Photo: Until recently, quantifying rates of tropical forest destruction was challenging and laborious. © Jabruson 2017 (www.jabruson.photoshelter.com)

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CHAPTER 7

Mapping Change in Ape Habitats: Forest Status, Loss, Protection and Future Risk

Introduction

This chapter examines the status of forested habitats used by apes, charismatic species that are almost exclusively forest-dependent. With one exception, the eastern hoolock, all ape species and their subspecies are classified as endangered or critically endangered by the International Union for Conservation of Nature (IUCN) (IUCN, 2016c). Since apes require access to forested or wooded landscapes, habitat loss represents a major cause of population decline, as does hunting in these settings (Geissmann, 2007; Hickey *et al.*, 2013; Plumptre *et al.*, 2016b; Stokes *et al.*, 2010; Wich *et al.*, 2008).

Until recently, quantifying rates of tropical forest destruction was challenging and laborious, requiring advanced technical

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skills and the analysis of hundreds of satellite images at a time (Gaveau, Wandono and Setiabudi, 2007; LaPorte *et al.*, 2007). A new platform, Global Forest Watch (GFW), has revolutionized the use of satellite imagery, enabling the first in-depth analysis of changes in forest availability in the ranges of 22 great ape and gibbon species, totaling 38 subspecies (GFW, 2014; Hansen *et al.*, 2013; IUCN, 2016c; Max Planck Institute, n.d.-b). Launched in 2014, GFW provides free access to spatially explicit, high-resolution forest change data derived from thousands of satellite images that are updated annually. The global forest change data set on GFW allows users to quantify annual change in forest cover within the geographic ranges of each ape subspecies and within protected and unprotected areas in those ranges (Hansen *et al.*, 2013; see Figure 7.1).

This chapter presents the first assessment of the distribution of forest habitat in IUCN-defined ape ranges across Africa and Southeast Asia. It also quantifies yearly loss of ape-range forest from 2000 to 2014 in a spatially explicit manner. Abundance data are not available for all ape subspecies for this period. In future assessments, combining population and habitat data streams will be essential because hunting threatens ape population viability across taxa. Even so, the integrity of ape habitat can serve as a useful threshold for estimating ape occupancy until demographic information becomes available.

The chapter presents these data in combination with current protected area (PA) coverage to assess the adequacy of protection for each subspecies. Various lar gibbons (*Hylobates lar*) and western black-crested gibbons (*Nomascus concolor*), as well as Grauer's gorillas (*Gorilla beringei graueri*), are already confined mainly to PAs (IUCN, 2016c; Maldonado *et al.*, 2012). Protected areas are increasingly important refuges for all ape subspecies (Geissmann, 2007; Tranquilli *et al.*, 2012; Wich *et al.*, 2008).

In addition, the chapter projects future habitat loss rates for each subspecies and uses these results as one measure of threat to their long-term survival. GFW's new online forest monitoring and alert system, entitled Global Land Analysis and Discovery (GLAD) alerts, combines cutting-edge algorithms, satellite technology and cloud computing to identify tree cover change in near-real time, thereby allowing those involved in ape conservation at the local level to monitor changes and generate critical information to enhance their conservation efforts.

The key findings show that gibbons are in crisis:

- Gibbons receive less attention in the public eye than African apes and orangutans, yet gibbon habitats have been degraded to a far greater degree. By 2000, ten taxa of gibbons had already lost more than 50% of their forest habitat, and five gibbon taxa native to the Asian mainland had each had their habitats reduced to less than 5,000 km^2 (500,000 ha).
- In Indonesia, three others—the agile gibbon, Malaysian lar gibbon and siamang—lost more than 30% of their forest cover between 2000 and 2014.
- During the period under review, the ranges of Asian apes lost up to 25% of their protected forests (median 5%), at a rate that must slow if apes are to persist over the next few decades. Eight gibbon subspecies lost more than 8% of their protected habitat. Two of them—the Malaysian lar gibbon and Abbott's gray gibbon—lost more than 13%.
- Plantations account for more than 75% of the loss of forest habitat of three gibbon subspecies—the agile gibbon (76%), Malaysian lar gibbon (87%) and the moloch gibbon (77%)—as well as more

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than 50% of habitat loss of nine other Asian gibbon and orangutan subspecies.

- Based on the trends of the period 2000–14, nine ape subspecies, all gibbons, are expected to lose all their habitat by 2050 unless decisive action is taken to stop or at least slow forest loss. Most of these species have enough area in legally defined conservation units to persist if reserves are managed effectively.
- Better protection of existing reserves within the ranges of 18 of the 25 gibbon subspecies should be able to support more than 1,000 family groups.

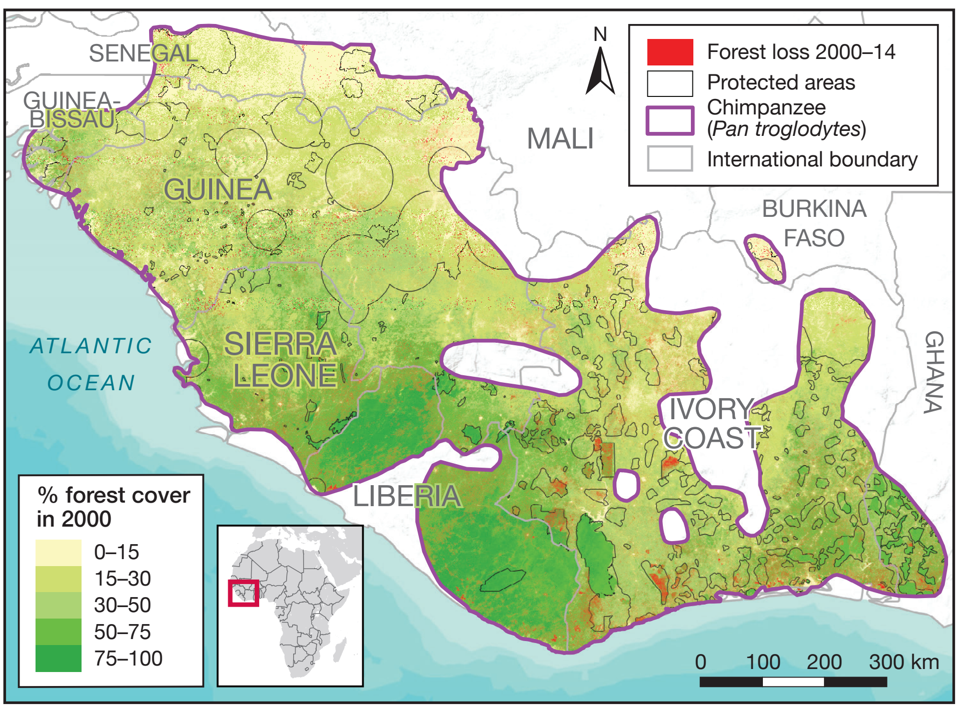
Ape conservation faces grave challenges:

- Between 2000 and 2014, Indonesia lost 226,000 km² (22.6 million ha) of forest cover, which constituted 63% of total habitat loss in Asia and 50% of the total loss of ape habitat globally. Large-scale agricultural plantations account for the majority of forest loss within ape ranges in Malaysia (84%) and Indonesia (82%), as well as nearly 30% of loss in Cambodia.
- Altogether, ape habitat around the world shrank by more than 10%—from nearly 4.4 million km² to under 4 million km² (440 million ha to under 400 million ha).
- Ape forest habitat in Asia shrank by 21% (357,500 km² or 35.8 million ha) between 2000 and 2014. African habitat fared relatively well, losing less than 4% (95,400 km² or 9.5 million ha) of forest cover in that period, despite increasing human population density, insurgencies and activities such as illegal logging.
- Africa was home to two-thirds of the remaining global ape habitat in 2014, but major transportation infrastructure has already begun to speed deforestation

FIGURE 7.1

Forest Cover and Loss in Ape Ranges and Protected Areas in Asia and Africa, 2000 and 2014[1]

