is the Kali Biru swamp. Previous research (Subagyo 2000) revealed that *M. malabatrichum* is not dominant in Kali Biru. However, recently the plant has covered 88% of this swamp area with a density of 30 individuals/m² (Master et al. 2018).

Kali Biru swamp in WKNP is a swamp formed by a tidal run-off of a river that runs in the middle. This location is important for animals in WKNP, especially the ungulates because the availability of grass is always green in this location (Master et al. 2020). The gathering of various animals in this location attracts sumatran tiger as predator and an important location for prey hunting. Tigers are very dependent on the abundant of prey animals (Thapa & Kelly 2016). With the invasion of *M. malabatrichum* which covers the location, the grass as ungulate's food cannot grow, this cause ungulate population decline (Master et al. 2020). This certainly has an impact on sumatran tiger which utilizes the location as a hunting area.

The conservation of prey species is an important factor for sumatran tiger survival (Carbone & Gittleman 2002). As a carnivore, tigers entirely depend on the existence of their prey as food source. Although tigers can inhabit various forest types, they need suitable prey bases to survive (Harihar & Pandav 2012; Sunarto et al. 2012; Hebblewhite et al. 2014).

Plant invasion has become a global concern. This is due to the negative impacts of the uncontrolled development of these plants in the conservation area causing biodiversity loss (Master et al. 2013). Indonesian Ministry of Environment reported that there were at least 1936 invasive plant species in Indonesia (S. Tjitrosoedirdjo et al. 2016), and *M. malabatrichum* is one of the most 75 threatening invasive species (S. S. Tjitrosoedirdjo et al. 2016).

The invasion of *M. malabatrichum* has been suggested to cause grazing areas to change into shrubs which are not preferred by tiger preys. These changes will affect the populations of prey species and will have a direct influence on tiger populations (Karanth et al. 2011). This study aimed to compare the presence of sumatran tiger preys between *M. malabatrichum*-invaded location and eradicated location.

METHODS

Study Site
The study was conducted in Kali Biru tidal swamp, Way Kambas National Park, Lampung Province, Indonesia (105°47'44''E, 4 °59'50''S) on December 2018 - December 2019. This tidal swamp area is included in the Tiger Elephant Rhino Monitoring Area (TERMA) location, which is an intensive monitoring location of priority animals in WKNP (sumatran tiger, sumatran elephant, and sumatran rhino) determined based on the decree of the Head of WKNP Hall No. 13/BTN.WK-1/2015. The topography of the WKNP area is relatively flat and bumpy with a height between 0 - 50 meters above sea level (Balai Taman Nasional Way Kambas 2012). WKNP area has five vegetation types namely mangrove forest, coastal forest, riparian forest, tidal

swamp, and lowland forest. Based on the land cover, most of the lowland forest is dryland forest followed by reeds and shrubs (Amalina et al. 2016).

Eradication of *M. malabathricum*

Kali Biru swamp has an area of approximately 140 ha, of which about 88% is currently covered by *M. malabatrichum*. In this study, the experiment was carried out to eradicate the invasion of these plants on a plot measuring 80 x 60 m². Eradication was performed manually by pulling out to the roots by hand. The eradication of *M. malabatrichum* was conducted in December 2018. Plots measuring 2 x 2 m² as many as 6 sub-plots were placed randomly in the *M. malabatrichum* plot to count the number of individuals of each species that grew after the withdrawal of *M. malabatrichum*. Post-revocation monitoring was performed 6 times, in January, February, March, May, June, and September 2019 by recording all types and number of plants contained in the sub-plot (Figure 1).

Based on the Schmidt and Ferguson classification, WKNP and its surroundings are included in type B climate (Balai Taman Nasional Way Kambas 2012). This study was carried out in the rainy season (January to April 2019) and the dry season (May to September 2019). Rainfall conditions also affect the condition of the Kali Biru swamp where the swamp is inundated during the rainy season and is dried in the dry season (Master et al. 2020).

