# Effectiveness, risk, and impacts of orangutan conservation interventions

Julie Sherman

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**List of abbreviations**

BKSDA: *Balai Konservasi Sumber Daya Alam* (Indonesian Natural Resource Conservation Agency)

CITES: Convention on the International Trade in Endangered Species of Wild Fauna and Flora

FORINA: Forum Orang-utan Indonesia

FSC: Forest Stewardship Council

GRASP: United Nations Environment Programme – Great Apes Survival Partnership

HD: *Hutan desa* (village forest)

IUCN: International Union for the Conservation of Nature

MEF (see also MoEF): Ministry of Environment and Forestry

MoEF: Ministry of Environment and Forestry

NGO: Nongovernmental organisation

NP: National Park

OU: Orangutan

PA : Protected area

PHVA: Population and Habitat Viability Analysis

PVA: Population Viability Analysis

RSPO: Roundtable for Sustainable Palm Oil

**Abstract**

Conservation interventions conducted without evaluating empirical evidence o their impacts on target species and habitats can lead to conservation funding being directed to ineffective or counterproductive measures. My research filled an important gap by assessing the conservation effectiveness of interventions to protect Critically Endangered Bornean orangutans (*Pongo pygmaeus*), Sumatran orangutans (*Pongo abelii*), and Tapanuli orangutans (*Pongo tapanuliensis*) in Indonesia. All three species are critically endangered at risk due to habitat conversion and fragmentation, killing, and trade, but few of the interventions that aim to conserve them have been evaluated. I built novel datasets from primarily public data sources to examine the relative prevalence and costs of orangutan conservation interventions, whether they were monitored, and their impacts on individual orangutans and orangutan populations. I first assessed orangutan conservation action plans implemented in 2007 – 2017. Although orangutans and forests in Indonesia declined during this period, the study provided valuable information on what interventions were attempted. I then evaluated the outcome of one of the most widely applied interventions, orangutan "rescue"—seizure or surrender of illegally held orangutans and capture of wild orangutans perceived to be at risk—and the orangutans' subsequent release (translocation) into natural habitats. Although rescues are thought to aid law enforcement efforts, rescue of 1517 orangutans between 2007 and 2017 suggested high poaching rates and a flourishing local pet trade in spite of rescue efforts. I also assessed disease and conservation risks of orangutan translocations and identified pathogen transmission pathways to wild orangutan populations and for zoonotic diseases. Risks were highest for wild orangutans captured and removed from insecure situations and released elsewhere (wild-to-wild translocation), which had few biosafety controls and high risks for negative conservation outcomes. I analysed killing, capture, and trade affecting Indonesian orangutans from 2007 - 2019 and found records of 2229 reported crimes, only 22 (0.9%) of which ended in court cases. Most orangutan trade crimes (an average of 98% of the crimes for all species) involved local, not international, trade. At expected detection rates, killing rates exceeded the 1-2 % orangutan hunting mortality threshold expected to drive populations to extinction, showing that killing remains a serious threat to orangutans. Finally, we conducted a counterfactual analysis of the orangutan protection and cost effectiveness of conservation interventions from 2000 - 2019. We found habitat protection and anti-poaching patrols were the most effective activities overall, while rescue and translocation had little effect on species populations. My research elucidated the relative

effectiveness of key orangutan conservation interventions, enabling informed decision making and prioritisation of conservation activities. My studies provide replicable approaches for evaluating species conservation impacts in situations with limited or no systematically collected monitoring data.

## Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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## Author contributions

| **Publication Title** (Chapter) | **Author role** | **Author contribution description** | **Author contribution percentage** |
|---|---|---|---|
| Envisioning a future for Bornean orangutans: Conservation impacts of action plan implementation and recommendations for improved population outcomes (Chapter 2) | Lead | Conceptualized article based on research conducted with coauthors. Acquired and analysed data. Drafted/edited the article. Obtained/managed grant funding. | 80% |
| Shifting apes: Conservation and welfare outcomes of Bornean orangutan rescue and release in Kalimantan, Indonesia (Chapter 3) | Lead | Conceptualized article with input from coauthors. Acquired 95% of the data presented. Conducted all data analyses. Drafted/edited the article. Obtained/managed grant funding. | 80% |
| Disease risk and conservation implications of orangutan translocations (Chapter 4) | Lead | Conceptualized article with input from coauthors. Acquired data and conducted all analyses. Drafted/edited the article. Obtained/managed grant funding. | 70% |
| Orangutan killing and trade in Indonesia: Wildlife crime, enforcement, and deterrence patterns (Chapter 5) | Lead | Conceptualized article with input from coauthors. Acquired and analysed data with coauthor input. Dr Voigt visualized crime data and created map figures. Drafted/edited the article. Obtained/managed grant funding. | 70% |
| Effectiveness of 20 years of conservation investments in protecting orangutans (Chapter 6) | Coauthor | Contributed substantially to conceptualization. Acquired 60% of the financial data, 30% other data. Dr Santika led design and data analyses and drafted with Prof. Meijaard. Contributed to data analysis. Drafted article sections, developed 3 figures, contributed to editing. Obtained and managed the grant funding. | 30% |

# Chapter 1. General Introduction

## 1.1 Great apes in crisis

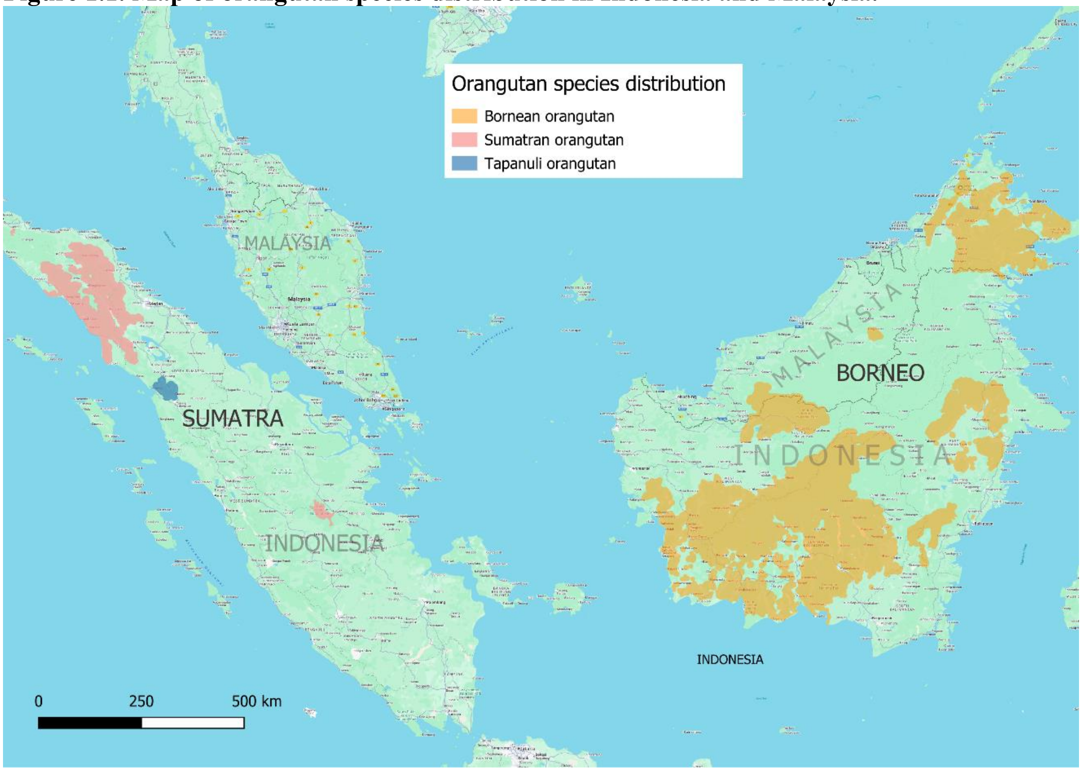
The great apes—gorillas, chimpanzees, bonobos, and orangutans—have long been considered to have unique importance to humanity because they are our closest relatives in the animal kingdom (e.g., Cagan et al., 2016; Rosenbaum & Kuzawa, 2023; Wrangham, 1987). Great apes also play a key role in maintaining biodiversity and ecosystem services through seed dispersal (e.g. Aguado et al., 2022; Blackburn et al., 2021) and as flagship, umbrella species that can draw attention and funding, and drive establishment of protected areas, forest restoration, or improved habitat management practices (Inogwabini, 2020; Marshall et al., 2016; Morgan et al., 2023; Reuter et al., 2022; Supriatna & Ario, 2015). Despite their special status and important role in biodiversity conservation, and decades of legal protection, all great ape taxa are listed as Endangered or Critically Endangered on the International Union for Conservation of Nature (IUCN) Red List of Species, and are at risk of extinction if not protected from habitat loss, hunting and transmission of human diseases (Ancrenaz et al., 2024; Fruth et al., 2016; Humle et al., 2016; Maisels et al., 2018; Nowak et al., 2024; Plumptre et al., 2019; Singleton et al., 2024). Although there is extensive literature on great apes and widespread understanding of their conservation plight (e.g. Estrada et al., 2017; Gillespie & Leendertz, 2020; Junker et al., 2024; Mitani et al., 2024), there is limited empirical evidence and analysis of the conservation activities aiming to address the threats and underlying factors that drive their decline (Junker et al., 2019; Junker et al., 2020). Understanding which interventions can be effective and under what circumstances, based on empirical evidence and robust analysis, is crucial to halting great ape population declines and securing a future for our closest wild relatives and the ecosystems they inhabit. This thesis presents analyses of available evidence on outcomes of key interventions to protect wild orangutans and considers the conservation impact and cost effectiveness of actions for stabilizing wild populations. My research aims to strengthen orangutan conservation and advance uptake of demonstrably effective actions by improving knowledge of intervention impacts and efficacy.

## 1.2 The case of the red ape

The only living great ape native to Asia, the three species of famously red-haired orangutans are no exception to the pattern of great apes at risk of extinction due to hunting and habitat loss in spite of laws intended to secure their survival. Orangutans live only in the provinces of Aceh and North Sumatra on the island of Sumatra, Indonesia, and in the

Indonesian region of Kalimantan and the Malaysian states of Sabah and Sarawak on the island of Borneo (Figure 1.1). They have been legally protected in Indonesia since 1924 (Rijksen & Meijaard, 1999) and in Malaysia since 1959 (Pandong et al., 2019), but their populations have declined precipitously, and all species are now classified as Critically Endangered by the IUCN Red List of Species (Red List) (Ancrenaz et al., 2024; Nowak et al., 2024; Singleton et al., 2024).

**Figure 1.1. Map of orangutan species distribution in Indonesia and Malaysia.**




The large numbers of orangutans that fell prey to hunting or capture for zoos, circuses, pets, and biomedical research, coupled with destruction or degradation of their habitats for timber and agriculture, and a paucity of data on their distribution range and abundance in the wild, first caused the IUCN to list orangutans as Endangered on the Red List in 1965, and for some zoo associations to prohibit members from buying illegally caught orangutans (Ancrenaz et al., 2024; Borner, 1976; Rijksen & Meijaard, 1999). At this time, the IUCN Red List status covered all orangutans, then considered a single species (*Pongo pygmaeus*) with two subspecies the Bornean orangutan (*Pongo pygmaeus pygmaeus*) on the island of Borneo, and a single subspecies, the Sumatran orangutan (*Pongo pygmaeus abelii*), on the island of Sumatra (Delgado Jr & Van Schaik, 2000; Goossens et al., 2009). *P. p. abelii* and *P. p. pygmaeus* were recognized as separate species in 1999, with the latter having three subspecies (*P. p. pygmaeus, P. p. wurmbii*), and *P. p. morio*) (Groves, 1999).

Tapanuli orangutans, (*P. p. tapanuliensis*), a distinct population of orangutans in North Sumatra province of Sumatra, were recognized as a species in 2017 (Nater et al., 2017).

Orangutans inhabit a range of tropical forest biomes: peat swamp forest, inundated (freshwater) forest, alluvial forest, montane forest, and lowland dipterocarp forest (Galdikas, 1988; Rijksen & Meijaard, 1999; Wich et al., 2009). They are found in areas with a mix of these forest types, and in mosaic landscapes of forest and other vegetative communities, and have also been recorded in agricultural areas, exotic tree plantations, and grasslands (Galdikas, 1988; Kuswanda et al., 2021b; Rijksen & Meijaard, 1999; Wich et al., 2009). Extensive forest clearing in Borneo and Sumatra for logging, agricultural and tree plantations, and human settlements, accompanied by drought and severe forest fires, reduced Borneo's natural forest extent by 39% between 1973 and 2010 (Gaveau et al., 2014), and Sumatra's forest cover by nearly 50% (Wich et al., 2008; Wich et al., 2011a). Deforestation and the market for live orangutans and orangutan skulls as trophies, as well as increasing interactions between humans and orangutans facilitated illegal orangutan killing and trade (Meijaard et al., 2011a; Rijksen & Meijaard, 1999). These factors drove steep declines in the orangutan population and distribution range, culminating in Bornean orangutans being uplisted from Endangered to Critically Endangered on the Red List in 2016 due to an estimated population decline of more than 80% over three generations (Ancrenaz et al., 2024), and both Sumatran and Tapanuli orangutans being assessed as Critically Endangered in 2017 based on observed losses and predicted population declines of more than 80% over three generations (Nowak et al., 2024; Singleton et al., 2024).

### 1.2.1 The local conservation context

Direct, or proximate, threats to orangutans and their habitats are the human actions or natural processes that directly affect population size, namely removal of individuals from the population (offtake) by capture, hunting or direct killing for any reason, destruction, fragmentation and modification of their habitats, and climate changes that reduce the amount of suitable habitat (Gregory et al., 2012; Struebig et al., 2015). These proximate threats can in turn be driven by a myriad of contributing factors that affect orangutan offtake, birth rates, health, and habitats. Examples of contributing factors include socioeconomic pressures, the presence and enforcement of laws protecting the species and natural forests, and the perceptions and behaviours of people who interact with orangutans and their habitats.

#### 1.2.1.1 Proximate threats

*Habitat loss and fragmentation*

The lowland forests that are prime habitat for orangutans are also the most in demand for development for human habitation, infrastructure and industry (Rijksen & Meijaard, 1999). Consequently, the expansion of agriculture, tree plantations, mining and other resource extraction, hydropower projects, buildings, roads and other infrastructure within orangutans' geographic range drives deforestation and shrinks the extent of orangutan distribution (Meijaard et al., 2021; Rijksen & Meijaard, 1999; Voigt et al., 2018). In the process, orangutans are killed when forests are destroyed or are rendered accessible to poachers and traders, and may starve or suffer malnutrition and lower birthrates if they can no longer access sufficient food or find mating opportunities (Wich et al., 2019). Development also enables increased human access to orangutan habitat, which leads to accelerated human interactions and conflict with orangutans, which can in turn facilitate killing, capture and trade (Jong & Simangunsong, 2023; Laurance et al., 2020; Stack, 2019; Sulistiyono & Zahirah, 2024). Habitat loss and fragmentation can also interrupt gene flow among the fragmented orangutan population in the area (Ancrenaz et al., 2021b; Seaman et al., 2024; Seaman et al., 2021). Forest clearing and fragmentation, and the agricultural, logging, and mining activities that replace previously forested areas, can have a number of secondary impacts that may affect orangutans, including changes in soil function, increased water pollution, diminished access to water, and increased risk of zoonotic diseases (Comte et al., 2012; Mapulanga & Naito, 2019; Morand & Lajaunie, 2021; Veldkamp et al., 2020).

*Killing and capture*

Orangutans are killed to obtain meat, body parts for trophies, and infants for the pet trade (Davis et al., 2013). The frequency of orangutan killing varies by religion and ethnicity, and is influenced by people's purpose in entering forests where orangutans reside and if they perceive orangutans as a pest impacting their crops or a risk to their safety (Davis et al., 2013; Meijaard et al., 2011a). Nonetheless, orangutan killing occurs across the species' geographic ranges regardless of religious and cultural variations (Massingham et al., 2023a; Meijaard et al., 2011a, Chapter 5). Orangutans are generally killed opportunistically and are not the primary target for hunters seeking meat, although consumption was the primary reason for killing per analyses conducted in 2008-2009 (Meijaard et al., 2011a). They are also killed by indiscriminate hunting methods such as snaring (Chapter 5). Orangutans are targeted and killed in retaliation for real, assumed, or potential crop foraging and interactions with humans, because people are afraid of them, and when they are found in places they are not wanted such as farms and plantations (Massingham et al., 2023a; Meijaard et al., 2011a). In areas where orangutans are present, they are often assumed to be responsible for crop damage or consumption by wildlife, however, many species present in the orangutans' geographic range are also known to crop forage or damage human property, including long-tailed macaques, pig-tailed macaques, Thomas's leaf monkey, elephants, and wild boars (Berliani et al., 2018; Campbell-Smith et al., 2010; Linkie et al., 2007; Marchal & Hill, 2009; Utami et al., 2016). Although orangutans generally avoid humans, the perception that they are a danger to humans appears common in communities that live alongside them (see: Runtu et al., 2024; Schreer, 2023).

Orangutan killing, capture and trade are linked: obtaining infant orangutans for display or the pet trade nearly always requires killing of the mother orangutan, and may also involve additional deaths to secure a live, saleable infant (Harrisson, 1961). Orangutan development patterns make it relatively easy to capture any dependent infants when adult female orangutans are captured or killed. Infant orangutans are dependent on their mothers for a remarkably long time—their weaning period of 6 to 9 years is the longest of any primate species (Schuppli et al., 2016a; Wich et al., 2004). This intensive maternal investment leads to high natural survival rates (van Noordwijk et al., 2018), but also is exploited for capture of orangutan infants. There is a strong bond between mother orangutans and their infants that last until they are fully independent at nine to 11 years old (van Noordwijk, 2009). For their first three months, infants are in nearly constant body contact with their mother, and until two years old cannot travel between trees on their own and thus spend most of their time in body contact with their mother, or within sight and hearing distance of a few meters (Mendonça et al., 2017; van Noordwijk, 2009; van Noordwijk & van Schaik, 2005). Young orangutans between four and eight years old will gradually decrease their time in body contact with their mother and will feed without body contact but generally stay only a few meters from their mothers while using the same food source and tree until they are eight or 10 years old (Mendonça et al., 2017; van Noordwijk, 2009).

Wild infant orangutans have been kept as pets since at least the 1800s (Rijksen & Meijaard, 1999). In Sabah and Sarawak, Malaysia, enforcement of legal protections appears to have dramatically diminished the trade in Malaysia (Pandong et al., 2019, Chapter 2), but they remain locally popular as pets in Indonesia (see Chapters 3 and 5). Poaching and trade of orangutans for display in zoos, circuses, and as pets was identified as a serious issue for their conservation in the 1960s (Harrisson, 1961; Nijman, 2017; Rijksen & Meijaard, 1999; Russon, 2009). A flourishing illegal local pet trade, and a much more limited illicit international trade of live orangutans for display or pets, and demand for orangutan body parts as trophies continues to drain wild populations (Beastall et al., 2016; Nijman, 2017).

Wild orangutans are also captured with the aim of relocating them (wild-to-wild translocation) when they are crop foraging, are considered at risk from habitat clearing, forest fires, or conflict with humans, and when they are thought to be in "inappropriate" areas – namely outside protected forests or around crops or other areas of human activity (Chapter 3; Appendix I). Removal of these wild individuals from their social network and metapopulation—the dispersed orangutan population in the geographic area—not only decreases local population numbers, but also reduces its number of active or potential breeding individuals (Ancrenaz et al., 2021b; Seaman et al., 2024). Even if immediately released in another forest area, translocated individuals may be unlikely to survive in the long term and may pose risks to the welfare and survival of the wild population they are released into (Chapters 3 and 4; Appendix I).

*Forest fires*

The tropical forest biomes inhabited by orangutans are not fire-adapted. In their natural state, alluvial, inundated, and peat swamp forests are very moist environments, with areas of standing or flowing water, and rarely experience fire (Miettinen et al., 2017). Decades of forest clearing and draining of peat swamps and inundated forests have dried soils and flora, increased runoff, and caused droughts (Alisjahbana & Busch, 2017; Rijksen & Meijaard, 1999). Fires set to clear forests for agriculture, to create access for hunting, and as a weapon in land tenure or land use disputes (Dennis et al., 2005) have resulted in periodic severe forest fires during the dry seasons (Alisjahbana & Busch, 2017; Miettinen et al., 2017). These fires have dramatically reduced available orangutan habitat, particularly in Indonesia (Harrison et al., 2016; Rijksen & Meijaard, 1999; Thoha et al., 2024). Fires can kill orangutans that cannot escape the burning, and destroy the available orangutan foods within forest habitats, leading to nutritional stress or deficiencies, and increases in agonistic encounters between unrelated orangutans over limited food resources (Ashbury et al., 2022; Harrison et al., 2016). Smoke inhalation can also harm, weaken or kill orangutans (Erb et al., 2018; Harrison et al., 2016).

*Climate change*

The orangutan range is limited by fruit availability, temperature and rainfall, and elevation (Marshall et al., 2021; Wich et al., 2016; Wich et al., 2014), major roads, and large rivers (Nietlisbach et al., 2012; Seaman et al., 2024). They are primarily found below 500 meters asl but can occupy areas as high as 1,500 meters asl, albeit at lower densities (Ancrenaz et al., 2024; Singleton et al., 2004; Wich et al., 2016). Orangutan populations are denser in lowland peat swamp forests, mosaics of multiple forest types, and in Sumatra where fruit availability is likely higher (Husson et al., 2009; Marshall et al., 2021; Wich et al., 2011b). They have large home ranges—up to 2500 hectares for Sumatran males (Singleton, 2000)—and travel to find sufficient nutrition, with movements particularly driven by access to diverse fruit species and to synchronous mass fruiting events (masting) that occur every few to every several years (Knott, 1998; Marshall et al., 2021). Orangutans also seek out preferred fruits which tend to be uncommon taxa with rare large fruit crops (Marshall et al. 2021). These nutritional needs, the climatic and elevation limits of the orangutan range, and the species' diverse diets mean climate change likely poses a serious threat to their survival (Gregory et al., 2012; Struebig et al., 2015). If temperatures exceed the survival limit for food taxa that fulfil important nutritional needs, or for orangutans themselves, they may not be able to survive by moving to higher and cooler climes.

#### 1.2.1.2 Contributing factors

*Law enforcement and corruption*

Legal protections for orangutans and their habitats can only be successful if there is adequate enforcement or other means of deterring prohibited actions. Researchers have been sounding the alarm on failure of enforcement for orangutan protections since the 1960s (Harrisson, 1961), particularly in Indonesia (Nijman, 2005, 2009, 2017; Rijksen & Meijaard, 1999). Similarly, the effectiveness and enforcement of a moratorium on clearing of primary forests in Indonesia has been questioned by conservation NGOs and researchers (Alisjahbana & Busch, 2017; Jong, 2021; The Tree Map, 2023; Wijaya et al., 2019). Corruption—any effort to gain benefit from or avoid detection and sanction for illegal acts—is seen as a predominant cause of the poor law enforcement and lack of deterrence of illegal actions affecting Indonesian orangutans and wildlife globally (see: Nijman et al., 2024; Wyatt et al., 2018; Chapter 5).

*Planning and land management*

Spatial planning (zoning of land uses into demarcated areas), and land rights allocation impact the persistence of tropical forest cover and management of land within the orangutan range. Designation of large areas of primary and secondary forest for oil palm plantations and other agriculture, selective logging or tree plantations, mining, and other development has led to a dramatic diminution of suitable orangutan habitat across the species distributions (Abram et al., 2015; Rijksen & Meijaard, 1999; Santika et al., 2017a; Voigt et al., 2018; Wich et al., 2016). Although 61% of orangutan habitat in Sabah, Malaysia is now fully protected, in Indonesia only 17% of the orangutan range is strictly protected while 83% is zoned primarily for other purposes (Meijaard et al., 2022), wherein potential habitat degradation or clearing may be legal. Spatial planning that furthers human access to orangutan habitats can also lead to increased interactions and conflict between humans and orangutans.

Global demand for palm oil, timber, pulp and paper products is growing, and thus it is expected that the amount of land dedicated to their production will expand, likely resulting in further deforestation of orangutan habitats (Meijaard et al., 2023; Voigt et al., 2022). Orangutan populations can persist in forests and forest patches within palm oil plantations and selective logging concessions if these are managed to prevent illegal logging and orangutans are effectively protected from killing and allowed freedom of movement to access sufficient food resources (Ancrenaz et al., 2010; Meijaard et al., 2020). However, orangutans in concessions are often not afforded these protections. The majority of the nearly 10,000 estimated orangutans that reside in palm oil concession in Kalimantan—about 12% of the approximately 83,000 orangutans estimated in Kalimantan as of 2019 (per Voigt et al., 2018; Chapter 5)—are in plantations that have not attained international sustainability certification (Meijaard et al., 2017). A further issue is that oil palms need to be replanted after 25 years to maintain productivity. The process of clearing the mature oil palms that orangutans are using for nesting and possibly food for replanting would put those individuals at immediate risk. Clearing and replanting  across vast areas of agricultural mosaic landscapes would have negative effects on local orangutans unless forested corridors enable their movement, and replacement of the mature oil palms is carefully managed to prevent harm or disruption to resident orangutans (Ashton-Butt et al., 2019).

### *Poverty*

The geographic range of orangutans overlaps with significant human populations largely in rural areas where there are fewer job opportunities and poverty is a significant concern, particularly in Indonesia (Miranti et al., 2013). Nearly 26 million people in Indonesia, or 9.36% of the population, live below the poverty line as of 2023, and more than 9.9 million (3.6%) suffer from multidimensional poverty, meaning they are deprived of multiple resources and services necessary for well-being (UNDP, 2023). In Malaysia, 8.4% of the population (nearly 3 million people) lived below the national poverty line in 2020, and 0.1% suffered from multidimensional poverty in 2019 (World Bank, 2023). Interventions to address livelihoods and wellbeing in Indonesia have been heavily focused on development of industries that boost production, notably expansion of palm oil plantations and processing facilities, and creation of a vastly expanded domestic food production capacity. The national food security programme allows conversion of some protected forests to agriculture, including in areas within orangutan range (Loasana, 2020). Unsurprisingly, forest conversion for industry and food production are often carried out at the expense of orangutan habitats and populations (Santika et al., 2017a; Voigt et al., 2018) and have had equivocal effects on poverty reduction and wellbeing to boot (Santika et al., 2019c). Another Indonesian government programme to alleviate poverty is focused on granting community forest management rights, or *hutan desa* (village forests) to improve biodiversity conservation and human wellbeing outcomes (Santika et al., 2019b).

### *Human-orangutan interaction and conflict*

Agriculture, tree plantations, mining, and other development within the orangutan range displace orangutans from forest habitats and reduce their access to native foods, while simultaneously facilitating increased human access to formerly remote orangutan habitats (e.g., Laurance et al., 2020). This leads to more interactions between humans and orangutans, and results in conflicts with orangutans that are crop foraging or encountered near humans or human properties (Kuswanda et al., 2021b; Runtu et al., 2024). Orangutans in these settings are sometimes killed for food, trophies, to obtain infants as pets, in retaliation for crop foraging, or out of fear for human safety (Davis et al., 2013; Meijaard et al., 2011a, Chapter 5).

*Perceptions of orangutans*

How orangutans are perceived by people who live and work near them directly influences orangutan killing and human-orangutan interactions. Cultural and religious differences across the orangutan range have a strong influence on orangutan killing. Some cultures traditionally do not hunt or eat orangutans while others do not have this restriction (Davis et al., 2013). Local community culture and experiences affect reactions to orangutan crop foraging, presence near humans, and sightings of orangutans when using forests or agricultural area (Chua et al., 2020). While some communities have developed strategies to coexist peacefully with orangutans (Ancrenaz et al., 2021b), in other areas orangutans are viewed as a crop pest and economic burden or a source of fear, and in some villages, funds and effort spent on orangutan protection contrasted with lack of similar support for human communities is a source of resentment (Chua et al., 2021; Kuswanda et al., 2021a; Maskulino et al., 2021; Schreer, 2023).

*Incorporating modern understanding of orangutan ecology into conservation practice*

Long-term field studies in Borneo and Sumatra beginning in the 1970s (Delgado Jr & Van Schaik, 2000; Galdikas, 1978; Mackinnon, 1974; Rijksen & Meijaard, 1999) and 1980s (Knott, 1998), and continuing today, have dramatically improved understanding about orangutan ecology and behaviour (e.g., Ancrenaz et al., 2014). Knowledge of orangutans' home range size, terrestrial behaviours, and their ability to use disturbed habitats and survive periods of low fruit availability is critical to effective species conservation planning and management of orangutan habitats (Meijaard et al., 2022; Meijaard et al., 2012).

Although it was long believed that orangutans inhabited only primary tropical forests, studies have since shown that orangutans use selectively logged forests, palm oil and tree plantations as well as numerous other agricultural lands, and can survive within small forest patches in landscapes with mixed forests and agriculture or other development if they are not disturbed and killed (Ancrenaz et al., 2015; Ancrenaz et al., 2021b; Meijaard et al., 2016; Seaman et al., 2021). Once thought to be almost entirely arboreal, orangutans are now known to spend time on the ground to access food and water, avoid conspecifics, and to travel (Ancrenaz et al., 2014; Ashbury, 2020; Spehar et al., 2018). Bornean orangutans are observed on the ground much more frequently than Sumatran and Tapanuli orangutans, for reasons which are still being explored, but which may relate to the absence of tigers in Borneo and their presence across the orangutan range in Sumatra (Ashbury et al., 2021).

Although able to make use of a variety of human-modified habitats, orangutans require access to natural forests. Orangutans are largely frugivorous but also eat seeds, flowers, leaves, plant pith and bark, lianas and epiphytes, and insects (Knott, 1998; Mackinnon, 1974), and even small mammals (Hardus et al., 2012), and may choose non-fruit foods even when fruits are available, possibly to meet their individual nutritional needs (DiGiorgio et al., 2023). During low fruit periods, orangutans will consume primarily flowers or bark, leaves and insects, depending on seasonal availability (Knott, 1998). Orangutans consume a great variety of taxa, numbering at least 1693 recorded taxa of fruit and insects on Borneo (Russon et al., 2009b). They rely on masting events and fruiting seasons to gain weight, largely through heavy fruit and seed consumption, that enables them to survive leaner times when fruit is scare or unavailable and their bodies catabolize muscle to meet energetic needs (Knott, 1998; Marshall et al., 2021; O'Connell et al., 2021). Hence, orangutans' use of the habitats within their range varies over seasons and years as food availability changes (Marshall et al., 2021).

Orangutan males disperse away from their mothers and establish new ranges or travel to seek food or find females, while females are strongly philopatric and tend to settle permanently in areas near where they were raised (Arora et al., 2012; Nietlisbach et al., 2012). Although orangutans were long considered largely solitary, with both adult males and females being generally intolerant of each other, females do maintain long-term associations with their female relatives, and even unrelated individuals will feed in proximity during masting events (Knott et al., 2008; Knott, 1998; Spillmann et al., 2016; van Noordwijk et al., 2012).

Taken together, these aspects of orangutan behaviour and ecology suggest that they are best left undisturbed and allowed to move through landscapes to find food and mates and avoid conspecifics, and that protecting remaining natural forests and connections among forest patches and preventing killing and capture of wild individuals are the highest priorities. Our research showed that funding and interventions for conservation of wild orangutans have in many cases not embraced this modern understanding of orangutan ecology and instead focus on lower priority, less effective actions such as the capture and translocation of wild orangutans (Chapters 3 and 6; Appendix I).

## 1.3 Evidence for effectiveness of orangutan conservation interventions

Conservation of remaining biodiversity and natural ecosystems is an urgent need in the modern age (IPBES, 2019; WWF, 2020). Monitoring and evaluating empirical evidence on the impacts of conservation actions is vital to understanding whether they positively impact species and landscapes (Ferraro, 2009; Ferraro & Pattanayak, 2006). In contrast to fields like medicine with globally recognized standards for evidence and quantitative indicators of success, reliance on evidence for decision-making in conservation is both relatively new, and not widely applied (Cook et al., 2010; Salafsky et al., 2019). Many conservation interventions are performed for years or even decades without monitoring or evaluating their effectiveness (Ferraro & Pattanayak, 2006; Sutherland, 2022; Sutherland et al., 2004). This has led to an "Evidence Crisis," (Sutherland, 2022), where conservation management decisions are based on opinions, experiences, and emotions rather than evidence, even in cases where empirical evidence is available. This can have serious consequences for imperilled ecosystems and species when it leads to limited conservation funding being directed to ineffective, inadequate, or even counterproductive measures. Over the past few decades there has been a growing call for evidence-based conservation (EBC) and evaluation of conservation impacts (Christie et al., 2020; Cook et al., 2010; Ferraro & Pattanayak, 2006; Salafsky et al., 2019).

Interventions intended to conserve great apes are among the conservation interventions often implemented without monitoring and evaluating empirical evidence (Cox et al., 2020; Junker et al., 2020; Wicander & Coad, 2018). My research sought to address this gap for Critically Endangered Bornean orangutans (*Pongo pygmaeus*), Sumatran orangutans (*Pongo abelii*), and Tapanuli orangutans (*Pongo tapanuliensis*) in Indonesia. Protecting these species requires prioritizing effective interventions that have a strong likelihood of positive outcomes with low risks.

### 1.3.1 The orangutan evidence crisis

In Indonesia, the predominant activities for orangutan conservation appeared to be education about orangutans and translocation-focused activities, namely rehabilitating and reintroducing illegally held orangutans and capturing wild orangutans in purportedly unsuitable areas and translocating them into other habitats (Chapters 2 and 3). Orangutan rehabilitation, translocation, and awareness raising have been conducted in Indonesia for several decades, typically without monitoring and evaluation of their conservation outcomes, despite a lack of empirical evidence of positive impacts on wild populations. Little published information was available on the conservation effectiveness of interventions to protect orangutans in Indonesia when my research project began in 2016. A single published update on progress against indicators in Indonesia's 2007-2017 national action plan for orangutan conservation was available for the period of 2013 to 2015 (FORINA, 2014), along with one regional update for the years 2011 to 2013 (FORINA, 2013b). Neither update included evaluation of impacts, instead focusing on the implementation of activities. An analysis in 2014 modelled projected Indonesian orangutan population changes under two approaches—either rehabilitating, reintroducing, and protecting displaced or confiscated orangutans, or instead improving protection of forests within the orangutan range—concluding that over the long-term, forest protection activities were significantly more cost effective (Wilson et al., 2014). I collected spatially specific information on funds spent and actions implemented to protect orangutans and their habitats, and, where available, published analyses of their outcomes and impacts, as is outlined below.

### 1.3.2 Orangutan conservation interventions

There is published evidence on the status of specific orangutan populations and species population trends, as well as on trends in tropical forest cover and deforestation, which is discussed in more detail in following subsections. However, few studies have assessed the outcomes of the individual interventions implemented or the effects of multiple interventions that are often implemented concurrently or consecutively within the same area (Chapter 6). Morgans et al. (2019) introduced a cost-allocation tool to guide decision-making on the cost-benefit of various orangutan conservation strategies, but, due to the paucity of published data, the tool relied on financial data and self-reported outcomes from three orangutan rehabilitation organizations. Morgans et al. (2019) and other researchers identified orangutan rescue, rehabilitation, translocation, and protection from illegal trade and killing as key interventions and challenges for effective orangutan conservation (Nijman, 2017; Rijksen & Meijaard, 1999; Wilson et al., 2014). My research built on this work and expanded the evidence base for orangutan conservation intervention effectiveness. I identified and collated available information on implemented activities and when and where they occurred and conducted in-depth analyses of the outcomes and impacts of orangutan rescue and translocation and efforts to address orangutan killing and trade. With my research collaborators, I assessed the spatially specific conservation outcomes and cost-effectiveness of orangutan conservation actions across their geographic range compared to a counterfactual of no action (Chapter 6). In the following subsections I outline the array of activities implemented to protect orangutans and conserve natural forests and highlight published analyses of their effectiveness.

*Legal framework*

Orangutans have been protected under Appendix I of the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) since 1978 (CITES, 1976, 1979), which bans international commercial trade, and requires that any non-commercial trade must "not be detrimental to the survival of the species" (CITES, 1973). Both Indonesia and Malaysia have national legislation that prevents trade in contravention of the CITES convention.

Indonesia Act Number 5 of 1990 prohibits capture, injury, killing, transport, trade, and possession of orangutans (Republic of Indonesia, 2024). Act Number 5 of 1990 has recently been amended via Law Number 32 of 2024, with changes increasing the maximum penalty for wildlife trafficking to 5 billion rupiah ($421,300) from a maximum of 100 million rupiah previously, while jail time has increased from 5 years up to 15 years. The maximum penalty for corporations and corporate traffickers is 50 billion rupiah and jail time of up to 20 years (Republic of Indonesia, 2024). Indonesian Law 45 of 2004 concerns forest protection and establishes a permitting system for extractive forest activities, and, together with Law 19 of 2004, prohibits the burning forests in many, but not all, circumstances (Muadi, 2021).

Orangutans have been a protected species in Malaysia since 1959 (Pandong et al., 2019). Each state of Malaysia has its own enactments, with the Sabah Wildlife Conservation Enactment of 1997 (State of Sabah, 1997) and the Sarawak Wildlife Protection Ordinance of 1998 (Sirat et al., 2023) covering orangutans' geographic range within Malaysia Borneo. Malaysia has federal legislation as of 2008 and 2010 addressing international trade in CITES-listed species (CITES-LEX, 2024).

Indonesia and Malaysia both have had government-created conservation action plans to guide implementation of conservation action for orangutans in line with legal frameworks. Indonesia's plan spanned 2007 to 2017 (Ministry of Forestry, 2009). A new plan was created and published in 2019, and then withdrawn by the government (Foresthints, 2019).

It has not been officially reissued to date, and no alternate plan has been published. Malaysia has had a plan in force since 2020 (Sabah Wildlife Department, 2020).

In Chapter 2, I analysed the implementation and impacts of Indonesia and Malaysia's orangutan conservation action plans through 2017. In Chapter 5, I assessed the scope and scale of illegal activities affecting orangutans in Indonesia and the deterrence impact of law enforcement actions.

*Habitat protection and management*

The designation of national parks and other totally protected areas relates to the persistence of orangutan populations in protected primary and secondary forests (Pandong et al., 2019; Sabah Wildlife Department, 2020; Utami-Atmoko et al., 2017b; Voigt et al., 2018). Globally, protected areas are an effective tool to protect biodiversity and ecosystems (Langhammer et al., 2024), and many Indonesian and Malaysian protected areas are strongholds of orangutan populations (Utami-Atmoko et al., 2017b). The quality of protected area management and enforcement of laws and regulations is as important as designation of these protected areas themselves (Neal, 2024). Evidence presented in this thesis supports indications from other studies that protected areas in Indonesia have not been sufficient in themselves to prevent orangutan killing and capture in Indonesia (Neal, 2024; Voigt et al., 2018; Chapter 5).

Other government tools to conserve orangutans and their forest habitats include legal moratoria on clearing forests for new agricultural concessions and granting of land rights to traditional owners. Indonesia enacted a moratorium on new licenses for agricultural, logging and wood fibre concessions in primary forest, peatlands, and other forest conservation zones in 2011 (Leijten et al., 2021). The ban excluded existing licenses, and although it was made permanent in 2019, the areas it applies to have been modified multiple times (Leijten et al., 2021). Indonesia's community forest programme (*hutan desa*) grants forest management rights to traditional owners to resolve land tenure issues and slow deforestation, with the caveat that the lands must generate income for the community (Kraus et al., 2021).

Fire prevention and suppression activities, including government-constituted Fire Management Units, fire alert programmes, community education programmes, and rewetting of peat swamp forests are employed to curtail the extent of forest destruction from annual dry season fires (Budiningsih et al., 2022; Lestari et al., 2022; Murdiyarso et al., 2021).

Forest changes and fires can be tracked via remote sensing data, hence these aspects of orangutan conservation are regularly evaluated. Evaluation of the moratorium on new concessions showed it provides some level of protection for forests outside national parks, but also indicates it has a significant "leakage" effect that displaces deforestation activity into adjacent forests not covered by the ban (Leijten et al., 2021). This impacts orangutan habitats, many of which are outside the boundaries of the 2021 moratorium map (Ancrenaz et al., 2024; Leijten et al., 2021). Additionally, a projection of recent deforestation levels suggests that, if unchanged, Indonesian forest losses could eliminate habitats occupied by 26,200 Bornean orangutans by the 2030s (Voigt et al., 2022). Researchers who investigated the deforestation and community wellbeing impacts of the *hutan desa* programme found it did not decrease deforestation overall but did lessen forest loss in lands slated for timber production (Kraus et al., 2021), and that its effectiveness depended on circumstances including local capacity and support for development of community corporations to manage income generation and distribution, as well as access to markets (Kraus et al., 2021; Santika et al., 2019b).

*Commodity sustainability standards and certification*

Commodity production practices, including what is produced where, how it is extracted or harvested, and supply-demand economics for resulting products all relate to the extent and persistence of natural forests (Meijaard et al., 2023). Numerous commodity sustainability certifications have been developed to encourage production that addresses forest and biodiversity losses, other environmental impacts, and human wellbeing. Two international standards relevant to orangutan conservation are the Roundtable for Sustainable Palm Oil (RSPO) and the Forest Stewardship Council (FSC). Notably, both RSPO's and FSC's certification standards include protection of High Conservation Value (HCV) forests that are important for protected species, biodiversity, and ecosystem functions (FSC, 2020; RSPO, 2022).

Deforestation was about five percent lower across FSC-certified forests in Borneo compared to uncertified forests (Miteva et al., 2015). Surveys found that in Sabah, Malaysia, orangutan populations were largely stable in lightly logged forest, but areas with intensive logging practices had lower densities, suggesting the extractive activities drove orangutans to seek refuge in less impacted forests (Ancrenaz et al., 2010). Occupancy modelling of orangutans in Sabah's commercial forest reserves similarly showed orangutans using larger areas within FSC-certified versus non-certified forests (Sollmann et al., 2017). Modelling of the cost-benefit impacts of orangutan reintroduction versus forest management strategies found that implementing sustainable forestry practices performed well as a conservation strategy if forest protections are efficient, particularly at intermediate timescales (Wilson et al., 2014).

Analysis of remote sensing data shows deforestation for palm oil in Indonesia has slowed notably in recent years, but clearing of critical orangutan habitats is still ongoing (Gaveau et al., 2022; The Tree Map, 2023). RSPO-certified palm oil plantations did not show improved environmental sustainability outcomes compared to uncertified plantations, although they did have improved yields of fruit (Morgans et al., 2018). Rates for forest loss from 2000 - 2015 in RSPO were nearly half the losses in uncertified plantations, although orangutan loss rates relative to their density were consistent across both RSPO and uncertified plantations (Meijaard et al., 2017).

*Patrolling, monitoring, and law enforcement*

Surveillance of orangutan habitats and populations is used to deter poaching and illegal logging, detect poachers and remove hunting snare or traps, and monitor orangutan population changes and behaviour. Several long-term orangutan research sites in Indonesia and Malaysia provide a regular presence (including on site personnel and remote monitoring such as camera trapping and acoustic monitoring) that can detect and deter illegal activities. Forest rangers, community rangers, and other monitors are active in some parts of the orangutan range, mainly in National Parks and other protected areas (Chapter 5).

Although some orangutan populations are regularly surveyed (e.g., Galdikas et al., 2023; Knott et al., 2021; Yuliani et al., 2023), there are few published data on the performance of patrols and monitoring for orangutan protection, despite that their effectiveness has been demonstrated for primates (Campbell et al., 2011; Junker et al., 2019) and other rare wildlife in Indonesia (Linkie et al., 2015). For example, Sugardjito and Adhikerana (2010) measured the performance of orangutan patrol units in and around Gunung Palung National Park in West Kalimantan, Indonesia from 2004-2007, finding that patrols significantly deterred illegal entries and forest crimes within the park.

Following detection of possible crimes, other law enforcement activities are investigation of potential criminality, arrest, prosecution, and sentencing. Rijksen and Meijaard (1999) and Nijman (2017) suggest that these law enforcement actions for orangutan-related crimes are rare in Indonesia. My findings corroborate this, as discussed in Chapter 5.

*Behaviour change*

Many interventions aim to change human behaviours that put orangutans at risk, namely habitat destruction or degradation and orangutan killing, possession, and trade. Activities implemented to drive behaviour change range from increasing knowledge of orangutans and problematic human behaviours to providing livelihood opportunities as an alternative to income from logging, hunting, or other resource extraction, or offering social or financial incentives to adopt new behaviours.

Conservation education on orangutan-specific topics, also called sensitization or awareness raising, has been conducted at the national level and in selected sites across the orangutan range for several decades (Aveling & Mitchell, 1982; Supriatna et al., 2014; Chapter 5). These efforts have focused on improving awareness of orangutans and appreciation for their intrinsic value and their role in rainforest ecosystems, increasing appreciation for conservation activities in general, and ensuring knowledge of the protected status of orangutans and potential sanctions for their killing, capture, and trade (e.g., Knott et al., 2021; Supriatna et al., 2014).

Generally, researchers have found that interventions that strive to change attitudes and beliefs are not effective at changing behaviours compared to interventions that help people overcome challenges to accepting and implementing the desired behaviours, including by offering social or financial support or other incentives (Albarracín et al., 2024). Educational activities for orangutan conservation are rarely formally evaluated, excepting for knowledge of survey respondents on questions regarding conservation status and legal protection of orangutans (e.g., Meijaard et al., 2011a; Rainer et al., 2020). Freund et al. (2020) and Robinson et al. (2024) evaluated orangutan-focused conservation education programmes and found they resulted in knowledge gains as well as improved attitudes towards conservation. Supriatna et al. (2014) looked at a conservation awareness programmes in North Sumatra that addressed orangutans, forests, and biodiversity, concluding that these actions improved local appreciation of forest ecosystem services and wildlife.

Direct interventions with local communities also aim to change behaviour. These are commonly related to the livelihoods of people living within the orangutan distribution range, such as providing income-generation opportunities designed to replace livelihoods or sustenance from hunting, and income from logging or wildlife trade (Jones et al., 2020). Other interventions seek to improve the environmental sustainability and effectiveness of existing livelihoods by providing capacity building and support for permaculture practices, reducing pesticide and herbicide use, increasing crop yields, and securing market access or premium pricing, or supporting the cultivation or sustainable harvesting of certain crops (Bersacola et al., 2023; Knott et al., 2021). Some interventions do not directly affect orangutans or their habitats but instead provide direct social, financial, or health and welfare benefits to communities, such as provision of medical care, in exchange for or to encourage behaviours protecting orangutans and forests (Jones et al., 2020).

As with educational programmes, alternative livelihoods and community benefit programmes are rarely empirically evaluated. In Sumatra, researchers assessed self-reported behaviour changes toward orangutans and forests as a result of external (economic incentives or pressure to act) or internal motivations (intrinsic desires or self-motivation), and found the economic incentives motivated improved views of orangutans, but protection of forests required combined external and internal approaches (Nilsson et al., 2016). In Kalimantan, Indonesia, Jones et al. (2020) established a local health care clinic with alternative payment options and discounts tied to conservation actions and halting illegal logging practices. They found that forest losses decreased significantly around villages with highly engaged participants, was unchanged for villages with medium engagement, and increased in the least engaged villages (Jones et al., 2020). An assessment by Russon and Susilo (2014) of the outcomes of orangutan tourism programmes found that although the programmes were popular and generated revenue, most revenues went to large commercial enterprises, not local salaries. Further, these programmes did not provide expected local economic, conservation or educational benefits, and had serious negative consequences that did not outweigh benefits, including negative impacts to orangutan habitat, and disease transmission risks and over-habituation to humans posed by the direct human-orangutan contact allowed in some programmes (Russon & Susilo, 2014).

I looked at spatial overlap of behaviour change activities and orangutan-related crimes in chapter 5, and in Chapter 6 we assessed the conservation and cost effectiveness of these interventions.

*Human-orangutan conflict management*

Interventions that help local residents to avoid or manage conflicts with orangutan are implemented in some situations, although information on the specific conflict management tactics used and where they are implemented is sparse. Some orangutan rescue centres and wildlife conservation NGOs report using noise deterrents (banging on trees, bamboo drums, firecracker cannons) to drive orangutans away from human use areas (Anon., pers. comm. 2018, 2022; Campbell-Smith et al., 2012). Dogs and pellet guns are also used to scare away orangutans, but pose high risks to the orangutans (Oram, 2023). Other interventions being tested are planting coffee and other crops unpalatable to orangutans as a buffer around desirable fruit crops. Some plantations use small canals to deter orangutans from crossing into palm oil plants (E. Meijaard, pers. comm., 2019; A. Russon, pers. comm. 2019). Compensation for orangutan damage to human property or crops has been used in several instances to address conflicts with reintroduced orangutans (e.g., BOSF, 2015). The Central Kalimantan provincial division of *Balai Konservasi Sumber Daya Alam* (BKSDA), Indonesia's national agency for natural resource conservation, reported setting and baiting live traps in areas where local residents have reported orangutans crop foraging or even where they have only been seen near crops (Balai KSDA Kalteng, 2021a).

Campbell-Smith et al. (2012) evaluated the performance of human-orangutan conflict mitigation strategies in Sumatra and changes in farmer attitudes toward orangutans before and after mitigation. The researchers found that netting fruit trees significantly decreased crop foraging by orangutans, but it was not implemented by farmers following the study as they preferred to use the easier to implement but less effective noise deterrents (Campbell-Smith et al., 2012). Farmer attitudes toward coexistence with orangutans improved markedly after the Campbell-Smith et al. (2012) study, with a clear majority (58%) stating that mitigation was better than removing orangutans. I examined issues around protecting orangutans in situ rather than translocating them away from areas of conflict with humans, as discussed in the section below and in Appendix I.

*Rescue, rehabilitation and translocation*

Orangutans orphaned as a result of poaching and those seized or surrendered from illegal possession are generally taken to specialized orangutan rescue centres that focus on care, rehabilitation, and release back into natural habitats (Chapter 3). Intake of orangutans into care and rehabilitation facilities is colloquially known as "rescue". Translocation is the overarching term for any type of human-mediated movement and release of wildlife species (IUCN/SSC, 2013). The types of translocation used for orangutans are: 1) reintroduction, where individuals are released into areas outside their current species distribution from which they were previously extirpated, 2) reinforcement, where individuals are added to existing wild populations that are likely to benefit from addition of more breeding individuals or more genetic diversity, and 3) wild-to-wild translocation, where wild individuals are captured and promptly moved to a new location (IUCN/SSC, 2013; Chapter 3 and Appendix I). Rescue, rehabilitation, and translocations of orangutans have been conducted since the 1960s (Rijksen & Meijaard, 1999; Russon, 2009).

The effectiveness of rehabilitation in establishing wild behaviours in seized, surrendered, or orphaned orangutans has been assessed by several researchers (e.g., (Grundmann, 2006; Lokuciejewski, 2019; Russon, 2009; Russon et al., 2009a; Russon et al., 2016), concluding that practices have improved notably over the decades but challenges remain due to the species' social learning pattern, notably around preventing humanising influences and effectively fostering and assessing the survival competencies of translocation candidates (Preuschoft et al., 2021). Few published studies have evaluated the species and habitat conservation outcomes of orangutan rescue and translocations. Assessment has been limited by lack of data on post-release survival (e.g., Kelle et al., 2013) and has thus focused instead on the number of individuals released (e.g., Andau et al., 1994). Russon (2009) looked at establishment of reintroduced populations that could potentially be viable for the long-term, defined as persisting for 1000 years assuming adequate habitat size and adequate control of hunting and deforestation (Singleton et al., 2004), and concluded that two populations could possibly meet these criteria, while in a third site 85% of the reintroduced individuals had died, disappeared or been recaptured and translocated. One of the two potentially viable populations, Meratus, was later determined to have also lost most of its released population, possibly linked to uncontrolled hunting (Siregar et al., 2010). The other potentially viable site, Bukit Tigapuluh National Park, is still an active reintroduction site (YEL, 2018). Kelle et al. (2013) conducted a population viability analysis (PVA) for this population which indicated that decreased adaptation time before released individuals can contribute to reintroduction would improve the likelihood of viability. The authors also suggested that population persistence was unlikely unless some of the unaccounted for or less competent orangutans survive to reproduce (Kelle et al., 2013).

I quantified orangutan rescues, surrenders, seizures, and wild-to-wild translocations from 2005 to 2022, and evaluated available data on their conservation outcomes and orangutan welfare impacts in Chapter 3 and Appendix I.

### 1.4 Thesis structure

I studied orangutan conservation efforts with the following research objectives:

1. Evaluate whether orangutan conservation action plans are effective for species and habitat conservation, how their effects are monitored, and what interventions are being implemented (Chapter 2);
2. Assess the prevalence, spatial distribution, and, where possible, the outcomes of key interventions for orangutan conservation (Chapters 2 and 6);
3. Quantify orangutan rescue and translocation activities and assess their likely impacts on conservation of wild orangutans (Chapter 3);
4. Quantify orangutan wild-to-wild translocations and their risks and benefits for orangutans and their habitats (Chapters 3 and 4, Appendix I);
5. Quantify orangutan-related crime and trade and its effects on the species (Chapter 5);
6. Identify what interventions are implemented to protect orangutans and how these interventions are spatially distributed (Chapter 6);
7. Assess the contribution of orangutan conservation investments to species conservation over time and across the orangutan range, and identify the most effective actions to maintain and recover wild orangutan populations (Chapter 6).

My research elucidates the effects of key orangutan conservation interventions and offers replicable approaches for evaluating species conservation impacts in situations with limited monitoring data.

Chapter 2 is the paper **Envisioning a Future for Bornean Orangutans: Conservation Impacts of Action Plan Implementation and Recommendations for Improved Population Outcomes**, an assessment of the monitoring and performance of orangutan conservation action plans based on publicly reported data, expert-elicited data, satellite data on forest changes, and published analyses of orangutan population changes between 2007 and 2017. While limited published data prevented a counterfactual-based analysis of plan activities, I identified and collected numerous sources of data on rescue, translocation, and law enforcement outcomes, and Dr Maria Voigt compiled orangutan population trends and forest changes by area, enabling us to look at several lines of evidence against a more robust set of conservation impact indicators I created for the Indonesian actions plan.

Chapter 3 presents **Shifting apes: Conservation and welfare outcomes of Bornean orangutan rescue and release in Kalimantan, Indonesia**, a quantification and evaluation of the conservation and welfare outcomes of orangutan rescue and translocation in Indonesia between 2007 and 2017. I built a dataset detailing ten years of Bornean orangutan rescues, confiscations, surrenders, captures of wild orangutans considered to be in unsuitable situations, and translocations, using a wide array of mainly public sources: newspaper reports; interviews with orangutan researchers, conservationists, and rescue centres; research, conservation, and rescue centre annual reports, news blogs, tax and charity commission reports; and data from practitioners. Quantitative data on orangutan rehabilitation and reintroductions were last published by Russon (2009), but published data on wild-to-wild orangutan translocations specifically were not available. I built on Russon's work by assessing rescue type and rationale, the orangutans' condition, translocation type (reintroduction, reinforcement, wild-to-wild translocation) and law enforcement, habitat conservation, and socioecological aspects. I examine translocation risks and outcomes in Chapter 4 and in a supporting paper, **Outcomes of orangutan wild-to-wild translocations reveal conservation and welfare risks** (Appendix I), and assess orangutan-related crimes and law enforcement in Chapter 5.

Chapter 4 is the paper **Disease risk and conservation implications of orangutan translocations**, which details results of the work I led with orangutan veterinary specialists Dr Steve Unwin, Dr Dominic Travis, Dr Ricko Jaya and Dr Marc Ancrenaz to assess the disease and conservation risks of orangutan translocations. Orangutan disease outbreaks have happened in captive facilities (Faizal, 2011) with known instances of infected individuals being translocated (Bonner, 1995). Although orangutan pathogens and parasites have been studied (Nurcahyo et al., 2017) and risks of orangutan pathogen transmission have been modelled (Carne et al., 2014), surveillance of wild orangutan diseases and zoonotic transfer is limited. We found no published Disease Risk Analysis (DRA) for orangutan translocation. Our assessment laid the groundwork for the first orangutan translocation DRA.

Chapter 5 presents **Orangutan killing and trade in Indonesia: Wildlife crime, enforcement, and deterrence patterns**. This paper is an analysis of reported killing, capture, and trade affecting Indonesian orangutans between 2007 and 2019, and the interventions undertaken to deter these crimes. I built a spatially-specific dataset from the same range of sources identified in chapter three. Our study expanded on previous analyses of orangutan trade in Indonesia by Nijman (2005, 2009, 2017) and Freund et al. (2017). We analysed spatial and temporal trends in orangutan-related crime along with associated interventions intended to deter killing, capture and trade. We also provided orangutan killing estimates based on expected detection rates that compared with the findings from Meijaard et al. (2011a). I analysed spatial and temporal trends and Dr Maria Voigt visualized the reported crimes.

Chapter 6 ties together the findings of the studies presented in Chapters 2 through 5. in the paper **Effectiveness of 20 years of conservation investments in protecting orangutans**. This paper is an output of the research project I led with Professor Truly Santika, Professor Erik Meijaard, Dr Marc Ancrenaz, and Professor Serge Wich to evaluate the impacts and cost effectiveness of rescue, translocation, patrols and enforcement, habitat protection, education, and other key conservation interventions to protect the three orangutan species between 2000 and 2019. We used both evidence-based and statistically generated counterfactuals for this evaluation. Our ground-breaking analysis expanded on earlier examinations of the cost effectiveness of Bornean orangutan conservation strategies that compared a few key interventions (Wilson et al., 2014) or used a limited set of financial data (Morgans et al., 2019). I designed and led data collection on spatially specific spending on orangutan conservation activities and Professor Santika developed models to determine the activities' effectiveness at preventing orangutan population losses compared to no action, and the cost effectiveness of each activity type per orangutan. The models included the most recent analysis of orangutan occurrence based on nest surveys and encounter data for 2015 through 2019.

Chapter 7 discusses the conclusions of my research and their implications for orangutan conservation in the context of findings from evidence-based evaluation of conservation effectiveness for other iconic protected species. I provide comments on further research directions and recommendations for priority actions to conserve orangutans and their habitats. Additional publications that contributed to our understanding of orangutan conservation effectiveness and outcomes are shown in Table 1.1.

**Table 1.1. Supporting publications**

| Title | Author role |
|---|---|
| **Sherman, J**., Voigt, M., Ancrenaz, M., Meijaard, E., Oram, F., Williamson, E.A., Russon, A.E., Seaman, D.J.I., Caurant, C., Byler, D., Wich, S.A. (2025). Outcomes of orangutan wild-to-wild translocations reveal conservation and welfare risks. *PLOS ONE* 20 (3): e0317862. | Lead |
| Meijaard, E., Unus, N., Ariffin, T., Dennis, R., Ancrenaz, M., Wich, S., Wunder, S., Goh, C.S., **Sherman, J**., Ogwu, M.C., Refisch, J., Ledgard, J., Sheil, D., Hockings, K., 2023. Apes and agriculture. *Frontiers in Conservation Science*: 4. | Coauthor |
| Massingham, E., Meijaard, E., Ancrenaz, M., Mika, D., **Sherman, J**., Santika, T., et al. (2023). Killing of orangutans in Kalimantan - Community perspectives on incidence and drivers. *Conservation Science and Practice, 5*(11): e13025. | Coauthor |
| Seaman, D.J.I., Voigt, M., Ancrenaz, M., Bocedi, G., Meijaard, E., Oram, F., Palmer, S.C.F., Santika, T., **Sherman, J**., Travis, J.M.J., Wich, S., Humle, T., Supriatna, J., Struebig, M.J., 2024. Capacity for recovery in Bornean orangutan populations when limiting offtake and retaining forest. *Diversity and Distributions*: e13852. | Coauthor |
| Meijaard, E., Sheil, D., **Sherman, J**., Chua, L., Ni'matullah, S., Wilson, K., Ancrenaz, M., Liswanto, D., Wich, S.A., Goossens, B., Kühl, H.S., Voigt, M., Rayadin, Y., Kurniawan, Y., Trianto, A., Priatna, D., Banes, G.L., Massingham, E., Payne, J. and Marshall, A.J. (2022). Restoring the orangutan in a Whole- or Half-Earth context. *Oryx* 1-12. | Coauthor |
| Voigt, M., Kühl, H.S., Ancrenaz, M., Gaveau, D., Meijaard, E., Santika, T., **Sherman, J**., Wich, S.A., Wolf, F., Struebig, M.J., Pereira, H.M. and Rosa, I.M.D. (2022). Deforestation projections imply range-wide population decline for critically endangered Bornean orangutan. *Perspectives in Ecology and Conservation* 20 (3): 240-248. | Coauthor |
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| Meijaard, E., Ni'matullah, S., Dennis, R., **Sherman, J**., Onrizal and Wich, S.A. (2021). The historical range and drivers of decline of the Tapanuli orangutan. *PLOS ONE* 16: e0238087. | Coauthor |
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## 1.5 Methods

Lack of monitoring and the resulting paucity of empirical evidence on the outcomes of orangutan conservation interventions is a significant hurdle in determining what is effective for species protection. I collated data on direct and proxy indicators and looked at multiple lines of evidence to address this lack of data, and with my coauthors analysed the effects of conservation interventions on threats and orangutan populations and habitats.

### 1.5.1 Data collection

I built datasets from primarily public data sources to address the research questions on orangutan rescues, rehabilitation, and translocation, orangutan-related crimes, and the costs and locations of orangutan conservation interventions, whether they were monitored, and if positive impacts on orangutan populations, habitats, and local conservation outcomes were observed. Records obtained directly from governments and rescue centres are a preferred source for rescue, seizure, surrender, capture, rehabilitation and translocation, and crime data, but few entities are willing to share such reports even confidentially. Hence, I also used media reports and rescue centre intake information, which are commonly used as a proxy for poaching and illegal trade (e.g., Polisar et al., 2023; Shepherd et al., 2020; Siriwat & Nijman, 2018; Trayford & Farmer, 2013). I also found reporting issues in most rescue and translocation data: numbers and dates differed even among documents from the same organization, requiring careful comparison on records from a variety of sources to weed out duplicate or incorrect data (Chapter 3 and Appendix I). I reached out to all involved entities to request data, and to confirm the accuracy and completeness of data I collated from public sources but received few responses.

For the studies in Chapters 2-5, I reviewed relevant scientific literature and collected public data from newspaper articles, wildlife trade databases and reports from non-governmental organizations (NGOs) and CITES, government websites, social media, and reports, and the websites, social media, annual, charity commission and public tax reports from orangutan conservation practitioners. I collected some data for each paper directly from orangutan conservation practitioners or through surveys and direct communications. Conservation practitioners in this context includes all entities that conduct orangutan conservation interventions including corporations, NGOs and other parties implementing activities related to protection of orangutans and their habitat.

For the cost effectiveness analysis in Chapter 6, we collected data on investments in orangutan conservation interventions from public grant and funding databases or repositories (Foundation Centre Online, REDD+, European Commission), foreign government aid and overseas conservation funds (e.g. Norway International Forest and Climate Initiative, United States Agency for International Development), NGO annual reports, charity commission and public tax reports, government statistics reports and annual budgets, and the annual reports, sustainability or social responsibility reports, and sustainably commodity certification reports (RSPO and FSC) of agribusiness and natural resource extractive businesses operating in the orangutan range. We also did follow up emails and calls as needed to request specific information on how spending was apportioned among conservation interventions and geographic locations.

### 1.5.2 Data interpretation and analysis

To prevent selection bias for the studies in Chapters 2-5, I reviewed and harvested any usable data from all reports and news/social media articles that I found on orangutan-related crimes and orangutan rescues, seizures, surrenders, and captures for translocation. I discarded data only where it was duplicative, and used all available identifying information on event date, description of event, orangutan name, sex, age, condition, description, and entities involved to ensure each incident and orangutan quantified were unique. I used an iterative grounded approach (e.g. Tadie & Fischer, 2013; Waters et al., 2019) to interpret collated orangutan rescue, release, and crime records. This involved identifying and coding results categories (e.g. reasons for orangutan capture) as information emerged from the evidence, rather than first defining these categories *a priori*. Categories and coding were further refined using constant comparative analysis (Chun Tie et al., 2019). Cassidy and Mills (2012) provide an example of a similar approach applied to a dataset of newspaper articles, online stories, and television media. News media stories on orangutan killing and seizure records of infants are not direct measures of poaching levels, and are often significant underestimates (Paudel et al., 2022), therefore I collated published estimates of detection rates for wildlife and environmental crime to extrapolate a range of the likely population-level impacts for orangutan killing.

For the study on orangutan-related crime in Chapter 5, we used recently published estimates of orangutan populations in Borneo and Sumatra (Voigt et al., 2018; Wich et al., 2016), and derived provincial orangutan population estimates in Kalimantan by determining the slope of the line between the Voigt et al. (2018) provincial population estimates for 2008 and 2014, and using this rate to extrapolate the provincial populations for 2017. I used the Mann-Kendall trend test (McLeod, 2022) to assess trends in annual crime numbers over the study period and the Ljung box test (Lemon, 2006) to assess serial autocorrelation in annual crime numbers. I ran both tests in R (R Core Team, 2020). We used Python (Python Software Foundation, 2019), ArcGIS Pro (Esri, 2020), and QGIS 3.14.0-Pi (QGIS, 2020) for all spatial manipulations, and aggregated, analysed, and visualized data using Python, R, ArcGIS Pro and QGIS.

Our analysis for the study in Chapter 6 determined that sufficiently detailed data on orangutan conservation interventions and their locations and costs were lacking in many cases. We therefore lumped interventions into six broad categories: 1) habitat protection and management, 2) habitat restoration, 3) patrolling and law enforcement, 4) rescue and rehabilitation, 5) translocation and reintroduction, and 6) public outreach and capacity building. The last category covers all behaviour change interventions such as education and alternative livelihoods. I coded conservation investment data by sector of the investor, namely national government, foreign government, NGO, agribusiness or resource extraction business, and research centre. We addressed gaps in the investment data by calculating a mean annual expenditure total and a rate of change in mean expenditure per intervention type over time from available data for each sector and using these calculated figures to extrapolate expenditure levels by intervention type for missing data within that sector. We had detailed data for several investors from each sector, hence we believe this method provided a reasonable estimate of mean values by sector. We reflected real values across political boundaries within the orangutan distribution by adjusting nominal values of investments using reported inflation rates from the World Bank Consumer Price Index (Lakner et al., 2018a). A comparable method is described by Correa et al. (2024).

Chapter 6 shows the results of a Generalized Boosted Regression Modelling (GBM) approach (Li & Wang, 2013) used to fit the orangutan presence-absence data by time period and region of species distribution using 15 environmental predictors. We used a theory of change (results chain) following the Open Standards for the Practice of Conservation and the Conservation Measure Partnership Conservation Action Classification (Conservation Measures Partnership, 2007, 2016) to consider expected conservation outcomes for each conservation intervention. We developed counterfactuals of no action where the conservation interventions were not applied by estimating how each activity modified the predictor variables in the GBM models. For most predictors, this was calculated as a distance from the implemented action (actual distance X 100). For protected areas, habitat restoration, rescue/rehabilitation, and translocation, we calculated an effect based on data for observed results compared to areas without the conservation treatment. We multiplied the translocation and reintroduction strategy benefit by 50%, the median value of reported post-release survival rates between 20% and 80% depending on release site, time since release and individual animal condition and circumstances (Russon, 2009; Sherman et al., 2020a; YEL, 2018).

# Chapter 2. Envisioning a future for Bornean orangutans: Conservation impacts of action plan implementation and recommendations for improved population outcomes

Julie Sherman[1,*], Marc Ancrenaz[2,3], Maria Voigt[4,5], Felicity Oram[6], Truly Santika[5,7], Serge Wich[8], Erik Meijaard[2,5,7,**]

1. Wildlife Impact. PO Box 31062, Portland, OR 97217, USA. Tel./Fax.: +1503-5483013, *email: julie@wildlifeimpact.org.
2. Borneo Futures. Block D, Unit 8, 1st Floor, Shakirin Complex,Spg 88, Kg Kiulap, BSB BE1518, Negara Brunei Darussalam. Tel./fax.: +31-615350744, **email: emeijaard@gmail.com.
3. HUTAN-Kinabatangan Orangutan Conservation Programme. P.O. Box 17793, 88874 Kota Kinabalu, Sabah, Malaysia
4. German Centre for Integrative Biodiversity Research (iDiv), Halle-Jena-Leipzig, Deutscher Platz 5e, 04103 Leipzig, Germany
5. Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent. Canterbury CT2 7NR, UK
6. PONGO Alliance. L-1-8 The Peak Suites, Jalan Signal Hill Park, 88400 Kota Kinabalu, Sabah, Malaysia
7. School of Biological Sciences, University of Queensland. QLD 4072, Australia
8. School of Natural Science and Psychology, Liverpool John Moores University. Tithebarn St Liverpool L2 2QP, UK

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**Abstract**

Populations of the Critically Endangered Bornean orangutan (*Pongo pygmaeus*) are declining despite more than 10 years of conservation action plan implementation. Here we analyzed the impacts on species' population and habitat from orangutan conservation strategies implemented between 2007 and 2017. We also assessed data on investments into orangutan conservation, orangutan population trends and landcover change in orangutan range between 2007 and 2017. Diverse strategies addressed the range of threats to orangutans but were not implemented at scales that impacted species' level populations and habitats. Since 2007 orangutan populations and forests across orangutan range have declined, with orangutan killing and deforestation as the major drivers of loss. Protected areas have increased since 2007, notably in Malaysian range states and in Central Kalimantan, Indonesia. However, 80% or tens of thousands of orangutans, live outside protected areas in Kalimantan alone. Our results underscore scientific findings that have demonstrated this species' resiliency and modified previous understanding of their habitat use. Orangutans are regularly found using agriculture landscapes (acacia, oil palm, and timber plantations), and exploited forests. This plasticity must be considered to design more effective orangutan conservation strategies. We need to revise the notion of "orangutan habitat" to extend beyond forests alone, incorporating all landscapes where *P. pygmaeus* can be found. Orangutans cannot survive in exclusively monoculture production areas; they need some natural forest to fulfill their ecological requirements. However, individuals surviving in isolated forest patches or mosaic landscapes play an important role in sustaining the long-term viability of the local metapopulation through provision of crucial genetic, reproductive and socioecological connectivity. Our findings suggest that removing these individuals through translocations weakens overall metapopulation health. All necessary efforts must be made to maintain individuals in isolated forest patches or mosaic landscapes in order to support healthy metapopulations. Improved orangutan population outcomes will require addressing habitat connectivity at the landscape level, incorporating both non-forested and anthropogenically modified areas, and developing efficient management strategies for human and orangutan co-existence within these multiple-use landscapes.

## 2.1 Introduction

The primary habitat for the Bornean orangutan is lowland mosaic and alluvial forests below 500m a.s.l. in Sarawak and Sabah, Malaysia, and Kalimantan, Indonesia (Husson et al., 2009; Wich et al., 2008). Orangutan distribution range is further limited by high mean annual rainfall, as this leads to soil leaching and decreased forest productivity (Wich et al., 2012). The range also reflects early settlement on Borneo (Santika et al., 2017a), with subsequent likelihood of orangutan hunting (Davis et al., 2013). There are three subspecies of *Pongo pygmaeus*: *P. p. wurmbii* (mainly in Kalimantan, Indonesian Borneo), *P. p. pygmaeus* (mainly in Sarawak, Malaysia, and northern West Kalimantan), and *P. p. morio* (mainly in Sabah, Malaysia, and North Kalimantan). Although all these three subspecies are fully protected under both Malaysian and Indonesian laws, they continue to be threatened by habitat loss, degradation and fragmentation due to forest conversion for agriculture, mining and infrastructure development (Gaveau et al., 2013; Santika et al., 2015), and by illegal hunting for bushmeat (Davis et al. 2013; Abram et al. 2015), which can in turn lead to wildlife trade of infants following killing of mothers, or retaliatory killing as a result of conflict with humans (Meijaard et al., 2011a). Other threats include fire, climate change or diseases (Ancrenaz et al., 2016a). The Bornean orangutan (*Pongo pygmaeus*) was recently classified as Critically Endangered by the IUCN, and the populations of all subspecies are considered to be declining (Ancrenaz et al., 2016a).

Management strategies for the Bornean orangutan have been outlined in three action plans, the Sabah Orangutan Action Plan (SAP), the Orangutan Indonesia Conservation Strategies and Action Plan (SRAK), and the Orangutan Strategic Action Plan for the Trans-boundary Biodiversity Conservation Area of Batang Ai, Lanjak-Entimau Wildlife Sanctuary and Betung Kerihun National Park (Transboundary Plan). The SAP was primarily developed via a series of consultation workshops led by the Sabah Wildlife Department (SWD) and HUTAN, and covered the years 2012-2016 (Sabah Wildlife Department, 2012). The SRAK was developed following an Orangutan Population and Habitat Viability Assessment (PHVA) in 2005, and government and stakeholder planning workshops on conservation action strategies. The SRAK covered Sumatran and Bornean orangutan management for the years 2007-2017 (Ministry of Forestry, 2009). A SRAK covering the years 2019-2029 was published in August 2019 but was later withdrawn for further revisions (Foresthints, 2019). The Transboundary Plan was created by Wildlife Conservation Society (WCS) Malaysia and the Sarawak Forestry Corporation in cooperation with the International

Tropical Timber Organization and Sarawak Forest Department. The plan covers the areas of Sarawak, Malaysia and Betung Kerihun National Park in West Kalimantan province, Indonesia for the period of 2010-2020 (Gumal & Braken Tisen, 2010).

We conducted an independent evaluation of all these action plans, providing the first Borneo-wide appraisal of the implementation and impacts of conservation activities covering the entire Bornean orangutan range. We assessed available evidence on the impacts of implemented actions on Bornean orangutan populations and habitats between 2007 and 2017, and developed recommendations for strategic interventions going forward. Our aim is to disseminate findings to stakeholders including range state governments, non-governmental organizations, researchers, industry, and donors to inform and guide decision-makers on effective strategic actions for the protection of the Bornean orangutan across its range.

## 2.2 Materials and methods

### Study area

This study focused on Bornean orangutan range in Kalimantan, Indonesia and Sabah and Sarawak, Malaysia (Figure 2.1).

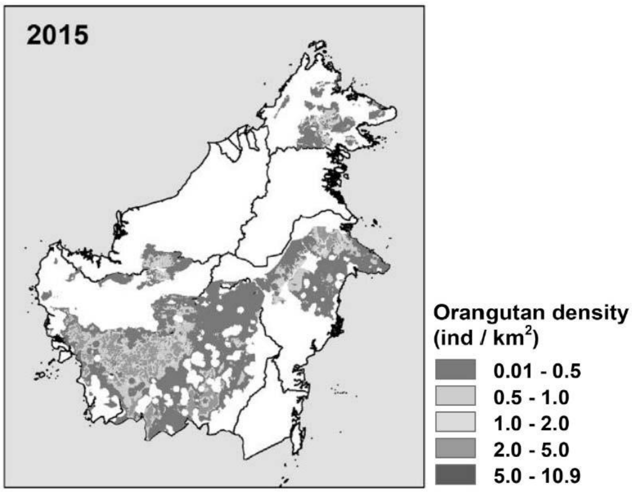


**Figure 2.1.** Map showing island of Borneo and the range and density variation of the Bornean orangutan in 2015. Figure from Voigt et al. (Voigt et al. (2018).

### Procedures

For this study, we compiled publicly available data on orangutan conservation interventions and impacts on orangutan populations and habitat between 2007 and 2017.

We developed a conceptual model as a framework to investigate: (1) how the three orangutan action plans addressed the range of conservation interventions focused on orangutans; (2) what conservation impacts are expected from those interventions; and (3) what risks and opportunities are entailed by each intervention type.
Conservation interventions were broadly categorized as: (1) research; (2) habitat protection (legal designation, community land reserve, habitat purchase, land and fire management); (3) patrolling and law enforcement; (4) community outreach, training, and policy (awareness-raising, education, capacity building, policy development, and advocacy); (5) orangutan rescues, rehabilitation, reintroduction, and translocation; (6) habitat restoration; and (7) organization management, salaries, buildings, vehicles, and other administrative costs. We collected additional data on primary components of orangutan conservation action: (1) financial data on investments made into orangutan conservation for the latest available year (2016); (2) law enforcement data; (3) orangutan rescue and release data; (4) land cover change in orangutan range; and (5) orangutan population trends. Six categories of stakeholders conducted these activities: government; multi-lateral agencies (agencies representing multiple countries, such as the United Nations Environment Programme); corporate (timber, oil palm, pulp and paper companies, carbon trade, other); orangutan sanctuaries and rescue organizations; conservation non-governmental organizations (NGOs); and research organizations.

Data were gathered from direct communications with stakeholders (via phone, email and in-person interviews), review of published literature and unpublished data, and from publicly available data sources. These compiled data were used to assess progress first against the three action plans' self-determined measures of success (plan indicators), and secondly in terms of their implementation, outcomes, and impacts. Our aim was to seek potential improvement in the effectiveness of orangutan conservation activities, rather than to point out wrongdoing by any individual or group. Hence stakeholder inputs and publicly available data attributable to individual stakeholders were kept confidential and anonymous, with data collated by sector and strategy rather than by entity.

We undertook stakeholder outreach via a series of meetings, interviews, and consultations at the Orangutan Veterinary Advisory Group (Banda Aceh, July 2018), the Sabah Wildlife Department (SWD) (Kota Kinabalu, October 2018), and the West Kalimantan Balai Konservasi Sumber Daya Alam (BKSDA) (February 2019) and the SRAK national consultation process workshop (December 2017). We emailed questionnaires to 113 stakeholders representing government (agencies/entities emailed=12; respondents=1), industry (corporations emailed=24; respondents=8), research centers and universities (organizations emailed=13; respondents=4), zoos (organizations emailed=17; respondents=4), and NGOs (organizations emailed=47; respondents=15). Questions were designed to investigate: (1) respondents' awareness of the actions plans; (2) whether respondents used these plans to guide their activities; (3) the respondents' staff and yearly budget directed to orangutan conservation activities; (4) the impacts on orangutan conservation from respondents' orangutan-related activities; and (5) challenges faced. The project team held in-person or remote meetings/communications with an additional 47 stakeholders (orangutan socioecology, behavior, ecology or population researchers, n=16; great ape rescue and release or conservation researchers, n=3; orangutan conservation practitioners, n=7; government personnel, n=5; representatives of eight orangutan rescue organizations, n=16). Questionnaire recipients and other stakeholders were kept anonymous to maintain confidentiality.

We also collect[ed] data from newspaper articles by searching Prokal and TribunNews (Kalimantan), Jakarta Post (Indonesia), and Borneo Post, Star, Malay Mail, Daily Express, New Sarawak Tribune, and Borneo Today (Malaysia and Borneo regional) websites, using the search terms "orangutan" (Indonesian and Malaysian sources) and “orang-utan” (Malaysian sources) to capture any relevant news published between 2007 and 2018. Financial data were collated from annual reports and websites, email communications and direct interviews, while enforcement data were compiled from published sources, CITES reports, newspaper articles, government reports and NGO sources. Rescue and release data were collected from rescue centers' annual reports and tax filing or charity commission reports, direct communications with practitioners, and from websites and social media posts of NGO and government rescue centers holding Bornean orangutans in Kalimantan, Sabah and Sarawak. We provided initial datasets to each rescue center for their review and input in June 2017.

**Data analysis**

*Action plan implementation and stakeholder intervention analyses*

We reviewed available implementation data collected from stakeholder outreach, review of published and unpublished literature and publicly available sources, and coded every indicator for each action plan as: (0) not completed or unsuccessful in achieving indicator condition; (1) completed or successful in achieving indicator condition; (2) in progress; (3) unknown. For the Indonesian action plan we further cross-referenced the appropriateness of the indicators based on what they measured as follows: (0) process or implementation progress; (1) indirect impact-creating enabling conditions for conservation (e.g., building capacity for law enforcement action or gazetting protection of orangutan habitat); (2) and direct impact on orangutan populations and habitat. We reviewed and summarized stakeholder questionnaire responses by respondent sector, prevalence of intervention types, reported results, and relation to relevant orangutan action plans.

We compiled data on annual captive populations and annual rescues and releases. We also compiled and coded available data on every individual instance of rescue and of release. We aggregated data by country and by rescue center or other entity and identified possible duplicates using any available combination of animal name, age, date, and circumstances of rescue. We excluded all duplicates and any records where it was unclear if the case had been previously recorded in our dataset. We classified rescues as: (1) confiscation (seizure from owner); (2) surrender (willing handover by owner or rescuer); (3) wild capture (purposeful capture of wild orangutans, including for translocation to another habitat); (4) other rescue types (medical interventions or other rescues that are not seizures, surrenders or wild captures); and (5) re-captures of previously released orangutans. Releases were classified as: (1) reintroduction (release of ex-captive rehabilitated orangutans who spent more than six months in a captive facility); (2) wild-to-wild translocation ("translocation" per practitioner terminology; any wild orangutan captured and held six months or less); (3) wild captured orangutans held for more than six months in rescue center facilities; and (4) re-releases (release of previously released and recaptured orangutans).