a. West Africa



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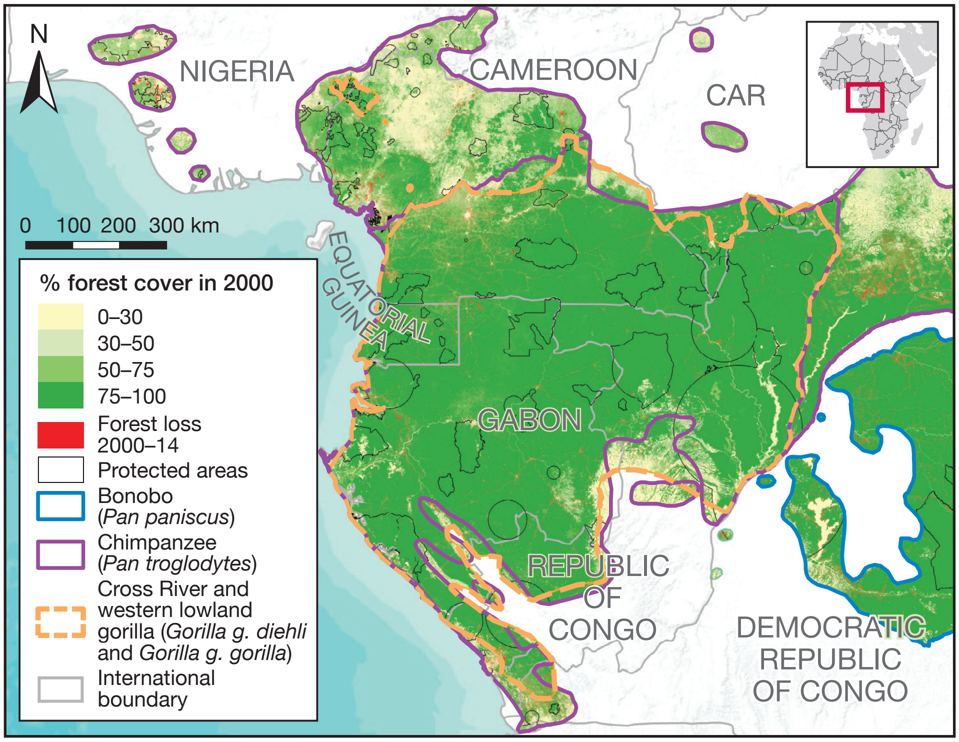
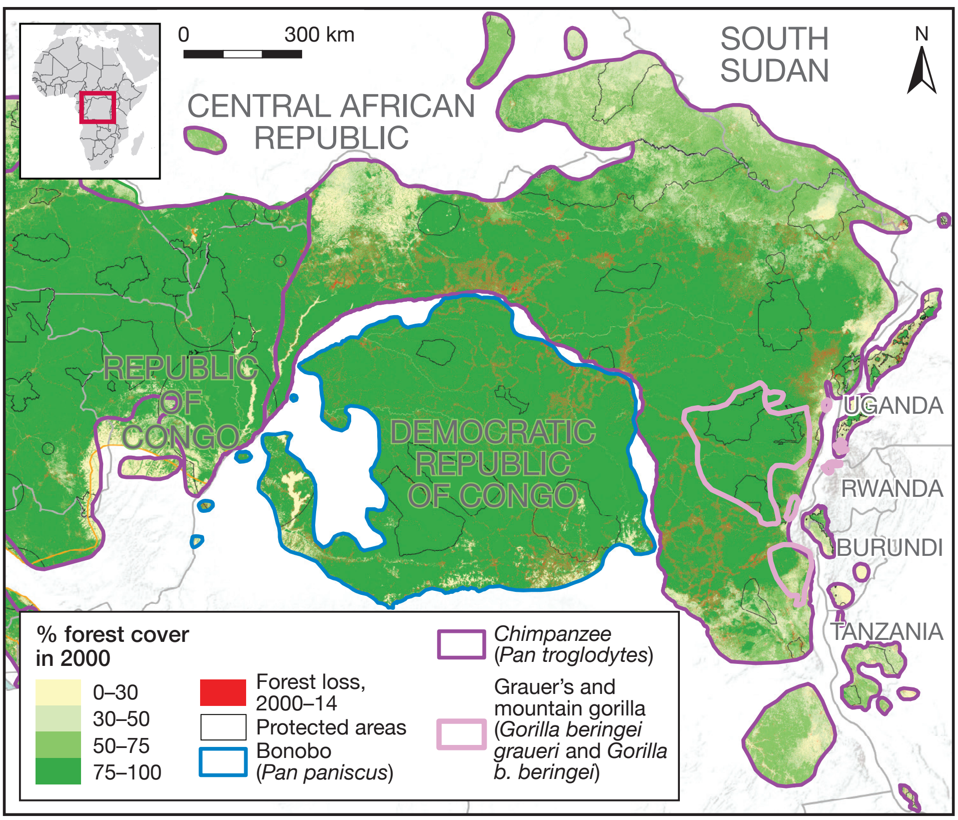
b. Central Africa



c. East Africa



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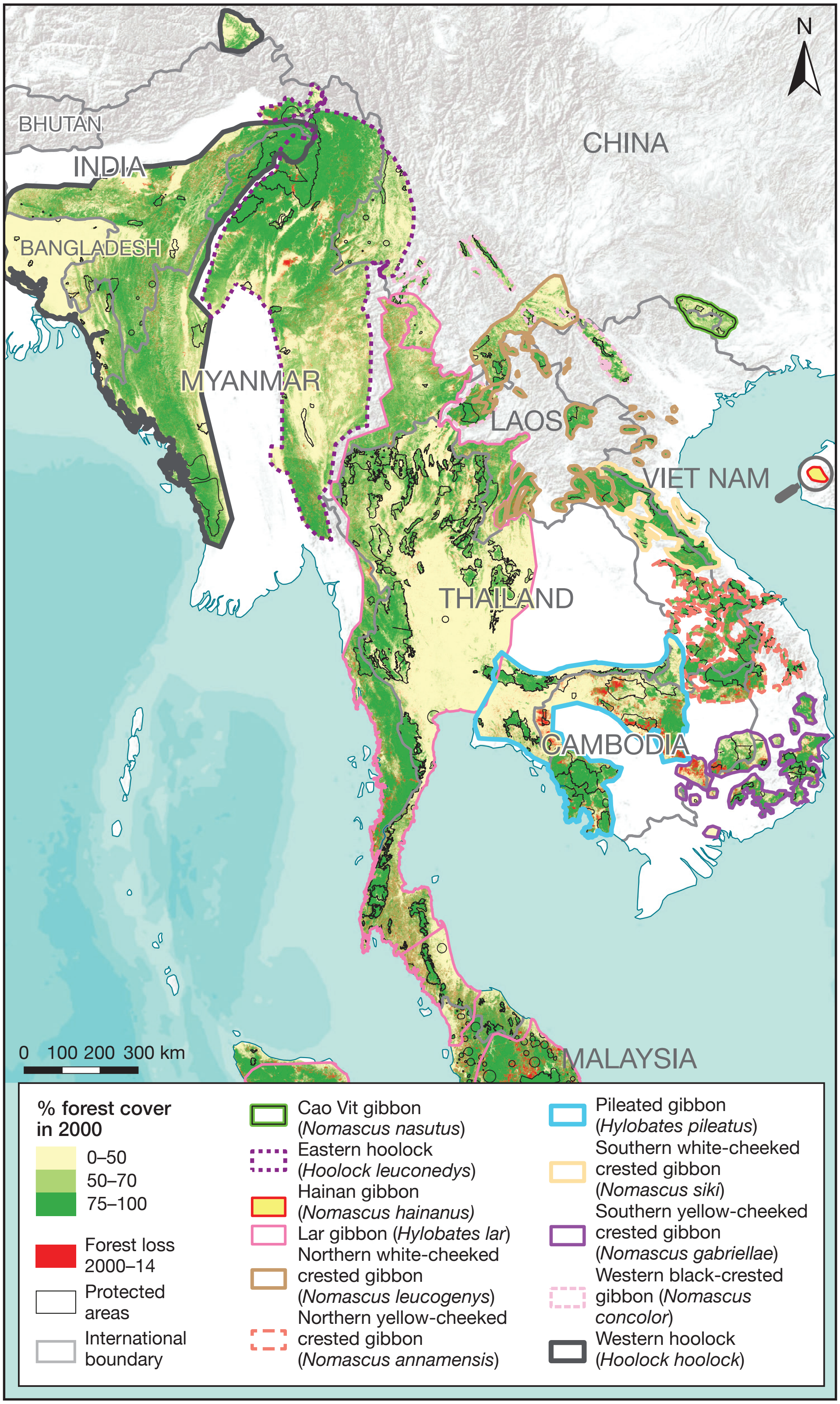
d. Northern Asia



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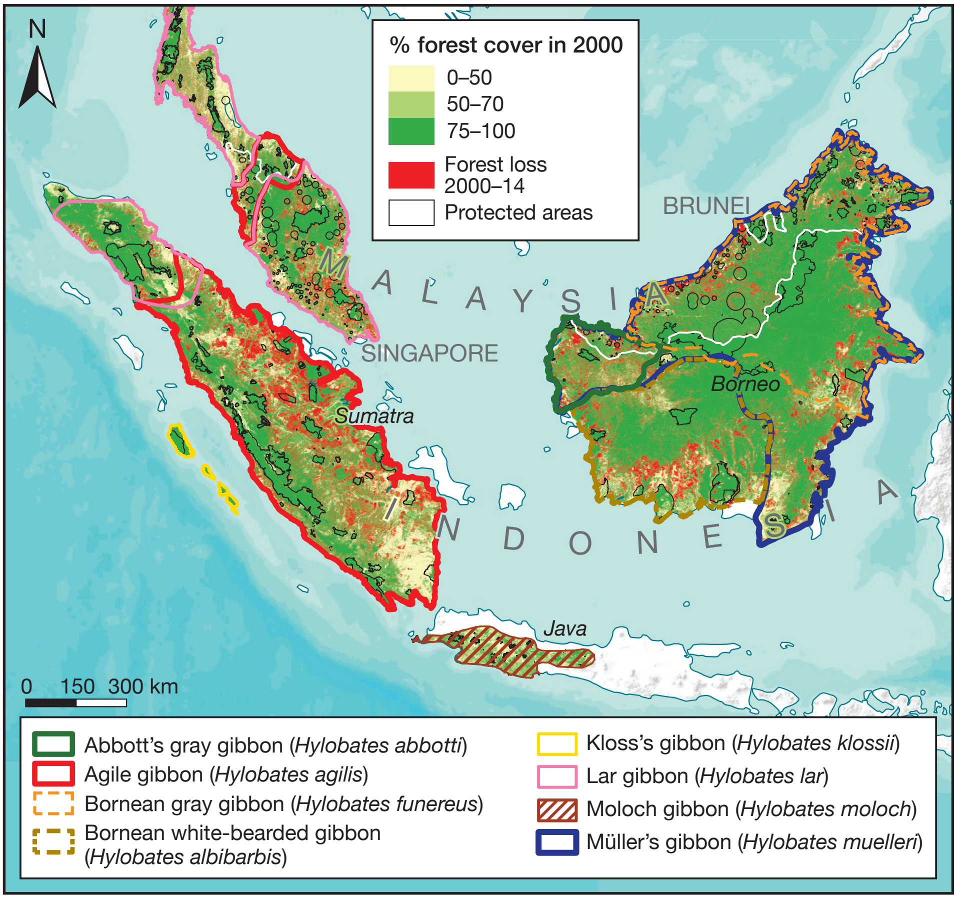
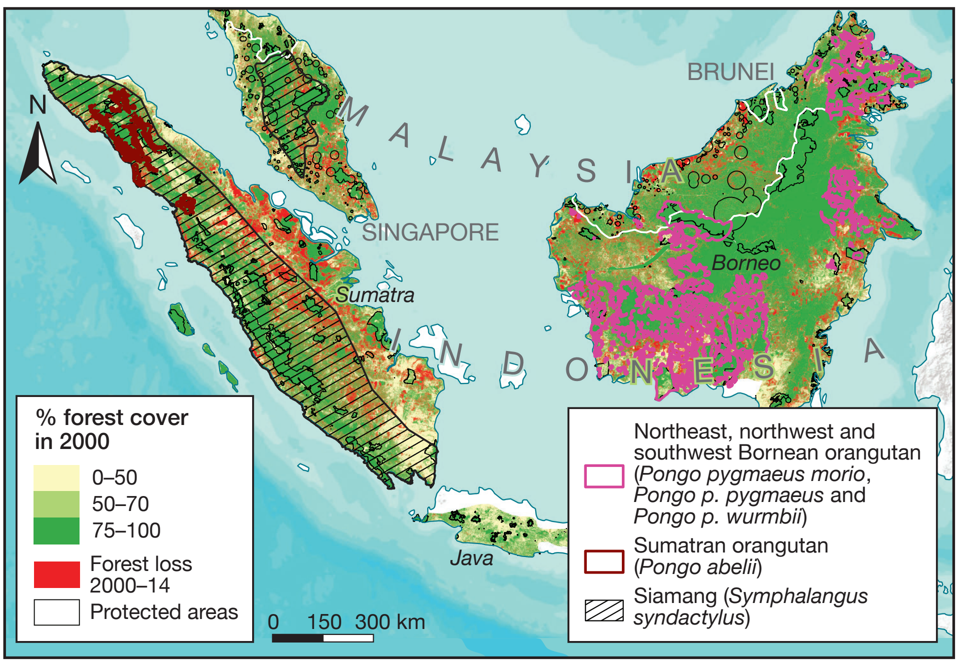
e. Southern Asia



f. Southern Asia



Data sources for Figure 7.1 a–f: GLAD (n.d.); Hansen *et al*. (2013); IUCN and UNEP-WCMC (2016)

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and associated development (see Section 1).