Wildlife Species Monitoring

Camera traps were placed in two different habitat conditions, the first location was the location invaded by *M. malabatrichum*. Both locations are in Kalibiru Swamp known as the sumatran tiger home range in WKNP. At the first location, a camera trap was placed on the edge of the forest bordering the invaded location. The second location was in the grazing area of the eradicated plot from *M. malabatrichum*. At the edge of the eradication plot
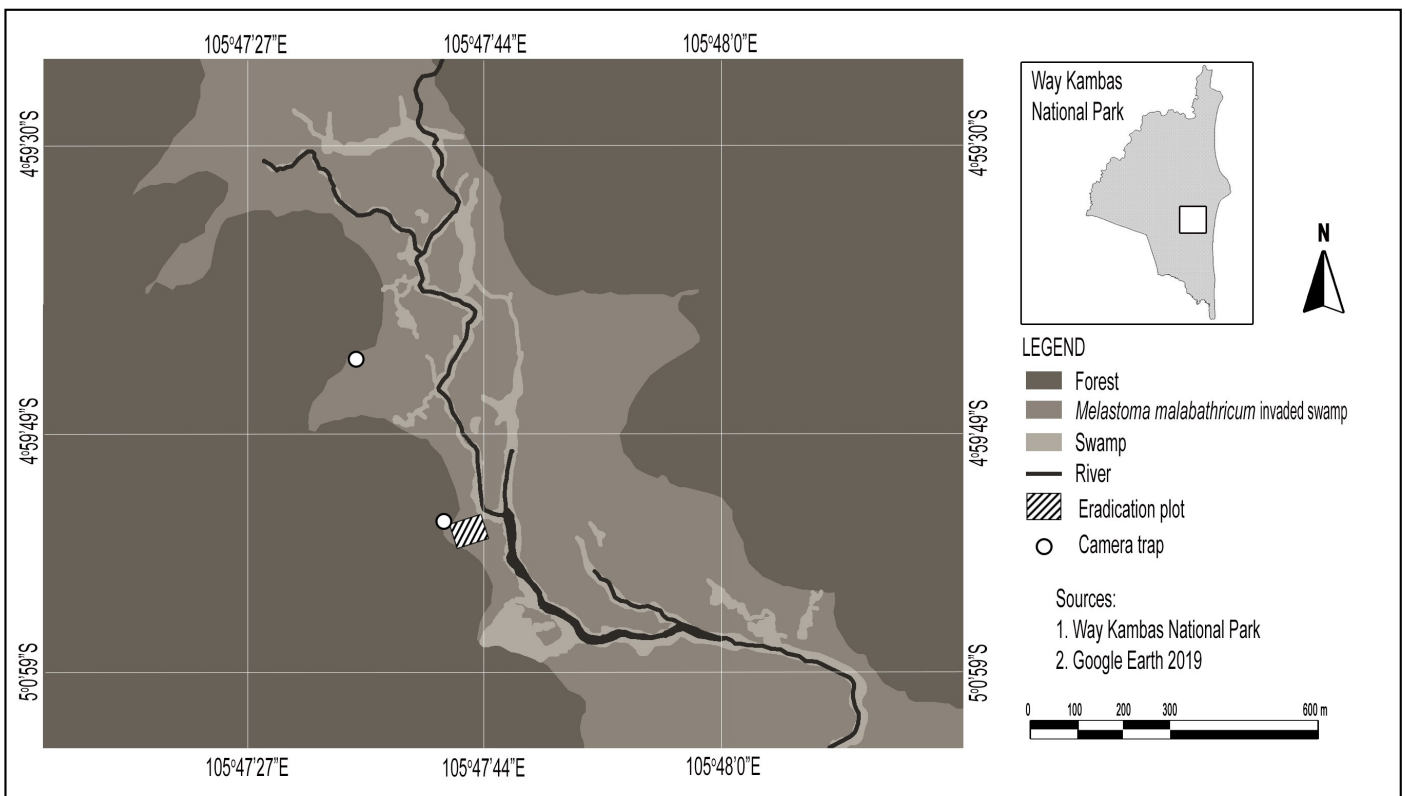
Figure 1. Research location and placement design of eradication plot and camera trap in the Kali Biru Swamp, Way Kambas National Park (WKNP), Lampung Province, Indonesia.

were camera traps that were placed at transitional locations. It is because tigers and their prey species were more easily found in transitional areas between forests and grasslands (Siswomartono et al. 1994).

Each location had a camera trap attached to the tree. The camera trap was installed 40 cm from the ground facing the animal crossing. Camera traps were installed for 382 days (14 December 2018 - 25 December 2019) with a checking period once a month. The value of the encounter rate (ER), which is the rate of encounters of animals against camera traps or the frequency of animals recorded by cameras, was calculated based on the formula (O'Brien et al. 2003): $\Sigma ER = \Sigma f / \Sigma d \times 100$, where ER = encounter rate; Σf = Total number of photos obtained; Σd = Total number of camera operation days.

