Deforestation and it is Implications for Sumatran tigers in Bukit Barisan Selatan National Park, Sumatra
(Deforestasi dan Implikasinya terhadap Populasi Harimau Sumatra di Taman Nasional Bukit Barisan Selatan, Sumatra)

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ABSTRACT
Bukit Barisan Selatan National Park (BBSNP) consist complex ecosystem starting from lowland tropical forest included mangrove forest until highland tropical forest. This park identified as a high priority tiger conservation area (Tiger Conservation Unit 1). However, much forest cover has been cleared. Deforestation is not only great threat to forest conservation, but also for the population of Sumatran tiger. This study linked data series of satellite imageries and long-term camera trap tiger surveys to identify patterns of deforestation, tiger population, and the implications of deforestation for Sumatran tigers. The result showed around 27% of forest cover in BBSNP had loss. In one decade (1998 – 2006), the average rates of deforestation were 18.76 km^2/year. The number tiger population declined dramatically from 57 individual in 1998 to 22 individual in 2006, and tiger density was also drop from 2.25 individual/100km^2 to 1.16 individual/100km^2. Tiger habitat is varied from lowland forest included mangrove forest until montane forest.

Keywords: Deforestation, Mangrove, Camera Trap, Satellite Imagery, Sumatran tiger, Bukit Barisan Selatan National Park.

ABSTRAK
Taman Nasional Bukit Barisan Selatan (TNBBS) memiliki ekosistem yang lengkap mulai dari hutan dataran rendah termasuk hutan mangrove hingga hutan dataran tinggi. Taman nasional ini teridentifikasi sebagai area konservasi prioritas utama untuk harimau sumatra (*Tiger Conservation Unit 1*). Akan tetapi, banyak tutupan hutan yang di gunduli (deforestasi). Deforestasi bukan hanya menjadi ancaman besar bagi kelestarian hutan tetapi juga terhadap populasi harimau sumatra. Penelitian ini menghubungkan data citra satelit Landsat dengan data survei harimau menggunakan kamera otomatis (*camera traps*) untuk mengetahui pola deforestasi, populasi harimau, dan implikasi deforestasi terhadap populasi harimau. Hasil penelitian menunjukan sekitar 27% tutupan hutan di TNBBS telah hilang. Rata-rata laju deforestasi dalam satu dasawarsa terakhir (1998 - 2006) sebesar 18,76 km^2/tahun. Jumlah harimau menurun dari 57 individu pada tahun 1998 menjadi 22 individu di tahun 2006, dan kepadatan populasinya juga menurun dari 2,25 individu/100km^2 menjadi 1.16 individu/100km^2. Harimau di TNBBS memiliki habitat yang bervariasi mulai dari hutan dataran rendah termasuk mangrove ikutan hingga dataran tinggi.

Kata Kunci: Deforestasi, Mangrove, Camera Trap, Citra Satelit, Harimau Sumatra, Taman Nasional Bukit Barisan Selatan

INTRODUCTION

Bukit Barisan Selatan National Park (BBSNP) is one of the unique protected areas in Sumatra. It includes diverse forest types ranging from low land forest (including mangrove in the in south) to mountain forest on the north side of the park. BBSNP contains some of the largest tracts of lowland forest remaining on Sumatra and is the major watershed for southwest Sumatra (FAO 1981). The park is important habitat for Sumatran tigers (*Panthera tigris sumatrae*), and it

has been identified as a high priority tiger conservation area (TCU I = Tiger Conservation Unit I) for tropical moist evergreen forest in Southeast Asia by the Wildlife Conservation Society and the World Wildlife Fund (Wikramanayake *et al.* 1998). The UNESCO also declare BBSNP a World Heritage site (decision 28COM 14B.5) to conserve natural resource and biodiversity.

The only remaining tiger species in Indonesia is the Sumatran tiger; the other subspecies, such as the Javan tiger (*Panthera tigris sondaica*) and the Bali tiger (*Panthera tigris balica*), are extinct. Panwar (1987) reports that the tiger is frequently used as a key species in Asian land-use plans aimed at conservation, restoration of degraded lands, and sustainable natural resource use. In addition, the tiger is a top predator that has important effects on lower levels in the food web (Schmitz & Suttle 2001). Karranth (1995) reports the tiger has been used as a charismatic flagship species for protection of biodiversity. However, this species is critically endangered; the IUCN classified the tiger as Appendix I under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The Indonesian government also protects this species under the Act of the Republic of Indonesia No.5 of 1990 concerning Conservation of Living Resources and their Ecosystems (*UU No.5 Tahun 1990 Tentang Konservasi Sumberdaya Alam Hayati dan Ekosistemnya*).