- By 2014, individual African ape subspecies retained an average of 388,000 km² of forest habitat; Asian apes retained an average of just 41,000 km².

A Summary of the State of the Apes through the Lenses of Forest Cover and Protection, 2000–14

More so than other ape species, gibbons are in peril. Prior to 2000—the year used as a baseline for forest extent in this assessment—three gibbon taxa had each lost more than 60% of their historic habitat. The Cao Vit gibbon (*Nomascus nasutus*) retained just 26% of its forest habitat in China and Viet Nam; the Yunnan lar gibbon (*Hylobates lar yunnanensis*) had 27% in China; and the pileated gibbon (*Hylobates pileatus*) had 40% in Cambodia, Lao People's Democratic Republic and Thailand (Hansen *et al.*, 2013; IUCN, 2016c; see Table 7.1). Equally worrying are the situations of subspecies with highly restricted geographic ranges and limited forest cover, including the Hainan gibbon (*Nomascus hainanus*), with just 91 km² (9,100 ha) in 2000, and the Central Yunnan black-crested gibbon (*Nomascus concolor jingdongensis*), with just 672 km² (67,200 ha; see Figure 7.2).

Worldwide, ape ranges in 2000 contained 4.4 million km² (440 million ha) of forest habitat, about two-thirds of which was in Africa and the remaining one-third of which was in Southeast Asia (see Figure 7.1 and Box 7.1). In 2000, the median area of forest habitat within IUCN ranges of Asian apes (48,608 km² or 4.9 million ha) was one-tenth the area of forest habitat found in ranges of African apes (400,983 km² or 40 million ha; see Table 7.1). In 2000, eight countries each contained more than 200,000 km² (20 million ha) of potential ape habitat (see Figure 7.4). The Democratic Republic of Congo (DRC) and Indonesia, in particular, retained large expanses of tropical rainforest that supported multiple ape taxa. Most ape ranges in Sumatra and Borneo still contained high proportions of forest through 2000, despite high deforestation rates in the two previous decades (Gaveau *et al.*, 2016).

BOX 7.1
Synopsis of Methods

The Global Forest Change 2000–14 data set, which is freely available on the Global Forest Watch (GFW) site, served as the basis for the habitat analysis (GLAD, n.d.; Hansen *et al*., 2013; see Annex VIII). Tree canopy cover in the year 2000 served as a baseline forest cover; annual change in forest cover was calculated using tree cover data from Hansen *et al*. (2013), which is updated annually.

Potential habitat (hereafter, *habitat*) for apes can be categorized by each subspecies' capacity to persist over time under varying degrees of canopy openness (see Table 7.1 and Annex IX). For example, eastern and western chimpanzees (*Pan troglodytes schweinfurthii* and *Pan t. verus*) have evolved in forests that are drier than those of their central African conspecifics and are believed to tolerate a more open canopy (L. Pintea and K. Abernethy, personal communication, 2016). To estimate forest change for each subspecies, this analysis applied values of "canopy density" that reflect the subspecies' tolerance of canopy openness and the overall vegetation cover in their respective ranges (IUCN, 2016c; see Annex IX). The GFW platform allows users to select canopy density values and thus recalculate the habitat assessment presented here with different estimates of canopy density. For more details on methods, see annexes VIII, IX and X.

Forest Dynamics and Loss from 2000 to 2014

Forest Dynamics in the Geographic Ranges of Subspecies

In 2000, ranges of the 38 ape taxa contained a median of 78% forest habitat, based on a range of 26%–99% (see Table 7.1). Between 2000 and 2014, these ranges lost 1% to 44% of their forest habitat, with a median of 4.8%.

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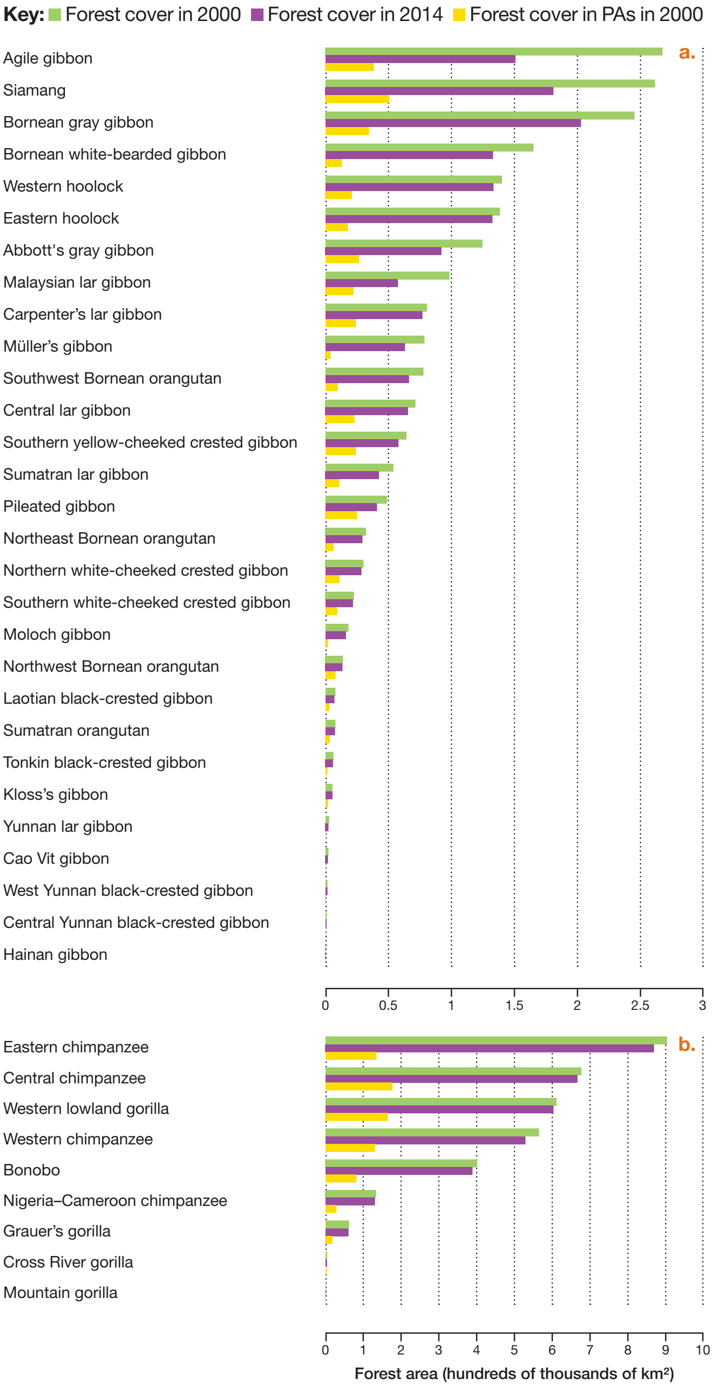
FIGURE 7.2

Forest and Protected Areas in the Ranges of (a) Asian and (b) African Apes, by Subspecies, 2000 and 2014



Notes: Subspecies are sorted by the amount of forest cover in the year 2000. PA-related data reflect area covered by PAs in 2016.

Data sources: GLAD (n.d.); Hansen *et al*. (2013); IUCN and UNEP-WCMC (2016)

Ranges of Asian apes lost more of their forest—from 2% to 44% (with a median of 8.3%)—than those of African apes, which lost anywhere from 2% to 6% (with a median of 2.1%).

The greatest recent loss of forest occurred in Southeast Asia within the ranges of orangutans and at least 11 gibbon subspecies (see Figure 7.1). The data reveal noteworthy variations. For example, the once-wide range of the agile gibbon (*Hylobates agilis*)—an area of 387,445 km^2 (38.7 million ha)—had already lost about 30% of its forest by 2000; it lost another 44% of its remaining forest cover in the following 14 years. In contrast, the extremely limited range of the Cross River gorilla (*Gorilla gorilla diehli*)—a mere 3,648 km^2 (364,800 ha) in Cameroon and Nigeria—was reduced by less than 1% over the same period.

The ranges of 15 Asian taxa overlap with mapped tree plantations, which have accounted for more than 50% of forest habitat loss in 12 of the ranges (see Box AX1 in Annex XI). Plantations correspond to more than 75% of the loss of forest habitat of three gibbon subspecies: the agile gibbon (76%), the Malaysian lar gibbon (*Hylobates lar lar*, 87%), and the moloch gibbon (*Hylobates moloch*, 77%). Plantations also overlap with distributions of all four orangutan subspecies (*Pongo* species (spp.)), representing 42%–59% of forest loss within their ranges.

Taxa of Conservation Concern

This analysis reveals that the forest cover in the ranges of 23 of 38 ape subspecies was reduced by almost 30% prior to 2000 (see Table 7.1). Forest loss before 2000 exceeded 50% in the ranges of ten gibbon subspecies, particularly those in mainland Southeast Asia (Bleisch and Geissman, 2008; Bleisch *et al*., 2008; Gaveau *et al*., 2016; Geissmann and Bleisch, 2008).