We compiled publicly reported instances of infractions against orangutan protection laws and associated law enforcement. Data on illegal actions affecting orangutans included capture or possession of orangutans as pets, harassment, attacks or injury to orangutans, and orangutan killing. We excluded duplicate records of the same event and calculated the total number of incidents and the relative frequency of law enforcement actions of investigation, confiscation, arrest, and conviction.

*Financial analysis*

We analyzed data on 145 organizations' expenditures during 2016. The organizations include: government (n = 21); multi-lateral (n = 4); corporate (n = 59); sanctuaries/rescue centers (n =12); other NGOs (n = 23); and research organizations (n = 26). Data were actual figures published in the annual reports of government institutions, companies and NGOs, and estimates as to what percentage of the overall budgets were spent on different orangutan conservation strategies based on qualitative information in the annual reports, or data provided by the organizations' representatives in response to email requests for information. For oil palm concessions, we used 32 known Roundtable on Sustainable Palm Oil (RSPO)-certified concessions and their budget allocations for managing an estimated 275 orangutans in their estates and concessions (Meijaard et al., 2017). The choice to focus only on RSPO-certified concessions was based on the requirement for these companies to implement management that maintains orangutan populations in their concessions, and the independent audits of such management (RSPO, 2018). For timber concessions, we used only those concessions certified by the Forest Stewardship Council (FSC), within *P. pygmaeus* range, because they would be regularly audited on the FSC requirement to prevent illegal hunting in their concessions (FSC, 2009).

*Habitat changes, orangutan population trends and conservation considerations for metapopulations*

Last, we assessed recent orangutan population and habitat trends within state and province level geopolitical units of the orangutan range. Province (for Indonesia), state (for Malaysia) and country borders (for Brunei) were downloaded from the Global Administrative Areas database (GADM, 2012), and combined within the extent of the island. Land use and management classes were assessed using a layer from Santika et al. (2017) of protected areas, selective timber extraction (hereafter selective logging) concessions in natural forest, industrial timber and industrial oil palm plantation concessions in 2006 and 2012. Suitable habitat was defined as pixels of all areas with orangutan densities higher than 0.01 ind/km$^2$ (i.e. one orangutan per 100 km$^2$) and that was forested (Santika et al., 2017a; Voigt et al., 2018). All layers were resampled to a resolution of 1 km, the highest resolution available for all layers, using nearest neighbor resampling for categorical and bilinear for continuous predictors. We extracted forest and suitable habitat extent, as well as orangutan numbers for the administrative units and land use classes on Borneo. To analyze the relative importance of small habitat patches within Bornean orangutan range, we also extracted the numbers of forested fragments smaller than 25 and 50 km2 in Sabah, Sarawak and Kalimantan. All spatial calculations were done in Python, using numpy (Oliphant, 2016), before being aggregated, analyzed and visualized in R (R Core Development Team, 2016) and ArcGIS (ESRI, 2014). We reviewed published scientific literature, along with expert knowledge and unpublished results from orangutan research projects to investigate how population and habitat trends relate to current threats, orangutan habitat use and metapopulation functions, and conservation considerations.

## 2.3 Results and discussion

### Action plan implementation analyses

Orangutan Conservation Action Plans covered most of the necessary actions to address the scope of threats to orangutan population and habitat. Our review found that 91% of the 164 indicators were measures of process or implementation effort and not effects of implemented actions (Figure 2.2). There was a strong focus on development of guidelines, Standard Operating Procedures (SOPs) and holding workshops, and dissemination of or access to these products. Only a few indicators measured direct impact to orangutan populations (n=2), habitat (n=4), or law enforcement (n=1), or indirect impacts (n=7). Both direct and indirect impact indicators lacked specifics such as number of hectares covered or percent of target areas addressed and thus were a count of activities rather than a measure of relative progress in habitat protection, reduction of threats, or behavior change in target stakeholder groups. For example, indicators include, “Revision to land use patterns that accommodate the habitat requirements of endangered species (esp. orangutans)", "Rehabilitation of 5 orangutan habitat areas", and "At least 1 area restored as an orangutan habitat". To measure impact, these indicators need to specify spatial extent and geographic information, otherwise, even one or a few instances mean the indicator is met without any relevance to the percentage of pertinent locations, relative amounts of orangutan habitat covered, and the salience of the particular location to orangutan population recovery or stabilization.

Although most actions described in the SRAK plan were underway, some of the most critical actions have been implemented only rarely, or not implemented at scales sufficient to influence species status and available habitat. Further, some actions were not based on best available science and understanding of orangutan behavior and habitat use (see results sections on Rescue and release, Law enforcement, Management of orangutans in concessions, and Changed thinking-what makes a habitat and what is an orangutan population?).

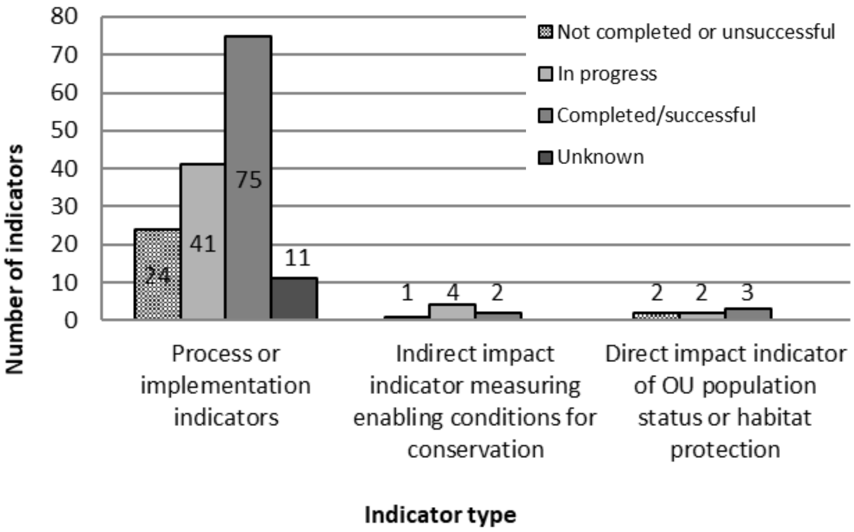


**Figure 2.2. Progress on SRAK implementation by indicator type.**

The Sabah Malaysia SAP called for the State to create a Sabah Orangutan Conservation Alliance (SOCA) to develop a feasible work plan and budget to implement the SAP. SOCA was not created during the study period, yet various organizations and partners undertook to deliver tangible results towards the completion of the plan. Most site-specific actions under the plan were completed during the study period, with the majority of non-site-specific actions being completed or in progress.

The Transboundary Plan indicators measure impacts on orangutan populations and habitats. Activities under the plan are monitored and measured against the plan indicators by the Sarawak Forestry Corporation (SFC), WCS Malaysia and other partners. Mid-terms successes have been documented including several high-profile arrests and subsequent prosecution (Pandong et al., 2019). The Transboundary Plan also details many activities to be undertaken by the Province of West Kalimantan to protect and manage *P. pygmaeus*. However, the Province authorities and their partners made very few references to this Transboundary Plan during the review and the revision of the Indonesian Action Plan.

The socialization of the three plans appears to be rather weak in all cases (see following section, Stakeholder interventions).

### Stakeholder interventions

We received 32 responses from a stakeholder questionnaire sent to government, NGO and industry stakeholders. The most common stakeholder activities were awareness-raising, reforestation and forest protection (including patrols) (Table 2.1). Most stakeholders did not have or did not share empirical evidence of whether or how these activities were impacting orangutan populations and habitats. A total of 10 respondents (or 31%) were aware of the Sabah State Action Plan; 15 of the Indonesian Action Plan (48%); 3 of the Transnational Plan (10%), and 7 (22.5%) were not aware of any plan. Only one partner was aware of all three plans. Only four respondents were aware of how their activities might impact the status of orangutan populations or threats to these populations as a whole. Therefore it appears that most efforts are locally focused and do not address orangutan conservation issues at wider scales.

**Table 2.1.** Summary of the different types of conservation activities that are the primary focus of the questionnaire respondents.

| Activity category | Number of respondents conducting strategy |
|---|---|
| Orangutan research activities | 3 |
| Orangutan monitoring | 4 |
| Creation of protected areas | 3 |
| Habitat protection (include patrolling) | 7 |
| Conservation management capacity and community outreach | 6 |
| Awareness | 8 |
| Land use planning | 4 |
| Reforestation and creation of corridors | 7 |
| Policy | 3 |

### Rescue and release

We were conducting a full analysis of rescues and releases in Kalimantan between 2007 and 2017 [at the time of publication], and here report the trends shown in preliminary results. The Indonesia SRAK had a stated goal of emptying all rehabilitation centers by 2015. In practice, rescue centers in Kalimantan have maintained fairly constant capacity, with more than 1000 orangutans held in their facilities in 2017, nearly the same number as held there in 2007. The pace of rescues continues to exceed that of releases despite more than 600 ex-captive orangutans having been released since 2007. Most rescues were orangutans held as pets or captured from areas where they could potentially interact with humans, principally agricultural concessions and local community lands. Interdiction of illegal trade played a minor role in orangutan rescues, with only a few rescued orangutans seized from traders. Consumption of human crops was specified or alluded to in only a small percentage of rescue records. A larger number of orangutans were affected by fires set to clear lands, which rescue centers report drive orangutans from forests into agricultural lands or villages where they could interact with humans.

We found more than 1200 detailed records on individual orangutans rescued, more than half of which represent crimes, including killing, possession, harassment/injury, sale or trade of orangutans. Nearly all orangutans surrendered (voluntarily handed over by a possessor), or confiscated by authorities were illegally held as pets. Nearly half of the total orangutans rescued were wild orangutans captured by orangutan management practitioners during the study period. Most of these wild orangutans were captured in situations where they were perceived to be at risk of potential interactions with humans, or where there was a perceived risk to human safety, food crops or property. Recorded orangutan consumption of human crops was specified in only a small percentage of the rescue records.

Of more than 1000 individual orangutans released into natural habitats between 2007 and 2017, 44% were rehabilitated and reintroduced. More than half of these were adults 10 years or older that were captive for more than 10 years. Practitioners commonly reported that released animals had "behavioral issues" and "difficulties in adapting to social and ecological conditions" as well as conspecific conflicts, and, to a lesser degree, conflicts between rehabilitants and wild orangutans. Many rehabilitated orangutans were recaptured and released, sometimes repeatedly because they were malnourished to the point of starvation or due to reports of consumption of human crops or other interactions with humans or with other orangutans. Systematic post-release monitoring beyond three years (the typical maximum life span of radio-tracking implants) was rarely reported although some animals were recorded *ad hoc* by patrols or noted around feeding platforms on occasion. Many individuals were not seen again following release, regardless of monitoring schemes. Rescue centers tended to consider these unmonitored individuals to be alive but dispersed outside of monitoring range or with non-functioning tracking implants, but there was not clear evidence available to support this assumption. Some reports from long term release sites suggest that medium to long term survival rates for reintroduced orangutans may be lower than 20%.

Between 2007 and 2017, wild orangutans were captured and moved in large numbers from concession lands slated to be cleared, and from areas that rescue centers considered marginal habitat or with high likelihood of human-orangutan interaction. Orangutans were mainly captured from the wild to pre-emptively avoid potential interactions with humans, including when people reported only seeing the orangutan or fearing it, but without any physical conflict or reported damage to property, such as crop consumption. Crop consumption and other orangutan damage to human property were specifically reported in one-fifth of the wild captures. The vast majority of wild orangutans were healthy at the time of capture. However, some were rescued from urgent situations where their welfare was under direct threat from humans attacking or harassing them, or when they were starving, dehydrated, or seriously injured. Rescues of the small minority of starving or malnourished animals were commonly associated with fires set to clear land. Approximately one-fifth of all the wild orangutans were captured when no suitable release site was available. These animals were held in captivity for several years before release.

Researchers we interviewed reported that mitigation or management of human-orangutan interactions is extremely rare, and translocations are the default answer to people wanting orangutans out of their way. There were multiple instances of these translocations being requested by corporations planning to clear land or to prevent orangutans in local forest patches from feeding in plantations. Anecdotal reports and available evidence of forest change in these areas suggest that following removal of the orangutans (the protected or "High Conservation Value" (HCV) species that cannot be moved or harmed under Indonesian conservation law UU 5 of 1990, and per certification requirements for sustainable timber and oil palm), these lands are rapidly cleared. While several wild-to-wild translocation release sites have been extensively studied prior to their approval, stakeholders we communicated with reported that other release sites appear to be selected *ad hoc* without the necessary wild orangutan population surveys, food availability and other assessments needed to comply with IUCN Guidelines for Reintroduction (Beck et al., 2007; IUCN/SSC, 2013). Few data are available on short term survival, and essentially none on long term survival of wild orangutans translocated to new habitats. Available short term survival data on a few radio-tracked translocated orangutans show two-thirds were not seen again after two years.

The state governments of Sabah and Sarawak, Malaysia, each operate rescue centers—Sepilok Orangutan Rehabilitation Centre (Sabah), and Semenggoh and Matang Wildlife Centers (Sarawak). Malaysian centers had rescued only a few orangutans annually during the study period. These rescues were almost exclusively infants. Both Sepilok and Matang release orangutans into the protected forests adjoining their rescue centers. Few publicly available data were found on these activities. However, it is highly likely success of reintroduction and translocation are limited in Malaysia by the same factors as in Indonesia.

### Law enforcement

We were conducting a full analysis of orangutan-related crimes and law enforcement contexts [at the time of publication], and here report trends from initial results. Systematic review of news articles and rescue data for this study showed that between 2007 and 2017 there were at least 946 incidents of orangutan-related crime in Kalimantan, Indonesia, and at least 50 incidents of orangutan-related crime in Sabah and Sarawak Malaysia. Few orangutan-related crimes perpetrated in Kalimantan were investigated, prosecuted or convicted during the study period. Indonesia did not make any convictions based solely on illegal orangutan possession between 2007 and 2017, although one person was convicted for local trade of a Bornean orangutan (Freund et al., 2017; Karokaro & Hanafiah, 2019; Nijman, 2017). Indonesia made six successful convictions of orangutan-related crime between 2007 and 2017, a conviction rate of less than 0.6% for all reported criminal activities during the study period. Malaysia made three successful convictions, a conviction rate of 6% for all orangutan-related crimes between 2007 and 2017.

### Management of orangutans in concessions

Our stakeholder questionnaire data from eight concession companies and 15 NGOs indicate there is limited implementation of Best Management Practices (BMPs) at the local level in industrial concessions. Stakeholders reported that use of deterrents to keep orangutans out of crop areas in Kalimantan was uncommon, although we are aware of some instances of isolating an area with drains filled with water (since orangutans cannot swim). Stakeholders also reported concession managers do not plan operations in ways that would deter orangutans from crop-foraging.

### Financial analysis

We analyzed the 2016 budgets of 145 organizations working on orangutan conservation, and allocated their funding within six broad orangutan conservation strategies (Figure 2.3). Most of the conservation investments were allocated in 2016 to rescues, rehabilitation, reintroduction, and translocation of orangutans (USD $5,365,873), then community outreach, training and policy (USD $4,093,106); habitat protection (USD $3,941,563); law enforcement and patrolling (USD $2,871,262); habitat restoration (USD $2,835,977); and research (USD $2,235,782). The largest investor was the private sector, mainly concessions, (USD $7,463,094), just ahead of the orangutan rescue centers (USD $7,141,367). Government investment was fairly small comparatively, with approximately USD $1.7 million focused on orangutan conservation implementation.

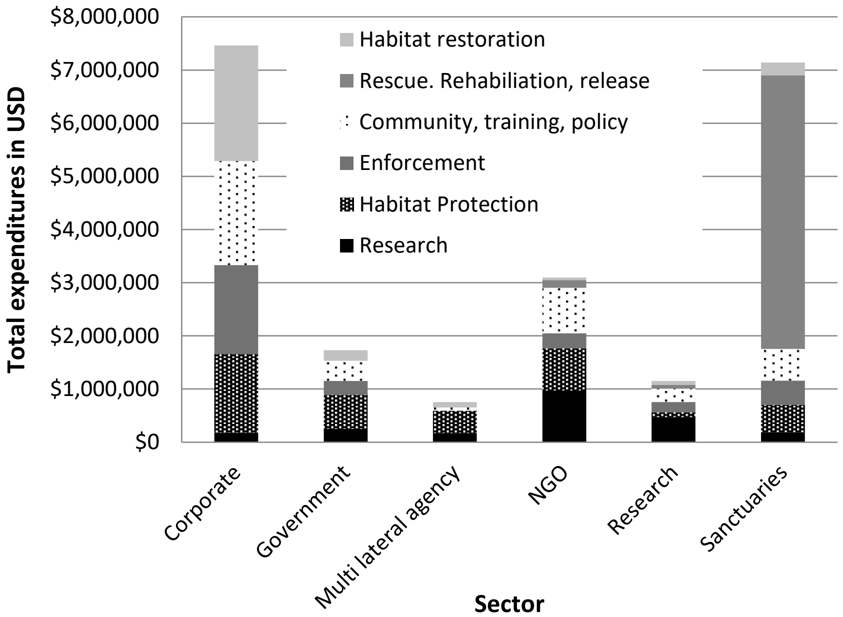


**Figure 2.3. Annual estimated budget allocations in 2016 to six different conservation strategies by six different types of organizations.**

## Habitat loss and habitat protection

Forests in orangutan range have declined since 2007 (Figures 2.4 – 2.5). However, protected areas have increased, most notably within Sabah and Sarawak, Malaysia, and in Central Kalimantan (Figure 2.6). The Malaysian states of Sabah and Sarawak have decided to fully protect most of the orangutan range as a conservation strategy, and the recent surveys show the populations in these two states are becoming stable (Simon et al., 2019), except in non-protected or in fragmented forests. The network of fully protected forests in Kalimantan is smaller relative to forest extent and the prevalence of detected illegal activities (see Results sections on Rescue and release, and Law enforcement).

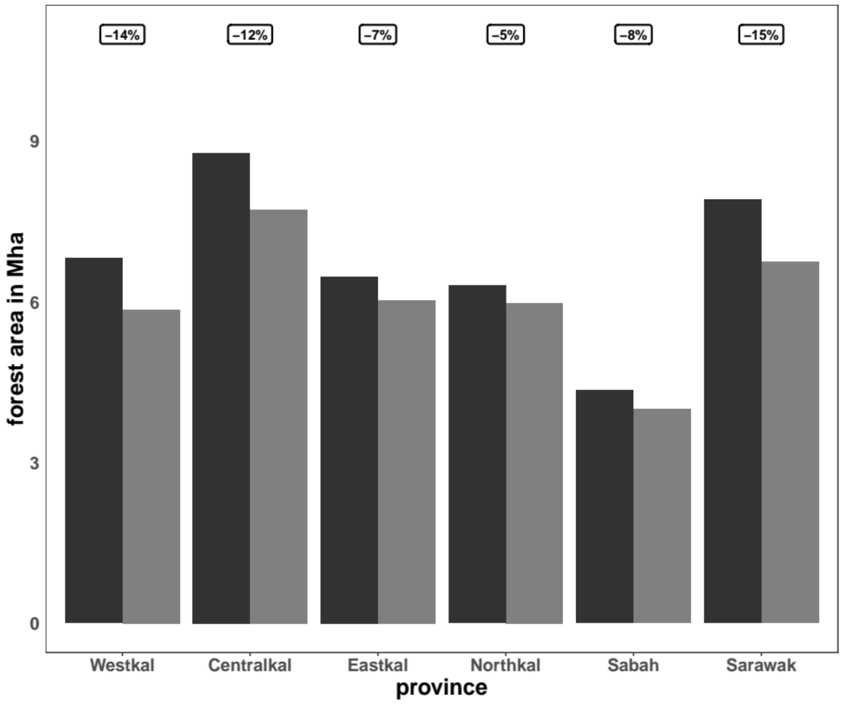


**Figure 2.4. Forest change in Borneo by province between 2007 and 2017.** Percent change is indicated in the rectangle. Forest cover is based on maps by (Gaveau et al., 2016a).

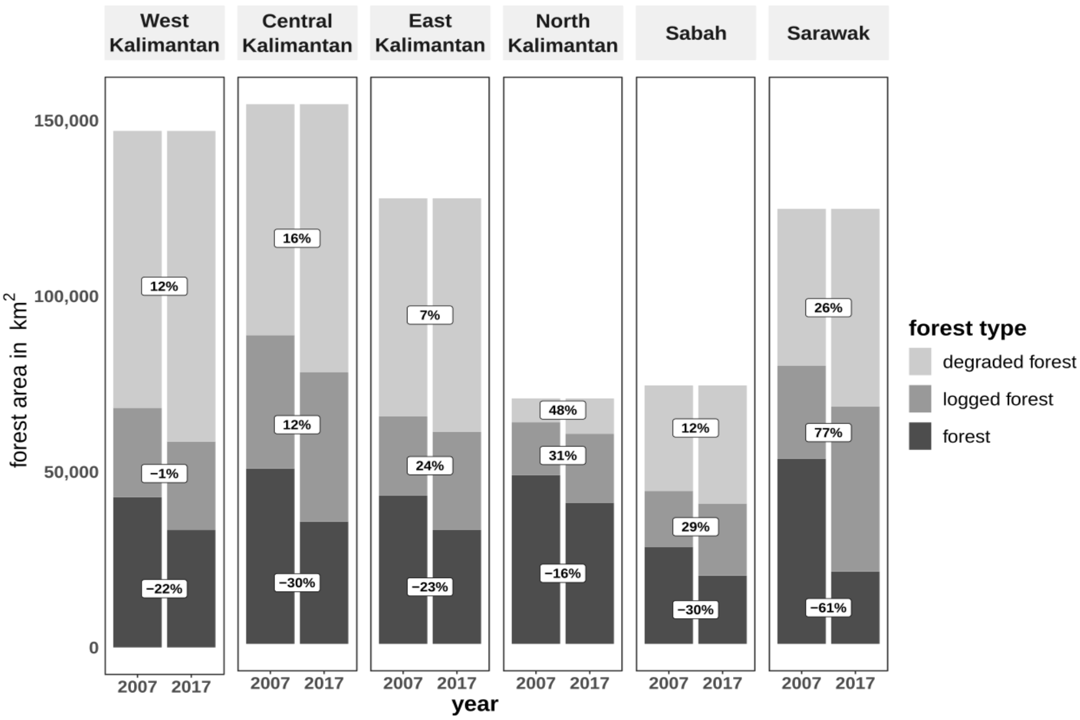


**Figure 2.5. Forest change, degradation, and logging in Borneo by province, 2007-2017.** Categories are: forest (unlogged, 100% forest cover); logged (50-100% forest cover); and degraded (>0-50% forest cover). Percent change is indicated in the rectangles. Forest cover is based on maps by Gaveau et al. (2016a) and percent is derived from the percent 30x30m pixels within a 1x1km pixel that were deforested.

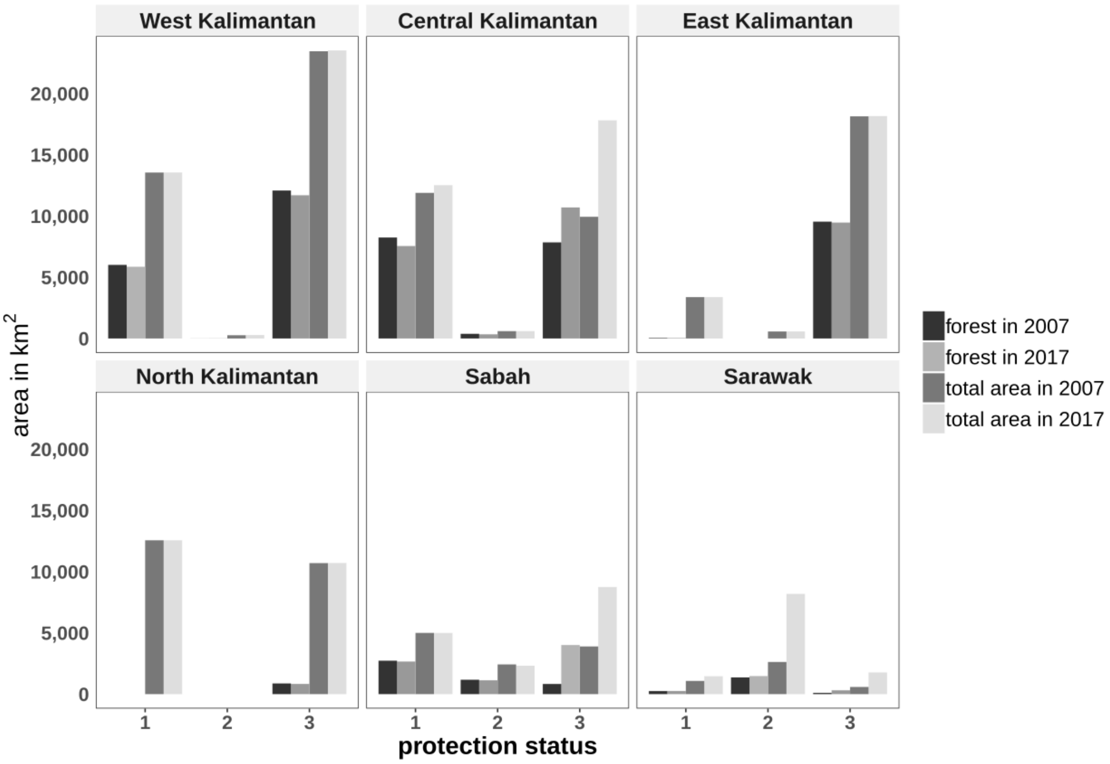


**Figure 2.6. Change in forest area and total area under protection status by province, 2007-2017.** Protection status 1 is IUCN category 1-3, status 2 is IUCN category 4-6, as well as "not reported" or "not applicable", status 3 are all other protection categories as included in Santika et al. 2017, such as Hutan Lindung (Kalimantan) and permanent forest reserves, virgin jungle reserves and wildlife reserves (Sabah).

## Orangutan population trends

Recent studies have strongly indicated that actual (not estimated) population size has dramatically decreased over the past 200 years (Goossens et al., 2006; Meijaard et al., 2010) and that this decline has continued over recent decades (Santika et al. 2017; Voigt et al. 2018). Contrary to these findings noted above, the Indonesian government has recently published monitoring data showing orangutan populations dramatically increasing, even in some cases more than doubling over a few years, a rate which is not biologically possible for orangutans (Meijaard et al., 2018; MOEF, 2018). Some of the government monitoring data were from sites used for orangutan introductions or translocations (e.g., Bukit Baka-Bukit Raya National Park), implying that any net positive change in the monitored sites was inevitably preceded by at least an equally large negative change in non-monitored populations from which orangutans had been initially removed (KSDAE, 2018b). All the government monitoring sites are within protected areas, whereas the majority of orangutans occur in non-protected lands. It is thus scientifically unjustified to extrapolate population trends from these sampling sites to the total range of the species (Meijaard et al., 2018).

### Threats to the orangutan populations

The loss of orangutans in primary and selectively logged forests between 1999 and 2015 accounted for between 67% and 83%, respectively, of the total orangutan decline on Borneo, indicating that killing was an important driver of declines (Voigt et al. 2018). Deforestation and industrial oil palm and paper pulp plantations appeared to be responsible for about 9% of the total loss of orangutan abundance (Voigt et al. 2018). Nonetheless it is apparent that the deforestation, plantation development and killing in conflict situations often go together as drivers of orangutan population declines (Santika et al., 2017a).

### Changed thinking - what is orangutan habitat and what makes a population?

Orangutan habitat is popularly described as intact native forest. However, wild orangutans have been increasingly found using forest fragments located in agricultural landscapes (Ancrenaz et al., 2015; Spehar & Rayadin, 2017). Those fragmented forests and even the agricultural land used by orangutans are what make up their habitat (i.e. any area the animals use). Further, the full extent of this varied habitat should be considered part of the orangutan metapopulation habitat. Indeed, field observations show these small forest patches are used by resident female orangutans and visited by traveling males, demonstrating the role of these patches in providing connectivity within metapopulations (Ancrenaz et al., 2015). Removing and translocating animals found in these patches, and destroying these fragments, results in loss of connectivity and movement among elements of the orangutan metapopulation, posing risks to metapopulation viability (Figure 2.7).

### Value of forest fragments for orangutan conservation

There are at least 6,620 $km^2$ of forest fragments between 1 and 50 $km^2$ in size across Borneo (Figure 2.8).

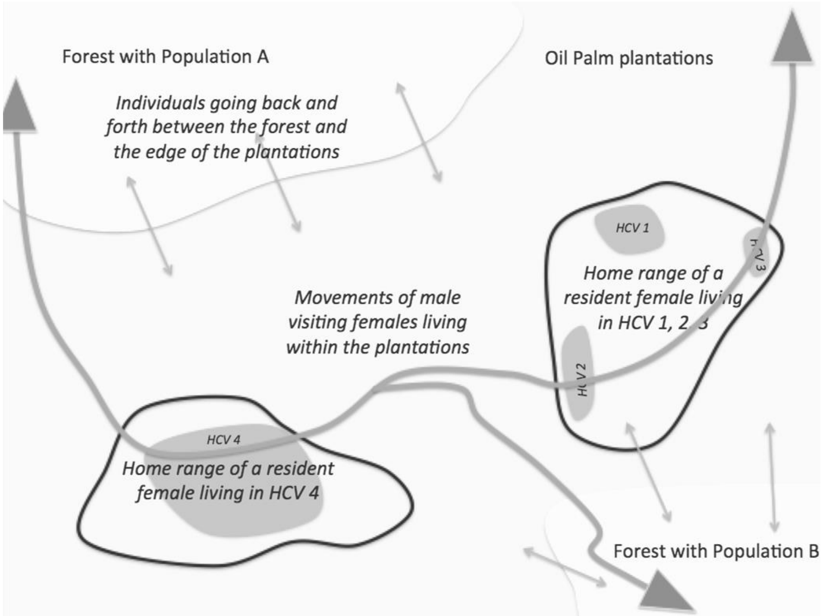


**Figure 2.7. Movement patterns of orangutans in mosaic landscapes.** Data from HUTAN-Kinabatangan Orang-utan Conservation Program

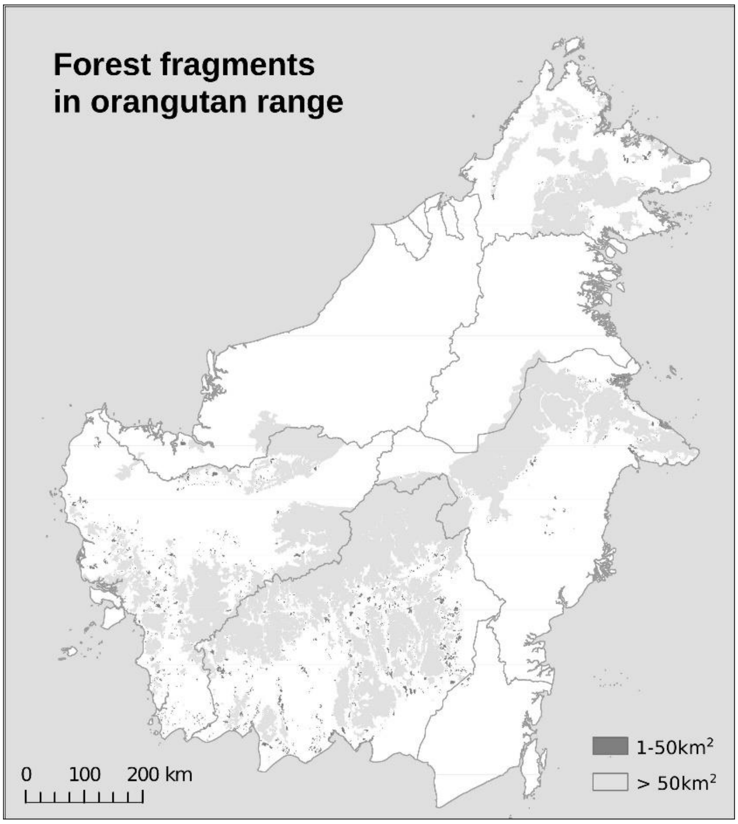


**Figure 2.8. Orangutans in forest fragments.** These fragments are essential links between the major orangutan populations in larger habitat areas (larger orangutan habitat areas are shown in light grey). This map does not show fragments that are less than 1 km2, but these tiny fragments are also vital to sustain connectivity between isolated forests. There may be tens of thousands of such tiny fragments

## 2.4 Discussion

Research findings indicate orangutans can survive in disturbed and human-dominated landscapes, meaning a key management focus should be to minimize the killings that often occur in landscapes where people and orangutans frequently meet. In the absence of killing, orangutans survive in highly fragmented forest areas embedded in industrial agriculture dominated landscapes. The large majority of orangutans on Borneo occur in areas where they frequently encounter people, and thus conservation solutions must effectively incorporate these people.

### The role of rescue, rehabilitation, and reintroduction

Rescue of animals seized during law enforcement action, and provision of improved welfare for these animals, is an important role of rescue centers (Sherman & Greer, 2018). Rehabilitation and reintroduction can likewise provide an opportunity to re-establish locally extirpated populations and reinforce populations below carrying capacity (Beck et al., 2007; IUCN/SSC, 2013). In the case of Bornean orangutans, possibilities for well-managed releases that comply with IUCN reintroduction guidelines are constrained by the sheer number of orangutans in captive care, coupled with the limited available habitats with absent or sufficiently low resident wild orangutan populations that can be adequate protected from poaching and land clearing (CITES/GRASP, 2006; Russon, 2009). Together with the apparent feedback cycle that encourages turnover of pet orangutans to rescue facilities without a connection to increased deterrence of illegal orangutan harm, killing and possession (Karokaro & Hanafiah, 2019; Nijman, 2017), this underscores that rescue and reintroduction should not be seen as the primary intervention to secure long-term viability of *P. pygmaeus*. At best, it should be viewed as a tool to provide a chance for a relatively small number of psychologically, behaviorally and physically suitable individuals to be readapted to semi-wild or wild conditions of life.

### Wild capture and translocation of orangutans

Wild-to-wild translocations are seen as a solution for orangutans living outside protected areas in Indonesia. In Kalimantan, translocations have been removing and translocating entire viable populations from agricultural mosaic landscapes they could likely have thrived in if properly managed. The single available estimate suggests the majority of the translocated animals have disappeared and may not have survived after a few years, which means these populations could be simply lost, and that individual welfare of released animals is not ultimately improved. While there are isolated cases where capture and translocation is warranted, the practice of moving orangutans to prevent potential conflict appears to be creating the expectation that people need not accept living near these animals and that moving them out of the way is a positive outcome for orangutan conservation and people (ProKal, 2017). A new paradigm is needed to prevent removal of wild orangutans except in the most extreme circumstances. The number of orangutans outside protected areas may number in the tens of thousands in Kalimantan alone (Utami-Atmoko et al., 2017a). Removing this number is beyond the capacity of rescue programs, and suitable release sites do not exist to accommodate such numbers. It is therefore important to refocus efforts on protecting orangutans in forest patches outside the State Forest land (Indonesia) and protected lands in both Indonesia and Malaysia. This will require additional efforts on law enforcement and effective conflict mitigation, and increased buy-in from the government authorities to address *in situ* solutions.

**Enforcement of orangutan protection laws**

The vast majority of illegal actions against orangutans in range countries likely go unremarked by authorities. The apparent *modus operandi* of both the government and rescue centers of focusing on rescue without accompanying investigation and prosecution of law-breaking has been identified by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and wildlife crime researchers as a systemic failure (CITES/GRASP, 2006; Nijman, 2017). Orangutan killing rates continue to be high, as most of the animals coming into rescue centers are in some way associated with killing (i.e. dependent infants recovered without their mothers) or outright injury (gunshot or knife wounds) to orangutans. It is obvious from newspaper reports and rescues that significant numbers of orangutans are being lost in this manner and that this is a threat that needs to be taken more seriously. Overall, conviction and prosecution of people keeping, harming or killing orangutans are extremely low, and insufficient to provide deterrence. Nijman (2017) and Freund et al. (2017) provide detailed recommendations to improve law enforcement. We encourage the prompt adoption of these suggestions which are predicated on increased willingness to pursue enforcement action for illegal activities. Nijman (2017) recommends investigation and prosecution of every instance of orangutan trade (trade encompasses buying, selling trading or keeping orangutans). We additionally encourage rational sentencing guidelines that take into account the prevalence of orangutan trade by both local villagers and large corporate concessions. Freund and others (2017) recommend higher fines and prison time for concessions that illegally clear lands outside their boundaries. Nijman (2017) and Sherman and Greer (2018) recommend rescue centers' agreement to take in illegally held animals on behalf of the government should be explicitly tied to government agreement to investigate and prosecute offenders. Prosecutions should be widely publicized to encourage deterrence (Nijman, 2017; Sherman & Greer, 2018). We also recommend studies be conducted to test messages, tools, and training that would foster human-orangutan conflict mitigation and mutual tolerance, including compensation for crop-raiding and other orangutan related losses. Ongoing studies on the anthropology of orangutan killing will be helpful to inform the kind of messages that could result in lasting perception and behavior change.

Moving orangutans from their habitat are also forbidden under Indonesian law UU 5 of 1990 unless this is needed to save the species or if the animal is a threat and could harm people. Nonetheless, capture and removal of orangutans from industrial agriculture and forestry concessions is commonplace despite its undermining the intactness and functions of orangutan metapopulations and thereby the species' conservation. Although the need for BMPs for rare species on industrial plantations is fairly well understood and accepted at senior and mid-management level, the uptake and their field implementation are relatively limited. Indeed, these BMPs need to be translated into practical "Standard Operation Procedures" (SOPs) that in turn must be incorporated into actual on-the-ground management. This is challenging for most companies because they lack the capacity to understand, interpret and implement these kinds of BMPs and associated SOPs. Most of the time, companies will rely on outside consultants or NGOs to deal with an "orangutan issue," missing an opportunity to become actively engaged in orangutan management themselves. A necessary first step for companies would be to institutionalize orangutan management through developing their own in-house capacity to identify, monitor, and manage biodiversity elements that occur within their estates. Companies should employ their own teams of ecologists to monitor and manage all HCV forests in their plantations. These teams need to have sufficient authority to influence estate planning that would be more in line with company commitments towards biodiversity conservation. Because the core business of these companies is not biodiversity conservation, developing such an approach may require attaching the services of primatologists and professional orangutan experts to guide management strategies and to train the in-house sustainability teams on orangutan management and monitoring. Developing and implementing management plans for protected species including orangutans is becoming a requirement for certification, indicating that willingly or not, private estates operating in orangutan range will increasingly be held responsible for managing this species within their boundaries. Very little information is available about smallholder interactions with orangutans. Considering the small size of their plots smallholders rarely set aside forest patches in their fields. Orangutans are often perceived as a "pest" by most smallholders, and have been for a long time (De Telegraaf, 1934), and the majority of the people prefer to not see an orangutan within their fields. Despite full legal protection of orangutans, people who encounter orangutans on their land will either try to drive the orangutan away from their fields; ask a governmental or non-governmental organization to translocate the problem animals; or sometimes kill the animal (Davis et al. 2013; Abram et al. 2015). Considering that smallholders represent about 40% of the total surface area planted with oil palms across Borneo (Naylor et al., 2019), and acknowledging that several thousands of orangutans are found within oil palm landscapes, it becomes urgent to reach out to smallholders to shift their mindset and increase their tolerance toward orangutans. In particular, there is a need to work with them to identify peaceful mitigation options in case of conflicts (including compensation); and to design better connectivity in the landscape by considering an entire jurisdiction. Payments to communities who effectively protect local orangutan habitat and populations could also be considered.

**Orangutans in forest fragments**

Translocating orangutan from small forest patches in agricultural landscapes is an increasingly common tool in orangutan conservation. The arguments are that the forest patches are doomed anyway to be converted to non-forest, and that the orangutans would otherwise be killed. Our analysis of translocation outcomes and recent scientific studies on orangutan habitat use indicate that removing orangutans from forest patches that are still connected by vegetation types used by orangutans for dispersal (including mature oil palm and acacia plantations), undermines the metapopulation structure (Ancrenaz et al., 2015; Oram, 2018; Oram et al., 2019; Spehar & Rayadin, 2017). One other problem with the argument for removal and translocation is that once the orangutans are removed from a forest patch (or at least those animals that could be captured), the forest patch and its other remaining wildlife are more likely to be lost, because the forest patch has lost what little protection it received because it contained orangutans. The loss of the forest patch thus means the loss of all other wildlife that was not rescued as well as loss of ecosystem services provided by the forest. Riparian forests in Indonesia and Malaysia need to be maintained by law and to comply with oil palm certification standards (Barclay et al., 2018; Republic of Indonesia, 2011; Sabah Water Resources Enactment, 1998) but are nonetheless often converted to non-forest. These riparian forests provide habitats for a range of species, and maintain water quality and freshwater diversity, thus providing services to local communities (Abram et al., 2014; Mitchell et al., 2018; Sudrajat & Putro, 2019a). Similarly, forest patches in agricultural landscapes provide habitat for a range of mammals, including orangutans, birds, and insects that use these as stepping stones in transient landscapes (Bernard et al., 2014; Lammertink, 2004; Lucey et al., 2014; Sudrajat & Putro, 2019b). Furthermore, forest patches and linear fragments play important roles in preventing floods (Wells et al., 2016).

A better decision-making tool is needed to determine the best option between the two strategies of "rescuing" orangutans from isolated forest patches or investing in retaining these patches with their orangutans and other wildlife, and ecosystem services. While the rescue of orangutans entails a short term cost and effort compared with the long term cost and management effort of maintaining forest patches, these patches enable survival not only of resident orangutans but other wildlife, as well as securing water quality, flood prevention, and associated human wellbeing benefits. In some rare circumstances orangutans may be in immediate danger from humans or fires, need medical care, or be isolated in an area where access to other forest habitat is entirely blocked or too distant, in which cases rescue and translocation may be an alternate solution. In general, however, orangutans are able to travel on the ground or through non-forest habitats to access food resources and other socioecological needs in other forest patches (Ancrenaz et al., 2014; Spehar et al., 2018). Further, interviewees for this study report that evidence is lacking on whether orangutans are likely to survive their removal to another habitat where they do not have established social relationships with other residents nor knowledge of where to find food resources (Kaye, 2016; Oram et al., 2019). Currently, given the hundreds of orangutans rescues annually, the choice to rescue is taken relatively easily, but there is insufficient consideration of the impacts this has on the overall orangutan metapopulation, other wildlife and ecosystem services that are likely lost once orangutans are rescued. Multiple stakeholders reported to us that, as rescue and some news stories data collected for this study also suggest, rescue and translocation create a framework in development and conservation thinking in which orangutans that are in the way of development or are inhabiting forest fragments can simply be "rescued" and moved elsewhere as a "win-win" for conservation and development, without consideration of the costs to overall conservation objectives and environmental health (Asrianti, 2011; Kaye, 2016; ProKal, 2017).

Clear-cutting forest patches make the overall landscape less and less suitable for orangutans and other wildlife. Where hunting is not an issue, orangutans can use an extensive oil-palm or forestry plantation landscape, but to do so they need forest corridors and forest patches (Ancrenaz et al., 2015; Ancrenaz et al., 2014; Spehar & Rayadin, 2017). If these small islands of forests are removed, the animals cannot use the landscape anymore and the population becomes extremely fragmented and not viable in the long-term. The long-term option would be to design landscapes that incorporate existing plantations, which could also accommodate orangutans. The goal for these mosaic landscapes should be saving natural habitat (whatever size the patches) that can help support orangutan populations, versus removal of individual animals at the cost of losing habitat for local wild orangutans. A paradigm shift is needed about how people view what is a proper orangutan habitat: Along with critically important protected forests, well designed agricultural landscapes could play a role in helping to sustain the species.

**A future for the Bornean orangutan**

Effective conservation of Bornean orangutans is both necessary and feasible given the species' flexibility in habitat use, but will require refocused and renewed efforts by stakeholders. Key recommendations for improved orangutan populations outcomes are: (1) Forest fragments in orangutan habitat range should be protected and connected; (2) Law enforcement in Indonesia must be improved and strategies must be developed to help manage and mitigate human-orangutan conflict without removal of animals in multiple-use landscapes; (3) Rescue, rehabilitation and reintroduction or reinforcement of existing wild populations should not be considered the primary means to ensure population viability; and (4) Wild-to-wild translocation is not an appropriate conservation strategy for orangutans. We are continuing our studies to determine the most cost-effective strategies for maintaining current wild orangutan populations or increasing them to a new stable and viable population size.

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# Chapter 3. Shifting apes: Conservation and welfare outcomes of Bornean orangutan rescue and release in Kalimantan, Indonesia

Julie Sherman[a,*], Marc Ancrenaz[b,c], Erik Meijaard[b,d,e]

a. Wildlife Impact, PO Box 31062, Portland, OR, 97217, USA
b. Borneo Futures, Block D, Unit 8, 1st Floor, Shakirin Complex, Spg 88, Kg Kiulap, BSB BE1518, Brunei Darussalam
c. HUTAN-Kinabatangan Orang-utan Conservation Programme, P. O. Box 17793, 88874, Kota Kinabalu, Sabah, Malaysia
d. Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Canterbury, CT2 7NR, UK
e. School of Biological Sciences, University of Queensland, QLD, 4072, Australia

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**Abstract**

For more than 50 years, Critically Endangered Bornean orangutans (*Pongo pygmaeus*) have been rescued from poachers or captors, then rehabilitated and released into natural habitats. Wild orangutans are also translocated—intentionally captured from habitat patches and insecure situations for the purpose of releasing them into areas considered to be safer. Although these activities are widely applied, data on orangutan conservation and welfare effects are lacking. Our study improves understanding of these outcomes through analysis of Bornean orangutan rescues and releases conducted in Kalimantan, Indonesia between 2007 and 2017. We collected data on orangutan rescues (n = 1517) and releases (n = 1219) from rescue facility reports, newspaper articles, and scientific publications, and assessed outcomes in relation to action plans, international standards for wildlife releases, law enforcement, and wild orangutan population and habitat conservation. High levels of orangutan killing and illegal possession drove rescue facility intake, while deforestation, actual or potential human-orangutan interactions, and fires drove large-scale wild orangutan translocations. We found rescue facilities held 1112 orangutans in 2017, a number largely unchanged since 2007 despite 1219 reported releases including 605 ex-captive orangutans and a minimum of 523 translocated wild orangutans. Rescue has not facilitated notable changes in law enforcement, nor forestalled wild orangutan losses. Translocations in particular pose serious risks to conservation of orangutan metapopulations and individual welfare. Substantial changes in law enforcement, human attitudes and behaviors toward orangutans, and improved management of human-orangutan coexistence are needed to disrupt the current cycle of orangutan killing and illegal possession followed by rescue and release. These changes would enable a much-needed renewed focus on protecting wild orangutans in their natural habitats.

**Keywords**
Bornean orangutan, Conservation, Reintroduction, Translocation, Law enforcement

## 3.1 Introduction

The Bornean orangutan, *Pongo pygmaeus*, is classified as Critically Endangered by the IUCN Red List of Threatened Species (Ancrenaz et al., 2016a). The main threats to Bornean orangutans in Indonesia are forest clearing for industrial agriculture, forestry plantations, mining, smallholder cultivation, and rural development, fires, and killing for bushmeat, human-orangutan conflict, and live capture (Abram et al., 2015; Santika et al., 2017a; Voigt et al., 2018; Wich et al., 2012; Wich et al., 2008). Indonesia's Act Number 5, 1990, prohibits capture, injury, killing, transport, trade, and possession of orangutans, which is punishable by up to five years imprisonment and/or a maximum fine of IDR 100 million, or approximately $7100 USD at September 2019 exchange rates (Nijman, 2017). International trade of orangutans is likewise prohibited under Indonesia's Act Number 8, 1999. Nonetheless, killing, possession and trade—primarily national—of orangutans is widespread in Indonesia (Davis et al., 2013; Freund et al., 2017; Nijman, 2017). Forest clearing and increased human access to orangutan habitats are contributing factors as both can result in orangutans coming into more frequent contact with people, facilitating killing of adults and capture of infants, which are often kept or sold as pets (Freund et al., 2017; Gaveau et al., 2013; Meijaard et al., 2011a; Santika et al., 2017a). Orangutan infants are strongly dependent on their mothers for an average period of eight years or more (van Noordwijk et al., 2018), thus obtaining infants requires mothers to be killed in nearly all instances (Freund et al., 2017; Meijaard et al., 2012; Russon, 2009; van Noordwijk, 2009).

For more than 50 years, removing orangutans from illegal situations such as trade or possession as pets (commonly called 'rescue') and subsequently releasing them into natural habitats has been a prominent conservation strategy (Grundmann, 2006; Harrisson, 1961; KLHK, 2018; Rijksen & Meijaard, 1999; Russon, 2009; Sugardjito & van Schaik, 1992). Two categories of rescue and release are commonly practiced in Kalimantan. The first category begins with surrender or confiscation of orangutans illegally held, orphaned, or legally held in unsuitable situations, that are then taken into rescue centers. These animals are rehabilitated, and, if deemed suitable candidates for survival in the wild, released into natural habitats. Practitioners call releases of these ex-captives 'reintroduction,' although technically these activities encompass both reintroduction (release into indigenous range areas where previous populations have been extirpated), and reinforcement (release of individuals into existing conspecific populations) (IUCN/SSC, 2013). The second category is translocation of wild orangutans purposefully captured by rescue practitioners from perceived unsuitable habitats or insecure situations and released into natural habitats elsewhere (Kaye, 2016; Maruf & Rayadin, 2015; ProKal, 2017). These translocations are also conducted when wild orangutans are stranded away from natural food sources, are captured or attacked by humans, or are in need of medical intervention (Beech, 2019; Mendonça et al., 2016; Tabuchi, 2016). Despite the widespread use and significant resource allocation to rescue, rehabilitation and reintroduction, as well as to wild capture and translocation, there are few peer-reviewed studies of the conservation outcomes of these activities (Russon, 2009; Wilson et al., 2014).

Indonesia's orangutan action plan for 2007-2017 (*Strategi dan Rencana Aksi Konservasi*, called 'SRAK 2007') mandated all orangutans to be released from rescue facilities by 2015 (Ministry of Forestry, 2009). SRAK 2007 also called for preventing any loss of orangutans from concession lands, and concluded that translocation of wild orangutans from "damaged habitat" should be a last resort (Ministry of Forestry, 2009). A 2019-2029 orangutan action plan (called 'SRAK 2019'), was published in 2019 but has been withdrawn for further revision (Foresthints, 2019). The draft SRAK 2019 stated that rescue centers are over capacity, and called for all suitably rehabilitated ex-captive orangutans to be released into natural habitats by 2022 (KSDAE, 2019d). It further authorized wild orangutan translocations from forestry, mining and agricultural concessions when the animals are in unsustainable or insecure situations but did not provide details about such qualifications, and indicated such translocations should be minimized (KSDAE, 2019d). Both the SRAK 2007 and the draft SRAK 2019 plans stipulated orangutan releases should comply with relevant IUCN guidelines (KSDAE, 2019d; Ministry of Forestry, 2009).

The IUCN developed international standard guidelines for wildlife releases conducted primarily for conservation purposes, and best practice guidelines for great ape reintroduction, both aimed at preventing harm to wild conspecific populations, improving success for released animals, and promoting self-sustaining populations (Beck et al., 2007; IUCN/SSC, 2013). These guidelines are bounded by precautionary principles of: (1) not endangering resident wild conspecifics via disease, hybridization, excessive social disruption or exacerbated competition for habitat resources; (2) not endangering other interacting native taxa or the ecological integrity of the area; and (3) prioritizing conservation of the taxon and of resident wild conspecifics over the welfare of individual releasable animals (Beck et al., 2007; IUCN/SSC, 2013). Releases conducted solely to improve individual welfare, reduce captive populations, secure funds or publicity, or move animals for economic development purposes do not meet IUCN criteria for conservation releases (IUCN/SSC, 2013).

Today several assumptions underpin orangutan rescues and releases: (1) the act of rescuing illegally held orangutans facilitates law enforcement efforts (Sherman & Greer, 2018); (2) release of ex-captive orangutans can provide individuals a chance to live independently in natural habitats (Russon, 2009); (3) releases support conservation by protecting habitats; and (4) releases help to re-establish locally extirpated populations or bolster diminishing wild populations, thereby meeting IUCN guidelines (CITES/GRASP, 2006; Grundmann, 2006; Palmer, 2018; Russon, 2009). The welfare of surrendered or confiscated orangutans is also assumed to be improved through transfer to rescue centers (Trayford & Farmer, 2013); however, analysis of this aspect of rescue is outside the remit of this study. Peer-reviewed studies testing these assumptions are lacking, although some studies have looked at some specific aspects of rescue and release success. Russon (2009) investigated orangutan rehabilitation and release elements including rehabilitation success, survival after release, and success in establishing self-sustaining populations. Wilson et al. (2014) looked at cost effectiveness of rehabilitation and reintroduction, and Palmer (2018) addressed the ethics of rescue and release. To improve orangutan conservation outcomes, it is vital that management decisions on Bornean orangutan rescue and release are based on empirical evidence of risks and effectiveness in meeting conservation goals. We collected 10 years of available data on Bornean orangutan rescue and release activities, with the objective of improving understanding of how orangutan rescue and release strategies are applied in practice, and their conservation and welfare outcomes and risks.

This paper aims to answer the following research questions: (1) did rescue facilities meet SRAK 2007 goals to release all ex-captive orangutans by 2015, and is the SRAK 2019 goal to release all suitable ex-captive orangutans by 2022 achievable given current progress?; (2) what are the reasons for orangutans being taken into captive care facilities?; (3) do rescues of illegally held orangutans facilitate law enforcement?; (4) what are the welfare and survival outcomes for released ex-captive orangutans?; (5) what are the reasons for capture and translocation of wild orangutans?; (6) are wild orangutan translocations employed as a last resort, as per SRAK mandates?; (7) do translocations support wild populations and released individuals' welfare?; (8) do releases of ex-captive orangutans and translocations of wild orangutans support habitat protection?; and (9) do releases comply with IUCN guidelines?

## 3.2 Methods

We conducted a systematic review of public and unpublished data on Bornean orangutan rescues and releases between January 1, 2007 and December 31, 2017 (Appendix 3A). These data covered an estimated 85% of the total number of the rescues and releases in public reports from practitioners. We determined this percent coverage by comparing the total numbers of individual rescue and release events we found data on with the total numbers of rescues and releases in practitioners' public reports. We collected data from self-published reports and public tax/charity commission records of Bornean orangutan rescue centers in Kalimantan, as well as third party published sources, and peer-reviewed studies. We also collected data from archived newspaper articles by searching Prokal and TribunNews (Kalimantan), Jakarta Post and Jakarta Globe (Indonesia), Borneo Post, and Borneo Today (Borneo regional) websites, using the search term "orangutan" to capture any relevant news published between 2007 and 2018 (the hyphenated term orang-utan is not commonly used in Indonesia). We presented initial sets of compiled self-reported annual data to each rescue center for review and input in June 2018. We also sent an email survey to rescue and release practitioners and orangutan researchers about their views on post release monitoring (PRM) best practices. The survey was sent to 10 orangutan rescue centers and nine orangutan researchers (Appendix 3A). We received six responses, three from rescue and release practitioners and three from researchers not associated with orangutan rescue and release. Additional unpublished data or contextual information were gathered through semi-structured interviews with 43 stakeholders via phone, email and in person (Appendix 3A). We compiled data on annual captive populations and annual numbers of orangutans rescued (sum of total animals rescued annually between 2007 and 2017 = 1517), annual release numbers by type (reintroduction/reinforcement, translocation, wild captured orangutans held for more than six months in captivity, re-release) (sum of total animals released annually between 2007 and 2017 = 1219), and annual births and deaths at rescue facilities, as well as mortality incidences during translocation or post-release. These data were taken from rescue centers' annual reports, tax or charity commission reports, and from annual summary data on websites or social media where formal reports were not provided. Where numbers from various sources were in conflict, we selected the number best supported by most sources or verified by communications with rescue centers. We also compiled and coded available data on as many of the individual instances of orangutans rescued and released as available, a subset of the 1517 rescues and 1219 releases that were identified from annual records (n = 1285 total number of individual orangutans rescued; n = 1031 total number of individual orangutans released). Sources are listed in Appendix 3A. We excluded from our dataset records of large-scale captures and translocations of an additional 1224 orangutans by industry and private companies because we were unable to verify if these instances were represented elsewhere in our dataset. We aggregated data by rescue/release entity and identified possible duplicates using any available combination of animal name, age, date and circumstances of rescue or release. We excluded all duplicates and any records where it was unclear if the animal had been previously recorded. We compiled data by individual orangutans where possible, including name, sex and age, or when these identifiers were not available, by date, location and/or description of rescue or release circumstances. Rescues were classified as: (1) confiscation (seizure of animal by law enforcement authorities); (2) surrender (willing handover by captor or rescuer); (3) wild capture (for translocation to another habitat); (4) other rescue types (medical interventions, transfer of legally held animals in unsuitable conditions); and (5) re-captures of previously released orangutans (Appendix 3B). Releases were classified as: (1) reintroduction/reinforcements (release of ex-captive orangutans that spent more than 6 months in rehabilitation facilities); (2) wild-to-wild translocation ('translocation' per practitioner terminology; any wild orangutan captured and released within six months or less); (3) wild captured orangutans held in captivity at rescue centers for more than six months; and (4) re-releases (release of previously released and recaptured orangutans) (Appendix 3B).

Our aim was to seek potential improvement in the effectiveness of orangutan conservation activities, rather than to point to concerns related to specific entities conducting rescue and release. Hence stakeholder inputs and data attributable to individual stakeholders were kept anonymous, and data are presented by variables rather than by entity.

Due to inconsistencies in data reporting and availability across sources, we made a set of assumptions to classify data systematically (Appendix 3B). We used dependence on mother and age of sexual maturity to define infant and adult age classifications, respectively. Bornean orangutans are strongly dependent on their mothers until they are weaned at 6-9 years old (van Noordwijk, 2009). To avoid overestimating the number of dependent orangutans and thus the capture of infants associated with killing of mothers, we used the lower bound of this range—six years—as the age at which orangutans could become independent juveniles, and we classified orangutans five years and younger as infants. We based our adult age class of >15 years on the age of first reproduction for wild Bornean orangutans (Russon, 2009; van Schaik et al., 2009).

Reasons for rescue of both surrendered/confiscated and wild captured orangutans were based on the proximate rationale provided in rescue records, such as illegal possession as a pet, or desire to prevent a wild orangutan consuming human crops (Appendix 3B). We also collected available data on underlying factors, such as fires or forest clearing in orangutan habitats, which in turn can result in orangutans traveling or foraging in agricultural fields (Appendix 3B). Capture, harm, possession, sale, or trade of orangutans is illegal whatever the motivation, excepting intake and release of orangutans by permitted facilities such as rescue centers. Hence, motivations that may be driving people to illegally obtain or keep orangutans, such as concern for their welfare, were not considered here. Previous analyses found that most rescued orangutans were illegally held as pets, and more rarely were intended for sale or trade, or were victims of bushmeat poaching or of retaliatory killings over orangutan crop consumption or other human-orangutan interactions (Freund et al., 2017; Nijman, 2017; Russon, 2009). The subset of records in our dataset which provided detailed information on rescued orangutans' history showed that 96% of the orangutans illegally held captive were kept as pets at some point. We thus considered illegally held orangutans were kept as pets unless rescue records noted other reasons. Records of other reasons for orangutans being held captive were rare, and included being sold, used as a tourist attraction, found orphaned and immediately delivered to authorities, or being held in relation to a negative interaction with humans. To decrease the proportion of instances with missing data, we also inferred that all records of illegally held orangutans which lacked any explanation for their captivity were held as pets. Parameters and assumptions used to code raw data are detailed in Appendix 3B.

We estimated killing by counting the number of orangutans (OU) reported killed in rescue records, and added the sum of an estimated one adult (the mother) killed for each rescued infant for all records wherein no such information was provided. Other crimes including possession, trade or harm were recorded and summed whenever noted in rescue incident records. The number of crimes (Y) was determined by the equation: $Y = K_{\text{OU reported or estimated killed}} + A_{\text{OU reported captured, attacked or injured}} + Pe_{\text{OU held captive}} + Po_{\text{OU snared/seized from hunters}}$.

## 3.3 Results and discussion

**Performance against SRAK 2007 goals for ex-captive orangutans**

Rescue and release activities were conducted by nine entities in Kalimantan: specialized care facilities (rescue centers), private businesses and corporations, and by *Balai Konservasi Sumber Daya Alam* (BKSDA), the Indonesian agency for natural resource conservation. The BKSDA rescue centers in Kalimantan were treated as a single facility.

Each non-governmental (NGO) rescue center organization was treated as a single facility, even if it had multiple care centers or pre-release habitats, i.e. semi-natural managed habitats used for rehabilitation.

The SRAK 2007 mandated release of all captive orangutans by 2015. In 2007, there were 1100 orangutans in five rescue facilities including BKSDA (Figure 3.1). Four new facilities began accepting surrendered or confiscated orangutans, one each year in 2009, 2013, 2015 and 2017. During this period one of the initial five facilities was emptied and its animals transferred to one of the remaining three facilities. Later during the study period, it was reopened and began again accepting rescued orangutans. Captive births were a regular occurrence at two rescue centers and their associated pre-release habitats, and rare at other facilities. At least 119 orangutans were born in captivity during the study period. Forty-nine of these captive born orangutans (63%) were released into natural habitats between 2007 and 2017. Captive populations remained fairly stable over the study period, fluctuating from a low of 1100 orangutans in 2007 to a high of 1258 in 2016 (Figure 3.1). Captive populations reported for 2007–2008 and 2017 may be underestimated as most rescue centers did not have publicly accessible annual reports for those years at the time of this study.

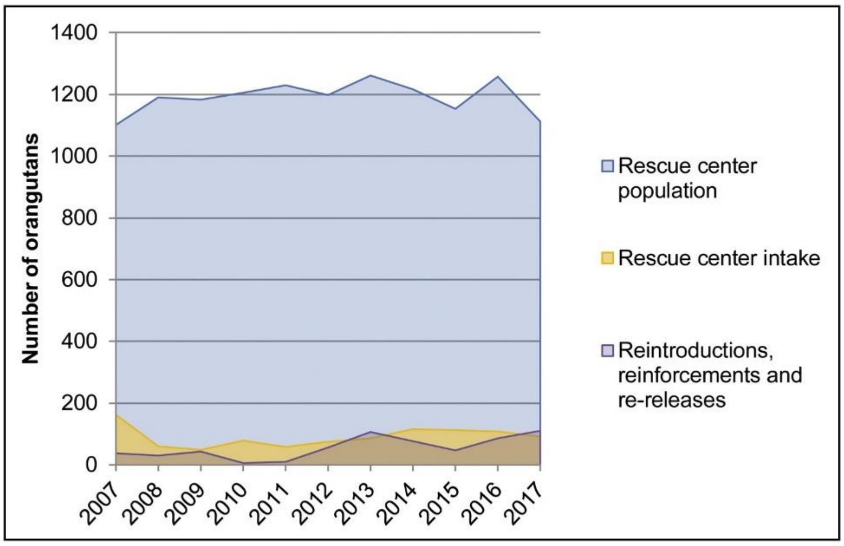


**Figure 3.1. Trends in orangutan rescue center captive populations, intake, and reintroductions, reinforcements and re-releases 2007-2017.** Intake and release numbers based on the larger of either the number presented in published annual reports, or the sum of individual orangutans reported rescued and released in each year. Wild orangutans captured and held more than six months in captivity are included under intake and reintroduction (n = 98).

A total of 994 orangutans were taken into rescue centers between 2007 and 2017, at an average rate of 90 animals per year (Figure 3.1). This intake excludes 523 wild captured and translocated orangutans, many of which were held in captive facilities for several days up to six months prior to their release in another location. Annual intake peaked in 2007, following the repatriation of 52 orangutans confiscated in Thailand (TRAFFIC, 2015), and extensive clearing for plantation expansion (Austin et al., 2019; Santika et al., 2017a). Captive population peaks followed rescue peaks, and also reflected a 2013 peak in captive births at one rescue center, concurrent with opening of a sixth rescue center which added new captive care capacity (Figure 3.1).

Practitioners released 605 ex-captive orangutans during the study period. The pace of ex-captive releases rose sharply after 2011 when new release habitats in Bukit Baka Bukit Raya National Park, Bukit Batikap Protection Forest, Mount Tarak Protection Forest and Kejhe Sewen Restoration Ecosystem were selected. The total number of rescues nonetheless exceeded that of ex-captive releases (Figure 3.1). Captive populations decreased at only one of the nine rescue centers, and increased in seven, with the eighth having the same number of animals in 2007 and 2017 following large numbers of both releases and rescues.

**Reasons for intake of orangutans to rescue centers**

Orangutans appeared to be popular pets in Kalimantan, with 632 (90%) of the 699 orangutans confiscated or surrendered coming from illegal ownership. Illegal trade played a minor role in orangutan rescues (n = 11; 2%), with five orangutans rescued from persons selling them nationally, and six seized from international trade. Nearly all persons holding orangutans as pets claimed to have found them as infants alone on the ground or been given them already orphaned. A recent study in West Kalimantan by Freund et al. (2017) also found captors made this claim. However, only five of the recorded instances described situations in which this appeared plausible; that is, the orangutan was found in circumstances not related to negative human-orangutan interactions, and the person who found it immediately sought help for the orangutan rather than selling or keeping it as a pet. Well-intentioned concern for orphaned orangutans' welfare may drive people to buy or accept infant orangutans; this is often the case with buyers of protected wildlife, although it is illegal nonetheless and actually fosters poaching and trade rather than reducing it (Sherman & Greer, 2018). Eight orangutans (1%) were rescued from poaching events such as snaring, and another 11 (2%) from capture, harassment or attacks by humans. Twenty-eight animals (4%) were rescued from captive care facilities with unsuitable conditions. One additional animal was rescued from a tourist attraction and two more were rescued to address illnesses or injury from natural causes, such as injuries from a fall or agonistic interactions with conspecifics or other wildlife. Many illegally held orangutans were kept in horrific or deadly conditions where rescue likely saved their lives and enabled improved welfare.

**Relation of rescues to law enforcement**

Our dataset provides a measure of detected and reported orangutan crime from 2007–2017. This is presumed to be a small subset of actual crimes, most of which are likely undetected. Detection rates in Kalimantan are expected to be low due to limited effort, corruption and a reluctance to punish local citizens (CITES/GRASP, 2006; Nijman, 2017), as well as the difficulty of access and remoteness of many areas where orangutans are found. Killing of orangutans remains a significant issue, based on recent science (Freund et al., 2017; Meijaard et al., 2011a; Trayford, 2013) and the indications in our dataset. All researchers and rescue centers we spoke with said orangutans are still being killed in the areas where they work. Most also told us that killing instances had locally decreased following their work with surrounding communities, but evidence was not available to assess this.

There were a total of 719 orangutans affected by crimes—killing, and injury, harassment, possession, sale or purchase of orangutans—in the 1285 records we compiled on individual rescues (Figure 3.2). Most crime was related to animals confiscated or surrendered (n = 699). Of the 699 orangutans confiscated or surrendered 670 (96%) involved orangutan crime. Illegal possession as pets was most common, accounting for 632 animals (90%), of which 599 (86%) were infants five years or younger (Appendix 3C). Another 21 animals (3%) were harmed, in trade, or held captive for reasons other than being a pet. The 29 cases (4%) which did not involve crime were handovers of animals from zoos/other facilities and orangutans found orphaned. Other types of rescue—wild captures, medical and other rescues, and recaptures of previously released orangutans—(n = 586) accounted for 52 crimes (9%).

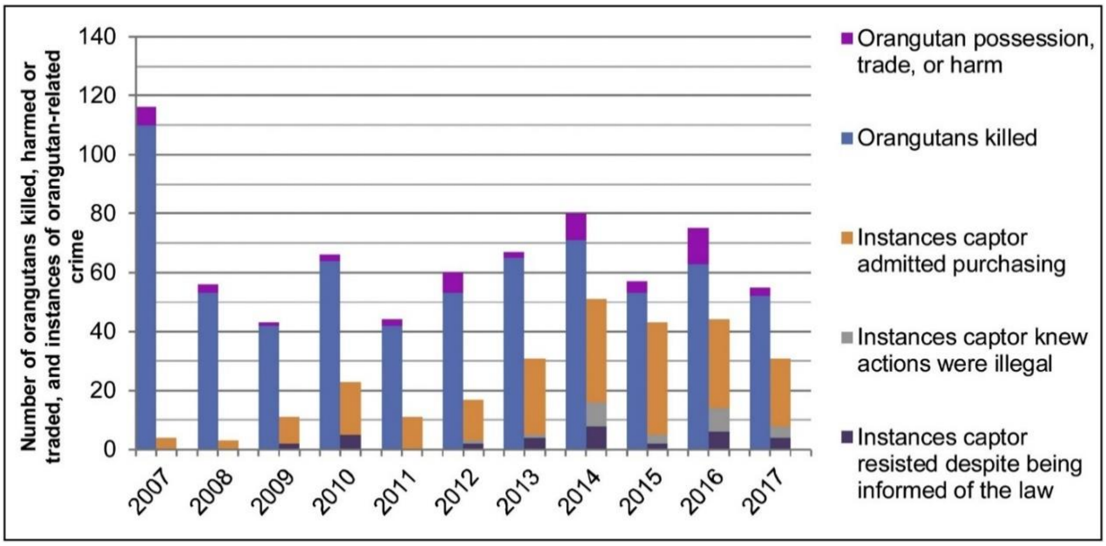


**Figure 3.2. Law enforcement aspects of rescues 2007-2017 (n = 719 orangutan-related crimes).** Orangutan trade is purchase, sale, barter or gifting of animals. Harm to orangutans includes physical injury and harassment. Instances of captor purchase, knowledge of illegality, and resistance are a subset of orangutan killing and other orangutan crimes. These instances were noted where reported and are not mutually exclusive. For years where a variable is not displayed those data were missing or unclear.

While killing estimates were highest in 2007 due to the number of infants rescued that year, killings and reported illegal purchases of orangutans did not decrease overall between 2008 and 2017 (Figure 2). Additionally, in 33 instances captors showed resistance to following the law despite being informed that their actions were illegal (Figure 2). Rescue center reports indicate authorities often will not seize illegally held orangutans if owners do not wish to give them up. There were four instances of law enforcement outcomes during the 10-year study period: one conviction, two arrests and one additional inconclusive investigation. The conviction rate for this dataset is 0.1%, which is not an improvement over previous assessments of orangutan-related law enforcement (Freund et al., 2017; Nijman, 2005, 2017). We are conducting more detailed analysis of law enforcement contexts for subsequent publication.

The surrender or confiscation of illegally held or traded animals alone does not represent successful law enforcement (Nijman, 2017), although it does provide the potential for improved orangutan care at specialized care centers. These rescue centers can play a direct role in wildlife law enforcement by providing both care for seized animals and facilitation of law enforcement outcomes by tying acceptance of animals to authorities' willingness to investigate and prosecute perpetrators (Nijman, 2017; Sherman & Greer, 2018).

**Welfare outcomes of ex-captive releases**

Researchers we interviewed said that rehabilitation practices have improved over time, but that selection of reintroduction and reinforcement candidates and release sites is not necessarily grounded in current understanding of *P. pygmaeus* behaviors such as the maternal knowledge transfer necessary for effective foraging (Schuppli et al., 2016b), male territoriality (Utami Atmoko et al., 2009), and female philopatry (van Noordwijk et al., 2012). Extended time in captivity has also been suggested as a risk to success of released orangutans (Grundmann, 2006). We analyzed the age class, sex and time in captivity of released orangutans (n = 431). Thirty-nine percent of released orangutans were adults 15 years or older, and 75% were 10 years or older. Released orangutans were predominantly female (60.4%), while 38.2% were male, and 1.4% of unreported sex. Fifty-two percent of released animals were captive for more than 10 years. Thirty percent were captive between five and 10 years, and 18% were captive five years or less.

Data available from hard releases, where released animals were not provided supplementary food or other support, showed most rehabilitants struggled during the first few months while learning how to forage locally (Anon. rescue center reports; Basalamah et al., 2018). Limited data for a single rescue center suggest that compared to wild conspecifics, some hard released orangutans spent an abnormally high amount of time resting and sleeping instead of foraging. This center found that five of 59 animals (8%) were found or presumed dead within 12 months of release (one after only eight weeks), while an unspecified number of animals had to be provisioned or recaptured due to starvation or malnutrition. The center has subsequently altered its practices to include provisioning when released animals show signs of malnutrition.

Rescue center reports of post-release behaviors suggested that competition among individuals might explain some rehabilitants' difficulties in adapting. Previously released females with established home ranges near release sites were also suspected to limit newly released females' dietary choices and arboreal behavior. Aggressive behaviors among newly and previously released adult males were also reportedly common, as were resultant serious injuries. Many reintroduced large males and some adult females were reported as being aggressive to humans (see Table 3.1). Total numbers of these incidents, or of their relative prevalence among released animals, were not reported.

**Table 3.1. Reasons for recapture of released orangutans (n = 69).** Ill/injured by resident wildlife indicates injury was caused by species other than orangutans.

| Reason for recapture | Number of orangutans |
|---|---|
| Ill/injured by resident wildlife | 1 |
| Orphaned | 1 |
| Potential interaction/perceived risk | 2 |
| Captured/attacked/harassed | 4 |
| Failure to adapt | 5 |
| Intraspecific orangutan conflict | 6 |
| Starving /malnourished/underweight | 6 |
| Aggressive to humans | 8 |
| Crop foraging | 18 |
| Ill/injured - unknown cause | 18 |

These issues can result in recapture of released orangutans, which in turn causes additional stress to the animals (Wilson & McMahon, 2006). Researchers and some rescue centers we interviewed suggested that most recaptures were not officially recorded nor used to improve management of rehabilitation and releases. We found records of 69 previously released orangutans being recaptured (Table 3.1). Four orangutans (6%) subsequently died while in captive care; 38 were re-released. Three of these 38 animals (8%) died following re-release. Ten of the 38 re-released individuals had been recaptured multiple times. Some individuals were responsible for multiple incursions into camps or crop fields. In one example, eight released orangutans were responsible for 18 instances of crop foraging and other damage to human property, with one orangutan responsible for seven cases and another responsible for three. One rescue center publicly reports these data, and, following deaths of recaptured and re-released orangutans, changed its policy to make recapture and re-release a last resort. They are instead focusing on better managing negative human-orangutan interactions, typically by providing compensation payments to villagers for property damage or consumption of human foods by released orangutans.

**Post-release monitoring and survival of ex-captives**

Monitoring rehabilitated and reintroduced ex-captive orangutans is difficult, but recent developments in implantable radio tracking devices have improved potential (Robins et al., 2019). All six of the rescue centers releasing ex-captive orangutans use tracking implants on some or all released animals (Table 3.2). Post release monitoring (PRM) of reintroduced orangutans was viewed as critical by all respondents to our PRM survey. Practitioners felt that monitoring should last at least one annual cycle to determine home range and cover seasonal variation of food availability which drives orangutan behavior.

One practitioner stated orangutans should be followed daily for the first month due to their being in an unfamiliar area with unfamiliar resources and unfamiliar orangutans and thus especially vulnerable to getting lost or to aggressive encounters with resident orangutans. However, all researcher respondents felt monitoring needed to be conducted for much longer to establish reliable survival estimates. Rescue center reports indicated PRM beyond three years (the typical maximum life span of radio tracking implants) was conducted opportunistically (Table 3.2). Regardless of the PRM scheme, many released individuals were not seen again. Public data on post release monitoring results are rare, but as shown in the examples below, reported percentages of animals not re-encountered were as high as 55-95%, depending on the site and time since release (Anon. rescue center reports; Siregar et al., 2010). Rescue centers' public reports considered unencountered animals to be alive but with non-functioning tracking implants or to have dispersed out of tracking implant and/or feeding platform range, while unpublished data acknowledged death as a possible explanation. Evidence to support either outcome was lacking.

**Table 3.2. Post-Release Monitoring (PRM) regimes for ex-captive orangutans.** We found five different PRM practice regimes among the six rescue and release facilities.

| PRM regime type | Monitoring methods | Frequency | Duration of monitoring after release | Notes |
|---|---|---|---|---|
| 1 | Radio tracking implant + ground follows | Daily first 2-3 days, after this ad hoc during daily patrols | Nest to nest follows first 2-3 days, then radio tracked. 1 month intensive, 1 year | Nearly all can be followed for 1 month, see only 40-50% after this |
| 2 | Radio tracking implant + ground follows | Unknown | 3 months to 3 years, dependent on rehabilitation history | |
| 3 | Visual monitoring at feeding platforms | opportunistic | Opportunistic | |
| 4 | Visual monitoring at feeding platforms + radio tracking implant | Unknown | 2 weeks | |
| 5 | Radio tracking implant + ground follows | Daily or as often as possible | Plan to continue for decades | |

Russon (2009) found rescue facilities reported post-release survival rates for Kalimantan of 20-80% from 1971-2007. Public data on survival rates were insufficient to update this analysis. However, there is some evidence that long-term survival rates for some released ex-captive populations may be lower than 20%. For example, a follow up survey in 2000 by Grundmann (2006) found only 11 of the 191 orangutans (6%) released in Meratus forest between 1997 and 1999, while Siregar et al. (2010) reported that 16-18 of 345 animals released (5%) were encountered in 2009, and a 2016 analysis estimated 30-40 surviving animals from a total of 349 (9-11%) released between 1997 and 2002 (Utami-

Atmoko et al., 2019b). One rescue center publicly reported post release survival outcomes at one site for releases conducted between 2012 and 2015. During the first two years post-release, 44% of the released animals were actually seen again 15 months after release and 19 % were seen 28 months after release. The site had survival rates of 71% after one year post release, 41% after two years, and 27% after three years, with 10% of released animals found dead. In all cases, unencountered animals were assumed to be alive. Together these examples suggest long-term survival rates could be as low as 6-27%.

Rehabilitated orangutans have been released in several areas with the goal of creating self-sustaining populations through reinforcement of small wild populations. Data were available for three such areas in addition to the Meratus population discussed above: (1) two rescue centers released totals of 17 and 69 animals by 2017 in two units of a single habitat area, respectively, with no wild births by rehabilitants reported; (2) 160 animals were released by 2017, and there were six births; and (3) 73 animals were released by 2017, and there were two births. It was not possible to determine if these populations could be self-sustaining over the long term due to the recent release dates and lack of available data.

**Capture and translocation of wild orangutans**

The capture and translocation of wild orangutans by release practitioners has been heralded as a solution for orangutan survival in the face of forest conversion (CITES/GRASP, 2007). One researcher stated the government and local people are "really excited and really proud" of translocation; their view is, 'We are going to take orangutans that would otherwise be killed and we are going to put them in the forest and save them.' Researchers confirmed that over the past 10 years there has been a push to train teams to catch orangutans in plantations and move them elsewhere. Indonesian government regulation P.53/Menhut-II/2014 appears to encourage translocation of "healthy" animals from areas where they could potentially interact with humans. Wild orangutans captured for the purpose of translocation (n = 621) were nearly equivalent to the total number of ex-captive orangutans released between 2007 and 2017 (n = 605). Most of the wild captures resulted in translocations to new habitats within 6 months (n = 523; 84%) while another 98 wild orangutans (16%) were held in captivity more than six months, and in some cases held two to five years or longer before suitable release sites could be found. Translocations were highest in 2015 and 2016 in the aftermath of the extensive 2015 forest fires. During this period orangutans were removed from areas affected by forest fires and from areas considered to have a high risk of human-orangutan interactions. Practitioners reported that orangutans entered these human-modified areas as a result of fires in their natural habitats, and in some cases had to be moved from burned areas where no standing trees or other food resources were available.

**Reasons for capture and translocation of wild orangutans**

News stories and rescue centers' accounts suggested wild orangutans were captured and moved in large numbers from concessions, generally when the concession wanted to clear an area but not run afoul of the law, or wished to prevent crop foraging by orangutans living in or near the plantation (Aji, 2011; Asrianti, 2011). Large translocations have also been conducted to move orangutans out of what rescue centers considered marginal habitat, although this approach has been controversial (Kaye, 2016). At least three rescue/release organizations reported having contractual agreements with industrial agriculture, forestry and mining concessions to find and translocate orangutans that are considered a "problem" or to be "at risk." Some interviewees reported these organizations were paid up to US$2000 per orangutan by concessions for conducting translocations. Many researchers and practitioners we spoke with noted that translocations often go unreported, with orangutans "dumped," often into inappropriate locations, with neither formal documentation nor post-release monitoring. One practitioner noted that information on removal of wild orangutans from concessions is unavailable because contracts between concession companies (such as oil palm or pulp and paper) and rescue/release organizations are covered by Non-Disclosure Agreements. Government reports on SRAK implementation also referred to translocations with no details beyond, "some activities carried out by parties that are not monitored," and, "Relocation of orangutans in one population group in one landscape" (FORINA, 2013a).

