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Deforestation of Primate Habitat on Sumatra and Adjacent Islands, Indonesia

Jatna Supriatna[1,2], Asri A. Dwiyahreni[2], Nurul Winarni[2], Sri Mariati[3,4] and Chris Margules[2,5]

[1]*Department of Biology, FMIPA Universitas Indonesia, Depok, Indonesia*
[2]*Research Center for Climate Change, Universitas Indonesia, Depok, Indonesia*
[3]*Postgraduate Program, Trisakti Institute for Tourism, Pesanggrahan, Jakarta, Indonesia*
[4]*Conservation International, Indonesia*
[5]*Centre for Tropical Environmental and Sustainability Science, College of Marine and Environmental Sciences, James Cook University, Cairns, Australia*

Abstract: The severe declines in forest cover on Sumatra and adjacent islands have been well-documented but that has not slowed the rate of forest loss. Here we present recent data on deforestation rates and primate distribution patterns to argue, yet again, for action to avert potential extinctions of Sumatran primates in the near future. Maps of forest loss were constructed using GIS and satellite imagery. Maps of primate distributions were estimated from published studies, museum records and expert opinion, and the two were overlaid on one another. The extent of deforestation in the provinces of Sumatra between 2000 and 2012 varied from 3.74% (11,599.9 ha in Lampung) to 49.85% (1,844,804.3 ha in Riau), with the highest rates occurring in the provinces of Riau, Jambi, Bangka Belitung and South Sumatra. During that time six species lost 50% or more of their forest habitat: the Banded langur *Presbytis femoralis* lost 82%, the Black-and-white langur *Presbytis bicolor* lost 78%, the Black-crested Sumatran langur *Presbytis melalophos* and the Bangka slow loris *Nycticebus bancanus* both lost 62%, the Lar gibbon *Hylobates lar* lost 54%, and the Pale-thighed langur *Presbytis siamensis* lost 50%. Two species, the Pagai langur *Presbytis potenziani* and the Pagai macaque *Macaca pagensis*, both from the southern part of the Mentawai islands, are not represented in national parks or protected areas at all, and a further five species are found in only one protected area. The causes of deforestation are many and varied, but by far the leading causes are logging, followed by fire and/or conversion to plantations. Enforcement of existing regulations protecting primates, disentanglement of land claims and overlapping boundaries, a halt to logging in existing forests, a halt to road building through forests, clarification of how traditional *adat* law relates to protected areas, and the creation of new, enforceable laws protecting species from trade and exploitation will all be needed if Indonesia is to uphold the commitments to primate conservation that it has already made.

Keywords: deforestation, Indonesia, primates, primate habitat, Sumatra

Introduction

There are 22 primate species that occur on Sumatra and its neighboring islands. Three are ranked as Critically Endangered on the IUCN Red List of Threatened Species (Pagai macaque *Macaca pagensis*, Pig-tailed langur *Simias concolor*, and Sumatran orangutan *Pongo abelii*) (Roos *et al.* 2014; Supriatna and Ramadhan 2016), and a further ten are listed as endangered (Siberut macaque *Macaca siberu*, Black Sumatran langur *Presbytis sumatrana*, Mitred langur *P. mitrata*, Black-and-white langur *P. bicolor*, Black-crested Sumatran langur *P. melalophos*, Siberut langur *P. siberu*, Kloss's gibbon *Hylobates klossii*, Lar gibbon *H. lar*, Agile gibbon *H. agilis*, and Siamang *Symphalangus syndactylus*). Nine of the 22 species are endemic (MacKinnon and MacKinnon 1980; Brandon-Jones *et al*. 2004; Roos *et al*. 2014).

Sumatra was still densely forested as recently as 1950, but then clearing began in the lowland areas where topography and soil fertility were most favorable to human settlement and agriculture. Clearing for plantations and clearing for crops and settlements associated with transmigration programs in the 1970s and 1980s occurred largely in the lowlands or on gently sloping foothills (Whitten *et al*. 1987). Estimates vary, but recent sources suggest that Sumatra has lost 5 million ha of forest between 1990 and 2000 (Gaveau *et al*. 2012) and a further 3 million ha between 2000 and 2012 (Margono *et*

al. 2014) for a total of 8 million ha due to legal and illegal logging, conversion of natural forests to industrial plantations, and forest encroachment by communities. The analysis reported here estimates that 3.5 million ha were lost between 2000 and 2012. The difference of 500,000 ha is likely due to our use of the Ministry of Forestry classification of forest and non-forest.

Sumatran forests are suffering one of the highest rates of destruction in the world (Collins *et al*. 1990; Margono *et al.* 2014). There are now only small scattered remnants of undisturbed lowland forest outside of protected areas. This lowland forest is the home of most Sumatran primates. Many (for example, orangutans, gibbons, some restricted range and endemic langurs, and some macaques) are sensitive to disturbance caused by logging, hunting and other human activities (Yanuar and Chivers 2010). Consequently, these species have little chance of surviving in highly fragmented or disturbed forests. For example, tree availability, as a source of food and nesting sites, is one of the most influential factors affecting the density of orangutans (van Schaik *et al*. 2001; Ancrenaz *et al*. 2005).

