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Issue: *The Year in Ecology and Conservation Biology***Not by science alone: why orangutan conservationists must think outside the box**Erik Meijaard,^{1,2} Serge Wich,^{3,4} Marc Ancrenaz,⁵ and Andrew J. Marshall⁶

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Orangutan survival is threatened by habitat loss and illegal killing. Most wild populations will disappear over the next few decades unless threats are abated. Saving orangutans is ultimately in the hands of the governments and people of Indonesia and Malaysia, which need to ensure that habitats of viable orangutan populations are protected from deforestation and well managed to ensure no hunting takes place. Companies working in orangutan habitat also have to play a much bigger role in habitat management. Although the major problems and the direct actions required to solve them—reducing forest loss and hunting—have been known for decades, orangutan populations continue to decline. Orangutan populations in Sumatra and Borneo have declined by between 2,280 and 5,250 orangutans annually over the past 25 years. As the total current population for the two species is some 60,000 animals in an area of about 90,000 km², there is not much time left to make conservation efforts truly effective. Our review discusses what has and has not worked in conservation to guide future conservation efforts.

Keywords: deforestation; great apes; hunting; Indonesia; Malaysia; nongovernmental organizations; orangutan; palm oil; plantations; *Pongo abelii*; *Pongo pygmaeus*

Introduction

Orangutans (*Pongo* spp.) are among the most iconic species in wildlife conservation. Popular television programs such as *Orangutan Island* produced by Animal Planet and *Orangutan Diary* by the British Broadcasting Corporation (BBC) are testimony to the public's interest in these great apes. People's affinity with orangutans is at least partly based on the red ape's behavior, facial expressions, and mannerisms, which can be uncannily human. Indeed, genetic comparisons and morphological, cognitive, and behavioral similarities do indicate the close evolutionary relationship between humans and orangutans.^{1–3}

Despite their similarities, the evolutionary paths leading to orangutans and to humans diverged some 9–13 million years ago.⁴ After that evolutionary

split, a range of orangutan-like taxa or pongins evolved, including *Gigantopithecus*, the largest ape that ever lived. These species primarily occurred in present-day Europe and mainland Asia. Of this diverse lineage, only the genus *Pongo* survives. In this respect, orangutans are not simply two endangered species of great ape, but also represent the sole living representatives of a diverse clade that included dozens of distinct pongin species and genera that occurred for some 10 million years across Asia and Europe.

Although most of pongin evolution occurred in Asia, the human lineage primarily evolved in Africa. Not until the Pleistocene, when species such as *Homo erectus* inhabited Asia, did the orangutan and human lineages meet, and only some 70,000 years ago did our own species, *H. sapiens*, disperse into the orangutan's realm.⁵ The co-occurrence of humans

and orangutans has since then led to the rapid decline of the latter, but it is unlikely that humans were the sole cause of the orangutan's decline. The dramatic environmental changes that occurred in Asia from the late Miocene to the Pleistocene probably contributed to the extinction of many of the Asian apes⁶ and may have substantially reduced orangutan population sizes as well. Broadly speaking, climatic changes such as increased aridity, more intense monsoons, and increased frequency and severity of glacial-inter-glacial cycles caused once widespread evergreen rainforests, the habitat of orangutans, to be increasingly restricted to isolated pockets close to the equator.^{7,8}

The genus *Pongo* could be found until the Late Pleistocene, or some 40,000 years ago, from as far north of southern China to the island of Java.^{9,10} The present habitat of the Sumatran Orangutan (*Pongo abelii*) and Bornean Orangutan (*P. pygmaeus*) is probably less than 5% of the original *Pongo* distribution range. Even on the two islands of Borneo and Sumatra, where the species still occur, their populations had been much reduced by the early 19th century when orangutans became first known to science.^{11–13} Orangutans have been hunted by people at least since the Late Pleistocene,^{14,15} and a recent study suggests that over-hunting is one of the main reasons for these historic local extinctions of the species.¹² Orangutan populations have declined even more dramatically over the past few decades; both species are considered in danger of becoming extinct in the wild soon.^{16,17}

Orangutan distribution and density

In many high-income countries, orangutans are a symbol for the unsustainable management and conversion of tropical rainforests on Borneo and Sumatra, especially where this concerns the development of oil palm plantations (*Elaeis guineensis*), which many consider a major culprit in the orangutan's decline.^{18,19} As shown above, the decline of orangutans goes back much further than the last few decades. The southern half of Sumatra had probably lost all its orangutans by the time Alfred Russel Wallace and other early explorers and naturalists first described the orangutan (but see Ref. 13), whereas southeastern and northwestern Borneo, as well as the central highlands of the island, were also devoid of the species. Obviously there is more to declining orangutan populations than simply oil palm

expansion, suggesting that better analysis is needed of the threats to orangutans and the orangutans' distribution.

One of the main challenges in orangutan conservation science has been, and continues to be, the development of accurate population estimates so that populations can be monitored. Early estimates in the 1960s and 1970s varied between a few thousand orangutans and 156,000 for all of Borneo^{20–22} and between 4,500–10,000 for Sumatra.²³ New approaches based on absence/presence maps,¹³ island-wide interview surveys,²⁴ and aerial surveys^{25–27} led to more accurate estimates of at least 54,000 individuals for Borneo.¹⁷ Even this figure should be considered a center point in a wide range of possible real population numbers, because no local densities are known for many parts of the species' range (Fig. 1). The population estimate for Sumatra is *ca.* 6,600, which was recently considered a conservative estimate. What we do know is that the area of orangutan habitats has been in a rapid decline for over 50 years now.^{11,13,28}