Orangutans were also translocated at the request of local community members or smallholder plantations. Some practitioners reported that they comply with translocation requests regardless of the situation to prevent potential harm to the orangutans. Only two of the nine facilities we spoke with said they had refused at least once to move orangutans. One practitioner commented that it is "better to relocate them than leaving them in oil palm, since it is better for them to be in natural forest," and "better they are translocated than killed."

We found 539 records that identified reasons for capture and translocation of wild orangutans (Figure 3.3). We based our classification on the primary rationale for capture or rescue (Appendix 3B). For example, in cases where villagers alerted authorities or rescue centers about orangutans in the village or foraging in crops as a result of fires driving the animals out of their natural forest habitats, the reason for capture was “potential interaction/perceived risk” or “crop consumption,” respectively (Appendix 3B). In such cases fires were the driver of the orangutan displacement or unusual foraging patterns, but the primary reason for capture was the villagers’ concern about the animal in village areas or crops.

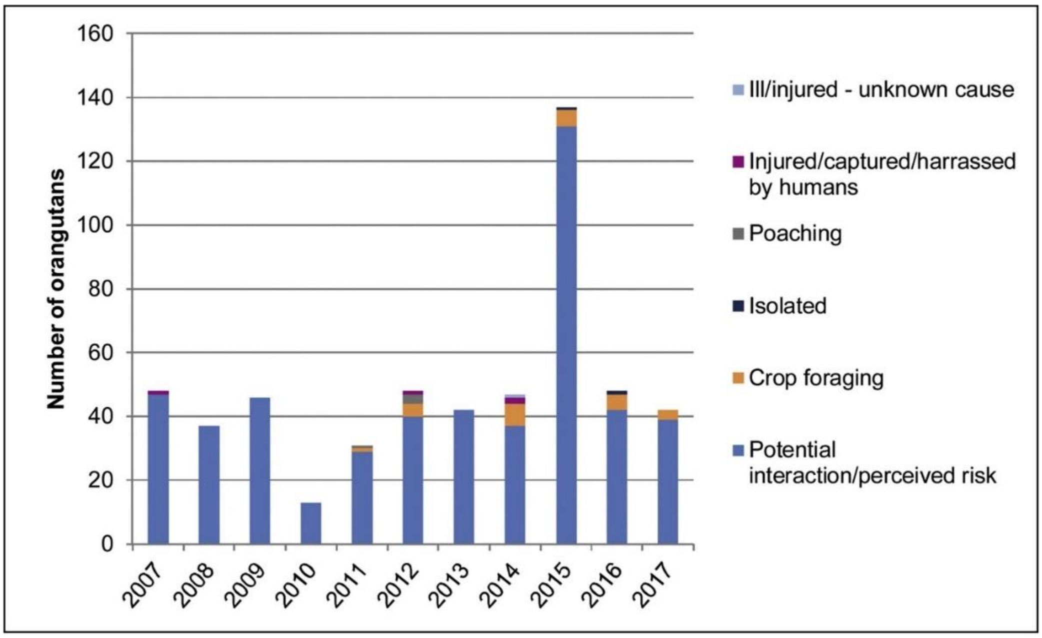


**Figure 3.3. Reason for capture and translocation of wild orangutans (n = 539 orangutans).** Poaching indicates animals were snared or pursued by poachers at the time of rescue. Isolated animals were rescued from a location where they appeared to have no local food sources and no route to natural vegetation.

Orangutans were mainly captured to pre-emptively avoid potential interactions with humans (Figure 3.3). Crop consumption was reported for 5% of translocated orangutans. Few were rescued from injuries, capture, or harassment by humans, although there were several additional instances of orangutans with human-inflicted injuries where the primary reason for capture was to remove the orangutans from situations where they could interact with humans (Figure 3.3). Orangutans are able to travel on the ground and in anthropogenically modified areas (Ancrenaz et al., 2014; Spehar et al., 2018). We therefore did not consider orangutans captured in small forest patches, human crop areas, or even in an area with only a few trees or a single tree to be isolated unless their situation was described as being devoid of any food sources or proximity to natural vegetation.

Available data on 539 translocated orangutans suggest they were predominantly healthy (92%) when captured from the wild, indicating that these animals had managed to survive rather well in these habitats perceived as inhospitable (Figure 3.4). Of the few (4%) that were starving, malnourished or underweight, at least half appeared to have been driven out of their habitats by forest fires.

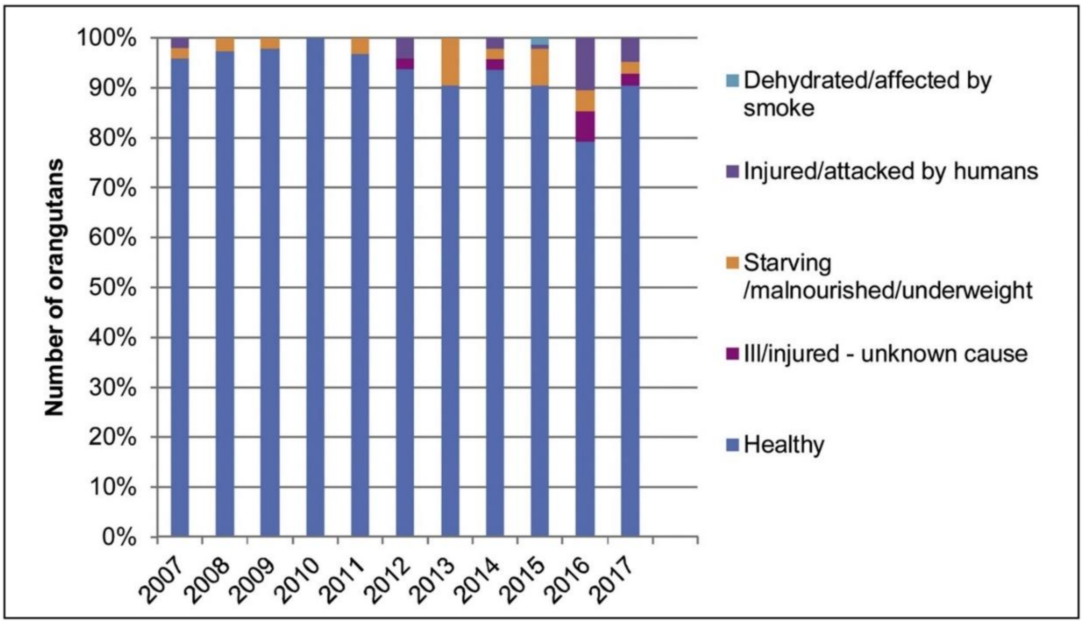


**Figure 3.4. Condition of translocated wild orangutans at time of capture (n = 539).** Translocated orangutans were coded as healthy unless otherwise described in the record of their capture or rescue. Human agency in orangutan injuries or illness was coded only where noted in rescue records, otherwise injured animals were listed as Ill/injured – unknown cause.

**Translocation as a last resort**

Effective methods to prevent orangutan crop foraging have been trialed in Sumatra and Sabah Malaysia, with success limited by participants' appropriate implementation (Ancrenaz et al., 2007; Campbell-Smith et al., 2012; Campbell-Smith et al., 2010). Nonetheless, interviewees for this study indicated little or no use of deterrents in Kalimantan to keep orangutans out of crop areas, except by isolating an area with drains filled up with water since orangutans cannot swim. We found mention of mitigation measures to drive orangutans away from some community lands in West Kalimantan as a means to avoid translocation, as well as records of translocations following these efforts, and two stories on local honey growers, who wanted a physical barrier to deter orangutans' honey consumption (Fachrizal, 2013, 2014).

All orangutan rescue centers in Kalimantan conducted awareness raising activities during the study period. Several reported that these activities addressed human-orangutan interactions. However, researchers and rescue centers concurred that local people nonetheless preferred to have orangutans moved away from their gardens, plantations and homes, even where these adjoin or are near forests. Newspaper and rescue center articles on orangutan conflict directed the public to call authorities or rescue centers when an orangutan is sighted so the animal can be "protected" by its removal to a "safe location." One rescue center news blog stated, "This is the fifth rescue [the rescue center] team has carried out in the area because the forest is being cleared and the wild orangutans are being pushed closer and closer to the village. The local people are very helpful and have always contacted BKSDA to report any orangutan they see," (Anon. rescue center news blog, 2014). Another post noted this outcome as a direct result of outreach efforts: "by working closely with villagers and oil palm companies to mitigate human-wildlife conflict...[t]his strategy is working, as the [rescue center] is called upon to rescue stranded orangutans, rather than the individuals being harmed. Within one week…staff were called upon to translocate four orangutans that had entered villager's farm land…the land owner did the right thing by requesting that the orangutan be translocated," (Anon. rescue center news blog, 2014). Government likewise espoused this approach, advising the public via newspaper articles that, for example, "[government official] hopes that all the people of [region] who might be aware of the existence of wild orangutans on plantations or residential areas, to immediately contact or convey to the BKSDA to immediately take action as soon as possible," (ProKal, 2017). Some practitioners expressed concern that these messages, while intended to forestall orangutan killing, also promote translocation in lieu of conflict mitigation. As one researcher noted, "If you ask people who tolerate orangutan crop raiding if they have problems, then people will say yes and want you to take the orangutan." Researchers also reported that such pre-emptive moves are the norm for concessions since addressing orangutan protection takes time, money, and landscape-level planning.

**Welfare outcomes of wild orangutan capture and translocation**

All researchers we communicated with expressed strong concerns about the welfare and survival of translocated orangutans, and noted that empirical studies are critically needed. The captures themselves pose risks and increase stress, particularly for older individuals (Mendonça et al., 2016; Wilson & McMahon, 2006). Data were not available on the estimated number of orangutan injuries or death associated with capture. Several researchers concurred that translocating elderly males is not good for their welfare. Some researchers noted this is particularly true for males coming to forest edges to forage in crop areas because they are outcompeted by younger males. Similarly, researchers stated adult females would have trouble establishing home ranges as unrelated females will not tolerate each other. However we found the majority of translocated orangutans (60%) were adults, with 31.8% males and 28.5% females (Appendix 3C).

**Translocation of viable populations**

Several large-scale translocations were reported during the study period, including 75 from the Wilmar Group, 166 from the Makin Group (possibly a subset of 983 orangutans reported, but unconfirmed, as rescued from the Makin Group (Asrianti, 2011)) and 77 from a Central Kalimantan riparian forest. The recent population and habitat viability analysis (PHVA) estimates that populations of at least 100 individuals of Bornean orangutans meet the minimum viable population standard (dependent on conditions including threats and whether the animals are related), and even as few as 50 individuals could be a viable population providing they have space to increase their numbers, the habitat is effectively protected and hunting is prevented (Utami-Atmoko et al., 2019b). By these definitions as many as three viable orangutan populations have been moved since 2007 (Asrianti, 2011). At least one of these populations was released into an area with an already viable resident orangutan population. Researchers we interviewed pointed out that large-scale translocations bring risks of increased competition and potentially lowered resident orangutan birth rates, or of exceeding carrying capacity in the release habitat. Scientists interviewed for a news story about large scale translocations remarked that translocated orangutans could experience decreased welfare as they would not know where to find food, and could be at risk of being killed by resident orangutans (Kaye, 2016).

**Habitat suitability**

We found reports of multiple releases into several protected areas, including Gunung Palung National Park, Tanjung Puting National Park, Betung Kerihun National Park, Kutai National Park, Mawas Conservation Area, and Sebangau National Park, all of which have viable orangutan populations (Utami-Atmoko et al., 2019b). Practitioners told us BKSDA decided where releases could occur. Some researchers and practitioners we interviewed noted that some selected sites were inappropriate due to resident orangutan populations or proximity to villages or crop foraging opportunities. One interviewee indicated that community or concession forests accepting translocated orangutans may be ignoring concerns about carrying capacity or other issues because they receive payment or other benefits. Practitioners and researchers alike stated that it is extremely difficult to find suitable areas for translocation. One scientist, who is also a rescue center practitioner, noted that suitable release sites do not exist, “because any “suitable” forest will be either already populated to the brim with [orangutans], or be unsuited e.g. because of hunting. I have not heard of any proper suitability analysis before translocations are being made.”

**Translocation monitoring and survival**

Practitioners reported they did not collect monitoring data for translocated orangutans due to the practical difficulties of following them, but all assumed that these animals would do well because as wild animals they know how to survive in the wild. One rescue center radio-tracked 38 wild captured and translocated orangutans, and found 35 animals (92%) alive after the first year, 20 after the second year (53%), and 12 after three years (32%), with one animal found dead and 25 (66%) unaccounted for. Translocation practitioners we interviewed said they often had no choice but to capture and move these animals, as they would otherwise not survive in fragmented habitats or would be killed by local people. The assumption that orangutans cannot survive in plantations or fragmented habitats is contrary to current understanding of orangutan use of oil palm and timber plantations (Ancrenaz et al., 2015; Oram, 2018; Rayadin & Spehar, 2015; Seaman et al., 2019). It is also fundamentally incompatible with the belief that once captured and released into an unfamiliar habitat, orangutans will thrive and are likely to be alive even if not monitored or seen again.

**Habitat protection outcomes**

Rescue centers regularly advocate for orangutan habitat protection, and several of them were instrumental in purchase of key habitat areas and the establishment of a number of formally protected areas used for releases, including Mawas Conservation Area and an extenstion to the Lamandau River Wildlife Reserve, as well as community forests, ecosystem restoration concessions and High Conservation Value habitat set asides within concessions. Rescue facilities also provided regular monitoring, patrol and firefighting staff for release sites, which include many of the national parks within orangutan range. Further, many ran advocacy campaigns seeking improved protection for threatened landscapes and their wild orangutan populations, including the Sungai Putri and Tumbang Koling forest areas.

**The importance of maintaining orangutan metapopulations across landscapes**

There is a need for further research to assess how habitat edges and forest fragment areas are impacted by removal of wild orangutans for translocations, and how this in turn may affect orangutan metapopulations. Metapopulations are composed of one or multiple orangutan subpopulations in a larger area bounded by geophysical barriers to dispersal, such as non-forested areas and large rivers (Voigt et al., 2018). Insights from Sabah (Malaysian Borneo) indicate that orangutans, even resident females, can sometimes survive in small forest patches for years or even decades, and males travel through agricultural landscapes to visit them, maintaining gene flow among populations (Oram et al., 2019). Breaking up these metapopulations via removal of animals from forest patches could negatively impact the overall population dynamics and increase risk of population extirpation.

**Compliance with IUCN guidelines**

The IUCN guidelines for great ape translocations require habitat suitability assessment before release, and preclude releases into viable wild great ape populations to prevent disease transmission, competition and other negative impacts (Beck et al., 2007). Several release sites were used across Kalimantan but in many cases no site name or information was provided in public records beyond "a safer location" or a "forest." Few data are publicly available on analysis of any release habitat suitability. We found records of numerous releases into habitats with viable wild orangutan populations. Further, poaching, habitat encroachment and negative human-orangutan interactions remain threats within some of these release sites (Utami-Atmoko et al., 2019b), which therefore do not meet the IUCN guidelines for suitable great ape reintroduction habitat, in which previous causes of decline must be addressed such that they no longer pose a threat to the taxon (Beck et al., 2007).

The guidelines also preclude release of individuals that are overly human-focused or otherwise not behaviorally suited to survive in the wild (Beck et al., 2007). Many orangutans in rescue facilities are not suitable for release, and in some cases behavioral assessments to determine suitability may be insufficient, resulting in release of individuals unlikely to successfully adapt post-release (Trayford, 2013; Trayford & Farmer, 2013), which contravenes IUCN guidelines.

The IUCN guidelines define success as any or all of: establishing self-sustaining, viable populations, improving conservation status, facilitating the persistence of traits or other benefits beyond individual welfare, and restoration of lost ecosystem function (Beck et al., 2007; IUCN/SSC, 2013). The IUCN guidelines for conservation translocations (including reintroductions and reinforcements) exclude release of confiscated captive animals for welfare or rehabilitation purposes as being primarily for individual and not population level benefits, in addition to posing high behavioral, genetic and disease risks to wild populations (IUCN/SSC, 2013; Moehrenschlager, 2019). Further, these guidelines stipulate that reinforcement must provide a conservation benefit to the receiving population as opposed to only the released individuals in order to be considered a conservation release (IUCN/SSC, 2013). While there is ample evidence Bornean orangutan species conservation status has not improved over the past decades (Ancrenaz et al., 2016a; Santika et al., 2017a; Voigt et al., 2018), lack of available post release monitoring data, and in some cases the short time elapsed since releases began, precluded analysis on whether self-sustaining, viable populations have been established.

## 3.4 Conclusion

**Caveats**

Public access to orangutan management data is scarce in Indonesia. The SRAK 2007 mandated publicly accessible databases on rescues, human-orangutan interactions, and captive populations; however, none were accessible at the time of writing. Although we spoke with all nine Kalimantan rescue facilities, only two provided detailed data in response to our queries. Many do not have detailed data accessible online. Individual facilities' available data were often inconsistent among reports and news even for the same variable in the same year. Few data were available on rescues and releases conducted by parties other than NGO rescue centers, e.g. government-led facilities, concessions and other private businesses. Our results indicated large numbers of rescues and releases, particularly those conducted by or for concessions, may not be reported publicly. Improved transparency on rescue and release activities would enable further research to improve effectiveness of these strategies. Our dataset provides some information on 85% of the publicly reported rescue and release events conducted by rescue centers between 2007 and 2017. The missing 15 %, if made available, could affect the outcomes of our analyses, as could information that was overlooked.

**The urgent need to review orangutan conservation strategies**

Despite releasing more than 600 animals since 2007, rescue facilities housed more than 1,000 orangutans in 2017 (Figure 3.1). At current rescue and release rates, captive populations will not decrease, particularly if captive births continue apace (Figure 3.1). Lack of suitable release sites, ongoing forest loss, and carrying capacity limit potential for releases. Achieving the SRAK 2019 goal of emptying rescue centers will not be possible even beyond 2024 without cessation of the killing and negative human-orangutan interactions that result in animals coming into captive care (Figure 3.2, Figure 3.3).

Orangutans were rescued primarily because they were held illegally as pets (which is related to orangutan killing) (Figure 3.2), and to remove mostly healthy wild orangutans from perceived unsuitable habitats or insecure situations (Figure 3.3, Figure 3.4). Local popularity of orangutans as pets has held for decades (Nijman, 2017) despite more than 50 years of rescue activity. This appears unlikely to change without substantial alteration in application of wildlife laws. The rarity of investigation, arrest and prosecution among the 719 orangutan-related crimes in our dataset, along with evidence that legal prohibitions are well known (Meijaard et al., 2011a), and our findings that these prohibitions have been willfully ignored even in the face of confrontation by law enforcement authorities suggest effective deterrence is lacking (Figure 3.2). Deterrence is created when the risk of detection or punishment is perceived as high (Nagin, 2013; Rowcliffe et al., 2004), which could be addressed through investigation of all reported crimes, followed by prosecution and application of penalties appropriate to the severity of the crime and financial circumstances of the perpetrator.

Contrary to the SRAK mandate for zero losses from concession lands, hundreds—or possibly more than one thousand—orangutans were lost or removed from these habitats between 2007 and 2017 (Figure 3.3, Figure 3.4). This could be indicative of concessions' continued focus on moving out unwanted orangutans. Recent studies indicate that the role of industrial plantations in orangutan habitat deforestation and destruction has been reduced between 2010 and 2017, and that fires and smallholder agriculture are now the dominant factor driving deforestation (Austin et al., 2019; Gaveau et al., 2019). We therefore expect that demand for rescues in smallholder agriculture settings will increase while demands in concessions continue, unless human behaviors changes and alternative human-orangutan interaction mitigation measures are implemented. As much as 80% of

Kalimantan's orangutan population—tens of thousands of animals—are outside protected areas (Utami-Atmoko et al., 2019b), with close to 10,000 animals estimated in concessions (Meijaard et al., 2017). It is obvious that rescuing this number far exceeds the capacity of rescue programs, and suitable release sites do not exist to accommodate so many (Figure 3.1). In order to protect wild orangutans, there appears no choice but to ameliorate human attitudes and behaviors towards orangutans, and to improve management practices in unprotected habitat, including small forest patches distributed across agricultural landscapes.

Wild orangutans were typically captured and translocated as a first response rather than a last resort, even when no release sites were available. Welfare and conservation outcomes of removing wild orangutans for translocation have been little studied despite regular use. The potential risks to released animals' welfare and to the conservation of resident wild populations are high, and the current practices of ad hoc release site selection and of releasing orangutans into viable wild populations do not meet IUCN guidelines to avoid endangering wild conspecifics. Studies are urgently needed to determine translocated orangutan welfare and survival rates, and impacts to resident conspecifics and rescue habitats. Similarly, further study of longer term impacts of ex-captive orangutan reintroductions/reinforcements are needed to understand welfare impacts and effectiveness in establishing self-sustaining viable populations.

**Acknowledgements**

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## Chapter 3 Supplementary information

### Appendix 3A

**Table 3A1 Facilities/entities conducting rescue and release of Bornean orangutans.**

| Rescue/release entity | Entity type | Years covered by available data |
|---|---|---|
| Balai Konservasi Sumber Daya Alam (BKSDA) - Tenggarong and other BKSDA holding facilities | Government agency | 2007 -2017 |
| Bornean Orangutan Survival Foundation (BOSF) | NGO | 2007-2017 |
| Centre for Orangutan Protection (COP) | NGO | 2015-2017 |
| Ecositrop | Private business | 2007-2017 |
| International Animal Rescue – Ketapang (IAR) | NGO | 2012-2017 |
| Orangutan Foundation International (OFI) | NGO | 2007-2017 |
| Orangutan Foundation-United Kingdom (OF-UK) | NGO | 2012-2017 |
| Sintang Orangutan Centre (SOC) | NGO | 2013-2017 |
| Yayasan Jejak Pulang (YJP) | NGO | 2017 |

**Table 3A2. Researchers and practitioners interviewed.** Information received via in person or Skype/Whatsapp interviews or email communication.

| |
|---|
| Anonymous orangutan socioecology and behavior, ecology or population researchers (n=15) |
| Anonymous great ape rescue and release or conservation researchers (n=3) |
| Anonymous orangutan conservation practitioners (n=3) |
| Anonymous Indonesian government personnel (n=5) |
| Anonymous representatives from eight orangutan rescue center organizations: Bornean Orangutan Survival Foundation; Centre for Orangutan Protection; Cikananga Wildlife Center; International Animal Rescue – Ketapang; Orangutan Foundation International; Orangutan Foundation-United Kingdom; Sintang Orangutan Centre; and Yayasan Jejak Pulang (n=16) |
| Anonymous researchers from Kalimantan concessions in orangutan range (n=1) |

**Table 3A3. Data sources orangutan rescue and release in Kalimantan 2007 -2017**

| Source type | Source name / description | Citation or web address |
|---|---|---|
| **Self-published reports** | Bornean Orangutan Survival Foundation (BOSF) Independent Auditor's Report on Financial Statements December 31, 2007 and 2006 | BOSF. (2008). Independent Auditor's Report on Financial Statements on the Years Then Ended December 31, 2007 and 2006. HLB Hadori & Rekan, Jakarta, Indonesia. |
| | 2008 Annual Report BOS Germany | BOS Deutschland. (2009). Rechenschaftsbericht und Mittelverwendung 2008: Bericht aus den BOS-Projekten, Aktivitäten und Ausblicke 2008 / 2009. Berlin, Germany. |
| | BOSF Independent Auditor's Report on Financial Statements December 31, 2008 and 2009 | BOSF. (2010). Independent Auditor's Report on Financial Statements on the Years Then Ended December 31, 2008 and 2009. HLB Hadori & Rekan, Jakarta, Indonesia. |
| | 2009 Annual Report BOS Germany | BOS Deutschland. (2010). Rechenschaftsbericht und Mittelverwendung 2008: Bericht aus den BOS-Projekten, Aktivitäten und Ausblicke 2008 / 2009. Berlin, Germany. |
| | 2010 Annual Report BOS Germany | BOS Deutschland. (2011). Jahresbericht und Mittelverwendung 2010: Bericht aus den BOS-Projekten. Berlin, Germany. |
| | BOSF Annual Report 2011 | BOSF. (2012). Borneo Orangutan Survival Foundation Annual Report 2011. Bogor, Indonesia. https://www.dropbox.com/s/w43cr7nrdzaahai/AnnualReport-2011-Eng-Final.pdf?dl=0 Accessed 10 August 2019. |
| | BOSF Annual Report 2012 | BOSF. (2013). Borneo Orangutan Survival Foundation Annual Report 2012. Bogor, Indonesia. https://www.dropbox.com/s/s0agak01w8h8pf0/Lowres-Annual-Report-2012.pdf?dl=0 Accessed 10 August 2019. |
| | BOSF Annual Report 2013 | BOSF. (2014). Borneo Orangutan Survival Foundation Annual Report 2013. Bogor, Indonesia. https://www.dropbox.com/s/tpwqi5gwnokpytm/FINAL-Annual-Report-2013-eng.pdf?dl=0 Accessed 10 August 2019. |
| | BOSF Annual Report 2014 | BOSF. (2015). Borneo Orangutan Survival Foundation Annual Report 2014. Bogor, Indonesia. |

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|---|---|---|
| | | https://www.dropbox.com/s/eqzrrb8tjkl1f89/Annual-Report-2014_Eng.pdf?dl=0 Accessed 10 August 2019. |
| | BOSF Annual Report 2015 | BOSF. (2016). Borneo Orangutan Survival Foundation Annual Report 2015. Bogor, Indonesia. https://www.dropbox.com/s/2p1yuk0z552xxqc/2015-Annual-report.pdf?dl=0 Accessed 10 August 2019. |
| | BOSF Orangutan Conservation 2007-2015 | BOSF. (2015). BOS Foundation Orangutan Conservation 2007-2015. https://www.dropbox.com/s/dhjwkz1ad1t82y5/OU-timeline-2007-2015-ENG-lowres.pdf?dl=0 Accessed 10 August 2019. |
| | BOSF Annual Report 2016 | BOSF. (2017). Borneo Orangutan Survival Foundation Annual Report 2016. Bogor, Indonesia. https://www.dropbox.com/s/bu6mm66epxcg45d/AnnualReport%202016-ENG.pdf?dl=0 Accessed 10 August 2019. |
| | 2017 Annual Report BOS Germany | BOS Deutschland. (2018). Tätigkeitsbericht bos deutschland für 2017. Berlin, Germany. |
| | BOSF Highlights 2017 | BOSF. (2018). Bornean Orangutan Survival Foundation Highlights 2017. Bogor, Indonesia. https://www.dropbox.com/s/xg3lrtxn9pbtu30/highlight%202017.pdf?dl=0 Accessed 10 August 2019. |
| | BOSF Highlights 2018 | BOSF. (2019). Bornean Orangutan Survival Foundation Highlights 2017. Bogor, Indonesia. https://www.dropbox.com/s/h1s5lnd1wrz20t5/%5BLowress%5D%20Highlight%202018.pdf?dl=0 Accessed 10 August 2019. |
| | BOSF Progress Report | BOS Foundation and RHOI. (2013). Progress Report: Orangutan Post Release Monitoring in Kehje Sewen Forest, East Kalimantan. BOS Foundation and Restorasi Habitat Orangutan Indonesia (RHOI). Bogor, Indonesia. https://www.dropbox.com/s/r4pwx023ufk1o1g/FINAL-PRM-Kaltim-2013.pdf?dl=0 Accessed 10 August 2019. |
| | BOSF Progress Report | BOSF. (2015). Progress Report #4: Orangutan Reintroduction and Post-release Monitoring in Bukit Batikap Conservation Forest, Murung Raya August 2013 - December 2014. BOS Foundation - Central Kalimantan Orangutan Reintroduction Program at Nyaru Menteng. Bogor, Indonesia. https://www.dropbox.com/s/lw4q1osp9cdz856/FINAL-ENG-Progress-Report-4-Batikap-2013-2014.pdf?dl=0 Accessed 10 August 2019. |
| | BOSF Progress report | BOSF. (2016). Progress report: Post-release Monitoring Of orangutans in the Kehje Sewen forest, East Kalimantan 2015. Bogor, Indonesia. https://www.dropbox.com/s/g0zlql65f10jxbp/PRM%20RHOI%202015.pdf?dl=0 Accessed 10 August 2019. |
| | BOSF Orangutan Reintroduction and Post-release Monitoring | BOSF. (2016). Orangutan Reintroduction and Post-release Monitoring in Bukit Batikap Conservation Forest, Murung Raya Central Kalimantan January 2015 to December 2015. Orangutan Reintroduction Program at Nyaru Menteng. Bogor, Indonesia. |
| | BSOF Orangutan Reintroduction and Post-release Monitoring | BOSF. (2018). Orangutan Reintroduction and Post-release Monitoring Update on the Reintroduction Programs in Bukit Batikap Conservation Forest and Bukit Baka Bukit Raya National Park January 2016 to October 2017. https://www.dropbox.com/s/c1olo0d8u92xh7i/PRM%202016-2017%20eng.pdf?dl=0 Accessed 10 August 2019. |
| | International Animal Rescue (IAR) Annual Report 2012 | International Animal Rescue. (2013). Annual Review 2012 Taking action to protect endangered animals. https://www.internationalanimalrescue.org/sites/default/files/client/iar_annual-review_2012_web.pdf Accessed 10 August 2019. |
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| | IAR Annual Report 2015 | International Animal Rescue. (2016). The Rescuer 2015 Dedicated to the rescue and rehabilitation of suffering animals. https://www.internationalanimalrescue.org/sites/default/files/client/iar_16_page_leaflet_web.pdf Accessed 10 August 2019. |
| | IAR Annual Report 2016 | International Animal Rescue. (2017). The Rescuer 2016 Dedicated to the rescue and rehabilitation of suffering animals. |

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## Appendix 3B

**Table 3B1 Variables, definitions and assumptions. Assumptions outline how data coding decisions were made.**

| *Data fields* | *Subfields* | *Definition/description/assumptions* |
|---|---|---|
| Intake facility | | |
| **Name** | | Center providing care and/or conducting releases. Where center was not listed, it is coded as BKSDA. |
| Rescue types | | |
| **Confiscated** | | Legal action by authorities; story notes confiscation or seizure. |
| **Surrendered** | | Handed over without force or formal legal action. Assumed for all OU obtained from people but not noted as confiscated or seized. Includes wild OU held, captured or otherwise under the control of people. All intake from people where confiscation not noted are considered surrenders. |
| **Other rescue** | | Any rescue where OU was not obtained from people e.g. wild OU in a concession not captured/held. |
| **Unknown** | | |
| OU name, details | | OU name and rescue circumstances where known. |
| OU Sex, Age | | Where an age range was given we used the lower number. Ages were rounded to lowest whole number. |
| **Infant <6** | | #OU per incident younger than 6. Includes OU described as "baby" or "infant" where no age given. |
| **Juvenile 6-9** | | # OU per incident 6 years or older. Includes OU described as "young," where no age given. |
| **Adolescent 10-14** | | |

| | | |
|---|---|---|
| **Adult ≥15** | | # OU per incident 15 years or older. Includes OU described as "adult" where no age given. |
| Date | | |
| Location | | |
| **Origin** | | Or closest known source location. |
| **Collection location** | | If different than origin. |
| #OU | | # OU involved in each rescue incident. |
| OU condition at time of rescue | | Estimated from photos of capture/intake where such are available and no other information is provided. |
| **Healthy** | | OU was assumed healthy unless record(s) indicated otherwise. |
| **Starving** | | OU is noted as starving. |
| **Malnourished/ underweight** | | OU was recorded as malnourished or underweight. |
| **Injured by humans** | | OU was wounded or injured by humans. |
| **Injured - unknown cause** | | OU is injured due to natural causes (not injured by humans). |
| **Ill** | | OU was recorded as ill. |
| **Dehydrated** | | OU was recorded as dehydrated. |
| Death or illness | | Death or illness during capture, captivity or following release. |
| Reason for rescue (proximate cause) | | |
| **Illegal trade** | **National, international** | OU is held by trader or was in trade when rescued. |
| **Pet** | | Any OU held captive other than being taken from international trade, offered for national or international sale at time or rescue, used as a tourist attraction, or held/attacked over interactions with humans. All OU handed over by people with no explanation are assumed to have been a pet. |
| **Tourist attraction** | | OU is displayed or used for entertainment purposes. |
| **Orphaned** | | OU collected by locals but immediately reported or turned in. Does not include adults captured and held by villagers or plantation/concession workers to prevent crop consumption or potential interactions with humans and reported to authorities/rescue centers by others (i.e., human-orangutan interaction is proximate cause). |
| **Crop consumption** | | All instances where OU were caught or reported consuming crops. |
| **Captured/attacked/harassed** | | OU held captive by humans but not as a pet. Includes babies clinging to mothers killed by humans and OU captured and/or attacked by humans due to reported crop consumption or other actual/potential interactions. |
| **Potential interaction/perceived risk** | | All instances where no interaction has yet occurred but is feared or presumed. |
| **Ill/injured - unknown cause** | | OU is ill or injured but not obviously as a result of human attack or harassment. |
| **Fires** | | OU was recorded as driven out of its habitat by fire, or needed medical attention due to fires. |
| **Poaching** | | OU was seized from hunters or was snared. |
| **Isolated** | | OU was found seemingly trapped in an area with no trees and no connection to forests or plantations. |
| **Rescued from other facilities** | | OU were seized or surrendered from another captive facility. |
| **Starving /malnourished/ underweight** | | OU was recorded as needing medical attention or immediate recourse to additional food sources due to being starving, malnourished or underweight. |
| Reason for recapture | | Previously rehabilitated OU recaptured. |
| | **Ill/injured – unknown cause** | Injury is not human caused or no cause known. |
| | **Crop consumption** | All instances where OU were caught or reported consuming crops. |
| | **OU-OU conflict** | Ill, injured or having trouble adapting/surviving due to conflict with other OU at the site. |
| | **Ill/injured by resident wildlife** | Ill or injured due to interaction with wildlife other than OU. |

| | | |
|---|---|---|
| | **Starving/malnourished/ underweight** | OU was recorded as needing medical attention or immediate recourse to additional food sources due to being starving, malnourished or underweight. |
| | **Potential interaction/perceived risk** | All instances where no interaction has yet occurred but is feared or presumed. |
| | **Aggressive to humans** | OU was recorded attacking or being aggressive towards humans. |
| | **Failure to adapt** | Behavioral or other problem adapting to release site (other than reasons above). |
| | **Other/unknown** | |
| | **Ill/injured unknown cause** | Capture of OU for medical care not related to HOC. |
| <u>R2 (ultimate cause or driver)</u> | | Underlying reason for rescue, if noted. e.g. OU attacked by humans for crop raiding after driven out of its habitat by fires, then Reason for rescue = crop raiding; and R2 = fire. |
| <u>Illegal activity</u> | | Killing, injury, harassment, possession, trade. |
| **Purchased**; **Price** | | |
| **Captor knew having OU is illegal** | | Coded only in instances where record noted captor did or did not know. |
| **Resisted despite being informed of law** | | Record noted owner reluctance to give up OU despite being informed it was illegal. |
| **Killing** | | # OU related to presumed killing (OU was a pet and/or under 6 years of age; OU was rescued from a poaching incident; Captor reportedly killed other OU associated with recorded orphan). |
| <u>Law enforcement</u> | | |
| **Arrest** | | |
| **Conviction** | | |
| | **Fine** | Amount of fine ordered. |
| | **Jail time** | Duration of jail time ordered. |
| | **Other repercussions** | |
| <u>In or near a plantation/concession or related to clearing</u> | | Record noted any deforestation for agriculture or natural resource extraction or habitat modification which led to rescue. |
| **Yes** | | |
| **No** | | |
| <u>Habitat modification or clearing type</u> | | |
| **OP plantation** | | Oil palm. |
| **Rubber** | | |
| **Banana** | | |
| **Coconut** | | |
| **Pineapple** | | |
| **Rambutan** | | |
| **Community gardens/village farms/other food** | | Community garden or other personal or community food crops besides rambutan, coconut, banana and pineapple. Includes community or private gardens or plantations with no crop specified. |
| **Gold mining** | | |
| **Coal mining** | | |
| **Mining – unknown type** | | |
| **Road building** | | |
| **Other human development** | | Buildings or other infrastructure or development-related clearing. |
| **Forestry plantation** | | |
| **Community forest** | | |
| **Plantation – unknown type** | | |
| **Clearing – Unknown type** | | |
| <u>P2</u> | | Secondary crop or clearing type if listed. |
| <u>Plantation/concession owner type</u> | | Owner type of smallholder or industrial provided under “Habitat modification or clearing type” field and “P2” field. Where owner type was not clear in rescue record, |

| | | |
|---|---|---|
| | | plantation names or site names searched on Google to confirm ownership type. Where no online information was available local experts were consulted. Instances where no clear type could be determined were coded "unknown". |
| **smallholder** | | Record notes clearing related to personal or community activities. Any records noting an individual's land was designated as smallholder. |
| **industrial** | | Company is identified or commercial ownership is indicated in rescue record. |
| **Unknown** | | Records that indicated clearing related to rescue but did not mention any of the above factors |
| Releases | | |
| **Name of entity doing release** | | Facility, person, business or government. |
| **Translocation** | | Wild to wild translocation. Movement of wild OU from one location to another. Can include medical care at facility for short term but not behavioral rehabilitation. |
| **Reintroduction** | | Reinforcement or reintroduction through release of rehabilitated OU– Not wild caught animals, animals that are confiscated or surrendered. |
| | **Time in care or rehabilitation** | Days, months, years. |
| **Origin location** | | |
| **Rescue location if different** | | |
| **Release location** | | |
| **# OU released** | | |
| **PRM type** | | |
| | **None** | |
| | **Microchip** | |
| | **Feeding platform observations** | |
| | **Ground follows** | |
| | **Implant** | |

## Appendix 3C

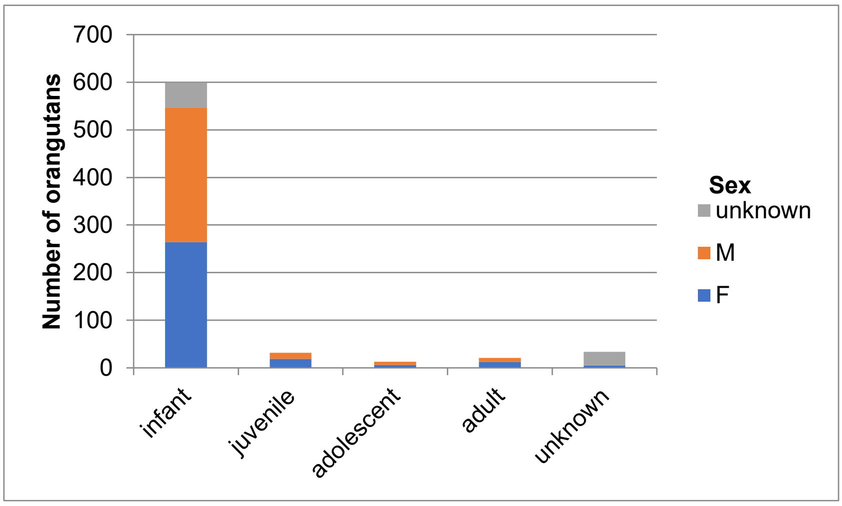


**Figure 3C1 Age class and sex of confiscated or surrendered orangutans.** n=699.

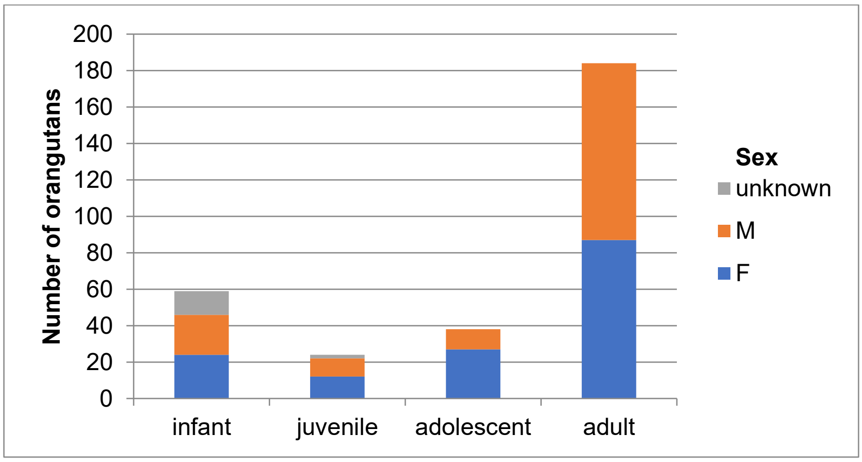


**Figure 3C2 Age class and sex of wild captured and translocated orangutans. n=305.**

# Chapter 4. Disease Risk and Conservation Implications of Orangutan Translocations

Julie Sherman[1*], Steve Unwin[2], Dominic A. Travis[3], Felicity Oram[4], Serge A. Wich[5], Ricko L. Jaya[6], Maria Voigt[7], Truly Santika[8], Emily Massingham[9], Dave J. I. Seaman[7], Erik Meijaard[7,9,10], Marc Ancrenaz[4,10,11]

[1]Wildlife Impact, Portland, OR, United States
[2]School of Biosciences, University of Birmingham, Birmingham, United Kingdom
[3]One Health Division, Department of Veterinary Population Medicine, College of Veterinary Medicine, University of Minnesota, St. Paul, MN, United States
[4]Pongo Alliance-Kinabatangan, Kota Kinabalu, Malaysia
[5]School of Biological and Environmental Sciences, Liverpool John Moores University, Liverpool, United Kingdom
[6]Orangutan Information Centre, Medan, Indonesia
[7]Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Canterbury, United Kingdom
[8]Natural Resources Institute, University of Greenwich, Chatham, United Kingdom
[9]School of Biological Sciences, University of Queensland, St Lucia, QLD, Australia
[10]Borneo Futures, Bandar Seri Begawan, Darussalam, Brunei
[11]HUTAN, Sandakan, Malaysia

**Keywords:** translocation, reintroduction, reinforcement, COVID-19, orangutan, conservation, disease

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https://www.frontiersin.org/journals/veterinary-science/articles/10.3389/fvets.2021.749547/full

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## Abstract

Critically Endangered orangutans are translocated in several situations: reintroduced into historic range where no wild populations exist, released to reinforce existing wild populations, and wild-to-wild translocated to remove individuals from potentially risky situations. Translocated orangutans exposed to human diseases, including Coronavirus Disease 2019 (COVID-19), pose risks to wild and previously released conspecifics. Wildlife disease risk experts recommended halting great ape translocations during the COVID-19 pandemic to minimize risk of disease transmission to wild populations. We collected data on orangutan releases and associated disease risk management in Indonesia during the COVID-19 pandemic from March 2020 to March 2021 and developed a problem description for orangutan disease and conservation risks. We identified that at least 15 rehabilitated ex-captive and 27 wild captured orangutans were released during the study period. Identified disease risks included several wild-to-wild translocated orangutans in direct contact or proximity to humans without protective equipment, and formerly captive rehabilitated orangutans that have had long periods of contact and potential exposure to human diseases. While translocation practitioners typically employ mitigation measures to decrease disease transmission likelihood, these measures cannot eliminate all risk, and are not consistently applied. COVID-19 and other diseases of human origin can be transmitted to orangutans, which could have catastrophic impacts on wild orangutans, other susceptible fauna, and humans should disease transmission occur. We recommend stakeholders conduct a Disease Risk Analysis for orangutan translocation, and improve pathogen surveillance and mitigation measures to decrease the likelihood of potential outbreaks. We also suggest refocusing conservation efforts on alternatives to wild-to-wild translocation including mitigating human-orangutan interactions, enforcing laws and protecting orangutan habitats to conserve orangutans *in situ*.

## 4.1 Introduction

Translocation is the human movement of wildlife between habitats or from captive facilities into natural habitats. Translocation is widely practiced to recover wild populations, release animals confiscated from the illegal wildlife trade, and address negative human-wildlife interactions (IUCN/SSC, 2013; Rivera et al., 2021). Great apes—chimpanzees, gorillas, bonobos, and orangutans—are among the taxa translocated in these circumstances (Beck et al., 2007). Translocation is an especially common practice in Indonesian orangutan management (Sherman et al., 2020a). Orangutans in Indonesia are translocated in two situations: 1) wild orangutans are captured due to actual or potential conflict with humans, perceived isolation in forest fragments, or rescue from forest fires, and moved to a new location immediately or within a short period (wild-to-wild translocation); and 2) individuals rescued from illegal trade or captivity are rehabilitated and released to supplement wild populations (reinforcement) or re-establish populations within historic range (reintroduction) (Ancrenaz et al., 2021b; Sherman et al., 2020a).

Bornean orangutans (*Pongo pygmeaus*), Sumatran orangutans (*Pongo abelii*) and Tapanuli orangutans (*Pongo tapanuliensis*) are listed as Critically Endangered by the International Union for Conservation and Nature (IUCN) Red List of Threatened Species (Ancrenaz et al., 2016a; Nowak et al., 2017; Singleton et al., 2017). Orangutan conservation efforts are confounded by a range of anthropogenic factors including poverty among humans sharing orangutan habitats, high demand for use of these habitats for agriculture and natural resource extraction, movement of humans into orangutan habitats, and human-orangutan interactions and conflicts (Meijaard et al., 2012). Due to these many deeply entrenched issues, orangutan conservation has been described as a “wicked complex” problem that cannot be easily resolved (Chua et al., 2020; Game et al., 2014). Over the past several decades, translocation has been embraced as a means to protect individual orangutans by moving them away from areas of human use or habitation, and as a conservation strategy to re-establish or reinforce wild populations (Sherman et al., 2020a).

IUCN has published best practice guidelines for wildlife translocations, including for great apes (Beck et al., 2007; IUCN/SSC, 2013). The precautionary principle for any great ape release requires that, above all, it must not endanger resident wild populations via communicable disease, hybridization or genetic issues, excessive social disruption or exacerbated competition for resources (Beck et al., 2007). IUCN guidelines further stipulate that individual welfare benefits alone are not considered a valid rationale for a conservation release and that conservation of the taxon and wild conspecifics takes precedence over the welfare of captive individuals (Beck et al., 2007; IUCN/SSC, 2013). IUCN is not a regulatory body, hence guidelines are only enforceable if mandated by government or local decision makers. The 2007-2017 Indonesian Orangutan Action Plan and the draft 2019-2029 plan refer to IUCN guidelines and incorporate some of their recommendations, including avoiding release of orangutans with infectious diseases into wild populations (Ditjen KSDAE, 2019; Ministry of Forestry, 2009).

Although translocation is an important conservation tool for many species (IUCN/SSC, 2013; Soorae, 2016), there are increasing concerns about its effectiveness for orangutans. This is due to the risks that translocation poses to wild populations and its use of funds and political will, which might otherwise be available for habitat conservation and anti-poaching efforts. Specific risks of translocation for orangutans include: disease transmission, competition and social stress for released and wild orangutans; suspected high incidences of mortality following release; and negative impacts on genetic and socioecological functioning of the source populations if individuals are removed through wild-to-wild translocation (Ancrenaz et al., 2021b; Banes et al., 2016; Grundmann, 2006; Kaye, 2016; Marzec et al., 2016; Sherman et al., 2020a). While translocations are never entirely without risk, infectious disease transmission from released animals to wild populations can pose particularly consequential risks to wild individuals and to population health (Köndgen et al., 2008). These risks exist even if few orangutans are translocated, but are compounded as translocation numbers rise.

The potential for released individuals to transmit disease to wild populations is particularly pertinent as the world struggles to contain the COVID-19 pandemic. Being our close living relatives, non-human primates are particularly sensitive to human communicable diseases (Devaux et al., 2019; Dunay et al., 2018). Wild and captive apes in proximity to researchers, caregivers, tourists, and community members can easily contract spillover diseases of human origin (Dunay et al., 2018; Kilbourn et al., 2003; Mul et al., 2007; Mynářová et al., 2016). Consequently, releases of apes into natural habitats can expose resident wild populations to significant health risks (Kaur et al., 2008; Reid et al., 2006; Schaumburg et al., 2012). The COVID-19 pandemic is an example of one such disease of concern. The disease, caused by a coronavirus, SARS-CoV-2, has infected captive gorillas and several other wildlife taxa, and likely can infect orangutans and other primates (Gibbons, 2021; Gillespie & Leendertz, 2020; Gryseels et al., 2021; IUCN SSC, 2021; IUCN SSC Primate Specialist Group, 2021; Melin et al., 2020). Gorillas in at least two zoos have contracted COVID-19 from caregivers, despite the caregivers wearing masks, observing other COVID-19 safety protocols, and being asymptomatic (Bobek, 2021; Gibbons, 2021).This risk is increased by recent COVID-19 variants including the more transmissible Delta variant, which has already infected several zoo gorillas, likely via a fully vaccinated but infected and asymptomatic keeper who was observing all safety protocols (Firozi, 2021).

For this study, we sought to answer the questions, "Can orangutan translocation pose infectious disease transmission and species conservation risks?," and "What are the implications of these risks in the COVID-19 era?" To address these questions, we collected publicly reported and unpublished data on orangutan translocations in Indonesia between March 15, 2020 and March 14, 2021, the period covering the first two waves of COVID-19 human infection in the country. We reviewed these records on wild-to-wild translocations and releases of rehabilitated orangutans to identify trends in translocation practice and disease risk management during the COVID-19 pandemic. We considered peer-reviewed published literature and the authors' unpublished data to assess best available evidence on orangutan conservation priorities and challenges, and the health and conservation impacts of orangutan translocation. We used these translocation, health, and conservation data and the World Organization for Animal Health (OIE) and IUCN wildlife disease risk procedures (OIE & IUCN, 2014) to develop a problem description and a list of potential disease risk pathways in orangutan translocations. This problem description identifies risks specific to the three different types of translocations practiced with orangutans: reinforcements, reintroductions and wild-to-wild translocations. The problem description is the precursor to a full Disease Risk Analysis (DRA) for orangutan translocations, which is planned as part of an orangutan translocation practitioner and conservation stakeholder workshop later in 2021. Finally, we present a qualitative logic matrix, employing COVID-19 as an example of pathogen transmission risk, which can be used or adapted to weigh relative health and conservation risks of orangutan translocation. These considerations are applicable across great ape taxa and to many other non-human primate species.

## 4.2 Materials and Methods

### Orangutan Translocation Data Collection and Analysis

We collected data on orangutan translocation events between March 15, 2020 and March 14, 2021. To obtain these data we reviewed online newspapers, government reporting, and reporting by non-governmental organizations (NGOs) focused on orangutan rescue, rehabilitation and release. We searched the department of Natural Resources and Ecosystem Conservation [*Konservasi Sumber Daya Alam dan Ekosistem* (KSDAE)] newsblog, and Indonesian newspaper websites ANTARA News, Prokal, TribunNews, Kompas, and The Jakarta Post, using the search term "orangutan" to capture any relevant news published during the study period. We also performed a Google Advanced Search for news results in both English and Bahasa Indonesia for the search term “orangutan” published during this period. The term “orangutan” is typically spelled the same in both languages, although searches for “orangutan” also returned results for the alternate spelling “orang-utan.” We compiled reported information from the ten organizations that held and released orangutans within Indonesia as of 2020, namely Bornean Orangutan Survival Foundation, Centre for Orangutan Protection/Borneo Orangutan Rescue Alliance, International Animal Rescue-Ketapang, Orangutan Foundation International, Orangutan Foundation–UK, Orangutan Information Centre, Sintang Orangutan Centre, Yayasan Jejak Pulang, and government facility BKSDA Tenggarong. Provincial departments of KSDAE, the *Balai Konservasi Sumber Daya Ekosistem* (BKSDA) also rescue and release orangutans and may temporarily hold them but do not operate long-term captive care facilities. Data on BKSDA releases were collated from the KSDAE online newsblog, and from online newspaper sources. Data on NGO releases were collected from these organizations' newsblogs, press releases, social media posts, annual reports, monitoring reports. Articles in Bahasa Indonesia were translated using Google translate, and we referred questions on meaning or nuance to Indonesian speaking authors of this paper.

For each record referencing orangutan translocations, we extracted any available data on: (1) rescue and release dates; (2) number of animals; (3) individual animal's age, sex, name, physical condition; (4) any description of health checks and post-release monitoring; (5) the origin and release locations; and (6) the entities conducting the translocation. Wherever possible we analyzed multiple sources to confirm data and address gaps within individual records. We excluded any possible duplicate records by reviewing for repeat mentions of combinations of available information on release date; animal name, age, and sex; and the translocation location and circumstances. We excluded all records where it was unclear if the animal had been previously counted. Releases were classified as: (1) reintroduction/reinforcements if they involved ex-captive orangutans that spent 6 months or more in rehabilitation facilities, or (2) wild-to-wild translocation if they involved wild orangutans captured and released within six months or less. Re-releases of previously released and recaptured orangutans were classified as the type of release originally conducted.

Release rates are the annual sums of individual animals released by release classification. For comparison of release rates before the COVID-19 pandemic, we used our published data on orangutan rescues and releases from 2007–2017 (4), and authors' dataset on 2018–

2019 rescues and releases (Sherman, Ancrenaz and Meijaard unpublished data, Jaya unpublished data). The collection methods for these data are the same as described here for 2020 data.

**Problem Description and Qualitative Logical Risk Assessment Matrix**

The authors comprise a group of wildlife health, conservation and orangutan experts including orangutan translocation practitioners, orangutan conservation practitioners, and specialists in orangutan population, socioecology, health, and welfare. These practitioners considered the research questions of whether orangutan translocations can pose disease transmission and conservation risks, and specifically COVID-19 transmission risks. We followed the problem description questions posed by the OIE and IUCN Manual on Procedures for Wildlife Disease Risk Analysis (2014) in considering these queries. A problem description identifies the questions and issues being considered, assesses the cultural, political and social contexts that affect these issues, and identifies potential pathways by which risk is introduced (Wolf et al., 2019). Here, we reviewed data to identify four elements of potential risk: (1) is the problem (pathogen transmission and conservation risk) potentially occurring?; (2) in which ways could the problem occur?; (3) what is the scope and context of the problem?; and (4) how should the problem description inform action? Some authors of this paper will also participate in the upcoming orangutan Disease Risk Analysis workshops, while others are not part of the workshop group, and serve here to provide external, independent views on the problem description. Having separate and independent problem description and hazard identification/DRA processes has been recommended to prevent political and social biases (Hartley & Sainsbury, 2017).

To determine whether transmission is potentially occurring (element 1 of potential risks, as described above), we reviewed the available data on orangutan translocations during the COVID-19 era (Orangutan Translocation Data Collection and Analysis). To examine which ways the problem could occur (element 2), we used published literature and author's expert knowledge to identify the “risk pathways” –logical routes by which pathogens could be introduced to orangutans from humans, or vice versa, or could spread amongst orangutans in captivity or in the wild (Table 4.1). It was necessary to answer OIE and IUCN (OIE & IUCN, 2014) problem description questions separately for each translocation type (reinforcement, reintroduction, and wild-to-wild translocation), as each translocation type has a distinct set of risks and uncertainties. Element 3 required consideration of the conservation, policy and cultural contexts underpinning orangutan translocations, using published literature and author's unpublished data. Elements 1–3 are summarized in Table 4.2, a matrix of answers to the OIE and IUCN (OIE & IUCN, 2014) problem description questions.

**Table 4.1. Pathogen risk pathways in orangutan rescue, rehabilitation and translocation.** Rscue, rehabilitation and release activities associated with potential pathogen risk pathways**.**

| Translocation activity | Potential pathogen risk pathways | Activity relevance by translocation type |
|---|---|---|
| Orangutan interactions or conflict with humans; capture and translocation of wild orangutans encountered in habitats occupied or regularly used by humans | • Human proximity or direct contact from tourism, research, or local communities in shared habitats<br>• Injury or contact with human equipment or other possible fomites<br>• Wildlife vectors in human-occupied habitats (rodents, insects, etc.)<br>• Human, pet or livestock waste or other infected matter | Wild-to-wild |
| Time in human captivity (other than at rescue center) | • Prolonged human proximity and direct contact with humans<br>• Prolonged proximity with other captive apes potentially source of pathogens<br>• Exposure to or direct contact with livestock or pets<br>• Injury or contact with human equipment or other possible fomites<br>• Stress leading to increased susceptibility or recurrence of latent disease<br>• Wildlife vectors in human residences or businesses (rodents, insects, etc.)<br>• Human, pet or livestock waste or other infected matter | Reinforcement; Reintroduction |
| Intervention to move orangutans in conflict situations - darting and capture for wild-to-wild translocation | • Prolonged human proximity and direct contact with humans<br>• Injury or contact with human equipment or other possible fomites<br>• Stress leading to increased susceptibility or recurrence of latent disease | Wild-to-wild |
| Live capture by hunters or in snare | • Human proximity and direct contact with humans<br>• Injury or contact with human equipment or other possible fomites | Wild-to-wild; Reinforcement; Reintroduction |
| Physical examination and emergency care | • Human proximity and direct contact with humans<br>• Exposure to or direct contact with humans and other wildlife<br>• Injury or contact with human equipment or other possible fomites | Wild-to-wild; Reinforcement; Reintroduction |
| Transport to care facility | • Human proximity and direct contact with humans<br>• Injury or contact with human equipment or other possible fomites | Wild-to-wild; Reinforcement; Reintroduction |
| Captive care and rehabilitation in rescue center | • Prolonged human proximity and direct contact with humans, including staff, volunteers, researchers and tourists<br>• Exposure to or direct contact with conspecifics, other wildlife, and pets<br>• Injury or contact with human equipment or other possible fomites<br>• Stress leading to increased susceptibility or recurrence of latent disease<br>• Wildlife vectors in captive environments (rodents, insects, etc.) | Reinforcement; Reintroduction |

| | | |
|---|---|---|
| | • Human, pet, livestock, or other captive center wildlife waste or infected matter | |
| Transport to release site | • Human proximity and direct contact with humans<br>• Injury or contact with human equipment or other possible fomites | Wild-to-wild; Reinforcement; Reintroduction |
| Release | • Human proximity and direct contact with humans<br>• Direct contact with conspecifics and other wildlife<br>• Exposure to novel pathogens in new habitats<br>• Introduction of novel pathogens to resident conspecific populations | Wild-to-wild; Reinforcement; Reintroduction |
| Post-release | • Direct contact with conspecifics and other wildlife<br>• Exposure to novel pathogens in new habitats<br>• Introduction of novel pathogens to resident conspecific populations<br>• Proximity or interactions with humans and human equipment during PRM activities and provisioning | Wild-to-wild; Reinforcement; Reintroduction |

**Table 4.2. Orangutan disease risk problem description.** Questions from OIE and IUCN Manual for Procedures for Wildlife Disease Risk Analysis (2014). Summary descriptions for each question are based on data collected for this paper, and published and unpublished sources listed.

| Question | Summary description | Sources |
|---|---|---|
| What is the nature of the problem? | • Pathogen risk mitigation strategies do not appear to be consistently applied; lack of crowd control at rescue and release events, lack of PPE use, and limited pathogen surveillance pose notable risks of pathogen transfer to rehabilitant and wild populations<br>• Orangutans are Critically Endangered. Deforestation, habitat fragmentation and killing are most pressing needs<br>• Translocation is often viewed as the preferred solution despite higher cost and risks<br>• Diverse stakeholder needs<br>• Wicked complexity of orangutan conservation issues | (Ancrenaz et al., 2021b), (Chua et al., 2020; Meijaard et al., 2012), (WHO, 2021a), (Santika et al., 2017a; Voigt et al., 2018), (Meijaard et al., 2021) |
| What are the management goals and decisions needed? How will the risk analysis help? | Goals:<br>• Design and implement regular surveillance of pathogens in wild, captive, and translocated orangutans<br>• Quantify the risk of pathogen transfers in orangutan translocation<br>• Improve viability of wild orangutan populations<br>• Improve protection of habitats, biodiversity and human safety | |
| | Risk analysis benefits:<br>• Determine circumstances wherein translocation is likely to provide a net benefit to orangutan conservation that outweighs conservation and biosecurity risks<br>• Develop and implement appropriate measures to limit disease risk<br>• Beta test the pathogen transfer management system for diseases of concern including COVID-19<br>• Promote regime of accurate sampling to avoid false negatives due to poor sampling techniques and to create stored samples for further analysis | |
| What is the ecological level of concern (population, community, ecosystem)? | All orangutan species are Critically Endangered, and all populations are at risk from killing, deforestation, and habitat degradation and fragmentation. Orangutan metapopulations are at risk from these same factors and may be harmed by removal of animals by wild-to-wild translocation. In areas of orangutan distribution where habitats have been degraded, fragmented or deforested, ecosystem functions are likely also compromised | (Ancrenaz et al., 2021b), (Santika et al., 2017a; Voigt et al., 2018), (Seaman et al., 2021), (Meijaard et al., 2021) |
| Are there any policy or regulation considerations? | Government policy calls for:<br>• Preventing loss of orangutans across all habitats<br>• Translocation of all releasable rehabilitated orangutans<br>• Use of wild-to-wild translocation only as a last resort | (Ministry of Forestry, 2009), (Ditjen KSDAE, 2019) |

| | | |
|---|---|---|
| What precedents are set by similar DRAs and previous decisions? | • Decision by practitioners at OVAG: no wild-to-wild translocations during COVID-19 pandemic<br>• IUCN SGA guidance: no wild-to-wild translocation during COVID-19 pandemic; improve pathogen transmission risk management for any activities involving great apes | (IUCN SSC, 2021); Unwin unpublished data |
| What is the cultural and political history and current context of the problem as represented through the eyes and values of different stakeholders? | • Wildlife health experts are concerned about: 1) effectiveness of pathogen risk mitigation strategies as currently implemented, and how these strategies are evaluated; 2) lack of resources to allow sample storage and analysis; and 3) reluctance on part of practitioners to collect samples at time of translocation as a baseline. Specific concerns for pathogen transfer include lack of official crowd control and prevalence of people with no PPE in contact or <6 foot distance to orangutans for $\geq$15 minutes potential exposure time, lack of sampling for surveillance and probabilities of zoonotic transmission based on data from other great apes<br>• Orangutan scientists and conservationists are concerned about: 1) lack of demonstrated evidence of population and species-level benefits from wild-to-wild translocations and reinforcements of likely viable wild populations; 2) weak law enforcement– only a small fraction of orangutan habitat is covered by patrols, rules are not enforced consistently and prosecution and sentencing for crimes affecting orangutans are exceptionally rare; 3) there are conflicting policies on promoting land development and protecting rare species habitat, and 4) orangutan conservation funding and activities to date have proven insufficient for species recovery<br>• Local community members living in orangutan range who suffer from poverty, insufficient wellbeing, and lack of livelihood opportunities feel conservation regulations and practices indicate orangutans are valued more than people<br>• Translocation practitioners and government are concerned that: 1) orangutans in potential conflict with humans may be harmed or killed; 2) orangutans encountered in forest fragments or in agricultural plantations may suffer from lack of food or poor nutrition; 3) lack of space in rehabilitation facilities; and 4) orangutans living in plantations, forest fragments, or in rehabilitation facilities may have poorer welfare than those living in large protected forests | (Ancrenaz et al., 2021b; Sherman et al., 2020a), (Chua et al., 2020; Meijaard et al., 2012; WHO, 2021a), (Sherman et al., 2020b), (Meijaard et al., 2021), (Santika et al., 2022) |
| What resources (e.g. personnel, time, money) are needed and available? | • Investments in orangutan translocation are substantial, but significantly increased resources are needed for long term monitoring, development and implementation of solutions for human-orangutan coexistence, as well as for disease surveillance<br>• More buy in is needed from translocation practitioners for significant increases in surveillance and disease testing<br>• Equipment, funding and other resources for pathogen surveillance are needed locally. While laboratories and equipment are available internationally, the organizations implementing translocations locally cannot always access them. Capacity building, financial and equipment resources, personnel and staff time are needed for sampling and sample storage | (Sherman et al., 2020b), (Wilson et al., 2014), (Santika et al., 2022) |
| What level of risk is acceptable? | Views on acceptable risk differ among stakeholders. Wildlife health experts, orangutan scientists and conservationists urge a precautionary approach that would involve increased surveillance, a DRA, consistently applied risk mitigation measures, and cessation of most wild-to-wild translocations due to high risk and uncertain benefits. Most translocation practitioners are comfortable with the risks posed by current translocation practices | Authors' unpublished data, (Sherman et al., 2020a), (Palmer, 2018) |
| What documents or data exist to describe the state of knowledge of the problem? | See references cited for this paper. Data are available on some aspects of orangutan socioecology and habitat use, population status, zoonotic disease risks, and the outcomes and impacts of translocation and other conservation interventions | |

To exemplify how the problem description could inform decision making and action (element 4), we used SARS-CoV-2—an example of a human to non-human primate transmissible pathogen—to develop the qualitative risk matrix tool (Figure 4.5). We considered published data on COVID-19 disease presence in humans and great apes, and in other wildlife and domestic animals. We used qualitative categories of risk because data were not available for captive and wild orangutan exposure and transmission of the SARS-CoV-2 pathogen in Indonesia, and to make the matrix more useful to the diverse array of orangutan translocation stakeholders and decision makers (Hartley & Sainsbury, 2017). We made a logical stepwise matrix of risk categories based on the likelihood of active infection; exposure of susceptible individuals; and consequences of susceptible recipients becoming infected, getting sick or dying, and spreading the disease (28, 32). The risk matrix is based on Risk = Likelihood × Consequences. Likelihood and consequence category definitions are provided in the cells bounding the risk matrix. Category definitions are based on human health and safety risk likelihood and consequence definitions (Curtin University, n.d.; University of Melbourne, 2018). We also factored in mitigations including personal protective equipment (PPE), disease testing, and vaccination, as well as uncertainties about disease transmission and its consequences (Gibbons, 2021; IUCN SSC Primate Specialist Group, 2021). We weighed associated conservation risks using the IUCN precautionary principles, which state that great ape releases should not endanger wild conspecifics, other taxa within the release habitat, or habitat ecosystem functions (Beck et al., 2007; IUCN/SSC, 2013).

## 4.3 Results

### Orangutan Translocations During COVID-19 Pandemic

Our results suggest that the problem—pathogen transmission between humans and orangutans—is potentially occurring. Orangutans are being handled by or are in physical proximity with humans for extended periods. Translocated orangutans are highly likely to be in contact with wild orangutans after release. Other than the two sites in Sumatra, where wild-to-wild translocated and rehabilitated orangutans are reintroduced within historical range but outside current distribution (Kelle et al., 2013), orangutans are purposefully released into wild populations, or into areas where they have the potential to disperse into existing wild populations (Lokuciejewski, 2019; Russon, 2009; Sherman et al., 2020a).

Orangutan translocations decreased in frequency but continued throughout the COVID-19 pandemic. We identified releases of at least 15 rehabilitated ex-captive orangutans (reintroductions or reinforcements), and 27 wild-to-wild translocations in Indonesia from March 15, 2020 to March 14, 2021 (Table 4.3). At least two wild-to-wild translocations occurred during the March–May 2020 Indonesian government moratorium on captive wildlife releases. Three wild orangutans, one *P. pygmaeus*, one *P. abelii* and one *P. tapanuliensis*, were translocated multiple times during the study period. Total orangutan releases declined 74% and wild-to-wild translocations declined 64% during the study period compared to the average annual rate over the 5 years before COVID (2015–2019) (Figure 4.1). Notably the number of wild-to-wild translocations was highest in 2015, likely induced by the greater incidence of fires during the El Nino phase that year. The annual wild-to-wild translocation rate dropped from 155 in 2015 to 61 in 2016, and varied between 57 and 26 between 2017 and 2019.

**Table 4.3. Orangutan translocations during the COVID-19 pandemic in Indonesia.** Translocations recorded between March 15, 2020 and March 14, 2021. Each translocation event is a release of one or more animals together at the same site on the same day. Event 9 covers 10 animals reported released in 2020 with no further detail provided on number of events or specific dates; however no public records of these translocations were found between January 1 and March 14, 2020, so these releases were assumed to have occurred March 15, 2020 or later. Orangutan is abbreviated as OU. BKSDA is *Balai Konservasi Sumber Daya Alam*, the government natural resources agency, a part of KSDAE. Recapture of wild OU are captures and rereleases of previously released wild orangutans. Three individuals are listed more than once as they were translocated multiple times (female "Maria" in events 2 and 3, male "Boncel" in events 4, 10 and 18, and female "Gisel" in events 12 and 15).

| Event # | Species | Translocation type | Animal source | # OU released | Date | Source |
|---|---|---|---|---|---|---|
| 1 | *P. pygmaeus* | Wild-to-wild | Wild captured | 3 | 23 Mar. 2020 | KSDAE (2021b) |
| 2 | *P. abelii* | Wild-to-wild | Recapture of wild OU | 1 | 20 Apr. 2020 | (KSDAE, 2020c) |
| 3 | *P. abelii* | Wild-to-wild | Recapture of wild OU | 1 | 7 Jul. 2020 | (KSDAE, 2020d) |
| 4 | *P. pygmaeus* | Wild-to-wild | Wild captured | 1 | 24 Aug. 2020 | (IAR, 2020c) |
| 5 | *P. abelii* | Wild-to-wild | Wild captured | 1 | 15 Sept. 2020 | (OIC, 2020a) |
| 6 | *P. abelii* | Wild-to-wild | Wild captured | 1 | 15 Oct. 2020 | (OIC, 2020b) |
| 7 | *P. tapanuliensis* | Wild-to-wild | Recapture of wild OU | 1 | 23 Nov. 2020 | (Gunawan, 2020) |
| 8 | *P. pygmaeus* | Reinforcement | Ex-captive rehabilitated | 5 | 17 Dec. 2020 | (IAR, 2020b) |
| 9 | *P. pygmaeus* | Wild-to-wild | Wild captured | 10 | During 2020 | (BOSF, 2020c) |
| 10 | *P. pygmaeus* | Wild-to-wild | Recapture of wild OU | 1 | 14 Jan. 2021 | (IAR, 2021) |
| 11 | *P. abelii* | Wild-to-wild | Wild captured | 1 | 30 Jan. 2021 | (OIC, 2021c) |
| 12 | *p. pygmaeus* | Wild-to-wild | Wild captured | 1 | 30 Jan. 2021 | (COP, 2021b) |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13 | *P. abelii* | Wild-to-wild | Wild captured | 1 | 5 Feb. 2021 | (OIC, 2021b) |
| 14 | *P. abelii* | Wild-to-wild | Wild captured | 1 | 9 Feb. 2021 | (OIC, 2021a) |
| 15 | *p. pygmaeus* | Wild-to-wild | Recapture of wild OU | 1 | 10 Feb. 2021 | (COP, 2021c) |
| 16 | *p. pygmaeus* | Reinforcement | Ex-captive rehabilitated | 7 | 16 Feb. 2021 | (BOSF, 2021) |
| 17 | *p. pygmaeus* | Reinforcement | Ex-captive rehabilitated | 3 | 16 Feb. 2021 | (BOSF, 2021) |
| 18 | *p. pygmaeus* | Wild-to-wild | Recapture of wild OU | 1 | 22 Feb. 2021 | (KSDAE, 2021b) |
| 19 | *p. pygmaeus* | Wild-to-wild | Wild captured | 1 | 10 Mar. 2021 | (Balai Ksda Kalteng, 2021b) |

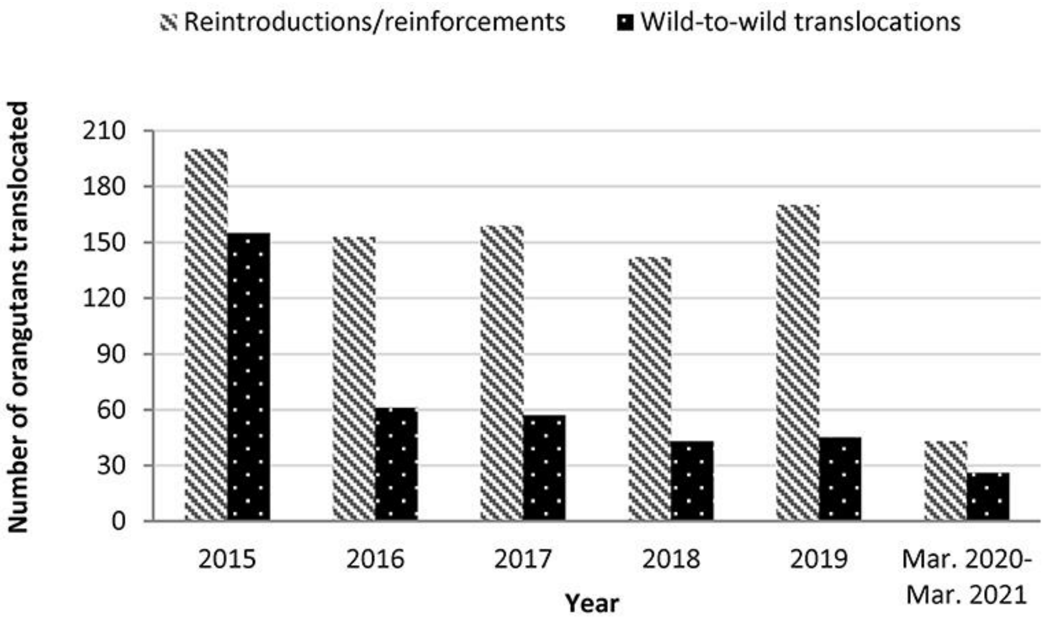


**Figure 4.1**. Orangutan translocations in Indonesia since 2015. Annual rates are estimated from (Sherman et al., 2020a), available rescue center annual reports and news blogs, KSDAE news blog and unpublished data. Release rates shown may be lower than actual releases, as some rescue centers did not have publicly available data for all years.

In March 2020, IUCN Primate and Wildlife Health specialist groups recommended halting all releases of great apes in light of the extraordinary risk posed by the potential transmission of COVID-19 from humans to non-human great apes (Gillespie & Leendertz, 2020; IUCN SSC Primate Specialist Group, 2021). The Indonesian government prohibited captive wildlife releases in mid-March 2020 to prevent disease transmission to wild populations (Gokkon, 2020a; Paddock, 2020). On May 20, 2020, the Indonesian Ministry of Environment and Forestry released a circular lifting this moratorium and providing technical instructions for wildlife releases during the COVID-19 pandemic (Gokkon, 2020b; KSDAE, 2020g). The circular stipulates that all animals, including wild individuals that have been near humans, must go through medical examination and receive a certificate of health from KSDAE prior to release, and that the number of personnel involved in the release should be limited to the smallest number feasible to safely conduct release activities (KSDAE, 2020g). All wildlife rescues and releases are conducted by Indonesian government personnel from the KSDAE (KSDAE, 2020e; Nijman, 2005). Results of the implementation of the circular were not publicly available.

While some safety measures have been taken to prevent the spread of COVID during translocations, these measures have been inconsistent and insufficient to avoid potential pathogen exposure risk to wild populations. Photographs in news and social media reports showed some precautionary measures such as personal protective equipment (PPE) were applied during the study period (BOSF, 2021; KSDAE, 2021a; OIC, 2020b), but use was not consistent. Photographs show many people present at releases, often in direct contact with orangutans (Figure 4.2). Some examples include: (1) a wild-to-wild translocated *P. tapanuliensis* surrounded by seven people, four of whom were not wearing any PPE (KSDAE, 2020b); 2) a wild-to-wild translocation during the captive wildlife release moratorium (March 23, 2020) with at least 10 people present, and three people wearing masks below their nose or mouth (KSDAE, 2020h); and 3) two people next to an anesthetized wild-to-wild translocated orangutan, both with masks below their chins (Balai Ksda Kalteng, 2021b). Such situations also occurred in release records prior to COVID (KSDAE, 2019a, 2019e, 2020a) (Figure 4.3). We could not assess the proportion of releases during the study period with adequate vs. inadequate protective measures because published photographs were not available for every translocation event, and when available do not capture every aspect of the entire procedure. However, the available images illustrate the reality of the disease transmission risks during orangutan translocation.

**Figure 4.2**. PPE use and human proximity in wild-to-wild orangutan translocations during COVID-19 pandemic. Pictures showing examples of mixed use of PPE and human proximity to orangutans during captures and releases of wild orangutans between March 15, 2020 and March 14, 2021. The orangutans are in the blue sling and the orange and black net, respectively. Identifiable human features and organizational logos are obscured to protect anonymity. Image credits from left to right: BBKSDA Sumatera Utara via KSDAE Top News blog http://ksdae.menlhk.go.id/assets/uploads/ou_sipirok2.JPG (KSDAE, 2020b); BKSDA Kalimantan Tengah via Facebook https://www.facebook.com/BKSDAKalimantanTengah/posts/1365289040500502 (Balai Ksda Kalteng, 2021b).

**Figure 4.3**. PPE use and human proximity in wild-to-wild orangutan translocations prior to COVID-19 pandemic. Pictures showing examples of mixed use of PPE and human proximity to orangutans during capture and releases of wild orangutans prior to March 15, 2020. The orangutan in the top photo is in the orange and black net. Identifiable human features and organizational logos are obscured to protect anonymity. Image credits from top to bottom: BKSDA Aceh via KSDAE Top News blog http://ksdae.menlhk.go.id/assets/news/Translokasi_ortu1.jpeg (KSDAE, 2019e); BKSDA Kalimantan Tengah via KSDAE Top News blog http://ksdae.menlhk.go.id/assets/news/gambb.jpg (KSDAE, 2019a).

**Pathogen Risk Pathways in Orangutan Translocations**

Pathogen transmission can occur via numerous pathways inherent in the orangutan rescue, rehabilitation and translocation process (Table 4.2). This includes consideration of transmission risks posed by exposure times, e.g. 15 minutes or longer for COVID-19 (WHO, 2021a). The table addresses pathways for other pathogens of concern that can cause morbidity or mortality in orangutans, can be transmitted to wild orangutans, and have been identified in captive orangutans. Examples of these pathogens include members of the viral families Hepadnaviridae, Picornaviridae, Phabdoviridae (Orangutan Conservancy, 2010; Philippa & Dench, 2019), bacteria such as *Streptococcus sp, Burkholderia pseudomallei* (Philippa & Dench, 2019) and *Mycobacterium tuberculosis* complex (Dench et al., 2015), and parasite species including *Plasmodium sp*. (including strains that also infect other non-human primate species and humans) (Nurcahyo et al., 2017), *Entamoeba histolytica* and *Strongyloides sp*, that would all likely result from contact or proximity to humans (Anggraini et al., 2023; Labes et al., 2010). Pathways of zoonotic disease transmission between humans and orangutans or among orangutans include direct and indirect contacts (abiotic transfer via fomites and other transmission ways), and animal vectors.

**Problem Description**

Based on evidence that the problem can potentially occur through a variety of pathways inherent in the orangutan translocation process, we developed a problem description (Table 4.2). We included data presented in this study, along with contextual information on conservation, socioeconomic, political, and ethical considerations from published literature (see discussion) to answer the problem description questions posed by OIE and IUCN (2014). This problem description highlights a large number of data gaps and assumptions, indicating that a qualitative method of assessment based on the precautionary principle will likely be needed in the first iteration of a DRA for orangutan translocation.

**Qualitative Logic Matrix for SARS-CoV-2 Risk in Orangutan Translocation**

We used the data summarized in the problem statement to make a qualitative risk assessment matrix that can be used by practitioners to consider overall threats associated with orangutan translocations (Figure 4.4). Likelihood for transmission from humans multiplies as more people interact with or are in proximity to the orangutan, and as exposure times lengthen. We also considered available information on mitigation measures and uncertainties, all of which modify likelihoods and consequences.

| Qualitative rank definitions |
|---|
| Severe risk: Translocation is not advisable; other conservation solutions should be pursued |
| High risk: Translocation into wild populations is not advisable; extreme caution should be used for reintroduction |
| Moderate risk: Translocation may not be advisable; additional information is needed before proceeding |
| Negligible or low risk: Translocation is not expected to have marked negative impacts |
| COVID-19 transmission and morbidity/mortality risk rating for orangutan rehabilitation and translocation scenarios |

| | | | Consequences | | | | |
|---|---|---|---|---|---|---|---|
| | | | **Insignificant** | **Minor** | **Moderate** | **Significant** | **Catastrophic** |
| | ***Species & ecosystem conservation consequences and likelihood*** | | No expected risk to conspecifics, other taxa, or ecosystem | Low risk to conspecifics or ecosystem; possible risks to other taxa | Some risks for conspecifics and/or other taxa | Significant risk of possibly lethal effects in conspecifics and/or other local taxa; possible ecosystem effects | Lethal effects pose population or species risk; likely negative effects on other taxa or ecosystem |
| | | ***Health & biosecurity consequences and likelihood*** | No health effect; little or no transmission risk | No long term health effect; little or no transmission risk | Some health effects, moderate transmission risk | Moderate risk of transmission and/or morbidity and mortality | High risk of transmission, morbidity / mortality, disease spillover |
| **Likelihood** | | | | | | | |
| **Near certain** | Species or ecosystem effects often occur in OU releases | Transmission or disease in OU happens regularly | | | | | |
| **Likely** | Species or ecosystem effects have occurred multiple times in GA or OU releases | Transmission or disease in GA or humans working with GA has occurred multiple times | | | **Reintroduction:** Lower initial risk of disease presence due to mitigation. Opportunities for infection through captivity, release and post-release human proximity. Released OU populations susceptible and non-immune; other taxa may be also | **Wild-to-wild translocation and reinforcement:** Many people in contact/proximity to OU. Confirmed human-GA transmissibility; all wild OU susceptible and non-immune; other taxa may be susceptible | **Tapanuli translocation:** Infection, death and transmission could pose catastrophic species impact and effect ecosystem; disease spillover to other taxa and local human populations possible |
| **Possible** | Species or ecosystem effects have occurred at least once in OU or other primate releases | Has happened at least once before in GA or other primates, or in humans involved in GA care | | **Captive OU:** Lowered risk of disease presence due to mitigation; any active infection poses high risk to OU which are susceptible and non-immune | | | |
| **Unlikely** | Species or ecosystem effects have occurred but not in primate releases | Has not happened in GA but has in other animals | | | | | |
| **Rare** | Species or ecosystem effects have not been recorded in wildlife releases | Possible; has not been detected in wildlife | | | | | |

**Figure 4.4**. Qualitative risk matrix for orangutan translocation using COVID-19 example. OU = orangutans; GA = great apes. Colored cells inside double lines denote overall qualitative rank. Consequence definitions are presented in the two cells beneath each category name, with species and ecosystems in the top cell and health and biosecurity in the cell below. Likelihood category definitions are presented in the two cells to the right of each category name, for species and ecosystems and then for health and biosecurity from left to right. Cells relevant to OU translocation scenarios have a thick border and list factors considered in risk ranking.