The many documented declines in forest cover and therefore primate habitat (for example, Supriatna *et al*. 2001, 2002; Mittermeier *et al*. 2007; Mariati *et al*. 2014; Supriatna and Mariati 2014), have largely been ignored by government and the private sector. Forest loss has continued to proceed at a high rate. Here we present recent data on the extent of deforestation and primate distributions and propose actions that will be necessary if extinctions in the near future are to be averted.

Methods

Mapping forest loss

Forest loss, or deforestation, is defined as the change from forest cover in 2000 to non-forest cover in 2012. We used the deforestation data from the Ministry of Forestry. Landsat 7 Enhanced Thematic Mapper (ETM) satellite images from 2000 and 2012 were used to calculate changes in the forest cover that coincided with the distribution of each primate species. Images of Sumatra were selected from 2000 and 2012, with cloud cover less than 50%, and all forested areas such as parks, protected forest, company concessions and other forested lands were included. This covered primary and secondary forest but did not include tree crops or production forest. Forest cover results were then validated using Google Earth (www.google.com/earth/) and ESRI online base map (www.esri.com) from the same time period. The rate of deforestation was also calculated using the formula described by Puyravaud (2003). The formula is based on Compound Interest Law and is considered more intuitive than the one proposed by FAO (see Puyravaud 2003). It is as follows:

$$r = 1/(t2 - t1) \times Ln\ (a2/a1)$$

where r is the rate of change, and $a1$ and $a2$ are the forest cover estimates at time $t1$ and $t2$ respectively.

Primate distributions

Primate surveys in different parts of Sumatra have been carried out by many researchers, including Crockett and Wilson (1980), Kawamura and Megantara (1986), Supriatna *et al*. (1996), Supriatna and Hendras (2000), Supriatna *et al*. (2001), Whittaker (2005, 2006), Geissmann *et al*. (2006), Supriatna and Gursky-Doyen (2010), and Supriatna and Mariati (2014). Additional data on taxonomic status and distributions were gathered from Groves (2001), Brandon-Jones *et al*. (2004), Mittermeier *et al*. (2013), and Roos *et al*. (2014). We examined all records of primates on Sumatra in the Bogor Museum, and updated the distribution data of Groves (2001). These were published in Supriatna and Ramadhan (2016). Ground-truthing of these geo-referenced distribution maps was conducted throughout Sumatra between 2012 and 2014, except for the southern islands (Pagai and Sipora) of the Mentawai archipelago. Survey locations were chosen using the following criteria: areas likely to have species that had not been studied intensively, for example, species recently described; areas with species whose systematics had recently been revised; areas that had been recently logged and/or converted to plantations; and areas that had been recently burnt by forest fires. Further aspects of primate ecology and conservation status were gathered from primatologists who have studied these issues in the field (Indra Yustian, Sunarto, Tatang Mitrasetia, pers. comm.) and the considerable experience of most of the present authors, especially the senior author.

Based on primate distribution data from these sources, we plotted the current known distributions of each primate species. We then overlaid these geo-referenced distribution maps onto current forest cover maps and maps of forest lost between 2000 and 2012. In this way, we mapped changes in available habitat for all primate species and calculated current available habitat, defined as forest cover.

Results

Extent of forest loss

Deforestation in the provinces of Sumatra between 2000 and 2012 ranged from 3.74% to 49.85%, with a total of 3,547,740.60 ha (22.08 %) lost (Table 1). The highest rate was found in the provinces of Riau, Jambi, Bangka Belitung, and South Sumatra (Fig. 1). Most clearing took place in already degraded production forests and not in primary conservation forests, except in Tesso Nilo National Park in Riau Province, where the highest rate of forest loss was found (9.28% per year, Mariati *et al.* 2014). In the rest of Riau province, deforestation occurred mainly in production forests, which were converted to acacia and oil palm plantations. Illegal logging was widespread in the Giam Siak and Rimbang Baling protected areas and in Tesso Nilo National Park (Supriatna and Mariati 2014). Similar trends have occurred in Jambi Province in the mid-western part of the island, close to Bukit Tigapuluh National Park, where many companies have