The assumption used to identify individuals using independent videos was videos sequentially recorded on one file in a memory card that has been filtered based on time. Videos were said to be independent if (1) videos of different species or different individuals on a memory card, (2) sequential videos of the same individual (same species) in a video file with a span time of more than 30 minutes, or sequential videos of different individuals if it can be clearly distinguished, and (3) videos of the same individual or the same species that are not consecutive on one memory card file (Kelly et al. 2008; O'Brien et al. 2003).

RESULTS AND DISCUSSION

Habitat Conditions After Eradication of *M. malabathricum*

The control of *M. malabathricum* invasion in conservation areas has not been widely studied. Most of the controls on cultivated land use systemic herbicides for woody weeds. The use of herbicides in the Kali Biru swamp has a high risk of biodiversity in that location because the area is waterlogged so that the herbicides spread quickly around the treatment area and pollute the waters.

Manual weed control by pulling out has also been carried out to control the invasion of *Acacia nilotica* in Baluran National Park because control by cutting and burning of *A. nilotica* has not shown optimal results (Basari 2012). *M. malabathricum* has a shrub habitus, so it is easier to do it manually than *A. nilotica* which has tree habitus.

Before controlling, the plot was overgrown by *M. malabathricum* with a density of 30 individuals/m² and a height of up to 2.1 m. Under the *M. malabathricum* stand, there were only two species of grass namely *Cyperus* sp. and *Cynodon* sp. with a density of 5 individuals/m² and 1 individual/m² respectively. These plants cannot compete with *M. malabathricum* because the density of *M. malabathricum* causes other plants to not get enough sunlight so that the growth is stunted (Figure 2). In addition, *M. malabathricum* has allelopathic compounds to reduce germination rates and lengthening of grassroots and shoots (Faravani et al. 2008; Sari & Prakusya 2020).

The *M. malabathricum* control was performed manually by pulling out to the roots by hand. *M. malabathricum* control aimed to restore the function of the invaded ecosystem to grazing areas. After *M. malabathricum* was removed, grass for herbivores began to grow. There were 12 types of plants grown after the treatment namely *Fimbristylis* sp., *Limnophila* sp., *Cyperus* sp., *Cynodon* sp., *M. malabathricum*, and several unidentified species. Post-eradication, forage crop was originated from the seed bank and seed dispersal from around the plot. The seeds can be scattered into the plot assisted by wind, water, and animal activity, especially herbivores such as the Sambar deer (*Cervus unicolor*).

Figure 2. Invasion of *Melastoma malabathricum* in the Kali Biru Swamp, Way Kambas National Park (WKNP), Lampung Province, Indonesia. *Melastoma malabathricum* a. flower, b. fruit.

During the observation period, there was a fluctuation in the number of individual plants in each plot, this was caused by the growth and activity of herbivorous animals eating these plants. Not only grass, but *M. malabathricum* returned to grow with the second-highest amount after *Fimbristylis* sp. Post-control *M. malabathricum* was originated from the seed bank in the soil or the seeds fell during the *M. malabathricum* pull out or from the seeds being spread from locations around the plot where *M. malabathricum* was grown. In addition to seeds, *M. malabathricum* shoots were grown from broken stumps and remain in the ground when uprooted. Based on the graph in Figure 3, only *M. malabathricum* did not experience a decrease in the number of individuals during January – July. This is possible because *M. malabathricum* is not eaten by animals and has a better competitive ability than other plants. From July to September, the number of individuals of each plant species decreased due to drought (Figure 4).