A closer examination of the data reveals several important findings for gibbons, Grauer's and Cross River gorillas, and both

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TABLE 7.1

Ape Subspecies and Forest Cover Status and Loss, 2000 vs. 2014

Name	Range area (km²)	Forest cover, 2000* (km²)	% forest, 2000	Forest cover, 2014 (km²)	% forest lost, 2000–14	% PA forest, 2000	% PA forest lost, 2000–14
Bonobo (*Pan paniscus*)**	418,809	400,983	95.7	387,931	3.3	20.2	1.9
Central chimpanzee (*Pan troglodytes troglodytes*)**	710,681	676,693	95.2	666,152	1.6	26.2	0.8
Eastern chimpanzee (*Pan t. schweinfurthii*)**	961,246	902,867	93.9	869,160	3.7	14.9	1.2
Nigeria–Cameroon chimpanzee (*Pan t. ellioti*)**	168,393	133,806	79.5	130,257	2.7	21.4	2.6
Western chimpanzee (*Pan t. verus*)**	660,332	564,032	85.4	528,817	6.2	23.1	5.9
Cross River gorilla (*Gorilla gorilla diehli*)**	3,648	3,388	92.9	3,363	0.7	53.5	0.5
Grauer's gorilla (*Gorilla beringei graueri*)**	64,684	61,861	95.6	60,562	2.1	30.4	0.6
Mountain gorilla (*Gorilla b. beringei*)**	783	768	98.0	761	0.8	97.7	0.8
Western lowland gorilla (*Gorilla g. gorilla*)**	695,076	610,453	87.8	602,982	1.2	27.1	0.6
Northeast Bornean orangutan (*Pongo pygmaeus morio*)	32,931	32,149	97.6	29,163	9.3	19.9	7.1
Northwest Bornean orangutan (*Pongo p. pygmaeus*)	14,119	13,965	98.9	13,492	3.4	56.3	0.4
Southwest Bornean orangutan (*Pongo p. wurmbii*)	81,148	77,542	95.6	66,065	14.8	12.8	6.7
Sumatran orangutan (*Pongo abelii*)	7,848	7,783	99.2	7,452	4.3	46.8	2.0
Eastern hoolock (*Hoolock leuconedys*)	281,864	138,283	49.1	132,326	4.3	12.9	1.9
Western hoolock (*Hoolock hoolock*)	320,251	140,061	43.7	133,308	4.8	15.1	1.7
Abbott's gray gibbon (*Hylobates abbotti*)	147,330	124,499	84.5	92,208	25.9	21.2	13.3
Agile gibbon (*Hylobates agilis*)	387,445	267,607	69.1	150,787	43.7	14.4	8.5
Bornean gray gibbon (*Hylobates funereus*)	276,487	245,352	88.7	202,593	17.4	14.0	8.5
Bornean white-bearded gibbon (*Hylobates albibarbis*)	200,590	165,009	82.3	132,744	19.6	8.0	6.5
Carpenter's lar gibbon (*Hylobates lar carpenteri*)	265,446	80,531	30.3	76,918	4.5	29.9	1.1

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Name	Range area (km²)	Forest cover, 2000* (km²)	% forest, 2000	Forest cover, 2014 (km²)	% forest lost, 2000–14	% PA forest, 2000	% PA forest lost, 2000–14
Central lar gibbon (*Hylobates l. entelloides*)	154,385	71,498	46.3	65,564	8.3	32.0	1.9
Kloss's gibbon (*Hylobates klossii*)	6,031	5,479	90.8	5,315	3.0	32.2	0.7
Malaysian lar gibbon (*Hylobates l. lar*)	137,898	98,344	71.3	57,445	41.6	22.7	25.0
Moloch gibbon (*Hylobates moloch*)	39,400	18,056	45.8	16,071	11.0	11.6	7.0
Müller's gibbon (*Hylobates muelleri*)	103,652	78,653	75.9	62,853	20.1	5.2	8.4
Pileated gibbon (*Hylobates pileatus*)	122,073	48,608	39.8	40,797	16.1	51.4	9.9
Sumatran lar gibbon (*Hylobates l. vestitus*)	73,254	53,886	73.6	42,519	21.1	19.9	2.6
Yunnan lar gibbon (*Hylobates l. yunnanensis*)	9,512	2,619	27.5	2,490	4.9	9.0	3.1
Cao Vit gibbon (*Nomascus nasutus*)	8,332	2,161	25.9	2,107	2.5	16.2	5.8
Central Yunnan black-crested gibbon (*Nomascus concolor jingdongensis*)	1,270	672	52.9	659	1.9	23.1	0.1
Hainan gibbon (*Nomascus hainanus*)	165	91	55.1	87	4.8	18.2	8.0
Laotian black-crested gibbon (*Nomascus c. lu*)	8,912	7,848	88.1	7,069	9.9	38.8	5.7
Northern white-cheeked crested gibbon (*Nomascus leucogenys*)	51,481	30,249	58.8	28,402	6.1	36.8	3.2
Southern white-cheeked crested gibbon (*Nomascus siki*)	26,634	22,674	85.1	21,817	3.8	39.4	1.6
Southern yellow-cheeked crested gibbon (*Nomascus gabriellae*)	95,205	64,243	67.5	57,912	9.9	37.3	5.0
Tonkin black-crested gibbon (*Nomascus c. concolor*)	13,097	6,149	47.0	6,012	2.2	25.0	0.8
West Yunnan black-crested gibbon (*Nomascus c. furvogaster*)	3,114	1,498	48.1	1,473	1.7	30.6	0.7
Siamang (*Symphalangus syndactylus*)	341,872	261,502	76.5	181,091	30.7	19.3	8.7

Notes: * Forest cover in 2000 is defined using the canopy density associated with each subspecies. ** African apes.

Data sources: GLAD (n.d.); Hansen *et al*. (2013); IUCN and UNEP-WCMC (2016)

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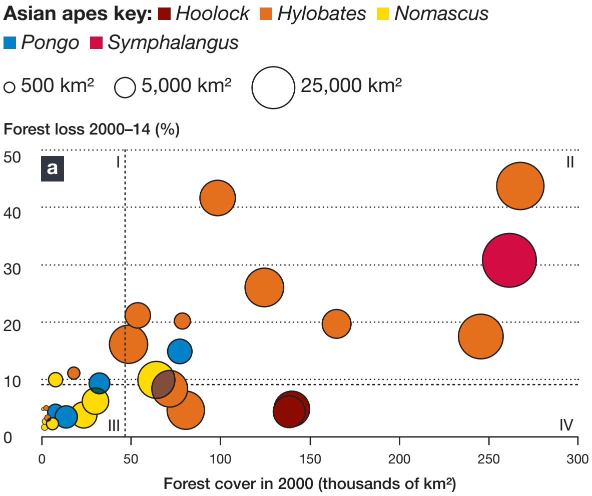
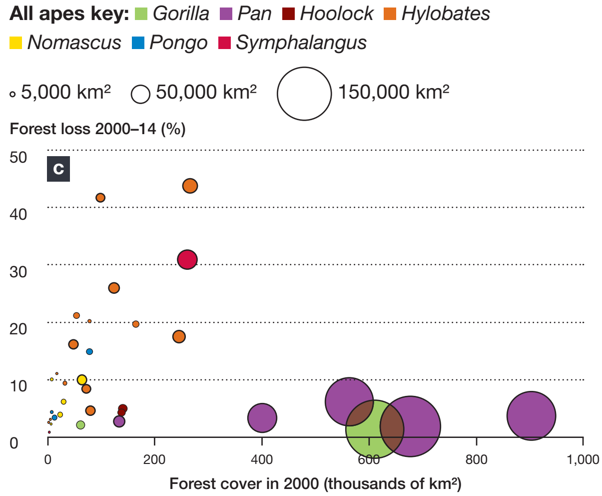
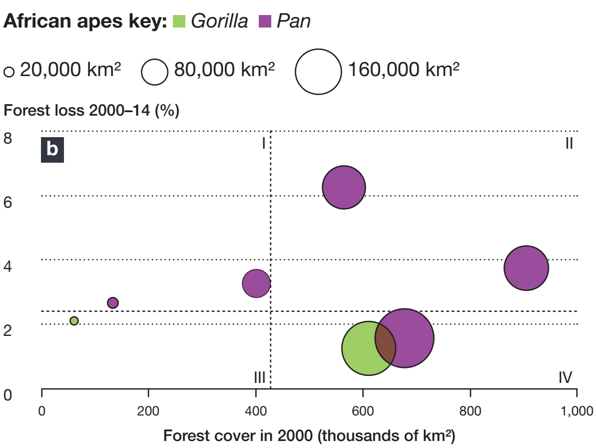
FIGURE 7.3

Forest Cover, Protection and Loss between 2000 and 2014 in (a) Asian, (b) African and (c) All Ape Ranges, by Subspecies







Notes:

The graphs show forest cover in 2000 and forest loss evident in 2014 in the ranges of (a) Asian, (b) African and (c) all ape subspecies.

The horizontal dotted lines in Figures 7.3(a)–(b) reflect the median percentage of forest loss for Asian (8.3%) and African (2.1%) apes.

The vertical dotted lines in Figures 7.3(a)–(b) show the median forest cover in Asian (48,600 km²) and African (401,000 km²) ape ranges in 2000.

The four resulting regions group subspecies according to the relative forest cover security of their ranges, from: (I) insecure (limited forest cover in 2000, high forest cover loss from 2000 to 2014) to (IV) secure (extensive forest cover, low forest cover loss).

Circle sizes in all graphs indicate the area of protected forest in each subspecies' range.

Data sources: GLAD (n.d.); Hansen *et al.* (2013); IUCN and UNEP-WCMC (2016)

orangutan species. Figure 7.3 combines effects of forest loss prior to the year 2000 and ongoing deforestation by dividing the data for each taxon into regions according to habitat remaining in 2000 and the percentage of habitat lost since then. The size of the circles in Figure 7.3 indicates the area of forest in PAs per range. In 2000, PAs covered 17 km²–50,470 km² (5%–56% of each range's forest cover) in Asia and 750 km²–177,300 km² (15%–98%) in Africa (see Table 7.1).

The subspecies in Region I are of greatest concern, as they have experienced the greatest forest loss in ranges with the most limited forest cover.

Habitat for several gibbons—the agile gibbon, the Bornean white-bearded gibbon (*Hylobates albibarbis*), the Bornean gray gibbon (*Hylobates funereus*) and the siamang (*Symphalangus syndactylus*)—was relatively extensive up to 2000 but decreased by 17%–44% from then until 2014 (see Figure 7.3a). These and other subspecies in Region II occur in areas where forest was relatively widespread in 2000 but was reduced substantially over the following 14 years.