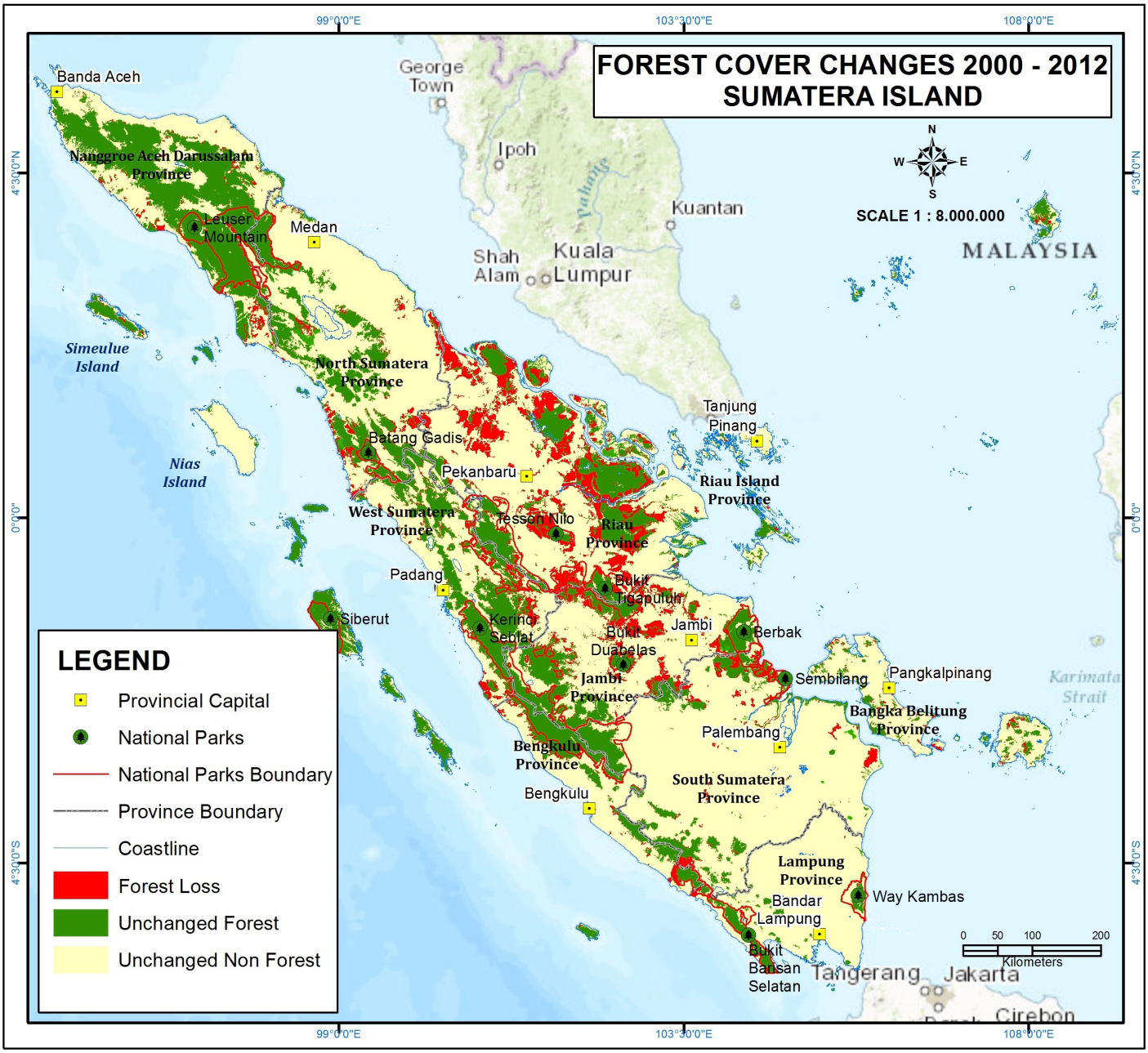

Figure 1. Deforestation in Sumatra (by province) between 2000 and 2012. Green areas show forest cover remaining in 2012 and red areas show forest lost between 2000 and 2012. National Parks are also shown.

converted their forest concessions into plantations of acacia and oil palm**.**

In North Sumatra, most forest was lost in the region of the Rawa Singkil Game Reserve, on the southern border of Gunung Leuser National Park. It is located between Gunung Leuser National Park and Batang Gadis National Park (Fig.1). Several companies converted their forest concessions into oil palm plantations. Illegal logging has also affected many areas in the Gunung Leuser National Park itself. All of those affected areas are the habitat of the Critically Endangered Sumatran orangutan *Pongo abelii*, as well as other primates, such as Thomas's langur *Presbytis thomasi*, the Lar gibbon *Hylobates lar*, and the Siamang *Symphalangus syndactylus*.

Figure 2 shows the trend in the rate of forest loss between 2000 and 2012. All provinces show rates of forest loss trending downward. Even provinces with relatively low total forest loss, such as Aceh and Lampung (Table 1) are showing the same downward trend. In Lampung, where there is little forest cover left, this suggests the possibility that none will remain in the near future. Way Kambas National Park may even be at risk. In Aceh, where there is still substantial forest cover remaining, it shows how the opportunity that exists now to arrest decline is disappearing.

Table 2 shows the percentage of forest lost across the range of each Sumatran primate species. The greatest impact was on the Banded langur *Presbytis femoralis*, in Tesso Nilo Forest and on Kampar Peninsula, both in Riau. This species

Table 1. Changes in forest cover in each province of Sumatra between 2000 and 2012.

Province	2000 (ha)	2012 (ha)	Deforestation (ha)	Deforestation (%)
Aceh	3,420,356.1	3,190,664.8	229,691.30	6.72
Bangka-Belitung	319,716.2	254,409.4	65,306.80	20.43
Bengkulu	807,772.0	709,978.8	97,793.20	12.11
Jambi	1,872,869.2	1,297,884.7	574,984.50	30.70
Riau Islands	297,664.3	271,572.3	26,092.00	8.77
Lampung	309,401.8	297,841.9	11,559.90	3.74
Riau	3,700,863.9	1,856,059.6	1,844,804.30	49.85
West Sumatera	2,219,120.9	1,955,018.7	264,102.20	11.90
South Sumatera	1,156,946.5	972,495.9	184,450.60	15.94
North Sumatera	1,959,816.4	1,710,860.6	248,955.80	12.70
Grand Total	**16,064,527.30**	**12,516,786.70**	**3,547,740.60**	**22.08**

Table 2. Loss of Sumatran primate habitat due to deforestation, between 2000 and 2012.