After decades of survey work, it is reasonably well known where orangutans occur (Fig. 1). In the two Malaysian States (Sabah, Sarawak) on Borneo, and in Sumatra, this knowledge is relatively accurate. Several areas in Kalimantan have also been surveyed quite well, but large areas of unprotected habitat have only been surveyed in a cursory manner. The clumped distribution of orangutans¹³ and high spatial variation in density make it impossible to extrapolate density estimates from one area to another. The variation in orangutan population estimates is therefore more due to an uncertainty about local densities than to a lack of information about the extent of the two species' ranges. Many factors have been hypothesized to limit orangutan densities, including the density of fig trees, altitude, forest type, degree of forest degradation, hunting intensity, and possibly the density of salt licks, or even past and current disease outbreaks.^{29–34} Measuring these densities, however, is not easy. Orangutans are difficult to survey directly, and accurately estimating densities requires time-consuming surveys of indirect indicators such as their sleeping platforms or "nests."^{35–37} This is mostly done on foot, but increasingly remote approaches such as aerial surveys are used.^{25,38} These methods have in common that the estimation of the number of orangutans is based on the number and spatial distribution of their nests. This requires

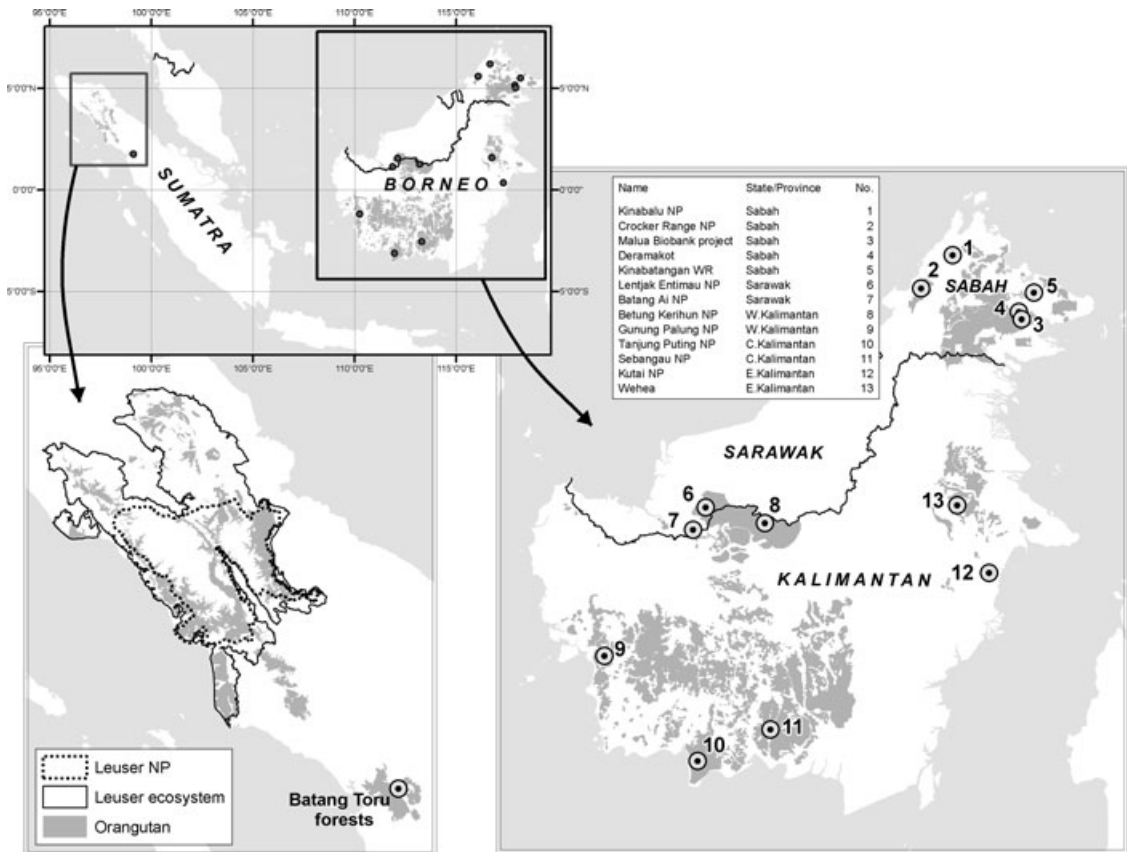


Figure 1. Orangutan distribution based on 2003 surveys, with orangutan populations mentioned in the text indicated on the map.

the determination of two factors: the rate at which orangutans build nests and the rate at which these nests decay over time. Recent studies have shown considerable variation in especially the latter factor, with average nest decay rates varying from 81–602 days, depending on factors such as the species of tree in which the nest is built, height of the nest, as well as the species of orangutans.³⁹ Nest surveys rarely determine decay rates locally, and the confidence intervals around previous density estimates are therefore large.^{40,41} New approaches to nest surveys have been considered,⁴² but none effectively overcomes the immense investment of labor and time that would be needed to accurately determine local densities across some 90,000 km² of dense, relatively inaccessible rainforest. Until new methods emerge, such as the direct detection from the air of orangutans with a thermal scanner, the best approach appears to be the combined use of on-the-ground nest surveys with remote nest counts, as well

as the use of interview surveys, which provide better tools to determine and quantify human threats, such as hunting and agricultural conflict killings.²⁴ Resources made available for conservation are scarce and should be allocated strategically: assessing spatial variation in threats and ways to manage their impact on major populations is therefore crucial for the survival of the species.