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Photo: Is there enough habitat for gibbons? The ranges of Asian apes lost up to 25% of their protected forests from 2000 to 2014. © Andrew Walmsley/ Borneo Nature Foundation

The habitats of more than half of African and Asian ape taxa fall within Region III; these ranges had diminished forest cover in 2000 and experienced limited subsequent forest loss. On the whole, Asian apes lost roughly four times more of their forest habitat between 2000 and 2014 than did African apes (with a median loss of 8.3% vs. 2.1%, respectively).

The few African subspecies in Region IV have relatively large geographic ranges with more extensive forest cover (see Figure 7.3b). This group consists of the western lowland gorillas (*Gorilla gorilla gorilla*) and central chimpanzees (*Pan troglodytes troglodytes*). Of great conservation concern is the combination of limited forest cover and extensive forest loss within Asian ape ranges.

Forest Dynamics Inside vs. Outside Protected Areas

Protected areas are vital to the persistence of ape populations. Evidence indicates that areas that have undergone large-scale clearing of forest, such as for plantations, will not sustain viable ape populations over time, even though some ape species can make use of industrial plantations as supplemental food sources or corridors in the short term (Ancrenaz, Calaque and Lackman-Ancrenaz, 2004; Wich *et al*., 2012b). Apes use agricultural habitats primarily in the absence of an alternative, if the natural forest in their range is cleared for agricultural and other uses, yet all need some natural tree canopy to find food and nesting substrate (Ancrenaz *et al*., 2015a; Hernandez-Aguilar, 2009; Hockings *et al*., 2015; IUCN, 2016c; W. Brockelman, personal communication, 2016).

Overall, about 26% of African ape habitat in 2000 was within PAs (median 81,152 km²/ 8.1 million ha of subspecies' geographic ranges). A slightly lower median proportion —21%, or 9,917 km² (991,700 ha)—of the habitat of Asian apes was protected that year. From 2000 to 2014, forest loss was detected within all PAs, although at lower rates than outside PAs. In African ape ranges, forest cover in PAs declined by less than 1%, which resulted in a median 79,573 km² (7.9 million ha) of protected habitat in their ranges in 2014 (see Table 7.2). Asian apes lost roughly 5% of protected forest during this period, which left their ranges with a median of 9,255 km² (925,500 ha) of protected habitat.

Median loss outside PAs in African ape ranges was three times higher than inside PAs. While it is encouraging that the mountain gorilla (*Gorilla beringei beringei*) experienced only a 0.3% decline in habitat outside PAs, such unprotected areas comprise less than 3% of this subspecies' entire, highly restricted range (see Table 7.1).

TABLE 7.2

Percentage of Forest Loss in Ranges of Asian and African Ape Subspecies, 2000 vs. 2014

	Asian ranges (n = 29)			African ranges (n = 9)		
	Lowest	Median	Highest	Lowest	Median	Highest
Inside protected areas	0.1	5.0	25.0	0.5	0.8	5.9
Outside protected areas	1.9	9.8	49.6	0.3	2.7	6.3
Overall range	1.7	8.3	43.7	0.7	2.1	6.2

Data sources: GLAD (n.d.); Hansen *et al*. (2013); IUCN and UNEP-WCMC (2016)

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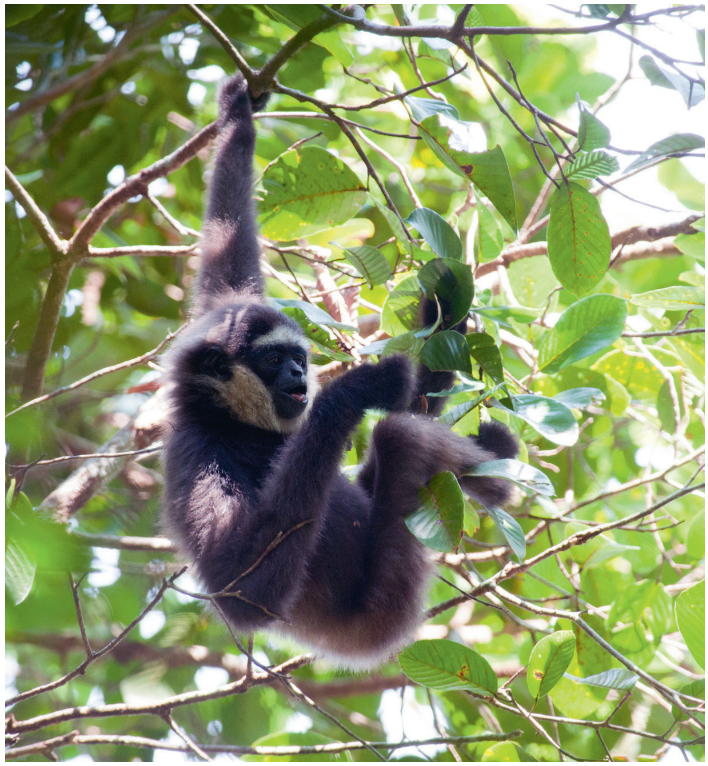
Among Asian apes, habitat loss inside PAs ranged from 0.1% (Central Yunnan black-crested gibbon) to 25% (Malaysian lar gibbon), with a median loss of 5%. Eight gibbon subspecies lost more than 8% of their protected habitat; two of them—the Malaysian lar gibbon and Abbott's gray gibbon (*Hylobates abbotti*)—lost more than 25% and 13%, respectively (see Table 7.1). Four gibbon subspecies and the northwest Bornean orangutan (*Pongo pygmaeus pygmaeus*) lost less than 1% of their habitat inside PAs. However, all five of these taxa have small ranges, with forest covering less than 15,000 km² (1.5 million ha) in 2000.

Not surprisingly, habitat loss was greater outside of PAs. Among the Asian ape ranges, median habitat loss outside PAs was nearly 10% and ranged from 1.9% (Cao Vit gibbon) to 50% (agile gibbon). Five subspecies, comprising four *Hylobates* gibbons and the siamang, lost more than 25% of their unprotected habitat. African ape ranges lost 2.7% (with losses reaching from 0.3% to 6.3%) of their unprotected 2000 habitat.

Given the rates of loss outside PAs, species may increasingly rely on the forest remaining inside PAs, where loss rates are lower. Yet, a relatively high proportion (more than 20%) of total annual loss of forest habitat of four mainland Asian gibbons and the Sumatran orangutan occurred in PAs.

Buffer zones, comprising habitats just outside parks, can play a critical role in preventing isolation of protected forests and enhancing their capacity to maintain healthy populations of apes and other wildlife (Hansen and DeFries, 2007; Laurance *et al.*, 2012). Forest loss between 2000 and 2014 within 10-km buffer zones did not differ statistically from loss outside of PAs overall (median = 8.7% vs. 6.1%, respectively), although it was substantially higher than loss within PAs (2.6%). Nevertheless, areas with greater forest loss in buffer zones also faced greater forest loss inside PAs.



Is There Enough Space for Gibbons to Persist in the Wild?

The results of this habitat assessment show that enough protected forested area may exist to support hundreds and even thousands of groups of most gibbon subspecies, if it is managed appropriately for native wildlife (see protection status in Table 7.1).

Gibbon densities range from 0.5–2.0 groups per square kilometer, such that a well-managed 5,000-km² park could technically support viable gibbon populations. This conclusion is based on the area of protected forest as calculated by this analysis and a conservative density estimate of one group per 2 km² (IUCN, 2016c).

In numerous ape-range countries, however, management of and law enforcement in parks has only been able to slow, rather than stop, the encroachment into and the loss of these forests (Curran *et al.*, 2004; Tranquilli *et al.*, 2014). Poor enforcement

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of laws against forest encroachment and poaching in PAs signals an urgent need for improved management, protection, patrolling and community involvement (Geissmann, 2007).

The ranges of Asian apes lost up to 25% of their protected forests (median 5%) from 2000 to 2014, a rate that must slow if apes are to persist over the next few decades (see Table 7.1). Other factors, such as hunting and disease, will intensify the effects of these projected habitat losses on population densities. In parts of Africa, habitat loss may be less of a concern than hunting (see Box 7.2). There is still enough time to prevent the decline seen in Asia from being replicated in Africa.

Based solely on the extremely limited amount of habitat remaining, it is clear that certain species will need more protected forest area to persist over time. The following gibbons are especially vulnerable:

- Abbott's gray gibbon;
- the Hainan gibbon;
- the pileated gibbon; and
- the southern yellow-cheeked crested gibbon (*Nomascus gabriellae*).

Gibbons and some great ape subspecies (mountain and Grauer's gorillas) persist primarily in protected conservation areas; they continue to face threats from hunting in PAs that are not well patrolled (Geissmann, 2007; IUCN, 2016c; Maldonado *et al.*, 2012). To be able to persist, the following species will, at a minimum, need better management of existing reserves within their ranges:

- both species of orangutan;
- the agile gibbon;
- the Malaysian lar gibbon;
- the West Yunnan black-crested gibbon (*Nomascus concolor furvogaster*);
- the Central Yunnan black-crested gibbon; and
- the mountain gorilla.

To remain viable in the face of reduced connectivity among populations, some species may need to be managed as metapopulations, linked by dispersal, by connecting reserves and buffer areas via forest corridors. However, results of this analysis also show that forest inside 10-km buffer zones around PAs, which would necessarily form the basis of dispersal corridors for apes, is as

BOX 7.2

Hunting May Wipe Out Ape Populations Sooner than Forest Loss

Assessing forest loss alone may greatly underestimate changes in ape population densities. Increased hunting associated with fragmenting and opening up of closed-canopy forest may, in fact, decimate ape populations before the loss of habitat quality does (Hicks *et al.*, 2010; Ripple *et al.*, 2016).

Deforestation facilitates access to previously intact forests, which, in turn, enables poaching for wild meat, participation in the wild animal trade, and disease transmission from humans (Köndgen *et al.*, 2008; Leendertz *et al.*, 2006; Poulsen *et al.*, 2009). Indeed, once people start cutting forest, they hunt game and target large mammals, including apes. While a substantial decrease in forest cover in an ape range—for example, from 90% to 30%—might not wipe out local species on its own, associated hunting may very well do so (Meijaard *et al.*, 2010b; Tranquilli *et al.*, 2014). Western lowland gorillas, for example, face a greater threat from hunting and disease than forest loss (Maisels *et al.*, 2016b; Walsh *et al.*, 2003).