Species	2000 (ha)	2012 (ha)	Deforestation (ha)	Deforestation (%)
Nycticebus coucang	16,269,872	11,609,881	4,659,991	28.64
Nycticebus bancanus	683,587	257,496	426,091	62.33
Cephalopachus bancanus	1,971,709	1,708,159	263,550	13.37
Presbytis siamensis	454,319	228,749	225,570	49.65
Presbytis sumatrana	1,955,141	1,708,159	246,982	12.63
Presbytis bicolor	3,236,717	726,554	2,510,163	77.55
Presbytis mitrata	1,412,558.50	792,381	620,178	43.90
Presbytis thomasi	3,355,323	3,149,562	205,761	6.13
Presbytis femoralis	1,152,684	203,485	949,199	82.35
Presbytis melalophos	1,815,742.50	697,812	1,117,931	61.57
Presbytis potenziani	810,125	777,728	32,397	4.00
Simias concolor	810,125	777,728	32,397	4.00
Trachypithecus cristatus	17,192,006.50	12,106,052	5,085,955	29.58
Macaca fascicularis	16,269,872.50	11,609,881	4,659,992	28.64
Macaca nemestrina	16,269,872.50	11,609,881	4,659,992	28.64
Macaca siberu	190,500	182,880	7,620	4.00
Macaca pagensis	182,887	160,940	21,947	12.00
Hylobates klossii	810,125	777,728	32,397	4.00
Hylobates lar	6,912,123	3,207,166.60	3,704,956	53.60
Hylobates agilis	9,857,169	7,891,990	1,965,179	19.94
Symphalangus syndactylus	16,269,872	11,609,881	4,659,991	28.64
Pongo abelii	5,310,464	4,857,722.40	452,742	8.53

lost 82% of its habitat or 949,199 ha of forest between 2000 and 2012. Other species suffering high rates of forest loss include the Bangka slow loris, *Nycticebus bancanus* (62%), the Black-and-white langur *Presbytis bicolor* (78%), and the Black-crested Sumatran langur *Presbytis melalophos* (62%).

Protected areas and primate habitat

Table 3 shows that two primates are not represented in the protected area and national park system at all, and that a further five are found in only one protected area. The two unrepresented species are the Pagai macaque, *Macaca pagensis*, and the Mentawai langur, *Presbytis potenziani.* Both occur on Sipora and the Pagai islands off the west coast of Sumatra (Whittaker 2005, 2006). There was a proposal to create a game reserve of 84,500 ha on Sipora, but it has lapsed. There may be only 17,569 ha of intact forest left on the three islands: Pagai North, Pagai South and Sipora (Pemerintah Kabupaten Padang Pariaman, 2014). A subspecies of *C. bancanus*, the Belitung tarsier *C. bancanus saltator*, occurs on Bangka and Belitung islands. There is some forest remaining on these islands, but no protected areas or national parks have been established there. Some of the remaining forest on Belitung has been proposed as a protected watershed. It would not have the same legal status as a national park.

Discussion

While logging itself does not cause deforestation, logging followed by conversion to agriculture and plantations does. The process is as follows. Although Indonesia's forest law allows selective logging under a system that would give the forest 35 years to recover, commercial logging companies often over-log areas deliberately. After over-logging, an application is submitted to the government to have the over-logged area declared "degraded", which implies that the area is no longer fit to be called a forest and can now be converted to a plantation. This change in status requires an official reclassification of the forested land. Once that change is approved, another company—often a sister company belonging to the same conglomerate—applies for a license to convert that new "wasteland" forest to plantations of either oil palm or acacia for pulp wood. Once the license is issued, the remaining trees are removed and go to a pulp mill. Then plantations are established, the products of which go to mills likely to be owned by members of the same conglomerate (WWF 2004). Companies often cannot prevent local cooperatives, farmers' associations, village organizations, fake companies, and smallholders from encroaching their logging concession, further exacerbating the problem. The above process has been widespread and continues to occur over and over again (Gaveau *et al*. 2009).

This kind of land use change has affected the largest remaining lowland forest blocks on non-peat soils. When the Bukit Tigapuluh National Park was designated in 1995, it was still connected with some of the surrounding forests. In 1996, the first two industrial timber plantation concessions, with licences to clear-cut the forest, appeared in this landscape.