The Presence of Sumatran Tiger Preys (*Panthera tigris sumatrae*)
The wildlife species encounter (ER) especially mammals is used to compare habitat use by wildlife species in two different locations. Videos of camera traps recorded at the two locations showed that more animals were found at the eradicated sites (Table 1) (Figure 5 and 6). Camera traps at eradicated locations recorded 19 species of wild boar as the animals with the highest ER values (55.23) followed by sambar deer (33.24) and long-tailed macaque (17.43), whereas in the location invaded by *M. malabatrichum* recorded 13 species with wild boar as animals that have the highest ER value (30.56) followed by sambar deer (14.75) and long-tailed macaque (14.48). These species are the main prey for sumatran tigers.
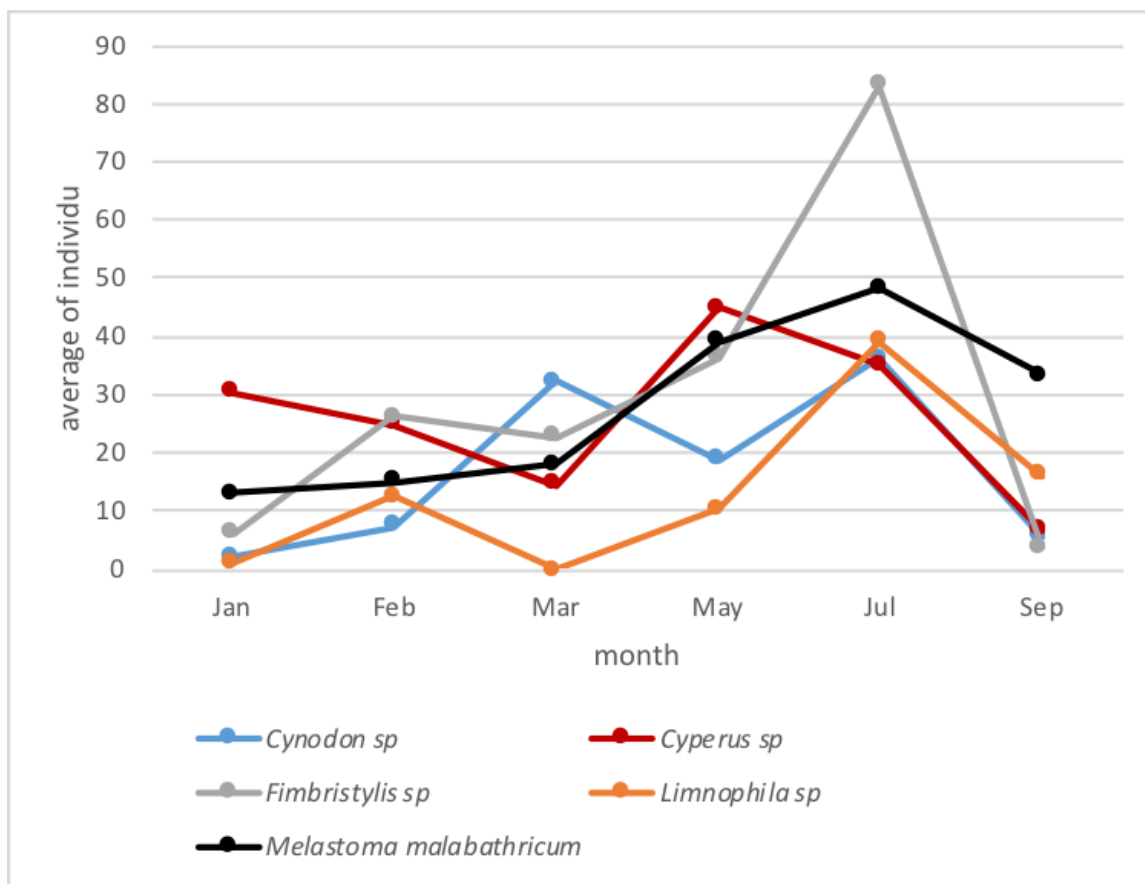
Figure 3. Plant composition and average from 6 monitoring plots after eradication of *Melastoma malabathricum,* January –September 2019.
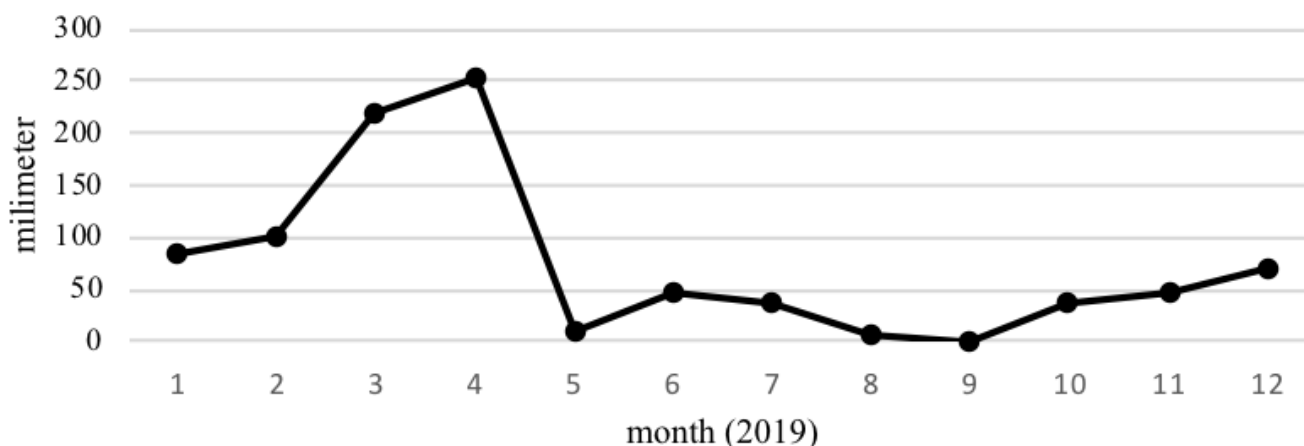