The context of threats

Recent analysis of forest conversion for oil palm suggests that at least 10,000 km², or 5% of the total orangutan range, was converted for oil palm between 2000 and 2010,⁴³ with the high-density orangutan populations in the lowlands of eastern Sabah, a Malaysian state in north Borneo; coastal peat swamps in Sumatra; and peat swamps in the Indonesian province of Central Kalimantan having been especially affected. Oil palm is indeed a considerable threat, but other factors such as unsustainable

timber extraction, development of tree plantations for pulp and paper, small-scale community agriculture, mining, and direct orangutan killing are important factors in the orangutan's decline as well. Singling out a particular industry as the main culprit in this process ignores the contribution from others and is unlikely to lead to lasting solutions.

Wild orangutans rarely require species-specific management (e.g., food provisioning or disease treatment), although rope bridges in Kinabatangan to reduce fragmentation effects have been successfully tested. The majority of conservation interventions entail protecting forests and preventing hunting. Despite initial impressions that the species was highly sensitive to forest disturbance,^{13,33,44} it is becoming increasingly clear that the species has considerable ecological flexibility, allowing it to cope reasonably well with such disturbances.⁴⁵ Some populations even use monocultural plantations, although it is doubtful whether their survival there could be long term without access to more natural forest stands.⁴⁶ What is clear, however, is that orangutan populations suffer greatly from hunting. In many parts of their range, orangutans are killed for food, the pet trade, and from conflicts that inevitably occur as natural forests are converted for small and large-scale agriculture. This is a major threat as orangutan reproductive rates are too low to recover from hunting rates > 1% females/year.⁴⁷ Rates of killing appear to far exceed this: a recent study estimated that annually between 750 and 3,500 orangutans are killed in Kalimantan.⁴⁸ Assuming a total population of some 42,500 animals in Kalimantan,¹⁷ this would imply annual female off-take rates between 0.9% and 3.6%. In addition to direct mortality, hunting and deforestation have resulted in a steady flow of rescued and confiscated orangutans into the ten orangutan quarantine, care, and rehabilitation centers in Indonesia and Malaysia.⁴⁹

The different threats to orangutans have related underlying causes. Poor land-use planning allows the degradation of known orangutan habitats. Poor forest management results in degraded, fire-prone forests with limited economic value, providing strong commercial and political incentives to convert these lands to agricultural or silvicultural lands. The resulting fragmentation of orangutan habitats leads to higher human-orangutan conflict and killing rates,¹⁷ which go unpunished because of

a lack of law enforcement.¹⁷ In addition, too often the quality of protected area management remains insufficient to prevent forest loss,⁵⁰ so even in these areas orangutans are not safe.

In the past, orangutans had significant cultural value among some of the tribes living in or close to forest areas where orangutans occurred.¹³ In the face of rapid development and modern consumerism, however, to many local people on Borneo and Sumatra the orangutan has become just another "monkey." In interviews with us, many local people express surprise regarding the amount of international attention for these species while these people themselves are still struggling to survive.⁵¹ A 2008 candidate for the governorship of East Kalimantan (Indonesian Borneo) declared that people should take precedence over orangutans—a politically pragmatic position that is unlikely to change soon in a country where recent figures indicated that 52.4% of the people live on less than US \$2 per day.⁵¹ However, losing wild orangutans would have considerable consequences. Orangutans play important ecological roles in forests as ecosystem engineers and seed dispersers^{52,53} and also provide a source of income for some forest communities through ecotourism.⁵⁴ More importantly, as one of the most recognized global conservation icons, their loss would imply that people are not able to develop life styles that are compatible with the ecological needs of our natural world. Losing a great ape from the wild would be a landmark failure. Not only would we have eradicated one of our closest genetic relatives, we would also substantially affect the forests that depend on orangutans, which would cause declines of many other taxa and erode the environmental services that forests provide and on which many people depend.

Abating the threat to orangutan survival is a political choice requiring societal approval and cooperation for comprehensive solutions that involve strict protection of key habitats, effective law enforcement against harmful illegal activities, and selection of compatible land-use practices. In democratic countries, governments will have to justify their choices in favor of species conservation against the opportunity costs of potentially more profitable land-use practices. In many cases, that justification is ethical rather than economic,⁵⁵ and the orangutans' future may depend on whether people are able to prioritize ethics over economics.

Past population trends

Uncertainties in population estimates have translated into widely ranging estimates of population trends, including the prediction in 2007 that orangutans would be virtually extinct in 2012.⁵⁶ Recent data allow us to better approximate annual population declines. Loss of orangutan habitat in Sumatra has been estimated at 1–1.5% per year between 1985 and 2001.²⁸ Based on these rates and the presently remaining area of habitat of 8,641 km² (Ref. 57), the estimated losses over the last 25 years range from 2,300 km² to 4,000 km². These habitat losses primarily occur in lowland forests, which have the highest densities,³¹ with a conservative average of 2.5 animals/km². This would suggest average annual losses on Sumatra of 230–400 animals over the last 25 years. Such estimates cannot be used to predict future declines, because they are based in forest loss rates in lowland forests, and these rates will likely be lower in remaining upland habitats.

Annual mortality rates of orangutans in Kalimantan are estimated at 750–3,500 per year.⁴⁸ In Sabah, the orangutan population is thought to have decreased by a minimum of 95% over the past few centuries based on analysis of population genetics.¹¹ This is consistent with the decline from a state-wide populations estimate in 1987 of 25,000 animals⁵⁸ to the presently remaining population size of 10,000 individuals,⁴⁵ suggesting annual losses of 1,250 individuals for Sabah only. No estimates are available for Sarawak, where a small, relatively well-protected population remains. We estimate that some 50–100 animals have been lost annually over the past 25 years to hunting, animal trade, or habitat loss.^{59,60} This would suggest annual losses for Bornean orangutans over the last 25 years between 2,050 and 4,850. This range fits the estimated annual habitat losses of 3,122 km² up to 2004,²⁸ which, with a density range between 0.5 and 1.5 animals/km² (Ref. 31), translates into a similar mortality range.