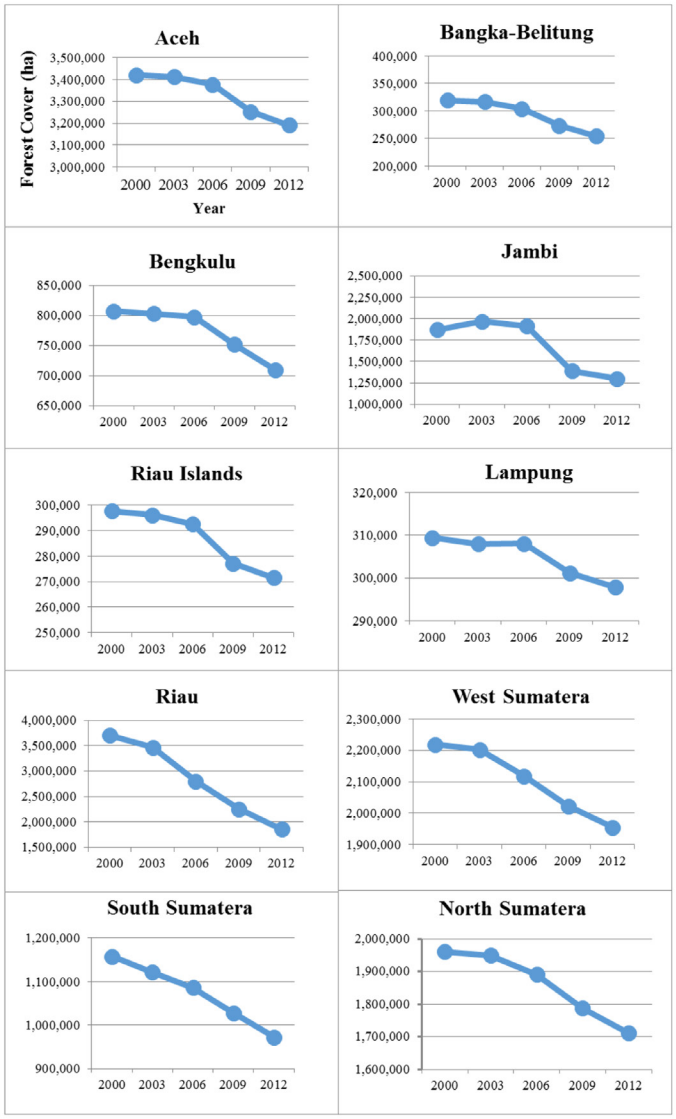

Figure 2. Rate of forest loss in Sumatran provinces between 2000 and 2012.

At that time, most of the unprotected natural forest (outside national park and protection forest boundaries) was inside selective logging concessions, supposedly safe from conversion by law. Today, Bukit Tigapuluh's approximately 320,000 ha of natural forest are isolated, surrounded by plantations and deforested lands. The endemic primates that occur in these areas are the Black-and-white langur, *Presbytis bicolor*, the Black-crested Sumatran langur, *Presbytis melalophos*, the Agile gibbon, *Hylobates agilis*, and the Siamang, *Symphalangus syndactylus*.

The difference between logging and land conversion for agriculture or tree plantation is that the latter leads to permanent forest loss, while logging (especially selective cutting) provides the opportunity for forests to regenerate. Moreover, land-clearing methods applied in the establishment of timber estates or commercial agriculture contributes to forest fires.

Forest fires are another major cause of deforestation in Sumatra. Although many point to natural causes such as El Niño, human activities and forest management practices play important roles in causing forest fires. In 1997–1998, the El

Table 3. Occurrence of primates in national parks and other protected areas in Sumatra. NP = National Park, PA = Protected Area.

Primate species	Leuser NP (1,092,692 ha)	Lingga isaq PA (80,000 ha)	Rawa Singkil Game Park (102,500 ha)	Batang Gadis NP (108,000 ha)	Tesso Nilo NP (83,018 ha)	Bukit tigapuluh NP (127,698 ha)	Bukit Dua belas NP (60,500 ha)	Kerinci seblat NP (1,375,359 ha)	Sembilang NP (205,100 ha)	Berbak NP (162,700 ha)	Way Kambas NP (130,000 ha)	Bukit Barisan NP (376,999 ha)	Siberut NP (190,500 ha)	Muh Hatta Game Park (71,807 ha)	Kampar PA (20,000 ha)	Total # of parks
Pongo abelii	×	×	×	×												4
Symphalangus syndactylus	×	×		×	×	×	×	×			×	×		×		10
Hylobates lar	×	×														2
H. agilis				×	×	×	×				×	×		×		8
H. klossii													×			1
Presbytis thomasi	×	×	×													3
P. sumatrana			×	×												2
P. melalophos						×	×	×				×		×		5
P. siamensis					×										×	2
P. femoralis															×	1
P. mitrata											×	×				2
P. bicolor						×	×									2
P. potenziani																0
P. siberu													×			1
Trachypithecus cristatus	×	×	×	×	×	×	×	×	×	×	×	×		×	×	14
Simias concolor													×			1
Macaca nemestrina	×	×	×	×	×	×	×	×	×	×	×	×		×		13
M. fascicularis	×	×	×	×	×	×	×	×	×	×	×	×		×	×	14
M. siberu													×			1
M. pagensis																0
Nycticebus coucang	×	×	×	×	×	×	×	×	×	×	×	×		×	×	14
Cephalopachus bancanus								×	×	×	×	×				5

Niño Southern Oscillation—a cyclical warming and cooling of the eastern Pacific Ocean—brought drought conditions to Sumatra, rendering forests on peaty soils especially vulnerable to fire. At the same time, the price of palm oil increased, and plantation developers in Sumatra, eager for land, deliberately burned large areas of forest. During this time fires reportedly destroyed almost 1 million ha of forests (World Bank 2001).