Biologists are creating comprehensive layers of data on ape population densities and areas most affected by wild meat hunting (Max Planck Institute, n.d.-b). Once available, the data will be able to be used to complement information on forest change, thereby greatly improving our understanding of the trajectory of ape populations and assisting the conservation community in identifying and safeguarding the most vulnerable sites.

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vulnerable to deforestation as other unprotected land. For some gibbon subspecies—such as the Hainan gibbon, whose habitat was reduced to less than 90 km² (9,000 ha) by 2014—remaining forest cover is insufficient in terms of both size and level of protection to enable metapopulation movements (see Table 7.1). The conservation community thus has only a few years to maintain or re-establish connectivity and to make sure that PAs are large enough and sufficiently protected to maintain viable populations of the subspecies.

Hunting is the other major threat. While the quantification of hunting within PAs is beyond the scope of this chapter, improved PA management will be needed to address this pressing concern (see Box 7.2).

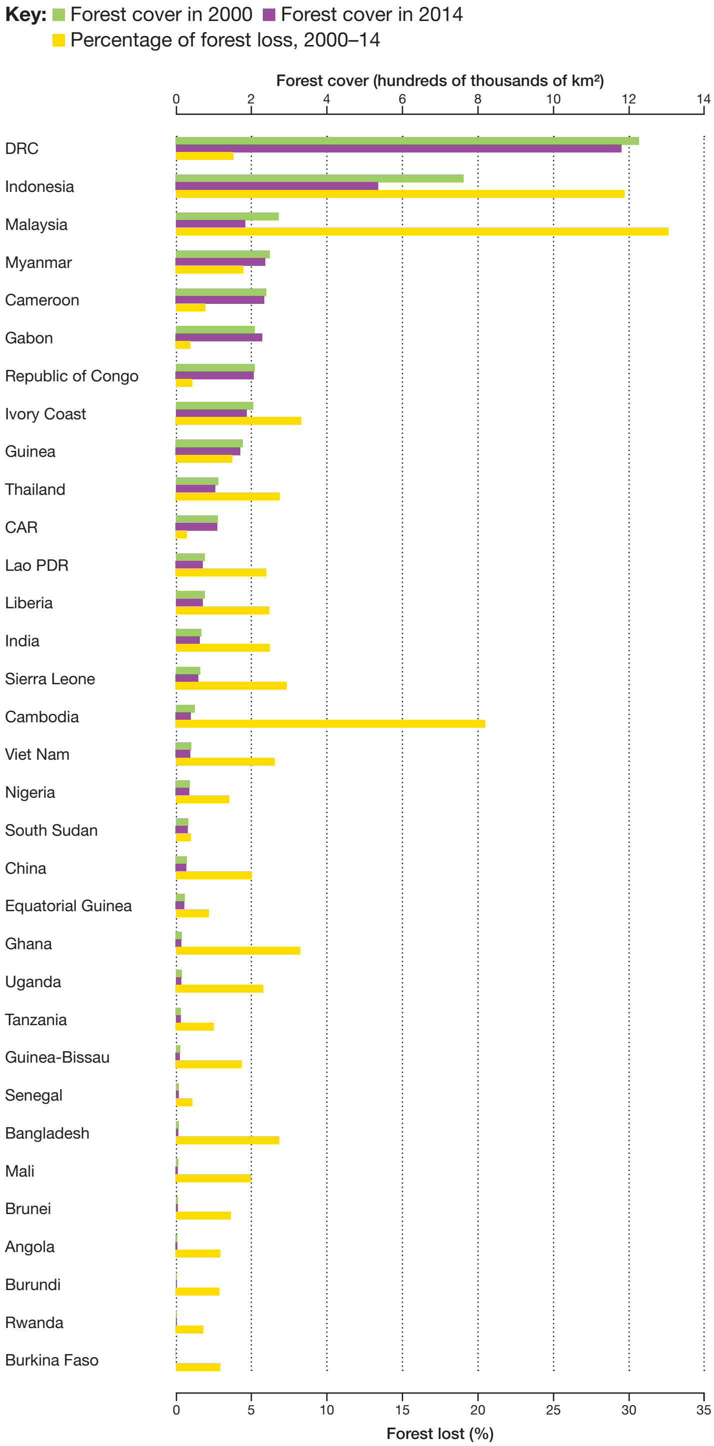
Forest Dynamics by Country

Between 2000 and 2014, apes worldwide lost 453,000 km² (45.3 million ha) of forest, or more than 10% of the 2000 baseline. Of that loss, 79% took place in Asia. Asian ape-range countries lost 357,500 km² (35.8 million ha) of forest cover, or more than 20% of their forest habitat, an area nearly four times as large as that lost in African range states, which shrank by 95,400 km² (9.5 million ha) or 4% of African apes' total forest habitat (see Figure 7.4).

Destruction of ape habitat for agriculture has dramatically altered the forest landscape in some Asian states. From 2000 to 2014, Malaysia lost 33% of its forest, Indonesia lost 30% and Cambodia more than 20%; these rates significantly exceeded those of all other ape-range countries, each of which lost less than 10% of its forest cover. Forest loss in Indonesia (226,063 km² or 22.6 million ha) far surpassed even that of Malaysia (88,763 km² or 8.9 million ha), accounting for 63% of the total habitat loss in Asia and 50% of the total destruction of ape habitat globally.

FIGURE 7.4

Forest Cover and Loss in Ape Range Countries, 2000 vs. 2014



Data sources: GLAD (n.d.); Hansen *et al*. (2013); IUCN and UNEP-WCMC (2016); see Box 7.1

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Large-scale agricultural plantations account for the majority of forest loss within ape ranges in both Malaysia (84%) and Indonesia (82%), as well as nearly 30% of loss in Cambodia. This expanding land use allocation affects at least ten gibbon taxa and all four orangutan taxa.

As noted above, Africa lost just 4% of its ape habitat over the same time frame. Much of that loss was concentrated in West Africa, where the highest percentage of forest base was lost in Ghana, Ivory Coast and Sierra Leone. The Central African Republic (CAR), Gabon and South Sudan each lost less than 1% of their ape habitat during this period. The DRC is home to the most ape habitat of any country—more than 1.2 million km² (120 million ha) or 28% of all ape habitat (see Figure 7.4)—and supports central and eastern chimpanzees (*Pan troglodytes schweinfurthii*), Grauer's gorillas and bonobos (*Pan paniscus*), of which the latter two taxa are endemic to the country. While the DRC lost more total forest cover (more than 46,000 km² or 4.6 million ha) between 2000 and 2014 than other African nations, this area represented less than 4% of its ape forest habitat, and the loss rate was only slightly higher than the median African rate of 2.9%.

Data indicate that the clearing of forest for plantations reduced the habitat of only one African ape subspecies, the western chimpanzee, between 2000 and 2014—by about 1% (GFW, 2014; Transparent World, 2015). The situation in Africa could rapidly change for the worse, however. Nearly 60% of oil palm concessions in Africa overlap with ape distributions, while 40% of unprotected ape habitat is in land suitable for oil palm (Wich *et al.*, 2014). Corporate demand to convert these concessions to palm is expected to increase sharply in Africa as land suitable for oil palm and other industrial-scale agriculture diminishes in Asia (Mongabay, 2016b).

Annual Forest Loss Trends in Ape Habitat

Cumulative Loss of Tree Cover

The availability of forest distribution data at 30-m resolution through the GFW platform allows for the tracking of annual forest loss for all ape taxa as of 2000. Annual data on cumulative forest loss over the study period reveals several worrisome trends (see Figure 7.5).

Ape taxa that lost the most forest habitat between 2000 and 2014 all live in tropical Asia (see Figure 7.5a). The period witnessed steady deforestation in previously extensive habitats of the agile gibbon, Malaysian lar gibbon and siamang, for example.

Figure 7.5b highlights ten subspecies that experienced the lowest cumulative forest habitat loss. Loss rates among the six African subspecies in this group have remained low but have increased, particularly since 2012, whereas those for the four Asian subspecies are tapering off. Absolute forest loss may be low in the habitats of these four subspecies, yet their forest cover was already restricted, ranging from less than 700 km² (70,000 ha) to just under 6,200 km² (620,000 ha) (see Table 7.1). In the limited forest that is left, each square kilometer lost is likely to have an outsized effect on the remaining population.

Data relating to the establishment of plantations were available only as single values for the period 2001–14, not on an annual basis. As a result, the cumulative annual loss values in Figure 7.5 exclude plantation data and so are only illustrative in their depiction of forest loss trends. Fifteen of the 38 ape subspecies, including the ten in Figure 7.5a, have faced substantially more extensive cumulative loss than is shown in Figure 7.5a, although the trends are indicative of the extent of their habitat loss (see Table 7.1). For example, the agile gibbon, Malaysian lar gibbon, Abbott's gray gibbon and siamang experienced the highest