The risk of catastrophic consequences is highest for wild-to-wild translocation of Tapanuli orangutans. Tapanuli orangutans are the world's rarest great ape species, with a population of <800 individuals under significant threat from human activities (Nowak et al., 2017). The capture and release of these orangutans puts them at risk of exposure to the virus from infected humans. COVID-19 is uncontrolled in Indonesia at the time of writing, with only 17% of the population vaccinated (New York Times, 2021), and it is possible that humans in proximity to translocated animals will not use adequate disease risk mitigation measures (Figures 4.2, 4.3). Translocation of these animals into a small, geographically constrained wild population that is susceptible and non-immune to COVID-19, and already at serious risk of extinction, poses marked risks. Slightly lower but still severe risk is posed by wild-to-wild translocation of *P. abelii* and *P. pygmeaus*, or their release to reinforce wild populations, again due to known susceptibility of the species to the COVID-19 pathogen, likely exposure of translocated orangutans to humans without protective measures, and that wild and formerly released animals are non-immune.

Reintroduction of rehabilitated ex-captive orangutans is somewhat lower risk due to extensive protective measures available for captive animals and staff. Nonetheless, the risk remains high due to pathways for infection during captivity or release, or following release (at provisioning or observation sites), and subsequent risk of pathogen transmission to susceptible and non-immune conspecifics at the release site. Captive orangutans pose a moderate risk overall, as protective measures can be employed consistently. As with reintroduction, opportunities for infection during captivity still persist due to human contact and proximity.

## 4.4 Discussion

Problem descriptions such as the one presented here can be useful tools to help forge agreement among stakeholders, which is vital for successful risk communication and advancing the DRA process and (Hartley & Sainsbury, 2017; OIE & IUCN, 2014). Anecdotally, the lack of a problem statement is where a lot of DRA processes fail: when stakeholders cannot agree on the problem, it is more challenging to convince decision makers to follow the DRA recommendations for risk management (Unwin, unpublished data). This paper poses questions that must be answered by the orangutan translocation community before progress can be made toward a full DRA. The context and drivers of orangutan translocations further complicate potential disease and conservation risks by creating pressure for translocation as an ostensibly rapid, short-term solution to protect orangutans.

Despite the popularity of translocation, survival rates of released orangutans are not well known. Orangutans are difficult to follow and radio collars have not worked well with orangutan anatomy, so Very High Frequency (VHF) implants are used for tracking rehabilitated and released animals (Robins et al., 2019). Wild-to-wild translocated orangutans are generally microchipped for identification but almost never monitored post release (Sherman et al., 2020a). This means their adaptation and survival following release are unknown unless they return to the areas where they were originally captured (see Table 4.3). Estimated survival rates of rehabilitated and released orangutans range from 6 to 80%, but 40–95% of these released orangutans are not re-encountered after release (Sherman et al., 2020a). Researchers also note that as many as 1,200 orangutans released in Kalimantan, Indonesia may have disappeared or died following release, but poor record keeping and reporting makes exact numbers impossible to verify (Preuschoft et al., 2021).

The 2007–2017 Indonesian national Conservation Strategies and Action Plan for Orangutans mandated release of all orangutans from rescue centers by 2015, which proved impossible given intake and birth rate. A draft 2019–2029 plan for Indonesian orangutan conservation called for all releasable orangutans to be translocated by 2024 (Sherman et al., 2020a). Though similarly unachievable due to lack of suitable release sites for the more than 1,000 orangutans in captive care, these plans create significant political pressure to release as many animals as possible. Some practitioners state that overcrowding at centers or pressure from donors is a rationale to continue releasing rehabilitated ex-captive orangutans (Gokkon, 2020a, 2020b; Sherman & Greer, 2018). Holding orangutans in captivity is costly, and most centers are already full or over-capacity (Gokkon, 2020a; Karokaro et al., 2017; Sator, 2018). The 2019 plan describes wild-to-wild translocation as a last resort option, but in practice both NGO and government officials publicly request that local residents report any orangutans they see in or near areas of human use, and practitioners note that community members view it as the government's job to move any such orangutans (Jaya, unpublished data; Sherman et al., 2020a). A diagrammatic view of the complexity of orangutan management and conservation is presented in Figure 4.5.

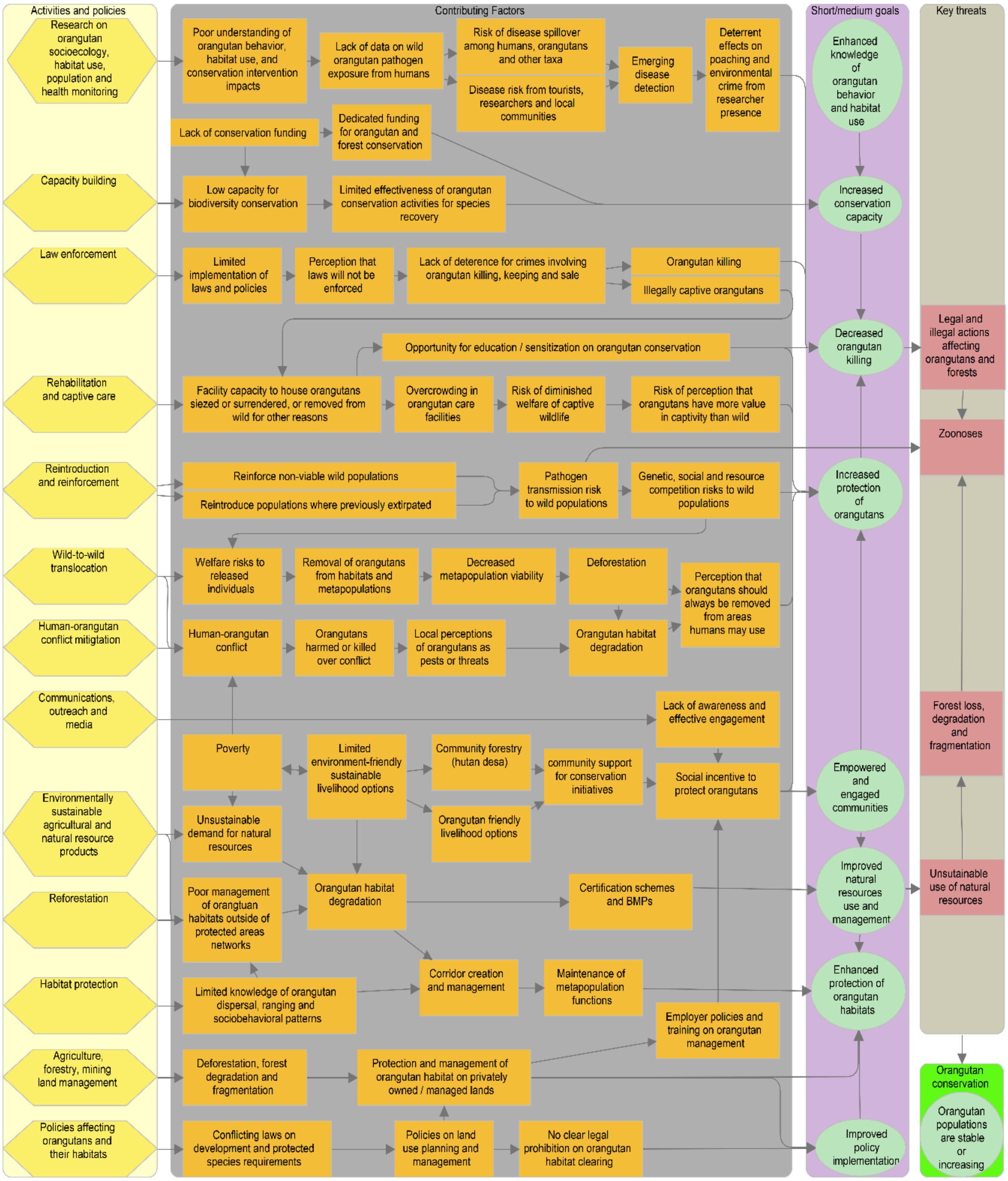


**Figure 4.5.** Orangutan conservation complexity. Cells in far left column are activities and policies affecting orangutans. Central section cells describe positive and negative factors that affect orangutan conservation outcomes. The second column from the right shows the interim goals of activities and policies. Key threats that activities and policies aim to address are in the far right column. Arrows indicate relationships between cells. High resolution figure available at https://www.frontiersin.org/files/Articles/749547/fvets-08-749547-HTML/image_m/fvets-08-749547-g005.jpg.

## Context and Drivers of Orangutan Translocation

Populations of all three species of orangutans are declining, primarily due to forest loss and killing (Ancrenaz et al., 2016a). The underlying drivers of these threats complicate efforts to conserve orangutans. Poverty and well-being are significant concerns across much of Indonesia, particularly in rural areas with limited access to markets (Miranti et al., 2013). Expansion of palm oil production, including in orangutan range, has been championed by industry and government as a solution for poverty alleviation, despite mixed results for human livelihoods and wellbeing (Santika et al., 2019c). Results for orangutans, on the other hand, have been markedly poor (Santika et al., 2017a; Voigt et al., 2018). However, conservation and management of orangutan populations within forest reserves and forested patches in palm oil plantations is possible if killing is avoided (Ancrenaz et al., 2021b; Meijaard et al., 2016; Seaman et al., 2021).

Where forests are cleared for agriculture, agro-forestry, natural resource extraction, or human settlements, orangutans are often driven out of their original habitats or have easier access to human crops (Arcus Foundation, 2013, 2015, 2017). This can lead to conflicts with people when orangutans are found crop foraging or using human-occupied areas. Orangutans are often injured or killed by humans in these situations (Meijaard et al., 2011a; Sherman et al., 2020a). Orangutans are also killed for food, for traditional medicine, or to obtain live infants for pets (Davis et al., 2013).

Capturing infant orangutans nearly always necessitates killing the mother (Sherman et al., 2020a). Although illegal, keeping infant orangutans as pets is common in Indonesia, as is injury or harassment of wild orangutans found in human-occupied areas (Nijman, 2017; Sherman et al., 2020a). On average, more than 115 wild or illegally captive orangutans are being surrendered, confiscated or otherwise rescued by wildlife rescue organizations and government annually (Sherman et al., 2020a). Many Indonesians who buy or take an infant orangutan are motivated to "save" or care for the animal, although most privately held animals are rescued from malnourishment and often horrific conditions (Rainer et al., 2020; Sherman et al., 2020a).

Against this background of poverty, strong demand for forest lands, high killing rates and consistent local demand for pet orangutans, translocation is often marketed to the public as a means to "save" orangutans (Sherman et al., 2020a). Investments into orangutan rescue, rehabilitation and release total millions of dollars annually, but have not halted the continued decline in species populations (Sherman et al., 2020b), although these investments have prevented losses from being even greater (Santika et al., 2022). Orangutan releases are considered a conservation necessity by some (Nellemann et al., 2007), while others note that releases do not address the taxon's most urgent conservation needs, namely preventing deforestation and fragmentation of natural forest habitats, and forestalling the loss of wild orangutans by addressing killing and capture (Meijaard et al., 2012; Sherman et al., 2020b). Rehabilitation and release also cost more than 12 times as much per orangutan as improved habitat protection (Wilson et al., 2014). Nonetheless, releasing captive orangutans back to the wild is considered the only ethical option by many practitioners (Palmer, 2018). Orangutan release also presents an ostensibly "quick and easy solution," while habitat protection or community engagement to address killing requires longer term investment and effort, particularly in lowlands where stakeholders with complex and vested interests exist (Santika et al., 2022). Reintroduction of orangutans into historical range but outside current distribution has resulted in establishment of two new Sumatran orangutan populations, which are projected to become self-sustaining over time if releases continue over the next ten years and habitat loss and killing are prevented (Utami-Atmoko et al., 2019b). Notably, habitat incursion and human-orangutan conflict are pressing concerns in at least one of these areas (Maskulino et al., 2021). Rehabilitated ex-captive and wild-to-wild translocated orangutans have also been released to reinforce viable and some small non-viable wild populations in both Kalimantan and Sumatra (Sherman et al., 2020a).

Orangutans metapopulations are multiple interacting individual orangutan populations bounded by geographic barriers. These metapopulations are projected to continue declining despite release activities, due to habitat fragmentation, forest loss and orangutan killing or removal (Utami-Atmoko et al., 2019b). This is partly explained by the fact that releases do not represent net additions of orangutans to wild populations. Most ex-captive orangutans represent a net loss of at least two wild orangutans from the source population (the mother, likely killed, and the captured infant), with the rehabilitated former infant released after years of rehabilitation into another population (Sherman et al., 2020a). Wild-to-wild translocations thus represent a lateral movement comprised of removal of the wild orangutan from one local population, and its release into another.

Orangutan behavior and socioecology pose challenges for rehabilitation and survival of released orangutans, further complicating the potential for releases to boost wild populations (Preuschoft et al., 2021). Wild adults of both sexes face difficulties in establishing a home range and adapting socially if translocated to a new location where the local orangutan population is unfamiliar to them. Wild-to-wild translocations are a particular concern in this regard, as they capture and remove wild orangutans from their metapopulation, disrupting the breeding and social structures of dispersed males and resident females (Ancrenaz et al., 2021b). Importantly, different forest types within orangutan range differ in their seasonal, annual and spatial distribution of fruit and other food resources (Marshall et al., 2021; Vogel et al., 2015), meaning orangutans may not know where and when to find important foods if they are translocated to unfamiliar locations (Sherman et al., 2020a). This may explain why wild-to-wild translocated orangutans often return to their capture site from following release, resulting in some animals being recaptured and moved multiple times (Table 4.3). Finding food in an unfamiliar habitat could also pose energetic stresses. Orangutans can exhibit decreased body weights and depleted fat stores during periods of low fruit availability (O'Connell et al., 2021). Wild orangutans with low body weights found foraging in oil palm plantations or other human crops are often considered to be starving and in need of being moved to new habitats, but instead may in some cases be going through a natural cycle of muscle catabolysis during low fruit availability.

**Disease Risks**

All this wicked complexity (Game et al., 2014; Meijaard et al., 2012) is happening in a context of limited information on orangutan disease surveillance and risk management. Orangutan veterinarians and rescue, rehabilitation and release NGOs and government agency staff are part of a long-running capacity development project, the Orangutan Veterinary Advisory Group (OVAG). OVAG provides capacity building on disease diagnosis and treatment, surveillance, risk management, and development of DRAs. Studies have been conducted on outbreaks in orangutan rehabilitation facilities (Faizal, 2011; Nurcahyo et al., 2017) and there have been instances of orangutans released with transmissible pathogens (Bonner, 1995). Surveillance for wild orangutan diseases, zoonotic pathogen transfer, disease spillover and emerging diseases is limited, and indeed most wild populations are not surveilled. We are not aware of any DRA for orangutan translocation, and there is a paucity of data available on the management and risk abatement of pathogens that could infect orangutans.

Practitioners may perceive zoonotic disease transmission as less likely for orangutans than for other great apes, because of orangutan's semi-solitary lifestyle, more arboreal behavior in natural conditions, and the lack of clear examples of diseases wiping out orangutan populations following releases (Carne et al., 2014; Kilbourn et al., 2003; Mul et al., 2007). But orangutans do come to the ground (Ancrenaz et al., 2014) and can contract human carried diseases, especially those transmitted via the fecal-oral or airborne transmission routes, respiratory viruses and bacteria in particular (Carne et al., 2014). Respiratory ailments sinusitis, airsacculitis and pneumonia are of particular concern for orangutans (Lawson et al., 2006; Steinmetz & Zimmermann, 2012). Further, males may travel among wild populations to find females (Ancrenaz et al., 2021b; Marshall et al., 2021). This underscores the suggestion that individual orangutans can be disease superspreaders among conspecifics (Carne et al., 2013). Importantly, orangutans captured due to their proximity to humans may have already been exposed to human diseases. For example, orangutans have been observed using small puddles and human-constructed drains as water sources, which are highly likely to be contaminated with human waste (Oram, unpublished data) and which can also facilitate infections such as malaria from insect vectors (Nurcahyo et al., 2017).

Active COVID-19 infections are circulating among humans in Indonesia at a reported rate of 2,931 average daily cases and 182 average deaths daily as of September 2021 (New York Times, 2021). At least one COVID-19 variant of concern, the more transmissible Alpha (formerly B.1.1.7), was verified in Indonesia as of March 16, 2021 (WHO, 2021b). Although orangutan-specific consequences of SARS-CoV-2 remain unknown, extensive contact with caretakers during rehabilitation, the number of people involved in orangutan care and release, and occasional contact or proximity with humans through post-release monitoring, field research activities, provisioning or tourism potentially exposes orangutans to becoming asymptomatic carriers of contagious diseases, including SARS-CoV-2 (Dunay et al., 2018; Gryseels et al., 2021). Humans can transmit COVID-19 several days prior to being symptomatic, as occurred with captive gorillas (San Diego Zoo, 2021). Transmission from humans to apes is thus classified as “likely” (Figure 4.4). Although rescue practitioners regularly use disease mitigation measures, wild-to-wild translocated orangutans are exposed to extensive human interactions that likely include humans without PPE or testing. Rehabilitation of ex-captive orangutans includes episodes of frequent exposure to human interaction over long periods (Sherman et al., 2020a), but likely with consistently applied mitigation measures, hence with lower overall risk. Nevertheless, there are unknowns for all releases including the potential for people to transmit disease even while using PPE or after vaccination.

Rescue centers mitigate many risks via disease surveillance and testing for likely zoonotic diseases in rehabilitated ex-captive orangutans, and government policies require proof of disease testing results, including for SARS-CoV-2, prior to release of ex-captives. Specifically regarding COVID-19, orangutan rescue organizations reported making significant efforts and financial outlays to implement precautionary protocols such as regular COVID-19 antigen testing for staff, use of PPE, and closures to tourism and volunteers (Arcus Foundation, 2020; BOSF, 2020a, 2020b; Gokkon, 2020b; IAR, 2020a; IAR Indonesia, 2020; Minh, 2020; OF-UK, 2020; OFI, 2020; SOCP, 2020). Rescue organization personnel are also getting vaccinated against COVID-19. Vaccination has been successful in preventing COVID-19 infections in captive populations of black-footed ferrets, an endangered species susceptible to the disease (Learn, 2021). In the United States some captive populations of orangutans and other great apes have been vaccinated (San Diego Zoo, 2021) and vaccination of captive Indonesian orangutans may become an option. However, species-specific healthcare and disease risk management expertise varies across orangutan facilities and personnel, as do efficacy of diagnostic tests and vaccines, and exposure of orangutans to humans. In particular, wild orangutans captured and translocated during the COVID-19 pandemic may be at greater risk of exposure per the World Health Organization's (WHO) definition (WHO, 2021a): During the process of capture, examination, transport, and release, these animals are in direct contact with humans and at distances of <2 m from people, many without any PPE (Figures 4.2, 4.3), for more than 15 min. In some cases, there are large numbers of people without PPE in contact or close proximity to the animals (Figures 4.2, 4.3).

It is likely that any infected orangutans released into wild or reintroduced populations could spread SARS-CoV2 among conspecifics, thus consequences qualify as at least "significant" (Figure 4.4). SARS CoV2 affects multiple species, meaning likelihood of further species spillover is high (Gryseels et al., 2021; Mahdy et al., 2020). Such spillover could pose catastrophic consequences to species, ecosystems and potentially humans (Figure 4.4). These considerations are applicable to any other transmissible diseases that could affect orangutans.

## 4.5 Conclusion and Recommendations

Our study suggests that orangutan translocations can pose considerable infectious disease transmission and species conservation risks. Pathways exist for released orangutans to potentially transmit COVID-19 to susceptible and non-immune wild populations. Captive situations with effective biosafety protocols including staff testing are expected to have low prevalence of transmissible diseases among associated humans and thus overall lower risk. Wild-to-wild translocations have increased disease exposure during human-orangutan conflict situations and during rescue due to increased incidence and duration of contacts with humans.

The IUCN Primate Specialist Group and great ape disease risk experts discourage translocating great apes during the COVID-19 pandemic, and particularly advise against wild-to-wild translocation as it could pose risks to wild conspecifics (Gillespie & Leendertz, 2020; IUCN SSC, 2020). Review of available data indicates that practitioners generally made significant efforts to manage disease risks while continuing to undertake wild-to-wild translocations, reintroductions, and reinforcements at reduced levels during the COVID-19 pandemic. However, we identified circumstances of extended human-orangutan contact and proximity that create additional disease transmission pathways.

Most orangutans in Kalimantan, Indonesia, live outside protected areas, and orangutans are frequently killed, injured or displaced by humans and human activity (Meijaard et al., 2011a; Sherman et al., 2020b). Practitioners' concern for the welfare of the individual orangutans and pressure from local communities to avoid further interactions or conflict with the orangutans drive wild-to-wild translocation decision making (Palmer, 2018). Wild-to-wild translocations account for 64% of orangutans released between March 15, 2020 and March 14, 2021 during the COVID-19 pandemic (Figure 4.1). Researchers found most wild-to-wild translocated orangutans were healthy based on physical examination when captured, suggesting they may have survived in their original habitat, even in small forest patches, if protected from killing (Ancrenaz et al., 2021b; Sherman et al., 2020a). Other individuals were rescued from situations of imminent harm like forest fires, human-inflicted injuries, and forest clearing (BBC, 2015; EEN, 2012; IAR, 2019; Mongabay, 2012). Wild-to-wild translocations are conducted without disease testing to facilitate quick release of animals (Jaya unpublished data; Kaye, 2016; KSDAE, 2019a, 2019e, 2020a). This lack of testing highlights the disease risks posed to Critically Endangered orangutan populations by frequent wild-to-wild translocations, especially during a pandemic. These risks outweigh the potential species conservation benefits of moving wild individuals. This is particularly the case for Tapanuli orangutans. One Tapanuli orangutan was translocated into a wild population during the pandemic, despite an estimated total species population of 760 animals or fewer, and the concomitant extreme risk posed by potential disease transmission into such a limited population. This animal was previously translocated in 2019 and had moved back into an area around humans (Meijaard et al., 2021).

We recommend that the next step for orangutan translocation stakeholders is to convene to discuss and accept the problem statement presented here. Subsequently a formal DRA process should be conducted for orangutan translocation including the risk pathways identified in this study. The goal will be to achieve a consensus among stakeholders on the relative disease risks as well as agreement on what level and degree of risk that they and their respective organizations are willing to accept. Due to high risks and high uncertainty of the pathogen transfer potential and outcomes of orangutan translocations identified in this problem description, the precautionary principle is indicated. Application of this principle means assuming the worst case of high mortality in captive, reintroduced, and wild orangutan populations unless or until evidence indicates otherwise. It requires preventing avoidable risks and focusing on biosecurity to break the transmission cycle. Releases are an unsuitable option in situations where there risk of catastrophic species and ecosystem effects and disease spillovers is greater than negligible or low (Figure 4.4). While zero risk is impossible, circumstances with manageable and acceptable risks pose reduced threats to species survival, ecosystem function, and disease spillovers.

Where reintroduction, reinforcement or wild-to-wild translocations are determined to be the best conservation option, we assert that minimum disease mitigation measure requirements should be enforced. These should stipulate use of effective PPE that fit tightly and cover the mouth and nose (IUCN SSC Primate Specialist Group, 2021), worn by all persons, even if vaccinated. Vaccinated persons can still carry and multiply the virus, and vaccines may be less effective in preventing disease transmission of the delta variant (Christie et al., 2021) and potential future variants. When cost or scarcity may make it difficult for release practitioners and community members to obtain adequate PPE, this should serve as a reason to forego translocations rather than to continue with inadequate mitigation measures. The number of people present at releases should be strictly limited. Samples (feces, urine, blood, and orifice swabs) should be taken from all translocated orangutans (Setchell & Curtis, 2011), regardless of apparent health status, and all should be tested for diseases of concern, including COVID-19. Diagnostic tests for humans and orangutans should be selected for proven detection effectiveness. The risks to wild captured orangutans rise with increased human contact, thus captured animals suitable for release should be translocated as quickly as possible to minimize exposure and limit stress and behavior changes.

A One Health approach to disease risk mitigation, public health engagement and conservation in line with the One Health approach is critical, including: (1) health surveillance of wild, captive and released orangutans, and information sharing among all stakeholders; (2) collaboration among government, local communities and NGOs to address health and biodiversity conservation; (3) a DRA conducted with orangutan conservation and translocation stakeholders and wildlife health experts; and (4) investment in education and policy that recognizes the direct dependence of human health on functional ecosystems and biodiversity (Gruetzmacher et al., 2021; OIE & IUCN, 2014). Improved law enforcement to address orangutan killing, trade, and clearance of orangutan habitats in agricultural concessions, addressing negative human interactions with orangutans, and protection of large intact forests and forest fragments have been identified as orangutan conservation priorities (Ancrenaz et al., 2021b; Sherman et al., 2020a; Sherman et al., 2020b).

As humans expand their presence across orangutan range, close proximity and contact between humans and orangutans will continue to increase. While translocations are one possible tool for addressing extinction risk, renewed focus on preventive action to protect habitats and mitigate negative human-orangutan interactions is needed.

Decisions about interventions for individual orangutans in undesirable situations involve complex ethical considerations, but we encourage adherence to the IUCN guidelines to weigh net risks and benefits to species conservation (IUCN/SSC, 2013). In extraordinary circumstances, wild-to-wild translocation will be the only option, such as when orangutans cannot escape forest fires, or people are likely to kill them and cannot be swayed by legal consequences or alternative solutions. Otherwise, outreach measures to protect orangutans in place rather than moving them should be pursued. Numerous resources exist for addressing human-wildlife interactions (HWCTF, 2021), some specific to great apes or to orangutans (Campbell-Smith et al., 2012; Finley, 2019; Hockings & Humle, 2009). Solutions that provide financial benefits, employment opportunities, or improved livelihoods should be determined in collaboration with local communities to address their specific needs. While there are few counterfactual-based studies on orangutan conservation interventions, demonstrated effective strategies include health care services tied to illegal logging reductions (Jones et al., 2020) and community forest management initiatives (Knott et al., 2021). In areas where orangutans need to move between forest blocks within agricultural landscapes, crops unpalatable to orangutans, like shade-grown coffee, may be helpful (PanEco, 2018). Other solutions to forestall potentially negative interactions could include engaging local community members to serve as "orangutan guardians," indirect incentives such as infrastructure and civic facilities (Maskulino et al., 2021), or direct financial incentives (Ravenelle & Nyhus, 2017). Rescue centers, research centers, and locally-based NGOs are crucial to developing solutions, as they have longstanding relationships with surrounding communities, and often serve as significant source of local employment (Knott et al., 2021).

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## Chapter 5. Orangutan killing and trade in Indonesia: Wildlife crime, enforcement, and deterrence patterns

Julie Sherman[a,*], Maria Voigt[a], Marc Ancrenaz[b,c,d], Serge A. Wich[e], Indira N. Qomariah[f], Erica Lyman[g], Emily Massingham[h], Erik Meijaard[c,h]

a Wildlife Impact, Portland, OR, United States of America
b Pongo Alliance - Kinabatangan, Kota Kinabalu. Malaysia
c Borneo Futures, Bandar Seri Begawan, DarussaLam, Brunei
d HUTAN, Sandakan, Malaysia
e School of Biological and Environmental Sciences, Liverpool John Moores University, Liverpool, United Kingdom
f Centre for Orangutan Protection (COP), Jakarta, Indonesia
g Lewis & Clark Law School, Lewis & Clark College, Portland, OR, United States of America
h School of Biological Sciences, University of Queensland, St Lucia, Australia

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**Keywords:** Awareness raising, Borneo, Orangutan, Illegal trade, Poaching, Sumatra

**Abstract**

Wildlife poaching and illegal trade threaten the survival of many rare species. We assessed spatiotemporal patterns in illegal killing, injury, capture, possession, and sale of orangutans, as well as law enforcement efforts, and conservation interventions affecting Critically Endangered orangutans in Indonesia from 2007 to 2019 using data collected from published and unpublished sources. We found 2229 reported crimes during the study period, including killing and non-lethal crimes. Annual crime rates did not show a declining trend overall during the study period. Most crimes, 99.6 % for Bornean orangutans (Pongo pygmaeus), and 95.7 % for Sumatran (P. abelii) and Tapanuli (P. tapanuliensis) orangutans combined, involved local not international trade. A total of 22 court cases (0.9 %) related to 2229 reported crimes; 20 of these cases led to convictions. At expected detection rates of less than 10 %, average estimated species mortality from killing was 14.3 % for Tapanuli and Sumatran orangutans combined, and 5.1 % for Bornean orangutans. This exceeds the 1–2 % orangutan hunting mortality threshold expected to drive populations to extinction. National parks with orangutans had 0.28–2.11 enforcement officers per 100 km2, below the 3–11 officers per 100 km2 considered global best practice to deter poaching. The most prevalent interventions to address orangutan crime—education and handovers of illegally held animals—have been conducted without an associated decline in crimes. These tactics alone are insufficient to address orangutan-related crimes. Substantial increases in patrols, investigations, arrests, and convictions, as well as community-focused solutions are urgently needed to halt orangutan killing and trade.

## 5.1 Introduction

Wildlife harvest for food and trade is a global threat to biodiversity (IPBES, 2019). The illegal wildlife trade in particular threatens numerous species and disrupts crucial ecosystem services (UNEP, 2016). Addressing this illegal trade is a component of the United Nations Sustainable Development Goals, which call for countries to urgently address both poaching and trafficking (United Nations, 2020). This is especially a concern for the southeast Asia region, which has emerged as a global hotspot of illegal wildlife trade (Felbab-Brown, 2011). Numerous species endemic to this region, including rhinoceroses, tigers, pangolins, gibbons, and orangutans, are protected by law but nonetheless illegally traded (Felbab-Brown, 2011; Krishnasamy & Zavagli, 2020). A key challenge is that illegal hunting and possession of protected wildlife are commonplace and conducted with impunity in several Southeast Asian countries (Krishnasamy & Zavagli, 2020). Further, in some parts of the region, possessing wild animals as pets is a cultural symbol of wealth and importance (Krishnasamy & Zavagli, 2020). Improved knowledge of wildlife crime patterns and outcomes of interventions to reduce demand and prevent poaching are important to develop effective deterrence for these imperiled species (Kurland et al., 2017).

Strategies to prevent wildlife crime aim to deter criminal acts and to reduce opportunities for these acts to occur (Kurland et al., 2017). There are numerous approaches to deterrence, which can be grouped as either (1) regulatory or law enforcement, an approach relying on monitoring, investigation of compliance, and punishment of law breaking; or (2) non-regulatory approaches which focus on economic, moral, social or other benefits or disincentives to encourage compliance (Kahler & Gore, 2012; Kurland et al., 2017). Diverse interventions to address wildlife crime have been implemented across the world (Kurland et al., 2017). Studies of anti-poaching patrols, such as those using SMART software, show patrolling is effective in reducing poaching crimes when strategically targeted and sufficiently frequent (Critchlow et al., 2017; Linkie et al., 2015). Studies on the effect of non-regulatory approaches suggest these strategies can also be important elements of a comprehensive and locally relevant deterrence program, particularly as they relate to wildlife crimes committed by subsistence hunters or in response to human wildlife interactions (Kurland et al., 2017; Moreto, 2019). However, without any law enforcement, non-regulatory approaches have not been sufficient to deter crime at broad scales (Fairbrass et al., 2016; Keane et al., 2008). The value of strengthening enforcement solely through increased severity of punishments is much debated, with both general criminological and wildlife crime-specific literature suggesting that the likelihood of apprehension, rather than severity of punishment, is crucial to successfully deterring crime (Nagin, 2013; Wellsmith, 2011). This study aims to contribute to understanding of crime trends and the effects of regulatory and non-regulatory approaches applied to address crimes affecting the three species of orangutans (*Pongo* spp.) in Indonesia.

This study analyzed trends in orangutan-related crime in Indonesia, the only country where Critically Endangered Tapanuli (*Pongo tapanuliensis*) and Sumatran orangutans (*P. abelii*) occur (Nowak et al., 2017; Singleton et al., 2017), and also home to approximately two-thirds of the Critically Endangered Bornean orangutans (*P. pygmaeus*) (Ancrenaz et al., 2016a). Orangutan capture, killing, harm (injury or harassment) and trade (possession, sale, purchase, exchange or barter) have been banned in Indonesia since 1932 (Ministry of Forestry, 1990). These crimes are subject to maximum penalties of five years imprisonment and fines of IDR 100 million (the equivalent of approximately $7000 USD as of September 2021), but sentencing is generally lenient (Nijman, 2017). Illegal killing and trade have been consistently identified as significant threats to orangutans for more than 50 years (Harrisson, 1961; Nijman, 2017; Rijksen & Meijaard, 1999). In Indonesia, orangutans are killed opportunistically for bushmeat, as a pre-emptive step to prevent crop foraging or interaction with humans, in retaliation for crop foraging or human interactions, and to obtain infants as pets (Meijaard et al., 2011a; Singleton et al., 2017). Obtaining dependent infant orangutans nearly always necessitates killing of the mother (Russon, 2009). Orangutans have been popular as pets in Indonesia for several decades ((Nijman, 2017; Rijksen & Meijaard, 1999), a situation that persists today (Sherman et al., 2020a). The orangutan distribution in Indonesia encompasses many cultures and religions, and significant income and wellbeing disparities, all of which play a role in differing perceptions of and behavior towards orangutans at the local level (Chua et al., 2020; Meijaard et al., 2011a; Santika et al., 2019b). Orangutan killing and local pet trade are also linked with forest clearing and other anthropogenic habitat impacts, and all are primary concerns for the survival of the species (Meijaard et al., 2021; Santika et al., 2017a; Voigt et al., 2018).

The law enforcement approach to orangutan-related crime in Indonesia has long been criticized as wholly inadequate because of its near exclusive focus on seizure or surrender of illegally held orangutans, (CITES/GRASP, 2006; Nijman, 2017; Sugardjito & van Schaik, 1992), and capturing and moving injured or at risk wild orangutans away from humans or out of fragmented forest patches (Sherman et al., 2020a). Few of these crimes have been investigated, and arrests, trials, prosecution, and convictions are extremely rare (Nijman, 2017; Sherman et al., 2020a). Authority for enforcement of wildlife laws, including patrolling and decisions on whether to investigate, confiscate, or to pursue arrests and prosecutions, rests with provincial government departments of the *Balai Konservasi Sumber Daya Alam* (BKSDA), Indonesia's Natural Resources Conservation Agency, which is a division of the Natural Resources and Ecosystem Conservation Directorate (Konservasi Sumber Daya Alam Ekosistem (KSDAE)) of the Indonesia Ministry of Environment and Forestry (Nijman, 2005). BKSDA also is responsible for management of protected areas outside national parks and patrols within these areas, while the Directorate General of KSDAE manages national parks and patrols therein (KSDAE, 2020f). Non-governmental organizations (NGOs) supplement or support government efforts on wildlife crime through care of illegally held orangutans, funding rangers and wardens, monitoring of selected habitats, public education on orangutan conservation and the laws protecting orangutans, capacity building for alternative livelihoods and mitigation of negative human-orangutan interactions, and detection and support for investigation and prosecution of orangutan crime cases.

Patrols, equipping and training rangers, and removing hunting snares have been found to be effective in reducing opportunities for poaching and decreasing killing of great apes, including orangutans (Junker et al., 2019; Sugardjito & Adhikerana, 2010). Monitoring and regular researcher presence has likewise been shown to deter great ape killing (Campbell et al., 2011; Junker et al., 2019; Sugardjito & Adhikerana, 2010).

Since the 1970s, both NGOs and government agencies in Indonesia have established rescue centers to facilitate law enforcement through care of confiscated or surrendered animals (Russon 2009). Demand reduction and awareness raising efforts, typically via rescue centers conducting community education on orangutan protection laws in local communities and in national and local media, have likewise been conducted in Indonesia since the 1970s (Aveling & Mitchell 1982). Surveys carried out in the past two decades show between 73 and 100 % of respondents in Kalimantan and Sumatra are aware of the laws protecting orangutans and the illegality of owning, selling, or killing them (Anon. pers. comm.; Meijaard et al., 2011a; Rainer et al., 2020). While education can support active regulatory efforts (Salazar et al., 2019),(Salazar et al., 2019), evidence suggests education alone is not effective in halting wildlife crime (Baruch-Mordo et al., 2011; St. John et al., 2018; Travers et al., 2019), and its effects are rarely well monitored (Cox et al., 2020; Veríssimo & Wan, 2019). NGOs also use human-orangutan interaction mitigation techniques in some areas (vide: IAR, 2018; OIC, 2019). However, the continued intake of illegal pet orangutans into rescue centers and recent high profile cases of orangutans severely injured or killed in interactions with humans in Sumatra (e.g. Stack, 2019) and Kalimantan (e.g. Galdikas, 2018) suggest that other interventions besides rescue and education, including stronger enforcement of existing wildlife laws, are needed to prevent orangutan crimes and protect wild populations.

Orangutan-related crime in Indonesia offers a valuable case study on the effects of addressing poaching and illegal trade of a threatened species primarily through seizures or surrenders and non-regulatory interventions centered on rescue and education. Our study builds on previous analyses of orangutan trade in Indonesia by Nijman (2005, 2009, 2017) and Freund et al. (2017) by assessing trends in orangutan-related crime and, where spatial data were available, comparing those with associated interventions across Indonesia from 2007 to 2019. We developed a unique dataset including orangutan-related crime data from local, national, and international news media; published literature; online wildlife crime datasets; publicly reported and unpublished orangutan rescue data; and orangutan conservation intervention data from practitioner-published materials.

This study addresses the following questions: 1) What are the spatial and temporal patterns in orangutan-related crimes and convictions in Indonesia?; 2) How has law enforcement presence been distributed spatially in provinces with orangutan populations?; 3) What are the likely impacts of crimes on orangutan species?; 4) What crime deterrence interventions are conducted across orangutan species distribution, and which of these interventions are spatially associated with changes in crime rates? We discuss recommendations for policy makers, conservation practitioners, and researchers to improve deterrence of orangutan-related crimes. These considerations are relevant to other heavily poached and traded species.

## 5.2 Methods

### Crimes and convictions

We compiled data on reported orangutan killing and non-lethal crimes (injury and trade crimes, i.e. capture, possession, sale, or barter) in Indonesia, and any related law enforcement actions. Our dataset includes available records of both apprehended crimes and crimes that were detected and reported but not acted on. Internationally traded orangutans were included if the animals reportedly originated from and were repatriated to Indonesia. We reviewed studies on orangutan related crime, government annual statistic reports, CITES illegal trade reports, CITES mission reports, newspaper articles, the TRAFFIC Wildlife Trade Portal, and NGO sources (Table 5A1). We searched Indonesian newspaper websites using the search term “orangutan” to capture relevant news on crimes that occurred in Indonesia between 2007 and 2019 (Table A1). We performed a Google Advanced Search in English and Indonesian to capture search terms “orangutan” and “orang-utan” in news publications from 2007 to 2019. Searches for local orangutan names (*mawas*, *mias*, and *maias*) did not yield relevant results. We compiled publicly reported information from all Indonesian rescue centers that held orangutans, NGOs involved in supporting or monitoring Indonesian wildlife law enforcement, and unpublished information from direct communication with practitioners (Table A1). Articles in Indonesian were translated using Google Translate with help from our Indonesian-speaking authors where necessary.

News articles and reports from rescue centers and government do not cover every detected crime. While we are confident our dataset provides a comprehensive overview of trends in criminal activity affecting wild orangutans in Indonesia, it does not capture undetected crimes and likely underestimates the total number of detected crimes and potentially their spatial extent due to the clandestine nature of wildlife crime and expected underreporting of detected crimes.

For each incident, meaning any situation of killing or non-lethal crime involving orangutans, we captured any available data on crimes, location, and law enforcement variables (Table 5A2). Many situations involve more than one animal and encompass both types of crime; for example, those involving infants were quantified as one killing crime (the mother) and one non-lethal crime (the illegally held infant). We checked animal name, sex, age, description, number of orangutans affected, incident details, arrest dates, names of persons involved, conviction date, and sentencing outcome for every crime and deleted any duplicates to ensure that each orangutan, crime, and conviction or other law enforcement outcome was represented only once in the dataset. Wherever possible we analyzed multiple sources to confirm information and address data gaps within individual records.

We quantified killing and non-lethal crimes in Indonesia from January 1, 2007 (the initiation of a 10-year Indonesian Orangutan Strategy and Action Plan) to December 31, 2019. Some deaths related to initially non-lethal human actions may have occurred subsequent to what our records suggest.

We quantified convictions by court case across Indonesia, and for Kalimantan and Sumatra to compare regional differences. Conviction and crime numbers were not directly comparable, as many cases resulted in convictions of multiple persons for crime affecting a single orangutan, and vice versa. Only 22 cases went to trial, hence data on specific criminal charges were not available for most incidents.

Reported apprehension locations reflect where the animals were discovered in captivity or reported killed. Particularly in the case of illegal pets, these orangutans are likely to have been captured elsewhere and then transported to human residences. This may introduce a bias towards crimes being reported in urban and suburban areas where animals can be sold or kept. Animals' origin location is typically recorded and reported if known, and thus we captured these data whenever possible. Where data were available, we recorded both origin and apprehension location. Where an instance represented both a killing crime (killing of adult female, generally) and illegal capture and trade or possession of an infant, we used the origin location for the killing crime and the apprehension location for the possession crime. We summed the annual number of killing and non-lethal crimes by administrative province, district (*kabupaten*), subdistrict (*kecamatan*), village (*desa*), and site name. We analyzed annual spatiotemporal changes in crimes using province and available combinations of district, subdistrict, and village location data using the 2014 administrative district boundary layers. All spatial manipulations were performed in Python (Python Software Foundation, 2019) ArcGIS Pro (Esri, 2020) and QGIS 3.14.0-Pi (QGIS, 2020) and data aggregated, analyzed and visualized in Python, R (R Core Team, 2020), ArcGIS Pro and QGIS.

Provincial orangutan population estimates in Kalimantan for 2017 were derived from Voigt et al. (2018) by determining the slope of the line between the provincial population estimates for 2008 and 2014, and using this rate to extrapolate the provincial populations for 2017.

We used the Mann-Kendall trend test (McLeod, 2022) to assess trends in annual crime numbers over the study period  and the Ljung box test (Lemon, 2006) to assess serial autocorrelation in annual crime numbers. Both tests were run in RStudio 1.3.959 (R Core Team, 2020).

**Detection rates and enforcement effort**

This study captures what is likely a small portion of actual orangutan crimes since our dataset includes only illegal incidents reported in the sources we reviewed. These reports encompass detected crimes including those apprehended and those not acted on. Orangutan crime detection rates in Indonesia are presumed to be low owing to the species' remote habitats; limited anti-poaching, investigation and prosecution efforts; corruption; and reluctance to punish local citizens (CITES/GRASP, 2006; Nijman, 2017; Sherman et al., 2020a).

We estimated enforcement effort in the national forest estate and in national parks based on the number of wildlife enforcement personnel per 100 km$^2$ of forest estate per province, and in all national parks within orangutan distribution. Data were not available on the number of enforcement staff assigned to specific protected areas outside national parks. Enforcement staff numbers were collected from annual government statistics reports. Although many projects conduct SMART patrols in orangutan habitats, we did not have access to these patrol coverage and effort data.

To assess the potential scope of actual orangutan-related crime, we considered how imperfect detection and errors in reporting might underestimate actual crimes. We looked at published detection rates for wildlife poaching and environmental crime—the percentage of actual or estimated total crimes that were detected by enforcement authorities—to determine what likely detection scenarios implied for orangutan killings reported during the study period. We found published rates for the percentage of actual poaching crimes detected in the United States (1.2%) (Beattie et al., 1977; Kaminsky, 1974); the percentage of illegal logging crimes detected in Indonesia (3.2%) (Akella & Cannon, 2004), and the percentage of wildlife crimes detected in the Philippines (6.2%) (Akella & Cannon, 2004), Cambodia and the United Kingdom (10%) (Claridge et al., 2005). We also tested two aspirational detection rates (24% and 70%) for snares found by SMART ranger patrols in Kerinci Seblat National Park in Sumatra (Linkie et al., 2015). Although these higher detection rates focus on snaring, a single type of poaching less common for orangutans (our data show most are killed with guns or machetes), they are nonetheless useful to investigate whether additional deterrence might be achieved with increased and strategically deployed patrol effort. We calculated the total number of killing crimes each of these six detection rates would represent for orangutan populations.

**Interventions to deter crime**

We assessed interventions to deter crime by collecting data on activities likely to influence crime deterrence in Kalimantan and Sumatra between 2007 and 2019. We used six activity categories that we deemed likely to affect crime: Research (long-term research projects with regular presence on the ground); Habitat management (habitat purchase, protection and management e.g. fire suppression and hunting controls such as snaring bans or prohibitions on orangutan killing enforced by land owners or managers); Law enforcement (patrols, monitoring, investigation, arrest and other enforcement action); Awareness raising (general public education); Community outreach & capacity building (targeted education and building capacity for alternative livelihoods or other behavior change); Human-wildlife conflict mitigation (deterrence tools, compensation or benefit sharing to address losses) (Table 5A3).

We identified 161 entities conducting relevant activities in orangutan habitat, 99 based in Kalimantan, 45 based in Sumatra, and 17 based outside orangutan distribution (Table 5A4), using author knowledge and consultation with local conservation experts. We collected activity data through direct requests to entities and via desktop research and review of publicly available data from grant and project databases, corporate sustainability reports, annual reports, tax filings and charity commission reports, and entity websites (Table 5A1).

To determine spatial and temporal overlaps in crime and interventions in villages (*desa*), we used the subset of the crime data that included village locations (n = 1042 in Kalimantan; n = 334 in Sumatra). To test trends in annual crime rates we compared totals of annual reported crimes in four categories of target areas within orangutan distribution provinces: (1) formally protected areas within orangutan distribution including national parks, wildlife reserves, and selected protection forests we identified as having orangutan conservation activities (PA); (2) areas outside formal protected areas but with focused orangutan conservation activities (called "conservation activity areas," encompassing rescue centers, orangutan reintroduction sites, long-term orangutan research sites, orangutan-related community conservation sites, and essential ecosystem areas (*Kawasan Ekosistem Esensial* (KEE)) (CA); (3) administrative boundaries of major cities and towns; and (4) all other unprotected areas (any villages outside PA and CA). Selected target areas are shown in Figure 5.1. Activities associated with each target area are detailed in Table 5A5.

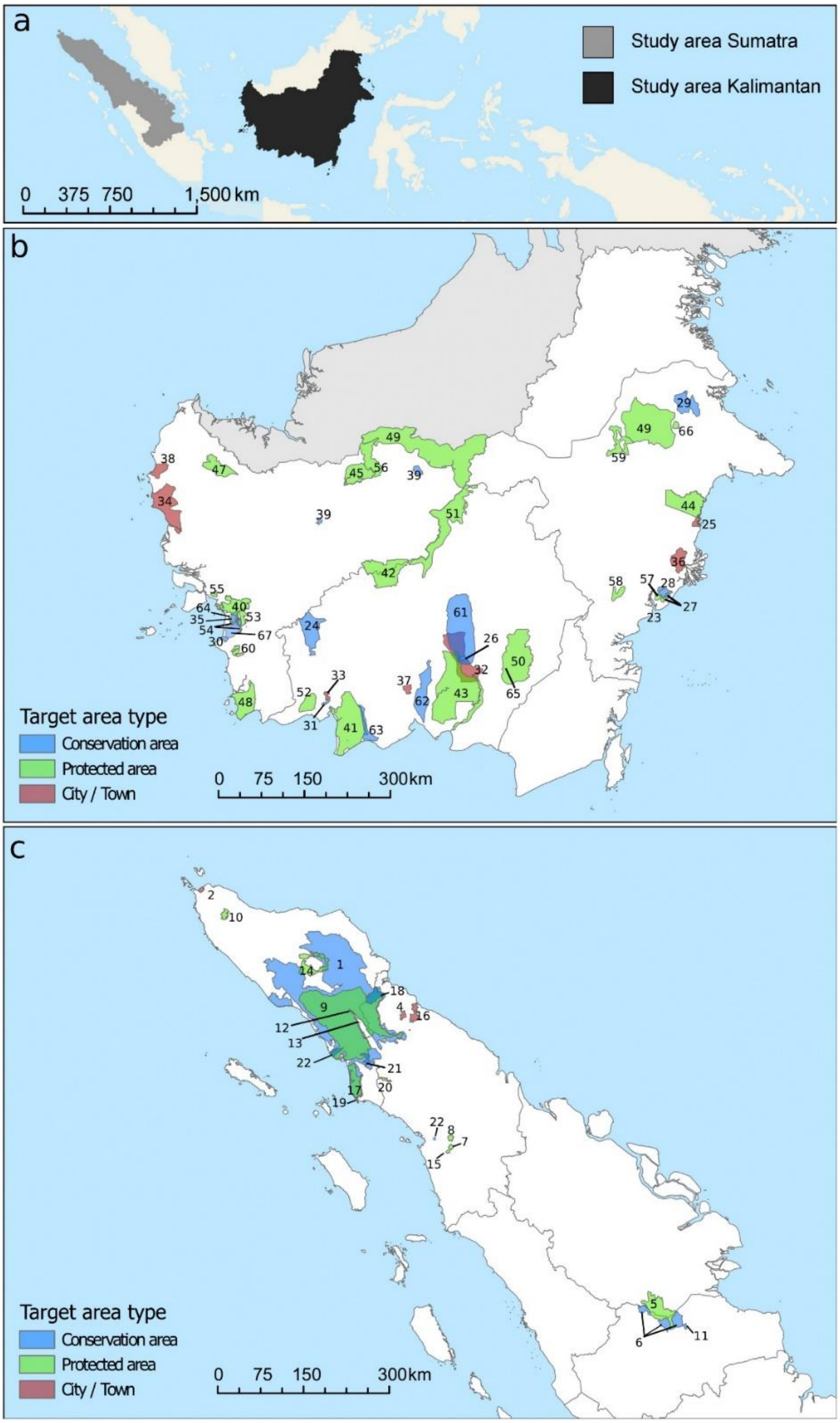


**Figure 5.1. Study area and target areas in Kalimantan and Sumatra, Indonesia.** (a) Overview of study area. Grey areas represent provinces in species distribution per Voigt et al. (2018) and Wich et al. (2016), and provinces with reintroduced orangutan populations. (b) and (c) show target areas by type (protected areas, conservation activity areas, and cities/towns) in Kalimantan and Sumatra, respectively. Target area numbers correspond to Table 5A5, which includes list of activities undertaken in each. Where shape files for a target area were not available, all village administrative units (*desas*) in the target area are shown. Kalimantan, Indonesia provinces in (b) are white, grey shaded areas are outside Indonesia.

To identify all districts, subdistricts and villages that were contained in or overlapped with target areas, we mapped crime and intervention locations using the 2014 administrative boundary layers; Indonesia protected area boundaries (IUCN & UNEP-WCMC, 2020); and shape files, maps or area descriptions from practitioners. Protected areas included buffer zones delimited by the boundaries of villages that overlap but are not entirely contained within these areas. Any villages not included in target areas were considered unprotected areas. Visualization of crime and intervention locations was done in QGIS.

Most areas had multiple simultaneous interventions, and very few data were available on systematically measured outcomes and impacts, particularly any that accounted for confounding social, political, and ecological factors. We compared available data on intervention types and annual reported crimes by province, target area category, and specific target areas (Tables 5A5 and 5A6). We used the Mann-Kendall trend test (McLeod, 2022) to determine positive and negative crime trends.

## 5.3 Results

### Spatial and temporal trends in orangutan crime

We found a total of 2229 reported crimes affecting orangutans in Indonesia between 2007 and 2019 (Figure 5.2). There were 1712 crimes affecting Bornean orangutans (an average 132 crimes annually), and 517 crimes affecting Sumatran and Tapaunli orangutans combined (average 40 crimes annually). Tapanuli orangutans were not recognized as a separate species until 2017 (Nowak et al., 2017), and may be underrepresented in crime reports. Annual crime rates did not show a declining trend in either Kalimantan or Sumatra (Table 5A6). Killing represented about half of the crimes affecting Bornean orangutans in all provinces (52 % in Central and West Kalimantan and 51 % in East Kalimantan), and 43 % of the crimes affecting Tapanuli and Sumatran orangutans combined (Table 5A7). The remaining non-lethal crimes were capture, possession or sale of infants, harm or capture of wild adult orangutans due to conflicts, and attempted poaching not resulting in death (such as an animal caught in a snare).

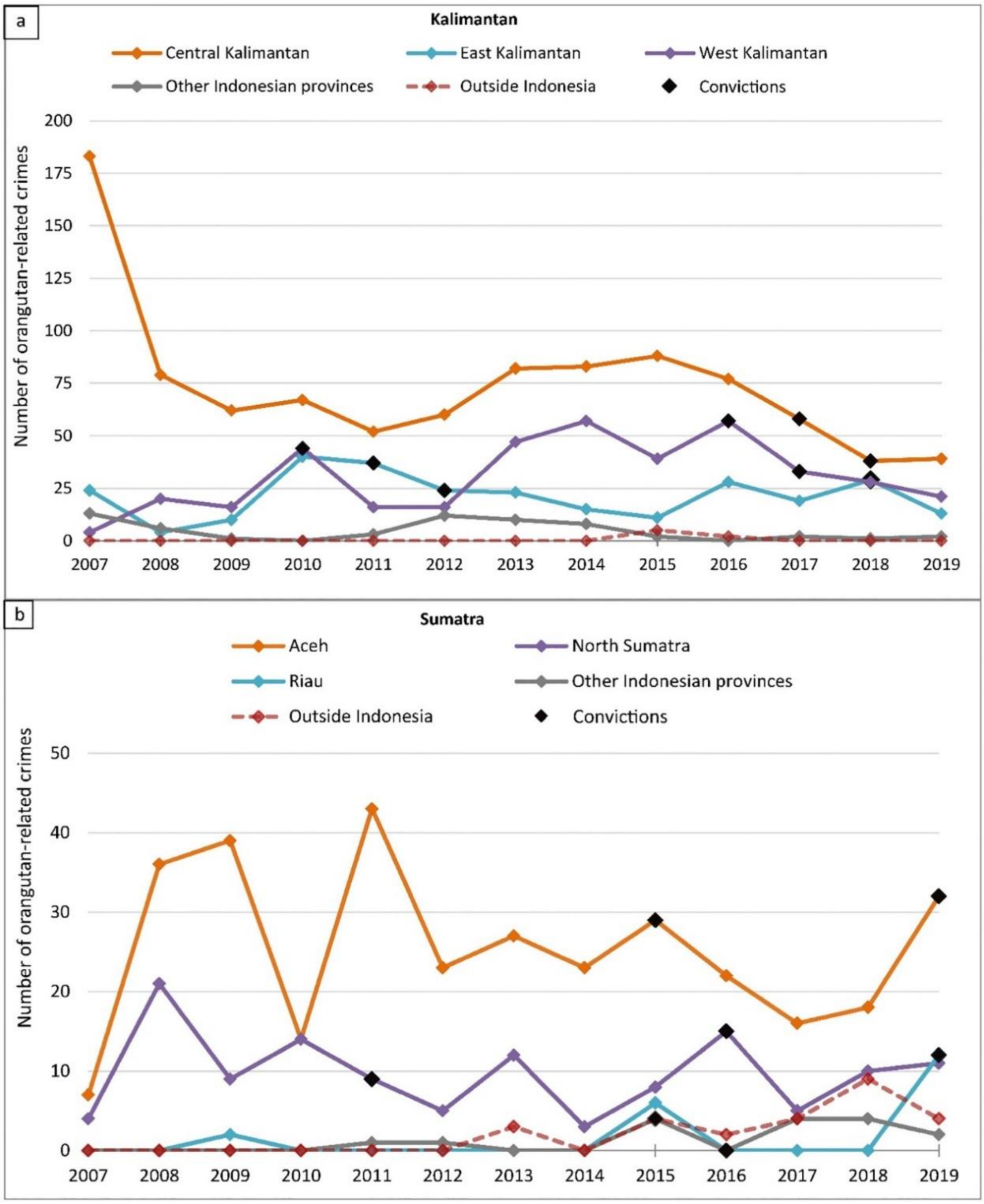


**Figure 5.2. Annual reported orangutan crimes and convictions in Kalimantan and Sumatra, Indonesia from 2007 to 2019.** a) Summed annual totals of reported crimes affecting Bornean orangutans detected within species distribution in provinces of Central, East, and West Kalimantan; in other Indonesian provinces outside species distribution; and international locations outside Indonesia. Orangutans are present in low numbers in North Kalimantan province but no crimes were reported there during study period. b) Summed annual totals of reported crimes affecting Tapanuli and Sumatran orangutans detected within species distribution in Sumatra provinces of Aceh and North Sumatra, and in Riau where a population has been reintroduced; in other Indonesian provinces outside species distribution; and international locations outside Indonesia. The reintroduced population also extends into Jambi province but no crimes were reported in there during study period. Black diamonds indicate years and provinces with court cases ending in convictions.

A total of 22 court cases related to the 2229 reported crimes. Twenty of these cases led to convictions of 31 people involved in 60 crimes (Fig. 2, Table 5A8). One additional case led to a customary law warning for five people for an incident involving two Bornean orangutans (Table 5A8). We found records of two additional cases in 2011 and 2018 that went to trial but did not result in convictions. Many individual crimes related by location or perpetrator, such as those occurring on one plantation or involving a specific trader, were tried together in a single court case, while other cases involved multiple persons convicted for killing a single orangutan. Crimes involving killing or injury of mothers and subsequent capture of infants might be expected to be tried together, but in practice the sources of illegally held infants, including killing of the mothers, were almost never investigated. The crimes in our dataset involving possession of infant orangutans were both temporally and spatially disparate from the killing of the mother in nearly all cases, as the possession crimes were apprehended after the killing when the infant was discovered at the home of its owner or, more rarely, for sale. Ten court cases ending in convictions were related to crimes affecting Sumatran orangutans; nine were related to Bornean orangutans, and one to Tapanuli orangutans. Reported cases leading to conviction have risen since 2013, from two court cases in Kalimantan during 2007–2013 to six during 2014–2019, and in Sumatra from one case during 2007–2013 to seven during 2014–2019 (Table 5A8). However, prosecutions and convictions remain extremely rare compared to crimes. The highest rate was three cases per year leading to convictions in 2015, 2017, and 2019, as compared to 196, 143, and 136 minimum reported orangutan crimes for those years, respectively (Table 5A7).

Orangutan-related crime in Central Kalimantan declined notably between 2007 and 2008, following extensive clearing for oil palm and associated human orangutan conflicts prior to 2007 (Santika et al., 2017a), but has not shown a declining trend overall (tao = −0.333, $p$ = 0.127) (Figure 5.3, Table A6). Crimes in East Kalimantan increased since 2015, while in West Kalimantan crimes remained relatively high since 2013. Neither province had a declining trend (tao = −0.013, $p$ = 1.000, and tao = 0.290, $p$ = 0.196, respectively). Nearly all reported crimes affecting Bornean orangutans in Indonesia (96 %) were in provinces within species distribution. Crimes outside distribution provinces (4 %, n = 69) were mainly reported in areas with international shipping ports or airports (Banjarmasin, South Kalimantan; Java), although only 0.5 % (n = 9) were definitively connected to international trade (repatriations from Thailand and Kuwait); the rest appeared connected to national trade. Eleven additional Bornean orangutans repatriated from international trade in 2015 were excluded from our dataset because the animals' capture and export from Indonesia likely occurred prior to the study period. The preponderance of crimes affecting

Sumatran and Tapanuli orangutans (92 %) occurred in orangutan distribution provinces of North Sumatra and Aceh, and in Riau province (Figure 5.4). Riau is outside species distribution but has a reintroduced population of Sumatran orangutans. Aceh has both wild orangutans and a reintroduced population outside species distribution. Crimes reported outside these provinces (8 %; n = 42) were primarily from Java, with 4.3 % (n = 24) of these connected to international trade (repatriations from Kuwait, Malaysia, and Thailand). Many internationally trafficked orangutans have not been repatriated (Beastall et al., 2016) and are excluded from these totals.

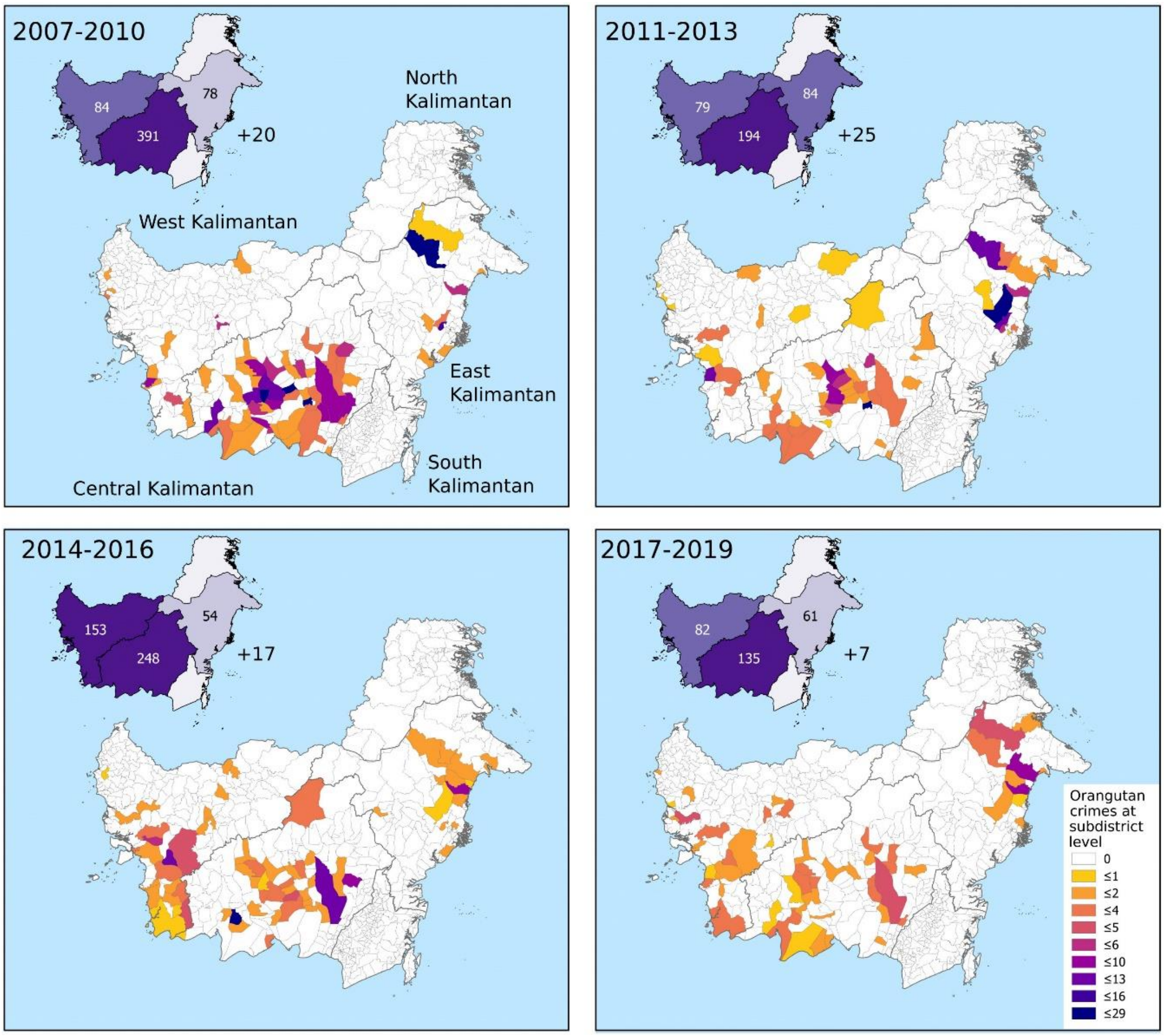


**Figure 5.3. Spatial distribution of reported crimes affecting *P. pygmaeus* from 2007 to 2019 in Kalimantan, Indonesia.** Upper left inset maps show total crimes (n = 1712) by time period across West, Central, and East Kalimantan provinces which encompass nearly the entirety of *P. pygmaeus* distribution (Voigt et al., 2018). Numbers in shaded province shapes are the crimes reported within those provinces; the number adjacent to map is the total of crimes reported in provinces outside species distribution within Kalimantan, and elsewhere in Indonesia. Main maps show the subset of crimes within West. Central, and East Kalimantan provinces with subdistrict location data (n = 1131). Few subdistrict location data were available for crimes in West Kalimantan from 2007 to 2010 hence these crimes may be underrepresented in the sub-district map for this time period. The 2007–2010 time period is expected to have more crimes overall as it includes an additional year of crime data compared to other periods, and it includes the year with the highest number of total crimes (2007; n = 224). Not all subdistricts shown in West, Central, and East Kalimantan have orangutan populations, but crimes were reported in subdistricts both inside and outside orangutan distribution.

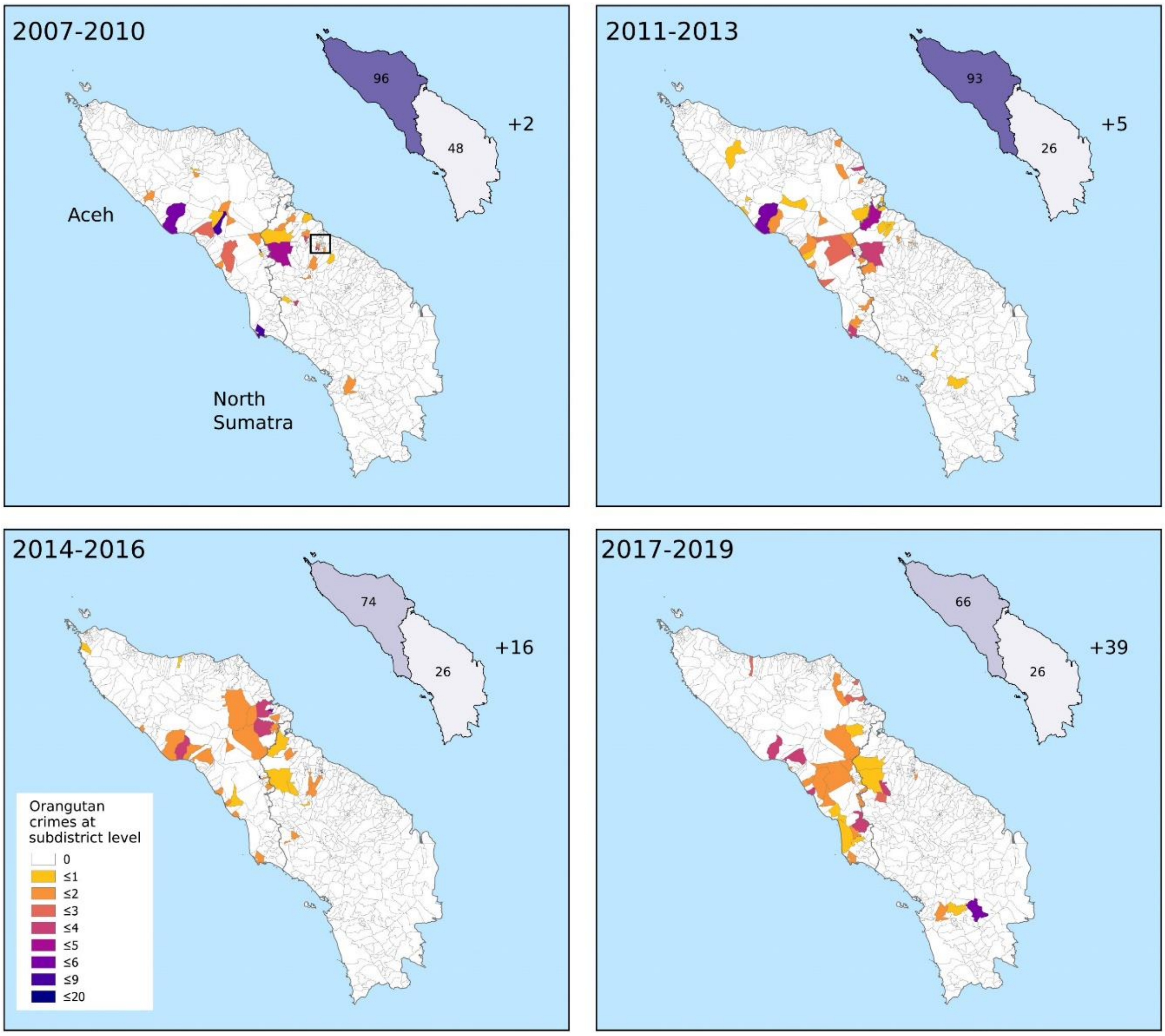


**Figure 5.4. Spatial distribution of reported crimes affecting *P. abelii* and *P. tapanuliensis* from 2007 to 2019 in Sumatra, Indonesia.** Upper left inset maps show total crimes (n = 517) by time period across Aceh and North Sumatra provinces which encompass *P. abelii* and *P. tapanuliensis* distribution per Wich et al. (2016). Numbers in shaded province shapes show the crimes reported within those provinces; the number adjacent to map is the crimes reported outside species distribution within Sumatra (including reintroduced populations in Riau and Jambi provinces), and from other areas in Indonesia. Main maps show crimes in Aceh and North Sumatra provinces with subdistrict location data (n = 409). The Medan urban area is marked with a rectangle. Detailed maps of Banda Aceh, Gunung Leuser National Park, and Tapanuli habitat area crimes are in Figs. A2 and A3. The 2007–2010 time period is expected to have more crimes overall due to the additional year of data compared to other periods. Not all subdistricts shown in Aceh and North Sumatra have orangutan populations, but crimes were reported in subdistricts both inside and outside orangutan distribution.

Reported crimes were higher in and around national parks and protected areas, and areas where rescue and research organizations work (Figure 5.1, Table 5A5). The spatial overlap of orangutan-related crimes in Kalimantan (Figure 5.3) and Sumatra (Figure 5.4) shows crime was present in all time periods in subdistricts in and around National Parks and other areas where rescue centers and anti-poaching efforts are focused (Figure 5.1, Table 5A4). Most areas of Kalimantan with relatively high numbers of crimes persisted throughout the study period from the earliest time period (2007–2010), as well as spreading further across orangutan distribution in subsequent time periods (Figure 5.3).

Crimes in Sumatra were reported in and around protected areas and the city of Medan (Figure 5.4), where rescue organizations are headquartered (Figure 5.4). Crimes reported around the city of Banda Aceh decreased over time, and none were reported in the latest time period (Figure 5A1). No crimes were reported in or around the reintroduced populations in Aceh (Jantho Nature Reserve), or in Riau and Jambi provinces (Bukit Tigapuluh National Park). Crimes reported within Tapanuli orangutan distribution increased in the latest time period (2017–2019) (Figure 5A2). At least 11 reported crimes involved Tapanuli orangutans, including five killings.

**Enforcement effort**

Density of enforcement officers—rangers and other government personnel with enforcement authority—is low in both Kalimantan and Sumatra, with 1.9 or fewer provincial officers per 100 km$^2$ of forested estate in all provinces in orangutan distribution and where orangutans have been reintroduced, and 2.1 or fewer officers per 100 km$^2$ of national park lands (Table 5.1). The highest enforcement officer density was 2.1 officers per 100 km$^2$ in Gunung Palung National Park in Kalimantan. Despite larger orangutan populations and habitat area in Kalimantan, the highest provincial enforcement officer density there (0.7 officers/100km$^2$ in East Kalimantan) is equal to the lowest provincial density in Sumatra (0.7 officers/100km$^2$ in Riau). Comparison of park size, enforcement officer density, and crimes rate showed that the largest parks have lower enforcement officer densities. The largest park, Gunung Leuser National Park, had 0.44 officers per 100 km$^2$ for 10,946 km$^2$, while Bukit Tigapuluh National Park had 1.66 officers per 100 km$^2$ in a 1442 km$^2$ park (Table 5.1). The highest crime rate (n = 42) was in Tanjung Puting National Park which had 0.51 officers per km$^2$, while Betung Kerihun National Park had the lowest officer density at 0.28 officers per 100 km$^2$ and no reported crime (Table 5.1). Practitioners we spoke with and unpublished patrol coverage maps indicated that only small portions of protected areas are covered by patrols, and additional personnel and resources including patrols stations and equipment are necessary to increase coverage (authors' unpublished data). Enforcement efforts are supplemented by NGO and community supported ranger patrols and wildlife crime investigators both inside and outside of federally protected areas, although these additional personnel do not have authority to make arrests or otherwise enforce laws and are not reflected in Table 5.1.

**Table 5. 1. Enforcement effort and reported crime rates in provincial forest estate lands and National Parks**

| **Provincial enforcement** | **Forested estate[1] area ($km^2$)** | **Enforcement officers[2] per 100 $km^2$** | **Total crimes reported, all years[3]** |
|---|---|---|---|
| Sumatra | | | |
| Aceh | 35,638.13 | 1.0 | 329 |
| North Sumatra | 30,557.95 | 1.9 | 128 |
| Jambi | 20,985.35 | 1.6 | 0 |
| Riau | 54,069.92 | 0.7 | 20 |
| | | | |
| Kalimantan | | | |
| West Kalimantan | 81,986.56 | 0.5 | 400 |
| Central Kalimantan | 126,971.65 | 0.4 | 962 |
| East Kalimantan | 83,391.51 | 0.7 | 277 |
| | | | |
| **Protected areas enforcement[4]** | **Protected land area ($km^2$)** | **Enforcement officers per 100 $km^2$** | **Total crimes reported, all years[3]** |
| Sumatra | | | |
| Gunung Leuser NP | 10,946.92 | 0.4 | 23 |
| Bukit Tigapuluh NP | 1,442.23 | 1.7 | 0 |
| | | | |
| Kalimantan | | | |
| Bukit Baka Bukit Raya NP | 1,810.9 | 0.7 | 0 |
| Sebangau NP | 5,421.41 | 0.3 | 13 |
| Tanjung Puting NP | 4,150.4 | 0.5 | 42 |
| Kutai NP | 1,986.28 | 1.4 | 20 |
| Gunung Palung NP | 900.01 | 2.1 | 1 |
| Danau Senatrum NP | 1,309.38 | 1.8 | 4 |
| Betung Kerihun NP | 8,166.93 | 0.3 | 0 |

Sources:

KLHK, 2019. Statistik Lingkungan Hidup dan Kuhutanan 2018. Sekretaris Jendral KLHK, Republic of Indonesia.

KSDAE, 2018. Statistik Direktorat Jenderal Konservasi Sumber Daya Alam dan Ekosistem Tahun 2017. Kementerian Lingkungan Hidup dan Kehutanan, Direktorat Jenderal Konservasi Sumber Daya Alam dan Ekosistem, Republic of Indonesia.

PHKA, 2015. Statistik Direktorat Jenderal 2014. Sekretarit Direktorat Jederal Perlindungan Hutan dan Konservasi Alam, Republic of Indonesia.

1. Hectares forested estate include kawasan konservasi, Hutan Lindung (HL), Hutan Produksi Terbatas (HPT), Hutan Produksi Tetap (HP), and Hutan Produksi yang Depat Dikonversi (PHKA 2015).
2. Enforcement officers include all police officer (*Polhut*) and natural resource protection officers (PPNS), excepting Polhut trainees. Annual reports indicate enforcement officer numbers have been relatively stable since 2009 (PHKA 2015; KLHK 2019).
3. Total crimes are all crime types found in this study for years 2007–2019.
4. National Parks enforcement officers are police officers (Polhut) assigned to the parks (KSDAE 2018).

## Detection rates for orangutan crimes

The actual number of orangutan-related crimes committed but not detected, and those detected but not acted on is unknown. The prevalence of crimes indicated by community survey responses and records of wildlife crime researchers and NGOs suggest that only a small percentage of actual orangutan crimes are detected and apprehended (Freund et al., 2017; Massingham et al., 2023a; Meijaard et al., 2011a). Low detection and apprehension rates are common for wildlife crime (Wellsmith, 2011). We applied six published detection rates to Kalimantan provincial orangutan populations calculated from Voigt et al. (2018) and Sumatra orangutan populations estimated in Wich et al. (2016) (Table 5.2). Under the most likely scenarios of detection rates below 10 %, the average percent orangutan mortality from illegal killing from 2017 to 2019 was 6.3 % for Bornean orangutans and 14.3 % for Sumatran and Tapanuli orangutans combined. A 10 % detection rate yielded population mortality rates of 1.4 % to 3.3 %.

**Table 5.2. Estimated orangutan population mortality rates from illegal killing.**

| **Province** | **Time period**[1] | **Approximate province level OU population**[2] | **Detected orangutan killings per time period**[3] | Percent population mortality rate from illegal killing at global wildlife and environmental crime detection rates[4] | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | **Detection rates** | | | | | |
| | | | | **1.2%**[5] | **3.2%**[6] | **6.2%**[7] | **10.0%**[8] | **24.0%**[9] | **70.0%**[9] |
| Central Kalimantan | 2007-2010 | 86,800 | 192 | 18.4% | 6.9% | 3.6% | 2.2% | 0.9% | 0.3% |
| | 2011-2013 | 75,600 | 104 | 11.5% | 4.3% | 2.2% | 1.4% | 0.6% | 0.2% |
| | 2014-2016 | 69,200 | 133 | 16.0% | 6.0% | 3.1% | 1.9% | 0.8% | 0.3% |
| | 2017-2019 | 60,400 | 64 | 8.8% | 3.3% | 1.7% | 1.1% | 0.4% | 0.2% |
| East Kalimantan | 2007-2010 | 30,400 | 39 | 10.7% | 4.0% | 2.1% | 1.3% | 0.5% | 0.2% |
| | 2011-2013 | 26,900 | 50 | 15.5% | 5.8% | 1.0% | 1.9% | 0.8% | 0.3% |
| | 2014-2016 | 25,400 | 27 | 8.9% | 3.3% | 3.5% | 1.1% | 0.4% | 0.2% |
| | 2017-2019 | 22,800 | 30 | 11.0% | 4.1% | 1.4% | 1.3% | 0.5% | 0.2% |
| West Kalimantan | 2007-2010 | 46,500 | 41 | 7.3% | 2.8% | 1.4% | 0.9% | 0.4% | 0.1% |
| | 2011-2013 | 41,200 | 43 | 8.7% | 3.3% | 1.7% | 1.0% | 0.4% | 0.1% |
| | 2014-2016 | 37,200 | 81 | 18.1% | 6.8% | 3.5% | 2.2% | 0.9% | 0.3% |
| | 2017-2019 | 32,500 | 38 | 9.7% | 3.7% | 1.9% | 1.2% | 0.5% | 0.2% |
| Sumatra | 2014-2016 | 14,600 | 48 | 27.4% | 10.3% | 5.3% | 3.3% | 1.4% | 0.5% |

1. The first time period in Kalimantan includes an additional year to enable direct comparison among all subsequent three year time periods. A single time period is used for Sumatra as population estimates for other time periods were not available.
2. Kalimantan populations calculated from Voigt et al (2018) and rounded to the nearest hundred. Sumatra populations of *P. abelii* and *P. tapanuliensis* combined from Wich et al. (2016).
3. Killing numbers are the subset of lethal crimes reported or calculated for provinces in orangutan species distribution and where orangutans have been reintroduced. Excludes 30 killings of Bornean orangutans and 13 killings of Sumatran orangutans detected in locations outside species distribution and reintroduction site provinces.
4. Percent mortality (detected killings × detection rate/100)/estimated OU population.
5. Based on undercover infiltration of United States poaching groups (Beattie et al., 1977; Kaminsky, 1974).
6. Estimate based on wildlife crime analyses of illegal logging in Papua, Indonesia (Akella & Cannon, 2004).
7. Estimate based on wildlife crime analyses of illegal fishing in Philippines (Akella & Cannon, 2004).
8. No methodology provided; estimate of maximum possible detection rate for wildlife crime in Cambodia (Claridge et al., 2005).
9. Model of predicted snares that would be encountered by ranger patrols in Sumatran national park (Linkie et al., 2015).