One of the greatest threats to tiger populations is deforestation (e.g., habitat loss). The international community is tasked to reduce deforestation as one of several measures to reduce global warming and maintain biological diversity (UNFCCC 2007). Habitat loss in BBSNP still attracts strong global attention as one cause of tiger population declines. Some conservation biologists use satellite-based datasets to assess deforestation; however many aspects related to deforestation cannot be measured using data from satellite-based sensors (Turner *et al.* 2001). Kinnaird *et al* (2003) examine the implications of deforestation for some endangered large mammals but do not focus on the Sumatran tiger. A further obstacle for tiger conservation in BBSNP is that recent data related to tigers are limited. Here, we use data from long-term (1996 to 2006) camera trap wildlife surveys and link these data to satellite imagery to identify patterns of deforestation and implications for Sumatran tigers. We examine how these patterns influence tiger populations and their habitat preferences. Our study found implications of deforestation for the declining the relative abundance of tigers. Tigers also avoid deforested edges and prefer interior forest habitat. Although our research did not incorporate recently collected tiger data, we believe that results are still useful for park management policies and for government wildlife export quotas.

MATERIAL AND METHODS

BBSNP (3568 km^2 at 4^o 31' to 5^o 57' S and 103^o 34' to 104^o 43' E) is located in the southwestern part of the island of Sumatra, Indonesia, in the provinces of Lampung and Bengkulu, and is the island's third-largest protected area. The park extends 150 km along the Bukit Barisan mountain range, and includes diverse topography. Rainfall is seasonal, ranging from 3,000 mm to 4,000 mm, and temperatures fluctuate between 22^{o}C and 35^{o}C. The park is narrow in shape, with a perimeter longer than 700 km in length, and is bordered by villages, agriculture, and plantations.

To generate maps of changing forest cover across BBSNP, we used LANDSAT scenes for the years 1998 (TM), 2000 (TM), 2002 (TM), 2004 (ETM), and 2006 (ETM). All scenes contained

negligible cloud cover (less than 1.0%). All images were registered to a 2006 scene that was georeferenced with ground control points collected in the field using handheld Global Positioning Systems (GPS). A 10-m resolution ASTER Digital Elevation Model was used to categorize forest types into three categories based on Kinnaird *et al.* (2003): lowland forest including associated mangrove forest (0–500 m), hill forest (501–1000 m), and mountain forest (>1001 m).

The images were manually interpreted through on-screen digitization. The time-series of images were interpreted as a temporal progression of land-use change, with forest cover at each point in time used as the base forest cover for the next point in time. The results of the manual interpretation were corrected using a field dataset of GPS points. The areas and rates of deforestation also were calculated based on the forest elevation categories.

Long-term camera-trap data of Sumatran tigers from the Wildlife Conservation Society were used in this study. Five tiger surveys were conducted between September 1998 and July 2006 in BBSNP using passive infrared camera traps (Camtrakers South Inc., Watkinsville, GA 30677). In an effort to detect edge effects on tiger distribution and presence, cameras were placed in 2.0 x 10-km sampling blocks (Figure 1) oriented from the park boundary toward the park interior. Camera trap sampling blocks were also oriented from the southern section of the park toward northern section, in an effort to include all forest types and to examine the tiger population in the three types of forest. Sampling blocks were spaced uniformly at 10-15-km intervals. The spacing of sampling blocks was based on maximum distance movement of Sumatran tigers. There were a total of camera sampling blocks, and each block was divided into 20 1-km^2 subunits (Figure 2) with a random UTM coordinate within each subunit.