Figure 4. Total monthly rainfall of Lampung Province in 2019 (Master et al. 2020).

The eradicated habitat provided resources needed by herbivorous animals. These animals respond to these habitats adaptively because herbivores depend on the abundance and distribution of plant species as food (Hale & Swearer 2017). A large number of herbivorous encounters which are tiger preys, in eradicated locations are caused by abundant food (grasses) after the eradication of *M. malabatrichum*. The abundant presence of prey animals in the location eradicated attracts the attention of sumatran tigers and other predators to come, such as clouded leopards and leopard cats.

The density of tiger population in a location is influenced by the quality of habitat and the availability of tiger preys because prey animals are one of

Table 1. Comparison of encounter rates using camera traps at the invaded location of *Melastoma malabathricum* and controlled location.

No	Species	IUCN Status	Potential Prey for Sumatran Tiger	Encounter Rate (Photos/100 days)	
				Eradicated location	Invaded location
1.	Wild boar (*Sus scrofa*)	Least Concern	√	55.23	30.56
2.	Sambar deer (*Cervus unicolor*)	Vulnerable	√	33.24	14.75
3.	Long-tailed macaque (*Macaca fascicularis*)	Least Concern	√	17.43	14.48
4.	Greater mouse-deer (*Tragulus napu*)	Least Concern	√	4.02	10.46
5.	Muntjac (*Muntiacus muntjak*)	Least Concern	√	3.75	2.95
6.	Lesser mouse-deer (*Tragulus javanicus*)	Data Deficient	√	2.68	5.36
7.	Asian Palm Civet (*Paradoxurus hermaphroditus*)	Least Concern	√	2.68	2.41
8.	Red Junglefowl (*Gallus gallus*)	Least Concern	√	1.88	0.54
9.	Malayan sun bear (*Helarctos malayanus*)	Vulnerable	√	1.61	0
10.	Leopard cat (*Prionailurus bengalensis*)	Least Concern		0.80	0.27
11.	Sumatran elephant (*Elephas maximus sumatranus*)	Critically Endangered		0.80	0
12.	Javan mongoose (*Herpestes javanicus*)	Least Concern	√	0.80	0
13.	Banded palm civet (*Hemigalus derbyanus*)	Near Threatened	√	0.80	0
14.	Asian water monitor (*Varanus salvator*)	Least Concern		0.27	0.27
15.	Sumatran tiger (*Panthera tigris sumatrae*)	Critically Endangered		0.27	0
16.	Clouded Leopard (*Neofelis diardi*)	Vulnerable		0.27	0
17.	Malayan Tapir (*Tapirus indicus*)	Endangered	√	0.27	0
18.	Malayan civet (*Viverra tangalunga*)	Least Concern	√	0.27	0
19.	Asian small-clawed Otter (*Aonyx cinerea*)	Vulnerable	√	0.27	0
20.	Pigtail macaque (*Macaca nemestrina*)	Vulnerable	√	0	0.80
21.	Crested Fireback (*Lophura ignita rufa*)	Near Threatened	√	0	0.80
22.	Masked palm civet (*Paguma larvata*)	Least Concern	√	0	0.27
	Number of species			**19**	**13**
	Total Individuals			**905**	**465**