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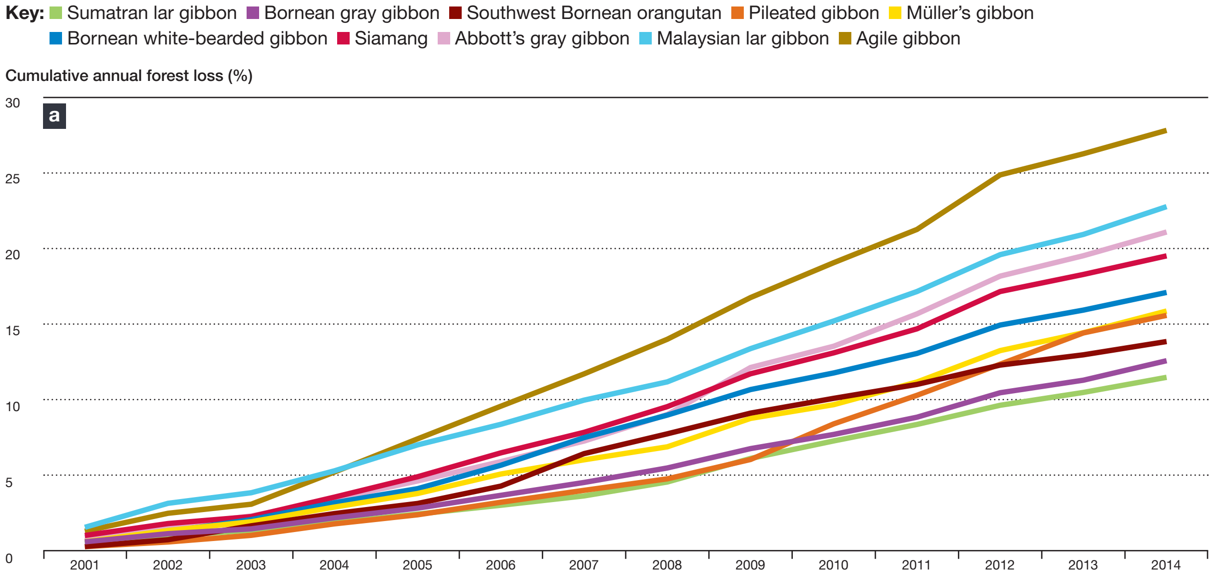
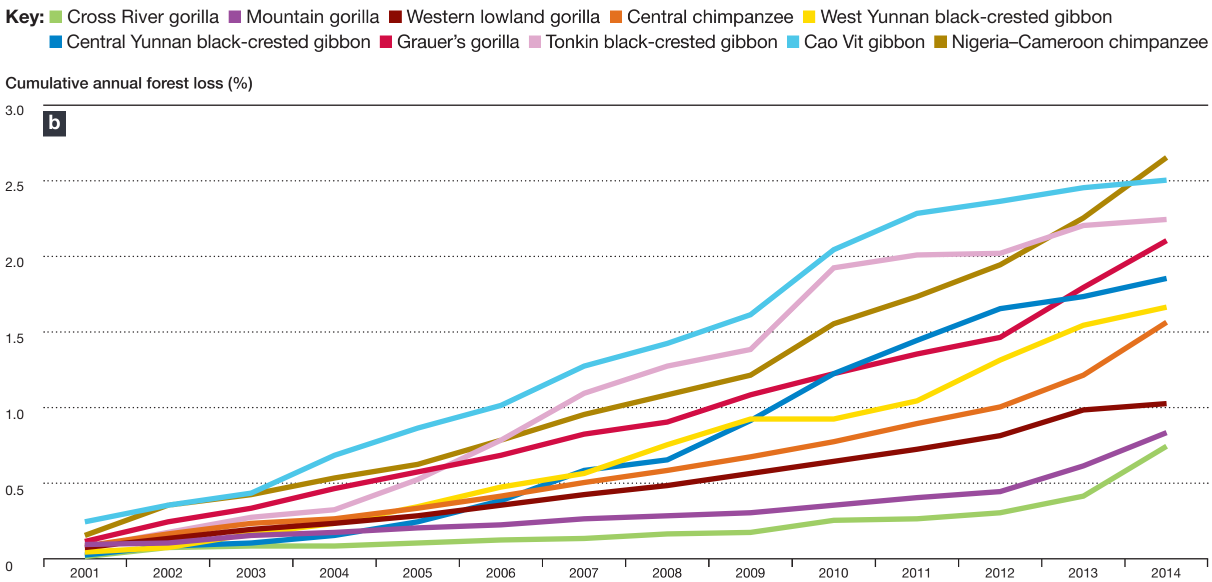
overall loss of habitat regardless of the inclusion of plantation data, and each showed even greater loss when plantations were fully included in the calculation (see Table 7.1 and Figure 7.5a). The amount of remaining habitat listed in Table 7.1 reflects the true 2014 habitat endpoint for subspecies whose ranges overlap with plantations.

FIGURE 7.5

Ape Ranges that Experienced the (a) Highest and the (b) Lowest Cumulative Annual Forest Loss, 2001–14





Notes: Plantation data were not available on an annual basis. Their inclusion would have increased the 2014 cumulative totals for all ten species in Figure 7.5a (plantations did not affect the subspecies in Figure 7.5b). For total cumulative loss values for all ape subspecies, see Table 7.1.

Data source: GLAD (n.d.); Hansen *et al*. (2013)

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Projecting Forward

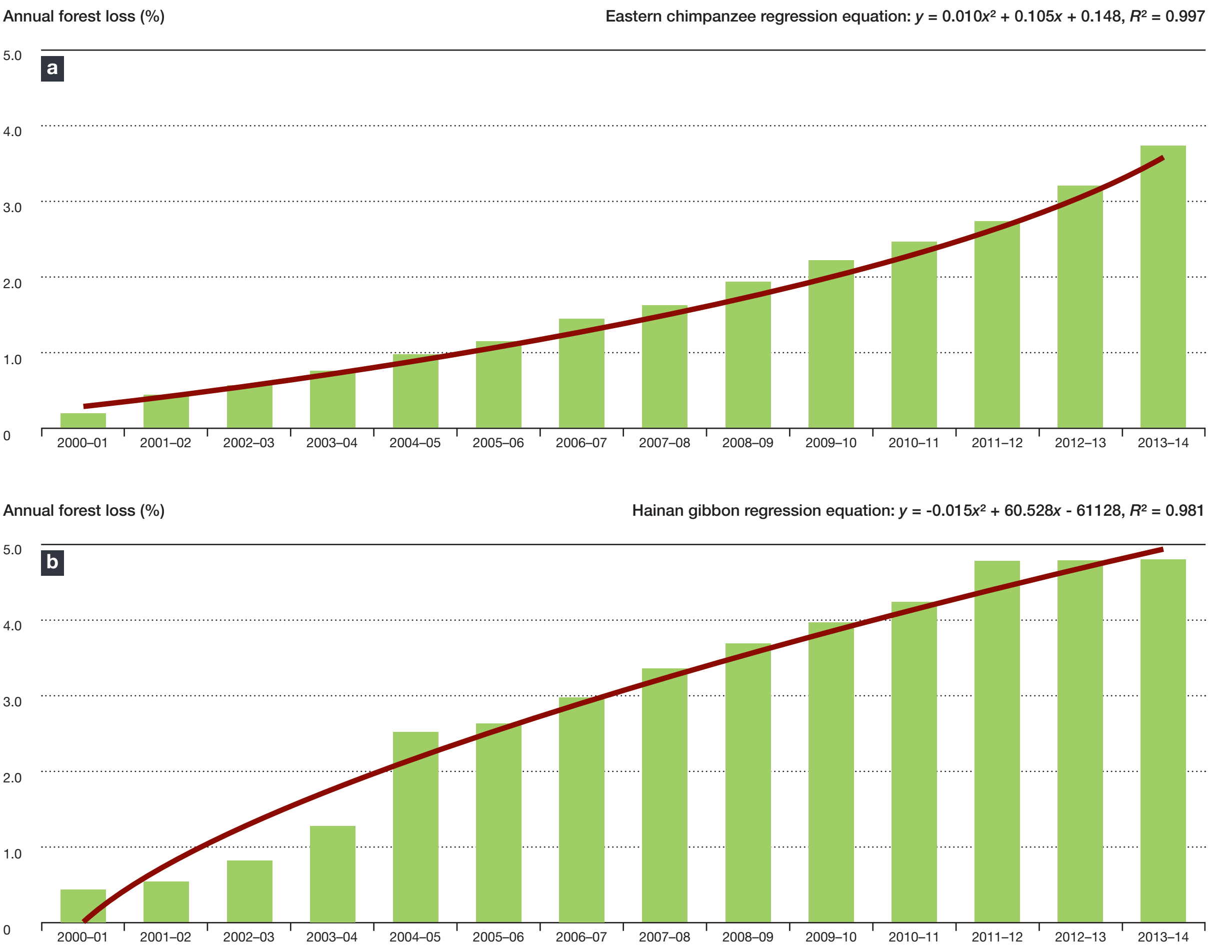
From 2000 to 2014, the annual rate of loss was relatively constant for most species, providing a rationale for projecting this same rate forward. Before future forest loss could be estimated, a regression line was fitted to the cumulative deforestation data; Figure 7.6 shows two examples. The resulting equations were then used to predict the amount of deforestation based on past trends, as discussed below.

The tight fit of the regression function to the data allowed future losses to be projected with a high degree of confidence (see Figure 7.7). The increasing loss rate for habitat of eastern chimpanzees stands in contrast to the decreasing loss rate of Hainan gibbon habitat (see Figure 7.6). The latter was severely diminished both before and during the study period, due to massive deforestation activities throughout Southeast Asia (Achard *et al.*, 2014). Hainan gibbons currently persist in a single island protected area.

The forest loss rates derived for each subspecies served as the basis for predicting remaining forest habitat in the medium term (2030) and longer term (2050), as shown in Figure 7.7. To avoid speculation about

FIGURE 7.6

Regression Lines Fitted to Cumulative Forest Loss for (a) the Eastern Chimpanzee and (b) the Hainan Gibbon, 2000–14



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changes in rates of forest loss, this assessment relies exclusively on forest loss data to make the projections.