## Trends in orangutan-related crime and interventions to deter crime

Using the subset of reported crimes with village locations within orangutan distribution provinces (n = 1042 in Kalimantan; n = 334 in Sumatra), we compared annual crimes in target areas with orangutan conservation interventions (Table 5A5). We tested for trends in annual crimes reported in the following areas in Kalimantan and Sumatra orangutan habitat provinces: (1) unprotected lands; (2) formally protected areas; (3) conservation activity areas; and (4) major cities and towns (Table 5A6). Target areas and cities and towns are listed in Table 5A5. Although orangutans do not occur within urban areas, we found many crimes involving wild orangutans were reported within the administrative boundaries of cities or towns, often at the edges of urban areas or in new developments in converted forests. Additionally, many pet orangutans were seized from or surrendered by city or town residents.

Mann-Kendall trend tests showed that annual reported crimes increased significantly across all unprotected lands in West Kalimantan (tao = 0.484, $p$ = 0.027) and decreased significantly across unprotected and protected lands in Central Kalimantan (tao = −0.487, $p$ = 0.024; tao = −0.468, $p$ = 0.032, respectively; Table A6). Reported crimes decreased significantly in major cities and towns across all orangutan distribution provinces in Kalimantan (tao = −0.581, $p$ = 0.007) and in Central Kalimantan (tao = −0.641, $p$ = 0.003). Reported crimes notably decreased in many areas following implementation of deterrence activities including patrols and community projects during the study period, for example in the Katingan Mentaya protected area (tao = −0.634, $p$ = 0.006) and Rungan Landscape conservation activity area (not a statistically significant trend) (Tables 5A5 and 5A6, Figure 5A3). Some protected areas with patrols, habitat management, and community projects including Lamandau River Wildlife Refuge, Betung Kerihun National Park, and Bukit Baka Bukit Raya National Park had no crimes during the study period, while Gunung Palung National Park had only one. However, crimes were reported in recent years in areas that partially overlap with national parks with key orangutan metapopulations in Tanjung Puting and Kutai National Parks despite ongoing deterrence activities (Figure 5A3). No crimes were reported in the Gunung Palung research site in West Kalimantan, but crimes were reported in the villages in Mawas conservation activity area and in Kutai National Park that overlap the Tuanan and Kutai research sites, respectively.

In Sumatra, annual reported crimes increased significantly across all protected areas (tao = 0.586, $p$ = 0.009) and all conservation activity areas (tao = 0.480, $p$ = 0.031), while crimes reported across major cities and towns decreased significantly (tao = −0.494, $p$ = 0.023) (Table A6). This decrease in reported crime in urban areas is largely due to the significant decline in Banda Aceh in Aceh province (tao = −0.516, $p$ = 0.027). Urban areas

Medan and Kutacane had statistically insignificant increases in crimes over the study period and remain areas of concern due to relatively high crimes rates since 2015 (Fig. A4). Reported crimes significantly increased in protected area Gunung Leuser National Park in Aceh province (tao = 0.523, $p = 0.029$), despite all types of interventions occurring throughout the study period. No crimes were reported at long-term research sites in Sumatra (Fig. A4), or in Bukit Tigapuluh National Park, Jantho Nature Reserve, Dolok Sipirok, Dolok Sibual-Buali, and Lubuk Raya protected areas, all of which had patrols or monitors.

Total numbers of reported crimes were highest overall in unprotected areas where in most cases education was the only orangutan conservation intervention conducted (Table 5A5, 5A9). Urban areas Bontang in East Kalimantan, Sampit in Central Kalimantan, and Medan in North Sumatra, have consistently been hotspots for orangutan crimes (Figure 5A3).

## 5.4 Discussion

### Crime trends

Orangutan-related crimes in Indonesia have not declined overall between 2007 and 2019. Crimes affecting Sumatran and Tapanuli orangutans were approximately two times higher than those affecting Bornean orangutans as a percentage of estimated species population (Table 5.2). This offtake pressure is a serious concern given the relatively small population and habitat extent of Sumatran orangutans, and the less than 800 remaining Tapanuli orangutans (Wich & Meijaard, 2021).

Changes in reported crimes in Kalimantan may reflect increases in detection and apprehension efforts by rescue centers. Central and East Kalimantan had higher reported crimes in the earliest time period when those areas had the only significant rescue center capacity in Kalimantan. Reported crimes expanded across West Kalimantan following the opening of two rescue centers in the province, one in the western coastal region which began accepting animals in 2009 and the other in the north central region in 2010 (Knott et al., 2021).

### Detection rates of orangutan crimes

All the Indonesian national parks with orangutans have government enforcement officer levels below the 3–11 officers/100 km$^2$ that is considered global best practice for effective protected area management (Bruner et al., 2001), and to address poaching of targeted species (Henson et al., 2016). Unprotected areas, which have the highest number of crimes overall (Table 5A9), do not have dedicated government enforcement officers but are served by provincial enforcement staff (Table 5.1).

Orangutan population viability assessment indicates that hunting mortality of 1 % of adults in suboptimal habitat or 2 % of adults in optimal habitats will likely lead to extinction (Marshall et al., 2009). The estimated orangutan mortality would meet or exceed the 1 % mortality threshold at all detection rates of 10 % or less in all habitats within the latest time period (Table 5.2). Even at an optimistic 10 % detection rate, the killing rates in East and West Kalimantan in the most recent time period would be expected to drive populations to extinction even in the highest quality habitats (Husson et al., 2009). In Sumatra, the killing rate would be three times this threshold even at a 10 % detection rate. During the most recent time period, mortality rates in Sumatra would drive populations to extinction in suboptimal habitats even under an aspirational 24 % detection rate.

Clustering of reported crimes in and around protected areas and conservation activity areas may reflect the greater presence of enforcement personnel, researchers, NGOs, and engaged community members in these areas (Figure 5.2, Figure 5.3), as well as higher orangutan densities. Most of the crimes in our dataset (67 %) were illegal pets or orangutans captured due to conflict. This suggests detection efforts are more successful in identifying crimes of orangutan possession and trade, but less so in finding killing and capture of orangutans. These crimes are much more difficult to detect, as they require intercepting poaching or capture or finding evidence of it in the animals' home range. Analysis of orangutan poaching rates using occupancy models to account for imperfect detection and reporting errors (e.g. Barber-Meyer, 2010) would be useful if data on ranger patrol and monitoring effort, orangutan surveys and information on orangutan sightings are available, although the lack of data from remote areas of orangutan distribution means there may still be a bias towards crime detection and occurrence in conservation activity centers and urban areas where illegal pet owners are apprehended.

NGO involvement in improved detection is crucial, as their personnel appeared to detect nearly all of the orangutan crimes apprehended in Indonesia during this study. NGOs provide resources to support patrols including funding, patrol posts, and personnel (Table 5A5) and operate “tip lines”, where people can call in to report orangutan conflict or crimes, and informal information gathering networks to identify illegally held orangutans.

**Efforts to address orangutan crime**

The laissez-faire law enforcement of orangutan crimes in Indonesia may stem from the government's publicly-stated position that orangutan populations are not in decline and will not go extinct (Foresthints, 2020), contrary to peer-reviewed science indicating that populations of all three species are in decline (Meijaard et al., 2018). There is also a strong government focus on reconciling wildlife conservation with sustainable development and poverty alleviation goals, and a concomitant reluctance to punish rural community members (Wiratno, 2018).

The fact that we only found 22r court cases since 2007 that resulted in successful convictions, and that there were instances of repeat offenders and lack of remorse over being caught (Rainer et al., 2020; Sherman et al., 2020a), suggest that perpetrators are confident that their crimes will not be detected or punished, and that the benefits of illegal activity outweigh the risks. Confiscations and handovers of orangutans, accompanied by public education, have been conducted in Kalimantan and Sumatra since 1971 (Aveling & Mitchell, 1982). While this awareness raising has presumably contributed to the broad public knowledge of orangutan protection laws, it has not appeared to decrease crimes, which have remained common, and are very rarely prosecuted (Nijman, 2017). This is a remarkably lax enforcement approach compared with that for other iconic Indonesian species. For example, over a ten year period, 619 crime investigations were conducted and 40 persons arrested for crimes affecting Sumatran tigers, with more than 90% of the arrests leading to prosecutions (Risdianto et al. 2016). Indonesian leopard crimes had a 48.8% prosecution rate for 41 seizure records (Gomez & Shepherd, 2021). These rates, while insufficient to address big cat trafficking, are nonetheless much higher than for orangutan crimes. The accepted paradigm of consequence-free seizures and handovers of orangutans, with general education as a stand-in for strategic demand reduction, has long proven insufficient to address rampant crime, and its continuance presages a bleak future for the species.

Investigative and prosecutorial support of government law enforcement has helped to advance some cases in West Kalimantan (Freund et al., 2017; Knott et al., 2021) and in Sumatra (authors' unpublished data). Several of the successful convictions reported here (Table A8) were obtained following both investigative support and long-term media and public pressure campaigns by NGOs, notably rescue centers and wildlife crime investigation organizations (COP, 2021a; Freund et al., 2017).

Crimes of trafficking and killing prosecuted during the study period typically resulted in light sentences, such as six months jail time and a 500,000 IDR fine (US$ 35) (Table 5A8). The government generally does not pursue any legal action if people are willing to surrender the animals (Nijman, 2017), and NGOs and officials have expressed reluctance to take legal action against local community members. High-ranking government officials who illegally keep orangutans have likewise not been successfully prosecuted (Karokaro & Hanafiah, 2019). The reluctance to prosecute local orangutan owners does not appear to apply to other species or situations. For example, local villagers have been prosecuted for crimes affecting tigers (Risdianto et al., 2016) and for illegal logging (SOS, 2021).

Deterrent effects of consistent researcher and monitor presence may partly account for low incidence of crimes in long-term research sites (Figures 5A3, 5A4). Crime rates declined in sites where a combined approach addressed conservation education, long-term community development and alternative livelihoods initiatives, and anti-poaching patrols or community forest monitoring in targeted areas where communities had issues with local orangutan populations (Figures 5A3 and 5A4). These activities, along with incentivizing forest protection, successfully protect orangutan habitat in Gunung Palung National Park (Jones et al., 2020).

Over the past few decades, government and NGOs have aimed to avoid orangutan crimes by capturing and translocating animals away from potential conflict. Public messaging is focused on alerting authorities or NGOs whenever an orangutan is sighted near homes or crops (Sherman et al., 2020a). Most people want the animals translocated elsewhere, a request that NGOs and authorities typically accommodate (Jaya, unpublished data). While this may prevent additional crimes, many translocated individuals in this study were already victims of crimes, including injury by bullets or machetes. Additionally, translocated orangutans often returned to capture sites (Sherman et al., 2021), meaning their removals were not successful for orangutans or humans, and may cause significant conservation harm to orangutan metapopulations (Ancrenaz et al., 2021b).

## 5.5 Recommendations

Much expanded and strengthened efforts on crime deterrence and law enforcement are urgently needed. Locally adapted Situational Crime Prevention (SCP) frameworks can be used to improve detection and enforcement while addressing local community needs. SCP employs diverse interventions to render crime more difficult, less rewarding, and riskier, while simultaneously addressing triggers such as human-wildlife conflict, and eliminating justifications for conducting crime (Kurland et al., 2017). Targeted SCP frameworks focusing on local community-identified needs may help address social concerns related to wildlife protection laws, such as the perceived fairness of the treatment of wildlife versus local people (Travers et al., 2019).

We recommend immediate implementation of:

1. Increased government buy-in for law enforcement

It is crucial that the government is informed about currently unsustainable crime and killing rates and the need for stronger enforcement. Without understanding of crime and lack of enforcement as a key threat to orangutans, none of the recommendations below are likely to be accepted. Scientists, NGOs, local citizens, and the media play key roles in informing and engaging the government and the public about orangutan crimes.

2. Strengthened and expanded patrols

Strengthened detection and deterrence through significant expansion of effectively planned and implemented SMART patrol capacity across orangutan habitats in both formally protected and unprotected habitats is crucial. Enforcement effort for all protected areas of all types—not just national parks—in orangutan distribution should be increased to at least 3 officers per 100 $km^2$ (Table 5.2), with sufficient patrol personnel to routinely cover all accessible areas of orangutan habitat. Patrols should be planned such that locations are sufficiently random to avoid being predictable to poachers.

The designation of selected non-government patrol personnel to supplement limited government capacity and budgets, as is done in Kerinci Seblat National Park in Sumatra and in Sabah, Malaysia, could improve enforcement capacity in Indonesian orangutan distribution. Honorary Wildlife Wardens in Malaysia are granted arrest authorities similar to government personnel (State of Sabah, 1997). Kerinci Seblat National Park ranger patrol units work with community members who are honorary park officers, and the units have authority to make arrests if other authorities cannot be present (Linkie et al., 2015). These ranger units manage a network of local community informants whose assistance significantly increased detection likelihood. The Kerinci Seblat informants are offered random, small incentives to build loyalty while avoiding false reporting.

Patrol coverage on unprotected lands should be dramatically increased to reach three patrol officers or monitors per 100 $km^2$. Patrolling of all forested lands within Tapanuli orangutan habitat is a priority, and patrolling of forests in agricultural, logging and mining estates and community lands is an urgent need for Sumatran and Bornean orangutans.

3. Investigation of all crimes and enforcement of wildlife laws
All illegal clearing of orangutan habitat, and harm, capture, killing, trade, or possession of orangutans should be investigated, perpetrators apprehended and prosecuted, and any consequences publicized widely to establish deterrence.

NGO support for investigation is important at least until government capacity is increased. Investigation teams with dedicated personnel that do not overlap with conflict response, community development, education, or other field teams are recommended to maintain trust of local community members.

4. Regular and fair sanctions and suitable regulation
Well-trained judiciaries, prosecutors, and police that appreciate the seriousness of wildlife crime and the full complement of applicable laws for its prosecution are critical. Rational sentencing guidelines are needed to address disparities of intent, circumstance, and income of law breakers to avoid unintended consequences, notably the perception that orangutans are more valued than people (Beech, 2019; Chua et al., 2021). This may require additional knowledge and capacity building around the importance of prosecuting wildlife crime and developing targeted sentencing guidelines.

Orangutan killing, sale, and clearcutting of identified orangutan habitat should be treated as serious crimes. Prosecutions for these crimes can be based on laws beyond species protection, including weapons possession, customs law, tax evasion, and animal welfare (Nijman, 2017). Sanctions should be stiffest for politicians, military, and other civil servants breaking the laws they are sworn to uphold, and for companies and management level employers who encourage or disregard intentional orangutan killing or habitat clearance, while those for workers paid to target the animals, or for local villagers who capture orangutans opportunistically could be more lenient. The surety of consequences—the application of even minor sanctions consistently—is more important than handing out stiff penalties particularly to impoverished villagers.

Surrender or seizure of illegally held orangutans should be directly tied to investigations to identify poachers, sellers, and those keeping the animals as pets. People who find or are given infant orangutans and promptly report the situation to recue centers or authorities should not face penalties, but those who intentionally keep or sell the orangutans are committing a crime. Although arresting every pet owner is politically impractical and may create heightened animosity towards orangutans, even a small number of well-publicized convictions for illegal orangutan possession may improve deterrence. At a minimum, every person surrendering an orangutan should have to sign a formal declaration to the government admitting the criminal action and acknowledging that any subsequent infractions will result in arrest. Repeat offenders should be arrested and sanctioned.

New regulations may be needed for hunting practices that unintentionally target orangutans, such as prohibitions on snaring in protected orangutan habitats.

5. Community engagement

Strategies targeted to local needs are required to change local perceptions of orangutans, as well as hunting and land management practices (Chua et al., 2021; Jones et al., 2020; Maskulino et al., 2021). Long-term engagement with local communities, characterized by an ethnographic focus of understanding people's lives and interests, is necessary to empower communities as equal partners and identify interventions that will effectively change illegal behaviors and incentivize orangutan conservation. Funders should support long-term community engagement, along with monitoring of implemented projects' effects on human wellbeing and orangutan conservation.

6. Incentivizing positive behavior change

Results from community engagement efforts should be used to build locally specific strategies that address identified livelihood and community needs. Community and traditional land rights are a vital element. Community agreements or customary laws prohibiting orangutan hunting, or forgoing snaring and tree-cutting in certain areas, can be helpful. Benefit sharing and other compensations or direct benefits may be required to offset crop losses, address livelihoods lost to restricted hunting and trading, or meet community development needs in exchange for compliance with orangutan protection measures. Examples include long-term employment opportunities in research and ecotourism, provision of health care services and payments for retirement of chainsaws and guns (Jones et al., 2020), and community land rights coupled with forest management plans (Knott et al., 2021). Rescue centers, research centers, and other local NGOs lead these efforts. Community members should be trained and deployed as orangutan monitors in known conflict areas, particularly protected area buffer zones and unprotected areas in Kalimantan and Sumatra. Their monitoring mission would be protecting local orangutans from harm, and defusing conflict without translocating the animals. Public messaging about orangutans near human use areas should not offer the animals' removal but instead should inform people to keep their distance and leave the protected animals unharmed.

7. Monitoring and evaluation of deterrence interventions
All crime deterrence interventions should be systematically monitored and evaluated, and results should inform modifications to avoid spending limited conservation funding and effort on well-intentioned yet ineffectual actions. Conservation funders should require and finance monitoring, as lack of funding for these activities is a barrier for practitioners.

## 5.6 Conclusion

Our study demonstrates that reported orangutan crimes continue at rates likely to far exceed the 1–2 % offtake of adults predicted to drive populations to extinction, and indeed recent studies show all orangutan species have declined dramatically in the past decade (Santika et al., 2022). Anti-poaching patrols and community monitors need to be dramatically expanded across protected and unprotected areas. Criminal investigation of all crimes and regular application of sanctions for law-breaking should be the norm. Conservation and community development interventions targeted to local needs while protecting wild orangutans and their habitats should be implemented, monitored, and evaluated, and successful practices scaled up to forestall further crimes. These lessons are applicable to many biodiverse tropical landscapes struggling with wildlife crime.

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## Chapter 5 Supplementary information

**Table 5A1. List of data sources.** Online links were last accessed on October 20, 2021 unless otherwise noted. Some data provided cannot be listed due to confidentiality issues. The table does not list webpage links for previously public sources that are no longer available online. We used additional publicly available and unpublished data from individuals and organizations not listed here due to confidentiality concerns. Google searches resulted in newspaper sources additional to those listed here; any such sources used are in the references in this document or the main paper. We subscribed to The Jakarta Post online to be able to access articles behind their pay wall.

| Source type | Source name / description | Citation or web address |
|---|---|---|
| **Newspaper searches** | ANTARA News | https://en.antaranews.com/ |
| | Google advanced search | https://www.google.com/advanced_search |
| | Kompas | https://www.kompas.com/ |
| | Prokal | https://news.prokal.co/ |
| | The Jakarta Post | https://www.thejakartapost.com/ |
| | TribunNews | https://www.tribunnews.com/ |
| **Published papers and reports** | Nijman (2005, 2017) | https://doi.org/10.1002/ajp.22652 |
| | Freund et al. (2017) | https://doi.org/10.1002/ajp.22620 |
| | CITES/GRASP (2006) | https://cites.org/sites/default/files/common/prog/ape/ID_mission06.pdf |
| **Wildlife trade databases** | CITES trade database | https://trade.cites.org/ |
| | WildEye Asia Wildlife Crime Map | https://oxpeckers.org/wildeyemap-asia/ |
| | TRAFFIC Wildlife Trade Portal | https://www.wildlifetradeportal.org/#/dashboard |
| **Protected areas database** | The World Database on Protected Areas (WDPA) | IUCN, UNEP-WCMC. The World Database on Protected Areas (WDPA) 2020 [Available from: https://www.protectedplanet.net/] |
| **Grant programs** | Tropical Forests Conservation Act – Sumatra (TFCA-Sumatra) | https://tfcasumatera.org/publikasi/ |
| **Government sources** | Balai Besar Konservasi Sumber Daya Alam (BBKSDA) North Sumatra | https://bbksdasumut.com/ |
| | Balai Konservasi Sumber Daya Alam (BKSDA) East Kalimantan | http://bksdakaltim.menlhk.go.id/ |
| | BKSDA Central Kalimantan | http://bksda-skw2.blogspot.com/ |
| | BKSDA West Kalimantan | https://ksdakalbar.wordpress.com/ |
| | Direktorat Jendral Konservasi Sumber Daya Alam dan Ekosistem (KSDAE) news blog | http://ksdae.menlhk.go.id/pencarian-berita.html |
| | KSDAE annual statistics | http://ksdae.menlhk.go.id/ |
| | Kementerian Lingkungan Hidup & Kehutanan (KLHK) | https://www.menlhk.go.id/ |
| **Practitioner-published reports, online new blogs and other website source** | Borneo Nature Foundation (BNF) Annual report 2018 | Borneo Nature Foundation Annual Report 2018: turning knowledge and science into on-the-ground-actions. (2019). Palangka Raya, Indonesia. |
| | BNF | https://www.borneonaturefoundation.org/project/rungan-community-development/ |
| | Bornean Orangutan Survival Foundation (BOSF) | https://www.orangutan.or.id/our-latest-stories |
| | BOS Australia – Adopt an orangutan | https://www.orangutans.com.au/meet-our-family/ |
| | BOSF Annual Reports 2006 - 2017 | No longer available online. Previously accessed through BOSF website, www.orangutan.id |
| | BOSF Annual Report 2019 | BOSF. (2020). Bornean Orangutan Survival Foundation Annual Report 2019. Bogor, Indonesia. No longer available online. |

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| BOS  Germany 2008 Annual Report | BOS Deutschland. (2009). Rechenschaftsbericht und Mittelverwendung 2008: Bericht aus den BOS-Projekten, Aktivitäten und Ausblicke 2008 / 2009. Berlin, Germany. |
| BOS Germany 2009 Annual Report | BOS Deutschland. (2010). Rechenschaftsbericht und Mittelverwendung 2008: Bericht aus den BOS-Projekten,<br>Aktivitäten und Ausblicke 2008 / 2009. Berlin, Germany. |
| BOS Germany 2010 Annual Report | BOS Deutschland. (2011). Jahresbericht und Mittelverwendung 2010: Bericht aus den BOS-Projekten. Berlin, Germany. |
| BOSF Highlights 2017 | BOSF. (2018). Bornean Orangutan Survival Foundation Highlights 2017. Bogor, Indonesia. No longer available online. |
| BOSF Highlights 2018 | BOSF. (2019). Bornean Orangutan Survival Foundation Highlights 2017. Bogor, Indonesia. No longer available online. |
| BOSF Independent Auditor's Report 2006-2007 | BOSF. (2008). Independent Auditor's Report on Financial Statements on the Years Then Ended December 31, 2007 and 2006. HLB Hadori & Rekan, Jakarta, Indonesia. |
| BOSF Independent Auditor's Report on Financial Statements 2008 and 2009 | BOSF. (2010). Independent Auditor's Report on Financial Statements on the Years Then Ended December 31, 2008 and 2009. HLB Hadori & Rekan, Jakarta, Indonesia. |
| BOSF Nyaru Menteng Official Release Stories | https://goingback2dforest.wordpress.com/ |
| BOSF Progress Report | BOS Foundation and RHOI. (2013). Progress Report: Orangutan Post Release Monitoring in Kehje Sewen Forest, East Kalimantan. BOS Foundation and Restorasi Habitat Orangutan Indonesia (RHOI). Bogor, Indonesia. No longer available online. |
| BOSF Progress Report | BOSF. (2015). Progress Report #4: Orangutan Reintroduction and Post-release Monitoring in Bukit Batikap Conservation Forest, Murung Raya August 2013 - December 2014. BOS Foundation - Central Kalimantan Orangutan Reintroduction Program at Nyaru Menteng. Bogor, Indonesia. No longer available online. |
| BOSF Progress report | BOSF. (2016). Progress report: Post-release Monitoring Of orangutans in the Kehje Sewen forest, East Kalimantan 2015. Bogor, Indonesia. No longer available online. |
| BOSF Samboja Lestari & Kehje Sewen Official Release Stories | https://orangutanforest.wordpress.com/ |
| BOSF Orangutan Reintroduction and Post-release Monitoring | BOSF. (2016). Orangutan Reintroduction and Post-release Monitoring in Bukit Batikap Conservation Forest, Murung Raya Central Kalimantan January 2015 to December 2015. Orangutan Reintroduction Program at Nyaru Menteng. Bogor, Indonesia. |
| BOSF Orangutan Reintroduction and Post-release Monitoring | BOSF. (2018). Orangutan Reintroduction and Post-release Monitoring Update on the Reintroduction Programs in Bukit Batikap Conservation Forest and Bukit Baka Bukit Raya National Park January 2016 to October 2017. No longer available online. |
| Centre for Orangutan Protection (COP) | http://orangutanprotection.com/ |
| Cikananga Wildlife Center | https://www.cikanangawildlifecenter.com/news/ |
| Conservation Action Network Borneo (CAN) | https://www.canborneo.id/ |

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| Direktorat Jenderal Konservasi Sumber Daya Alam dan Ekosistem (KSDAE) | http://ksdae.menlhk.go.id/pencarian-berita.html (search term "orangutan") |
| Fauna and Flora International (FFI) | https://www.fauna-flora.org/countries/indonesia; https://www.planvivo.org/Handlers/Download.ashx?IDMF=35e736f3-86ea-49e7-85b6-1680f97d7823 |
| Forest, Nature and Environment of Aceh (HAkA) | https://www.haka.or.id/?page_id=1008 |
| Forum Konservasi Leuser (FKL) | https://leuserconservancy.or.id/profile; https://leuserconservancy.or.id/what-we-do/community-empowerment/; https://leuserconservancy.or.id/what-we-do/research-station/ |
| Frankfurt Zoological Society project and annual reports | https://fzs.org/en/projects/indonesia/bukit-tiga-puluh/; https://fzs.org/en/news/filter/annual-report/ |
| Friends of the Earth Indonesia (WALHI) | https://www.walhi.or.id/ |
| Gunung Palung Orangutan Conservation Program (GPOCP) annual reports | https://savegporangutans.org/about/our-achievements/ |
| Hempel Foundation (Hempel) | https://www.hempelfonden.dk/en/what-we-do/nature/rawa-singkil-wildlife-reserve-in-indonesia/ |
| IDH | https://www.idhsustainabletrade.com/news/ketapang-pioneers-the-first-ppi-compact-of-west-kalimantan-landscape/ |
| International Animal Rescue (IAR) | https://www.internationalanimalrescue.org/news?currency=USD; https://www.internationalanimalrescue.org/projects/orangutan |
| Yayasan International Animal Rescue Indonesia (YIARI) | http://www.internationalanimalrescue.or.id/berita/ No longer available online. |
| International Animal Rescue (IAR) Annual Reports and website | https://www.internationalanimalrescue.org/annual-reports# |
| IAR Charity Commission Reports | https://register-of-charities.charitycommission.gov.uk/charity-search/-/charity-details/4029510/accounts-and-annual-returns |
| Jejak Pulang | https://www.four-paws.org/campaigns-topics/sanctuaries/orangutan-forest-school |
| Katingan Mentaya | https://katinganproject.com/; https://katinganproject.com/uploads/default/modular/8d288271d17b35c3b8b8b9073d9a1d17.pdf |
| Masarang Foundation (Masarang) | https://masarang.eu/about/about-masarang/willie-smits/ |
| Orangutan Foundation International (OFI) Annual Reports | Orangutan Foundation International. (2010). 2009 Annual Report.; https://orangutan.org/about/annual-report/ |
| OFI news blog | https://orangutan.org/blog/ |
| Orangutan Foundation-UK (OF-UK) | https://www.orangutan.org.uk/blog/ |
| Orangutan Foundation-UK (OF-UK) Charity Commission Reports | https://register-of-charities.charitycommission.gov.uk/charity-search/-/charity-details/3997163/accounts-and-annual-returns |
| Orangutan Information Centre (OIC) | https://orangutancentre.org/news/ |
| Orangutan Kutai Project (Kutai Project) | https://www.orangutan.com/orangutan-kutai-project-field-update-2016/ |
| Orangutan Republik | https://www.orangutanrepublik.org/what-we-do/mobile-education-and-conservation-unit-program/ |

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|---|---|---|
| | PanEco | https://paneco.ch/en/orangutan-conservation-programme/ |
| | People Resources and Conservation Foundation (PRCF) | https://prcfoundation.org/prcf-indonesia/current-initiatives/, |
| | Planet Indonesia | https://www.planetindonesia.org/news-and-press |
| | Profauna | http://www.profauna.net/en/publication/annual-reports |
| | Pronatura | https://pronaturafoundation.org/sungai-wain-protection-forest/ |
| | Rimba Raya | https://rimba-raya.com/our-initiatives/; https://infinite-earth.com/assets/uploads/VCS-CCB-3rd-Monitoring-Period-Verification-Report_v02-2015-1.pdf |
| | Scorpion Illegal Wildlife Trade Monitoring Network | http://www.scorpionmonitor.org/newslist |
| | Sintang Orangutan Centre (SOC) | https://soc.or.id/artikel/ |
| | Sumatran Orangutan Conservation Programme (SOCP) | https://www.sumatranorangutan.org/category/media/news/ |
| | SOCP, YEL and PanEco annual reports | https://www.sumatranorangutan.org/category/media/publications/ |
| | Sumatra Rainforest Institute | http://sumatranrainforest.org/ Not currently accessible online. https://www.globalgiving.org/projects/orangutan-protection-in-wild-tapanuli/#menu |
| | Tasikoko | http://www.tasikoki.org/latest-news/ |
| | Tuanan Research Site (Tuanan) | https://www.aim.uzh.ch/de/orangutannetwork/tuananorangutanresearchproject.html; https://coreborneo.com/tuanan-research-station/ |
| | The Borneo Initiative | https://theborneoinitiative.org/our-story/#reports |
| | Wildlife Conservation Society (WCS) | https://indonesia.wcs.org/Wild-Places/Leuser.aspx |
| | Wildlife Rescue Centre Jojakarta | https://wrcjogja.org/blog/ |
| | World Wide Fund for Nature (WWF) | https://wwf.panda.org/?209387/Corridor-Restoration-Together-with-community-to-answer-the-challenge-of-climate-change; https://www.worldwildlife.org/projects/thirty-hills |
| | Yayasan Ekosistem Lestari (YEL) | https://www.yel.or.id/environmental-education/ |
| | Yayorin | http://www.yayorin.com/ |
| **Social media** | Animal Sanctuary Trust Indonesia (ASTI) | https://twitter.com/ASTIndonesia |
| | BBKSDA North Sumatra | https://www.facebook.com/bbksdasumut; |
| | BKSDA Aceh | https://www.instagram.com/bksda_aceh/ |
| | BKSDA Central Kalimantan | https://www.facebook.com/BKSDAKalimantanTengah |
| | BKSDA East Kalimantan | https://www.facebook.com/bksdakaltim.bksdakaltim |
| | BOSF | https://www.facebook.com/BOSFoundation/ |
| | COP | https://www.facebook.com/saveordelete/ |
| | IAR | https://www.facebook.com/internationalanimalrescue/. |
| | SOC | https://www.facebook.com/orangutansintang/ |
| | FKL | https://www.facebook.com/leuserconservationforum |
| | Jakarta Animal Aid Network | https://www.facebook.com/jakartaanimalaidnetwork/ |
| | OFI | https://www.facebook.com/orangutanfoundationinternational/ |
| | OF-UK | https://www.facebook.com/orangutanfndn/ |
| | Sumatra Rainforest Institute | https://www.facebook.com/sumatrarainforestinstitute/about |

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| **Third party reports, data, and petitions** | "On the Trail - Information and analysis bulletin on animal poaching and smuggling" – RobindesBois.org | https://robindesbois.org/en/category/actualites/ |
| | Orangutan Appeal UK Newsletters | https://www.orangutan-appeal.org.uk/about-us/newsletter-archive |
| **FORINA database** | FORINA Orangutan Conflict Database | Previously available at http://forina.or.id/konflik/orangutan.php. No longer available online. |

**Table 5A2. Crime and location variables.**

| Variable | Variable Response | Definitions |
|---|---|---|
| Crime type | Killing crime | Any record that (1) noted killing of the animal or recorded dead animals or parts; (2) described orangutan death from human-inflicted injuries, whether immediate or otherwise; and (3) identified an illegally held, dependent infant (five years or younger), where the mother's killing could be assumed, even if her death was not reported |
| | Non-lethal crime | Any illegal actions involving orangutans that was not recorded as resulting in death, including harm (injury or harassment) or trade (possession, sale, purchase, exchange or barter) |
| Number of orangutans involved | Number of individuals killed | Each orangutan affected by crime was counted only once and each instance involving a particular individual was counted as a single killing or non-lethal crime |
| | Number of individuals affected by non-lethal crimes | |
| Incident locations | Province | Location where crime occurred, and where it was reported and apprehended. Site names can be protected area, agricultural concession, city, town, or any other area name |
| | District (*Kabupaten*) | |
| | Subdistrict (*Kecamatan*) | |
| | Village (*Desa*) | |
| | Site name | |
| Origin of animal | Province | Original location of the orangutan, as reported to enforcement officials or rescue center personnel. Protected area, agricultural concession, city, town, or any other area name |
| | District (*Kabupaten*) | |
| | Subdistrict (*Kecamatan*) | |
| | Village (*Desa*) | |
| | Site name | |
| Law enforcement outcomes | Investigation | Investigation by government authorities |
| | Arrest | Arrest by government authorities |
| | Prosecution | Tried and prosecuted |
| | Conviction | Tried, prosecuted and convicted of the crime |
| | Sentencing | Sentenced following conviction |
| Awareness of orangutan protection laws | Yes or No | Person's reported knowledge of orangutan protection laws prior to alleged crime |
| Reaction to law enforcement | Willing surrender of animal | The orangutan holder willingly handed over the animal to law enforcement authorities or to rescue center personnel during surrender or seizure |
| | Resistance to handover | The orangutan holder refused or was reluctant to hand the animal over to law enforcement authorities during attempted surrender or seizure |
| | Repeat offense | The person has been previously convicted of an orangutan-related crime or has been previously contacted by law enforcement due to alleged killing, harm or trade of orangutans |

**Table 5A3. Activity variables.**

| Variable | Variable Response | Definitions |
|---|---|---|
| Target area name | See Table S4 | |
| Activities implemented | Research | Long-term research projects related to orangutans that had regular researcher presence |
| | Habitat management | Firefighting, fencing or other infrastructure related to protection, habitat purchase and management, community or traditional land management including hunting controls, community forestry |
| | Law enforcement | Habitat patrols or monitoring by rangers, guards, community wardens or monitors; manning of guard posts; investigations of alleged criminal activity. Patrols and enforcement actions are carried out by government, while communities and NGOs may provide funding and support, wardens and monitoring personnel, equipment, or facilities. |
| | Awareness raising | General public education to untargeted audiences (through television, radio and newspapers, social media, billboards, other outreach media and in person education) |
| | Community outreach & capacity building | Community outreach and conservation education in target areas in orangutan range or trade hotspots; training and capacity building including for alternative livelihoods |
| | Human-wildlife conflict mitigation | Training and actions to deter crop foraging or orangutan presence, or compensation for loss of human property or crops |
| Location and spatial extent of activity implementation | Province | Location where activity implementation was reported. Other geographic descriptors can include GPS coordinates, hamlet (*Dusun*), or other site descriptions |
| | District (*Kabupaten*) | |
| | Subdistrict (*Kecamatan*) | |
| | Village (*Desa*) | |
| | Other geographic descriptors | |
| Initiation date of activity or land class status | Date by location and activity or protected area status designation | Initiation date of activity or land protection status |
| Duration of activity | Duration by activity and location | |

**Table 5A4. Entities conducting orangutan crime deterrence activities in species range in Kalimantan and Sumatra, Indonesia.**

**Organizations operating across all orangutan habitats or based outside of orangutan range**

1 IUCN SGA
2 UNEP
3 GRASP
4 Great Apes Film Initiative
5 Orangutan Conservancy
6 Yayasan Kehutanan Masyarakat Indonesia
7 Yayasan Swara Owa
8 Yayasan Ulos Heritage Indonesia (SCORPION)
9 FORINA
10 CIFOR
11 University of Kent DICE
12 Borneo Futures
13 Pronatura
14 ITTO
15 Cikananga Wildlife Center/ Wanicare
16 Wildlife Rescue Center Yogjakarta
17 Tasikoki Wildlife Rescue Centre

**Organizations operating in Indonesian Kalimantan:**

1 ADB/GEF (Sustainable Forest and Biodiversity Management in Borneo)
2 UNEP/Wetlands International Indonesia/Global Environmental Centre
3 UNDP – Kalimantan Indonesian International Rural Agricultural Development Foundation
4 Kalimantan Prima Coal
5 Agro Bukit (Goodhope Holdings)
6 Agro Wana Lestari (Goodhope Holdings)
7 Dewata Sawit Nusantara (DSN group)
8 Genting – Kalimantan
9 Globalindo Alam Perkasa (Musim Mas)
10 Harapan Sawit Lestari
11 Investa Karya Bhakti
12 Karya Makmur Bahagia
13 Karya Makmur Sejahtera (Goodhope Holdings)
14 Kridatama Lancar (Sime Darby)
15 Mentaya Sawit Mas (Wilmar)
16 Nabatindo Karya Utama (Bumitama)
17 Kalimantan Agro Lestari
18 Rea Kaltim Plantation
19 Sarana Titian Permata (Wilmar)
20 Sawit Sumber Mas Sarana
21 Sinar Mas – GAR
22 Sukajadi Sawit Mekar (Musim Mas)
23 Swakarsa Sinar Sentosa (Sinar Mas)
24 Tapian Nadenggan (Sinar Mas)
25 Makin Group
26 Katingan Mentaya Project
27 Rimba Raya Restoration Ecosystem
28 Acacia Andalan Utama
29 Balayan River Timber
30 Bina Ovivipari Semesta
31 Carus Indonesia
32 Djima Jaya Utama
33 Erna Djuliawati
34 Graha Sentosa Permai

35 Gunung Gajah Abadi
36 Karya Lestari
37 Narkata Timber
38 Royal Lestari Utama
39 Saratim (Sarmiento Parakantja Timber)
40 Sari Bumi Kusuma
41 Suka Jaya Makmur
42 Utama Damai Indah Timber
43 Wanasokan Hasilindo
44 Balai Konservasi Sumber Daya Alam Kalbar
45 Balai Konservasi Sumber Daya Alam Kalteng
46 Balai Konservasi Sumber Daya Alam Kaltim
47 Danau Sentarum National Park
48 Betung Kerihun National Park
49 Gunung Palung National Park
50 Bukit Baka/Bukit Raya National Park
51 Tanjung Puting National Park
52 Sebangau National Park
53 Kutai National Park
54 Badan Restorasi Gambut (Peat Restoration Agency)
55 Aidenvironment
56 Borneo Nature Foundation
57 CAN Borneo
58 FFI Indonesia
59 Friends of the National Parks Foundation
60 IDH Ketapang landscape
61 Integrated Conservation
62 Link-AR Borneo
63 Masarang
64 People Resources and Conservation Foundation (PRCF)
65 Planet Indonesia
66 Profauna
67 Save Our Borneo
68 TNC Indonesia
69 WALHI Indonesia
70 WCS Indonesia – Kalimantan
71 Wetlands International Indonesia
72 YTS/Wildlife Impact – community surveys
73 World Education – Indonesia
74 WWF Indonesia
75 Yayorin
76 Brunel University
77 CIMPTROP - University of Palangka
78 Wallacea Trust
79 Yayasan TITIAN
80 Gunung Palung Orangutan Conservation
81 Health in Harmony
82 Kutai Project
83 Mohammed bin Zayed Conservation Fund – in situ research funds, Kalimantan
84 Orangutan Land Trust
85 Tropenbos-International
86 Tuanan Orangutan Research Project/CORE Borneo
87 University College Birmingham – in situ research Kalimantan
88 BOSF Nyaru Menteng,
89 Wanariset Samboja/Samboja Lestari,
90 Mawas
91 RHO/BOSF
92 Center for Orangutan Protection/Bornean Orangutan Rescue Alliance

93 International Animal Rescue
94 Jakarta Animal Aid Network
95 Jejak Puleng
96 Orangutan Foundation UK
97 Orangutan Foundation International
98 Sintang Orangutan Centre
99 Tenggarong rescue/transfer facility

**Organizations operating in Sumatra**:
1 UNDP
2 TFCA/Leuser Conservation Partnership
3 Asia Pacific Resources International Limited (APRIL)
4 Royal Lestari Utama
5 North Sumatra Hydroelectric Company
6 Balai Konservasi Sumber Daya Alam Nangroe Aceh Darussalam
7 Balai Konservasi Sumber Daya Alam Sumatera Jambi
8 Gunung Leuser National Park
9 Bukit Tigapuluh National Park
10 Conservation International Indonesia
11 Forum Konservasi Lesuer (FKL)
12 Frankfurt Zoological Society
13 HAkA
14 INDECON
15 Institute Green Aceh (IGA)
16 Jantho Lestari Consortium
17 Lembaga Suar Galang Keadilan
18 Leuser Ecosystem Management Authority Employee Forum
19 Nature for Change
20 Orangutan Information Center
21 Orang Utan Republik/TOP
22 PADHI Foundation
23 Penyangga Tengah Kawasan Ekosistem Leuser
24 PETRA
25 Rainforest Action Network
26 Rainforest trust/KEHUS
27 Sumatra Ranger Project/Yayasan Cahaya Anak Nusantara
28 Sumatran Rainforest Institute/tapanuli Orangutan Conservation Project (TOCOP)
29 Universitas Nacional (Unas) Faculty of Biology
30 WALHI Indonesia
31 WCS Indonesia – Sumatra
32 Wetlands International Indonesia
33 Yayasan Konservasi Satwa Liar Indonesia (YKSLI)
34 Yayasan Leuser International (Leuser International Foundation, YLI)
35 Yayasan Ulos Heritage Indonesia (SCORPION)
36 Ketambe
38 Soraya
39 Sumatra Wildlife Centre and Ellis Park Sanctuary/ Jakarta Animal Aid Network
40 Sumatran Orangutan Conservation Programme (SOCP)
41 SKEPHI (Sekretariat Kerjasama untuk Pelestarian Hutan Indonesia
42 WildAid – Leuser project
43 Yayasan EKONA
44 Yayasan Perlindungan Lingkungan Hidup dan Pelestarian Alam (Yayasan Palapa)
45 Leuser Development Project
46 Sumatra Rescue Alliance (SRA)/OIC and COP

**Table 5A5. Target area protected status and activities.** Targets cover the key formally protected areas (PA) and conservation activity areas (CA) for orangutans (Santika et al., 2022), and cities/towns in and around the orangutan distribution. Numbers relate to maps in Figure 1. Activities are described in Table A3. Awareness raising & general public education has occurred across all target areas due to several entities conducting national or province-wide outreach on orangutan protection (Santika et al., 2022; Sherman et al., 2020a). Hence it is listed below exclusively where it was the only activity recorded. Initiation year of NGO activities is based on available public data or input from practitioners. Enforcement activities are conducted by government. We used the dataset from Santika et al. (Santika et al., 2022) as the initial basis for activity type and location data, with additional data gathered from sources in Table A1. Information sources are sources in Table A1 where we found data on activity type, start date, and location but are not exhaustive lists of entities involved in these activities.

| # | Province | Target area cate-gory | Target area subcategory[1] | Target area name | Activities[2] | Initiation year of activity/ protection status | Information sources[3] |
|---|---|---|---|---|---|---|---|
| | | | | *Kalimantan* | | | |
| 24 | Central Kalimantan | CA | Mixed use conservation activity area | Belunggu and Belantikap ecosystems | • Research<br>• Community outreach & capacity building | 1991 | OF-UK, Yayorin |
| 26 | Central Kalimantan | CA | Rescue center & rehabilitation sites | BOSF Nyaru Menteng | • Community outreach & capacity building<br>• Habitat management | 1999 | BOSF |
| 42 | Central and West Kalimantan | PA | National Park | Bukit Baka Bukit Raya National Park | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement<br>• HWC mitigation<br>• Awareness raising | Protected status since 1992; NGO orangutan activities since 2013 (West Kalimantan) and 2016 (Central Kalimantan) | KSDAE, WDPA, IAR, BOSF, (KSDAE, 2018d) |
| 51 | Central Kalimantan | PA | Protection forest | Bukit Batikap | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement<br>• HWC mitigation | Protected status since 2004; consistent NGO activities since 2012 | KSDAE, BOSF |
| 62 | Central Kalimantan | PA | REDD+ conservation area | Katingan Mentaya | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement | 2013 | Katingan Mentaya |
| 52 | Central Kalimantan | PA | Wildlife reserve | Lamandau River Wildlife Reserve | • Community outreach & capacity building<br>• Law enforcement<br>• Research<br>• Habitat management | Protected status and activities since at least 1998 | KSDAE, WDPA, OF-UK, (KSDAE, 2018d) |
| 50 | Central Kalimantan | CA | Conservation area | Mawas Conservatio | • Habitat management | 2002 | BOSF |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | n Area (Mawas) | • Community outreach & capacity building<br>• Law enforcement | | |
| 31 | Central Kalimantan | CA | Rescue center | OFI | • Community outreach & capacity building<br>• Habitat management | 1998 | OFI |
| 32 | Central Kalimantan | City/town | City/town | Palangka Raya | • Awareness raising | NGO activities since at least 1999 | BOSF |
| 33 | Central Kalimantan | City/town | City/town | Pangkalan Bun | • Awareness raising | NGO activities since at least 1998 | OFI |
| 63 | Central Kalimantan | PA | REDD+ conservation area | Rimba Raya | • Habitat management<br>• Community outreach & capacity building<br>• Law enforcement | 2013 | Rimba Raya |
| 61 | Central Kalimantan | CA | Mixed use conservation activity focus area | Rungan Landscape | • Research<br>• Habitat management<br>• Community outreach & capacity building | 2016 | BNF |
| 37 | Central Kalimantan | City/town | City/town | Sampit | • Awareness raising | NGO activities since at least 1999 | BOSF |
| 43 | Central Kalimantan | PA | National Park | Sebangau National Park | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement | Protected status since 2004 | KSDAE, WDPA, BNF, (KSDAE, 2018d) |
| 41 | Central Kalimantan | PA | National Park | Tanjung Puting National Park | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement | Protected status since 1982. NGO and research activities since at least 1971 | KSDAE, WDPA, OFI, (KSDAE, 2018d) |
| 65 | Central Kalimantan | CA | Research site in Mawas | Tuanan | • Research | 2003 | BOSF, Tuanan |
| 23 | East Kalimantan | City/town | City/town | Balikpapan | • Awareness raising | NGO activities since at least 1992 | BOSF, Masarang |
| 58 | East Kalimantan | PA | Protection forest | Beratus/ Meratus | • Awareness raising | Protected status since at least 1991 | KSDAE, WDPA, BOSF |
| 25 | East Kalimantan | City/town | City/town | Bontang | • Awareness raising | NGO activities since at least 1992 | COP, CAN, Jejak Pulang, Masarang |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 27 | East Kalimantan | CA | Rescue & rehabilitation center | BOSF Samboja Lestari | • Community outreach & capacity building<br>• Habitat management | 1992 | BOSF, Masarang |
| 29 | East Kalimantan | CA | Rescue center & rehabilitation site | Centre for Orangutan Protection | • Community outreach & capacity building<br>• Habitat management<br>• Law enforcement<br>• Awareness raising | 2007 | COP |
| 59 | East Kalimantan | PA | ERC | Kehje Sewen | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement<br>• HWC mitigation | 2010 | BOSF |
| 44 | East Kalimantan | PA | National Park | Kutai National Park | • Research<br>• Habitat management<br>• Law enforcement | Protected status since 1982; research since 1972; other NGO activities since 2010 | KSDAE, WDPA, Kutai Project, Profauna, COP, (KSDAE, 2018d) |
| 36 | East Kalimantan | City/town | City/town | Samarinda | • Awareness raising | NGO activities since at least 1992 | COP, CAN, Jejak Pulang |
| 57 | East Kalimantan | PA | Protection forest | Sungai Wain | • Law enforcement<br>• Habitat management<br>• Research | Protected status since 1998; research 1990-2010; patrolling and protection 2002-2012 and 2016-present | KSDAE, Masarang, Pronatura, (Tropenbos, 2017) |
| 49 | East Kalimantan | CA | KEE | Wehea-Kelay corridor | • Research<br>• Law enforcement<br>• Community outreach & capacity building<br>• Habitat management | 2001 | The Borneo initiative, TNC report |
| 28 | East Kalimantan | CA | Rescue center & rehabilitation site | Yayasan Jejak Pulang | • Community outreach & capacity building<br>• Habitat management<br>• Research<br>• Law enforcement | Ongoing activities since 2016, previous activities 1992-2006 | BOSF, Jejak Pulang, Masarang, |
| 66 | East Kalimantan | PA | Protection forest and release site | Sungai Lesan | • Research<br>• Habitat management<br>• Law enforcement | Protected status since 2013 | COP, TNC |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | • Community outreach & capacity building | | |
| 46 | West Kalimantan | PA | National Park | Betung Kerihun National Park | • Habitat management<br>• Law enforcement<br>• Community outreach & capacity building | Protected status since 1995 | KSDAE, WDPA, SOC, (KSDAE, 2018d), (Sunkar & Santosa, 2018) |
| 45 | West Kalimantan | PA | National Park | Danau Sentarum National Park | • Community outreach & capacity building<br>• Habitat management<br>• Law enforcement<br>• Research | Protected status as Suaka Margasatwa Wildlife Reserve since 1982, and as national park since 1999 | KSDAE, WDPA, PRCF, SOC, WWF, (KSDAE, 2018d) |
| 56 | West Kalimantan | CA | Mixed use conservation activity area | DS-BK Corridor | • Community outreach & capacity building<br>• Habitat management | 2011 | PRCF, SOC, WWF, (KSDAE, 2018d) |
| 47 | West Kalimantan | PA | Nature reserve | Gunung Nyiut | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement | Protected status since 1982; NGO activities since 2014 | KSDAE, WDPA, Planet Indonesia |
| 40 | West Kalimantan | PA | National Park | Gunung Palung National Park | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement<br>• HWC mitigation | Protected status since 1990; NGO activities since at least 2004 | KSDAE, WDPA, GPOCP, IAR, (KSDAE, 2018d) |
| 53 | West Kalimantan | PA | Protection forest | Gunung Tarak | • Habitat management<br>• Community outreach & capacity building<br>• Law enforcement<br>• HWC mitigation<br>• Awareness raising | Protected status since 1998; NGO activities since 2008 | KSDAE, WDPA, GPOCP, IAR |
| 55 | West Kalimantan | PA | Hutan desa | HD Gambut Simpang Hilir | • Habitat management<br>• Community outreach & capacity building | 2016 | GPOCP |
| 64 | West Kalimantan | PA | Hutan desa | HD Laman Satong | • Habitat management<br>• Community outreach & capacity building | 2013 | FFI |
| 60 | West Kalimantan | PA | Hutan desa | HD Sungai Besar-Pg. | • Habitat management | Initiation date | IAR |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | Gadung-Sungai Pelang | • Community outreach & capacity building<br>• HWC mitigation<br>• Law enforcement | unknown; NGO activities since at least 2011 | |
| 54 | West Kalimantan | CA | KEE | KEE Ketapang | • Habitat management<br>• Community outreach & capacity building<br>• HWC mitigation | 2018 | IAR, IDH |
| 48 | West Kalimantan | PA | Nature reserve | Muara Kendawangan | • Research | protected status since 1982 | KSDAE, FFI, (Fauna & Flora International, 2010) |
| 30 | West Kalimantan | CA | Rescue & rehabilitation center | International Animal Rescue Indonesia (YIARI)/ Sungai Awan | • Community outreach & capacity building<br>• Habitat management | 2008 | IAR, YIARI |
| 34 | West Kalimantan | City/town | City/town | Pontianak | • Awareness raising | NGO activities since at least 2004 | GPOCP, IAR, SOC |
| 35 | West Kalimantan | CA | HCV | HCV set aside (PT KAL) | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement<br>• HWC mitigation | Activities since at least 2011 | unpublished data |
| 38 | West Kalimantan | City/town | City/town | Singkawang | • Awareness raising | NGO activities since at least 2004 | GPOCP, IAR, SOC |
| 39 | West Kalimantan | CA | Rescue center & rehabilitation site | Sintang Orangutan Centre | • Community outreach & capacity building<br>• Habitat management | 2006 | SOC |
| 67 | West Kalimantan | CA | Conservation activity area | Sungai Putri | • Habitat management | 2018 | IAR, YIARI |
| | | | | *Sumatra* | | | |
| 2 | Aceh | City/town | City/town | Banda Aceh | • Awareness raising | NGO activities since at least 2001 | YEL, OIC, WALHI |
| 10 | Aceh | PA | Nature Reserve and release site | Jantho_ Hutan Pinus/ Janthoi Nature Reserve | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement | Protected status since 1984: NGO activities since 2010 | KSDAE, WDPA, SOCP, PanEco, YEL, |
| 12 | Aceh | CA | Research site | Ketambe | • Research | 2015 | FKL |
| 13 | Aceh | City/town | City/town | Kutacane town area | • Awareness raising | NGO activities | YEL, OIC, WALHI |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | since at least 2001 | |
| 14 | Aceh | PA | Game Reserve | Lingga Isaq | • Community outreach & capacity building | Protected status since 1978; NGO activity since 2011 | KSADE, WDPA, TFCA Sumatra, (KSDAE, 2018d) |
| 17 | Aceh | PA | Wildlife Reserve | Rawa Singkil | • Community outreach & capacity building | Protected status since 1998; no NGO activities found in study period | KSDAE, WDPA, Hempel, (KSDAE, 2018d) |
| 19 | Aceh | City/town | City/town | Singkil | • Awareness raising | NGO activities since 2001 | YEL, OIC, WALHI |
| 21 | Aceh | CA | Research site | Soraya | • Research | 2016 | FKL |
| 22 | Aceh | CA | Research site | Suaq | • Research | 1992-1998 and 2005-present | SOCP, PanEco, YEL, |
| 9 | Aceh and North Sumatra | PA | NP | Gunung Leuser National Park | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement<br>• HWC mitigation | Protected status since 1980; NGO activities began prior to 2006 | BBKSDA, KSDAE, WDPA, SOCP, PanEco, YEL, FKL, WCS, OIC, HAkA, (KSDAE, 2018d) |
| 1 | Aceh and North Sumatra | CA | Mixed use conservation activity focus area | Leuser ecosystem | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement<br>• HWC mitigation | special legal status since 2008; local activities since colonial times; NGO activity began prior to 2006 | BBKSDA, SOCP, YEL, FKL, HAkA, OIC, Orangutan Republik, WCS |
| 3 | North Sumatra | CA | Rescue center | Batu Mbelin center | • Community outreach & capacity building | 2002 | SOCP, YEL |
| 4 | North Sumatra | City/town | City/town | Binjai | • Awareness raising | NGO activities since at least 2001 | YEL, OIC, WALHI |
| 7 | North Sumatra | PA | Nature Reserve | Dolok Sibual-Buali | • Habitat management<br>• Community outreach & capacity building<br>• Law enforcement<br>• HWC mitigation | Protected status since 1982; NGO activities since 2005 | BBKSDA, KSDAE, WDPA, SRI, SOCP |
| 8 | North Sumatra | PA | Nature Reserve | Dolok Sipirok | • Habitat management<br>• Community outreach & capacity building<br>• Law enforcement<br>• HWC mitigation | Protected status since 1982; NGO activities since 2005 | BBKSDA, KSDAE, WDPA, SRI, SOCP |
| 11 | Jambi | CA | | Jambi | • Research | 2002 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | Release site in Bukit Tiga Puluh ecosystem | | • Habitat management<br>• Community outreach & capacity building<br>• Law enforcement | | SOCP, PanEco, YEL, WWF, FSZ |
| 15 | North Sumatra | PA | Nature Reserve | Lubuk Raya | • Habitat management<br>• Community outreach & capacity building<br>• Law enforcement<br>• HWC mitigation | protected status and NGO activities since 2005 | BBKSDA, KSDAE, WDPA, SRI, SOCP |
| 16 | North Sumatra | City/to wn | City/town | Medan | • Awareness raising | NGO activities since 2002 | SOCP, PanEco, YEL, OIC |
| 18 | North Sumatra | CA | Research site | Sikundur | • Research | 2000-2007 and 2013-present | SOCP, PanEco, YEL, |
| 20 | North Sumatra | PA | Wildlife Reserve | Siranggas | status of activities unknown | 1989 | KSDAE, WDPA |
| 6 | Jambi and Riau | CA | Mixed use conservation activity focus area and release site | Bukit Tigapuluh ecosystem | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement<br>• HWC mitigation | NGO activities since 2000 | FZS, SOCP, WWF |
| 5 | Jambi and Riau | PA | NP | Bukit Tiga Puluh National Park | • Research<br>• Habitat management<br>• Community outreach & capacity building<br>• Law enforcement<br>• HWC mitigation | protected status since 1995; NGO activities since 2000 | KSDAE, WDPA, FZS, SOCP, WWF, (KSDAE, 2018d) |

**Table 5A6. Trends by province, target area category, and target area in Kalimantan and Sumatra, 2007 – 2019.** Crime numbers were notably different in in 2007 than any other years (higher in Kalimantan, and lower in Sumatra), hence we tested the serial autocorrelations and the trends for all years, and with 2007 data removed, but this did not affect results. Where no trend was present we confirmed the data had no serial autocorrelation using the Ljung Box test with lag of time periods - 1. Data showed no autocorrelation except where noted. *p* values of < 0.05 for Mann-Kendall and Ljung Box test were significant. Specific target areas without trends are not listed. Tests were performed in Rstudio.

| Category | Province | Target area | Mann-Kendall Trend test | | |
|---|---|---|---|---|---|
| | | | tau | 2-sided p-value | Monotonic trend |
| **Kalimantan** | | | | | |
| *All crimes* | All provinces | | -0.179 | 0.428 | No trend |
| | Central Kalimantan | | -0.333 | 0.127 | No trend |
| | East Kalimantan | | -0.013 | 1.000 | No trend |
| | West Kalimantan | | 0.290 | 0.196 | No trend |
| *Crimes in target areas* | | | | | |
| Cities and towns | C, E, and W Kalimantan | | **-0.581** | **0.007** | **Decrease** |
| | Central Kalimantan | | **-0.641** | **0.003** | **Decrease**[1] |
| | | Palangaka Raya | **-0.693** | **0.003** | **Decrease** |
| | East Kalimantan | | -0.395 | 0.081 | No trend |
| | | Samarinda | **-0.478** | **0.038** | **Decrease** |
| | West Kalimantan | | -0.239 | 0.312 | No trend |
| | West Kalimantan | | **-0.538** | **0.019** | **Decrease** |
| Conservation activity areas C, E, and W Kalimantan | | | -0.309 | 0.173 | No trend |
| | Central Kalimantan | | -0.247 | 0.284 | No trend |
| | East Kalimantan | | 0.040 | 0.933 | No trend |
| | West Kalimantan | | -0.018 | 1.000 | No trend |
| Protected areas | C, E, and W Kalimantan | | -0.323 | 0.142 | No trend |
| | Central Kalimantan | | **-0.468** | **0.032** | **Decrease** |
| | | Katingan Mentaya | **-0.634** | **0.006** | **Decrease** |
| | East Kalimantan | | 0.357 | 0.134 | No trend |
| | West Kalimantan | | 0.071 | 0.844 | No trend |
| Unprotected areas | C, E, and W Kalimantan | | -0.385 | 0.077 | No trend |
| | Central Kalimantan | | **-0.487** | **0.024** | **Decrease** |
| | East Kalimantan | | -0.199 | 0.388 | No trend |
| | West Kalimantan | | **0.484** | **0.027** | **Increase** |
| **Sumatra** | | | | | |
| *All crimes* | Aceh, North Sumatra[2] | | 0.116 | 0.625 | No trend |
| | Aceh | | -0.065 | 0.807 | No trend |
| | North Sumatra | | 0.000 | 1.000 | No trend |
| *Crimes in target areas* | | | | | |
| Cities and towns | Aceh, North Sumatra | | **-0.494** | **0.023** | **Decrease** |
| | Aceh | | **-0.464** | **0.036** | **Decrease** |
| | | Banda Aceh | **-0.516** | **0.027** | **Decrease** |
| | North Sumatra | | -0.126 | 0.613 | No trend |
| Conservation activity areas Aceh, North Sumatra | | | **0.480** | **0.031** | **Increase** |
| | Aceh | | 0.379 | 0.094 | No trend |
| | North Sumatra | | 0.124 | 0.673 | No trend |
| Protected areas | Aceh, North Sumatra | | **0.586** | **0.009** | **Increase** |
| | Aceh | | 0.518 | 0.025 | No trend |
| | | Gunung Leuser NP | **0.523** | **0.029** | **Increase** |
| | North Sumatra | | 0.362 | 0.124 | No trend |
| Unprotected areas | Aceh, North Sumatra | | -0.222 | 0.326 | No trend |
| | Aceh | | -0.290 | 0.196 | No trend |
| | North Sumatra | | 0.108 | 0.663 | No trend |

1. These data were serially autocorrelated (Ljung Box test result: X-squared = 23.491, df = 11, p-value = 0.01506).
2. Riau and Jambi provinces have a reintroduced orangutan population but neither had any reported crime in target areas.

**Table 5A7. Annualized reported crimes by type in Kalimantan Indonesia 2007 – 2019.** Total annual reported crimes disaggregated by province. Other crimes are all crimes that were non-lethal at the time of the incident, including injury to and capture/harassment of orangutans that may have later resulted in fatalities. Crimes reported in provinces outside orangutan distribution (All other provinces) include only those crimes committed in Indonesia. For example, a smuggled orangutan intercepted in another country and repatriated to Indonesia is a victim of non-lethal crime in Indonesia; i.e. the capture and trafficking of the animal.

| Kalimantan | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Central Kalimantan | | East Kalimantan | | West Kalimantan | | All other provinces | |
| | Killing | Other crimes | Killing | Other crimes | Killing | Other crimes | Killing | Other crimes |
| 2007 | 90 | 93 | 12 | 12 | 2 | 2 | 6 | 7 |
| 2008 | 38 | 41 | 2 | 2 | 10 | 10 | 3 | 3 |
| 2009 | 31 | 31 | 5 | 5 | 8 | 8 | 0 | 1 |
| 2010 | 33 | 34 | 20 | 20 | 21 | 23 | 0 | 0 |
| 2011 | 30 | 22 | 28 | 9 | 9 | 7 | 2 | 1 |
| 2012 | 30 | 30 | 11 | 13 | 10 | 6 | 6 | 6 |
| 2013 | 44 | 38 | 11 | 12 | 24 | 23 | 5 | 5 |
| 2014 | 40 | 43 | 6 | 9 | 29 | 28 | 3 | 5 |
| 2015 | 59 | 29 | 5 | 6 | 18 | 21 | 2 | 5 |
| 2016 | 34 | 43 | 16 | 12 | 34 | 23 | 1 | 1 |
| 2017 | 28 | 30 | 9 | 10 | 16 | 17 | 2 | 2 |
| 2018 | 20 | 18 | 16 | 13 | 14 | 14 | 0 | 1 |
| 2019 | 16 | 23 | 5 | 8 | 8 | 13 | 0 | 2 |
| Total | 493 | 475 | 146 | 131 | 203 | 195 | 30 | 39 |

| Sumatra | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Aceh | | North Sumatra | | Riau | | All other provinces | |
| | Killing | Other crimes | Killing | Other crimes | Killing | Other crimes | Killing | Other crimes |
| 2007 | 2 | 5 | 1 | 3 | 0 | 0 | 0 | 0 |
| 2008 | 15 | 21 | 7 | 14 | 0 | 0 | 0 | 0 |
| 2009 | 17 | 22 | 3 | 6 | 1 | 1 | 0 | 0 |
| 2010 | 6 | 8 | 7 | 7 | 0 | 0 | 0 | 0 |
| 2011 | 20 | 23 | 4 | 5 | 0 | 0 | 0 | 1 |
| 2012 | 10 | 13 | 1 | 4 | 0 | 0 | 0 | 1 |
| 2013 | 13 | 14 | 5 | 7 | 0 | 0 | 0 | 3 |
| 2014 | 11 | 12 | 1 | 2 | 0 | 0 | 0 | 0 |
| 2015 | 14 | 15 | 4 | 4 | 3 | 3 | 4 | 4 |
| 2016 | 10 | 12 | 5 | 10 | 0 | 0 | 1 | 1 |
| 2017 | 7 | 9 | 2 | 3 | 0 | 0 | 4 | 4 |
| 2018 | 7 | 11 | 5 | 5 | 0 | 0 | 3 | 10 |
| 2019 | 15 | 17 | 5 | 6 | 6 | 6 | 2 | 4 |
| Total | 147 | 182 | 50 | 76 | 10 | 10 | 14 | 28 |

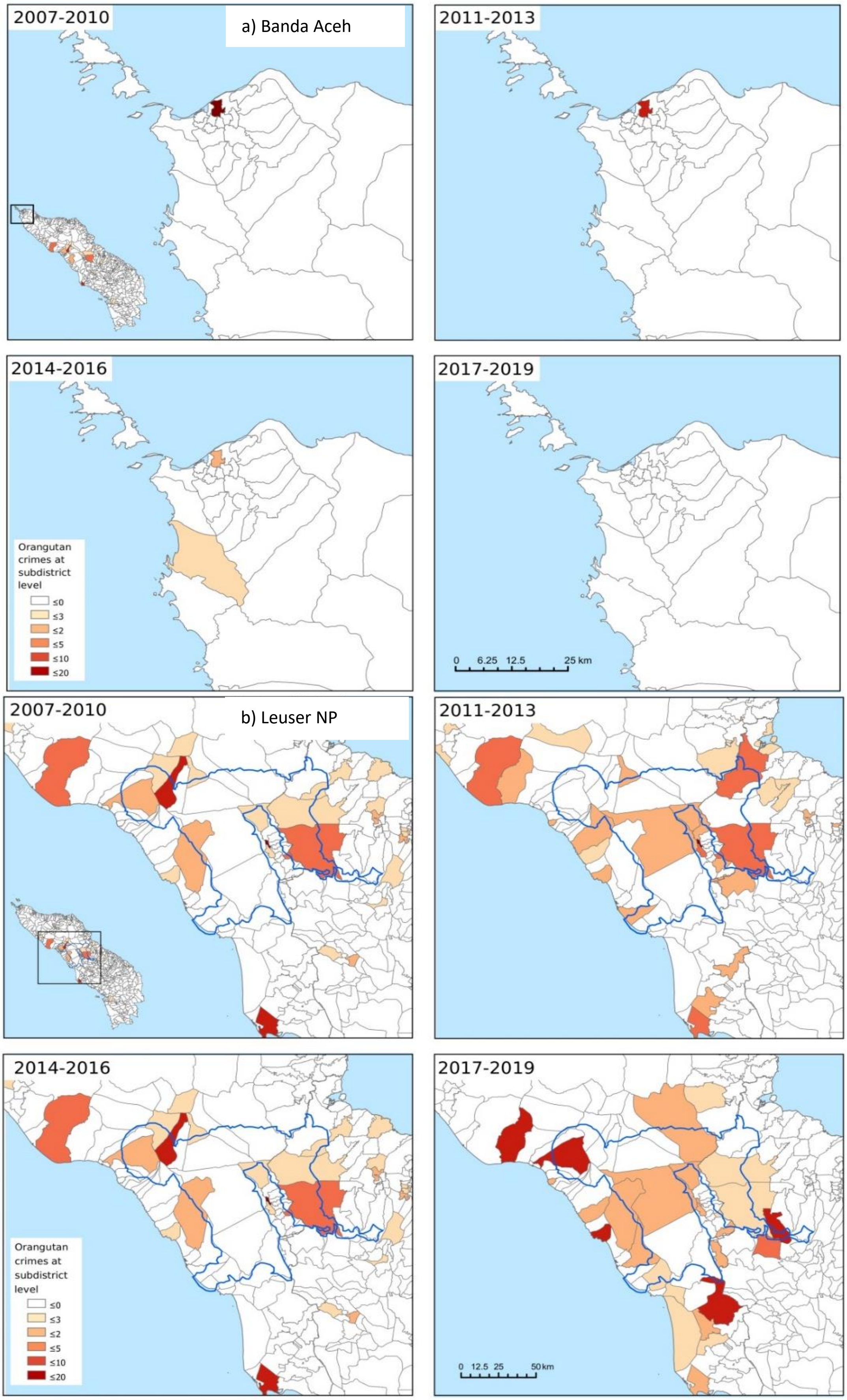


**Figure 5A1. Crimes reported in Sumatran orangutan range**. a) Crimes reported in Banda Aceh. Total numbers of all crimes (killing and non-lethal crimes) with location data provided that were reported in the city district (*kota*) of Banda Aceh. b) Crimes reported in Leuser National Park. Total numbers of all crimes (killing and non-lethal crimes) with location data provided that were reported in subdistricts (*kecamatan*) in and around Leuser National Park (thick boundary).

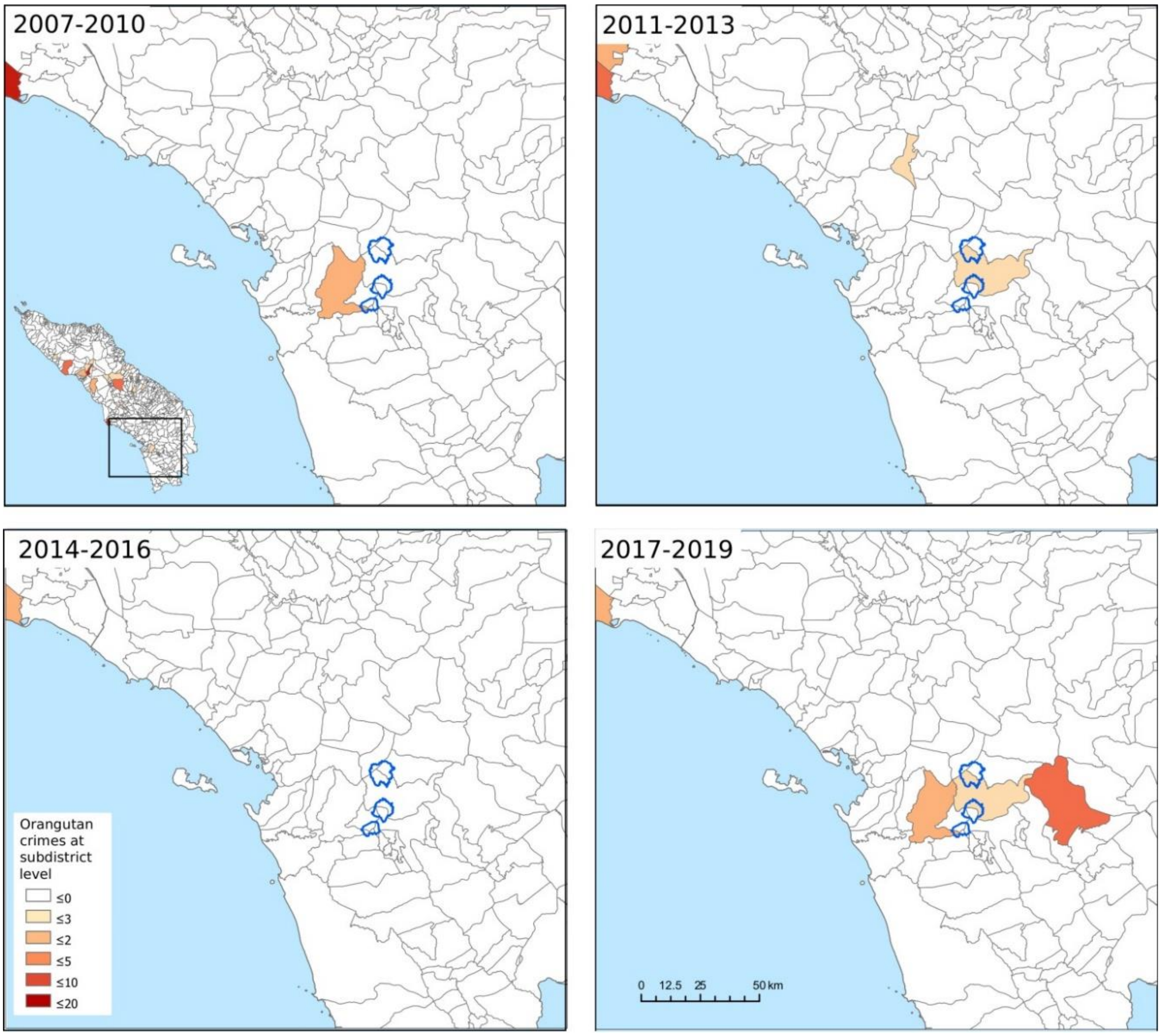


**Figure 5A2. Crimes reported in Tapanuli orangutan range.** Total numbers of all crimes (killing and non-lethal crimes) with location data provided that were reported in subdistricts (*kecamatan*) within Tapanuli orangutan range. Thick boundaries indicate protected areas (Dolok Sipirok, Dolok Sibual-Buali, and Lubuk Raya, from north to south).

**Table 5A8. Convictions and sentences for orangutan related crimes in Indonesia, 2007-2019.** Orangutan is abbreviated OU. Fines are shown in Indonesian Rupiah (IDR). As of September 2021, 1 million IDR was equivalent to USD $70.

| Year | OU name | Incident | Province or country | # OU | Sentence | People convicted | Sources |
|---|---|---|---|---|---|---|---|
| Kalimantan | | | | | | | |
| 2010 | Ongky | 2 year old male seized from traders | West Kalimantan | 1 | 8 months jail time, 1 million IDR fine | 1 | IAR (2010); Polisi Kehutanan Indonesia (2011); WCS (2010) |
| 2011 | | 20 orangutans killed, hunters were paid by plantation company | East Kalimantan | 20 | 8 months jail time, 30 million IDR fine each for two plantation managers; 20 million IDR fine each for two employees (hunters) | 4 | Karmini (2011); Robin des Bois (2013) |
| 2012 | | Killed and cooked orangutan, photos posted on social media | East Kalimantan | 1 | 10 months jail time, 50 million IDR fine or 2 months additional imprisonment. Court fee 5000 IDR | 2 | Chered (2012) |
| 2016 | | 13 orangutan skulls for sale | West Kalimantan | 13 | 9 months 10 days jail time, 50 million IDR fine | 1 | Scorpion Wildlife Trade Monitoring Group (2016) |
| 2017 | | Raid of online trafficker seized two live orangutans | West Kalimantan | 2 | 5 million IDR fine or 2 months in prison | 1 | IAR (2017); KSDAE (2017) |
| 2017 | Kalahien | Buried skeleton of orangutan beheaded by rubber tappers | Central Kalimantan | 1 | 6 months jail time, 500,000 IDR fine or 1 additional month imprisonment | 2 | KSDAE (2018c); Pro Kalteng (2018) |
| 2017 | | Orangutan killed, cooked and eaten | Central Kalimantan | 1 | 2 years 9 months jail time | 1 | Aditya (2017); Pro Kalteng (2017); Sastriono and Galih (2017) |
| 2018 | Kaluhara | Orangutan shot 130 times | East Kalimantan | 1 | 7 months jail time, 50 million IDR fine or 2 months additional imprisonment | 4 | KSDAE (2018a); Pro Bontang (2018) |
| 2018 | Baen | Orangutan shot 6 times and stabbed 3 times | Central Kalimantan | 1 | Sentencing details unknown | 2 | COP (pers. comm.) |
| *Sumatra* | | | | | | | |
| 2011 | Julius | Orangutan offered for sale | North Sumatra | 1 | 2 years jail time, 10 million IDR fine or 2 months additional imprisonment | 1 | Hadisiswoyo and Gea (2012) |
| 2015 | Citaria | Seized from local trader | Aceh | 1 | 2 years jail time, 10 million IDR fine or 1 month additional imprisonment | 1 | Nijman (2017); SOCP (2018) |
| 2015 | Koko, Kiki, Rambe Aprilia | Seized from local trader | Aceh | 3 | 2 years jail time, 50 million IDR fine or 3 months additional imprisonment | 1 | Nijman (2017) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2015 | Citrawan and Bobina | Two orangutans smuggled to Malaysia by two Indonesian and two Malaysian citizens | Malaysia | 2 | 2 years jail time, 50 million IDR fine | 1 | Hanafiah (2015); Robin des Bois (2016) |
| 2016 | | 4 orangutans seized from local trader, about to be smuggled to Jakarta | North Sumatra | 4 | 1 year 6 months jail | 1 | COP (pers. comm.) |
| 2016 | Sultan, Dara, Raja | Wildlife trade victim received from BKSDA West Java | Riau | 3 | 2.5 years jail time for two perpetrators, 2 years jail time for third perpetrator, 10 million IDR fine or 1 month additional imprisonment each | 3 | Nijman (2017); Rahmat (2015); Tanjung (2015) |
| 2019 | | Drugged 2 year old male confiscated from Russian man in Denpasar | Aceh | 1 | 1 year jail time, 10 million IDR fine or 2 months additional imprisonment | 1 | AFP (2019); KSDAE (2019b) |
| 2019 | Hope and infant | Tapanuli orangutan mother shot and baby forcibly taken away (baby later died) | Aceh | 1 | 6 months of social detention, calling the call to prayer because the perpetrator is a minor | 1 | KSDAE (2019c); Tribun News (2019) |
| 2019 | | Seized from local trader | Riau | 1 | 2.6 years jail time, 50 million IDR fine | 1 | Antara News (2019); Garda Animalia (2019); Harahap (2019); TRAFFIC (2020) |
| *Java* | | | | | | | |
| 2015 | | Seized from local trader | West Java | 1 | 1 year 7 months jail time | 1 | COP (pers. comm.) |
| 2016 | | Seized from local trader | Jakarta | 1 | 1 year 8 months jail | 1 | COP (pers. comm.) |
| Customary law outcomes | | | | | | | |
| 2010 | Paolo | 3-4 month old male fell from a tree when his mother shot by hunters | West Kalimantan | 2 | customary law warning with signed statement that any further incidents will result in formal legal action | 5 | IAR (2010); Kompas (2010) |

**Table 5A9. Annual orangutan-related crimes in protected and unprotected areas.**
Village administrative division (*desa*) or site name location data were available for 63% of all reported incidents (n= 1042 crimes) in Bornean orangutan range, and 65% of all incidents (n= 334 crimes) reported in orangutan range in Sumatra. Each orangutan affected represents one crime. Protected areas include all *desas* encompassed by or overlapping with formal protected area (PA) and conservation activity area (CA) boundaries, which created a buffer zone around each area determined by included *desa* administrative boundaries. Unprotected areas include cities and towns and all other unprotected areas. Percentages are rounded to nearest whole number.