the factors that determine the size of tiger territories (Sherpa & Maskey 1998). Based on the results of hair analysis found in sumatran tiger feces, the main animals of tiger prey in WKNP were wild boar, macaque, sambar deer, and sun bear (Franklin et al. 1999; Sriyanto 2003).
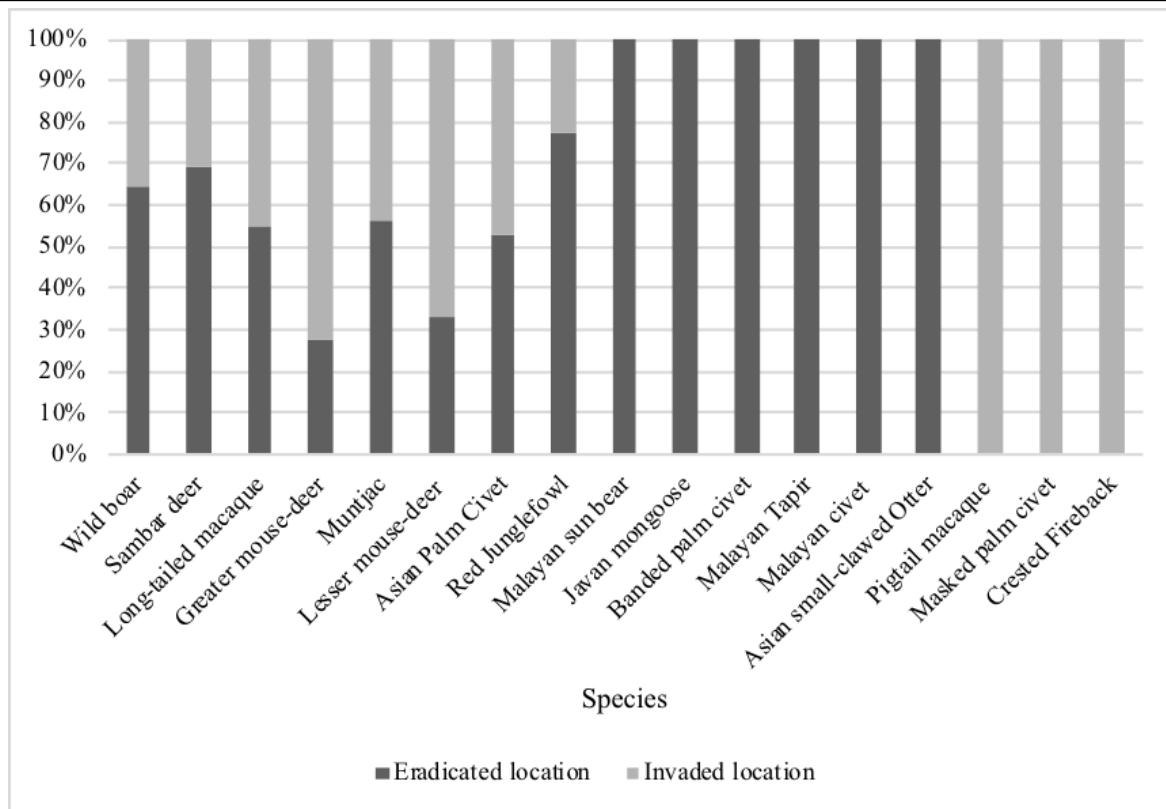
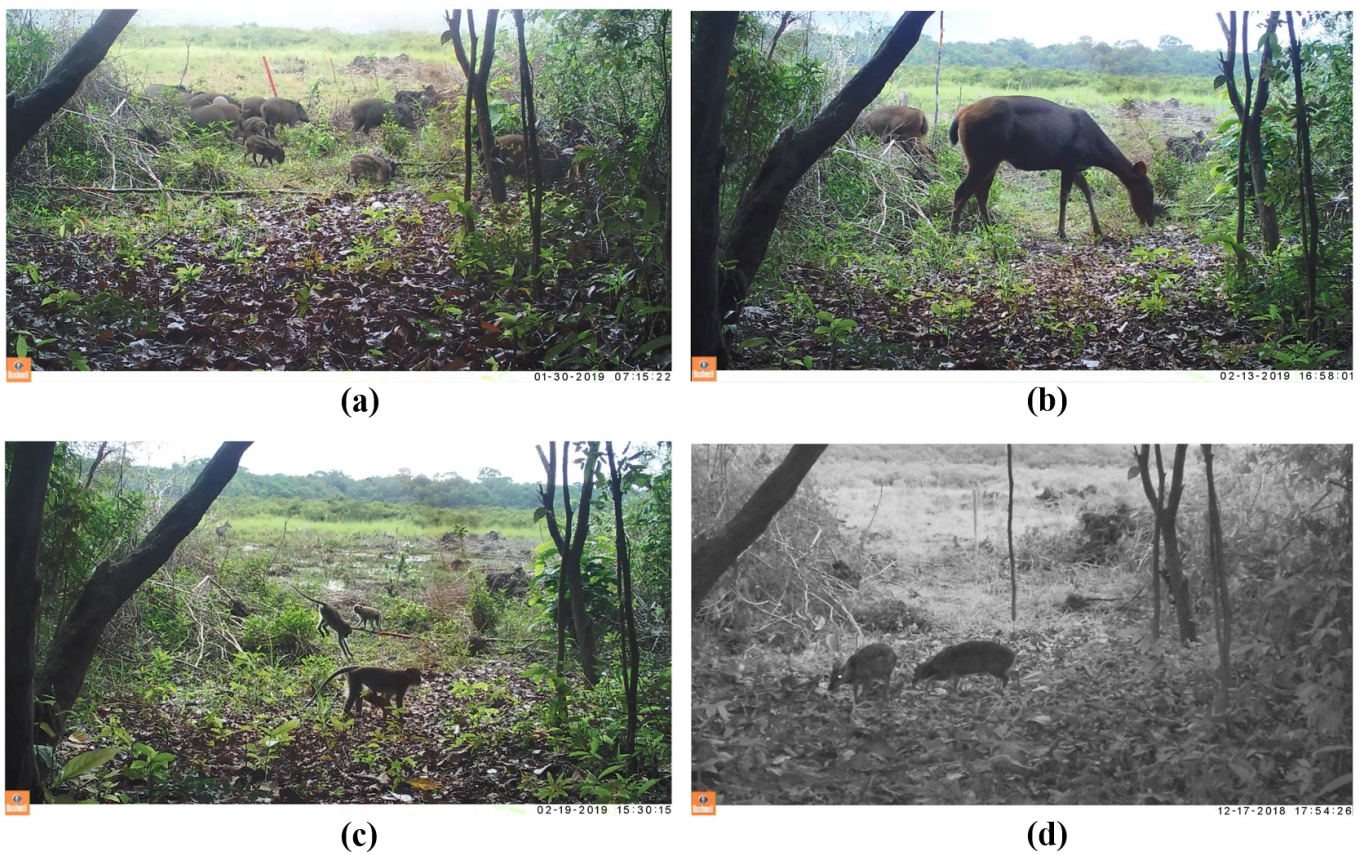**Figure 5.** The comparison of prey animal numbers at eradicated and invaded locations.