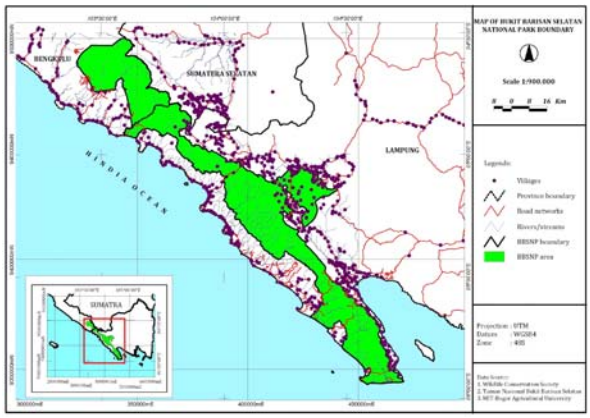

Figure 1. Study area of Bukit Barisan Selatan National Park

Estimating tiger abundance using capture-recapture techniques by direct count is problematic due to the animals' secretive nature and low densities. Because individual tigers have unique body stripe patterns, it is possible to estimate population size using capture-recapture methods. This study used Program CAPTURE (PWCR Software archive) to estimate the density and abundance of tigers and their capture probabilities. Multiple logistic regression analyses were employed to identify correlations of deforestation and Sumatran tiger populations. This research calculated the residuals between observed and expected photo captures and looked for natural breaks in the distribution of residuals with Jenk's optimization method (to calculate the goodness of variance fit). The Goodness of Variance Fit (GVF) identifies optimal breaks in data categories when alternative data classifications are used for the same set of numerical data. This method allows us to evaluate the implications of deforestation on the tiger preference of forest area.

RESULTS

Rates and Patterns of Deforestation

The image analysis for 1998 showed that 972 km^2 of forest cover had been lost in BBSNP

(27% loss of the park area of 3568.00 km²). From 1998 to 2006, the deforestation rate in BBSNP averaged 18.76 km² per year (0.71% per year). In contrast, the average rates of natural reforestation were only 0.67 km² per year (0.03 % per year). By 2006, BBSNP had only 2,468 km² of the original forest. This represented a loss of 7% from the 2,629 km² that remained in 1998. The vast majority (99%) of forest conversion in the park resulted from agricultural development. Table 1 shows statistic information on land cover change in the park over time (1998, 2000, 2002, 2004, and 2006).

Deforestation rates varied with the type of forest. The highest deforestation rates of 8.34 km²/year occurred in lowland tropical forest (which represents 43% of BBSNP area). Deforestation rates in hill tropical forest (38% of the park area) and mountain tropical forest (19% of the park area) were 7.30 km²/year and 3.11 km²/year, respectively. The area of associated mangrove forest in the park was relatively small; thus, we included this forest type with lowland tropical forest for the analysis. Deforestation rates from 1998 to 2000 increased dramatically from 6.04 km²/year to 15.11 km²/year for hill forest and from 0.98 km²/year to 7.49 km²/year for mountain forest. Next, from the year 2000 on, the deforestation rates in these forest types declined sharply and then increased again gradually in 2004. Deforestation rates in lowland forest fluctuated; they increased from about 3 km²/year in 1998 to 9 km²/year in 2006 (Figure 3).

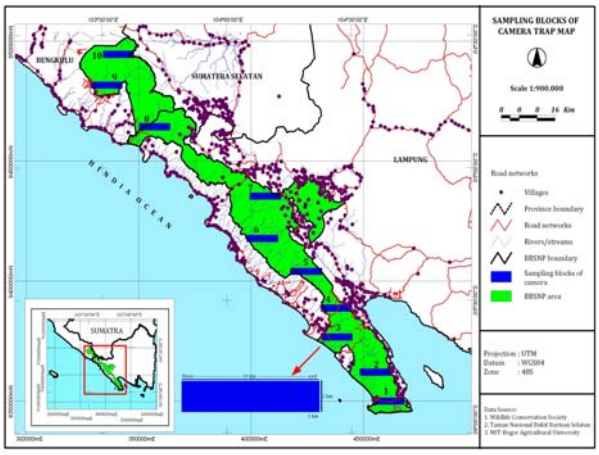

Figure 2. Sampling blocks of the camera traps and it oriented to three type elevation of forest in Bukit Barisan Selatan National Park