Forest fires in Indonesia have been recurrent for the last 17 years. In 2015, the fires were even more destructive than they were in 1997–1998, burning 3.4 million ha of forest. The smoke from deforestation by fire adversely affects the health of people in neighbouring countries as well as in Indonesia. The release of carbon into the atmosphere contributes to climate change. The cost of the 2015 fires is estimated to have been approximately US$14 billion and may be more if the costs of mitigating the impact in several other Southeast Asian countries are included (WRI 2015). Most of those fires were in Sumatra and Kalimantan.

Illegal logging

Logging occurs mainly in concessions granted to companies. However, as long as 16 years ago the Indonesian Ministry of Forestry (2002) officially stated an opinion that had been prevalent for some time:

"Illegal logging has come to constitute a well-organized criminal enterprise with strong backing and a network that is so extensive, well-established and strong that it is bold enough to resist, threaten, and in fact physically tyrannize forestry law enforcement authorities. Illegal cutting occurs in concession areas, unallocated forest areas, expired concessions, state forestry concessions, areas of forest slated for conversion, and in conservation areas and protected forests."

This continues to be the case today. Currently, illegal logging is increasing in conservation areas (protected areas and national parks) since these areas now have better timber potential than production areas. Many experts believe that the main actors in illegal logging are: (a) laborers from communities within the local forest area as well as from other areas; (b) investors, including traders, concession holders, or holders of legal timber cutting permits (IPK), and buyers of illegal timber; and (c) government officials (both civilian and military), law enforcement personnel and certain legislators (Supriatna *et al.* 2002).

Policy changes

Government policy also contributed to forest loss when decisions on forest use were decentralized from the Ministry of Forestry to district governments in 1999 and renewed in 2004. District governments have been allowed to allocate 100-ha forest concessions to be logged by small-holders and communities without appropriate planning and without an understanding of forest ecology (Supriatna 2009). The World Bank (2001) and Holmes (2002) predicted that with this kind of policy, lowland natural forest would be likely to disappear from Sumatra by 2005. There has been no follow up of Holmes's (2002) prediction to determine whether and at what rate forest loss is progressing. Although a recent review did confirm some of his prediction, that forest cover is being lost not only in production forest, but also in protected areas, including national parks, not all lowland forest has disappeared (Supriatna 2009).

It has been government policy to expand palm oil production since 2005, which has resulted in more deforestation. Everyone wants to grow oil palm. Decentralization also allowed government authorities to issue oil palm licenses more freely. This may have had an even more significant impact on forest loss than the 100-ha logging concessions.

Road construction

Roads built across the Tesso Nilo Forest block in Riau province to provide transport for pulp and paper companies have significantly increased deforestation rates by facilitating encroachment into the forest by local communities and illegal loggers from other places. More than 80 km of roads have been used by people, not only to cut trees along the roads, but also to access once remote parts of the forest (Mariati *et al*. 2014). The resulting picture looks like a comb: the roads acting as primary axes, with many new small access tracks to huts and new small business houses selling to people, encroaching along these main roads. These "fishbone" patterns have been found in many other tropical countries.

Satellite images, provincial public works plans and budget allocation documents reveal that roads are being constructed throughout Sumatra. Satellite images show thousands of logging roads penetrating deep into protected forests and national parks. Aceh Province has a plan to construct a system of feeder roads extending from Banda Aceh, south to the Leuser Ecosystem boundary. A road was recently constructed in the Kerinci Seblat National Park, Jambi Province, despite local and governmental agreement forbidding road construction. Accessibility of a forest is often the most important factor leading to deforestation (Etter *et al*. 2006; Laurance *et al*. 2009; Clements *et al*. 2014; Laurance *et al*. 2015).

Impact of deforestation on primates

The last review of population sizes, ecology and conservation status of Sumatra's primates, part of a review across all of Indonesia, was carried out in 2000 (Supriatna *et al*. 2001). Fifteen years later, many surveys have been conducted and the results of some long-term research studies are available. These are summarized below and compared to the review of Supriatna *et al*. (2001).

Human activities (predominantly the processes described above of logging, land conversion, and fire) have caused widespread forest fragmentation so that even where some high quality habitat remains, it is often disaggregated into small, isolated forest fragments. Fragmentation restricts the dispersal of primates. Their home ranges or territories become limited, sub-populations become isolated from one another, and there is competition for habitat (Groom *et al*. 2006). Limited

home ranges and the isolation of sub-populations causes population declines. Small populations are less viable than large ones (Cowlishaw and Dunbar 2000). Road construction patterns such as those described above indicate that habitat fragmentation will become increasingly widespread in the future.

Seven years ago, Indonesian and international experts on orangutans were invited by the Ministry of Forestry to discuss ways of preventing the extinction of Sumatran orangutans in the wild. Five hundred was considered by the expert panel to be the minimum size at which orangutan populations could be expected to have the necessary genetic diversity to cope with the various challenges posed by environmental change. Populations of fewer than 500 individuals lack the resilience to hold out against the prospect of extinction without the aid of environmental protection and population management efforts (Indonesia Ministry of Forestry 2009). Most isolated orangutan sub-populations now have fewer than 500 individuals.