Figure 6. Sumatran tiger preys in eradicated area: (a) wild boar, (b) sambar dear, (c) long-tailed macaque, and (d) greater mouse-deer.

Based on the results of camera traps, wild boar (*Sus scrofa*) was the most recorded prey animals both at the invaded and eradicated locations.

However, the rate of encounter of wild boar in the eradicated location was much higher than the invaded one. These animals were usually recorded in groups with a number ranging from 2-18 individuals. Wild boars have a wide range of areas and are active at night and daytime, so the level of encounter is high. The availability of food sources is one of the factors affecting the presence of wild boar in a location because most of its activities are used for foraging (Azhima & Vincent 2001). Wild boars are omnivores, these animals eat grass, roots, worms, and insects (Chapman & Trani 2007). High levels of wild boar encounter at locations eradicated due to the availability of grass and on the open ground due to *M. malabatrichum* revocation processes.

The next animal that has a high level of encounter was sambar deer (*Cervus unicolor*). Sambar deer is a dominant prey for tigers (Biswas & Sankar 2002; Joseph et al. 2007; Kumaraguru et al. 2011; Hayward et al. 2012), this animal occupies a variety of habitats, ranging from coastal forests, secondary forests, swamp forests, reed fields and in mountain areas. However, sambar deer habitat will never be far from water sources (Bagchi et al. 2003; Simcharoen et al. 2014). The availability of nourishment plants is also important for the existence of deer (Forsyth & Davis 2011; Ginantra et al. 2018). Kali Biru Swamp of WKNP is a good habitat for sambar deer because it provides grasslands as a source of food, swamps, and rivers as a source of water, and forests around the swamp as a shelter. The flat, open topography of Kali Biru Swamp is preferred by sambar deer because it makes it easy to detect the presence of predators (Simcharoen et al. 2014; Valeix et al. 2009).