What has been done in orangutan conservation?

Legally, orangutan conservation started in 1924 when the species was first protected in what is now Indonesia.¹³ New laws primarily involved the setting aside of protected areas on Borneo and Sumatra and included prohibition on the then very active zoo

trade in orangutans.⁶¹ This prohibition was not enforced, however, and significant trade in orangutans for European and American zoos and for biomedical research continued until at least the 1970s.⁶² These issues were brought to the conservation community's attention in the Western world by the efforts of Barbara Harrison,⁶³ and her work signifies the start of the serious study of orangutans and international attention to their conservation.¹³

To effectively address threats, orangutan conservation uses four main strategies: management of protected orangutan habitat, combating illegal trade and killing, rehabilitating and reintroducing ex-captives into their wild habitat, and developing orangutan-friendly management in nonprotected areas. These strategies sound relatively straightforward, and, in fact, the principles of orangutan conservation are simple: minimize unnatural deaths and maximize the availability of suitable habitat. We summarize the main issues for each strategy below and explain why things are more complicated than they appear.

Management of protected orangutan habitat

About 25% of all wild orangutans occur in formally protected areas.¹⁷ This does not necessarily mean that these populations are safe, because illegal logging, mining, and poaching continue in many of these protected areas and human–orangutan conflict occurs on their edges.^{17,64} Still, these areas provide some level of protection compared to the non-protected parts of their range.⁶⁵

In Sumatra, orangutans mainly occur in the Leuser Ecosystem, which includes the Gunung Leuser National Park, and in the Batang Toru forest blocks (Fig. 1). Conservation efforts for the Leuser area stem back from the 1930s,⁶⁶ but the Batang Toru population was only recently rediscovered,^{67,68} and conservation programs therefore began much more recently there. Effective management of the Leuser Ecosystem, which includes the national park and surrounding areas, started in the early 1990s and was boosted by significant European Union and Indonesian government funding and later by funding generated after the 2004 tsunami in Sumatra. We conservatively estimate that a total of US \$75 million have been spent on Sumatran orangutan habitat protection from 1990 to 2011. This is a substantial amount of funding and one might expect that there are clear measures that would account for

how successful this funding has been for conservation. Unfortunately, this is not as straightforward as it sounds, and we can only approximate the impact of that funding on orangutans. Based on recent forest loss estimates,⁶⁹ it has been estimated that between 1985 and 2007, the lowland forests of Aceh and North Sumatra Provinces, where most orangutans occurred, have been reduced by 36% and 61%, respectively.⁵⁷ Orangutan density is highest in forests on peatlands,^{31,35} and forest loss in those habitats was 33% for Aceh and 78% for North Sumatra. Still, the protected areas of Sumatra do reduce forest loss,⁶⁵ and the orangutan's situation would have been worse without them.⁷⁰ This is evident in Leuser, even though not all of the Leuser Ecosystem was classified as protected during this period. From 1985 to 2007, 11.7% of forest in the 25,000 km² Leuser Ecosystem was converted to other land uses,⁵⁷ or up to 20.1% if forest loss in lowland areas is considered. Most of the dryland forest was replaced with agroforestry (31%) and much less by oil palm (19%), but, on peatlands, 79% of the forest that was lost was replaced by oil palm plantations.⁵⁷ This is bad for orangutans, but again things would have been worse without the protected areas and the continued conservation efforts for protected and nonprotected areas. For Sumatra, it can therefore be tentatively concluded that protected areas and conservation does work to reduce forests loss, but not to halt it, and that their protected area management and conservation efforts still require much improvement.

Kalimantan (Indonesian Borneo) has more orangutans than any other location. It also has the biggest problems in terms of deforestation; forest degradation and fragmentation; and killing of orangutans for food, pets, and other reasons.¹⁷ Some key populations, such as those in the Gunung Palung, Tanjung Puting, Sabangau, and Betung Kerihun National Parks, are relatively well protected, although forest loss and degradation continue even in these areas. Outside these protected sites, habitat loss and degradation through development of small- and large-scale agricultural and silvicultural plantations is rapidly reducing the areas where viable populations can survive. Forest loss in Borneo between 2000 and 2010 was recently estimated at 500,000 ha/year.⁷¹ Most of this forest loss has occurred in lowland forest on mineral soils and in peat land, both of which are key orangutan habitats. One

protected area, Kutai NP (see Fig. 1), has lost much of its forest through illegal activities,⁷² although it still maintains a significant orangutan population of over 1,000 animals. Illegal killing of orangutans in Kalimantan appears to impact remaining populations more than it does in Sumatra⁷³ and the Malaysian side of Borneo.¹¹ This suggests that protected areas, where the potential for law enforcement is higher than outside them, are especially important in Kalimantan as areas where populations can be protected from hunting.