**Kalimantan**

| Province | Year | Total crimes with location data | % crimes (#) in PAs, CAs, and buffer zones | % crimes (#) in unprotected areas |
|---|---|---|---|---|
| | | (n=1049) | (n=221) | (n=821) |
| Central Kalimantan | 2007 | 152 | 22% (34) | 78% (118) |
| | 2008 | 68 | 29% (20) | 71% (48) |
| | 2009 | 42 | 29% (12) | 71% (30) |
| | 2010 | 45 | 22% (10) | 78% (35) |
| | 2011 | 39 | 21% (8) | 79% (31) |
| | 2012 | 46 | 22% (10) | 78% (36) |
| | 2013 | 45 | 16% (7) | 84% (38) |
| | 2014 | 39 | 28% (11) | 72% (28) |
| | 2015 | 52 | 85% (44) | 15% (8) |
| | 2016 | 38 | 39% (15) | 61% (23) |
| | 2017 | 43 | 5% (2) | 95% (41) |
| | 2018 | 13 | 23% (3) | 77% (10) |
| | 2019 | 15 | 40% (6) | 60% (9) |
| East Kalimantan | 2007 | 22 | 14% (3) | 86% (19) |
| | 2008 | 4 | 0 | 100% (4) |
| | 2009 | 10 | 0 | 100% (10) |
| | 2010 | 26 | 0 | 100% (26) |
| | 2011 | 35 | 0 | 100% (35) |
| | 2012 | 19 | 11% (2) | 89% (17) |
| | 2013 | 7 | 29% (2) | 71% (5) |
| | 2014 | 14 | 14% (2) | 86% (12) |
| | 2015 | 8 | 50% (4) | 50% (4) |
| | 2016 | 21 | 43% (9) | 57% (12) |
| | 2017 | 7 | 29% (2) | 71% (5) |
| | 2018 | 15 | 13% (2) | 87% (13) |
| | 2019 | 8 | 37% (3) | 63% (5) |
| West Kalimantan | 2007 | 0 | 0 | 0 |
| | 2008 | 8 | 0 | 100% (8) |
| | 2009 | 8 | 0 | 100% (8) |
| | 2010 | 25 | 16% (4) | 84% (21) |
| | 2011 | 12 | 17% (2) | 83% (10) |
| | 2012 | 12 | 8% (1) | 92% (11) |
| | 2013 | 14 | 0 | 100% (14) |
| | 2014 | 27 | 0 | 100% (27) |
| | 2015 | 20 | 0 | 100% (20) |
| | 2016 | 41 | 10% (4) | 90% (37) |
| | 2017 | 22 | 0 | 100% (22) |
| | 2018 | 10 | 0 | 100% (10) |
| | 2019 | 17 | 18% (3) | 82% (14) |

**Sumatra**

| Province | Year | Total crimes with site location data | % crimes (#) in PAs, CAs, and buffer zones | % crimes (#) in unprotected areas |
|---|---|---|---|---|
| | | (n=334) | (n=87) | (n=247) |
| Aceh | 2007 | 7 | 0 | 100% (7) |
| | 2008 | 20 | 10% (2) | 90% (18) |
| | 2009 | 23 | 17% (4) | 83% (19) |
| | 2010 | 11 | 9% (1) | 91% (10) |
| | 2011 | 35 | 29% (10) | 71% (25) |
| | 2012 | 19 | 11% (2) | 89% (17) |
| | 2013 | 19 | 5% (1) | 95% (18) |
| | 2014 | 18 | 11% (2) | 89% (16) |
| | 2015 | 24 | 25% (6) | 75% (18) |
| | 2016 | 19 | 58% (11) | 42% (8) |
| | 2017 | 16 | 25% (4) | 75% (12) |
| | 2018 | 18 | 50% (9) | 50% (9) |
| | 2019 | 22 | 64% (14) | 36% (8) |
| North Sumatra | 2007 | 4 | 0 | 100% (4) |
| | 2008 | 6 | 17% (1) | 83% (5) |
| | 2009 | 5 | 0 | 100% (5) |
| | 2010 | 7 | 29% (2) | 71% (5) |
| | 2011 | 3 | 67% (2) | 33% (1) |
| | 2012 | 2 | 50% (1) | 50% (1) |
| | 2013 | 11 | 45% (5) | 55% (6) |
| | 2014 | 4 | 0 | 100% (4) |
| | 2015 | 6 | 17% (1) | 83% (5) |
| | 2016 | 16 | 12% (2) | 88% (14) |
| | 2017 | 2 | 0 | 100% (2) |
| | 2018 | 10 | 30% (3) | 70% (7) |
| | 2019 | 7 | 57% (4) | 43% (3) |

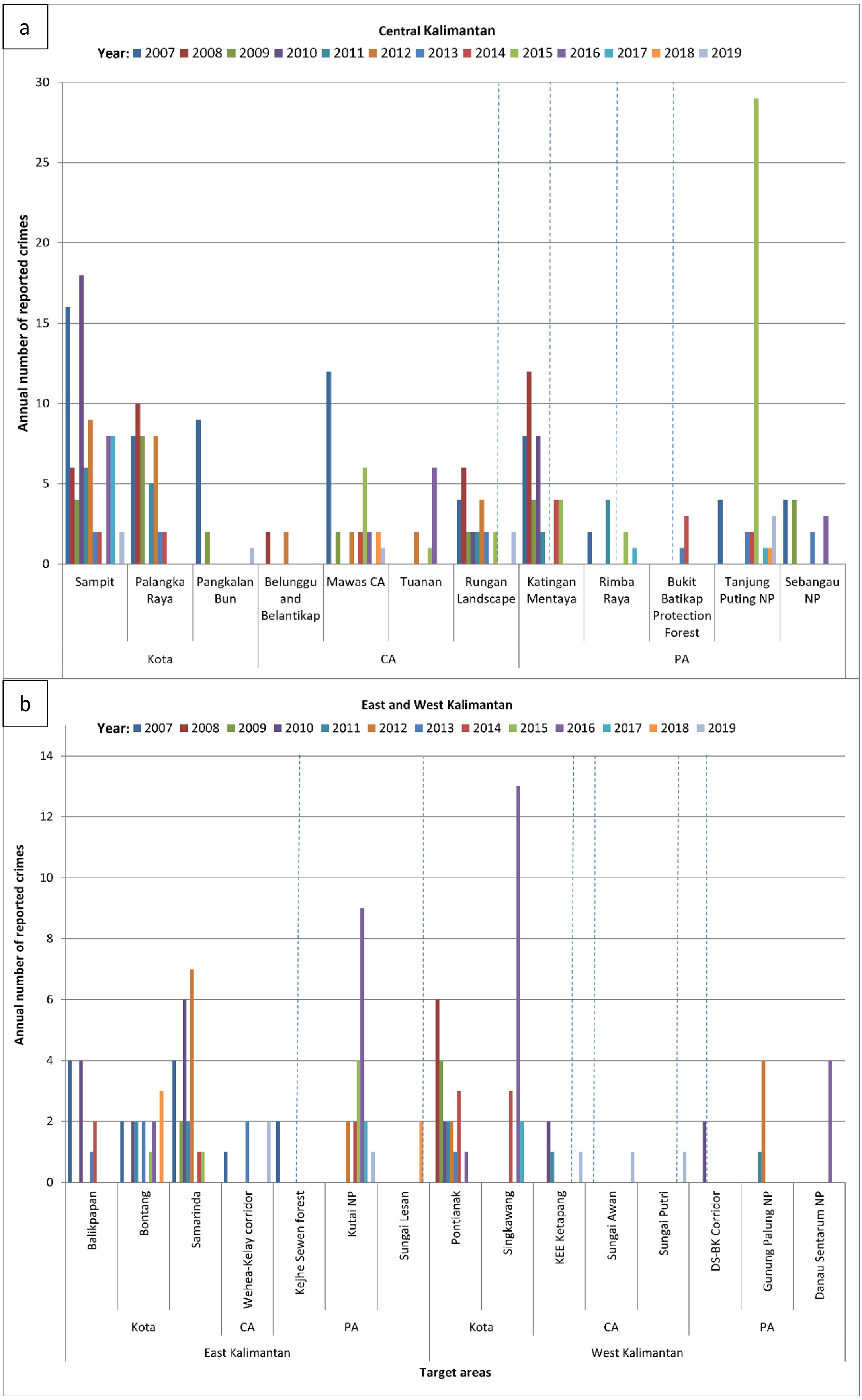


**Figure 5A3. Annual crime in target areas in Kalimantan 2007-2019.** Target areas are listed in Table A5. Target areas not shown had no reported crimes. Crimes were reported in three of four Kalimantan provinces where orangutans are extant: Central (a), East and West Kalimantan (b). No crimes were reported in North

Kalimantan. For each area, every bar represents one year. Absent bars indicate no crime during that year. Dotted vertical lines show the start of protection or activities during the study period. CA are conservation activity areas, and PA are formally protected areas. NP is National Park, DS-BK is Danau Sentarum–Betung Kerihun, KEE is Essential Ecosystem Area.

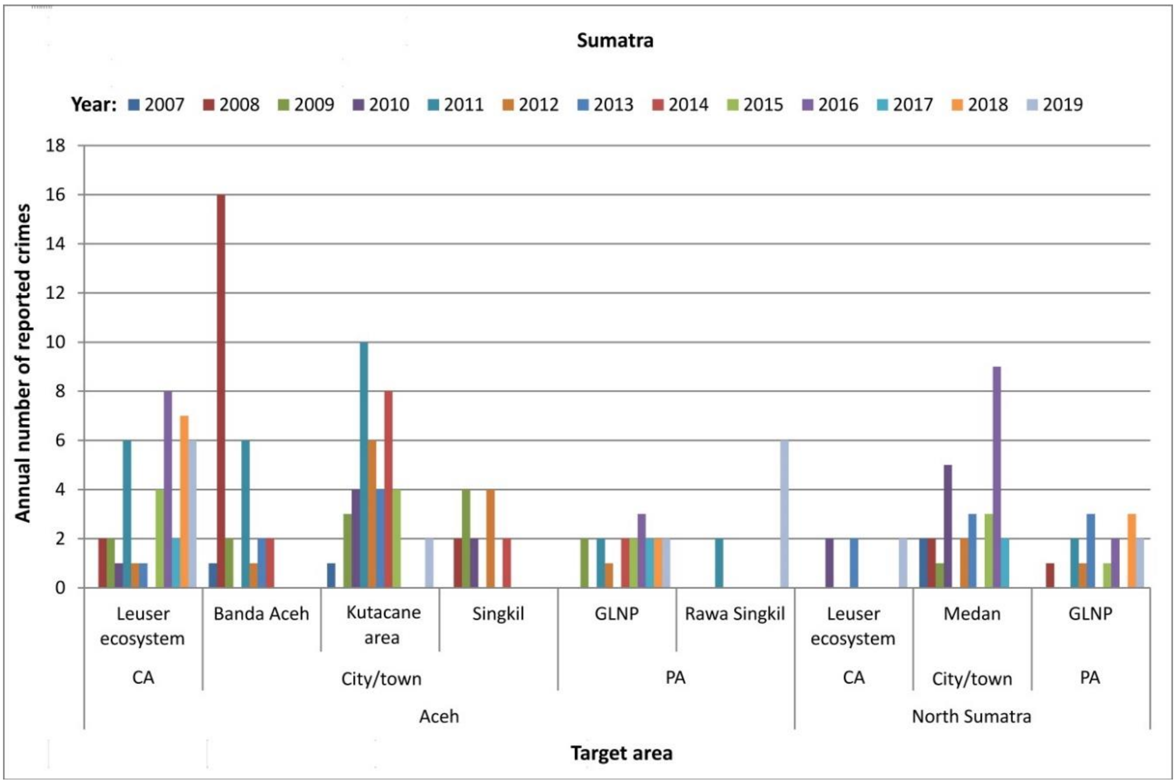


**Figure 5A4. Annual crime in target areas in Sumatra 2007-2019**. Target areas are listed in Table A5. Target areas not shown had no reported crimes. Crimes were reported in Aceh and North Sumatra provinces where orangutans are extant. No crimes were reported in target areas in Riau or Jambi provinces outside *P. abelii* distribution where orangutans have been reintroduced. For each area, every bar represents one year. Absent bars indicate no crime during that year. CA are conservation activity areas, PA are formally protected areas. GLNP is Gunung Leuser National Park. HD is *hutan desa* (community forest). GLNP and the larger, overlapping Leuser Ecosystem area are in both Aceh and North Sumatra provinces. Crimes shown in Leuser Ecosystem were those reported within the ecosystem conservation activity area but outside GLNP.

# Chapter 6. Effectiveness of 20 years of conservation investments in protecting orangutans


Truly Santika[1,54], Julie Sherman[2], Maria Voigt[3], Marc Ancrenaz[4,5], Serge A. Wich[6], Kerrie A. Wilson[7], Hugh Possingham[8], Emily Massingham[8], Dave J.I. Seaman[3], Alison M. Ashbury[9,10,11], Taufiq S. Azvi[12,13], Graham L. Banes[14], Elizabeth J. Barrow[15], David F.R.P. Burslem[16], Robert A. Delgado[17], Andi Erman[18], Gabriella Fredriksson[19], Benoit Goossens[20,21,22], Max Houghton[23], Tito P. Indrawan[24], Ricko L. Jaya[25], Tomoko Kanamori[26], Cheryl D. Knott[15,27,28], Ashley Leiman[29], Darmawan Liswanto[30,31], Martin Mach[32], Andrew J. Marshall[33], Julien G.A. Martin[34], Lelyana Midora[2], Adam Miller[35], Sol Milne[16], Courtney Morgans[3], Nardi Nardiyono[36], Dyah Perwitasari-Farajallah[37,38], Dolly Priatna[39,40], Robert Risch[41], Galuh M. Riyadi[42,43], Anne Russon[44], Juhardi Sembiring[45], Endro Setiawan[46], Mohammad Sidiq[42], Donna Simon[47], Stephanie Spehar[48], Matthew J. Struebig[3], Ibrahim Sumardi[46], Albertus Tjiu[49], Rizki Wahyudi[46,52], Achmad Yanuar[50], Erik Meijaard[3,5,51]

1. Natural Resources Institute (NRI), University of Greenwich, Chatham Maritime ME4 4TB, UK
2. Wildlife Impact, P.O. Box 31062, Portland, OR 97231, USA
3. Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, Marlowe Building, University of Kent, Canterbury, Kent CT2 7NR, UK
4. HUTAN-KOCP, P.O. Box 17793, 88874 Kota Kinabalu, Sabah, Malaysia
5. Borneo Futures, 8th Floor, PGGMB Building, Jalan Kianggeh, Bandar Seri Begawan BS8111, Brunei Darussalam
6. School of Biological and Environmental Sciences, Tom Reilly Building, Byrom Street, Liverpool John Moores University, Liverpool L3 3AF, UK
7. Queensland University of Technology, 2 George Street, Brisbane, QLD 4000, Australia
8. Centre for Biodiversity and Conservation Science, The University of Queensland, Brisbane, QLD 4072, Australia
9. Department of Biology - Fach 618, University of Konstanz, Universitätsstraße 10, 78457 Konstanz, Germany
10. Department for the Ecology of Animal Societies, Max Planck Institute of Animal Behavior, Bücklestraße 4, 78464 Konstanz, Germany
11. Department of Anthropology, Winterthurerstrasse 190, University of Zurich, 8057 Zurich, Switzerland
12. Universitas Nahdlatul Ulama Sumatera Utara, Jl. Gaperta Ujung No.2, Tj. Gusta, Kec. Medan Helvetia, Kota Medan, Sumatera Utara 20125, Indonesia
13. Pesona Tropis Alam Indonesia (PETAI), Komplek Tasbi 2, Jl. Ring Road Blk. V No.21, A M P L A S, Kec. Medan Amplas, Kota Medan, Sumatera Utara 20122, Indonesia
14. Wisconsin National Primate Research Center, University of Wisconsin–Madison, Southwest Commuter Path, Madison, WI 53715, USA
15. Gunung Palung Orangutan Conservation Program, P.O. Box G, 1661 Massachusetts Avenue, Lexington, MA 02420-2020, USA
16. School of Biological Sciences, University of Aberdeen, Tillydrone Avenue, Aberdeen, Aberdeenshire AB24 2TZ, Scotland, UK
17. U.S. National Science Foundation, 2415 Eisenhower Avenue, Alexandria, VA, USA
18. GFA/KWF, Kapuas Hulu Program, Pontianak, West Kalimantan, Indonesia
19. Vocabolo Ca' di Bracco, Via Migianella 381, Loc Molino Vitelli, 06019 Umbertide, PG, Italia
20. Danau Girang Field Centre, c/o Sabah Wildlife Department, Wisma MUIS, Block B 5th Floor, 88100 Kota Kinabalu, Sabah, Malaysia
21. Organisms and Environment Division, Cardiff School of Biosciences, Cardiff University, Sir Martin Evans Building, Museum Avenue, Cardiff CF10 3 AX, UK
22. Sustainable Places Research Institute, Cardiff University, 33 Park Place, Cardiff CF10 3BA, UK
23. Research Centre in Evolutionary Anthropology, and Palaeoecology, School of Natural Sciences and Psychology, Liverpool John Moores University, James Parsons Building, Byrom Street, Liverpool L3 3AF, UK
24. Forum Konservasi Orangutan Kalimantan Barat, Lab 515 Building, 3rd Floor Jl. Salihara No. 41A, Pasar Minggu, Jakarta 12520, Indonesia

25. Orangutan Information Centre, Bunga Sedap Malam XVIII C No. 10, Medan Selayang, Medan, North Sumatra 20131, Indonesia
26. Primate Research Institute, Kyoto University, Inuyama, Aichi 484-8506, Japan
27. Department of Anthropology, Boston University, 232 Bay State Road, Boston, MA 02215, USA
28. Department of Biology, Boston University, 5 Cummington Mall, Room 101, Boston, MA 02215, USA
29. Orangutan Foundation, 7 Kent Terrace, London NW1 4RP, UK
30. Yayasan Titian Lestari, Jl. Komp. Alex Griya Permai I, Bangka Belitung Darat, Kec. Pontianak Tenggara, Kota Pontianak, Kalimantan Barat 78124, Indonesia
31. Yayasan SINTAS, Jl. Merdeka Barat No.665, Mariana, Kec. Pontianak Kota, Kota Pontianak, Kalimantan Barat 78243, Indonesia
32. Bumitama, Jl. Melawai Raya No.10, RT.3/RW.1, Melawai, Kec. Kby. Baru, Kota Jakarta Selatan, Daerah Khusus Ibukota Jakarta 12160, Indonesia
33. University of Michigan, Department of Anthropology, Department of Ecology and Evolutionary Biology, Program in the Environment, School for Environment and Sustainability, Ann Arbor, MI 48109, USA
34. Biology Department, University of Ottawa, Gendron Hall, Room 160, 30 Marie Curie, Ottawa, ON K1N 6N5, Canada
35. Planet Indonesia, Webster Groves, MO 63119, USA
36. Austindo Nusantara Jaya, Menara BTPN, 40 Floor, Jl. Dr. Ide Anak Agung Gde Agung, Kav. 5.5-5.6, Kawasan Mega Kuningan, Jakarta 12950, Indonesia
37. Department of Biology, Gedung Biologi, Jalan Agatis Kampus IPB Dramaga, Bogor 16680, Indonesia
38. Primate Research Center, IPB University, Jl. Lodaya II/5, Bogor 16151, Indonesia
39. Graduate School of Environmental Management, Pakuan University, Jl. Pakuan, RT.02/RW.06, Tegallega, Kecamatan Bogor Tengah, Kota Bogor, Jawa Barat 16129, Indonesia
40. Belantara Foundation, Dimo Space, Jl. Timor No.6, RT.9/RW.4, Gondangdia, Kec. Menteng, Kota Jakarta Pusat, Daerah Khusus Ibukota Jakarta 10350, Indonesia
41. Rhino and Forest Fund, Auf dem Stein 2, 77694 Kehl, Germany
42. Universitas Tanjungpura, Jl. Prof. Dr. H Jl. Profesor Dokter H. Hadari Nawawi, Bansir Laut, Kec. Pontianak Tenggara, Kota Pontianak, Kalimantan Barat 78124, Indonesia
43. Malaysian Environmental Consultants, 82 Jalan Ampang Hilir, 55000 Kuala Lumpur, Malaysia
44. Glendon College of York University, 2275 Bayview Avenue, Toronto, ON M4N 3M6, Canada
45. Universitas Nahdlatul Ulama Sumatera Utara, Jl. Gaperta Ujung No.2, Tj. Gusta, Kec. Medan Helvetia, Kota Medan, Sumatera Utara 20125, Indonesia
46. Gunung Palung National Park Office, Padu Banjar, Kec. Simpang Hilir, Kabupaten Ketapang, Kalimantan Barat 78857, Indonesia
47. WWF-Malaysia, Suite 1-6-W11 6th Floor, CPS Tower, Centre Point Complex No. 1, Lorong Centre Point, Pusat Bandar, 88000 Kota Kinabalu, Sabah, Malaysia
48. Sustainability Institute for Regional Transformations, 4483 Sage Hall, 835 High Avenue, Oshkosh, WI 54901, USA
49. World Wide Fund for Nature-Indonesia (Yayasan WWF Indonesia), WWF Indonesia Gedung Graha Simatupang, Tower 2, Unit C, 7 Floor, Jl. Letjen TB. Simatupang Kav. 38, Jakarta Selatan 12540, Indonesia
50. Graduate School, Department of Biology, Universitas Nasional, Jl. Sawo Manila, Pejaten Ps., South Jakarta 12520, Indonesia
51. Department of Ecology, Faculty of Science, Charles University, Viničná 7, Prague 2, 12844 Prague, Czech Republic
52. In Memoriam

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https://www.cell.com/current-biology/fulltext/S0960-9822(22)00315-3

This chapter was published in March 2022 and modified to fit the thesis requirements.

**Highlights**

• Efficient investment requires knowing what to best spend where, when, and on what

• Our analyses of 20 years of orangutan conservation funding inform optimal spending
• Conservation strategies differ in cost effectiveness of the number of orangutans saved
• Cost effectiveness varies geographically due to threats and costs of land and labor

**Keywords:** biodiversity, conservation finance, evidence-based conservation, great apes, impact assessment, Indonesia, Malaysia, orangutan, Pongo, tropical forest

**Summary**

Conservation strategies are rarely systematically evaluated, which reduces transparency, hinders the cost-effective deployment of resources, and hides what works best in different contexts. Using data on the iconic and critically endangered orangutan (*Pongo* spp.), we developed a novel spatiotemporal framework for evaluating conservation investments. We show that around USD 1 billion was invested between 2000 and 2019 into orangutan conservation by governments, nongovernmental organizations, companies, and communities. Broken down by allocation to different conservation strategies, we find that habitat protection, patrolling, and public outreach had the greatest return on investment for maintaining orangutan populations. Given the variability in threats, land-use opportunity costs, and baseline remunerations in different regions, there were differential benefits per dollar invested across conservation activities and regions. We show that although challenging from a data and analysis perspective, it is possible to understand the relationships between conservation investments and outcomes and the external factors that influence these outcomes. Such analyses can provide improved guidance toward a more effective biodiversity conservation. Insights into the spatiotemporal interplays between the costs and benefits driving effectiveness can inform decisions about the most suitable orangutan conservation strategies for halting population declines. Although our study focuses on the three extant orangutan species of Sumatra and Borneo, our findings have broad application for evidence-based conservation science and practice worldwide.

## 6.1 Introduction

The three orangutan species—*Pongo pygmaeus* in Indonesian and Malaysian Borneo and *P. abelii* and *P. tapanuliensis* in Sumatra, Indonesia—are in rapid decline (Santika et al., 2017a; Utami-Atmoko et al., 2019a; Voigt et al., 2018; Wich et al., 2016), and there is a global concern about the risk of their extinction in the wild (Ancrenaz et al., 2016a; Nowak et al., 2017; Singleton et al., 2017). The main drivers of orangutan decline are the loss and degradation of forest habitat, mostly for agricultural development (Santika et al., 2017a; Utami-Atmoko et al., 2019a; Voigt et al., 2018; Wich et al., 2016), and killing (Abram et al., 2015; Davis et al., 2013). Over the past 50 years, a diversity of activities has been implemented to reduce and mitigate threats to orangutans (Morgans et al., 2019; Rijksen & Meijaard, 1999). Which activities lead to the best outcome, however, is subject to extensive debate (Chua et al., 2020; Wilson et al., 2014). Furthermore, the species are distributed across four regions (Sumatra and Kalimantan [Indonesia] and the Malaysian states of Sabah and Sarawak) (Figure 6.1) with differential exposure to threats, heterogeneous biophysical and socioeconomic characteristics, and diverse government policies. As a result, the extent to which the activities and the concomitant funding are benefitting species persistence is unknown as are the key externalities that shape these benefits (Chua et al., 2020).

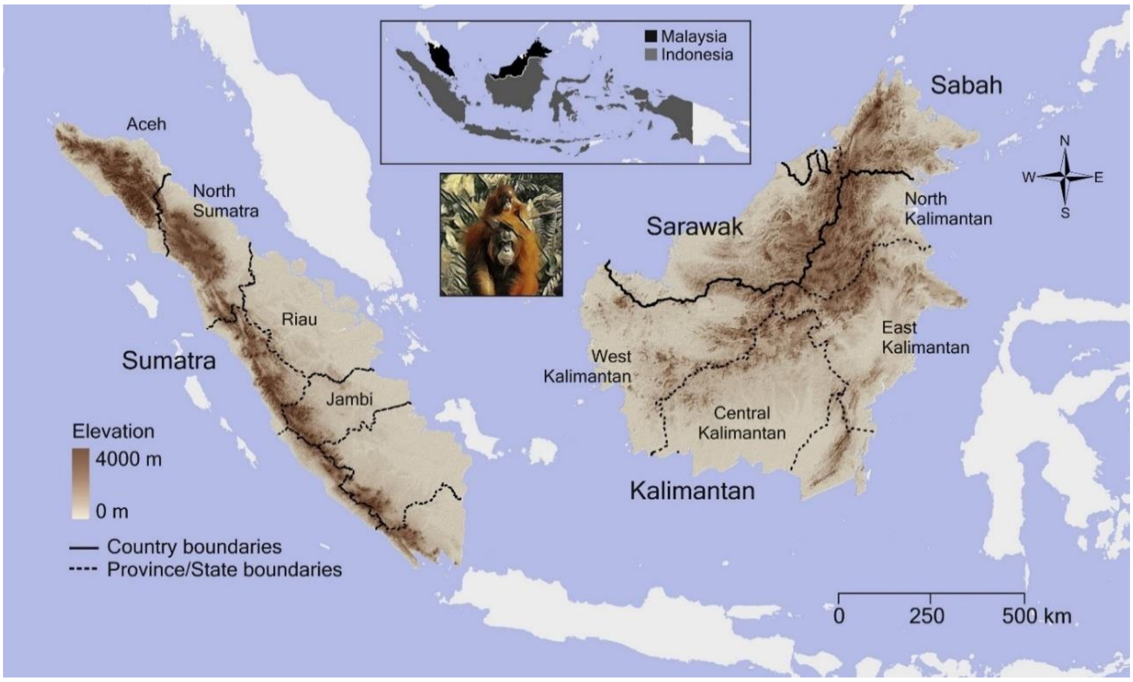


**Figure 6.1. Islands covering the orangutan range**. Sumatra, Indonesia (470,000 km2) and Borneo (including Kalimantan, Indonesia and Sabah and Sarawak, Malaysia) (740,000 km2). See also Figure 6S4.

We developed a comprehensive framework to assess the impact of conservation investments in wildlife conservation across spatial and temporal scales. We applied this framework to investments in orangutan conservation activities across Kalimantan, Sabah, and Sumatra between 2000 and 2019. We collected data on financial investments from private and public organizations involved in orangutan conservation in these regions. The benefit of a given conservation activity was estimated as the improvement in the predicted orangutan occurrence compared with the counterfactual of no activity. By comparing the spatiotemporally explicit investments with the estimated benefit, we evaluated the efficiency of two decades of investments in six activities aiming to reduce orangutan population declines: (1) habitat protection and management, (2) habitat restoration, (3) patrolling and law enforcement, (4) rescue and rehabilitation, (5) translocation and reintroduction, and (6) public outreach and capacity building. The orangutan conservation theory of change (ToC) pathways representing the chain of outcomes resulting from the conservation activities are shown in Figures 6S1 and 6S2. The estimated investment in research on orangutans and their habitats (excepting those exclusive to orangutan rehabilitation and translocation) was also quantified (Figure 6S3). Through application of our framework to orangutan conservation, we were able to answer the following: (1) Which conservation activities have been conducted, at what costs, and how were they distributed spatially? (2) What was the net benefit of each conservation activity? (3) Within the contemporary range of wild orangutan, which activities yielded the greatest return on investment, and how did this vary between regions?

## 6.2 Results

### Investment in conservation activities for orangutans

In the period between 2000 and 2019, the total nominal investment on orangutan-related conservation activities across Kalimantan, Sumatra, and Sabah was US$870 million. In real value, i.e., the nominal value adjusted for inflation (Methods, section 6.6), this equates to US$1.16 billion. The annual average of the nominal investment in the period 2015–2019 was US$67 million, which was a nearly 3-fold increase compared with the annual average of US$26 million from 2000 to 2005 (Figure 6.2A). The real value of investment had increased 1.3 times (Figure 6.2A) and varied by region. Between 2000 and 2019, an average annual operating expenditure valued at $24–26 million had been allocated in both Kalimantan and Sabah, whereas in Sumatra, there was an average annual expenditure of $8 million (Figures 6.2B and 6.3). Considering regional differences in the available habitat, Sabah had the greatest per unit habitat investment overall, with an average annual operational expenditure of $676 per km$^2$ of orangutan habitat (Figure 6.2C). Comparatively, Sumatra invested $272 per km$^2$ annually, whereas Kalimantan only invested $85 per km$^2$ annually on average.

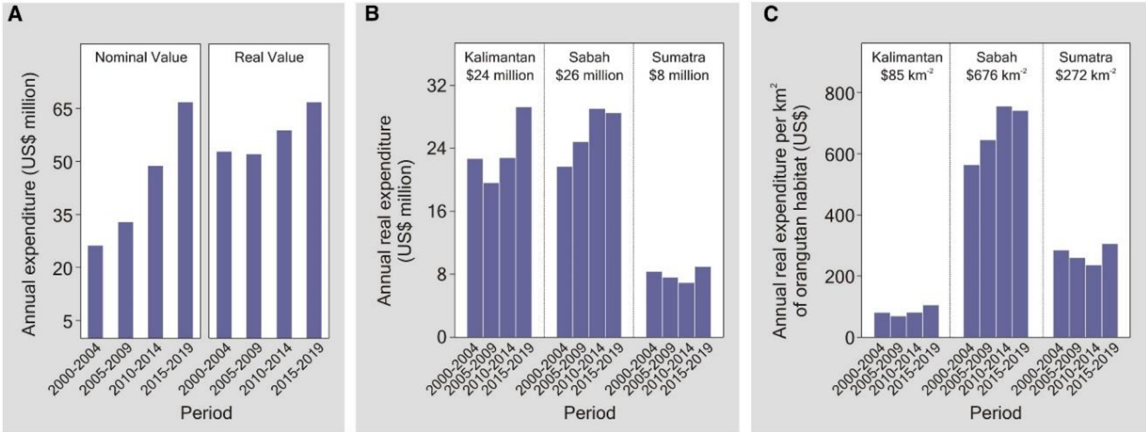


**Figure 6.2. Changes in nominal and real investments into orangutan conservation over time and by region.** (A) Total investment (nominal and real value, in US$) spent annually on orangutan-related conservation activities across Kalimantan, Sabah and Sumatra. (B) The annual total real expenditure of conservation activities, and (C) per km2 of orangutan habitat, broken down by region. Conservation activities assessed include the six core activities in which the impacts on orangutan survival may be captured over a short time period (five years): habitat protection, habitat restoration, patrolling and law enforcement, rescue and rehabilitation, translocation and reintroduction, and public outreach and capacity building, and research-related activities considered influencing conservation and land use management decision in the long term.

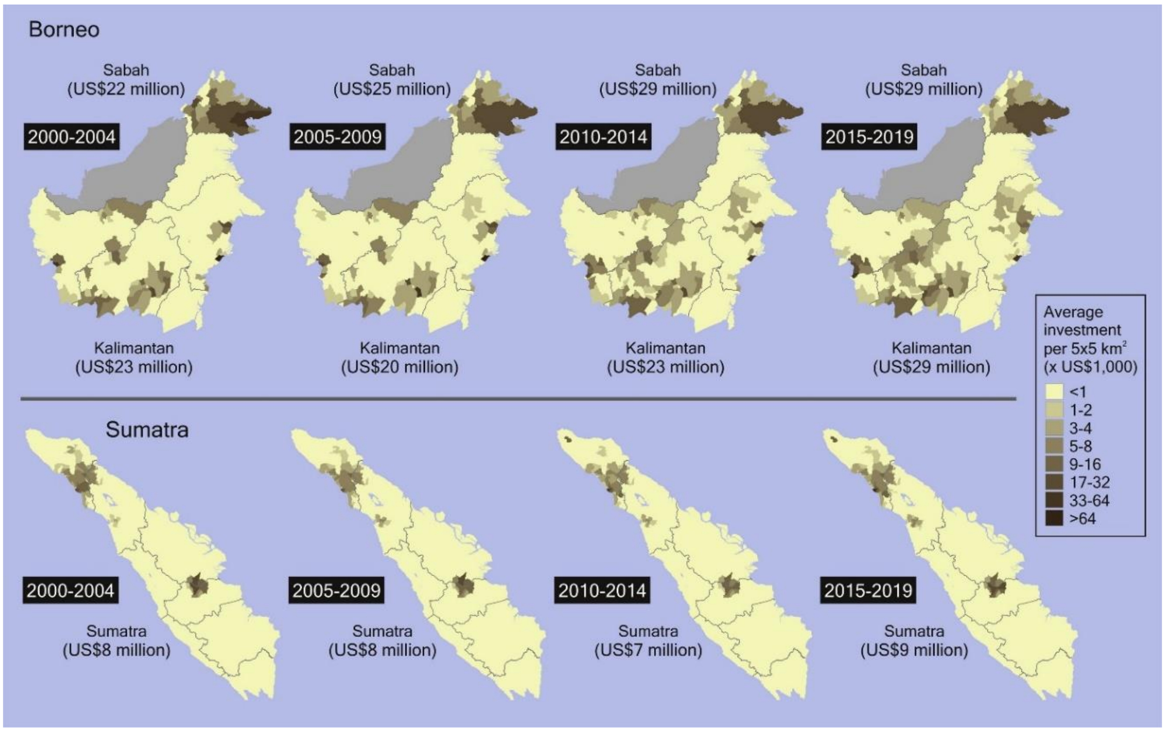


**Figure 6.3. The change in the distribution of investment to orangutan conservation in Borneo and Sumatra, aggregated to sub-district level**. Values inside the parenthesis represent the annual total real expenditure for a given period and region. In the first period (2000-2004), investments in Borneo were focused in Sabah and spread across the orangutan range in West, Central and East Kalimantan. Investments in later periods gradually became clustered more around orangutan sanctuaries near the Gunung Palung, Tanjung Puting, Sebangau, and Kutai National Parks and the interior part of Borneo. In Sumatra, the main increase in investment was in the Jantho Nature Reserve at the northern part of the island and Batang Toru. Relates to Figure 6S5.

The allocation of investments to different conservation activities differed between regions (Figure 6.4A). In Kalimantan, the largest proportion of the total annual investment was assigned to habitat protection (31%), followed by rescue and rehabilitation (18%) and public outreach (16%). In Sabah, patrolling and law enforcement made up the largest proportion of the total annual expenditure (38%), followed by habitat protection (20%) and outreach programs (15%). In Sumatra, a substantial proportion of the total annual investment was allocated to habitat protection (47%), followed by patrolling (20%) and public outreach (14%).

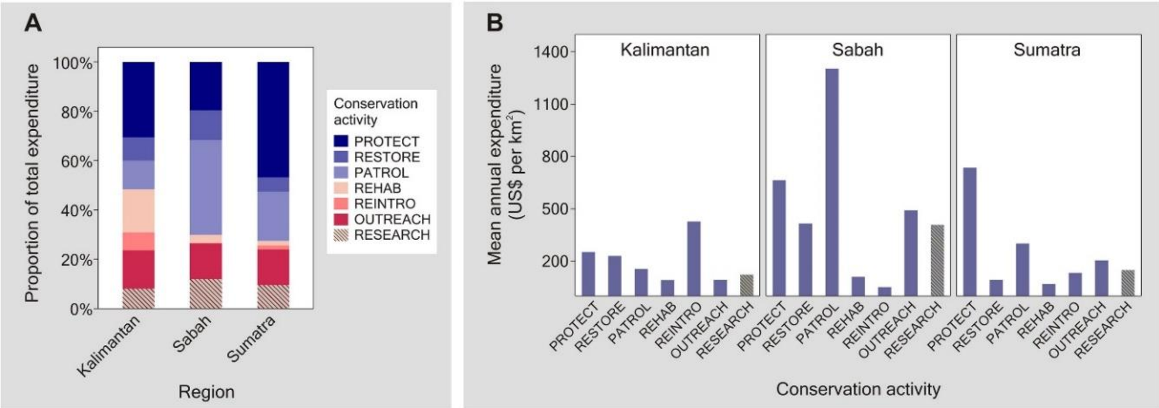


**Figure 6.4. Expenditure allocation to different strategies.** (A) Proportion of total expenditure allocated to different conservation activities, and (B) mean annual real expenditure for different activities (US$ per km2) broken down by region. The costs of conservation activities assessed include the six core activities considered affecting the orangutan survival in the short term (five years): habitat acquisition and protection (PROTECT), habitat restoration (RESTORE), patrolling and law enforcement (PATROL), rescue and rehabilitation (REHAB), translocation and reintroduction (REINTRO), and public outreach and capacity building (OUTREACH), and research-related activities considered influencing orangutan persistence in the long term (RESEARCH). See also Figure 6S5.

In Kalimantan, orangutan translocation and reintroduction programs were the most expensive activity (\$427 per km$^2$), whereas habitat protection was \$252 per km$^2$ (Figure 6.4B). In Sabah, patrolling was the most expensive activity (\$1,303 per km$^2$), double that of habitat protection. In Sumatra, habitat protection was the most expensive approach (\$734 per km$^2$), double that of patrolling activities. Sabah had the greatest investment in research (\$407 per km$^2$ per annum) compared with less than \$150 per km$^2$ per annum in Kalimantan and Sumatra.

### Benefits of conservation activities for orangutans

Between 2000–2004 and 2015–2019, the mean probability of orangutan occurrence across the wild orangutan contemporary range in Kalimantan, Sumatra, and Sabah declined by approximately 20%. Based on our analysis of the relationship between the species' probability of occurrence and density (Figure 6S4), this translates to an estimated decline from 17.4 to 13.8 (95% confidence interval [CI]: from 15.1–19.7 to 11.4–16.2) individuals per 5 × 5 km$^2$ grid cell on average between 2000 and 2019 for Kalimantan, from 13.9 to

11.4 (95% CI: from 10.6–17.2 to 7.6–15.2) individuals per grid cell for Sabah, and from 10.3 to 8.7 (95% CI: from 7.9–12.7 to 6.3–11.1) individuals per grid cell for Sumatra (Figure 6S4).

The benefit of a conservation activity was estimated by comparing the orangutan occurrence probability (given existing conservation actions) with the counterfactual in the absence of conservation activity. Across the three regions, habitat protection and patrolling were estimated to generate the greatest benefits in maintaining orangutan occurrence (Figure 6.5A). In Kalimantan, habitat protection and patrolling were associated with an average 13% and 3.6% improvements, respectively, in the species' occurrence probability per 5 × 5 km$^2$ grid cell every 5 years between 2000 and 2019 compared with the counterfactual of no investment in these activities (Figure 6.5B). In Sabah, habitat protection and patrolling were estimated to improve orangutan occurrence by 8.7% and 12%, respectively, whereas in Sumatra, they contributed to 16% and 12% improvements in occurrence, respectively (Figure 6.5B). Besides these two conservation activities, public outreach activities generated a large benefit for the orangutan populations in Sabah, providing 7.4% improvement in the occurrence probability compared with the counterfactual of no outreach programs (Figure 6.5B).

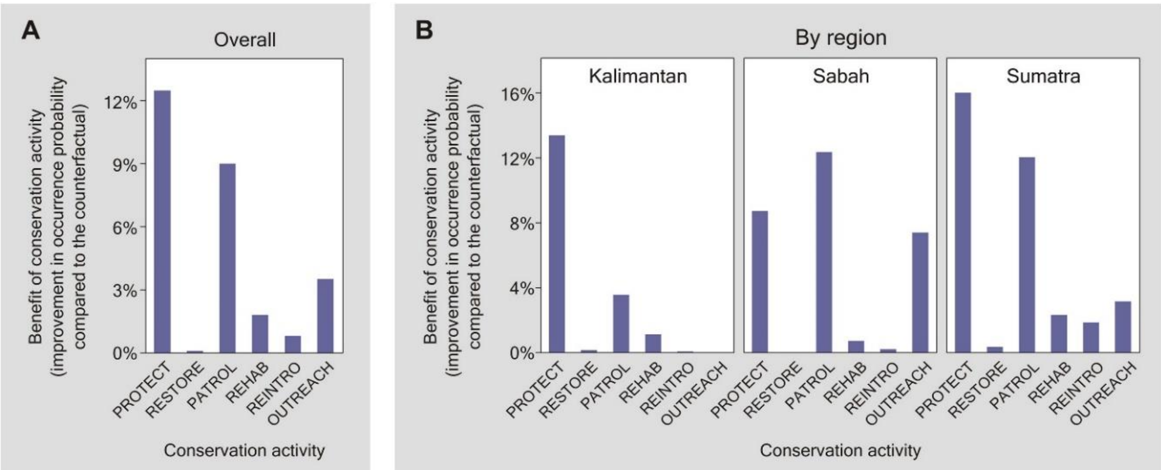


**Figure 6.5. The benefit of six orangutan conservation activity within the wild orangutan contemporary range**. (A) estimated by comparing the orangutan probability of occurrence (given existing conservation actions) with the counterfactual in the absence of conservation activity, (a) averaged across the three regions, and (B) individually by region. Conservation activities evaluated include the six core activities: habitat protection (PROTECT), habitat restoration (RESTORE), patrolling and law enforcement (PATROL), rescue and rehabilitation (REHAB), translocation and reintroduction (REINTRO), and public outreach and capacity building (OUTREACH). Research-related activities (RESEARCH) was excluded from the benefit analysis as it is considered to primarily influence conservation actions and land use management decisions in the long term. See also Figure 6S4.

### Return on investment of orangutan conservation activities

The return on investment for a given orangutan conservation activity was estimated as the improvement in the species' occurrence probability compared with the counterfactual in the absence of the activity divided by the investment cost for that activity. Across Kalimantan, Sabah, and Sumatra and within the orangutan's contemporary range, habitat protection was estimated to generate the highest return on investment overall, providing an average 12% improvement in orangutan probability of occurrence per 5 × 5 km$^2$ grid cell per annual investment of US$10,000 compared with the counterfactual (Figure 6.6A). Patrolling activities had moderate benefit per dollar, providing a 9.2% improvement in the orangutan occurrence probability.

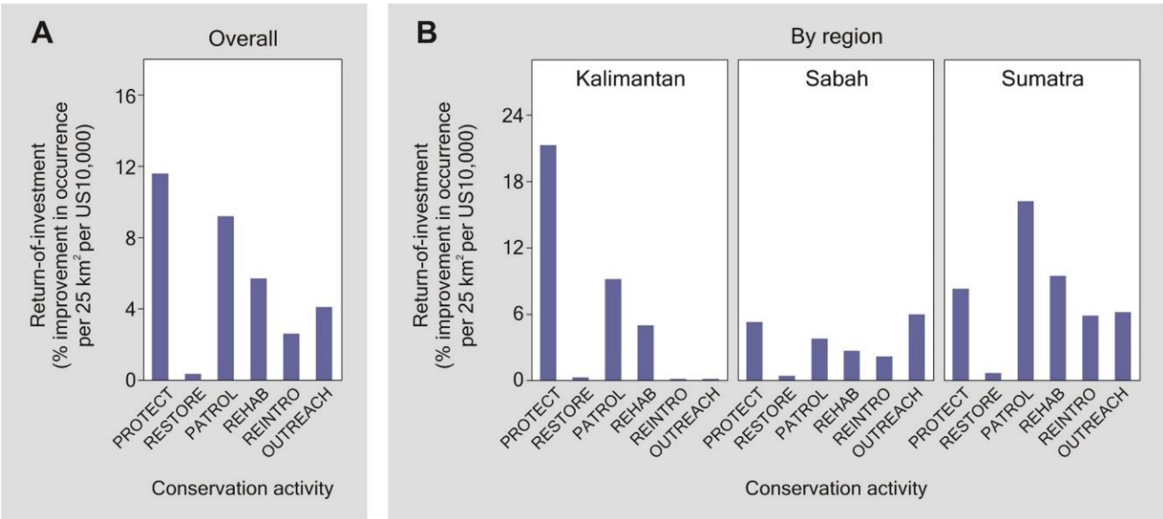


**Figure 6.6. Return-on-investment of six orangutan related conservation activities.** Defined as the percentage improvement in orangutan probability of occurrence per 5x5 km2 per US$10,000 investment. (A) overall across the three regions, and (B) broken down by region. Conservation activities assessed include the six core activities: habitat protection (PROTECT), habitat restoration (RESTORE), patrolling and law enforcement (PATROL), rescue and rehabilitation (REHAB), translocation and reintroduction (REINTRO), and awareness raising, capacity building and policy (OUTREACH). Research-related activities (RESARCH) was excluded from the return-on-investment analysis as it is considered as primarily influencing conservation actions and land use management decisions in the long term.

There were variations in the return on investment of conservation activities across the different regions (Figure 6.6B). In Kalimantan, habitat protection had the highest benefit per dollar (providing an average improvement of 21% in the orangutans' probability of occurrence per 5 × 5 km$^2$ grid cell per US$10,000 annual investment compared with the counterfactual), followed by patrolling (9.4%). This translates to an estimated density benefit of 7.4 orangutans per 25 km$^2$ for every annual expenditure of US$10,000 for habitat protection and a density benefit of 3.2 orangutans for patrolling activities. In Sabah, outreach programs had the highest benefit per dollar invested (average improvement of 6.1% in occurrence probability per 5 × 5 km$^2$ grid cell per US$10,000 annual investment compared with the counterfactual), followed by habitat protection (5.3%). This translates to a density benefit of 2.2 orangutans per 25 $km^2$ for every annual expenditure of US$10,000 for each activity of outreach and habitat protection. In Sumatra, patrolling had the highest benefit per dollar (average improvement of 16% in occurrence probability per 5 × 5 $km^2$ grid cell per US$10,000 annual investment relative to the counterfactual). This translates to a density benefit of 2.3 orangutans per 25 $km^2$ for every annual expenditure of US$10,000.

## 6.3 Discussion

### Implications for orangutan conservation policies in different regions

*Kalimantan*

In Kalimantan, habitat protection produced the best outcome in reducing the decline in the orangutan probability of occurrence (Figure 6.5B). Large-scale forest loss and the expansion of industrial agriculture, especially in unprotected lands (in non-state-forest zones and forest areas designated for land clearing and conversion to agroindustries) occurred at rapid rates, especially between 2005 and 2015 (Gaveau et al., 2016b). These lowland areas typically co-occur with orangutan populations, and without forest protection, extensive areas of orangutan habitats and subsequently large populations of orangutans would have been lost. The average investment per $km^2$ for habitat protection in Kalimantan was generally lower than that in Sumatra and Sabah ($252 per $km^2$ versus $734 and $664 per $km^2$ for Sumatra and Sabah, respectively) (Figure 6.4B), reflecting Kalimantan's earlier stage of development compared with the other two regions (Santika et al., 2021). Consequently, habitat protection by government, companies, or rural communities was considered to provide an excellent return on investment in reducing the decline in orangutan occurrence (Figure 6.6B).

Annual spending on translocation and reintroduction in Kalimantan had increased 4-fold since 2000 (from $0.7 million in 2000 to $2.8 million in 2019) (Figure 6S5), and this reflects the growing application of this conservation tool in response to increasing land pressure. Rapid large-scale deforestation over the past 20 years has led to escalated negative interactions between humans and wild orangutans (Abram et al., 2015; Santika et al., 2017a; Voigt et al., 2018). Rescue and translocation of orangutans to conservation areas or protected forests have provided readily implementable actions to remove animals from immediate danger arising from such negative interactions. Removing orangutans and translocating them to large forest blocks deemed more suitable for their survival may seem straightforward and is often presented as an efficient conservation tool, particularly when alternative conservation activities may require planning and extensive negotiation with multisectoral and multilevel stakeholders (Ancrenaz et al., 2021b). However, the relative success of this conservation approach is still not known and might be relatively low, and there is a potential negative impact of these exercises on the viability of metapopulations (Ancrenaz et al., 2021b). Furthermore, translocation and reintroduction can be costly and are associated with high mortality rates (Sherman et al., 2020a). In Kalimantan, translocations were the most expensive conservation activities in terms of operational cost per $km^2$, and the cost greatly exceeds those in other regions (\$427 per $km^2$ versus \$41 and \$121 per $km^2$ for Sabah and Sumatra) (Figure 6.4B).

The number of orangutans residing outside of protected areas is substantial in Kalimantan (Santika et al., 2017a; Voigt et al., 2018). Hence, continuing land clearing in this region is anticipated to lead to frequent negative interactions between orangutans and people, and potentially higher prevalence of orangutan removal. An ongoing and increasing focus on translocation and reintroduction programs in Kalimantan could potentially undermine the allocation of funding to other activities with substantially higher and lasting benefits such as habitat protection, patrolling, and outreach programs. There is a need to seek solutions that would enable orangutans and people to coexist, such as better land use planning through creation of buffer zones separating orangutan habitats and rural settlements and improved partnership between conservation actors and rural communities in building relationships of reciprocity, acknowledgment, and care (Chua et al., 2021).

The expenditure cost per square kilometer for habitat protection in Kalimantan was generally lower than that in other regions (Figure 6.4B), suggesting that it is relatively inexpensive to effectively reduce orangutan decline rates through this action. Habitat protection is therefore a worthy investment to pursue to allow orangutans to remain in their native habitats in this region. Further, given that the current conservation expenditure per square kilometer of orangutan habitat in Kalimantan is substantially lower than that in other regions (Figure 6.2C), increasing the amount of investment for habitat protection here could potentially reduce the orangutan decline rates significantly.

The costs associated with patrolling activities in Kalimantan were \$155 per $km^2$ and significantly lower than that in other regions (\$1,303 and \$302 per $km^2$ for Sabah and Sumatra, respectively), whereas outreach programs were \$93 per $km^2$ and also lower than that in other regions (\$491 and \$204 per $km^2$ for Sabah and Sumatra) (Figure 6.4B). This is likely because human population density, remuneration rates, and market influence in Kalimantan are generally lower compared with other regions (Santika et al., 2021). Larger investments can therefore potentially be allocated to these activities to monitor, prevent negative human-wildlife interactions, and assist rural communities living within close proximity to forests inhabited by orangutans (Chua et al., 2020). Local communities are also likely to benefit from maintaining forest cover, as forests can support and sustain the flow of ecosystem services and provide benefits to broader community well-being (e.g., by preventing soil erosion and floods and regulating air quality) (Merten et al., 2021; Santika et al., 2017b; Yuliani et al., 2018).

*Sabah*

In Sabah, patrolling produced the best outcome in reducing the decline in orangutan occurrence probability, followed by habitat protection (Figure 6.5B). During the study period, the Sabah government increased the size of protected areas from 12% to nearly 30% of the state land area (Bryan et al., 2013; Sabah Wildlife Department, 2020), and by 2020, more than 70% of orangutans in Sabah were found inside protected areas (Ancrenaz et al., 2021b; Sabah Wildlife Department, 2020). This is quite different from the situation in Indonesia where most terrestrial protected areas were established before 2005 (currently covering 23% of the total land area for Kalimantan and Sumatra) and the expansion of forest protection since 2005 was mainly through the establishment of community-based land tenure and acquisition of private land by conservation non-government organizations (NGOs). Consequently, a high level of investment specifically from the Sabah government has been allocated to resource-intensive patrolling activities for these protected areas, but lower investment had been allocated to habitat protection since all these new areas were gazetted by the government without incurring any high significant direct cost or land purchase for their creation. Significantly higher baseline remuneration rates in Malaysia compared with Indonesia (Tran, 2013; Woo & Hong, 2010) have also likely contributed to the high cost associated with patrolling activities.

Public outreach programs, community engagement, and capacity building also provided benefits to protecting orangutan populations in Sabah (Figure 6.5B), and these programs were mainly carried out by various state agencies and their NGO partners. Despite higher operational cost per square kilometer for public outreach in Sabah than in Kalimantan and Sumatra (\$491 per $km^2$ versus \$93 and \$204 per $km^2$ for Kalimantan and Sumatra)

(Figure 6.4B), the activity provided the best return on investment in terms of orangutan occurrence benefits (Figure 6.6B). Unlike in Kalimantan and Sumatra, there has been a limited change in land cover in Sabah over the past 20 years as deforestation had mostly occurred before 2000 (Gaveau et al., 2016b). Consequently, only a low number of orangutan individuals were displaced and required rehabilitation or translocation between 2000 and 2019, and this explains why the expenditures for rehabilitation and reintroduction programs were small (Figure 6.4).

*Sumatra*

In Sumatra, habitat protection produced the best outcome in reducing the decline in the orangutan's probability of occurrence, followed by patrolling activities (Figure 6.5B). However, the cost of habitat protection was expensive compared with the cost of other activities in the region and compared with habitat protection in other orangutan regions in Indonesia (\$735 versus \$252 per $km^2$ for Kalimantan) (Figure 6.4B). This is likely attributed to the higher opportunity cost of land for conversion to agriculture and the cost associated with establishing and managing land in this relatively developed region (Santika et al., 2021). During the study period, several land acquisitions and their protection occurred across the orangutan range in Sumatra (e.g., within the Leuser Ecosystem). Such initiatives, consequently, incurred significant direct costs on land purchase and management establishment. Despite providing the highest benefit on orangutan occurrence (Figure 6.5B), due to the high land-related cost (Figure 6.4B), the protection strategy was considered less efficient in terms of monetary value (Figure 6.6B). On the other hand, the costs of patrolling were moderate (\$302 per $km^2$), which is higher than that in Kalimantan (\$155 per $km^2$) but substantially lower than that in Sabah (\$1,303 per $km^2$) (Figure 6.4B). This could be partly due to the lower baseline remuneration rates in Indonesia compared with Malaysia despite baseline prices of goods in both countries being relatively similar (Tran, 2013; Woo & Hong, 2010). Due to the moderate costs for patrolling, this activity provided the best return on investment in terms of orangutan occurrence benefit in Sumatra (Figure 6.6B).

Rescue and rehabilitation activities provided only a small benefit for maintaining the probability of occurrence of orangutans in their range (i.e., they provide limited deterrence to poaching and trafficking), and this is similar to the presence of reintroduction sites and outreach activities in the island (Figure 6.5B). Similar to the situation in Sabah, the investment in rehabilitation activities in Sumatra was minor (Figure 6.4); hence, the return on investment for probability of occurrence has limited applicability.

## 6.4 Caveats and limitations

There are four key limitations in our analysis. The first pertains to the accuracy of our investment dataset. Although we attempted to comprehensively collect information on all investment, it is likely that we missed a few. Additionally, in some instances, detailed information on the amount of investment for different activities for a particular organization was not available. To overcome this issue, we estimated activity expenditure amounts based on the activities described in the organization's reports or website and the costs of those activities undertaken by similar-sized organizations operating in the same region for which we had specific data. The second limitation is associated with the modeling approach and the implications on the estimation of conservation benefits. We assumed that the effect of a conservation activity on the orangutan presence can be adequately captured in the model mainly through variable distance to the location of that conservation program as a proxy (Methods, section 6.6). As such, in a grid cell where multiple activities are operating simultaneously with different levels of importance (e.g., patrolling is carried out with higher efforts than public outreach programs), the model assumes equal importance of all actions. As research programs usually co-occur simultaneously with other conservation activities, the impact of research is difficult to estimate accurately through our modeling approach. This was the reason why we excluded research from the cost-benefit analysis. The third limitation relates to the methodology for constructing the counterfactual scenarios. We applied the most sensible, relevant, and practical approach for defining the counterfactuals. In reality, these counterfactual scenarios are much more complicated and influenced by multiple biophysical and socioeconomic factors (Ferraro, 2009). The fourth limitation pertains to province-level differences in threats and government policies in Indonesia. Our cost-benefit analyses were aggregated to provide general and broad island-based inference to inform national policies. Province-level analysis would likely generate more nuanced outcomes from the modeling output to guide local policy at the subisland level. We have tried to adequately address these limitations wherever possible and are convinced that despite these caveats, the results of the analysis appropriately reflect the situation on the ground.

## 6.5 Conclusions and recommendations

Judicious planning for conservation under a constrained budget requires an understanding of the dynamics of conservation investments and activities and how they relate to species trends across their spatial range. Such an analysis is however rarely conducted, as it requires comprehensive spatiotemporally explicit data on the species, the natural environment and threats, conservation activities, investments in these activities, and an estimation of the counterfactual situation without the investment. Using orangutans as a case study, our analysis estimated that habitat protection, patrolling, and public outreach provided large benefits in slowing down the decline in orangutan numbers. However, given variability in threats and development circumstances and stages in different regions where orangutans occur, the most cost-effective conservation activity was different across regions. Our findings highlight the importance of accounting for regional differences in land pressure and socioeconomic elements to guide the focus of investment in different areas and contexts to achieve the desired conservation goals.

We recommend the application of our findings in planning for future funding and policy strategies for orangutan conservation to ensure optimal use of limited resources and application of the analytical framework to the conservation of other wildlife. It would be highly beneficial for orangutans and other species if data on their distribution and densities and detailed information on conservation programs, (i.e., where are they conducted and when, what kind of activities are specifically involved, and how frequently these activities are conducted) could be transparently and centrally coordinated, made publicly available, and regularly updated by participating organizations working in species conservation. Such transparency on spending could help facilitate open discussions about improving the existing strategies.

## 6.6 Methods

### Experimental model and subject details

We collected data on orangutan conservation investments across Borneo and Sumatra for the period 2000–2019, based on the most recent yearly budget allocations available, comprising a total of 259 investments. We identified initial lists of organizations that were carrying out orangutan conservation activities. An organization was considered to be conducting orangutan conservation activities if it met two criteria:

1) the goals or conservation activity descriptions specifically mentioned orangutans, or in the case of habitat conservation activities orangutans were specifically mentioned in relation to the affected habitat; and

2) the orangutan-related conservation activities were conducted on the ground in the orangutan range regions (Borneo and Sumatra) regardless of where the organization was headquartered.

For every investment, we recorded the entity or organization managing the conservation activity, the sector of the entity (e.g., government agency, non-government organization (NGO), and rescue centres), the location where the activity had taken place, the allocation of funds spent on each category of conservation activities during the latest available financial year (see below), the years between 2000 and 2019 when the activities were undertaken, and the investment amount.

Other data used are detailed in the key resources table.

**Method details**

Our study framework consists of four steps of analyses: (1) collating data on conservation investments; (2) modelling the change in the distribution of the species under study; (3) estimating the benefit of conservation activities on that species through changes in the species occurrence; and (4) estimating the return-on-investment.

Our study area covers the orangutan range in the island of Sumatra, Indonesia (470,000 km$^2$) and Borneo (including Kalimantan, Indonesia and Sabah, Malaysia) (740,000 km$^2$) (Figure 6.1). We excluded the Malaysian state of Sarawak, as we have insufficient data on orangutan surveys and conservation investment in this region. The orangutan range in Sarawak is small compared to the overall orangutan range and leaving out Sarawak should not affect our overall findings. For the spatial unit of analysis, we used a grid-cell with a resolution of 5×5 km$^2$. This resolution corresponds to the average home range of adult male orangutans, which overlaps with the home range of several females (Singleton & van Schaik, 2001). As the temporal unit of analysis, we used four time periods: 2000-2004, 2005-2009, 2010-2014, and 2015-2019.

*Collecting data on conservation investments*

We collected investment data through direct communications with identified organizations, and via desktop research and review of publicly available data on each organization’s expenditure reports (i.e., grant and project databases, corporate sustainability reports, annual reports, budgets and financial reports, tax filings of donors and implementing organizations and charity commission reports, and organization websites) (see Tables 6S1 and 6S2 for the source of information on investment and the list of organizations or entities). To avoid double counting investments from both donors and implementers, we only used data on investments made by organizations implementing orangutan conservation activities on the ground in orangutan habitat.

Where an organization's investment amounts by activity were not specified (i.e., data were only available on the overall amounts), we looked for data from any project grants related to orangutan conservation the organization received where amounts spent on specific activities were detailed. Where no detailed data were available for a given organization, we estimated activity expenditures amounts based on the activities described in the organization's reports or website, and the costs of those activities undertaken by similar-sized organizations operating in the same region for which we did have specific data. We tested these estimations for accuracy by requesting selected organizations to check our figures for their budgets. For government-funded habitat protection activities, we also included community-based forest management, especially the *Hutan Desa* (Village Forest) scheme in Indonesia. We only included *Hutan Desa* areas where the boundaries overlap with the orangutan range. We used an estimated cost of US$50 per ha for establishing *Hutan Desa* (Suhirman et al., 2012). For oil palm concessions certified under the Roundtable on Sustainable Palm Oil and timber concessions certified under the Forest Stewardship Council where no sustainability investment was specified, we estimated that US$10 per ha (RSPO) or US$1 per ha (FSC) was spent on High Conservation Value areas. These averages were based on data from several companies for which we had more detailed information on investment per unit area. The expenditure data we collected from various organization reports and databases were mostly in US$ (US Dollar). The amounts of spending in a given year originally provided in national currencies (Indonesian Rupiah and Malaysian Ringgit) were converted to US$ using the currency conversion rate applicable to that year.

We categorized organizations into six sectors: (1) government, including agencies, national parks, and government-funded community-based forest management; (2) bilateral or multilateral bodies; (3) non-governmental organizations (NGOs); (4) rescue centres, including sanctuaries for care of orphaned or seized wildlife, (5) commercial corporations including industrial agriculture, timber and pulp, logging, and mining; and (6) research centres and universities. For commercial corporations, oil palm plantation companies certified by the Roundtable for Sustainable Palm Oil (RSPO) that spent funds to maintain High Conservation Value lands which were known to have orangutans (based on the overlap with the species' ranges) were included even if the company reports did not specifically mention orangutan conservation. We did the same for timber plantations and logging companies certified by the Forestry Stewardship Council (FSC). This is because both RSPO and FSC require the conservation values (including orangutans) in the concession to be maintained, and independent audits are carried out to verify this (FSC, 2000; RSPO, 2018). We assumed that uncertified plantations, logging, or mining concessions did not invest in orangutan conservation unless our review of orangutan investment information identified them specifically as doing so. For research, funding for local studies of orangutans by researchers (local and foreign) was counted if: (1) the research was part of the work of an in-situ research centre focused on orangutans or including orangutan studies, and the studies met our criteria for relevance to orangutan conservation; or (2) the research project came up in search results for orangutan conservation investments and met both our criteria. Investments in orangutan habitat range by government agencies with direct management authority for orangutans or any orangutan habitat areas were included regardless of orangutan mentions.

For missing annual data on investment, we estimated the amount of spending by fitting an Ordinary Least Square (OLS) regression model to the available data covering different years. For an entity with limited investment data, we estimated the overall investment envelope based on the trends captured for similar-sized organizations. For NGOs and rescue centres, we identified a consistent pattern of a 2-3% increase in annual expenditure for orangutan conservation between 2000 and 2019 across Indonesia and Malaysia. Similarly, we identified a 4-5% increase in government's annual expenditure for orangutan conservation over the same period in Malaysia and wildlife conservation activities in general for Indonesia. For that reason, we applied 2.5% and 4.5% annual increases for missing NGO data and missing government data, respectively.

*Allocating investment data to activities*

Expenditure data by individual activities were not consistently available from all orangutan conservation entities, hence we grouped similar activity types into the six broad categories described below. For each investment unit, we first recorded the entity, entity sector, the location where the entity was operating, and funds spent during the latest available financial year on six categories of conservation activities based on the Conservation Measures Partnership Action Classifications (Conservation Measures Partnership, 2016). Six categories of activities related to orangutan conservation were identified across the three regions. The classification of activities were informed by the Conservation Measures Partnership (Conservation Measures Partnership, 2016) and include: (1) habitat protection and acquisition (PROTECT); (2) habitat restoration (RESTORE); (3) patrolling and law enforcement (PATROL); (4) rescue and rehabilitation (REHAB); (5) translocation and reintroduction (REINTRO); and (6) public outreach and awareness raising, capacity building and policy (OUTREACH) (Figures 6S1 and 6S2). Besides these six core activities, we also estimated investment in research activities that may influence conservation and land use management decisions (RESEARCH) (Figure 6S3). Details about the activity categories are as follows:

1) Habitat protection and acquisition (PROTECT), includes management and maintenance of the land, such as firefighting, invasive plant or animal control, fencing or other infrastructure related to protection, avoided deforestation payments or costs, habitat purchase, community land reserves or forestry including payment to communities to establish protection;

2) Habitat restoration (RESTORE), includes replanting, growing nursery stock, maintenance of restored forest by watering, and other activities needed to establish and maintain restored habitat;

3) Patrolling and law enforcement (PATROL), includes rangers and wardens and their associated expenses, infrastructure like guard posts and patrol equipment, and investigation, prosecution, and incarceration costs;

4) Rescue and rehabilitation (REHAB), includes activities related to intake, captive care and rehabilitation of orangutans;

5) Orangutan reintroduction and translocation (REINTRO), includes orangutan releases, post-release monitoring and research to identify release sites or release outcomes. Orangutan releases include: (a) the release of rehabilitated ex-captive orangutans to reinforce existing wild populations; (b) reintroduction of populations within historic range but outside the current distribution; and (c) wild-to-wild translocation of orangutans captured because they were considered an immediate or potential threat to humans and

human activities, or where the orangutans are themselves threatened by humans and human activities; and

6) Public outreach, awareness raising, capacity building and policy (OUTREACH), includes community outreach, training and capacity building for environmentally friendly livelihoods and human-orangutan conflict mitigation, policy development or advocacy on orangutan conservation related issues.

An additional expenditure category of administrative and overhead costs (costs for operation of the entity rather than the implementation of activities) was excluded from our model. Although the cost of operating the organizations, businesses and agencies is vital to the ability to deliver the orangutan conservation activities, and represents millions more dollars spent annually, these expenditures did not meet our criteria for conservation activities implemented within orangutan range.

*Orangutan conservation Theory of Change (ToC) pathways*

The Theory of Change (ToC) pathways for each orangutan conservation activity (Figures 6S1–6S3) represent the chain of outcomes resulting from the conservation activities within the short term (five years after the activity is initiated) and long term (more than five years after initiation) that can lead to reduced threats and positive impacts on species population trends. We considered the short term, five-year time interval in the ToC to conform to the data analysis and modelling approach we used. Under this ToC framework, it is assumed that PROTECT actions establish land regulation, management and enforcement to prevent habitat degradation and poaching. RESTORE actions facilitate forest regrowth, either through active restoration (e.g., reforestation and hydrological rehabilitation) or passive restoration (natural regeneration). The presence of PATROL activities helps reduce wildlife and forest crimes, and law enforcement actions can further establish this deterrence. REHAB includes the transfer of animals seized by authorities, a preliminary step in a legal process that, when it culminates in sanctions, can deter crime. Additionally, REHAB actions provide opportunities for releasable animals to become part of a successful release program. REINTRO actions facilitate orangutans released into natural habitats where they can improve the viability of existing wild populations or establish new viable populations. REINTRO actions can also pose real disease, genetic and behavioural risks to wild orangutan populations, and thus have the potential to have both positive and negative impacts on the species. OUTREACH actions assist communities in mitigating human-orangutan conflicts and supporting behavioural changes to facilitate coexistence between orangutan and people and support conservation of orangutans and their habitats.

Unlike these six core conservation activities whereby the benefits on orangutan survival are likely to be realized over the short term (within five years period), RESEARCH activities may take longer time to benefit orangutans. Most research consists of several stages of activities (e.g., field survey and data collection, data analysis, and consultation with different stakeholders) that may take several years to produce findings to inform or provide recommendations for conservation actions and policies. These policy recommendations subsequently may take several more years to be implemented and therefore begin to benefit the species. Nonetheless, research sites whereby researcher presence is maintained over the long term are recognized to have a deterrent effect on poaching and forest crimes (Junker et al., 2019).

*Orangutan survey data*

We used an existing database of orangutan survey data from 2000 to 2015 (Ancrenaz et al., 2010; Ancrenaz et al., 2021b; Meijaard et al., 2011b; Santika et al., 2017a; Utami-Atmoko et al., 2019b; Voigt et al., 2018; Wich et al., 2016) and new survey data from 2015 to 2019, from both Borneo and Sumatra. These data consisted of: (a) orangutan nest encounters obtained from transects surveys, both on the ground and from aerial surveys (occupied aircraft and drones); (b) orangutan or nest encounters obtained from reconnaissance or opportunistic surveys; and (c) sightings of orangutans reported by village residents through interviews. To reduce potential false detection of orangutans in the interview data, we selected only villages where more than 30% of respondents reported orangutan sightings as an indicator of orangutan presence. For each time period, any 5×5 $km^2$ grid-cell with orangutan sightings or nest encounters was assigned "presence", whereas grid-cells with one survey or more without any sightings of orangutans or nests was assigned "absence". Absence records in a grid-cell for a given time period can therefore represent real absence (the species never occurred in that grid-cell) or loss (the species used to be present in that grid-cell, but not anymore). Grid-cells without any survey were excluded in the model building.

**Quantification and statistical analysis**

*Inflation-adjusted value of investment*

The investment data represent the nominal value of investment. To obtain the real value of investment to facilitate intra-country comparison and discern the actual purchasing power of organizations in implementing activities on the ground across different regions, we adjusted the nominal value with inflation rates (Lakner et al., 2018b). Inflation rates have changed dramatically in Indonesia and Malaysia between 2000 and 2019 (https://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG). The consumer price indices (CPI) in both countries are similar and therefore were not employed in the adjustment. The real value of investment in time period 2000-2004 ($t$=1), 2005-2009 ($t$=2), and 2010-2014 ($t$=3) can be expressed in reference to the present period 2015-2019 ($t$=4), i.e.

$$\hat{C}_t = C_t \times (r_1 + 1)^{5\times b1} \times (r_2 + 1)^{5\times b2} \times (r_3 + 1)^{5\times b3}$$

with $(b1, b2, b3) = (1, 1, 1)$ if $t$=1,

$(b1, b2, b3) = (0, 1, 1)$ if $t$=2, or

$(b1, b2, b3) = (0, 0, 1)$ if $t$=3.

where $\hat{C}t$ is the real value of investment at time period $t$ relative to the present period; $C_t$ is the nominal value of investment at time period $t$; and $r_1$, $r_2$ and $r_3$ is the average inflation rates for time period $t$=1, $t$=2, and $t$=3, respectively.

We aggregated the yearly investment data into four time periods to conform to the baseline time interval used in the orangutan occurrence change analysis: 2000-2004, 2005-2009, 2010-2014, and 2015-2019. We also calculated the estimated investment in each 5×5 km$^2$ grid-cell for each of the six activities plus investments into orangutan-related research.

*Modeling the change in species distributions*

We used the Generalized Boosted Regression Modelling (GBM) approach (Ridgeway, 2007) to fit the orangutan presence-absence data for each of the four time periods for each orangutan region (i.e. Kalimantan, Sabah, and Sumatra) using 15 environmental predictors (Table 6S3). These regional divisions were chosen to account for the broad threat and socioeconomic patterns and government policies at the national and island levels. The environmental predictors included static variables over the timeframe of interest, such as elevation, long-term mean monthly rainfall during the dry and wet months, distance to nearest city, and percentage of peatland, and dynamic variables (with changing spatial configurations over the different time periods $t$), including forest cover ($FORST_t$), percentage of degraded peatland (<30% forest cover) ($DEGPT_t$), distance to nearest industrial oil palm plantation, and distance to conservation activities that are considered to be delivering benefits to orangutans. These conservation activities included forest protection through the establishment of protected areas (including national parks, nature reserves, watershed protection forest, and community-based forest management) ($PRTCA_t$), patrolling activities ($PTROL_t$), rehabilitation centres ($RHCTR_t$), orangutan translocation and reintroduction sites ($RINTR_t$), and orangutan-related public outreach and awareness raising ($COMRC_t$). To control for spatiotemporal effects of survey protocols on orangutan presence reports, we included survey effort (i.e., the number of surveys on orangutans conducted in each grid-cell) and distance to orangutan research centres or activities as predictor variables. All predictor variables were weakly correlated.

For each regional-based GBM model, we estimated the model parameters (Figure 6S6) and the change in the probability of occurrence of orangutans through the four time periods in each region. The baseline probabilities of occurrence differed between regions. To standardize the change in occurrence across the different regions, and to provide a practical representation of the population change through time to inform policy, we translated the probability of occurrence data to density estimates. This was done by assessing the correlation between the predicted orangutan probability of occurrence (generated from the GBM) and the density rates calculated directly from the orangutan transect dataset over grid-cells where transect surveys were conducted (Figure 6S4).

*Estimating the benefit of conservation activities and the return-on-investment*

The counterfactual scenario, reflecting the absence of conservation activity between 2000 and 2019, was calculated by estimating how each activity modifies the predictor variables in the GBM models. The association between the outcome potentially generated from each activity and the predictor variables was informed by the orangutan conservation Theory of Change (ToC) pathways (supplemental information; Figures 6S1 and 6S2). The habitat protection strategy (PROTECT) is assumed to affect forest loss and ecosystem protection more broadly (Santika et al., 2017b). Our analysis suggested that areas assigned to protected areas were able to halve deforestation rates (compared to the rates within 50 km of the protected area boundaries) in Borneo and reduce deforestation rates by a quarter in Sumatra (Figure 6S7A), and this is likely because pressure to convert forest to other land uses was stronger in Sumatra than in Borneo overall (Austin et al., 2019; Santika et al., 2021). Hence, the counterfactual scenario in the absence of PROTECT assumes that:
(a) the counterfactual forest loss rates inside protected areas were roughly 2 or 4 times the

actual rates for Borneo and Sumatra respectively (i.e. $FORST_{1,counterfactual} = FORST_0 - (r \times FLOSS_1)$, and $FORST_{t,counterfactual} = FORST_{t-1,counterfactual} - (r \times FLOSS_t)$ for $t>1$, where $r=2$ for Borneo and $r=4$ for Sumatra), (b) the counterfactual percentage of degraded peatland (<30% forest cover) inside protected areas ($DEGPT_{t,counterfactual}$) is higher than the actual ($DEGPT_t$); and (c) the counterfactual distance to forest protection was the actual distance multiplied by 100 (i.e. $PRTCA_{t,counterfactual} = PRTCA_t \times 100$), thus forest protection having negligible effect.

The habitat restoration strategy (RESTORE) is assumed to affect forest gain. Our analysis suggested that areas assigned to habitat restoration in Borneo and Sumatra were able to increase forest cover at twice the rate outside habitat restoration areas (Figure 6S7B). Hence, the counterfactual scenario in the absence of RESTORE assumes that the counterfactual forest gain inside restoration areas was half the actual forest gain (i.e. $FORST_{1,counterfactual} = FORST_0 + (0.5 \times FGAIN_1)$, and $FORST_{t,counterfactual} = FORST_{t-1,counterfactual} + (0.5 \times FGAIN_t)$ for $t>1$).

For conservation activities such as patrolling and law enforcement (PATROL), rescue and rehabilitation (REHAB), translocation and reintroduction (REINTRO), and outreach and advocacy (OUTREACH), the counterfactual scenario in the absence of the activity assumes that the counterfactual distance to the activity was the actual distance multiplied by 100 (i.e. $PTROL_{t,counterfactual} = PTROL_t \times 100$ for PATROL, $RHCTR_{t,counterfactual} = RHCTR_t \times 100$ for REHAB, $RINTR_{t,counterfactual} = RINTR_t \times 100$ for REINTRO, and $COMRC_{t,counterfactual} = COMRC_t \times 100$ for OUTREACH). Our analysis suggested that deforestation rates in areas with PATROL, REINTRO, or OUTREACH activities were similar to the rates in areas without such activities. Therefore, we assumed that the counterfactual forest cover is the same as the actual.

The benefit of each conservation activity in each 5×5 $km^2$ grid-cell was estimated as the percent improvement in the orangutan probability of occurrence compared to the counterfactual scenario. Specifically for the translocation and reintroduction strategy (REINTRO), we further multiplied the benefit by 50%. This is considering that post-release mortality rates of individual released orangutans can range widely between 20% and 80% (Russon, 2009; Sherman et al., 2020a; YEL, 2018), thus the median value of 50% was chosen. In calculating the benefit, we focussed only on activities that had occurred within the contemporary ranges of wild orangutans, therefore excluded reintroduction sites outside the orangutan range such as the Jantho Nature Reserve and Bukit Tigapuluh National Park in Sumatra.

Return-on-investment from orangutan conservation activity in each 5×5 $km^2$ grid-cell was estimated as the benefit of conservation activity in improving orangutan probability of occurrence compared to the counterfactual scenario divided by the cost of activity in that grid-cell. The conservation activities with the largest return-on-investment will deliver the largest improvements in orangutan occurrence per dollar.

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We thank the United States Fish and Wildlife Service, Orangutan Foundation of UK, Natural Sciences and Engineering Research Council of Canada (NSERC), Nacey Maggioncalda Foundation, Leakey Foundation, University of Wisconsin – Oshkosh, Disney Conservation Fund, Direktorat Perguruan Tinggi Republik Indonesia, the Sabah Biodiversity Council for research approval (ref: JKM/MBS.1000-2/2 JLD.6 (79)), the Department of Aviation Malaysia (ref: UMS/IBTP7.2/800), Yayasan Sabah Sdn. Bhd, Charles Garcia and Ronnie Bibi, the Sabah Forestry Department, UNDP-GEF for funding, Darwin Initiative for the Survival of Species (grant no. 09/016, DEFRA, UK), Nacey Maggioncalda Foundation, and University of Wisconsin – Oshkosh.

# Chapter 6 Supplementary Information

## 6.6.1 Key resources table

| REAGENT or RESOURCE | SOURCE | IDENTIFIER |
|---|---|---|
| **Deposited data** | | |
| Orangutan conservation investment data | This paper, Tables 6S1 and 6S2 | http://apesportal.eva.mpg.de/ |
| Orangutan nest surveys 2015-2019 | This paper | http://apesportal.eva.mpg.de/ |
| Orangutan or nest encounters and reconnaissance surveys 2015-2019 | This paper | http://apesportal.eva.mpg.de/ |
| Sightings of orangutans reported by village residents through interviews 2015-2019 | This paper | http://apesportal.eva.mpg.de/ |
| Orangutan survey data from 2000 to 2015 | Wich et al. (Wich et al., 2016) Voigt et al. (Voigt et al., 2018) and Santika et al. (Santika et al., 2017a) | http://apesportal.eva.mpg.de/ |
| Elevation (m a.s.l) *ELEV* | SRTM 90m Digital Elevation Database v4 (Ridgeway, 2007; Santika et al., 2021) | https://cgiarcsi.community/data/srtm-90m-digital-elevation-database-v4-1/ |
| Rainfall during the dry season (mm) *SDRY* | WorldClim2 (Austin et al., 2019) | https://www.worldclim.org/data/bioclim.html; BIO17 |
| Rainfall during the wet season (mm) *SWET* | WorldClim2 (Austin et al., 2019) | https://www.worldclim.org/data/bioclim.html; BIO16 |
| Distance to nearest city (km) *CITY* | Provincial map from the Geospatial Information Agency Indonesia (Russon, 2009) and GeoNames Gazetteer (Yayasan Ekosistem Lestari, 2018) | http://www.geonames.org/; https://tanahair.indonesia.go.id/portal-web |
| Percentage of peatland area *PEAT* | Peat hydrological area map (MEF) | http://pkgppkl.menlhk.go.id/v0/en/kesatuan-hidrologis-gambut-nasional-skala-1250-000/ |
| Percent forest cover *FOREST* | Global Forest Change dataset (Hansen et al., 2013) Indonesia's primary and secondary forest map (Margono et al., 2014) and Intact Forest Landscapes data (Potapov et al., 2017a) | https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.7.html; https://glad.umd.edu/dataset/primary-forest-cover-loss-indonesia-2000-2012 |
| Percentage of degraded peatland *DEGPT* | Peat hydrological area map (MEF) Global Forest Change dataset (Hansen et al., 2013) Indonesia's primary and secondary forest map (Margono et al., 2014) and Intact Forest Landscapes data (Potapov et al., 2017a) | https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.7.html; https://glad.umd.edu/dataset/primary-forest-cover-loss-indonesia-2000-2012; http://pkgppkl.menlhk.go.id/v0/en/kesatuan-hidrologis-gambut-nasional-skala-1250-000/ |
| Distance to oil palm plantations (km) *OPDST* | Oil palm plantation distribution map (Gaveau, 2019; Morgans et al., 2018; Santika et al., 2019c; Santika et al., 2021) | https://nusantara-atlas.org/ |

| **REAGENT or RESOURCE** | **SOURCE** | **IDENTIFIER** |
|---|---|---|
| Survey effort *SURV* | Orangutan survey datasets across Indonesia and Malaysia (Ancrenaz et al., 2021b; Conservation Measures Partnership, 2016; RSPO, 2018; Santika et al., 2017a; Wich et al., 2016) | See row 5, this table |
| Distance to research centres/activities (km) *RSCHR* | This paper | See Table 6S1 |
| Distance to protected areas (km) *PRTCA* | Forest Zone Maps (Ministry of Environment and Forestry of Indonesia (MEF); Santika et al., 2017a), Community Forestry areas (Ministry of Environment and Forestry of Indonesia (MEF)), and this paper | http://webgis.dephut.go.id:8080/kemenhut/index.php/id/peta/petapiaps and Table S1 |
| Distance to patrolling activities (km) *PTROL* | This paper | See Table 6S1 |
| Distance to rehabilitation centres (km) *RHCTR* | This paper | See Table 6S1 |
| Distance to reintroduction sites (km) *RINTR* | This paper | See Table 6S1 |
| Distance to public outreach programs (km) *COMRC* | This paper | See Table 6S1 |
| **Experimental models: Organisms/strains** | | |
| Bornean orangutan (*Pongo pygmaeus*) | N/A | N/A |
| Sumatran orangutan (*Pongo abelii*) | N/A | N/A |
| Tapanuli orangutan (*Pongo tapanuliensis*) | N/A | N/A |
| **Software and algorithms** | | |
| R software | N/A | https://www.r-project.org/ |
| R code | N/A | https://doi.org/10.5281/zenodo.6080322 |
| Arc-GIS | N/A | https://www.arcgis.com/index.html |
| **Other** | | |
| Computation of inflation adjusted investment | This paper | See method details |
| Computation of counterfactuals | This paper | See method details |
| Computation of cost effectiveness | This paper | See method details |

## Chapter 6 Supplementary figures

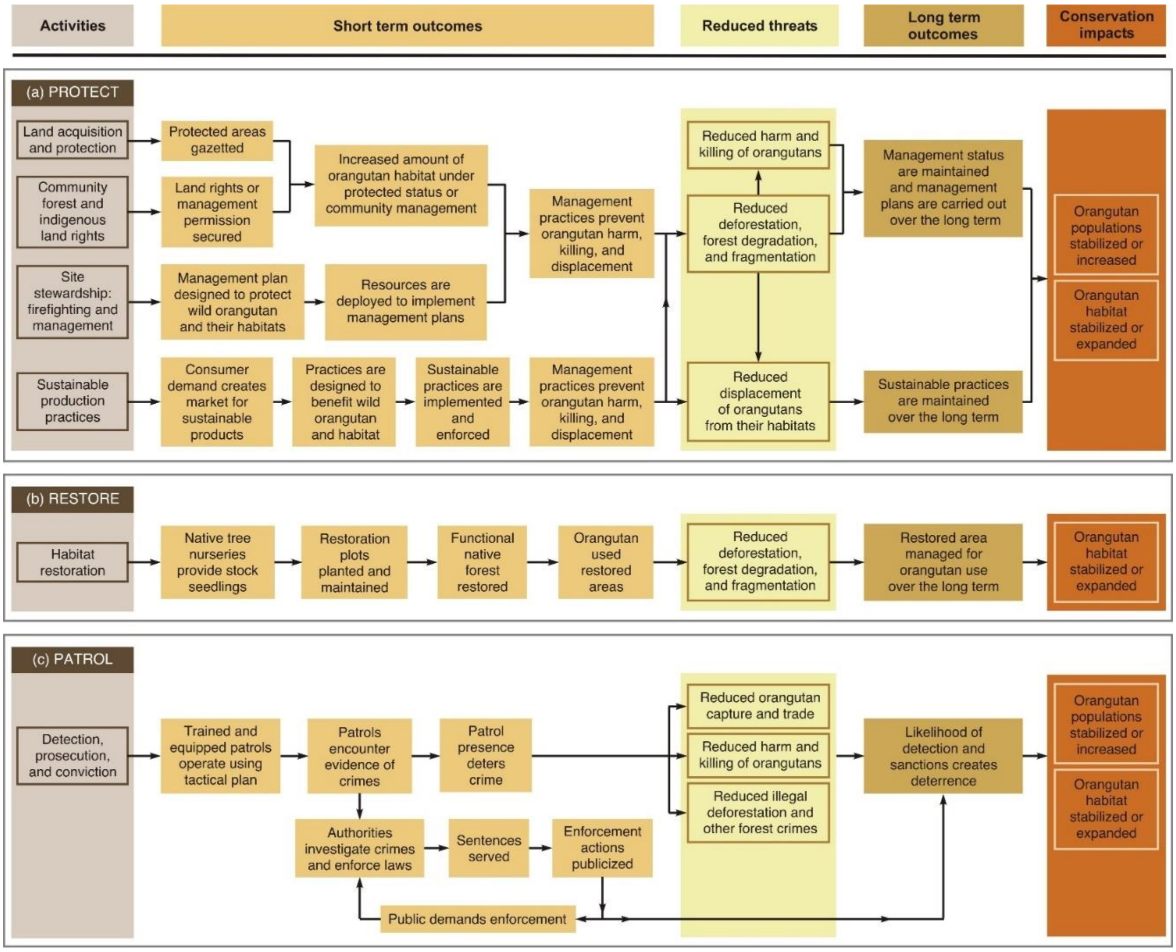


**Figure 6S1. Orangutan conservation Theory of Change (ToC) pathways for protection, restoration and patrolling**. **Related to STAR Methods.** (a) PROTECT, (b) RESTORE and (c) PATROL. The pathways represent the sequential outcomes possible from the conservation activity over the short term (within five years after the action is initiated) and long term (more than five years), and how these outcomes can lead to reduced threats and positive impacts for the species. Our study focuses on the short-term implications of the orangutan conservation activities (in grey background). Explanations of the ToC pathways are provided in the Data.