Sumatran Tiger Population

The estimated tiger population size for the first camera-trap sampling period (1998 to 2000) was 21 ± 4.47, with a 95% confidence interval (CI) of 12 – 30 individuals. The furthest distance between recaptures of the same individual tigers was 3.4 km, leading to an estimated total effective sampling coverage of 1118.4 km² for the 10 sampling blocks combined. Combining the estimated tiger population size with the effective sampling coverage, the research estimates the density of tigers to be 1.88 tigers/100 km² (95% CI = 1.09 - 2.68 tigers/100 km²). The last sampling period (2004 to 2006) identified 4 individual tigers from 7 tiger photographs. The estimated population size was 10 ± 3.26 tigers with a 95% CI of 4 – 18 and a coefficient of variation of 26.62%. The furthest distance between recapture of the same individual tiger was 3.98 km, and the estimate of the total effective sampling coverage for the 10 sampling blocks was 1,300 km². According to the population estimate and sampling area, the tiger density was 0.97 tiger/100 km² (95% CI = 0.43 -

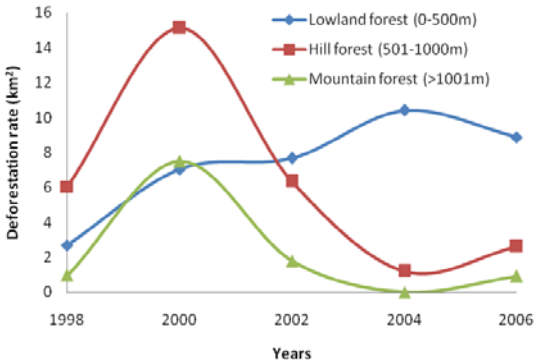

Figure 3. Deforestation patterns in lowland forest, hill forest, and mountain forest

Table 1. Statistic information of land covers change in BBSNP

Description	1998	2000	2002	2004	2006
Area of forest cover (km^2)	2629	2544	2515	2493	2468
Area of forest loss (km^2)	622	707	736	758	784
Percentage of BBSNP with forest	75	71	70	70	68
Deforestation rate (km^2/year)	9.71	29.65	15.81	11.64	12.49

1.41 tigers/100 km^2).

Our recent study (Suyadi et al, 2012) showed that tigers prefer the forest interior of BBSNP as their habitat. In addition, our analysis showed that tigers tend to avoid roads and deforested areas. Kinnaird et al (2003) suggested that only the forest interior is effective tiger habitat. Therefore, we calculated the effective habitat sampled by subtracting the amount of edge habitat from the total sampling coverage and then estimated tiger density based on the effective habitat. Our calculations show that the effective habitat is 932.6 km^2; this gives an estimate of tiger density of about 2.25 tigers/100 km^2 (95% CI = 1.29 – 3.22 tigers/100 km^2 of habitat) in the first camera -trap period and around 1.16 tigers/100 km^2 (95% CI= 0.52 - 1.84 tigers/100 km^2) in the last camera-trap period.

In sum, this research indicates that the total densities of tigers in BBSNP have decreased from 1.88 individual/100 km^2 in 1998 to 0.97 individual/100 km^2 in 2006. Given these densities, the tiger population in the park declined from approximately 80 tigers in 1998 to 36 in 2006. However, if based on the forest interior as effective tiger habitat, tiger densities decreased from 2.25 individual/100 km^2 in 1998 to 1.16 individual/100 km^2 in 2006, and the tiger population from 1998 to 2006 declined sharply from 57 to 22 individuals.

Effects of Deforestation on Sumatran tigers

The analyses indicate that forest area and deforested area were not correlated with the Relative Abundance Index (RAI) of tigers. However, the total area of forest lost was negatively correlated with the RAI of tiger ($r = -0.265$, $p = 0.063$) (Table 2). This means that the area of forest lost has implications for the relative abundance of tigers.

Sumatran tigers use a wide range of habitat types from lowland tropical forest (including associated mangroves) to mountain forest and from deforested edges to the forest interior. However, tigers were photographed more often (per camera) at 2 km from the deforested edges and 9 km from roads than at closer distances. The Jenk's optimization method located natural breaks in tiger distributions occurring at 1.99 km inside the forest (Figure 4) and at 8.99 km from the roads (Figure 5). This indicates that tiger tended to avoid deforested edges and roads. Our correlation analysis also showed that the distance to deforested edges correlated with tiger presence ($r = 0.72$) and tiger density ($r = 0.70$), and the distance to roads correlated with tiger presence ($r = 0.77$) and tiger density ($r = 0.71$). Although tigers tended to avoid

Table 2. Correlation matrix (n = 50) among relative abundance indices of tigers and variables related to deforestation (* $0.05 < p < 0.10$; **< 0.05; ***<0.01)