Sabah, Malaysian Borneo, has lost more than 40% of its forests over the past century, and the majority of its remaining forests are at different stages of degradation and regeneration due to past intense logging activities.⁷⁴ Today about 50% of the State is still covered with forest, and 13% of the State protected. Most of Sabah's lowlands used to be occupied by orangutans, and it is estimated that between 50 and 90% of the original orangutan population was lost over the past 100 years.¹¹ Most orangutan populations are currently found in the eastern side of the state, where nonhunting Muslim communities predominate. Sixty percent of Sabah's orangutans occur outside protected areas,²⁵ where they are mostly threatened by conflicts, hunting, road kills, lack of food resources, intense population fragmentation, and increased sensitivity of forest blocks to natural and human-made catastrophes. Still, forest loss is slowing in Sabah and protected areas are relatively well managed, although unfortunately most of them were established in marginal orangutan habitat, such as the highland forests of Crocker Range and Kinabalu National Parks (Fig. 1). The hope for Sabah is that relatively low hunting levels and stabilizing land use will allow the development of a network of interconnected, well-protected areas that would allow an orangutan population to survive in a mixed landscape of plantations, timber concessions, and protected areas. In addition, the State is trying to identify mechanisms to secure the long-term sustainable management of some unprotected forests through the development of mechanisms such as biodiversity credits in the Malua Biobank project and forest carbon initiatives. In addition, sustainably managed forests, such as the Deramakot timber concession, which is certified by the Forest Stewardship Council (FSC), are very important orangutan sites that appear to sustain and maintain viable orangutan populations. The State

aims to FSC certify all its commercial forests before 2020.

Finally, in Sarawak, Malaysian Borneo, most remaining orangutans occur in two protected areas, Lanjak Entimau and Batang Ai, for which a population of 1,143–1,761 orangutans has been estimated.¹⁷ Little information exists about the management of these populations, because conservation activities by nongovernmental organizations (NGOs) and research are not encouraged in the State.

Law enforcement

Orangutans are fully protected in both Malaysia and Indonesia. Large fines or jail sentences are mandated for those who kill, trade, or illegally keep orangutans or illegally clear their protected habitats. Hunting of orangutans for food, the pet trade, and to avoid crop damage is rampant in Kalimantan,²⁴ and hunting pressure is the strongest determinant of orangutan density in East Kalimantan Province.³⁰ Many illegal activities related to orangutans have been reported in the media, but only in 2011 did the first two prosecutions occur in West Kalimantan, Indonesia for people caught trading orangutans.⁷⁵ This reportedly resulted in prison sentences of eight months and one and a half years. Malaysia is somewhat stricter in the enforcement of its wildlife laws, but there offenders are rarely prosecuted.

With illegal logging and orangutan killing being among the major threats, improved law enforcement, together with effective public campaigns, are key strategies. Unfortunately, commitment from the government to enforce laws is generally lacking, and few resources have been made available to make law enforcement more effective.^{73,76} In addition, few orangutan conservation organizations focus on increasing law enforcement. This might be because it involves the risk of being considered in opposition of people that live alongside the orangutan. In addition, foreign private or government donors shy away from funding law enforcement because of the potential risk of being seen as meddling in internal affairs of another country. Interestingly, some of the best examples of law enforcement are seen among local communities themselves, such as the Honorary Wildlife Warden scheme in Kinabatangan, Sabah, or the Wehea forest in East Kalimantan (Fig. 1), which is managed and patrolled primarily by local community stakeholders.

With regard to law enforcement, most conservation organizations focus on the role of companies in the destruction of orangutan habitats, especially when this is illegal or semilegal. These semilegal cases involve the many gray areas in the legislation related to orangutan conservation. Importantly, among these is the fact that although orangutans are protected this does not mean that it is illegal to destroy their habitat, even though large-scale forest clearing clearly leads to the death of orangutans. For orangutan conservation to function better, governments need to clarify what it means to be a protected species and translate this into meaningful and operational legislation.

Orangutan rehabilitation, reintroduction, and translocation

Orangutan rehabilitation centers were first created in Malaysia in the 1960s, and the earliest efforts in Indonesia date to the 1970s. They were initially set up as law enforcement units in response to the growing number of captive animals seized by law enforcement authorities, with those in Malaysia run by the government and the Indonesian ones by NGO. These centers have been increasingly presented by NGOs and media as the frontline for orangutan conservation in Southeast Asia.⁷⁷ Between 1964 and 2008, Indonesian and Malaysian orangutan rehabilitation projects have taken in at least 3,320 animals and released around 1,250,⁴⁹ or about one third of the original intake. The intake number is certainly an underestimate, however, because of the high number of mortalities, especially among very young orangutans. Presently, an estimated 2,000 orangutans live in orangutan care centers waiting to be released back into forest habitats. Past efforts to release orangutans have had low success rates, with few orangutans reportedly surviving in one location where over 400 orangutans were released.⁷⁸ Mortality rates of reintroduced orangutans vary from 20% to 80%.⁴⁹ Assuming that survival rates in these unstudied populations are an average 50%,⁴⁹ *ca.* 625 orangutans have been successfully reintroduced over a 45-year period.

Translocation involves the transfer of orangutans from one area, often a forest on the verge of being cut down or an area where orangutans cause conflicts, to another, safer one. There are few published figures on the number of orangutans that have been translocated over the years (but see Ref. 79), nor have

follow-up studies been conducted regarding the fate of translocated animals. Similar to reintroductions, the challenge for translocations is to find areas of protected, good habitat into which orangutans can be released. Most of these locations are very remote, making it costly to transport orangutans there and to provide postrelease monitoring and care.

Despite the relatively low success rates, conservation investment in orangutan rehabilitation and reintroduction remains high. The cost of feeding and caring for an orangutan can be estimated from the operational costs of US \$3.2 million for about 1,200 orangutans reported by one program in 2007,⁸⁰ suggesting annual management cost per orangutan of US \$2,670. As this does not take into consideration acquisition and maintenance costs of land, buildings, and vehicles, a minimum cost of US \$3,000 per orangutan per year is more likely. In Kalimantan, where many orangutans are released in very remote sites, the one-off logistical cost of releasing one orangutan into the wild, not including postrelease monitoring, is about US \$5,000 per animal (M. Desillets, personal communication). With 63–97% of animals arriving in rehabilitation centers being younger than the minimum release age of seven years,⁴⁹ mean time from admission and release is likely to exceed three years. A minimum average cost of US \$14,000 per animal from rescue to release is realistic. These estimates consider only those animals that are successfully rehabilitated and reach the reintroduction stage. A significant number of orangutans cannot be reintroduced due to diseases or physical impairments and are kept in captivity for life, requiring long-term funding without direct conservation benefits.