The impacts of deforestation on gibbon populations in Sumatra have been studied by Yanuar and Chivers (2010). Agile gibbons are most dependent on closed canopy forests and year-round fruit availability. They were encountered or heard in relatively high numbers in undisturbed forest, where the related Siamangs also appeared to be abundant. Gibbons and Siamangs still occurred in selectively logged forests, but in lower numbers. Siamangs were encountered in forests without Agile gibbons, but not the other way round (Yanuar and Chivers 2010). Siamangs appear to be more resilient to forest degradation. This is not surprising considering that Siamangs are able to survive on a more folivorous diet, whereas the smaller gibbons need a higher proportion of fruit in their diets (Raemaekers 1979).

In Way Kambas National Park, Lampung, South Sumatra, langurs (*Trachypithecus* spp. and *Presbytis* spp.) have been observed in small forest patches and more heavily disturbed forests, and even in rubber plantations that still included some of the original forest trees. However, gibbons and Siamangs are absent. No primates were encountered in monoculture rubber plantations, although a group of Long-tailed macaques was observed on the periphery of one of them, suggesting that this particular species may have a high adaptive flexibility. Habitat degradation and logging were observed in virtually every forest (Geissmann *et al*. 2006).

In many villages in South Sumatra, pet primates are openly displayed or are shown without hesitation. They include species that are legally protected by Indonesian law, showing ignorance of, or disregard for, the law and a general lack of law enforcement. Primates are also illegally hunted in Sumatra for food, profit and trophies, and to fulfill obligations related to cultural rites of passage. Magnifying the problem, as a result of habitat fragmentation, many animals are now concentrated in smaller areas, making them easier targets for hunters, as well as making them less able to recover from population declines, especially when animals of reproductive age are taken (Supriatna *et al*. 2001).

The swamp area between Rawa Singkil Protected Area and Gunung Leuser National Park, has the largest remaining populations of Sumatran orangutans (Singleton *et al*. 2009). Estimates of the total population of Sumatran orangutan have declined dramatically over the last two decades due to habitat loss. Some surveys concluded that more than 1,000 orangutans were lost each year due to forest loss during the late 1990s (Singleton *et al*. 2009). According to survey results published in 2008, only around 6,600 Sumatran Orangutans remained in the wild (Wich *et al*. 2008; Singleton *et al*. 2009). Fortunately, a new survey conducted in 2015 estimated a total population of 14,613 (Wich *et al*. 2016). This was a more systematic survey then the earlier ones, finding orangutans at higher elevations than they were thought to occur at, in areas that had not been previously surveyed, and in some logged forests. This has extended the known range to 17,800 km^2. However, even given that there is a larger and more widely distributed population than previously thought, Wich *et al*. (2016) warn that with the current rate of forest loss, the total population is likely to be reduced to approximately 4,500 individuals by 2030.

Role and performance of national parks and other protected areas

Many of the protected areas in Sumatra cover regions with extremely rugged terrain, or with slopes or elevations unsuitable for agriculture. Most of the largest national parks and protected areas are located in the mountain range of Bukit Barisan, running from north to south on the western side of the island. Most Sumatran primates occur in lowland forest or forests of lower slopes, which are not well-represented in protected areas. Densities of fauna in most protected areas are therefore already low and will decline further unless dispersal between them is facilitated by, for example, corridors of natural habitat. Encroachment of people makes restoration and conservation of such corridors increasingly difficult. The protected areas themselves face a number of basic management problems, including poor staff morale and discipline; lack of incentives for good performance by staff; limited capacities and training; emphasis on park infrastructure rather than enforcement or awareness-raising activities; budget allocations made according to previous budgets rather than threats or needs on the ground at the present time; and emphasis on administration rather than field duties for park managers (Supriatna *et al*. 2002).

In addition, most parks have little support from local communities and decision-makers. The government of Indonesia made commitments to the special Consultative Group meeting on forestry issues in January 2000, including a commitment to stop illegal loggers, especially those operating in national parks. At that time, conservation donors maintained that there was little point in funding conservation efforts if they were not supported by effective government enforcement. Unfortunately, widespread illegal logging and corruption remain in evidence. In fact, illegal logging in Sumatra's protected areas may even be increasing (FWI 2001; FWI and GWF 2002; Gaveau *et al*. 2012)

In many conservation areas, especially in the nature reserves where no economic activity is allowed, the incentives for local people to preserve the natural habitat and to abstain from encroachment are very weak. It has been reported, for example, that 25 unlicensed sawmills were in the immediate vicinity of Bukit Tigapuluh National Park (Anggraeni 2000). These sawmills had no official allocation of legal timber and thus relied upon an illegal supply from the surrounding forest. The estimated processing capacity of those sawmills at that time was around 230,000 m of roundwood per year (Anggraeni 2000).

Existing protected areas are not secure and their protection effectiveness, if measured as the percentage of area degraded annually, is poor. Most Sumatran protected areas are under-resourced and some receive no regular budget at all. Priority conservation areas are reliant on supplementary donor financing, which covers only a limited project period. Several national parks are supported by international donors where, unfortunately, the annual forest loss is similar in size to under-funded areas (Supriatna 2009; Margono *et al*. 2012).