	Statistics	Forest	Deforested	Forest loss
RAI of tiger	*r*	0.127	-0.036	-0.265*
	p	0.378	0.803	0.063
Forest area	*r*	X	0.146	0.507***
	p	X	0.311	0.000
Deforested	*r*	0.146	X	0.390***
	p	0.311	X	0.005
Forest loss	*r*	0.507***	0.390***	X
	p	0.000	0.005	X

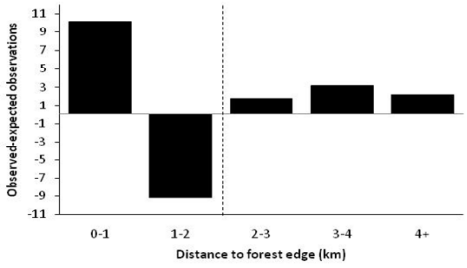

Figure 4. Distributions of deviation from expected number of photographs for tigers by distance to forest edge. Dashed lines show natural breaks in the distributions based on Jenk's optimization method.

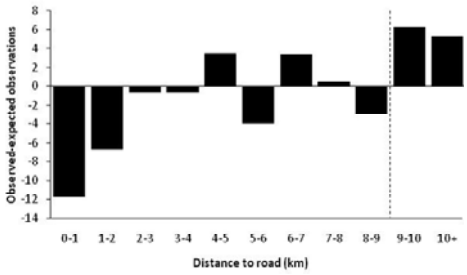

Figure 5. Distributions of deviation from expected number of photographs for tigers by distance to road. Dashed lines show natural breaks in the distributions based on Jenk's optimization method.

deforested edges, tigers were occasionally observed in the peripheral forest (0-1 km from deforested edges) and in deforested areas.

DISCUSSION

Deforestation in Bukit Barisan Selatan National Park

There are historical records of forest loss in Bukit Barisan Selatan National Park dating back more than half a century. The first study using satellite images to document deforestation in BBSNP was in 1985 (Kinnaird *et al.* 2003). Images from 1972 that were analyzed by Gaveau *et al.* (2007) also indicate that deforestation began before 1972. Household interview surveys in and around the park demonstrate that in the 1960s people began to clear more forest cover in BBSNP (Suyadi 2011). The present study shows that 27% of BBSNP forest cover was lost before 1998. The most common forest clearing in BBSNP begins at the park edges or buffer zone and progresses towards the inside of the park, with most forest converted to agricultural. Kinnaird *et al.* (2003) reported that the area of land classified as agriculture within BBSNP has more than doubled and has increased by 12% in the buffer zone.

Our results indicate that forests are being lost at an alarming rate in BBSNP; about 18.76 km^2 of forest was cleared yearly from 1998 to 2006. In comparison, the average rates of reforestation in the park were only 0.67 km^2 /year. Kinnaird *et al.* (2003) shows that between 1985 and 1999, BBSNP's forest cover lost more than 28% and the average rate of deforestation is approximately 2.00%/year (661 km^2 of forest). From 1972 to 2002, BBSNP's forest cover was reduced by 57,344 ha, representing a 19% loss of forest cover, at an average rate of 0.64% per year (Gaveau *et al.* 2007). Suyadi (2011) divided deforestation periods in BBSNP into three decades of deforestation. The highest deforestation rate occurred in the first decade (1972-1985) at around 28 km^2 per year. Subsequently, the deforestation rate decreased slightly in the second decade (1986-1996) to about 15 km^2 per year. However, during the last decade (1997-2006), the deforestation rate in the park increased to approximately 21 km^2 per year.

Deforestation rates varied by elevation; lowland tropical forest disappeared at a rate of 8.34 km^2/year, compared with 3.11 km^2/year in mountain tropical forest. This result agrees with Kinnaird *et al.* (2003) who used a longer time series of satellite images (1985 to 1999) and showed that deforestation rates were 25 km^2/year in lowland forests and 3.9 km^2/year in montane forests. In this paper, they also predicted that, at

these rates, all lowland forest in BBSNP would disappear by 2036. The acceleration of the deforestation rate in BBSNP is a serious threat to Sumatran tiger.