Developing orangutan-friendly management in nonprotected areas

With most orangutans occurring outside protected areas and with minimal chances that much more habitat will be formally protected, the inevitable conclusion is that the majority of orangutans will have to be managed in forests that are also used for other purposes. There is hope that well-managed forests, and even plantations, can provide habitat for orangutans, although much more research is needed here to examine which factors determine orangutan survival in multifunctional landscapes.^{45,46,81} For such multifunctional landscapes to provide viable habitat for orangutans as well as people, a signif-

icant shift in perspective is needed among conservation groups, governments, forest managers, and local communities.^{24,82} It will require that we stop seeing conservation in black and white terms of unprotected and protected or natural and unnatural.⁸³ We need to acknowledge that the orangutans' future will depend on their survival in human-made landscapes and not pristine habitats only.

There is a hugely important role for public awareness campaigns and educational programs to promote peaceful coexistence between people and orangutans. There is also a need to develop clearer management guidelines that prescribe how forests and plantations can best be managed to maximize the survival chances of orangutans (and other wildlife) while minimizing the costs to managers. Governments need to assist this process by making such management guidelines mandatory or to provide financial incentives, such as tax breaks, to offset the extra costs of wildlife-friendly management. Western or local markets could potentially play a role as well by paying higher prices for products harvested from orangutan-friendly sites or refusing to buy those from badly managed ones. This would require some transparent auditing process, however, and the costs of doing this are often higher than the potential gains from premium prices.⁸⁴

The role of research in orangutan conservation

Researchers like orangutans. A search in a scientific literature database (Current Contents) of keywords "Orangutan" and "*Pongo*" revealed about the same number of search hits ($n = 249$) as similar searches for "Tiger" and "*Panthera*" ($n = 284$), "Elephant" and "*Elephas*" ($n = 320$), and "Panda" and "*Ailuropoda*" ($n = 226$), all iconic conservation species. Orangutan research covers many fields including evolutionary genetics, ecology, behavior, disease and veterinary medicine, and field survey methodologies. Many orangutan studies justify their research by referring to the species' endangered status, but how relevant are they actually for orangutan conservation?

Although research has provided important data on behavioral ecology, habitat needs, and the genetic structure of populations, which are relevant for orangutan conservation, most research on orangutans provides little specific information or insights that can be directly applied to conservation

planning and management.^{85,86} For example, even though it has been suspected for a long time that illegal killing of orangutans was a major factor in their conservation,^{13,30} the first comprehensive, quantitative data set on this problem was not developed until 2009 and only exists for Kalimantan.²⁴ Similarly, we are still unable to provide accurate population estimates for the orangutans in the Indonesian part of Borneo, because coordinated research and survey efforts have not been undertaken. Many important practical questions remain unanswered, including the impact of roads and plantations on orangutan dispersal; the nature, causes, and possible solutions of human–orangutan conflicts; effectiveness and efficiency (cost–benefits) of different conservation strategies; orangutan survival in agroforestry or plantation landscapes; or the value of reforestation and corridor development for meta-population dynamics. This is not to say that orangutan researchers do not contribute to orangutan conservation. Often, simply by virtue of their presence, researchers keep hunters and illegal loggers out of areas that would otherwise be unprotected or even play an active role in the development and management of protected areas. Still, this concerns specific, research-intensive areas only and not the broader landscape level needed for successful orangutan conservation.

A specific shortcoming of orangutan conservation is that it receives limited input from local scientists. Many Malaysian and Indonesian scientists have been trained in conservation science or specifically worked on orangutans, but their contribution to further orangutan conservation science remains too limited.⁸⁷ A search in the scientific literature databases Current Contents and Web of Science for keywords “orangutan/orang-utan” and “conservation” indicated that between 1993 and the present about 1% of these publications were written by Malaysian or Indonesian scientists, as indicated by their position as first author.⁸⁷ The scientific literature on orangutan conservation is dominated by English, American, French, Dutch, Australian, Singaporean, and Japanese researchers. The consequence of this is that the role of indigenous researchers in translating research findings into locally relevant policy recommendations or media communications is underused. Successful orangutan conservation will require societal change in Malaysia and

Indonesia, and local scientists could play a much more pronounced role in facilitating that change. It is beyond the scope of the present publication to identify the underlying causes of this relatively weak role of indigenous conservation science, but examples from other developing countries indicate that level of economic development may not be a key factor. For example, a similar literature search for “Brazil,” “jaguar,” and “conservation” indicated that about 50% of the publications were written by Brazilian or Argentinean researchers; about 75% of the publications on “India,” “tiger,” and “conservation” had a first author of Indian nationality; and about 78% of the publication on “China,” “panda,” and “conservation” were first-authored by Chinese scientists. There is an urgent need to increase local scientific capacity and active engagement of these scientists in Indonesia and Malaysia, which should eventually result in better societal comprehension of the different aspects of orangutan conservation, improved political uptake of key environmental ideas, and more media attention to these issues supported by local rather than international conservation figureheads.