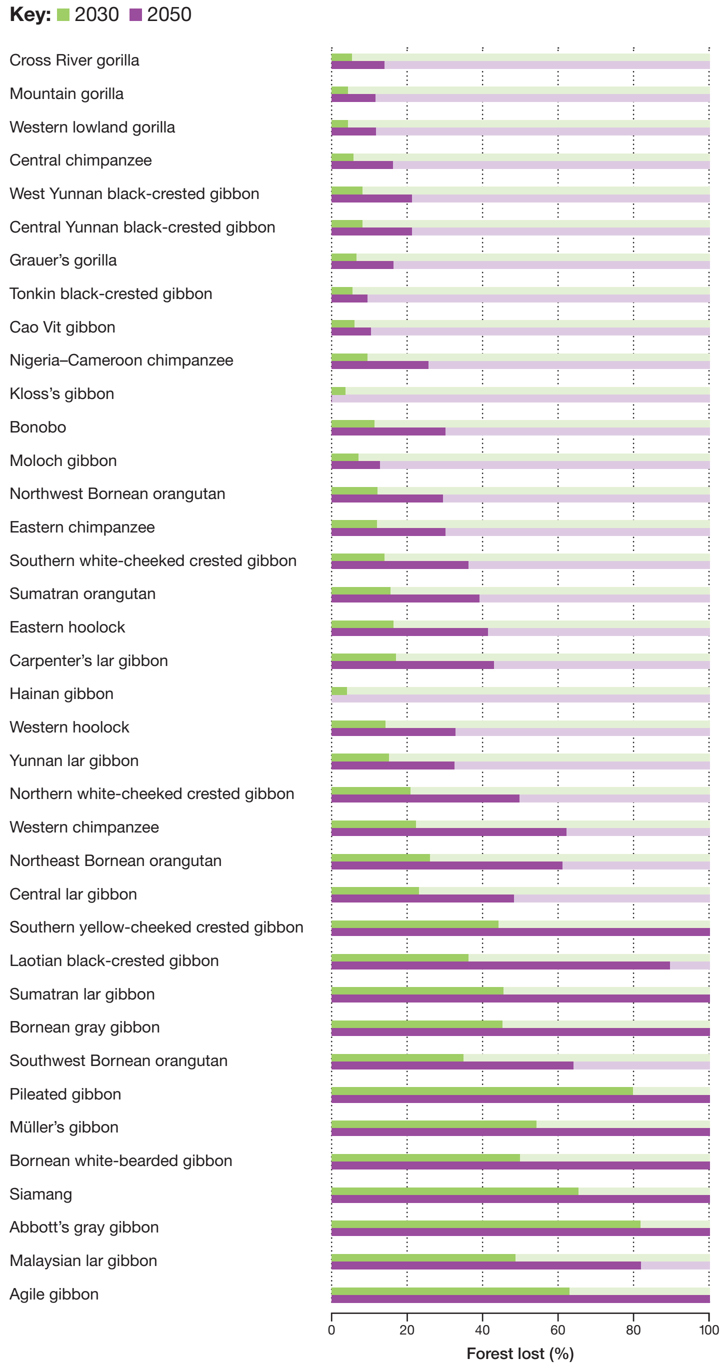
If forest loss continues at the same rate into the future as it has since 2000, consequences for apes, particularly Asian taxa, will be severe. Five subspecies are predicted to lose half of the habitat present in 2000 by 2030 (see Figure 7.7). Nine subspecies, all gibbons, are projected to lose all their habitat by 2050, assuming the rate of habitat loss remains constant (see Figure 7.7).

In most cases, forest loss rates are projected to increase. In some cases, however, the rate of habitat loss slowed over time, potentially to the point of becoming negative, indicating possible regeneration. For the Hainan gibbon and Kloss's gibbon (*Hylobates klossii*), the calculations project a reduced amount of loss in 2050 compared to 2030, based on quadratic equations that best fit the loss data for 2000–14. When extrapolated, the tapering loss rate for the Hainan gibbon shown in Figure 7.6b predicts a negative loss rate for the coming decades—and possibly forest regeneration.

These forest loss projections are simplistic, and land use changes are dynamic within ape-range countries. Slower rates of forest loss within PAs, as shown in Table 7.3, suggest that as a higher percentage of a given taxon's range is under protection—either because more area is protected or less unprotected forest remains—the rate of loss will be slower in the future. As discussed throughout this volume, however, massive transportation infrastructure investments in Southeast Asia and central Africa are expected to speed deforestation and associated agriculture and development, at least along new roads and railways (Dulac, 2013; Quintero *et al.*, 2010). The discovery of minerals underneath reserves has led to the downgrading or even degazetting of PAs to facilitate extraction (Forrest *et al.*, 2015; see Chapter 4, pp. 116–119). Exploration

FIGURE 7.7

Projected Loss of Forest Habitat, by Subspecies, 2000 vs. 2030 and 2050



Notes: Projections reflect the percentage of total forest habitat in 2000 that is predicted to be lost by (a) 2030 and (b) 2050, using best-fit regression equations based on annual percentage loss from 2000 to 2014. Ape subspecies are ordered by their cumulative loss during 2000–14. Nine subspecies, all gibbons, are projected to lose all their habitat by 2050, assuming a constant rate of habitat loss.

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and extraction could affect forest loss rates even in current reserves.

Regardless of the extent of forest cover, adverse impacts of human activities in ape habitats—such as hunting, forest degradation and disease transmission—are major conservation issues for apes. Even so, the availability of sufficient forest with adequate connectivity is a benchmark that must be planned against if these species are to persist into the future (Plumptre *et al.*, 2016b; Tranquilli *et al.*, 2012).

A critical finding of this is that gibbon subspecies with small geographic ranges face a particularly uncertain future. These taxa are little studied and poorly represented in conservation organization action plans; moreover, their plight is less recognized by the public and the media than that of chimpanzees or gorillas. Conserving remaining forest within gibbon ranges is possible, but only if the conservation community replaces this apparent complacency about the future of gibbons and dedicates the same attention and resources to gibbons that it does to the great apes.

Regular Monitoring of Forest Change

Forest loss in remote areas, including within and between PAs, often goes undetected until large areas have been cleared, as forest monitoring is typically limited to patrolling on the ground by park staff (Dudley, Stolton and Elliott, 2013). This chapter aims to help range-state institutions and conservation managers to:

(a) remain informed of habitat change in their areas of interest through frequent forest monitoring; and

(b) plan for enhanced ape protection by enabling them not only to identify areas of key forest habitat, but also to detect and respond to forest loss quickly.

Regular monitoring of remaining forest cover will be a critical conservation tool as surviving ape populations take refuge in increasingly isolated regions (IUCN, 2016c; Junker *et al.*, 2012). Early detection of the presence and location of forest loss can guide further investigation of a target area through higher-resolution aerial images or

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by rangers on the ground (see annexes XII and XIII).

Repeating analyses in particular areas would allow managers to monitor key performance indicators of ape habitat over time. Updated forest cover data provide a tool for primatologists and conservationists to integrate current habitat status information into their analyses of population status and local threats. If PAs are losing forest, it is likely that they are losing apes directly to hunting as well (Walsh *et al.*, 2003; Wich *et al.*, 2012a). Regular monitoring of habitat change can lead to more rigorous assessments once population and wild meat hunting data become spatially explicit across all ape species and habitats.

Photo: Large-scale agricultural plantations account for 52%–87% of detected forest loss within the ranges of at least 12 ape subspecies in Malaysia and Indonesia. © HUTAN–Kinabatangan Orang-utan Conservation Project

GFW now offers a new system of weekly tree cover loss alerts at 30-m resolution; for ape conservationists, this may be the most important tool released to date. GFW's online forest monitoring and alert system combines cutting-edge algorithms, satellite technology and cloud computing to identify where trees are growing and disappearing in near-real time. Having been piloted in a few countries in 2015, these GLAD alerts covered virtually all ape range countries by early 2017 and are to cover the entire tropics by the end of 2017 (M. Hansen, personal communication, 2017).

A new collaboration between GFW and RESOLVE will make GLAD alerts in critical ape regions easily accessible to the general public, along with a weekly feature called "places to watch," which highlights changes in tree cover that are of greatest concern to ape conservation. Alternatively, subscribers can receive these near-real-time alerts of detections of forest loss for whatever areas they select, be it a country, a forest reserve, a conservation landscape, a road buffer, or a hand-drawn polygon on the platform's interactive map.

Future habitat assessments could evaluate patterns of GLAD alerts as possible indicators of the intensity of imminent forest loss. In areas for which GLAD alerts have been set up, analyses could also track factors associated with forest loss, including slopes, distances to clearings, roads and towns (see annexes XI and XII).

Incorporating near-real-time GLAD alerts to improve the enforcement of existing PAs would go a long way towards conserving many ape populations, in particular the small gibbon populations and their remaining forest patches in both mainland and insular Southeast Asia. For these and other apes, the approach would allow managers to identify critical forest corridors and buffer zones that warrant conservation action and to enhance monitoring of forests within recognized corridors and buffer zones.

"Protected areas are becoming a last stronghold for remaining populations of a growing number of ape taxa, both in Asia, and, increasingly, in Africa."

Conclusion

The greatest recent forest loss has occurred within the ranges of at least 11 species and subspecies of gibbon and orangutan (see Table 7.1). Ape ranges in Sumatra and Borneo contained substantial forest through 2000 but lost it rapidly during the 2000–14 study period, as clearing for plantation agriculture in Indonesia and Malaysia triggered some of the world's highest rates of deforestation. Large-scale agricultural plantations account for the majority (52%–87%) of detected forest loss within the ranges of at least 12 ape subspecies in Malaysia and Indonesia, as well as nearly 30% of loss of ape habitat in Cambodia.

Available data reveal that plantations in Africa corresponded to just 1% of habitat loss for only one African ape subspecies, although nearly 60% of oil palm concessions occur within African ape ranges. Close to 40% of unprotected ape habitat in Africa is land suitable for oil palm (Wich *et al.*, 2014); as land available for expanding oil palm and other industrial-scale agriculture diminishes in Asia, corporate demand for undeveloped land is likely to increase in Africa. Such demand is likely to fuel a surge in both deforestation and degradation from associated infrastructure development (Barber *et al.*, 2014; Laurance *et al.*, 2015b).

In 2000, African ape ranges were 94% forested (see Table 7.1). By 2014, African apes still retained substantial forest cover in their ranges, but rates of loss had increased in the previous five years. In contrast, ape ranges in Asia were only 69% forested in 2000. While the overall rate of forest loss in Southeast Asia slowed somewhat in the following decade—particularly when compared to the extremely high rates caused by massive deforestation during the 1990s (Achard *et al.*, 2014)—apes there persist in isolated forest fragments and PAs.

Protected areas are becoming a last stronghold for remaining populations of a growing number of ape taxa, both in Asia, where forest loss continues to threaten ape populations, and, increasingly, in Africa. PAs experience lower rates of habitat loss than unprotected areas, but, as this analysis underscores, losses are still considerable (Gaveau *et al.*, 2009a; Geldmann *et al.*, 2013).

The need to act is most acute in Asia. If the frontier of deforestation is around PAs, where forest remains, and loss rates stay constant into the coming decades, forest connectivity will be lost, as will the chance to ensure that PAs are large enough and well protected enough to maintain viable populations of subspecies. Stabilizing expanses of protected forest and improving PA management effectiveness are priorities for ape conservation in the immediate future.

Acknowledgments

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Annexes VIII, IX, X, XI, XII and XIII: The authors

Reviewers: Leo Bottrill, Mark Cochrane, Mark Harrison and Fiona Maisels

Endnotes

1 Circular representation of protected areas: The authors used the April 2016 version of the World Database on Protected Areas (WDPA) for global spatial analysis. In the WDPA data layer, some protected areas are provided only as points, without boundaries. Circular buffers were created around these points, based on area information in the WDPA. These buffered points were then merged to create one visual layer for protected areas. This approach resulted in the circular representation of some protected areas in these maps.

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