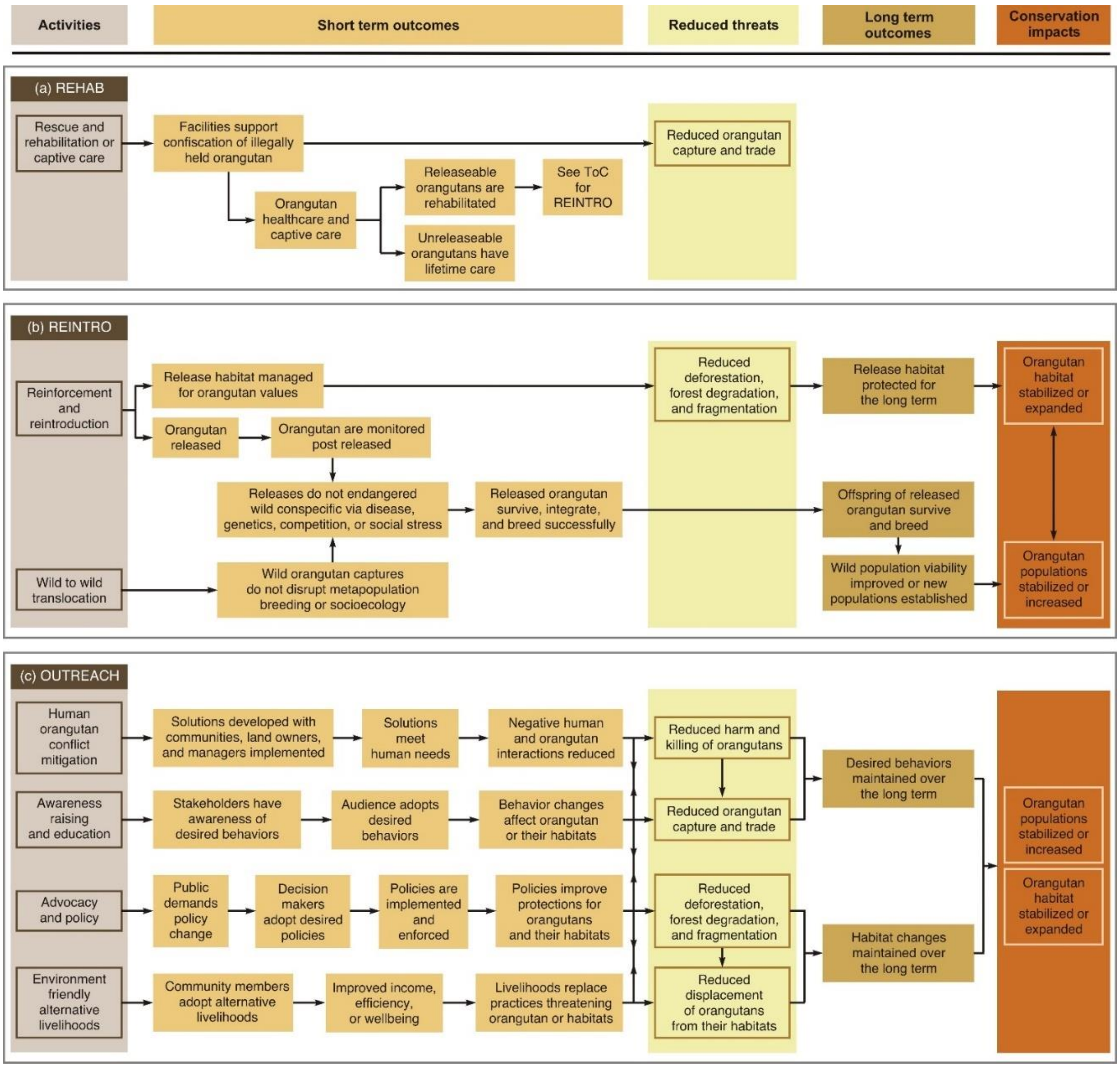


**Figure 6S2. Orangutan conservation Theory of Change (ToC) pathways for rehabilitation, reintroduction and outreach. Related to STAR Methods.** (a) REHAB, (b) REINTRO and (c) OUTREACH. The pathways represent the sequential outcomes possible from the conservation activity over the short term (within five years after the action is initiated) and long term (more than five years), and how these outcomes can lead to reduced threats and positive impacts for the species. Our study focuses on the short-term implication of the orangutan conservation activities (in grey background). Explanations of the ToC pathways are provided in the Data.

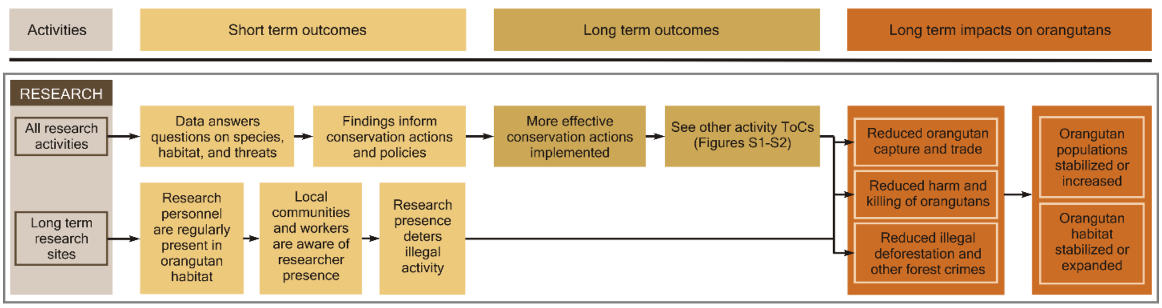


**Figure 6S3. Theory of Change (ToC) pathways for orangutan related RESEARCH activity. Related to STAR Methods.** This represents the chain of outcomes possible from the activity within the short term (five years) and long term (beyond five years).

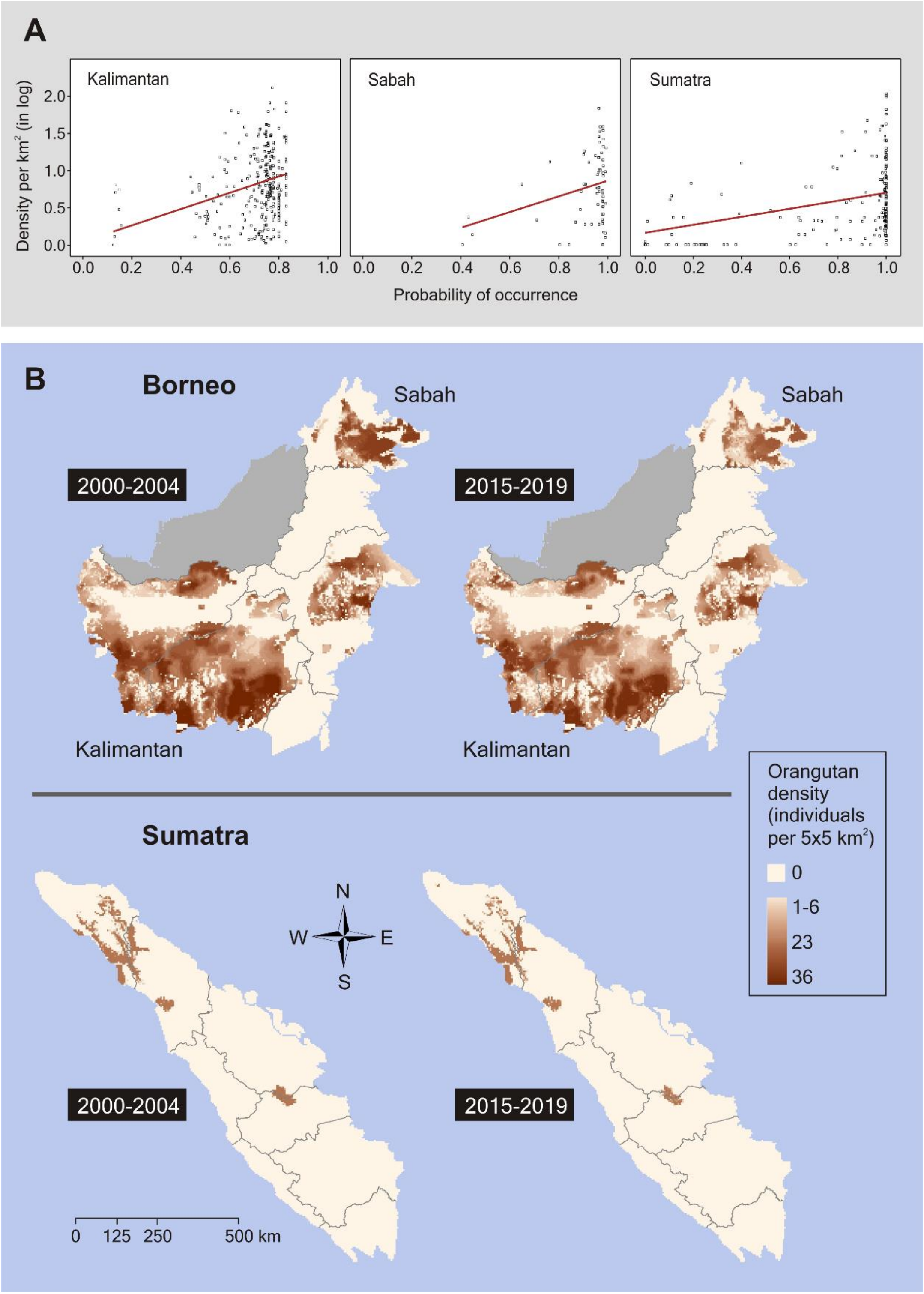


**Figure 6S4. The relationship between probability of occurrence and density and density change over time.** Related to STAR Methods and Figure 6.5. (A) The relationship between the orangutan probability of occurrence and density for the three study regions. Occurrence data were generated from the Generalized Boosted Regression Models – GBM. Density was estimated from the transect dataset. (B) Estimated change in density of orangutan populations between 2000-2004 and 2015-2019. Borneo and Sumatra. Three regional-based models were used to estimate the change in orangutan distributions in (1) Kalimantan and (2) Sabah, and (3) Sumatra.

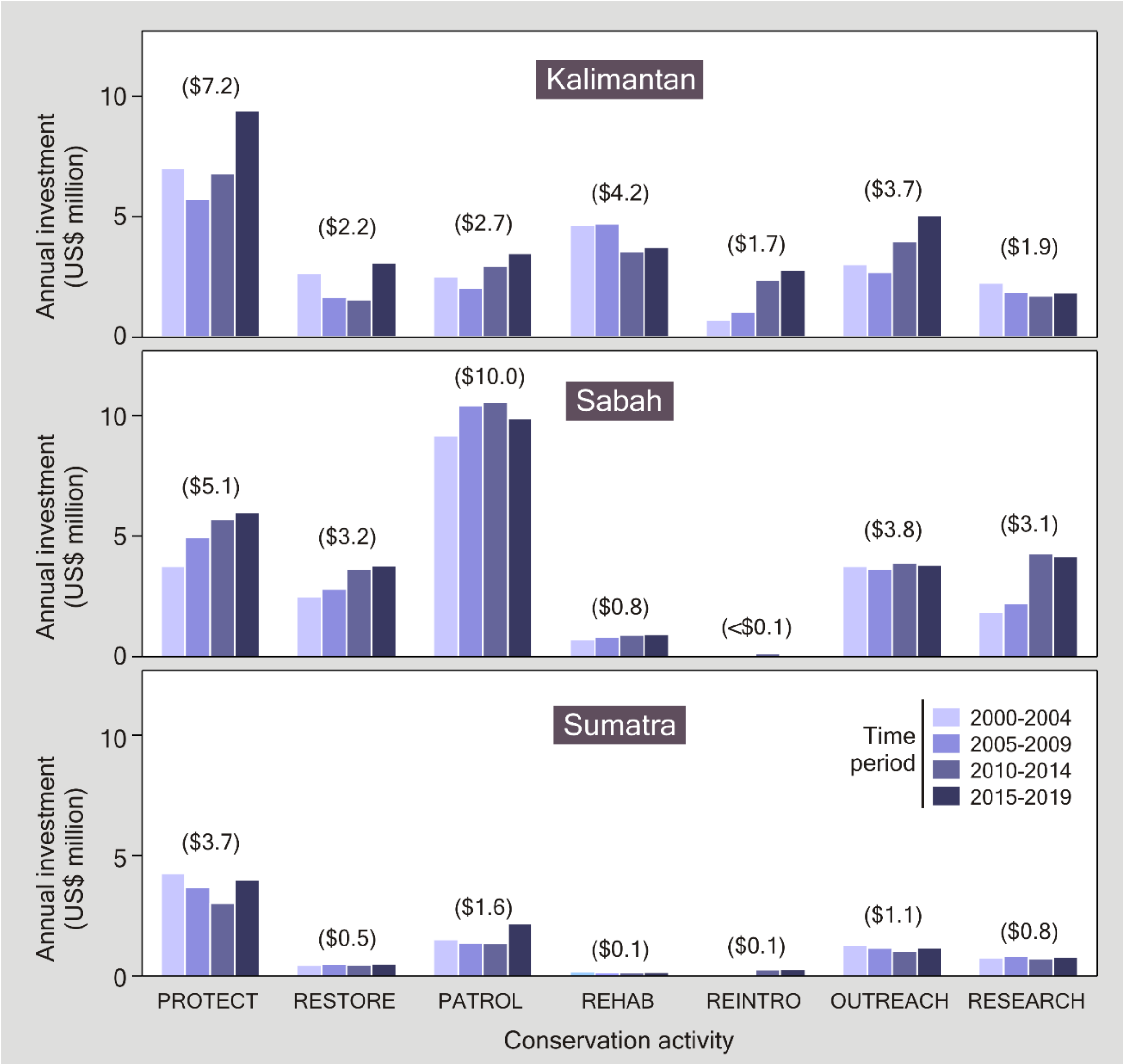


**Figure 6S5. Annual spending value on different conservation activities for the orangutan in Kalimantan, Sabah, and Sumatra over time**. **Related to Figure 6.4**. Conservation activities assessed include the six core activities considered affecting the orangutan survival in the short term: habitat acquisition and protection (PROTECT), habitat restoration (RESTORE), patrolling and law enforcement (PATROL), rescue and rehabilitation (REHAB), translocation and reintroduction (REINTRO), and public outreach and capacity building (OUTREACH); and research-related activities considered as primarily influencing conservation actions and land use management decisions (RESEARCH). The value inside the parenthesis represents the mean annual investment value between 2000 and 2019 for the associated action (in million US$).

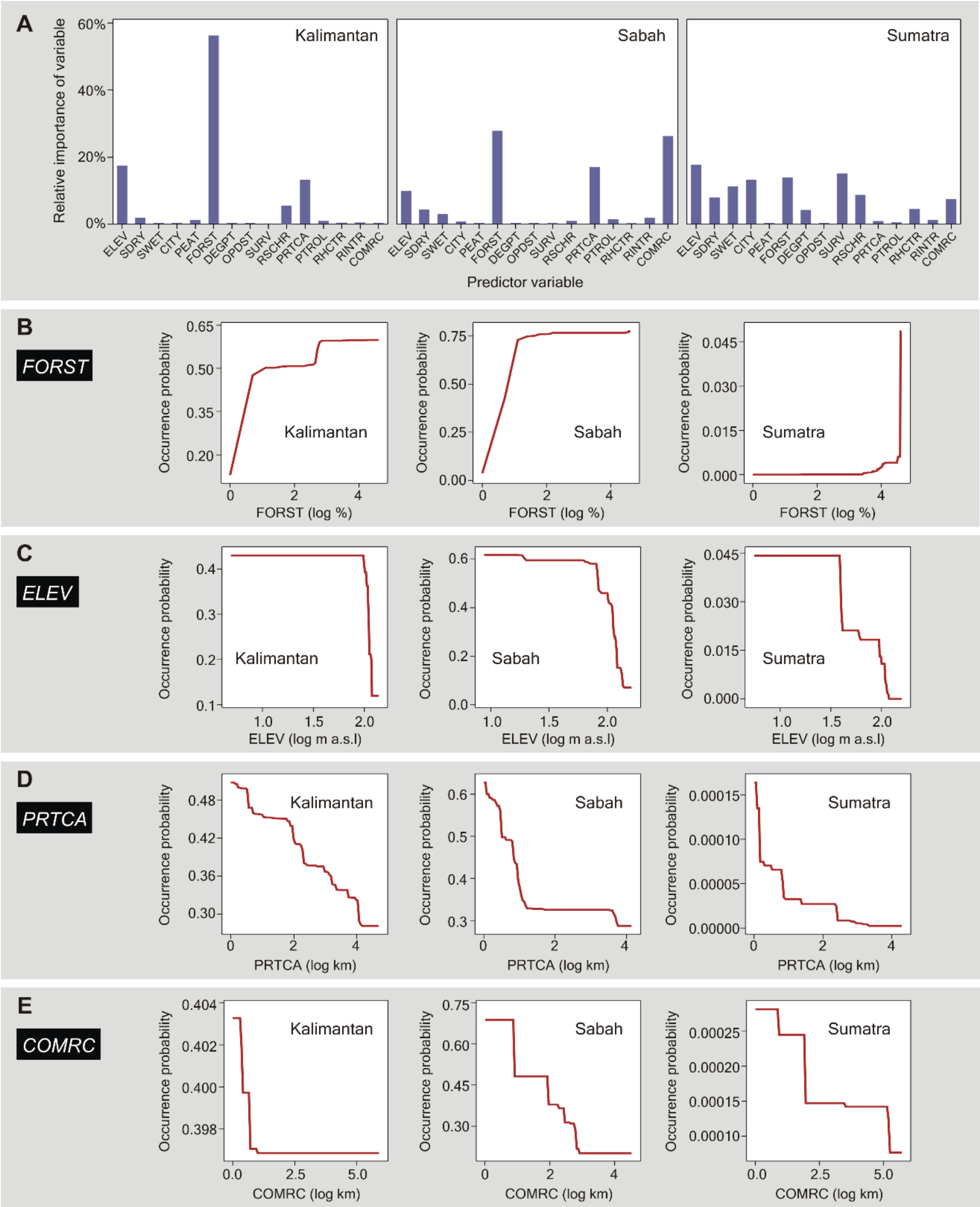


**Figure 6S6. Predictors of orangutan occurrence. Related to STAR Methods.** The relative importance of environmental predictors in affecting orangutan likelihood of occurrence, and the marginal effects of predictors with high importance obtained from the three region-based GBM models for Kalimantan, Sabah, and Sumatra, including variables: (B) forest cover (*FORST*), (C) elevation (*ELEV*), (D) distance to protected areas (*PRTCA*), and (E) distance to public outreach and awareness raising programs (*COMRC*). Survey effort had a negligible effect on the likelihood of orangutan reported as presence in Kalimantan and Sabah, but in Sumatra it had a large positive association with orangutan presences (A). Forest cover and elevation are the strongest predictors of orangutan distributions in the three islands (A). The species' probability of occurrence increases with increased forest cover and reduced elevation (B-C). In Kalimantan and Sabah, proximity to protected areas has a strong positive correlation with orangutan distributions (D). In Sabah, the probability of orangutan occurrence also markedly increases with proximity to community outreach programs (E).

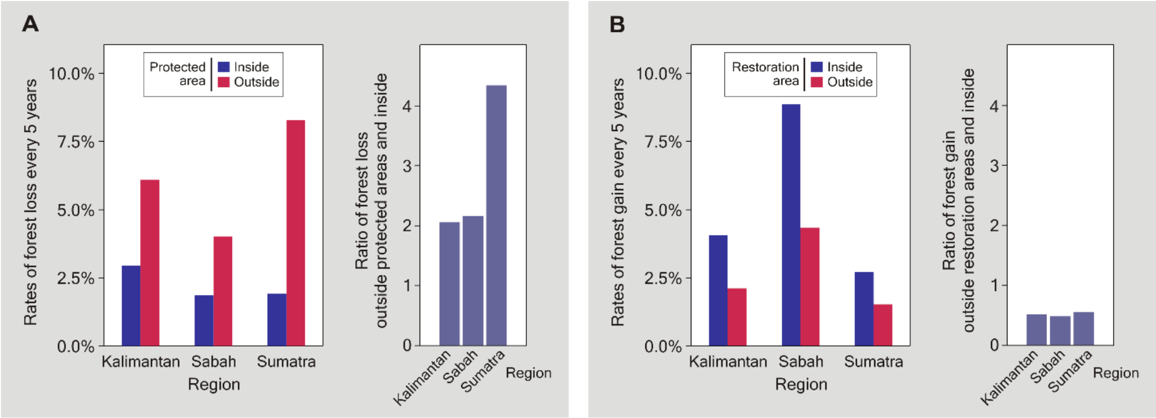


**Figure 6S7. Forest gain and loss data used in counterfactual analysis. Related to STAR Methods.** Rates of (A) forest loss inside protected areas compared to the rates within a 50 km buffer zone, and (B) forest gain inside restoration sites compared to the rates within a 50 km buffer zone, every five years between 2000 and 2019 in Kalimantan, Sabah, and Sumatra.

**Chapter 6 Supplementary tables**

**Table 6S1. Sources used to identify additional investments in orangutan conservation**. Related to Key Resources Table 6.6.1, Methods.

| | |
|---|---|
| **Published and unpublished datasets** | |
| United States Fish and Wildlife Service (USFWS) Multinational Species Conservation Fund - Great Apes grants to orangutan projects (data provided by USFWS) | |
| Dataset of oil palm companies operating in orangutan habitat (Morgans et al., 2019) | |
| Borneo Atlas (https://atlas.cifor.org/borneo/#en) | |
| Dataset of rescue centers operating in Borneo | |
| **Websites** | |
| *Site* | *Search terms* |
| United States Agency for International Development (USAID) LESTARI program (https://www.lestari-indonesia.org/en/) | |
| Tropical Forest Conservation Act (TFCA) Sumatra annual reports (http://tfcasumatera.org/publikasi_category/laporan-tahunan/) | |
| TFCA Kalimantan annual reports (https://www.tfcakalimantan.org/kanal/annual-report) | |
| European Union (EU) Commission funded projects by country (https://ec.europa.eu/budget/euprojects/search-projects_en) | |
| Critical Ecosystem Partnership Fund (https://www.cepf.net/grants/grantee-projects) | Taxon: "mammals"; Country: "Indonesia" and "Malaysia" |
| The Global Environmental Facility (GEF) project database (https://www.thegef.org/projects) | "Indonesia" and "Malaysia" |
| Mohammed bin Zayed Species Conservation Fund projects (https://www.speciesconservation.org/case-studies-projects/) | Species: "mammals"; Continent: "Asia"; Country: "Indonesia" and "Malaysia" |
| Darwin Initiative projects (https://www.darwininitiative.org.uk/project/) | Location; Country: "Indonesia" and "Malaysia" |
| Norway bilateral projects in Indonesia (https://www.norway.no/en/indonesia/values-priorities/deforestation-and-climate-change/bilateral-climate-and-forest-support/project-support/) | |
| Australian Agency for International Development (https://dfat.gov.au/geo/indonesia/development-assistance/Pages/development-assistance-in-indonesia.aspx) | |
| Japan International Cooperation Agency (https://www.jica.go.jp/indonesia/english/index.html and https://www.jica.go.jp/malaysia/english/index.html) | |
| Agence Française de Développement (https://www.afd.fr/en/page-region-pays/indonesia) | |
| Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (https://www.giz.de/en/html/about_giz.html) | Worldwide: "Indonesia" and "Malaysia" |
| Partnerships for Forests – Our Portfolio (https://partnershipsforforests.com/what-we-do/partnerships-and-projects/) | Location: "Indonesia" |
| The Arcus Foundation grantees (https://www.arcusfoundation.org/grantees/) | Focus: "Great apes and gibbons" |
| Prince Bernhard Nature Fund (https://www.pbnf.nl/projects/) | "Indonesia" and "Malaysia" |
| **Search engines** | |
| *Site* | *Search terms* |
| Foundation Directory Online | Keywords: "orangutan", "orang utan" and "orang-utan" |

**Table 6S2. List of entities included in orangutan conservation investment dataset**. **Related to Key Resources Table, STAR Methods.** The analysis includes publicly available financial data for organizations whose names have been excluded for confidentiality reasons.

| |
|---|
| **Organizations operating across all orangutan habitats:** IUCN SGA; UNEP; GRASP; Great Apes Film Initiative; Orangutan Conservancy; Yayasan Kehutanan Masyarakat Indonesia; Yayasan Swara Owa; Yayasan Ulos Heritage Indonesia (SCORPION); FORINA; CIFOR; University of Kent DICE; Borneo Futures; Wildlife Impact. |
| **Organizations operating in Indonesian Kalimantan:** ADB/GEF-funded project (Sustainable Forest and Biodiversity Management in Borneo); UNEP/Wetlands International Indonesia/Global Environmental Centre; Canadian Government (CIDA); UNDP – Kalimantan; Indonesian International Rural Agricultural Development Foundation; Kalimantan Prima Coal; Agro Bukit (Goodhope Holdings); Agro Wana Lestari (Goodhope Holdings); Dewata Sawit Nusantara (DSN group); Genting – Kalimantan; Globalindo Alam Perkasa (Musim Mas); Harapan Sawit Lestari; Investa Karya Bhakti; Karya Makmur Bahagia; Karya Makmur Sejahtera (Goodhope Holdings); Kridatama Lancar (Sime Darby); Mentaya Sawit Mas (Wilmar); Nabatindo Karya Utama (Bumitama); Kalimantan Agro Lestari; Rea Kaltim Plantation; Sarana Titian Permata (Wilmar); Sawit Sumber Mas Sarana; Sinar Mas – GAR; Sukajadi Sawit Mekar (Musim Mas); Swakarsa Sinar Sentosa (Sinar Mas); Tapian Nadenggan (Sinar Mas); Makin Group; Katingan Mentaya Project; Rimba Raya Restoration Ecosystem; Acacia Andalan Utama; Balayan River Timber; Bina Ovivipari Semesta; Carus Indonesia; Djima Jaya Utama; Erna Djuliawati; Graha Sentosa Permai; Gunung Gajah Abadi; Karya Lestari; Narkata Timber; Royal Lestari Utama; Saratim (Sarmiento Parakantja Timber); Sari Bumi Kusuma; Suka Jaya Makmur; Utama Damai Indah Timber; Wanasokan Hasilindo; Balai Konservasi Sumber Daya Alam Kalbar; Balai Konservasi Sumber Daya Alam Kalteng; Balai Konservasi Sumber Daya Alam Kaltim; Danau Sentarum and Betung Kerihun National Park; Gunung Palung National Park; Bukit Baka/Bukit Raya National Park; Tanjung Puting National Park; Sebangau National Park; Kutai National Park; Badan Restorasi Gambut (Peat Restoration Agency); Aidenvironment; Borneo Nature Foundation; CAN Borneo; FFI Indonesia; Friends of the National Parks Foundation; IDH Ketapang landscape; Integrated Conservation; Link-AR Borneo; People Resources and Conservation Foundation (PRCF); Planet Indonesia; Profauna; Save Our Borneo; TNC Indonesia; WALHI Indonesia; WCS Indonesia – Kalimantan; Wetlands International Indonesia; YTS/Wildlife Impact – community surveys; World Education – Indonesia; WWF Indonesia; Yayorin; Brunel University; CIMPTROP - University of Palangka; Wallacea Trust; Yayasan TITIAN; Gunung Palung Orangutan Conservation; Health in Harmony; Kutai Project; Mohammed bin Zayed Conservation Fund – in situ research funds, Kalimantan; Orangutan Land Trust; Tropenbos-International; Tuanan Orangutan Research Project/CORE Borneo; University College Birmingham – in situ research Kalimantan; BOSF Nyaru Menteng, Wanariset Samboja/Samboja Lestari, Mawas; RHO/BOSF; Center for Orangutan Protection; International Animal Rescue; Jakarta Animal Aid Network; Jejak Puleng; Orangutan Foundation UK; Orangutan Foundation International; Sintang Orangutan Centre; Tenggarong rescue/transfer facility. |
| **Organizations operating in Malaysian Sabah:** Anika Desiran; Deramakot Forest Reserve; INIKEA; Mayvin Grouping; PONGO Alliance; Sapulut; TSH Resources - natural forest management; TSH Resources -oil palm; Yayasan Sabah; Linbar 1 and 2 Estates; Litang Estate; Santosa Estate (Sime); Sg. Pin Estate; Sungai Segama II; Tabin Estate; Tagas Estate; Sabah Softwoods; Tungku Estate (Sime); Wilmar - Sabah Mas estate (Tabin) (excluding PONGO Alliance); Genting; Sabah Environmental Protection; Sabah Forestry Department; Sabah Parks; UE - REDD+; UNDP; Borneo Conservation Trust – Japan; Borneo Conservation Trust – Sabah; Ecohealth Alliance; Friends of the Orangutan (FOTO); HUTAN-KOCP; HUTAN - via Wildlife Connection; LEAP; Malaysia Palm Oil Wildlife Conservation Fund; Orangutan Appeal-UK (Sabah); Orangutan Appeal-UK (Sabah Wildlife Rescue Unit); Rhino and Forest Fund; PACOS; Rainforest Trust/SEARRP; Sabah Environmental Protection Association; WWF-Sabah; WWF-Sabah Living Landscapes; Danau Girang Field Center; Durrell Trust for Conservation; Liverpool John Moores University; Living Landscape Alliance; Orangutan Appeal-UK (Sabah _ tabin PRM project); SEARRP - SAFE Project; Yayasan Sime Darby; Sepilok. |
| **Organizations operating in Indonesian Sumatra**: UNDP; TFCA/Leuser Conservation Partnership; Asia Pacific Resources International Limited (APRIL); Royal Lestari Utama; North Sumatra Hydroelectric Company; Balai Konservasi Sumber Daya Alam Sumatera Utara; Balai Konservasi Sumber Daya Alam Sumatera Jambi; Gunung Leuser National Park; Bukit Tigapuluh National Park; Conservation International Indonesia; FKL; Frankfurt Zoological Society; HAkA; INDECON; Institute Green Aceh (IGA); Jantho Lestari Consortium; Lembaga Suar Galang Keadilan; Leuser Ecosystem Management Authority Employee Forum; Nature for Change; Orangutan Information Center; Orang Utan Republik/TOP; PADHI Foundation; Penyangga Tengah Kawasan Ekosistem Leuser; PETRA; Rainforest Action Network; Rainforest trust/KEHUS; Sumatra Ranger Project/Yayasan Cahaya Anak Nusantara; Sumatran Rainforest Institute/tapanuli Orangutan Conservation Project (TOCOP); Universitas Nacional (Unas) Faculty of Biology; WALHI Indonesia; WCS Indonesia – Sumatra; Wetlands International Indonesia; Yayasan Konservasi Satwa Liar Indonesia (YKSLI); Yayasan Leuser International (Leuser International Foundation, YLI); Yayasan Ulos Heritage Indonesia (SCORPION); Ketambe; FORINA (Sumatra); Soraya; Jakarta Animal Aid Network; SOCP; SKEPHI (Sekretariat Kerjasama untuk Pelestarian Hutan Indonesia; WildAid – Leuser project; Yayasan EKONA; Yayasan Perlindungan Lingkungan Hidup dan Pelestarian Alam (Yayasan Palapa); Leuser Development Project. |

**Table 6S3. Environmental predictors used in the Generalized Boosted Regression Models (GBM) to generate the estimated change in orangutan distributions**. **Related to Key Resources Table, STAR Methods.**

| **Variable** | **Variable abbreviation** | **Static/ Dynamic** | **Data sources** |
|---|---|---|---|
| Elevation (m a.s.l) | *ELEV* | Static | SRTM 90m Digital Elevation Database v4.1 (Jarvis et al., 2008) |
| Rainfall during the dry season (mm) | *SDRY* | Static | WorldClim (Fick & Hijmans, 2017) |
| Rainfall during the wet season (mm) | *SWET* | Static | WorldClim (Fick & Hijmans, 2017) |
| Distance to nearest city (km) | *CITY* | Static | Provincial map from the Geospatial Information Agency Indonesia (Geospatial Information Agency (BIG), 2016) and GeoNames Gazetteer (GeoNames, 2020) |
| Percentage of peatland area | *PEAT* | Static | Peat hydrological area map (Ministry of Environment and Forestry of Indonesia (MEF), 2017) |
| Percent forest cover | *FOREST* | Dynamic | Global Forest Change dataset (Hansen et al., 2013), Indonesia's primary and secondary forest map (Margono et al., 2014), and Intact Forest Landscapes data (Potapov et al., 2017b) |
| Percentage of degraded peatland | *DEGPT* | Dynamic | Peat hydrological area map (Ministry of Environment and Forestry of Indonesia (MEF), 2017), Global Forest Change dataset (Hansen et al., 2013), Indonesia's primary and secondary forest map (Margono et al., 2014), and Intact Forest Landscapes data (Potapov et al., 2017b) |
| Distance to oil palm plantations (km) | *OPDST* | Dynamic | Oil palm plantation distribution map (Gaveau & Salim, 2019; Morgans et al., 2018; Santika et al., 2019a; Santika et al., 2021) |
| Survey effort | *SURV* | Dynamic | Orangutan survey datasets across Indonesia and Malaysia (Ancrenaz et al., 2010; Ancrenaz et al., 2021a; Meijaard et al., 2011b; Santika et al., 2017a; Wich et al., 2016) |
| Distance to research centres/activities (km) | *RSCHR* | Dynamic | See Table 1 |
| Distance to protected areas (km) | *PRTCA* | Dynamic | Forest Zone Maps (Ministry of Environment and Forestry of Indonesia (MEF), 2010; Santika et al., 2017a), Community Forestry areas (Ministry of Environment and Forestry of Indonesia (MEF), 2018) |
| Distance to patrolling activities (km) | *PTROL* | Dynamic | See Table 1 |
| Distance to rehabilitation centres (km) | *RHCTR* | Dynamic | See Table 1 |
| Distance to reintroduction sites (km) | *RINTR* | Dynamic | See Table 1 |
| Distance to public outreach programs (km) | *COMRC* | Dynamic | See Table 1 |

# Chapter 7. General discussion and conclusions

## 7.1 Introduction

Interest in robust measurement of conservation impacts and effectiveness has grown over the past few decades (Langhammer et al., 2024) but evidence-based evaluations that test conservation interventions against a counterfactual of no action remain relatively uncommon (Burivalova et al., 2019; Pienkowski et al., 2021; Veríssimo et al., 2024). Evaluations assessing conservation cost effectiveness are particularly rare despite their value for conservation planning (Correa et al., 2024; Murdoch et al., 2007; Pienkowski et al., 2021; White et al., 2022). Recent evaluations of conservation impact for terrestrial taxa are primarily Green Status of Species analyses (Akçakaya et al., 2018), currently covering 70 species, which use expert-elicited estimates of the impact of all conservation interventions, but do not consider cost effectiveness (IUCN, 2024). Other taxon-specific studies include Correa et al. (2024), which modelled changes in African elephant populations with actual protected area management expenditures and known contextual factors affecting elephants but did not assess the species in unprotected areas or in relation to specific conservation interventions, and Mannan et al. (2023), which looked at investments and activities specific to seven national tiger conservation action plans. My studies of evidence-based conservation impact (Chapters 2 -5) and cost effectiveness for orangutans (Chapter 6) are unusually comprehensive because I collated available data from all known sources of investment and activity data from government, bilateral and multilateral, business, and NGOs in both protected and unprotected areas across the geographic distribution of orangutans.

My studies on the impact of conservation action plans (Chapter 2), outcomes of rescue and translocation (Chapters 3 and 4) and of law enforcement and non-regulatory interventions to address wildlife crime (Chapter 5), and, finally, our counterfactual analysis (Chapter 6) showed that land protections and law enforcement had the greatest overall positive conservation impact across Indonesia, but that rescue, rehabilitation, and translocation were more common and represented a larger proportion of orangutan conservation expenditures by area, despite being significantly less effective and posing notable risks to species conservation. Patrolling was a significant source of expenditures in Indonesian protected areas (Chapter 6), yet annual rates of killing, capture and illegal trade of orangutans remain high, indicating it is a priority to expand detection and enforcement coverage and effectiveness (Chapter 5). The high priority actions for orangutans—

protecting important habitats, improving crime detection and law enforcement, and addressing human-wildlife conflicts that lead to killing, capture, and translocations—align with urgent needs for other rare Indonesian species. As is the case for orangutans in Indonesia, much of the tapir, elephant and tiger populations in Sumatra occur outside strict protected areas, and all these species would benefit from enhanced government protection of lands designated for watershed management and logging production, in conjunction with multi-stakeholder, landscape-level habitat planning and management (Ardiantiono et al., 2021; Figel et al., 2024; Pinondang et al., 2024). Like orangutans, tigers, elephants, and tapirs in Sumatra are at risk of retaliatory killing, harassment or being driven away from food sources when foraging or hunting in gardens and plantations, especially those adjacent to protected areas, indicating a need for increased understanding of local community needs and development of coexistence strategies (Ardiantiono et al., 2021; Kuswanda et al., 2024; Lubis et al., 2020; Pinondang et al., 2024). Both targeted and opportunistic killings are a significant risk to tigers, tapirs, elephants (Campbell et al., 2019; Figel et al., 2023a; Moßbrucker et al., 2016; Sayuti et al., 2022) and orangutans (Chapter 5), pointing to a need for more extensive patrol coverage for all species' habitats. My studies on the effectiveness of orangutan conservation interventions (Chapters 2 - 6) are therefore of relevance to many other species facing similar threats. The cost effectiveness analysis in Chapter 6 shows the feasibility of comprehensive cost effectiveness analyses in conservation, including for species and situations with limited data (Chapter 6). This study thus provides an important guide for many conservation contexts.

In the remainder of this chapter, I discuss what my study findings mean for orangutan conservation, how effectiveness is stymied by (1) limited systematic monitoring and empirical evidence, (2) insufficient habitat protection across the orangutan distribution, (3) inadequate enforcement of laws and policies, (4) lack of community-driven solutions, and (5) conservation decisions that favour less effective interventions in lieu of long-term solutions to key threats. I highlight where evidence on other species and situations shows promise for addressing these challenges and consider orangutan conservation interventions in comparison with those for other iconic, legally protected megafauna, particularly the Sumatran tiger (*Panthera tigris sumatrae*), Asian elephant (*Elephas maximus sumatranus*), and Malay tapir (*Tapirus indicus*) in Indonesia. I conclude by summarising recommendations to maximise the effectiveness of orangutan conservation interventions (Table 7.1).

### 7.2 Limited systematic monitoring and empirical evidence

My analysis of 285 projects and surveys of 113 entities revealed that systematic monitoring of intervention impacts on orangutans is rare, with only 13% of respondents reporting measurable effects of their activities (Chapter 2). This is in line with previous findings on conservation interventions to address poaching of African apes (Schoneveld-de Lange et al., 2016), tropical forest conservation interventions (Burivalova et al., 2019), and for conservation interventions in general (Sutherland & Wordley, 2018).

I found that many orangutan conservation projects did not present data at all or did not show outcomes and impacts on orangutans (Chapters 2, 3 and 6). Alternative livelihood and capacity building project reports typically presented only anecdotal evidence of individual instances of sustainable behaviours, claimed community benefits were beneficial to orangutans without providing evidence of this, and did not monitor effects on local orangutan populations. Some projects that reported increased orangutan sightings had not collected baseline data on local orangutan populations and habitats to confirm this change. Most education projects did not publicly report empirical evidence of outcomes. Those that reported impact evaluated knowledge gain and attitudes based on pre- and post-testing administered immediately before and after delivery of the educational content, which does not capture sustained human behaviour changes linked to the knowledge gained, nor can it elucidate how behaviour changes contribute to orangutan protection (Nilsson et al., 2020; Veríssimo et al., 2024). Rescue, rehabilitation, and translocation projects published numbers of individuals taken into centres and numbers released (Chapter 3), not measures of successful reinforcement of non-viable populations or establishment of new self-sustaining populations, such as long-term post-release survival and population growth rate (see IUCN/SSC, 2013; Morris et al., 2021), although there were published assessments of post-release health and behavioural adaptation indicators (Ballare, 2021; Lokuciejewski, 2019).

My datasets showed that reporting quality differed by the sector and size of the implementing entity. Large for-profit corporations generally did publish data and impact analyses, especially agribusinesses that participate in sustainability certification programmes such as RSPO or FSC, which require reporting against environmental standards (RSPO, 2024). In contrast, many smaller non-profit NGOs told us they collected monitoring data but lacked resources to analyse them, suggesting that financial, staff time, and technical resources may influence conservation impact evaluations. Some non-profit NGOs reported they could not share monitoring data due to government restrictions on data sharing and publication (see: Pearce, 2023), while several agribusinesses did share data and did not voice these concerns.

Despite these data availability challenges, this thesis demonstrates that sufficient information can often be found to improve conservation decision making through extensive review of grey literature from governments, NGOs, businesses, research centres, newspaper articles and blogs, charity commission reports and tax forms, and direct communications with intervention implementers (see for example: Burivalova et al., 2019; Mannan et al., 2023). This is an important finding that allows for evidence-based decisions even in face of some notable information gaps. Swift action is needed to prevent further species population decline, hence it is important to act on what we do know, while encouraging improved monitoring and incorporation of counterfactual approaches to fill identified data gaps.

## 7.3 Habitat protection

Although there have been clarion calls for protection of remaining natural forests within the orangutan range since the early days of orangutan conservation (Mackinnon, 1974), and several key orangutan habitats were gazetted as protected areas, only Malaysia has succeeded in designating most of the areas where orangutans occur within its borders as strictly protected (Pandong et al., 2019; Sabah Wildlife Department, 2020), while the majority of the orangutan populations in Indonesia occur outside strictly protected lands (Utami-Atmoko et al., 2017b). Illegal incursions into Indonesian national parks have decreased their forest cover, shrinking rather than expanding the amount of orangutan habitat under strict protection (EIA, 2021). Additionally, the extent of some Indonesian protected areas, including Gunung Leuser National Park (e.g., Matthews, 2002, p. 21) and the Tropical Rainforest Heritage of Sumatra World Heritage Site (UNESCO, 2023), have been reduced from their original size to exclude cleared or degraded areas.

The efficacy of protected areas is strongly dependent on management effectiveness and financial resources (Baghai et al., 2018; Correa et al., 2024; Eklund & Cabeza, 2017; Geldmann et al., 2013; Graham et al., 2021). The research I presented in Chapter 5 confirms findings that Indonesian protected areas are under-resourced relative to their area (Nugraha et al., 2024). Indonesian government budgeting priorities may play a role in this shortfall. For example, tigers were more effectively protected in Nepal and India where the governments spent most of their tiger conservation budgets on field activities such as patrols and addressing human tiger conflicts and the least amount on planning, and less effective in Bangladesh where the government spent the majority of its budget on planning instead of field activities (Mannan et al., 2023).

Government budget shortfalls have been successfully addressed in some African protected areas through collaborative management partnership models where NGOs assume some or all of the responsibility for funding and managing protected landscapes (Baghai et al., 2018). This model has also been successful in India and Thailand's tiger protection programmes (Duangchantrasiri et al., 2024; Karanth et al., 2020). Specific elements funded by public-private partnership and other alternative financing models that have proven beneficial in reducing tiger killing, trade and conflict include provision of equipment and training of staff, employment incentives in the form of staff insurance and merit awards, and technical assistance and capacity building for governance, fundraising, and project implementation (Karanth et al., 2020). Given the low level of staffing and resources for Indonesian parks, alternative long-term finance mechanisms may be required to adequately protect those that harbour large orangutan populations.

Potential long-term finance mechanisms for conservation include multi-partner funds such as conservation trust funds (CTF), which are private legal entities managed by a board of directors to collect donations or revenues, generally invested in interest-bearing accounts, and distribute them to finance desired conservation actions (Doinjashvili et al., 2021; Meyers et al., 2020). Similarly, environmental funds (EF) are instruments that include CTFs as well as government-managed or bilateral funds dedicated to environmental conservation (Meyers et al., 2020). CTF and EF revenues can come from any source but often are composed of substantial philanthropic donations combined with government and private funds (CFA, 2020; Doinjashvili et al., 2021). One example of a multi-partner environmental fund relevant for orangutans is the UNDP Lion's Share Fund, managed by the UN Multi-Partner Trust Fund Office. The Lion's Share Fund is based on corporate funding contributed by businesses that use animal or wilderness images in their advertising (UNDP, 2024). One project of this fund supports protection and restoration of the Leuser ecosystem where Sumatran orangutans are resident (UNDP, 2024).

Importantly, reviews of alternative finance instruments have found that, whatever the funding mechanism, increased funds does not necessarily lead to improved conservation outcomes, and that good governance, transparency, management effectiveness, budget efficiency, and actions tied to site-specific conservation threats, drivers and financial constraints are critical for success (Berghöfer et al., 2017; Bonham et al., 2014). Notably, conservationists and researchers identified the limited role of government or the absence of government representatives in fund governance structures as a key determinant of success (Doinjashvili et al., 2021). This underscores the importance of NGO, corporate and other sectors in securing and delivering necessary conservation financing.

NGOs, businesses, and local communities play a critical role in identifying and designating protected areas with orangutans, and in supporting patrol coverage, fire suppression and other protective activities within established protected areas in the orangutan range (e.g., Ancrenaz et al., 2010; Ancrenaz et al., 2016b; Meijaard et al., 2016; Chapters 3, 5 and 6). Considering that most orangutans occur outside protected areas, significant improvements in conservation status of orangutans, and perhaps other sympatric wildlife, could be achieved through external investments that substitute for or complement government spending and weak governance. There are a variety of funding models that could be explored to support this, including business and market-centred approaches, philanthropy and development assistance, and policy instruments (Cumming et al., 2021; Kafley et al., 2014; Meyers et al., 2020). Ideally, support from non-governmental entities would be reinforced by government actions to protect rare species, such as a moratorium on new concession licensing, as has been proposed for elephant habitats in Sumatra (Magdalena et al., 2024). The flexibility of orangutans in using anthropogenically modified habitats underscores the urgency of protecting all remaining intact forests as well as fragmented forest patches, selectively logged forests, and degraded forests (Ancrenaz et al., 2010; Ancrenaz et al., 2021b; Oram et al., 2019; Oram et al., 2022; Seaman et al., 2024; Spehar & Rayadin, 2017). The habitat areas outside of intact natural forests are critical habitat for orangutans, which have large home ranges, particularly males (Singleton, 2000).

### 7.4 Enforcement of laws protecting orangutans

It is the clear responsibility of government to adequately enforce its wildlife and forest protection laws. Much of the land in the orangutan range in Indonesia is under federal ownership, and is zoned such that it could legally be managed to maintain natural forests if the government committed to enabling and enforcing its protection (Meijaard et al., 2022). Plantations and other concessions with natural forests would likewise need to commit to and implement protection and effective management of these forest patches (Ancrenaz et al., 2021b). Clearing does still happen in orangutan habitat (The Tree Map, 2023), despite a legal framework that should prevent it. Changing this would require government enforcement. Habitat protection, whether on government-owned or private land also needs to include preventive actions to avoid forest fires that episodically cause significant destruction (Purnomo et al., 2017; Thoha et al., 2024) and patrols to deter illegal logging and poaching of protected species including orangutans (Chapters 5 and 6) (see Table 7.1). These actions would likely aid the conservation of other sympatric high-profile protected species in Indonesia including tigers, elephants and tapirs in Sumatra (Campbell et al., 2019; Moßbrucker et al., 2016; Sanderson et al., 2023), and clouded leopards in Kalimantan and Sumatra (Gomez & Shepherd, 2021).

Enforcement of Indonesia's Law Number 5 prohibiting orangutan killing, ownership and trade (Ministry of Forestry, 1990; Republic of Indonesia, 2024) is clearly inadequate given the frequency of crimes affecting orangutans (Chapter 5). Effective deterrence will require that there be investigation of crimes when orangutans are received from illegal ownership, as well as enhanced detection and law enforcement, albeit with rational sentencing that avoid regressive punishments on impoverished citizens (Sherman & Greer, 2018; Chapter 5) (Table 7.1). The maximum fine under Law Number 5 through 2023, 100 million IDR, is equivalent to nearly three years of average annual income in Indonesia (37.1 million IDR in 2025 (BPS-Indonesia, 2025)), but such large amounts are rarely levied. The highest fine we found recorded through 2019 was 50 million IDR, while most fines were between 500,000 and 20 million IDR (i.e., less than a month of average salary), and in most cases fines could be avoided by serving additional jail time (Chapter 5).

Review of efforts to address poaching for African apes indicates that voluntary compliance did not work where legal enforcement was lacking (Schoneveld-de Lange et al., 2016). A positive example is provided by Malaysia, where orangutan-related crime is uncommon (Chapter 2), possibly because better deterrence has been established: nearly all of the crimes I found news reports on were investigated by authorities (Sabah Wildlife Department, pers. comm.) and 6% of the crimes reported between 2007 to 2017 were prosecuted as of 2018. Notably, investigations, arrests, and prosecutions for crimes affecting tigers and leopards in Indonesia appear more common than for those affecting orangutans (Gomez & Shepherd, 2021; Risdianto et al., 2016) (>90%, 48.8%, and 0.9%, respectively). There is no obvious reason for the differential prosecution outcomes for big cats versus orangutans. Although both orangutan and tiger crimes garner public attention in news media and in scientific literature (Chapter 5), the relative rarity of tigers compared to orangutans (Luskin et al., 2017) and the commensurately lower number of tiger-related crimes (Figel et al., 2023b), as well as broad public support for tiger protection (e.g., Bhattarai et al., 2021; Linkie & Christie, 2007) may inspire authorities to investigate and prosecute these crimes, while crimes affecting the more common orangutans—seen by many local people as "unexceptional" rather than special animals (Schreer, 2023)—are ignored. The outcomes for tigers and leopards suggest that better enforcement for orangutans would be achievable under existing Indonesian laws with political will for law enforcement.

Effective means for long-term deterrence of wildlife crime are much debated e.g. (Kahler et al., 2021; Lin et al., 2024), and examples of efficacious interventions in Indonesia are limited. Patrols aided by a network of local informants has been effective for preventing tiger poaching and snaring (which also impacts orangutans, albeit more rarely; see Chapter 5) in Kerinci Seblat National Park in Sumatra (Linkie et al., 2015). Patrols and monitoring in general have proven effective for orangutans (Sugardjito & Adhikerana, 2010) and African great apes (Campbell et al., 2011; Junker et al., 2019). However, snare removals have not addressed poaching over the long-term, and in the case of snaring levels at Kerinci Seblat, later rebounded following extensive removals (Risdianto et al., 2016), suggesting that interventions to address food insecurity, income, or other factors of wellbeing are likely needed in conjunction with patrols and monitoring. A similarly comprehensive approach to crime prevention such as Situational Crime Prevention (see: Kurland et al., 2017) that includes regulatory and non-regulatory , i.e. social and economic rather than legal, interventions is indicated for orangutans (Table 7.1). Research and reporting indicates some people feel resentful of the perceived preferred treatment received by orangutans over humans (Beech, 2019; Chua et al., 2021; Schreer, 2023), which suggests that Situational Crime Prevention or other approaches that consider social and economic factors driving crime would ideally result in situation-specific interventions that make orangutan-related crime less rewarding or more difficult, and provide social incentives for protection (Kahler et al., 2021; Kurland et al., 2017; Travers et al., 2019).

There are limited evidence-based evaluations published to demonstrate the success of these approaches (Delpech et al., 2021; Lin et al., 2024). Delpech et al. (2021) found five projects employing Situational Crime Prevention strategies to be effective within national parks: the Kerinci Seblat patrols plus informants for Sumatran tiger protection (Linkie et al., 2015), as well as two projects with patrols and informants for elephant and tiger protection in a Zambia park, patrols in a Tanzania park, and community outreach in conjunction with patrols in a Thailand park. Local informant networks resulted in decreased poaching (Jachmann & Billiouw, 1997; Leader-Williams et al., 1990; Linkie et al., 2015), as did cash bonuses paid to informants and patrol members for information leading to arrests or confiscation of illegal firearms or wildlife products (Jachmann & Billiouw, 1997).

The role of patrols in deterrence, irrespective of other non-regulatory actions, may be critical to stemming orangutan-related crimes. A study of tiger population recovery in three Thailand national parks showed that increasing spatiotemporal coverage of patrols was essential to prevent killing and enable recovery (Duangchantrasiri et al., 2024). The authors emphasised that strict protective actions are needed for tigers, their prey base, and their habitats, and that no tiger populations in tropical Asia had recovered when treated through community and livelihood measures alone (Duangchantrasiri et al., 2024). Sumatran tiger researchers suggested that a 9,500 $km^2$ forest block in Sumatra would require an additional 560-640 rangers to achieve the same patrol coverage used in the Thailand parks studied by Duangchantrasiri et al. (2024). For comparison, Indonesia's tiger stronghold Kerinci Seblat National Park had an annual average patrol effort that reached approximately 9% of the effort in the Thailand parks (Duangchantrasiri et al., 2024; Risdianto et al., 2016). Patrol effort in orangutan habitats is far below the levels employed for tiger protection in Kerinci Seblat or in Thailand, with only 1.9 or fewer provincial officers per 100 $km^2$ of forested estate across the orangutan distribution area and reintroduction sites in Indonesia, and 2.1 or fewer officers per 100 $km^2$ in Indonesian national parks with orangutans (Chapter 5). Global best practice is a minimum of 3 to 11 officers per 100 $km^2$ for effective protected area management (Bruner et al., 2001), and to address poaching of targeted species (Henson et al., 2016). However, even 11 officers per 100 $km^2$ would apparently be insufficient to address Sumatra's tiger poaching and indiscriminate snaring (Figel et al., 2024; Figel et al., 2023b), indicating that boosting patrol effort only to this level may be similarly inadequate to deter orangutan killing. Strengthening patrols of Indonesian parks and unprotected landscape within the orangutan range to levels commensurate with the Thailand tiger parks would result in dramatically more patrolling resources than deployed to date in the Indonesian orangutan range

(Chapter 5) and, while costly, should have a significant positive impact in slowing losses of orangutans and sympatric protected species.

## 7.5 Local community engagement

Human-wildlife interactions and coadaptation—behavioural changes on the part of both humans and wildlife based on their experiences with each other—and human-wildlife coexistence where some level of mutual tolerance is achieved, are well studied for many terrestrial species (e.g., Carter & Linnell, 2023; Fletcher & Toncheva, 2021; Ma et al., 2024; Orrick et al., 2024). A synthesis of global human-wildlife interactions and coexistence research by Carter and Linnell (2023) suggests that there are several patterns, or archetypes, of human and wildlife interactions defined by the risks and benefits to both parties. Using their definitions, human-orangutan interactions would primarily fall into the 'sporadic nuisance' and 'zero sum losers' archetypes, neither of which are compatible with sustainable coexistence (Carter & Linnell, 2023). Sporadic nuisance systems are characterised by sporadic management actions to remove the "nuisance" to humans, and by wildlife adaptations (Carter & Linnell, 2023), in this case the plasticity of orangutans enabling them to feed on oil palms and other cultivated fruits and tree parts, and to survive and breed within mixed-use landscapes. Nuisance removal actions are orangutan killing, potentially lethal harassment with guns, air rifles, or dogs, or non-lethal actions to remove orangutans (wild-to-wild translocation), driving them away by shouting, banging on trees, or firing air cannons, or deterring them using buffer crops or other non-lethal means (Campbell-Smith et al., 2012; Runtu et al., 2024; Appendix I). In areas where orangutans are not valued or are even actively resented, they become zero sum losers (Carter & Linnell, 2023) that are consistently translocated or killed, and thus decline proportionately with human use of the area. Ongoing habitat loss and fragmentation within the orangutan range (Voigt et al., 2022; Wich et al., 2016) means conflicts will continue to increase, risking a backlash from affected people that pushes the system more strongly towards orangutan being zero sum losers. Although "peaceful" coexistence may never be achievable for communities that feel resentment towards orangutans, they could be incentivised to move toward a 'fragile stability' archetype (Carter & Linnell, 2023) where orangutans are considered "uneasy neighbours" (Banerjee et al., 2024). In such a system, conflicts are constant but are managed and accepted (Banerjee et al., 2024; Ma et al., 2024). Importantly, management that excludes or drives orangutans from areas they use and forage in is inherently problematic. It is detrimental for species like orangutans with large ranges to restrict their movement as a means to avoid conflicts (Carter & Linnell, 2016). Because our findings showed humans in conflict with orangutans across their range (Chapters 2 and 6) it is imperative that resources and effort are directed to support local communities to co-adapt and develop sustainable coexistence strategies instead of trying to limit where orangutans range (Table 7.1).

Studies on perceptions of human-orangutan conflicts and mitigation strategies generally point to financial incentives, material benefits to community members, insurance schemes, and other compensation for crop losses as a means to make coexistence more appealing to affected local residents (Kuswanda et al., 2021b; Maskulino et al., 2021; Runtu et al., 2024). Nilsson et al. (2016) found it was more effective to have both financial motivations and intrinsic motivations, such as appreciation of the beauty of forests and orangutans and the ecosystem services they provide. Improved understanding of the local community needs and cultural, religious, and wellbeing context should be part of all community interventions (Ardiantiono et al., 2021; Schreer, 2023). In one example, elephant researchers in Sumatra indicated that while most villagers experiencing conflict had little interest in coexistence, this could be improved by collaborative efforts involving local communities, park managers, government, and conservation practitioners to develop mitigation measures led by local community members (Ardiantiono et al., 2021). Globally, coexistence researchers likewise recommend participatory decision making and community-driven development of interventions with external funding and technical support to generate locally accepted and enduring solutions (e.g., Banerjee et al., 2024; Carter & Linnell, 2023; Gopalan & Radhakrishna, 2022). Below I discuss specific community intervention types and their relevance for orangutans in Indonesia.

### 7.5.1 Deterring crop foraging

Deterrents that have worked for orangutans are netting fruit trees or making noise to scare away foraging individuals (Campbell-Smith et al., 2012), with the caveat that orangutans will become inured to noise and other efforts to scare them, and will return to desirable crops in spite of these actions (Appendix I). Netting fruit trees, while effective at deterring crop foraging, was considered expensive, time consuming, and difficult by farmers, and may have simply driven orangutans to forage in nearby un-netted trees (Campbell-Smith et al., 2012). Other options for great ape deterrence include putting zinc sheets around tree trunks, planting unpalatable buffer crops, and water-filled canals, although these latter can also pose disease risks for humans and wildlife (Hockings & Humle, 2009). Researchers found that Sumatran elephant crop foraging was deterred by a combination of active community guards and passive controls (e.g., trenches and fences) (Gunaryadi et al., 2017; Sugiyo et al., 2016). Importantly for long-term sustainability considerations, a project in Sumatra found villagers voluntarily adopted and funded methods to deter elephant crop foraging once NGO-funded tests in nearby villages proved effective (Gunaryadi et al., 2017).

Some orangutan rescue and rehabilitation organisations have conflict response teams that help drive away crop foraging orangutans, but they also generally capture and translocate the orangutans when requested to do so by the community or the government, which is an undesirable outcome (Appendix I). A more targeted approach that empowers and employs local residents to monitor and encourage protection of orangutans around their village may have promise to offer alternative livelihoods or supplemental income while simultaneously building intrinsic motivation for orangutan conservation among community members.

#### 7.5.2 Compensation schemes, payments for ecosystem services and other financial benefits

Compensation payments for income loss, property damage, or death/injury by wildlife are controversial (Ravenelle & Nyhus, 2017) but are successful in many instances that may prove instructive for orangutan conservation. Compensation is a long-running, successful approach in India, where the government supplies payments to compensate for losses incurred by protected wildlife (Karanth et al., 2020). Tiger protection programmes have had success in helping affected residents to apply for compensation funds and navigate other bureaucratic hurdles (Karanth et al., 2020). India and Thailand also compensated villagers to resettle outside tiger landscapes to enable authorities to consolidate landscape protections and prevent habitat fragmentation (Duangchantrasiri et al., 2024; Karanth et al., 2020). Although resettlement is associated with negative impacts in many cases, in the case of India’s Malenad Tiger Programme it was truly voluntary, based on villager demand and suitable compensation, and proved critical to successful protection of tiger habitats (Karanth et al., 2020).

An alternative proposal specifically relevant to Indonesia is to use the annual government payments to villages (*Dana Desa*) to reward villages that avoid conflicts with wildlife or take important conservation actions (Lubis et al., 2020). *Dana Desa* is paid annually to each *desa* (village administrative unit) within the country, with amounts per village determined by a formula taking into account a village’s population, poverty level, village area, and geographic remoteness (Arifin et al., 2020). Payments to 74,954 villages from

2015-2019 totalled 268 trillion IDR (19.14 billion USD) (Arifin et al., 2020). More remote, poorer communities receive more funding than urban villages, but in every case the funds must be managed by a village government structure which is held accountable for producing activity plans and meeting reporting requirements to receive continued disbursements(Arifin et al., 2020; Lubis et al., 2022; Muhammad et al., 2022). Villages funds can be used for community empowerment and village development activities of the village's choosing, including sustainable use of natural resources and environment, so long as the chosen activities achieve the objectives outlined in the village activity plan (Lubis et al., 2022). While this may limit the utility of Dana Desa for trialling new human-orangutan conflict mitigation and coexistence interventions, these payments could be valuable for implementing and sustaining proven effective interventions.

Some important observations on what characterises successful compensation schemes and payments for ecosystem services (PES) include addressing inequalities among potential recipients (Veríssimo et al., 2024) and providing benefit to those directly affected by conflicts with wildlife. Asian elephant researchers found the farmers most affected by elephant conflict did not directly benefit from ecotourism projects and therefore expressed unwillingness to coexist with elephants (Cabral de Mel et al., 2024). The authors suggest that for this to change, the affected farmers need to have assurances for their livelihood as the ecotourism project participants do (Cabral de Mel et al., 2024). A counterfactual test of three PES projects in Cambodia found that all projects significantly decreased deforestation and protected target species, but that the project providing direct payments to local resident serving as wildlife guardians benefitted the fewest people and lacked any local community management for sharing benefits more widely (Clements et al., 2010). Further, the direct payment project relied on an NGO to distribute the payments with no community governance system, making long-term sustainability less certain. Other PES projects that did have local governance took longer to establish but were better understood and supported by residents, and are more likely to help establish intrinsic motivations to drive positive behaviour changes (Clements et al., 2010; Clements & Milner-Gulland, 2015). Compared to the guardians project, these projects paid higher amounts, were more expensive and complex to establish, and had a higher cost of participation in terms of participants' time or crops, which presented an entry barrier to some residents but also enabled participants to earn more and receive additional wellbeing benefits (Clements & Milner-Gulland, 2015). All the Cambodia PES projects had conservation-related conditions for participation: the wildlife guardians received direct payments if they monitored and protected nests of rare birds, ecotourism activities were required to protect wildlife and habitat, and premium prices for conservation-friendly crops were contingent on following land use plans that prescribed wildlife and habitat protections (Clements, 2010).

Various types of payments are already used in orangutan conservation, such as ecotourism and reforestation work (Nilsson et al., 2016), as well as monitoring and patrolling (Chapter 5). The effect of these payments has been little studied, and orangutans would benefit from experiments and interventions with matched counterfactuals that investigate the delivery method, governance, amounts of compensation, and conservation impacts of various payment schemes.

### 7.5.3 Conservation education

Conservation education and awareness campaigns are recommended as an accompaniment to all interventions to reduce or avoid conflict with wildlife (Ardiantiono et al., 2021; Nilsson et al., 2016). As is the case for orangutans, many people living in elephant habitats view capture and translocation of problem animals as an ideal solution, and feel that these animals “belong” only in protected areas (Cabral de Mel et al., 2024; Sherman et al., 2025). Cabral de Mel et al. (2024) and Ardiantiono et al. (2021) suggest that conservation education campaigns are needed to improve residents’ understanding of why translocation is not a suitable response, its risks to the wildlife, and its ineffectiveness for conflict mitigation. Ardiantiono et al. (2021) noted that these campaigns should also emphasise the animals’ ecological, cultural, and economic values, while Cabral de Mel et al. (2024) suggested that communities need to learn about effective conflict mitigation options as an alternative. Training people to behave appropriately when they encounter elephants (Ardiantiono et al., 2021) or orangutans (Oram, 2023) is also crucial.

## 7.6 Conservation decision-making

This thesis demonstrates that reintroduction and reinforcement of wild orangutan populations and the capture and wild-to-wild translocation of orangutans have not had significant positive effects on protection of wild orangutans (Chapter 6, Appendix I). Considering this and the large numbers of orangutans rescued each year from killing and trade and captured and translocated from perceived unsuitable situations, it is not possible to achieve species conservation through programmes dominated by rescue and release. The prevalence of these rescues and releases and the large proportion of government and NGO funds spent on them (Chapters 3 and 6) are an indication that orangutan conservation decisions are driven by factors other than empirical evidence of species benefit.

Over the last several decades, advancements in specialized care and rehabilitation of orangutans created opportunities for improved welfare while driving a narrative that rescue and release were a means to secure species protection (Aveling & Mitchell, 1982; Rijksen, 1974; Russon, 2009). This narrative has taken hold in both local and international media (see Chapter 3), perpetuating public support for these actions as a supposed solution to human-orangutan conflicts, orangutan killing and trade, and habitat loss. The media attention has led to practitioners unintentionally exacerbating poaching and illegal trade risks by featuring humans interacting with orangutans in social media posts, potentially boosting public demand for orangutans and other wildlife as pets (Freund et al., 2024; Freund et al., 2021). Care and rehabilitation, and in some cases, responsible reintroduction of suitable candidates to re-establish extirpated populations, are an appropriate welfare option for the hundreds of orangutans affected by killing and trade. From a species conservation perspective, these actions should be considered ancillary to the primary goal of protecting wild orangutan populations and their habitats (Table 7.1). International Union for the Conservation of Nature (IUCN) guidance on the precautionary approach to great ape translocation indicates reintroduction and reinforcement are not conservation priorities for orangutans, and releases into viable populations should be avoided to prevent risks of negative social and genetic effects and transmission of communicable diseases (Beck et al., 2007; Chapter 3; Appendix I).

Wild-to-wild translocations put translocated orangutans at risk of poor welfare and mortality as well as depleting fragmented populations and disrupting gene flow and social networks in the local metapopulation. Wild-to-wild translocations in Indonesia appear to have largely emptied some small forest patches of orangutans, reducing the extent of species occupancy and potentially encouraging deforestation of emptied patches, and displacing the transient males that breed with dispersed resident females. Loss of transient males, whether through translocation or killing, can create negative genetic diversity impacts. Galdikas et al. (2023) found a dramatic decline in the number of transient males encountered in Tanjung Puting National Park over the past 50 years, which in turn appears to have decreased immigration of new alleles into the park population. Given the many wild males translocated into Tanjung Puting (Galdikas et al., 2023), this suggests that these individuals did not remain, or perhaps may not have survived in the long-term, and that transient males are disappearing from unprotected areas around the park. Unless wild-to-wild translocations are reduced and action is taken to protect the dispersed orangutan populations outside of national parks, this situation will worsen. Funding and implementing effective conservation and management of orangutan habitats at the landscape level in both formally protected areas and unprotected public and private lands and investing in fostering human-orangutan coexistence, are the only long-term solutions to change the trajectory of orangutan declines.

This is applicable to other Indonesian species as well: removing individuals from diminishing wild populations is posing a risk to leopards in Indonesia (Adhiasto et al., 2020), post-release survival of translocated tigers in Sumatra is likely low (Priatna, 2020), and translocation is discouraged for Asian elephants as they have high risks and are generally unsuccessful in preventing conflict (Cabral de Mel et al., 2024). Translocation is often not a sustainable long-term solution to address human-wildlife conflicts, and has proven overall ineffective in resolving these conflicts for numerous mammal species (IUCN, 2023; Sherman et al., 2025).

## 7.7 Methodological considerations and future research directions

My research involved collating many different types of data from a variety of sources, which varied in reliability, and using these data together to better understand orangutan conservation intervention outcomes. The resulting analyses have some notable limitations due to the inconsistent data availability and quality. Missing data and data that were not collected or reported systematically using comparable definitions and parameters across sources meant I could not always quantify specific variables for an entire study period or even annually. Due to the unfortunately large sample sizes owing to the number of orangutans and instances of crimes, rescues and translocations, it was nonetheless possible to look at trends and relative prevalence based on available data for most variables of interest. However, missing data did limit our exploration of relationships among variables and between variables and outcomes in Chapters 3, 5 and 6. Variable data quality also results in increased work to extract and interpret data systematically across sources. Accurately and systematically coding data required reading thousands of records multiple times to identify evidence-based categories, and to avoid confirmation bias by collating all relevant data from all available sources for each instance or individual orangutan. Interpreting these data also necessitated understanding conservation activities and their orangutan-specific contexts in some detail to identify and account for data collection, measurement and reporting biases that can occur, especially in annual reports and other self-published materials that aim to promote accomplishments. My professional background working with great ape rescue and rehabilitation issues was valuable in this regard, but most importantly, my research benefitted markedly from collaboration and consultation with experts on orangutan behaviour, socioecology and responses to habitat modification, orangutan conservation practice, and local cultural and socioeconomic considerations. Expanding this research model to other taxa would likewise require assembling expert teams and extensive review of available data. Improved availability of systematically collected data across species conservation interventions and their outcomes, effectiveness and costs would also greatly strengthen research outputs, allowing more robust exploration of relationships among conservation activities and their impacts on species populations and habitats.

Orangutan population monitoring data are sparse outside long-term research sites, protected areas, and sites of orangutan translocations, reforestation, or community interventions (Utami-Atmoko et al., 2017b; Chapter 6). This meant we could not trace specific patterns at more local scales and thus may not have captured localized intervention impacts (Chapter 6). Investigation of site level impacts using experimental design, matching, or other counterfactual thinking (Ferraro, 2009) could help answer crucial questions, such as whether patrol, habitat protection, and rescue efforts result in "leakage" of deforestation, poaching, and trade from treated to untreated areas (e.g., Ford et al., 2020). It is also important to determine whether orangutan captures for wild-to-wild translocation facilitate clearing of small forest patches and edges of larger forests once the orangutans are removed, as my research suggests may be happening in some sites (Appendix I).

Multiple types of interventions were implemented simultaneously at most sites and the interventions were weakly correlated in our GLMM, making effect size less clear. One example of this is the small conservation return on investment (ROI) we found for rescue and rehabilitation (Chapter 6), which logically is illusory. There is no logical means for the removal of individuals from wild populations to reduce losses of wild orangutans, except where there is a spillover effect from law enforcement and education interventions associated with the seizure or handover of the individual. Orangutan population benefits could occur if the individuals are later translocated and contribute to establishing new self-sustaining populations, but there is no indication of any reintroduced populations being self-sustaining without continued releases (Utami-Atmoko et al., 2017b), and we tested the effect of release separately from rehabilitation. We also suspect that some interventions may not work well in isolation. Evaluating the effectiveness of the combinations of interventions that best improve outcomes for orangutan populations and habitats would therefore be helpful. Social science studies of communities living alongside orangutans are also needed to understand possible interventions that could foster human-orangutan coexistence. Systematically monitored implementation of community-driven interventions, evaluated against counterfactuals, would be of considerable value to the orangutan conservation practitioners and to the conservation biology literature.

## 7.8 Conservation implications and specific recommendations

Although translocations return some individuals to natural habitats, my research confirms this does not counteract the losses to wild populations from killing and captures. This is for two key reasons: the additional mortality of wild orangutans that precedes capture, and the lack of deterrence of future orangutan killing. For every orphaned infant that is rehabilitated and released into the wild, the additional mortality that culminates in it entering captivity or trade means there was a net loss to the wild orangutan population of at least one, due to the presumed killing (or other mortality) of the infant's mother (Harrisson, 1961). Adults that are rescued from illegal possession are not able to contribute to the natural growth of the wild population while they were captive, plus they also likely entered captivity after their own mothers were killed.

Rescues, whatever their outcome, are also directly connected to orangutan-related crimes and law enforcement (Chapters 3 and 5). Each instance of an orangutan being confiscated or surrendered, or rescued is the result of one or more crimes leading to the individual becoming orphaned, captured or traded, injured, or its habitat degraded or cleared. Although I demonstrated in Chapter 5 that these crimes are viewed as likely to go undetected or be free of consequence, the government continues to condone handovers of illegally held orangutans without warnings or sanctions, and rescue centres feel obligated to accept these animals when the government asks them to, even without accompanying law enforcement action. Public demands that authorities investigate crimes and take any appropriate enforcement actions whenever orangutans are seized or surrendered could encourage strengthened enforcement and improve public understanding of the threat poaching, possession, and trade pose to orangutans (see: Sherman & Greer, 2018). Improved detection of orangutan-related crimes and consistently applied sanctions would help dispel the perception that crimes have no consequences and may thus enhance deterrence (Table 7.1).

Captures and translocations of wild orangutans are often conducted unnecessarily (Chapter 2; Appendix I). Our analysis of forest changes in a 5 kilometre buffer around GNSS coordinates where individual orangutans were captured showed that in most cases the individuals are captured from sites where they have been living and breeding for some time, and they are in or have access to forests and forest fragments where they could survive if left undisturbed (Sherman et al., 2025). The practice of wild-to-wild translocation should be used only in exceptional emergencies, while work with local communities, landowners and managers, and businesses to protect the orangutans in situ should be scaled up across the orangutan range. Although monitoring wild orangutans is a challenge, investing in concerted efforts to track wild-to-wild translocated individuals at several sites for at least three to five years would materially improve understanding of post-release survival. Our findings suggest that improved monitoring, analysis of empirical evidence, and data sharing is needed for all entities conducting any type of orangutan conservation intervention.

My research also underscored the critical roles played by NGOs, local communities, and businesses operating in the orangutan range, who are in place to make the decisions that lead to killing, trade, translocation, or protection of wild orangutans (Chapters 2 – 5; Appendix I). As a first step to improved protection for wild orangutan populations, it is vital that these stakeholders understand orangutan behaviours, particularly their habits of foraging in crops with periodic, heavy and nutrient-dense fruits and consuming bark during low fruiting periods, as well as the propensity of males to roam widely and of females to stay put, and how to react to orangutans in a manner ensuring human safety while enabling orangutans to move freely (Oram, 2023).

Orangutans in Indonesia would benefit from new or expanded strictly protected areas in their range, as well as commitments to protect community forests (*hutan desa*), watershed management forests, restoration concessions. and production forests (Meijaard et al., 2022). Patrols cover only a small portion of the orangutan range in Indonesia (Chapter 5), and they should be expanded significantly as well as be carefully designed and deployed to prevent criminals predicting and avoiding rangers and monitors (Critchlow et al., 2017; Figel et al., 2024; Moore et al., 2018), which orangutan conservationists report is happening in some areas (Anon., pers. comm. 2025) . This expansion across both protected and unprotected areas will require considerable additional funding to cover current unpatrolled areas. The existing level of patrolling already exceeds government allocations for patrols and is supplemented by NGO spending on equipment, training and personnel (Chapter 5), hence boosting patrol coverage will require considerable new or expanded funding, ideally from both government and non-governmental sources.

My research establishes clear priorities for orangutan conservation investment and action, focused on improving habitat protection, expanding crime detection and deterrence efforts, enhancing enforcement of existing laws, and centring local community needs to establish human-orangutan coexistence (Table 7.1). Researchers have found that a combination of interventions is needed to facilitate coexistence with orangutans (Nilsson et al., 2016), as well as an understanding of local cultural beliefs and personal motivations in the specific circumstances (e.g., Chua et al., 2021; Kuswanda et al., 2021a; Schreer, 2023). It is thus important that interventions be both community-driven and carefully monitored and evaluated to assess their impacts on the local community, orangutans, and forests. Social and wellbeing impacts need to be monitored alongside effects on forests and orangutans. Surveys suggest that people whose wellbeing needs are met are more likely to support orangutan conservation (Massingham et al., 2023b). Conservation funders and implementors should be willing to invest in monitoring for all types of interventions and should be aware that interventions will likely need to be sustained or adapted depending on monitoring outcomes.

**Table 7.1. Recommended actions for Indonesian orangutans by land use category, sector, and intervention type.** Rescue centres, research centres and all other non-governmental organisations are classified as NGOs. Funders are granting organisations, private donors, investment instruments and any other external funding source. Land use categories follow Indonesia's land use classifications. OU = orangutan(s).