Finally, conservation involves the manipulation of human–nature interactions with a view towards stabilizing ecological and environmental processes and trends. How these social and ecological systems interact, however, remains poorly understood.^{88,89} The lack of progress is largely due to the traditional separation of ecological and social sciences.^{90–92} Orangutan researchers who want to justify their work through its supposed positive impacts on orangutan conservation need to do a better job at identifying relevant questions for improving orangutan conservation. This may require a type of science different from the ecology and behavior focus that is normally associated with great ape research. Useful orangutan conservation research needs to delve into disciplines such as economics, political studies, law, sociology, forestry, and agricultural studies—that is, a much more multidisciplinary approach than traditional orangutan science. For conservation science to be useful, the conservation benefits should not be a serendipitous afterthought, but rather a clearly stated primary objective: what research do we need to conduct to achieve significant orangutan conservation outcomes?^{86,93}

What could the orangutan's future look like?

The orangutan's extinction is considered to be imminent by some,⁵⁶ while others have suggested that the species has good habitat strongholds and also possesses more ecological flexibility to cope with changing environmental conditions than previously thought.^{26,28,45,46,81} Despite that apparent flexibility, however, two factors work against the species: their inherently low reproductive rates and the ongoing high mortality rates caused by conflict killings, hunting, and habitat destruction. These factors, in addition to the continuing habitat conversion, make it difficult to predict whether any viable populations will remain a few decades from now. Key factors that will determine the outcome of this are the effectiveness of law enforcement that is needed to reduce orangutan killings and increased awareness leading to cultural change regarding land management and the treatment of protected species. The value of the latter is obvious in areas such as the Kinabatangan region in Malaysian Sabah, where traditionally people do not hunt orangutans and where despite severe fragmentation and degradation of original habitats, high densities of orangutans remain.^{11,26} The situation in this part of Malaysia indicates that orangutans and people can potentially coexist and that orangutan populations can be sustained if large enough forest areas are connected to permit dispersal. This will, however, require significant changes in the attitude of politicians; land-use planners; large-land holders such as plantations, timber operations, and mining companies; and the millions of rural people that share ever-diminishing forest resources with the remaining orangutan populations.

Population viability analyses indicate that, in moderate quality habitats, orangutan populations starting at 500 individuals can maintain sufficient size and genetic diversity to persist for hundreds of years.⁴⁷ At least on Borneo, orangutan population densities rarely exceed two individuals/km²,³¹ meaning that at least 250 km² is required to provide a reasonable chance of long-term persistence. This assumes that no other factors such as hunting or disease cause unnatural deaths. There is more to this story though, as is becoming clear in Kinabatangan, where populations have shown slow but steady decreases that might be caused by unflanged males leaving their natal population to look for other

areas in which to settle. To facilitate this interpopulation dispersal, habitat connectivity between major orangutan populations should be maintained or reestablished whenever possible.

We expect that the future of orangutans will very much depend on the long-term security of large, strictly protected areas where illegal logging and hunting are effectively controlled and orangutan populations are large enough to cope with potential catastrophic events such as fires or disease outbreaks. In addition, these areas need to contain ecological gradients that allow orangutans and their key resource requirements to adapt to more gradual changes, such as those brought about by climate change. Ideally, the core-protected parts of the orangutan range should remain connected with other forest areas. These would not necessarily have to be totally protected, but could also be used for commercial extraction purposes, at least for the orangutan subspecies with the ecological resilience to survive in such used forests.⁴⁵ Such an ecological network of protected areas, interconnected via forested watersheds, could in turn be buffered by low-intensity plantations, such as those used for pulp and paper and possibly also large-scale oil palm. This would then border on the high intensity-use areas where most people live, where infrastructure such as roads is concentrated, and where small-scale agriculture and silviculture are concentrated. Such a landscape would have ample room for economic development while optimizing the use of ecosystem services such as prevention of soil erosion, regulation of hydrology, and storage of carbon.⁵⁷

The above idealized picture of ecologically connected networks remains very far removed from the present paradigm of rapid economic development through exploitation of natural resources and conversion of forest landscapes to nonforest ones without large-scale future land-use planning. The type of planning needed to retain or regain ecological connectivity on Borneo and Sumatra urgently requires that political decision makers recognize the value of such landscapes for the long-term socioeconomics of these lands. For this, environmental values (economic, ethical, and legal) need to be considered much more specifically in the land-use planning process. Island-wide planning frameworks need to be created that show different tradeoff scenarios between short-term economic gains from land

development and longer-term benefits from maintaining sustainably managed forest environments. Based on this, governments can make an informed choice on how they envisage the long-term development of Borneo and Sumatra.

The way forward in orangutan conservation

Despite five decades of conservation attention for the orangutan, there has been frustratingly little progress. Even though we do not know how many orangutans existed some 50 years ago, we do know that every year large areas of orangutan habitat are degraded or lost at a rate of some 4,000 km² per year in Borneo and Sumatra.²⁸ This suggests that unless deforestation and hunting trends improve significantly, most wild orangutans will perish by 2025 and some important populations such as those in Tripa, Sumatra could disappear as early as 2015/16.⁵⁷ Even in protected areas, forests are not safe from illegal logging,^{50,94,95} and we are a long way away from the goal of the Indonesian government to stabilize all wild orangutan populations in Indonesia by 2017.⁹⁶ The obvious conclusion is that, despite local progress and conservation success, the orangutan conservation movement has not done enough to turn the tide of the orangutan's fate.

This is not to say there has been no success. Many protected and relatively well managed areas would not exist or would have lost most their forest without the major lobbying and management efforts of people or groups highly committed to the orangutans survival: Kinabatangan, the Leuser Ecosystem, Gunung Palung, Tanjung Puting, and Sabangau are good examples. Other areas, such as the Wehea community forest and the FSC-certified Deramakot timber concession show that forests do not have to be legally protected for orangutans to have a safe home. We should learn from these successes and replicate them where possible. At the same time, we should not lose sight of the fact that for most wild orangutans living outside these relatively protected areas (comprising some 75% of the total population), the immediate future remains grim if over-exploitation of forests and conversion of natural forests to planted or nonforest continues. Minimizing losses among these populations requires a major strategic change in how orangutan conservation is done.