Sambar is included in the intermediate feeder group because it can be both a grazer (grass eater) and a browser (bush eater) (Priyono 2007). Grasses are the most preferred and important diets for sambar deer (Maksudi et al. 2010; Mustari et al. 2016). The invasion of *M. malabatrichum* causes grasses as the source of food to decrease, while the palatability of sambar deer to *M. malabatrichum* is quite low (Ismail & Jiwan 2015). This is due to the invasion of *M. malabatrichum* blocking the light intensity received under the plants. The lower intensity of the light will negatively influence the growth of grass as a deer diet (Masy'ud et al. 2008; Kunarso & Azwar 2013; Araujo et al. 2018). After being eradicated, the grass grew back and this caused the rate of encounter of sambar deer at the eradicated location to be twice as high as that of at the invaded location.

Based on the level of predation, animals mentioned above were among the favorite / main prey animals of sumatran tigers because the meat composition is under what is needed by tigers. A tiger needs 5-6 kg of meat a day for its survival (Sunquist 1981). A tiger can kill a muntjac weighing 20 kg every 2-3 days or kill a deer and muntjac weighing 200 kg every few weeks (Sunquist 1981). Other prey animals recorded by camera traps at eradicated locations were a long-tailed macaque, greater mouse-deer, deer, asian palm civet, red junglefowl, bear, javan mongoose, striped weasel, tapir, and malayan civet. Some animals such as bear, javan mongoose, banded palm civet, tapir, and malayan civet were not found at invaded locations but Southern pig-tailed macaque, masked palm civet, and crested fireback were. Different types of animals that inhabit a particular habitat are caused by factors and the carrying capacity of its habitat following animal needs.

The availability of adequate food is a major factor in the abundance of tiger prey animals which are herbivores. Rivers, swamps, and grasslands surrounded by forests are suitable locations for ungulates. The loss of grass due to the invasion of *M. malabatrichum* causes the density of herbivores to decrease, especially grazer species. Sumatran tigers can occupy a variety of habitats, but the most preferred habitat is border areas between the forest and grassland which is usually inhabited by predominant species such as wild boar, deer, barking deer, and greater mouse-deer. Sumatran tigers prefer

places that have high prey biomass and meet their daily needs. Therefore, sumatran tigers usually inhabit habitats related to forests near the river, swamp forests, and grasslands, but are very difficult to find in bush vegetation areas that are too dense (Sastrapradja et al. 1992). Kali Biru Swamp in WKNP has habitat criteria favored by sumatran tigers. Hence, the growth of *M. malabatrichum* in that location needs to be controlled, because the invasion of *M. malabatrichum* causes the grass not to grow and the grasslands turn into dense shrubs. One of the main problems that are closely related to the survival of tigers is the unequal distribution of plant species which are the source of food for tiger prey animals. Management actions that need to be taken to maintain the preservation of sumatran tigers are to increase the carrying capacity of their habitat through habitat improvement activities.

The eradicated location is not only preferred by sumatran tiger preys, but also by several other threatened animals. Besides sumatran tigers, animals that have a Critically Endangered status based on IUCN caught on cameras at the eradicated location are sumatran elephants (Figure 7). Several other animals caught on cameras at the eradicated location have a status of Vulnerable to Endangered. This indicated that this location was an important habitat for animals and required immediate treatments from the invasion of *M. malabatrichum*.

CONCLUSION

The eradication of *M. malabatrichum* had a good impact on increasing the number of sumatran tiger preys due to the availability of food after being free from *M. malabatrichum* invasion. Several animals recorded by camera traps at the location which has been eradicated were higher (19 species) than those at invaded locations (13 species). The eradicated location also had a higher value of tiger prey encounters than the invaded location. Therefore, it is necessary to carry out habitat management to support sumatran tiger preys

AUTHORS CONTRIBUTION

J.M., I.Q., D.S., and N.S. designed the research and supervised all the processes, J.M. collected and analyzed the data and wrote the manuscript.

Figure 7. Critically endangered species in eradicated area: (a) sumatran tiger and (b) sumatran elephants.

CONFLICT OF INTEREST

The authors state no conflict of interest from this manuscript.

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