There are many overlapping and conflicting claims to lands within protected areas. According to newspaper reports, this situation has worsened with decentralization and new perceptions of local community land rights. Way Kambas National Park in Lampung Province is a good example. It is a high conservation priority lowland forest which is nearly 50% degraded because of conflicting ownership claims. Several thousand people have submitted court claims based on the perceived illegality of the original creation of the national park. The purpose and intention of the park has been noted on the provincial spatial plan or forest land use map, but little action leading to official gazettal is evident. It is only when local governments (governor, regent) have passed decrees based on field-level consultations with local communities, that an area can be legally gazetted, as set forth in a final decree issued by the Minister of Forestry. There is little incentive for this to happen.

Changing production forests into national parks by converting the tenure of logged-over areas would seem, on the face of it, to be a secure and effective way of reducing deforestation. However, even though some forests, such as Tesso Nilo and its surrounds have been proposed for conversion to national park status, the process of demarcating forest boundaries is slow and confusing, involving overlapping and conflicting claims to lands within the park and within other forested lands belonging to companies. This legal uncertainty makes it easier to excise land from proposed parks for other uses (Uryu *et al*. 2007). Issues with conflicting land tenure claims, imprecise boundaries and differences between *adat* (traditional) law and government law are recurring issues throughout Indonesia (for example, Riggs *et al*. 2016) that need to be resolved to secure primate habitat into the future.

In May 2011, the Government of Indonesia prohibited district governments from granting new forest concession licenses (President Instruction No. 10; Fajar 2013), which was extended for another two years in 2013, despite some opposition from powerful palm oil interests (Butler 2013). This moratorium covered licenses for three types of activities: (i) conversion of primary forests and peatlands to oil palm plantations (oil palm concessions); (ii) conversion of primary forests and peatlands to fast-growing tree plantations for pulp and paper (timber concessions); and (iii) logging of commercially valuable tree species in forests (logging concessions). It was meant to protect over 65 million ha of forest and peatlands (Sloan 2014). However, in the first two years, around 4.5 million ha were removed from the moratorium for mining and agro-industries, and it seems a further 5.5 million ha, which overlaps with current forest licenses may also become exempt. This has occurred mainly due to a lack of clarity of maps of the moratorium areas. Nevertheless, the moratorium is an important development and demonstrates a serious attempt by the government of Indonesia to protect Indonesia's forests (Butler 2013; Sloan 2014).

Conclusions

The loss of primate habitat will continue as human populations continue to increase and more and more forest is converted to plantation estates and agricultural lands, and roads are built across Sumatran forests. As a consequence, many primates will become forced to share what remains of their territories with people. The resulting conflict between the need for human livelihoods and the need to protect primates, especially those that are Critically Endangered such as the Sumatran orangutan, has quickly escalated. Using GIS and remote sensing imagery, we found that deforestation rates have increased in the habitats of many primates. Orangutan habitat in North Sumatra and Aceh has been severely reduced and the habitats of many other primates in the provinces of North Sumatra, Riau, Jambi and South Sumatra have also declined markedly in area. High deforestation rates have occurred as a result of legally converting natural forest into oil palm, rubber and Acacia plantations, and illegal logging of the forests, even in protected areas and national parks. The problem is exacerbated by the fact that Indonesia remains largely an agricultural country. A significant proportion of the population relies on farming for survival. Population pressure and the lack of off-farm employment leads to demands for more agricultural land, which can only come at the cost of forests. With recent taxonomic revisions, some primates such as those of the Mentawai islands of western Sumatra (*Presbytis potenziani*, *Macaca pagensis*) and the subspecies *Cephalopachus bancanus saltator* on Bangka and Belitung islands in eastern Sumatra, are not found in protected areas at all. The remaining habitat of these three species, covering only a few thousand hectares, is not enough for them to survive unless the forest remnants in which they occur become protected and connected with each other.

The results presented here now constitute a baseline against which improvements can be monitored. Any further loss cannot be countenanced. Habitat degradation cannot be allowed to continue if many of Sumatra's primates are to

survive. Enforcement of existing regulations, disentanglement of land claims and overlapping boundaries, a halt to logging in existing forests, a halt to road building through existing forests, clarification of how *adat* (traditional) law relates to protected areas, and the creation of new, enforceable laws protecting species from trade and exploitation will all be needed if Indonesia is to uphold its stated commitment to primate conservation.

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Authors' addresses:

Jatna Supriatna, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok, West Java, 16425, Indonesia, and Research Center for Climate Change, Kampus UI Depok, Universitas Indonesia, Depok, West Java 16424, Indonesia, **Asri A. Dwiyahreni** and **Nurul Winarni**, Research Center for Climate Change, Kampus UI Depok, Universitas Indonesia, Depok, West Java, 16424, Indonesia, **Sri Mariati**, Postgraduate Program, Trisakti Institute for Tourism, Pesanggrahan, Jakarta, Indonesia and Conservation International Indonesia, Jl. Pejaten Barat no. 16A, Kemang, Jakarta, 12550, Indonesia and **Chris Margules**, Research Center for Climate Change, University of Indonesia, and Centre for Tropical Environmental and Sustainability Science, College of Marine and Environmental Sciences, James Cook University, PO Box 6811, Cairns, 4870, Australia.

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