The two most important groups involved in conservation are the governments of Indonesia and Malaysia and a range of local and international NGOs. Governments are responsible for policy development, land-use planning, law enforcement, and conservation management in protected areas. It is obvious that, despite orangutans being fully protected, existing legislation and policy do not provide sufficient protection for them. Governments need to develop much more holistic policies that not only target economic progress, but also balance that progress with ecological and environmental sustainability. The Indonesian government has shown its commitment to this in its national orangutan action plan and its low carbon growth objectives,⁹⁷ but this general commitment needs to be translated into new land-use plans and new policies on land use that integrate protected area management with broader landscape-level management. Socio-ecological sustainability should become a general policy principle if orangutans outside protected areas are to survive. Governments also need to recognize the spatial heterogeneity of threats and design area-specific plans to reduce these threats. This links to the law enforcement and protected area management roles of the government, neither of which is up to standards at the moment. Governments need to seriously consider how they can improve their effectiveness in both these roles. Strengthening law enforcement needs to happen by ensuring that those that break the law are actually caught and prosecuted. This will require training of police, judges, and conservation authorities; effectively combating corruption in government offices; and also ensuring that the public understands why these laws are now taken seriously. The latter requires effective campaigns informing the public. This is needed because a recent study suggested that 27% of the people in Kalimantan did not know that orangutans are legally protected.⁴⁸ The Indonesian government has voiced the idea to privatize some of these functions, specifically aiming to outsource the management of national parks to the private sector.⁹⁸ How protected area management could be financially attractive to the private sector is unclear, however, and privatizing conservation management is unlikely to be a panacea.

Many NGOs are involved in orangutan conservation. These range from local activists groups that use public protests and graphic images of orangutan

suffering to engender public awareness and compassion to big global conservation organizations. What many of these organizations have in common is that they work by themselves on their own projects and rarely coordinate their activities with those of other groups. This lack of cooperation and absence of coherent joint planning is a significant weakness of the orangutan conservation community.⁹⁹ Attempts have been made to improve this, and the Indonesian orangutan conservation action plan of 2007 was a good example of different NGOs working together to effectively push for new legislation. This happens too rarely though, leaving much conservation action uncoordinated and not adding to an overall conservation framework. This is not to say that all conservation activities should be coordinated—great conservation gains have been made by people or organizations working on their own. The key, however, is to collaborate and team up with others when broader issues are at stake, such as the development of new legislation or the implementation of country-level management plans for orangutans, which requires coherent and generally supported lobbying effort to influence government.

Companies play an increasingly important role in orangutan conservation. Many of them have a number of key characteristics that would permit them to effectively address conservation goals, attributes, which are not always present in governmental and NGOs. Companies generally have well-trained staff and strong operational procedures for their management—slotting in orangutan-specific management should be relatively easy. Companies also tend to have significant financial resources at their disposal. The key question to them is whether the cost of investing in good environmental and species management is offset by the benefits. Those benefits can be a direct financial one (e.g., when markets pay premium prices for products from well-managed companies), but more often they are associated with having a green image, which in today's world can be a significant indirect financial benefit for companies. With most of the land outside the protected areas being managed by companies, there are obvious needs to involve this sector more in orangutan habitat management. Whether or not such companies are interested will depend greatly on regulatory requirements, the companies' sensitivity to public opinion, and the potential financial gains.

The most important and least engaged sector are the estimated 36.5 million people in Borneo and northern Sumatra that live alongside the approximately 60,000 orangutans (i.e., 605 people per orangutan). The day-to-day needs of these people and their aspirations in life play a hugely important role in what will happen to remaining orangutan habitats. The extent to which these people are willing to live next to orangutans might be the deciding factor for the great ape's future outside protected areas.^{24,81,82} Encouraging these people to support the principles of environmental conservation and sustainable development and be actively responsible for the management of their resources is therefore a crucial requirement for successful orangutan conservation.⁵⁴ Conservation groups need to think really hard about how this issue can be more effectively addressed. It would likely include the continuation of various small-scale education programs, but it would also require broader, regional, or national level campaigns with messages that do not just call for the protection of orangutans but challenge people to think of conservation in the context of their own lives. Linking conservation to other aspects of people's lives such as more efficient agricultural methods or health programs¹⁰⁰ might be more effective than simply telling people that they cannot harm orangutans. After all, people are sometimes confused. Why does the West pay so much attention to the protection of orangutans (i.e., "people of the forest" in the Malay language), while local communities consider themselves to be the people of the forest?⁵¹ Conservation needs to make sure that double standards and different viewpoints about conservation are clarified and addressed where possible.⁵⁸

Finally, who is going to pay for conservation? Orangutan conservation costs money. At least as long as markets are not paying for environmental services provided by forests, exploiting these forests or replacing them with more productive uses is always going to generate more revenue than conserving them. Some of these opportunity costs can be offset by legislation or ethics—we are legally obliged to protect these forests, or we feel it is the right thing to do—but in most situations the protection or sustainable management of orangutan habitats will have to be paid for. Carbon markets may provide some of these financial means required for this,^{57,101} while other sources of income could be from tourism, payments for water, and other

forest-related economic activities. Companies could also fund a significant part of the total financial requirements by implementing orangutan-friendly management on their land. Ultimately, however, the main responsibility for orangutan conservation lies with the Indonesian and Malaysian governments, which need to develop the financial and economic tools that allow their countries to continue economic development, but not at the expense of the few remaining orangutan habitats.

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Conflicts of interest

The authors declare no conflicts of interest.

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