Implications of Deforestation for Sumatran tigers

The population of Sumatran tigers in BBSNP has decreased dramatically. We estimated that the tiger population in the park declined from a mean of 57 in 1998 to 22 in 2006. The tiger population in BBSNP appears to have decreased by more than 70% over the last 14 years, from 68 tigers in 1992 (Tilson *et al*. 1994) to 22 tigers in 2006. An investigation of illegal killing of tigers in BBSNP and the vicinity revealed that 8-12 tigers were killed annually from 1997 to 2000 (O'Brien *et al*. 2003). Using camera-trap data from between 1998 and 1999, O'Brien *et al*. (2003) estimated a population of about 40-43 tigers in BBSNP. The estimation of Wibisono (2006), using camera-trap data taken between 1998 and 2004, was that the number of tigers in BBSNP was around 31 tigers. This study used a longer time period of camera-trap data (1998 to 2006) and produced an estimate of 22 tigers in the park.

Our result shows that the tiger density in 1998 was 1.88 tigers/100 km^2. This result was similar to that of Wibisono (2006) but higher than the 1.57 tigers/100 km^2 reported by O'Brien *et al*. (2003). This difference resulted from the definition of the sampling block. This research used the outermost camera locations, while O'Brien *et al*. (2003) used the 10 x 20-km rectangular area in which the traps were deployed to define the perimeter of the block. Wibisono (2006) explained that the outermost camera locations better represent the "true" coverage. The other critical piece in the calculation of population density in capture-recapture analysis is the distance between recaptured individuals, which is used to calculate the sampling area. Karanth and Nichols (1998) applied the mean maximum distance moved, while Kawanishi and Sunguist (2004) applied half of the absolute maximum distance moved. The current research and Wibisono (2006) applied the maximum distance between recaptured tigers. The difference between these two estimates produces a large difference in the estimated effective sampling coverage when applied to all of the sampling blocks.

Forest loss in BBSNP has implications for the relative abundance of tigers. Dinerstein *et al*. (1997) showed that the cause of the decline in Sumatran tigers was accelerated destruction of their natural habitat. Schneider (2001) also explains that wildlife populations decline as a result of habitat fragmentation. The total habitat area and the degree of fragmentation are often good predictors of wildlife abundance (Schneider 2001). Deforestation by subsistence farmers, as has occurred in BBSNP, also leads to increased human-wildlife conflicts. Between 1998 and 2003, at least 8 tiger-human incidents occurred in and around BBSNP. As a result of these incidents, 7 people were killed, and one was injured (Wibisono 2006). The combination of poaching, prey loss, and habitat destruction and fragmentation have greatly increased the threats to survival of tigers in BBSNP (Kinnaird *et al*. 2003).

Sumatran tiger use a wide range of habitat types from lowland tropical to mountain forest. They are able to live in the highland of the Himalayas and survive in both wet and dry areas (Karanth & Stith 1999). Schaller (1967) explains that tigers are capable of living in a variety of environments as long as sufficient prey animals are available. Seindensticker *et al.* (1999) report tigers are one of the big cats that enjoy swimming, so they also frequent wetland areas such as mangrove forests.

Tigers tend to avoid roads and deforested edges; they prefer to use the forest interior. Tigers use of forest interior indicates an avoidance of human activities that reduce forest cover and increase disturbance at deforested edges (Kinnaird *et al*. 2003). Deasy (1996) reported that the edge effects of roads (Sanggi-Biha Road) in BBSNP for large mammals extend to more than 2 km from the road. Although tigers tend to avoid deforested edges, tigers have also been recorded in the peripheral forest (0-1 km from deforested edges) and in deforested areas, as long as there is ample prey in the area. Wibisono (2006) explain that tiger also continue to survive outside of BBSNP due to the many prey species, such as muntjac (*Muntjiacus muntjac*) and sambar deer (*Cervus unicolor*), found in this area.

CONCLUSION

Forest cover in Bukit Barisan Selatan National Park (BBSNP) is an important habitat for tigers and has decreased dramatically. These forest losses have had great effects on the decrease in relative abundance of tigers, especially as tigers also avoid deforested edges and roads. Tiger numbers and densities in BBSNP have dropped by more than half between 1998 and 2006. To conserve Sumatran tigers and their habitats in BBSNP, we must take immediate and dramatic action focused on conserving the remaining forest within the park and reducing the pressure on tigers in peripheral forest areas. Park managers also need to consider restoration of deforested areas. These actions must supported by increasing participation by local communities and as well as comprehensive research to monitor tiger populations and forest cover in BBSNP.

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