<table>
<tr><th rowspan="2">Site or land use category</th><th rowspan="2">Sector</th><th colspan="3">Priority conservation actions needing increased investment</th><th colspan="4">Other actions</th></tr>
<tr><th>Habitat protection</th><th>Patrolling and enforcement</th><th>Education, outreach, community engagement</th><th>Habitat restoration</th><th>Rescue and rehabilitation</th><th>Reintroduction and reinforcement</th><th>Wild to wild translocation</th></tr>
<tr><td>All areas</td><td>Funders, NGOs</td><td colspan="4">Funding, staff resources and equipment for impact monitoring and evaluation</td><td rowspan="2">• Funding, staff resources and equipment to track health and welfare, and continue improving rehabilitation practice<br>• Encourage investigation of possible crimes tied to OU possession, and publicise to deter further crimes</td><td rowspan="5">• Not an orangutan conservation funding priority<br>• Funding, staff resources and equipment to track post-release survival, health, and breeding of released individuals and regularly survey numbers, demographics and health of recipient population</td><td rowspan="5">Not recommended; poses conservation risks</td></tr>
<tr><td>All areas</td><td>All sectors</td><td>Financial, technical, and social support to maintain natural forests and forest patches of any size and prevent/manage forest fires</td><td>Develop and support local monitoring and patrolling capacity to prevent OU killing and habitat encroachment</td><td>• Engage with communities to develop, implement and adapt community-driven strategies to improve coexistence, including financial incentives<br>• Provide education on OU behaviours, including repeated crop foraging and ways to avoid conflict that do not involve killing or harm, translocation, or restriction of OU ranging</td><td>Restore degraded areas in key OU habitats with native tree species as funding allows</td></tr>
<tr><td>All areas</td><td>Government</td><td colspan="4">• Implement policies on orangutan protection (national and customary laws, orangutan action plans, PHVA, etc.)<br>• Funding, staff resources and equipment for impact monitoring and evaluation</td><td>Investigate potential crimes leading to OU killing, seizure or surrender of illegally held/traded OU; apply rational sentencing to deter further crime</td></tr>
<tr><td rowspan="2">Protected areas</td><td>Government</td><td>Maintain protective management and prevent forest fires</td><td>Increased patrols and enforcement to prevent killing, capture, and habitat encroachment</td><td>Encourage community-driven strategies to improve coexistence with OU instead of translocation</td><td>Restore degraded areas in key OU habitats with native tree species as funding allows</td><td>Investigate potential crimes leading to OU killing, seizure or surrender; apply rational sentencing to deter further crime</td></tr>
<tr><td>NGOs</td><td>Maintain protective management and prevent forest fires</td><td>Increased patrols and enforcement to prevent killing, capture, and habitat encroachment</td><td>• Engage with communities to develop, implement and adapt community-driven strategies to improve coexistence<br>• Provide education on OU behaviours, including repeated crop foraging and ways to avoid conflict that do not involve translocation or restriction of OU ranging</td><td></td><td>• Support investigation and law enforcement of illegal actions<br>• Support improved welfare</td></tr>
</table>

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Protection and production forests & restoration concessions | Government | • Convert to permanent protected status if possible<br>• For areas without protected status, sustainably manage forests to maintain orangutan habitat needs and ecosystem functions<br>• In production forests, permanently prohibit conversion of natural forests to plantations | Increased patrols and enforcement to prevent killing, capture, and habitat encroachment | Encourage community-driven strategies to improve coexistence with orangutans instead of translocation | Restore connections between forest patches and larger forested areas with native tree species | Investigate potential crimes leading orangutan killing and seizure or surrender of illegally held or traded orangutans, and apply rational sentencing to deter further crime | | |
| | NGOs, businesses, and local communities | Sustainably manage forests to maintain orangutan habitat needs and ecosystem functions, and to prevent forest fires | Increased patrols and enforcement to prevent killing, capture, and habitat encroachment | • Engage with communities to develop, implement and adapt community-driven strategies to improve coexistence<br>• Provide education on OU behaviours, including repeated crop foraging and ways to avoid conflict that do not involve translocation or restriction of OU ranging | Restore connections between forest patches and larger forested areas with native tree species | Support investigation and law enforcement of illegal actions | | |
| Agricultural, selectively logged and mixed use landscapes, and fragmented forest patches | Government | Enforce government policy prohibiting clearing of natural forests and regulations protecting orangutans | | Encourage community-driven strategies to improve coexistence with OU instead of translocation | Restore connection and support reforestation of native tree species across the entire agricultural landscape | Investigate potential crimes leading orangutan killing and seizure or surrender of illegally held or traded orangutans, and apply rational sentencing to deter further crime | | |
| | Businesses, NGOs, and local communities | • Implement government regulations or voluntary company commitments to maintain forest patches and ecological networks<br>• Adopt and implement best management practices (BMPs) including certification | Company commitments and patrols to enforce rules forbidding OU killing or capture, and prevent habitat encroachment or degradation | • Engage with communities to develop, implement and adapt community-driven strategies to improve coexistence, including financial incentives<br>• Provide education on OU behaviours, including repeated crop foraging and ways to avoid conflict that do not involve translocation or restriction of OU ranging | | Support investigation and law enforcement of illegal actions | | |

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# Appendix I. Outcomes of orangutan wild-to-wild translocations reveal conservation and welfare risks

Julie Sherman[1 ¶], Maria Voigt[1 ¶], Marc Ancrenaz[2,3], Erik Meijaard[3], Felicity Oram[4], Elizabeth A. Williamson[5], Anne E. Russon[6], David J.I. Seaman[7], Christine Caurant[8], Dirck Byler[9,10], and Serge A. Wich[11]*

[1]Wildlife Impact, Portland, Oregon, United States of America
[2]HUTAN, Sandakan, Sabah, Malaysia
[3]Borneo Futures, Bandar Seri Begawan, Brunei Darussalam
[4]OrangJUGA, Kota Kinabalu, Sabah, Malaysia
[5]Faculty of Natural Sciences, University of Stirling, Stirling, United Kingdom
[6]Department of Psychology, Glendon College, York University, Toronto, Canada [retired]
[7]Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Canterbury, United Kingdom
[8]Independent Conservation Consultant, Lannion, France
[9]IUCN SSC Primate Specialist Group Executive Committee, c/o Re:wild, Austin, Texas, United States of America
[10]Re:wild, Austin, Texas, United States of America
[11]School of Biological and Environmental Sciences, Liverpool John Moores University, Liverpool, United Kingdom
*Corresponding author

[¶]These authors contributed equally to this work

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## Abstract

Wild orangutans (*Pongo* spp.) are captured and moved (wild-to-wild translocated) primarily to prevent crop foraging or out of concern for orangutans' survival in fragmented habitat. Little is known about wild-to-wild translocation frequency, circumstances, and possible species conservation and individual welfare outcomes. We investigated orangutan wild-to-wild translocations in Indonesia from 2005 to 2022 using primarily data from public sources and consultation with practitioners. At least 988 wild orangutans were captured for translocation during the study period, including many reproductively valuable resident females and adult males removed from unprotected fragmented forests and forest patches. Data on health condition (n = 808) indicated 81.7% were reported as healthy at time of capture. Information on post-capture disposition (n = 268) showed that only 23% were translocated immediately. Mean estimated killing combined with reported translocation removals was calculated to affect 3.3% of orangutans in Kalimantan, and 11.6% in Sumatra, both higher than the threshold of mortality from human actions expected to drive populations to extinction. Negative impacts are likely compounded where multiple individuals are translocated from the same area, and for the Tapanuli orangutan (*P. tapanuliensis*), which has the smallest population and range of all orangutan species. Data on reasons for capture (n = 743) indicated most translocations (69%) were conducted to address crop foraging and orangutan presence in or around croplands and plantations. Forest cover analysis around 104 orangutan capture sites with high resolution spatial information indicated that deforestation levels in the year preceding capture were not significantly associated with likelihood of captures for translocation. To improve conservation outcomes, wild-to-wild translocations should be used only in exceptional circumstances. Most orangutans should instead be monitored and protected in situ by addressing conflicts and maintaining the forests, including forest fragments, they are using. When translocation is necessary, post-release survival and potential conservation impacts must be monitored.

## Introduction

Conservation translocations are human-mediated transfers of organisms from one site to another for the purpose of protecting species and ecosystems (e.g.,IUCN/SSC, 2013). Wild-to-wild translocation entails capturing individual wild animals from areas where they are found and moving them to other sites within their species' range. Wild-to-wild translocation has become a common strategy to address or pre-empt negative interactions between humans and wildlife, and to remove wildlife from areas where humans prefer it not to be (e.g., Boast et al., 2016; Fernando et al., 2012; Goodrich, 2010; Massei et al., 2010; Shaffer et al., 2019; Sherman et al., 2020). While wild-to-wild translocations may remove individuals from situations where their lives are in immediate danger from humans, they have limited long-term success in mitigating human-wildlife conflicts and, in many cases, also have negative impacts on post-release survival and welfare of released individuals and on species conservation (IUCN, 2023). Unintended outcomes of wild-wild translocations undertaken to ameliorate conflicts include injury or death of individual animals during capture, translocation or release, and released individuals being killed by conspecifics or humans (e.g., Fernando et al., 2012; Galdikas, 2018; Mompoloki et al., 2021). Released individuals often return to sites from which they were removed, or cause conflict with humans in new areas (e.g., Boast et al., 2016; Goodrich, 2010; Sherman et al., 2021). Furthermore, translocations have resulted in inadvertent genetic mixing of species and subspecies, mixing of traits and local cultures specific to source populations, as well as disease transmission and negative social impacts, including competition with resident conspecifics (e.g., Arora et al., 2012; Banes et al., 2016; Goossens et al., 2005; Kock et al., 2010; Yan et al., 2018).

Orangutans (Pongo spp.) are severely threatened by conversion and fragmentation of their habitats to agricultural plantations, forestry, mining, hydropower, and other infrastructure, and by illegal killing, capture and trade (Voigt et al., 2018; Wich et al., 2019; Wich et al., 2016). For over three decades, the three species of orangutans, *Pongo pygmaeus* (Bornean orangutan), *Pongo abelii* (Sumatran orangutan), and *Pongo tapanuliensis* (Tapanuli orangutan), all listed as Critically Endangered by the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (Ancrenaz et al., 2024; Nowak et al., 2024; Singleton et al., 2024), have been wild-to-wild translocated in large numbers. Orangutans are translocated for the following reasons: 1) they are deemed at risk from human attacks or forest fires; 2) they are found in habitats perceived as unsuitable, such as small or isolated forest fragments in agricultural and other anthropogenic landscapes; 3) they are feeding on or otherwise damaging cultivated crops, or are assumed likely to do so; 4) they are deemed a risk to human safety or property; 5) they are in the path of planned forest clearing or development or considered at risk from potential deforestation; or 6) they are believed to be suffering from malnutrition (Sherman et al., 2020; Sherman et al., 2021). The distances orangutans are moved during translocations vary considerably, from a few kilometers to hundreds of kilometers from their capture sites (Sherman et al., 2020, this study). Limited empirical evidence is available to evaluate wild-to-wild translocation impacts on orangutans. A compendium of primate conservation actions (Junker et al., 2017) found a single published study related to orangutan wild-to-wild translocation, which reported translocation of one population of 84 animals, without post-release survival data (Andau et al., 1994).Orangutans are semi-solitary foragers but live in diffuse communities of related or familiar individuals, with philopatric resident females and dispersing males (Arora et al., 2012; van Schaik, 1999). Female orangutans are strongly tied to their natal areas, generally intolerant of unrelated females and may be aggressive towards them (Knott et al., 2008), and may pose a potential threat to the infants of unrelated females (van Noordwijk et al., 2012). Males compete intensively for mating access, while females mate with multiple males, flanged and unflanged, for each conception (van Noordwijk et al., 2023). Immature orangutans are wholly dependent on their mothers from birth until they are around seven to eight years old, a period when they learn how to process food and where and when to find it, after which they stay within their matrilineal home range refining these skills until they reach around 15 years of age (Schuppli et al., 2016; van Noordwijk, 2009).

Free-ranging orangutans live in intact tropical moist forests, degraded and selectively logged forests and mosaic habitats (mixed forest types or forest mixed with other vegetation types), and will use agricultural plantations, farms, gardens, and exotic tree plantations (Ancrenaz et al., 2015; Galdikas, 1988; Kuswanda et al., 2021; Meijaard et al., 2010; Rijksen & Meijaard, 1999; Wich et al., 2009). Females have been observed occupying small forest fragments for decades and are regularly seen with dependent infants and semi-independent juvenile offspring (Oram et al., 2022). Orangutans can maintain viable population densities in mosaic landscapes that include forest, industrial tree plantations, production forests, and diversified agricultural areas (Ancrenaz et al., 2010; Roth et al., 2020; Santika et al., 2017; Voigt et al., 2018). Human food crops may be easier for orangutans to process and may have higher sugar and nutritional content, making them very attractive to orangutans (see: McLennan & Ganzhorn, 2017), especially ranging males, even if sufficient natural foods are available in their home range (Oram, 2023). Orangutans will also consume oil palm shoots and fruits (Ancrenaz et al., 2015). More than 75% of orangutans are estimated to live outside protected areas in Sumatra and Indonesian Borneo (Ancrenaz et al., 2021; Utami-Atmoko et al., 2017). Although generally an arboreal species, orangutans travel significant distances on the ground, even in their natural habitats (Ancrenaz et al., 2014; Spehar et al., 2018).

Threats to orangutans and their habitats, notably land-cover changes and conflicts with humans, are taking place across the species' ranges (Abram et al., 2015; Voigt et al., 2022; Voigt et al., 2018). People increasingly report that orangutans are in or near farms, gardens, plantations, infrastructure developments, and other human-use areas (Schreer, 2023; Simangunsong, 2022). Removing these individuals by translocating or killing them increases population fragmentation and jeopardizes viability of the metapopulation (Ancrenaz et al., 2021; Oram et al., 2022; Seaman et al., 2024). A recent modeling analysis by Seaman et al. (2024) found that removing even very small numbers of orangutans through translocation or killing had marked negative effects on population viability. Rates of orangutan offtake by killing or capture and removal from translocation totaling 2% of the species population were projected to lead to long-term population declines averaging 76% over 250 years, while rates of 4% or higher were projected to cause functional extinction (Seaman et al., 2024). Similarly, an orangutan population viability analysis found that human-caused mortality affecting 1% of the species population would drive population extirpation in sub-optimal habitats, with even slightly higher mortality driving extirpation in higher quality habitats (Marshall et al., 2009). To better understand the effects of capturing and removing individuals from wild orangutan populations, we examined orangutan wild-to-wild translocations in light of current understanding of their socioecology, as well as threats and conservation management. Although our data on orangutan translocations are incomplete, public attention to the species and activities affecting its conservation have resulted in a large body of information compared to that available for wild-to-wild translocations of many other taxa. This case study thus adds to the body of knowledge on the uses and outcomes of wild-to-wild translocation and presents methods that can be adapted to assess translocation impacts for a broad range of taxa.

To assess the effects and better evaluate the necessity of translocations, we collected data on and reviewed circumstances of wild-to-wild translocations of the three Critically Endangered species of orangutans (*Pongo* spp.) in Indonesia. We investigated the following questions: 1) what were the age, sex and physical condition of the individuals captured, 2) were captured individuals translocated, and if so, where to, 3) what habitat types were orangutans encountered and captured in, and what were the conditions that led to the perceived need for translocation, 4) was deforestation related to perceived need for translocation and did deforestation change following translocations, and 5) what were the outcomes for species conservation and welfare. This study investigates orangutan wild-to-wild translocation of all three species using primarily public data combined with input from practitioners and a replicable mapping approach to consider landscape changes. We provide decision-making recommendations to prevent unnecessary and potentially harmful wild-to-wild translocations. Our findings point to the urgent need to better monitor, evaluate and manage wild-to-wild translocations to mitigate negative impacts to species and habitats. The process and recommendations herein can be applied to many other species that co-exist with humans.

**Methods**

We collected data on orangutans captured for wild-to-wild translocation between 2005 and 2022 in Kalimantan and Sumatra, Indonesia, from published sources (including scientific articles, newspaper articles, annual reports, grant reports, news blogs, charity commission reports, and conference presentations), unpublished sources, and direct communications with translocation practitioners and orangutan researchers (Table S1). We communicated with 54 practitioners and asked about their experiences with wild-to-wild translocations, the circumstances in which they captured and translocated orangutans, the factors that went into these decisions, and their views on expectations of the local communities and land managers they worked with. Sources of information on specific instances are generally not cited here to maintain confidentiality. Orangutan translocations in Sabah and Sarawak, Malaysia, are not included due to lack of available data.

We used the metric of 'wild orangutans captured for translocation' because not all captures resulted in translocation and, although rare, some wild individuals were captured expressly to provide medical care. After captures for translocation, some animals were not released because they died or were not suitable for release due to physical impairment, disease, or lack of appropriate release sites. In other cases, whether and where individuals were released was unreported or unclear. Our dataset underestimates the total number of orangutans captured from the wild for translocation because it includes only captures that could be confirmed as unique instances, so that each capture was counted only once. Many wild-to-wild translocations are not publicly reported (Sherman et al., 2020) because this action is considered sensitive by either practitioners or government entities. For example, we found no published records of wild-to-wild translocations in any province of Sumatra between 2005 and 2011, although given subsequent translocation rates, it is highly unlikely that no orangutans were translocated during these years.

For each capture instance, we collated all available information on the number of orangutans, their age, sex, and physical condition, the location where they were captured, reasons for capture, information about the individual orangutan's history plus human activities in the area, whether they were translocated and when, and the release location. Capture records usually highlighted any injuries or illness, thus we assumed animals were healthy unless otherwise noted. Trends in the annual numbers of orangutans captured for translocation were assessed using the Mann-Kendall trend test (McLeod, 2022), with serial autocorrelation in annual numbers checked using the Ljung box test (Lemon, 2006). Both tests were run in R (R Core Team, 2023).

We calculated estimated numbers of individuals removed from wild orangutan populations through captures for translocation. We compiled available data on population changes disaggregated by species, geographic and administrative boundaries. Mean annual rates of orangutan population change were calculated by averaging the annual declines shown by survey estimates and modeling projections in Santika et al. (2017), Voigt et al. (2018), Wich et al. (2016), and Utami-Atmoko et al. (2017) (Table S2). Although lack of precise location data for most captures prevents analysis of impacts to most local populations, localized effects were explored through analysis of captures within village administrative boundaries (*desa*) across the orangutan distribution. Village location data were available for 53% of the captures reported (n = 528 of 988). We also analyzed captures of Tapanuli orangutans to look at species-level effects. Standard deviations and confidence intervals for mean population estimates and annual translocation rates were generated in R (R Core Team, 2023). We estimated mortality rates from killing of each orangutan species using data on killings detected from 2007 to 2019 at likely wildlife crime detection rates of 1.2–10% per Sherman et al. (2022).

Global navigation satellite system (GNSS) coordinates are usually collected at locations where orangutans are captured for translocation, and at the locations they are translocated to, but these coordinates are not always reported publicly. Coordinates were available for 104 (10.5%) of capture records during the study period. Notably, the GNSS coordinates may not be indicative of the precise location at which an orangutan was foraging or living. The individual may have been encountered while it was traveling or been driven away from its original location by human actions, or the recorded point may have been a meeting point or key landmark to enable authorities and translocation practitioners to find the location (F. Oram, unpublished data). Translocation release site coordinates were available for only 47 captured orangutans (4.8% of capture records).

We mapped the 104 captures with GNSS coordinates to investigate how multiple captures might affect local populations and metapopulations. We assessed the habitat context of captures by quantifying forest cover changes between 1999 and 2020 around the recorded capture sites. We used the tropical moist forest, degraded forest, and forest regrowth classes from the annual change collection from Vancutsem et al. (2021) at https://forobs.jrc.ec.europa.eu/TMF/explorer, and extracted them in a 5-km circular zone around the capture coordinates. This 5-km buffer is based on the minimum distances orangutans are known to travel through plantations and other human-altered landscapes (M. Ancrenaz, unpublished data; Ancrenaz et al., 2015; Ancrenaz et al., 2021; Seaman et al., 2024). We extracted annual forest cover and loss within the buffer and used a Generalized Linear Model (GLM) framework to examine the influence of forest loss on the likelihood of capture events in subsequent years in and around sites where orangutans were captured. Given the high correlation (correlation coefficient > 0.7) between the percentage of intact forest loss one to four years prior, we limited our analysis to evaluating the influence of forest losses that occurred one and five years before the capture events. For captures between 2005 and 2017, we also looked at forest cover changes within five years after capture.

We exemplified translocation circumstances and habitat changes in the 5-km buffer for nine orangutan capture sites (five in Sumatra, and four in Borneo). These nine sites were selected based on availability of capture coordinate data and details on capture circumstances for each of the three orangutan species. For distance from orangutan capture location to release location, we used R (R Core Team, 2023) and sf package (Pebesma & Bivand, 2023; Pebesma., 2018) to measure the shortest distance between GNSS coordinates. For records without precise coordinates that had information on village administrative unit or protected area, we used the centroid of the boundaries.

## Results

### *Age, sex, and physical condition*

We found that at least 988 wild orangutans were captured for translocation in Indonesia between 2005 and 2022 (Figure 1). Sex and estimated age data were available for 693 of these 988 orangutans: 58% (404 individuals) were adults 15 years or older; 43.6% of these adults were female and 53.7% were male, while sex was not reported for 2.7% of the adults (11 individuals). Even elderly animals were captured and translocated: at least 96 individuals (24%) were estimated to be 25 years or older, with the oldest being a 60-year-old male captured and translocated to an unfamiliar habitat. Age data were not exact: 269 individuals were reported simply as belonging to an age category (infant, juvenile, adolescent, or adult), but the years encompassed by these categories were not provided.

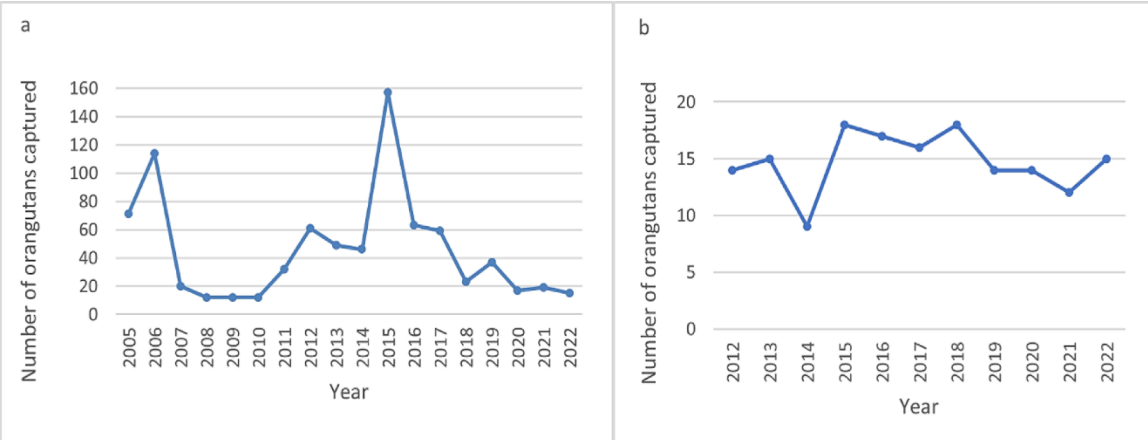


**Figure 1. Number of wild orangutans reported captured for translocations:** a) in Kalimantan between 2005 and 2022, and b) in Sumatra between 2012 and **2022.** No data were available on wild orangutans captured for translocations in Sumatra between 2005 and 2011, hence these years are excluded. Data were collected from published and unpublished sources including newspaper reports, orangutan rescue center news blogs, annual reports, charity commission reports, and social media posts. Any potentially duplicate records were excluded so each capture is only counted once.

Reported translocations included instances where dependent immatures (orangutans six years or younger, generally) were translocated to unfamiliar habitats without their mothers. This was typically because the mothers could not be captured or had been killed, and the immature's behavior was considered "wild" and thus deemed suitable for translocation. The frequency of such translocations is unknown, due to a lack of data on individuals seen traveling together at the time of capture. Older immature orangutans and adult females traveling together have also been separated by translocations.

Data on the orangutans' physical condition at time of capture were available for 808 of the 988 individuals captured during the study period. Of these, 660 (81.7%) were recorded as healthy, while 109 (13.5%) were reported to be ill or injured, although in some cases injuries were considered minor and not requiring veterinary care. Twenty (2.5%) orangutans captured were assessed by veterinary personnel as starving or emaciated, and another 19 (2.3%) were considered malnourished to some degree, although it is unclear whether their body condition was outside the normal range of seasonal weight variation.

### *Translocation*

Our dataset included  information on whether the individual was translocated and on the capture and/or release site locations for 268 (27%) of the 988 captured orangutans recorded in our dataset. Of these 268 captured orangutans, only 23.1 % (n = 62) were translocated immediately after capture (i.e., without being taken into a captive facility, although generally after being examined in the field by a veterinarian). Nearly half (49.2%, n = 132) were taken into a captive facility for care: 11.9% of the 268 orangutans (n = 32) were in care for less than six months and were subsequently translocated, 33.2% (n = 89) were in captive facilities for at least six months and up to four years prior to translocation, and 4.1% (n = 11) were still in care at the time when data were recorded. Six individuals (2.2%) died following capture, most from human-inflicted injuries sustained prior to capture (n = 4), while for two others a reason was not reported.  Data were absent or unclear for 68 of the orangutans (25.4%), and we thus could not confirm their status following capture.

For 79 capture instances involving 86 orangutans (8.7% of the 988 captured), we had sufficient information on both capture and release site locations to analyze distance to release site (Table S2). Capture and/or release coordinates were missing for 46% of the 86 orangutans, hence for these instances distance was inferred using the centroids from a village administrative unit or a protected area. Most wild translocated orangutans (89.5%, n = 77) were moved more than 10 km from the capture site, while only 5.8% (n = 5) were released within 5 km of their capture location (Table S2). Nearly a quarter (23.3%, n = 20) were released more than 50 km from their capture location. The longest distance translocations involved moving orangutans to sites outside current species distribution where there are reintroduced populations of orangutans, relocations of 282-706 km from their capture habitats. Median distances in Kalimantan (median = 47.5 km, SD = 25.5 km, max = 98.2 km, n = 28), where orangutan populations are distributed over a larger geographical area, were much longer than those in Sumatra (median = 13.6, SD = 116.3, max = 706.4 km, n = 50).

### *Capture habitats and circumstances*

Detailed capture records and consultation with practitioners indicated that translocation of wild orangutans generally begins with reports of orangutans seen in or near crops, villages or other infrastructure, or in forest patches or other ‘unexpected’ locations, where authorities or land managers assume they pose a risk of conflict, leading to calls for their removal. The process leading to captures was not detailed for most instances, but we found 99 captures that described local residents or land managers reporting the orangutan to authorities or NGOs.

We found records for 743 captures (75% of all instances in our dataset) with some information on the reason for capture (Table 1). Many captures were associated with multiple confounding circumstances, such as crop foraging that may have been driven by local deforestation, conflict with humans, or forest fires. Data on these potentially confounding factors were rarely available. We recorded the main proximate cause for capture, namely the primary reason someone was alerted to the presence of an animal or asked for it to be removed. For example, if the orangutan was found in a plantation, its presence there was recorded as the reason for capture, regardless of the factors that may have contributed to the animal's presence in the area.

**Table 1. Reported reasons for capture of wild orangutans for translocation in Kalimantan and Sumatra, 2005–2022.** Information on reason for capture was available for 743 of the total 988 captures. The other 245 captures (26% of 988) are excluded from the table, as reason for capture was unknown. The percentages in the table are of the 743 captures for which relevant data were available. We recorded the primary, proximate reason the animal was captured, namely why someone was alerted to the presence of an orangutan or why they asked for it to be translocated. The underlying reasons for an orangutan's presence in any particular location can be due to multiple factors such as availability of foods, intraspecific interactions, forest fires, and anthropogenic habitat changes, but lack of available data precludes a comprehensive analysis of these additional drivers.

| Primary reason for capture | Number of orangutans captured | % of orangutans captured (n=743) |
|---|---|---|
| **In or near crops and tree plantations** | **513** | **69.0%** |
| Seen in food crops or tree plantations | 218 | 29.3% |
| Seen in "area" of crops (reported as near or adjacent to but not in cropland) | 247 | 33.2% |
| Observed, reported, or assumed crop foraging | 48 | 6.5% |
| **Seen outside large contiguous forests or arboreal habitats** | **132** | **17.8%** |
| Seen in a forest patch or other "isolated" area | 107 | 14.4% |
| Seen in a forest considered unsafe/at risk | 22 | 3.0% |
| Seen on the ground | 3 | 0.4% |
| **Seen in or around villages** | **29** | **3.9%** |
| **Mining and infrastructure** | **11** | **1.4%** |
| Seen on or near roads | 6 | 0.8% |
| Seen near power plants, factories, other infrastructure | 4 | 0.5% |
| Seen in or near coal mining concession | 1 | 0.1% |
| **Medical or safety interventions** | **30** | **4.0%** |
| Medical intervention- injured or ill from unknown cause or by conspecifics/other wildlife | 13 | 1.7% |

| | | |
|---|---|---|
| Attacked, restrained, or harassed by humans | 17 | 2.3% |
| **Forest fires** | **17** | **2.3%** |
| **Other conflicts** | **5** | **0.7%** |
| Unspecified conflict with humans | 3 | 0.4% |
| In conflict with other orangutans | 2 | 0.3% |
| **Other reasons** | **6** | **0.8%** |
| Captured by plantation workers or villagers and brought to sanctuary | 4 | 0.5% |
| Orphaned or assumed orphaned | 2 | 0.3% |

Most captures (69% of 743 with relevant data) were initiated as a result of orangutan crop foraging, presence in, or proximity to plantations, gardens, or farms. The second-most common reason was to translocate orangutans considered isolated, stranded, or at risk when seen on the ground or outside of large contiguous forests in smaller fragmented forests, forest patches, or other "isolated" sites (17.8%). Rescue from active forest fires as the primary motive for capture, as opposed to the animal foraging or being reported in crops potentially as a result of forest fires, described 2.3% of captures (Table 1). However, forest fires may be a driver of increased orangutan crop foraging and presence in croplands, villages, and other perceived unsuitable locations; 127 of the 743 captures (17%) mentioned forest fires, even if they were not the primary reason for capture.

Orangutans were captured in or adjacent to natural forests, and in areas 5 km or more from intact forest and forest patches (Tables S3). When previously released orangutans were recaptured, it was often from their original capture site. Analysis of forest cover changes in a 5-km buffer around capture sites for a subsample of 104 orangutans (five in Kalimantan and 99 in Sumatra) with GNSS data showed that the majority were removed from areas that did not have high losses of intact tropical moist forest cover in the year prior to capture (Figure 2). Median intact tropical forest cover loss in the year prior to capture was 3%. Five percent of the sites had intact forest losses of 25% or higher in the year prior to capture. None lost more than 35%. The GLM using forest losses one year prior to capture events was not significantly associated with the likelihood of a capture event compared to the null model including only the intercept (likelihood ratio test, $\chi2 = 0.031$, df = 1, p = 0.86). Conversely, the GLM incorporating losses of intact forests five years prior to capture events was associated with significant likelihood of a capture event in a given year compared to the null model (likelihood ratio test, $\chi2 = 5.034$, df = 1, p = 0.0249), with a slight positive correlation between the percentage of intact forest loss and the probability of a rescue event (coefficient value: 0.01130, p-value: 0.023).

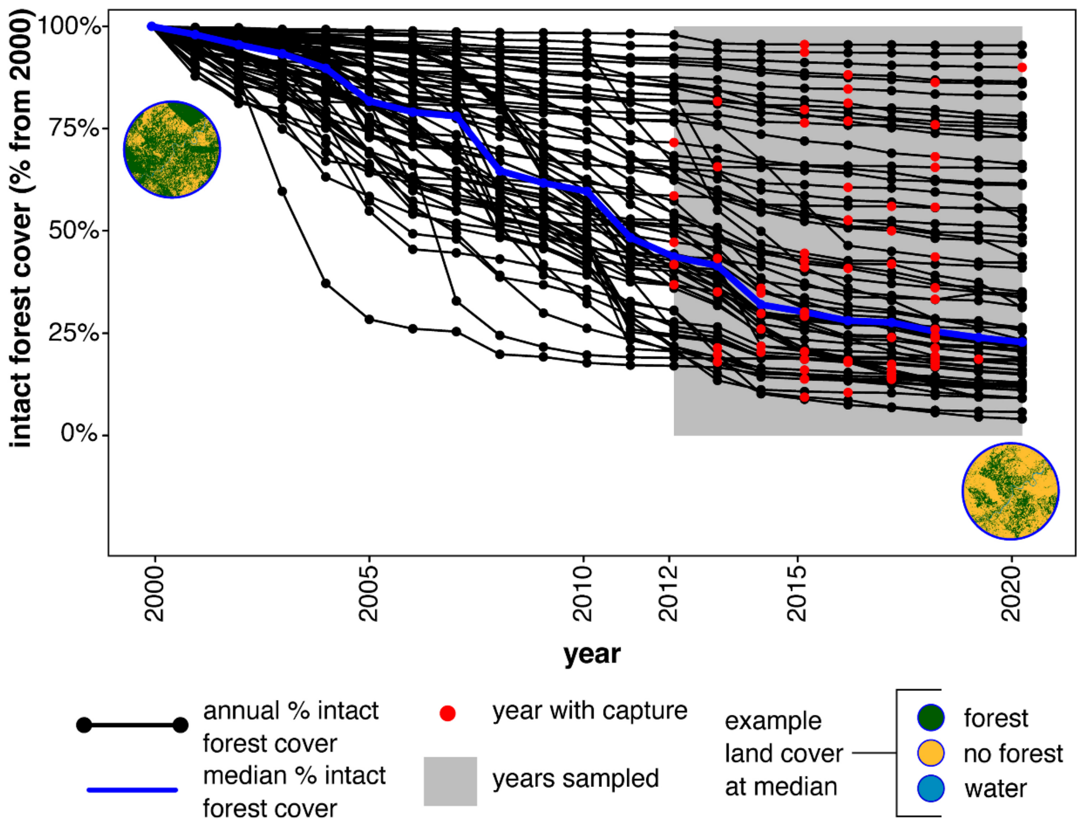


**Figure 2. Percentage intact tropical moist forest from 2000 to 2020 around orangutan capture sites.** Percentage annual intact tropical moist forest cover (black dots) between 2000 and 2020 was derived from Vancutsem et al. (2021). Annual tropical moist forest layer (at 30 m) and calculated within a 5 km buffer around the capture location (n = 104) is in comparison to cover in 2000. Red dots indicate the years in which wild orangutan captures for translocation took place. Grey shading indicates years where capture data is available. Absence of data does not indicate absence of translocation. The blue line is the median percentage forest cover across all capture points (GNSS coordinates). Land cover in the circles represents an example configuration at a location with percentage forest cover in 2020 at the median forest cover. Intact and degraded tropical moist forest and regrowth were combined into a single forest class (green). Remaining areas are either not forested (yellow) or water (blue). Source for forest cover: EC JRC.

For captures between 2005 and 2017 (n = 53), we assessed forest loss within a 5-km buffer over a five-year period post-capture. The median loss of intact forest across sites was 20% (SD 17%), with individual site losses ranging from 0% to 72%. However, due to data limitations, it was not possible to differentiate this loss from the background rates of deforestation in the study area.

To better understand the circumstances of translocations, we reviewed all available information about nine capture sites (five in Sumatra and four in Borneo), and mapped forest cover around these sites using a 5-km buffer (Figures S1 and S2). Maps of two sites are presented in Figures 3 and 4. At Site 1 (Figure 3), two healthy male Sumatran orangutans, one adult and one juvenile, were captured and translocated. At Site 2 (Figure 4), a healthy Bornean adult female and infant were captured and translocated.

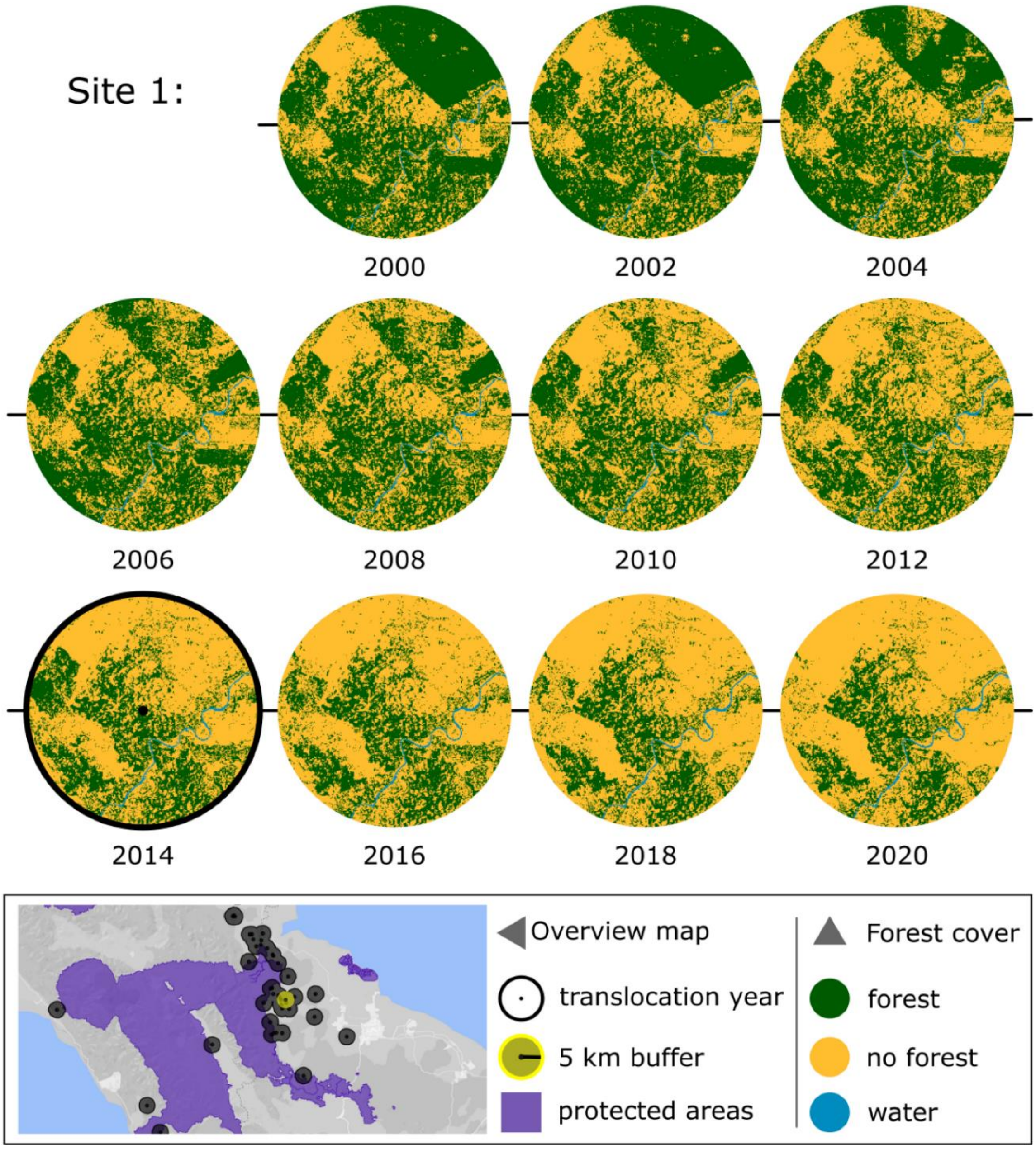


**Figure 3. Forest change in area surrounding orangutan capture for translocation site 1**. A breeding population of healthy Sumatran orangutans was using a smallholder oil palm and rubber plantation for several years; at the request of the owner to remove seven orangutans, an adult male and a juvenile male were captured and translocated, while an adult female was left on site after unsuccessful capture attempts. Year of capture (2014) is indicated with thick black bordered circle. Intact tropical moist forest, degraded tropical moist forest, and regrowth are combined into a single forest class (green). The map inset at the bottom is the location of the specific capture site and buffer (yellow) along with remaining locations where 97 other orangutans were captured for translocation (black). Basemap: Google Earth Engine. Forest map: EC JRC. Protected areas (purple): UNEP-WCMC and IUCN (2023).

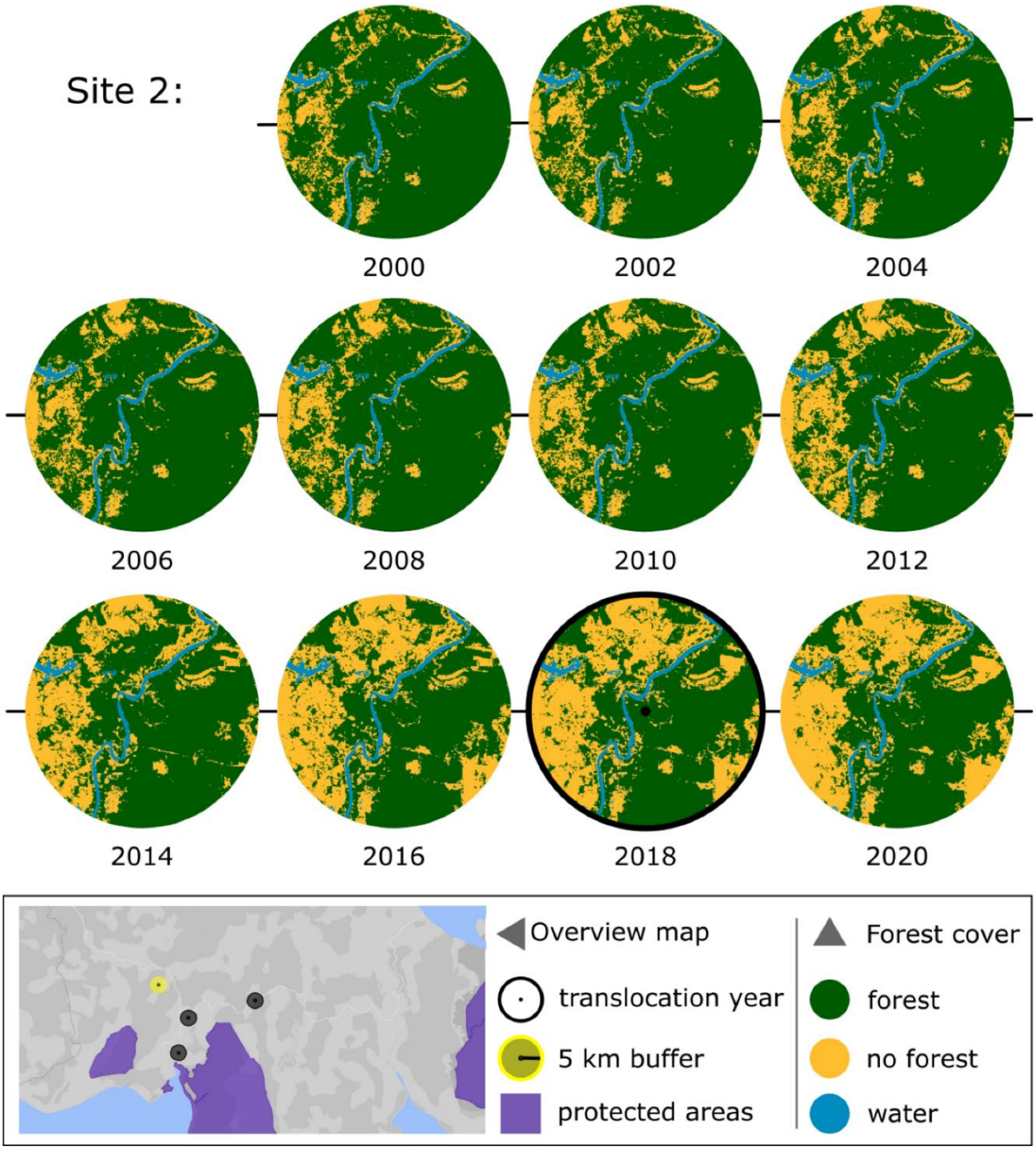


**Figure 4. Forest change in area surrounding orangutan capture for translocation site 2.** Healthy Bornean adult female and infant that were reported seen in a community rubber plantation and captured for translocation. Year of capture (2018) is indicated with thick black bordered circle. Intact tropical moist forest, degraded tropical moist forest, and regrowth are combined into a single forest class (green). The map inset at the bottom is the location of the specific capture site and buffer (yellow) along with remaining locations where three other orangutans were captured for translocation (black)—one additional orangutan was captured for translocation in an area of Kalimantan outside this map. Basemap: Google Earth Engine. Forest map: EC JRC. Protected areas (purple): UNEP-WCMC and IUCN (2023).

Maps of the remaining seven sites are presented in Supplementary Figures S3-S9. At Site 3 (Figure S3), a previously translocated, healthy Tapanuli adult male was recaptured and translocated. At Site 4 (Figure S4), an injured adult male Sumatran orangutan was captured at the edge of a protected forest. At Site 5 (Figure S5), a healthy female found traveling with an adolescent was translocated and the adolescent left on site without her; a second healthy adult female was translocated later. At Site 6 (Figure S6), a seriously injured adult male Tapanuli orangutan was rescued but died shortly thereafter. At Site 7 (Figure S7), a gravely injured juvenile male Bornean orangutan was rescued but died soon after. At Site 8 (Figure S8), a healthy adult male Bornean orangutan was captured and translocated for "disturbing" a durian garden. At Site 9 (Figure S9), a healthy adult male Bornean orangutan reported near a power plant and uninsulated electrical wires was translocated.

Analysis of the nine sites we selected showed the orangutan capture locations were in intact forest, forest patches, degraded forest, or within 5 km of these forests (Figures 3-4 and S3-S9). At six of the nine sites (67%), the orangutans were not at immediate risk from deforestation. In sites 1, 4 and 5, forest within 5 km around translocation site was cleared or degraded two to four years after the orangutans were removed. In sites 4, 6, and 7, the orangutans were at immediate risk of death due to injuries caused by humans (not directly related to forest loss), and no alternative to translocation was immediately available to protect their lives or health.

***Translocation rates***

On average, 46 (SD ± 39) orangutans were reported captured annually for translocation in Kalimantan, and 15 in Sumatra (SD ± 3). Annual reported translocation numbers did not show an increasing or declining trend during the study period in Kalimantan (tau = –0.11, 2-sided p value = 0.57) or Sumatra (tau = –0.08, 2-sided p value = 0.81). High variance in Kalimantan translocation numbers compared to Sumatra likely reflects peaks associated with events that impacted Kalimantan habitats, notably forest clearing for agricultural expansion in 2005–2007, and in the record fire years of 2015–2016 (Figure 1). The number of captures reported since 2018 was high in both Kalimantan and Sumatra, with 30–51 animals captured annually in both combined (Figure 1).

The annual number of orangutans removed through the wild-to-wild translocations reported here represented less than 1% of each orangutan species (Table 2). However, annual removals for translocation compound the annual population declines of 3.14% for Bornean (*P. pygmaeus*) orangutans across Kalimantan, and 2.17% for Sumatran (*P. abelii*) and Tapanuli orangutans combined (Table 2). Captured individuals that were taken into captive care prior to translocation or were not translocated (a combined total of approximately 77% of the recorded captures in our dataset) are lost to the wild population at least for the short term. Furthermore, the annual removal rate from wild-to-wild translocation we calculated is likely an underestimate due to probable underreporting of translocation events as well as illegal orangutan killing and capture offtake, which evidence suggests remains high (Massingham et al., 2023; Meijaard et al., 2011; Sherman et al., 2022). Mean estimated killing combined with reported translocation removals was calculated to have removed 3.30% (SD ± 2.61%) of orangutans in Kalimantan, and 11.63% (SD ± 9.49) of orangutans in Sumatra (Table 3). In Kalimantan, this summed estimate approaches the 4% offtake predicted to result in functional species extinction within 75–100 years (Seaman et al., 2024). Likewise, the summed estimated offtake and translocations in Sumatra exceed the 2% threshold Seaman et al. (2024) projected would cause a 76% population decline over 250 years (Table 3, S4).

**Table 2. Mean annual translocation removals as a percent of population size.** Mean annual species and provincial population estimates were calculated from Santika et al. (2017), Utami-Atmoko et al. (2017); Voigt et al. (2018), and Wich et al. (2016) (see Table S4 for details). Translocation removals are individuals captured from the wild for translocation but not immediately released into another wild population.

| | | Population impacts of removals for translocation 2005-2022 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Island** | **Area/species** | **Mean current population size**[1] | **Mean annual % decline**[1] | **Total reported translocations**[2] | **Total reported translocation as % of mean population** | **Mean annual translocations** | **% Mean population translocated annually** | **Mean annual decline + translocation removals**[3,4,5] |
| Borneo | Borneo (*Pongo pygmaeus*) | 83,575 | 3.14% | 829 | 1.00% | 46 (SD ±39) | 0.06% | 3.18% |
| Borneo | Central Kalimantan | 47,512 | 2.54% | 550 | 1.16% | 31 (SD ±36) | 0.06% | 2.58% |
| Borneo | East Kalimantan | 14,091 | 2.05% | 176 | 1.25% | 10 (SD ±9) | 0.07% | 2.10% |
| Borneo | West Kalimantan | 25,079 | 2.87% | 103 | 0.41% | 6 (SD ±6) | 0.03% | 2.89% |
| Sumatra | Sumatra (*P. abelii* & *P. tapanuliensis*) | 11,861 | 2.17% | 162 | 1.37% | 15 (SD ±3) | 0.13% | 2.27% |
| Sumatra | *Pongo abelii*[6] | 11,760 | - | 155 | 1.32% | 14 (SD ±3) | 0.12% | - |
| Sumatra | *Pongo tapanuliensis*[6] | 767 | - | 7 | 0.91% | 1 (SD ±1) | 0.13% | - |

1. Mean annual population estimates were calculated from Santika et al. (2017), Utami-Atmoko et al. (2017); Voigt et al. (2018), and Wich et al. (2016) (see Table S4 for details). Borneo population estimates are from 1999-2019 (Santika et al., 2017; Utami-Atmoko et al., 2017; Voigt et al., 2018). Sumatra population estimates are from 2010-2014 (Wich et al., 2016).
2. These numbers are an underestimate of total wild-to-wild translocations as not all translocations are reported, and not all records were available to the authors. Translocations shown for Sumatra are from 2012-2022; no data were available on translocations prior to this range.
3. Orangutan population estimates are based on available survey data, which are primarily from large metapopulations and protected areas, and modelled based on biophysical and threat predictors of orangutan abundance, and thus are not expected to account for movements of individual orangutans through wild-to-wild translocation.
4. Over time, annual offtake and translocation removals of more than 1% in additional to natural mortality is expected to drive orangutan populations to extinction in suboptimal habitats (Marshall et al., 2009), and is predicted to result in approximately 75% population decline at 2% or higher and to lead to functional extinction of populations at 4% or higher (Seaman et al., 2024).
5. % Mean population translocated was reduced by 23% to account for the estimated percentage of individuals immediately released into another wild population (Table S4) and assumed to survive, and thus not considered removed from the area/species population.
6. We did not calculate mean annual percent declines for Sumatran and Tapanuli orangutan species because published species-specific population numbers since 2016 were not available at time of writing

**Table 3. Impact of reported translocation removals and estimated killing offtake.** Orangutan killing estimates are calculated from the mean, minimum, and maximum rates in Meijaard et al. (2011) and crime detection rates of 1.2%–10% from Sherman et al. (2022).

1. Mean annual population estimates for Borneo population for 1999–2019 were calculated from Santika et al. (2017), Utami-Atmoko et al. (2017); Voigt et al. (2018), and Wich et al. (2016) (see Table S4 for details).
2. Mean annual population estimates for Sumatra for 2010-2014 were calculated from Wich et al. (2016) (see Table S4 for details).

| Island | Area/ species | Population size | Total trans-locations reported | Annual translocations (%)[3] | Killing estimates | Annual killing offtake (%) | Killing and trans-location removals (%)[6] | Source |
|---|---|---|---|---|---|---|---|---|
| Borneo | Kalimantan (*P. pygmaeus*) | 83,575[1] | 829 | 46 (0.06%)[4] | Mean annual | 2,540 (3.04%) | 3.08% | Meijaard et al. 2011 |
| | | | | | Minimum annual | 2,383 (2.85%) | 2.89% | |
| | | | | | Maximum annual | 3,882 (4.64%) | 4.68% | |
| | | | | | Minimum annual over lifetime | 630 (0.75%) | 0.80% | |
| | | | | | Maximum annual over lifetime | 1,357 (1.62%) | 1.67% | |
| | | | | | Mean at 1.2% detection rate | 8,232 (9.85%) | 9.90% | Sherman et al. 2022 |
| | | | | | Mean at 3.2% detection rate | 3,084 (3.69%) | 3.74% | |
| | | | | | Mean at 6.2% detection rate | 1,387 (1.66%) | 1.71% | |
| | | | | | Mean at 10% detection rate | 986 (1.18%) | 1.23% | |
| Sumatra | *P. abelii* & *P. tapanuliensis* | 11,861[2] | 162 | 15 (0.13%)[5] | Mean at 1.2% detection rate | 3,250 (27.40%) | 27.45% | Sherman et al. 2022 |
| | | | | | Mean at 3.2% detection rate | 1,222 (10.30%) | 10.35% | |
| | | | | | Mean at 6.2% detection rate | 629 (5.30%) | 5.35% | |
| | | | | | Mean at 10% detection rate | 391 (3.30%) | 3.35% | |

3. Numbers are an underestimate of total wild-to-wild translocations as not all translocations are reported, and not all records were available to the authors.
4. Translocations shown for Borneo are from 2005-2022. Mean annual translocation removal is equal to the total reported translocations/18 years.
5. Translocations shown for Sumatra are from 2012-2022; no data were available on translocations prior to this range. Mean annual translocation removals is equal to total reported translocations/11 years.
6. % Contribution of translocation removals was reduced by 23% to account for the estimated percentage of individuals immediately released into another wild population (Table S4) and assumed to survive, and thus not considered removed from the area/species population.

These estimated overall offtake and translocation removal rates are for the entire orangutan populations in Indonesian Borneo and Sumatra, but as the threats and rates of population decline vary among specific populations (Santika et al., 2022), the percentage for some populations would be much higher than the average shown here. Translocation removals did appear to pose higher risks in small or dispersed populations and may affect metapopulation function through the removal of breeding age individuals from local populations. Translocation rates appeared to pose a particularly high risk to the Tapanuli species, given their small population size. Tapanuli orangutans occupy a small, relic range (Meijaard et al., 2021) with considerable anthropogenic habitat changes and increasing human-orangutan conflicts (Jong & Simangunsong, 2023). The average of one animal per year removed through translocation during the study period represented 0.13% of the total estimated remaining species population (Table 2). Similarly, translocation removals appear to have more marked effects on dispersed populations and subpopulations for all species. A subsample of 528 captures with information on the village administrative unit (*desa*) location showed 11 *desa* (three in Sumatra and eight in Kalimantan) that each had at least seven orangutans captured and removed during the 2005–2022 study period (Table S5). Six of these *desa* had 15 or more individuals captured for translocation, the majority of which were adult (breeding age) females and males (Table S5). The largest translocation was 106 individuals removed from a single *desa* in Kalimantan, with 105 of them removed over a four-year period. The rationale for removing what was effectively an entire population of 105 individuals was that the habitat was fragmented and there were risks of further fragmentation and fire. In this *desa* (Tumbang Mangkutup, Table S5) 14,055 ha of forest (43%) were lost in the year following removal of 76 orangutans in 2015 per Nusantara Atlas (Nusantara Atlas, 2021). Forest losses in the year preceding the translocations totaled 695 ha, and were minimal in the years after 2016 (94 ha in 2018, and zero or a few hectares in all other years after 2016) (Nusantara Atlas, 2021).

Many reproductively valuable males and resident breeding females have been translocated away from fragmented forests and forest patches in unprotected areas and Figures 3-4 and S3-S9 indicate that these translocations have broken up dispersed genetic clusters. Some areas may have been largely emptied of orangutans in response to repeated requests from communities, industry or government agencies for animals to be removed from their properties or crops (see Table S5).

### *Post-release survival*

Translocated wild orangutans were rarely monitored, either not at all or only for a few days to a week post-release, due to the practical difficulties of following them. They are not typically given radio-tracking implants, which require surgery and recovery time in a medical facility (Robins et al., 2013). Consequently, only one small sample of survival data was available, which showed that for 21 individuals released over a two-year period, 14 orangutans were encountered over the course of 10 monthly monitoring surveys. This information is difficult to interpret as it does not include information on presence or population size of conspecifics in the release area, and it is not known how long after release any of the individuals were sighted. Communications with practitioners during this study did not yield any further evidence on survival of released individuals or overall survival rates across the wild-to-wild translocations they conducted. Thus, overall survival rate of orangutans wild-to-wild translocated in Indonesia since 2005 is unknown.

### *Welfare outcomes*

Videos and written reports of captures for translocation show orangutans that were being pursued displaying signs of extreme stress, including fleeing, screaming, and ultimately defensive aggression towards humans when approached and during capture. One captured orangutan was reported to have a dangerously high body temperature. Although this individual appeared to recover, it is not known how he fared after translocation. One set of records on 166 orangutans wild-to-wild translocated from oil palm plantations shows that 19 (11%) died during or shortly after capture, although at least one orangutan that died had been previously injured by humans. A few reported cases described orangutans being chased and darted with anaesthetic and then ultimately not captured and translocated, although we do not know how common this is. Welfare risks to the animals increase if they are already in physical stress (such as being malnourished, dehydrated, or pregnant, all of which have been recorded in captured orangutans), and with each capture or recapture attempt and each translocation.

Wild-to-wild translocated orangutans were recorded returning to the areas they were captured from or traveling to other areas with human food crops. Overall prevalence of recaptures is not known due to lack of consistent data on identity of captured individuals, but a study analyzing data from one year (March 15, 2020–March 14, 2021) showed that 31% of the 26 wild-to-wild orangutan translocations recorded were recaptures of previously captured and translocated orangutans (Sherman et al., 2021). This includes a female Sumatran orangutan who was captured translocated at least five times (KSDAE, 2020), and a flanged male Tapanuli orangutan captured and translocated twice (Gunawan, 2019, 2020).

**Discussion**

Data on wild-to-wild translocation of orangutans in Indonesia between 2005 and 2022 highlight the urgent need to carefully weigh the perceived necessity for each capture and translocation, as they likely have deleterious effects on orangutan populations and metapopulations, and often on individual orangutans. The probability of the individuals and populations surviving in their original habitat and in identified suitable release habitats should be carefully assessed, with focus on preventing risks to existing wild populations and genetic flow. Whenever wild-to-wild translocation is deemed necessary, it is critical that data on post-release outcomes are collected.

***Age, sex and health status***

Adult males (15 years or older) were the most commonly translocated age and sex class in our dataset. The dispersal and ranging patterns of adult males make them more likely to travel into areas that are less familiar to them and to encounter risks of both conflict with humans and being captured for translocation during their travels. Adult male orangutans exhibit bi-maturism with two distinct developmental phases: they are able to reproduce successfully in both phases, but in the unflanged phase they lack the full complement of the secondary sexual development of the flanged phase, characterized by prominent cheek pads (flanges), increased body size, and a larger laryngeal sac (Kunz et al., 2023). It is natural behavior for unflanged and flanged males to range widely across the landscape, following fruiting cycles and seeking reproductive opportunities, and at times avoiding competition with other males (Nietlisbach et al., 2012; Oram et al., 2022; Utami Atmoko et al., 2009). Because flanged males are aggressive towards each other (Utami Atmoko et al., 2009), translocating them puts them and any resident flanged males at a sudden increased risk of aggression, injury, or death after release. Translocated unflanged males will likely move away from the release area and may return to the area they were removed from or may enter other croplands.

Adult females were the second most commonly translocated age and sex class (n = 176), despite being known to have strong attachment to the sites where they live, and being intolerant of unrelated females (Ashbury et al., 2020; Knott et al., 2008; van Noordwijk, 2009; van Noordwijk et al., 2012). Capturing and moving females to unfamiliar habitats is likely to provoke resident females to be aggressive towards them and potentially exclude them from some food resources (Marzec et al., 2016; van Noordwijk et al., 2012). During periods of low food availability, orangutans have lower tolerance for each other, even for female kin (Ashbury et al., 2022). This could generate significant social stress and render translocated females unable to access adequate food.

Although less common, wild-to-wild translocations that separate dependent infants or immatures traveling with an adult female are a particular concern. Regardless of whether infant orangutans display abilities or behaviors appropriate for wild orangutans, they do not range independently until they are approximately eight years or older (van Noordwijk, 2009). Immature adolescent orangutans below 15 years old travelling with adult females are usually older offspring who continue to range alongside their mother in her matrilineal range while building their ability to range and forage independently (Oram et al., 2022; van Noordwijk & van Schaik, 2005). Separating and translocating these immature orangutans away from their mother, even if they are eight years old or more and traveling separately, means they may not be able to survive or thrive without her.

Evidence from this study does not support the frequently reported claim that adult orangutans seen in plantations or cultivated crops are generally starving or malnourished and in need of rescue, even when they appear to be underweight (Sherman et al., 2020). Orangutans' body weight and condition fluctuate with food availability, and in lean times they lose weight and even catabolize muscle (O'Connell et al., 2021). If translocated, they will almost certainly have a harder time finding sufficient food than if left in habitat they know, particularly if moved to an unfamiliar forest type (Marshall et al., 2021; Vogel et al., 2015) and if they have to compete with resident orangutans. Weakened body condition can make them more vulnerable to disease, and translocating malnourished orangutans would cause them additional strain, further lessening their chances for post-release survival, particularly if they have to find food in an unfamiliar habitat in addition to competing with resident orangutans. Healthy but malnourished orangutans are best left to continue foraging in the area they already know, unless it is physically impossible for them to find sufficient food—for example, if no food sources remain in the vicinity. Orangutans are known to travel at least five kilometers into plantations and other modified landscapes (M.

Ancrenaz, unpublished data; Ancrenaz et al., 2015; Ancrenaz et al., 2021; Seaman et al., 2024).

### *Capture habitats and circumstances*

Large- and small-scale deforestation in forested orangutan strongholds, clearing of forest patches and large trees in fragmented forests and agricultural landscapes, and clearing for mining, hydropower, and infrastructure have collectively resulted in marked reductions in forested orangutan habitats (The Tree Map, 2023; Voigt et al., 2022; Wich et al., 2019). These changes fragment orangutan populations, leaving females residing in dispersed forest patches left after clearing, and males traveling between these patches (Ancrenaz et al., 2021; Oram et al., 2022). These "isolated" orangutans are often assumed to be lost or stranded and doomed to starve unless translocated. Due to lack of empirical evidence on the threats to the orangutan at the capture site and on any interventions made to ameliorate those threats and protect the individual in situ, it was not possible to statistically assess what percentage of the captured orangutans in our dataset would have been in mortal danger had they not been moved. However, mapping of orangutan capture sites indicated that most translocated orangutans could have returned to larger forests on their own, moved to other areas (as is normal behavior for males), or continued living where they were (as is normal behavior for adult females) if undisturbed by humans and if remaining tree cover, including small patches, is left standing. This suggests that many translocations are not directly related to deforestation levels that would be life threatening for orangutans. This is also supported by the lack of significant correlation between recent deforestation and capture likelihood. The positive association we found between likelihood of a capture event and deforestation in the area five years prior could be influenced by increased crop foraging as orangutans modify their foraging habits to accommodate these habitat changes. This also may explain why deforestation one year prior was not significantly associated with capture likelihood—it takes some time for orangutans to start using new types of landscapes (Ancrenaz, unpublished data). Over time we expect to see an increasing number of orangutans foraging or traveling within these multiple-use landscapes. The data also show that deforestation in orangutan habitats is ongoing, which reduces native food availability and drives ever more overlap between orangutans and humans. This underscores the urgency to rethink how wild-to-wild translocation is used: as more orangutans are encountered in plantations, gardens, and multiple-use landscapes across their ranges, using translocation as a default management approach risks widespread negative impacts on local populations and metapopulations.

***Conservation and welfare outcomes***

Translocation is not a long-term solution to address human-orangutan conflicts or to assuage people's concerns over orangutan sightings. Nonetheless, approximately 20% of translocation practitioners we communicated with reported that government authorities required them to move orangutans as the first intervention, rather than attempt to sensitize people to orangutan behaviors and develop strategies to protect the animals in place. Most people who report orangutan sightings want them to be removed (Sherman et al., 2020). To stem the number of risky translocations and prevent negative human-orangutan interactions, it is critical to immediately invest across the orangutan range in simultaneously building realistic expectations of orangutan behavior and deploying strategies that ease immediate risks and inconveniences to humans (e.g., by creating financial benefits from coexistence with orangutans, or other compensatory benefits such as jobs or local services), while also protecting orangutans in situ.

Regardless of perceptions of translocation, orangutans will continue to find their way to appetizing crops even after they have been translocated to other sites. Removing all orangutans that visit crops or human-use areas will result in emptying the metapopulation of resident female clusters and ranging males, dramatically diminishing the genetic fitness and long-term viability of the three species. Furthermore, it would not be logistically and financially feasible to translocate the tens of thousands of orangutans that overlap with human-used lands or live near humans (Meijaard et al., 2017). Releasing so many individuals into existing protected areas with resident orangutan populations, as is commonly happening (Sherman et al., 2020), would cause extreme social disruption and likely result in increased competition for food resources, poorer nutrition, increased social stress, lowered birth rates, poor welfare, and increased mortality for both translocated and resident orangutans.

Orangutan socioecology, and instances of translocated orangutans found killed (Galdikas, 2018) or recaptured (Sherman et al., 2021) suggest that compromised survival and welfare of released individuals may be a common outcome. Although released orangutans are rarely found dead, this absence of data does not necessarily indicate a high likelihood of survival. Few animals are found dead in tropical forests (Park, 2002). Orangutan researchers report that dead orangutans are rarely encountered, even in sites where they are followed daily and studied intensively for decades (Wich, pers. obs.). Furthermore, orangutans are in some cases translocated into remote areas where it is even less likely their bodies would be detected.

Although preventing human-orangutan conflicts and reducing the potential for human killing or injuring of orangutans are common goals of wild-to-wild translocations, it is unclear how well they serve this function as currently applied. Translocation may avoid further injury and eventual death in cases where orangutans are attacked by humans at the capture site, but since translocated animals are rarely monitored, the survival and welfare of the released individuals are mostly unknown. Practitioners commonly noted that people threaten to kill orangutans that crop forage, but often orangutans reported by residents or land managers cannot be found by translocation teams and are thus left on site by default. However, in one published example, one wild-to-wild translocated male was killed after returning to the plantation where he was originally captured (Galdikas, 2018). Thus, wild-to-wild translocations do not necessarily prevent orangutans from being killed or injured by humans. At least 61 (8%) of the 797 orangutans with health data in our dataset had already been harmed by humans at some point, generally with air rifle bullets, and many had multiple recent bullet wounds.

More than 227 wild-to-wild translocated orangutans have been released into sites with viable orangutan populations that do not need supplementation, including Tanjung Puting, Gunung Palung, Kutai, and Gunung Leuser National Parks and the Mawas conservation area (Utami-Atmoko et al., 2017), where their release could provoke social stress and competition for natural resources, and pose disease transmission and genetic risks to resident orangutans (Sherman et al., 2021). In Sumatra, the prevalence of multiple captures in small areas are likely to negatively impact local populations and increase fragmentation of the orangutan metapopulations in these locations (Figure S2).

Sustaining viable metapopulations of orangutans across large landscapes will require engaging local communities and land managers to preserve the remaining forests (including forest fragments) and protect orangutans without resorting to translocation (Ancrenaz et al., 2021; Meijaard et al., 2022; Oram, 2023). We encourage those living or operating in the orangutan range to adopt policies following IUCN SSC Primate Specialist Group guidelines for orangutan wild-to-wild translocation (Sherman et al., 2025). These guidelines follow the precautionary principle, stipulating that where there is insufficient evidence to demonstrate that an action will not harm an individual orangutan's welfare or the conservation of the species, it must then be assumed this action could cause harm, and the action should thus be avoided.

**Recommendations**

We recommend an 'Identify, Monitor, and Protect' approach, explained below, focusing on preventing conflicts and avoiding interventions with wild orangutans except in extraordinary circumstances.

**Identify risk level.**

The first step in cases of habitat encroachment or clearing is to check and enforce any laws and local policies protecting orangutans and orangutan habitat. For areas already impacted by clearing or other human activities, map habitat and forest cover for at least 5 km surrounding the orangutan's location to determine if it could move away on its own. Updated, detailed information on habitat and forest cover can be obtained free of charge from satellite-derived landcover data (e.g., UM and WRI (2021)). If the immediate area is degraded or cleared, but there are forest blocks (large or small) or forest corridors within 5 km, translocation is not necessary. Be sure that human activity including monitoring is not so invasive that it restricts the orangutan's options and ability to move away without intervention.

People or companies actively trying to kill, injure, harass, drive away, or capture orangutans, should first be apprised of the illegality of these actions. Orangutans are fully legally protected in Indonesia and Malaysia, and harm, killing, or capture of orangutans is punishable under existing laws. Governments have the authority, and the responsibility, to enforce these laws if businesses and/or individuals are unwilling to comply. Providing alternative approaches, such as working with relevant parties to preserve natural forest habitat and to find non-lethal ways to address the conflict without translocation will also be vital. Orangutans at risk of being harmed or killed should be monitored from a safe distance (≥50 meters) to discourage defensive action by the animal or further stress or harm to the individuals.

**Monitor orangutans potentially at risk.**

Orangutans appearing underweight or with suspected human injuries should be monitored from ≥ 50 m for at least five days before any decision is made. Keep humans and dogs away, and do not surround the orangutan on all sides. It is often best, especially if the orangutan has no shelter, to leave the area and return to monitor periodically. If the orangutan moves and feeds within the five days, no intervention is needed. Orangutans with serious, human-inflicted injuries should be transferred to specialized rehabilitation centers.

**Protect transient and resident orangutans.**

There are many actions that can be proactively taken to protect orangutans in the spaces they use. The following actions are recommended for orangutan stakeholder communities and sectors:

Landowners and managers and in situ conservation projects can protect orangutans in place by preserving both large intact forests and forest fragments of any size in mixed-use landscapes. Building over-passes and/or aerial bridges for existing roads and other infrastructure will allow safe movement by orangutans. Orangutan rescue centers and conservation groups, in collaboration with social scientists, can conduct outreach designed to improve local understanding about orangutans foraging on cultivated crops even where large forests are available. Rescue centers, businesses, and government can collaborate with local communities to develop suitable coexistence strategies involving regular on-the-ground monitoring and developing understanding and, if necessary, incentives for communities to accept living alongside orangutans, and for local wildlife protection agencies to promote coexistence rather than translocation.

Individual orangutans can be wild-to-wild translocated responsibly when: 1) they are suffering from a serious human-caused injury and have been successfully treated by a veterinarian, or, 2) they have no path to escape from a severe threat in their current location, such as fire or flooding. With the recognition that these situations are indicative of deficits in conservation management, wild-to-wild translocation may be necessary for the following additional welfare reasons: 1) people are trying to harass, capture, or kill an orangutan despite attempts to enforce protection laws, 2) interventions to halt habitat clearing have failed and an orangutan has no path to escape, and 3) orangutan specialists have confirmed reports of unprovoked orangutan attacks on people. In the cases outlined above, orangutans should be translocated to a nearby well-protected forest area, and, if possible, into a community of related orangutans, and monitored post-release.

Wild-to-wild translocation is not suitable for addressing threats to multiple individuals living in the same area, to enable or offset clearing orangutan habitats, or to remove wild orangutans who are merely crossing human-use areas or visiting cultivated crops adjacent to or very near a forest (a few kilometers or less). The priority for effective species conservation is to preserve remaining habitat and protect both resident and transient orangutans in situ. Translocating populations to enable clearing or prevent crop foraging is contrary to the precautionary principle, violates existing laws that protect these Critically Endangered species, reduces natural habitat remaining, and diminishes species recovery potential.

Wild-to-wild translocation is not a long-term solution to most human-wildlife conflicts (IUCN, 2023), and can pose serious risks to the conservation of rare species. The approach outlined here would reduce use of high-risk interventions and promote long-term solutions for human-orangutan coexistence. It could be adapted for application to other species, especially wide-ranging species that are threatened by habitat fragmentation and the potential for interactions with humans in mixed use landscapes. It may become particularly relevant for the African great apes: although wild-to-wild translocation of African apes is extremely rare as of now, increased clearing and fragmentation of their habitats may drive demand for translocation as a means to facilitate development while supposedly “saving” great apes that are ‘in the way’ of planned land uses. However, wild-to-wild translocation could be even more problematic for African apes, which have more complex, less diffuse group structures than orangutans (see for example: Williamson, 2014). It would not serve to resolve underlying conflicts and would involve risks to resident conspecific and sympatric apes that would violate the precautionary principle for great ape translocations.

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## Appendix I Supplementary Information

Data tables on orangutan captures for translocation in Indonesia, 2005 to 2022 are available at https://doi.org/10.1371/journal.pone.0317862.s001.

Table S1, List of data sources is available at: https://doi.org/10.1371/journal.pone.0317862.s002.

**Table S2. Distance from capture site to release area.** Data were available for 86 captured and translocated orangutans. Locations were measured as straight line shortest distance between GNSS coordinates, or, where coordinates were not available, from the centroid of the capture village administrative unit (*desa*) and the centroid of the release area (protected area shape file or *desa*).

| | Distance | Count | % | Median | Standard deviation | Max |
|---|---|---|---|---|---|---|
| **All areas** | 5 km or less | 5 | 5.8% | | | |
| | 6-10 km | 4 | 4.7% | | | |
| | 11-20 km | 22 | 25.6% | | | |
| | 21-35 km | 20 | 23.3% | | | |
| | 36-50 km | 15 | 17.4% | | | |
| | 51-75 km | 5 | 5.8% | | | |
| | 76-100 km | 9 | 10.5% | | | |
| | more than 100 km | 6 | 7% | | | |
| | | | | 30.4 | 90.2 | 706.4 |
| **Kalimantan** | 5 km or less | 0 | 0% | | | |
| | 6-10 km | 0 | 0% | | | |
| | 11-20 km | 1 | 2.8% | | | |
| | 21-35 km | 11 | 30.6% | | | |
| | 36-50 km | 12 | 33.3% | | | |
| | 51-75 km | 3 | 8.3% | | | |
| | 76-100 km | 9 | 25% | | | |
| | >100 km | 0 | 0% | | | |
| | | | | 47.5 | 25.5 | 98.3 |
| **Sumatra** | 5 km or less | 5 | 10% | | | |
| | 6-10 km | 4 | 8% | | | |
| | 11-20 km | 21 | 42% | | | |
| | 21-35 km | 9 | 18% | | | |
| | 36-50 km | 3 | 6% | | | |
| | 51-75 km | 2 | 4% | | | |
| | 76-100 km | 0 | 0% | | | |
| | more than 100 km | 6 | 12% | | | |
| | | | | 13.6 | 116.2 | 706.4 |

**Table S3. Habitat types and crops where orangutans were encountered in Kalimantan and Sumatra, 2005–2022.** Sources: Records of captures for translocation (this study), published literature, and communications with orangutan researchers and translocation practitioners.

| **Habitat description** |
|---|
| Mixed primary and degraded forest |
| Mangrove forest |
| Degraded forest |
| Forest patches isolated from other forest areas |
| Plantations with small fragments of forest, or even just a few tall trees |
| Plantations without forests but near forests and forest fragments |
| Industrial tree plantations |
| Cropland or farms at protected forest edges |
| Cropland or farms with fragmented or isolated forest patches |
| Near villages with fragmented forest patches |
| Agroforest 5 km or more from natural forest patches |
| Boundary areas between forest and plantations, farms, infrastructure, villages, suburban housing, or other human development |
| **Crop types and settings (industrial or small holder plantations/farms)** |
| Banana fruits (*Musa* sp.) - smallholder |
| Coconut palms (Cocos nucifera) - smallholder |
| Durian fruits (*Durio* sp.) - smallholder |
| Jackfruit (*Artocarpus heterophyllus*) - smallholder |
| Jernang fruit (***Daemonorop***s sp.) - smallholder |
| Mangosteen fruit (*Garcinia mangostana*)- smallholder |
| Petai fruit (*Parkia speciosa*) - smallholder |
| Rubber trees (*Hevea brasiliensis*) - smallholder |
| Rambutan fruit (*Nephelium lappaceum*) - smallholder |
| Oil palm (*Elaeis guineensis*) plantations - smallholder |
| Salak fruit (*Salacca zalacca*) - smallholder |
| Rubber tree (*Hevea brasiliensis*) plantations - industrial |
| Eucalyptus tree (*Eucalyptus* sp.) plantations - industrial |
| Acacia tree (*Acacia* sp.) plantations - industrial |
| Albizia tree (*Albizia* sp.) plantations - industrial |
| Oil palm (*Elaeis guineensis*) plantations - industrial |

**S4 Table. Orangutan population estimates and mean annual rate of decline.** Population figures are based on most recent published estimates in the listed sources.

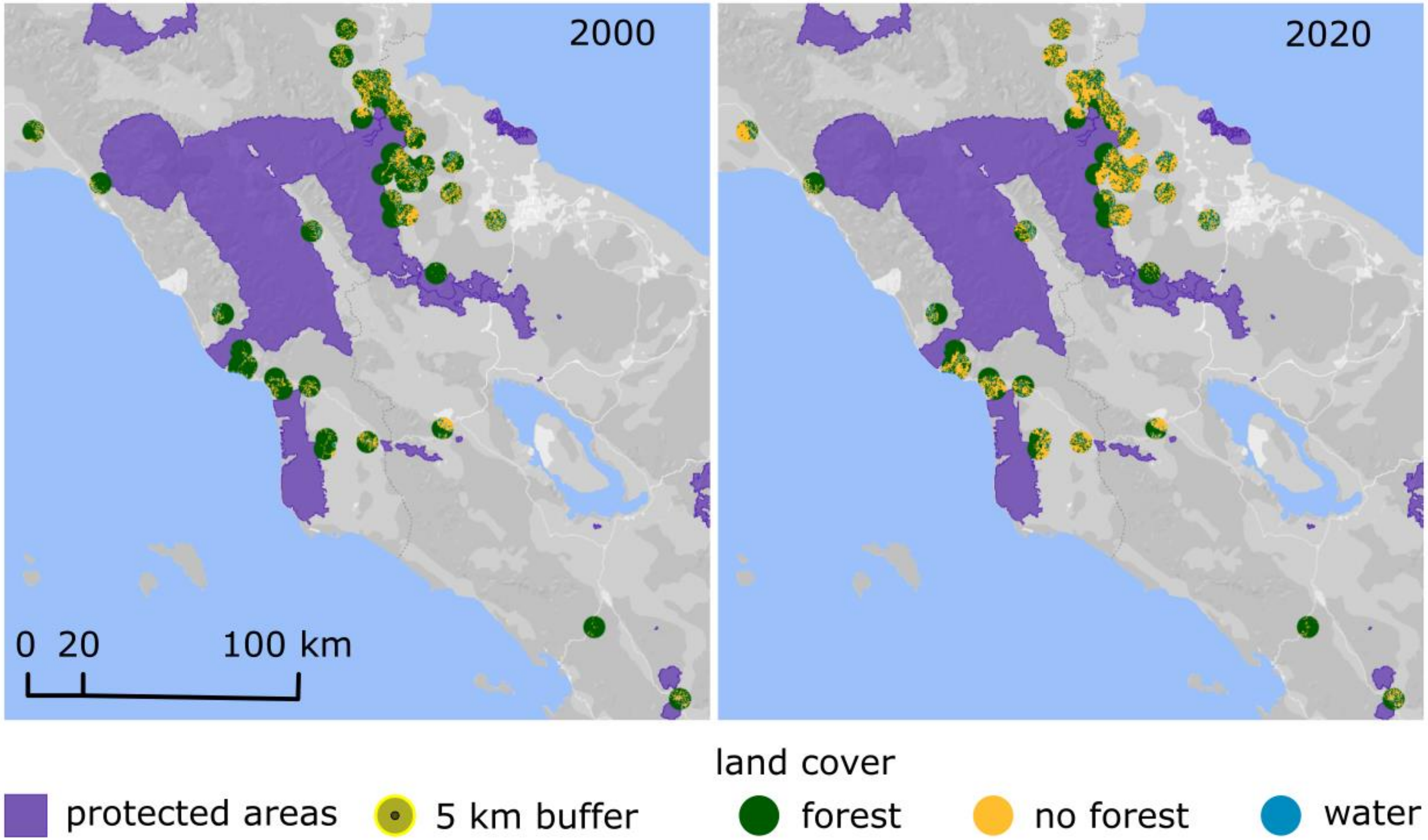
| Island | Area/species | Time period | Initial population size | Latest population size | Annual decline (%)[1] | Mean current population size | Mean annual decline | Mean annual % decline | Source |
|---|---|---|---|---|---|---|---|---|---|
| Borneo[2] | Borneo (*Pongo pygmaeus*) | 2000-2015 | 100,000 | 75,000 | 1,667 (2.22%) | 83,575 | 2,788 (SD ±1817) | 3.14% | Santika et al. (2017); Supp. Materials Fig. 3 |
| | | 2007-2019 | 163,656 | 105,033 | 4,885 (4.65%) | | | | Voigt et al. (2018); 2017-2019 extrapolation from Sherman et al. (2022) |
| | | 1997-2014 | 101,489 | 70,691 | 1,812 (2.56%) | | | | Utami-Atmoko et al. (2017); habitat extrapolation |
| | Central Kalimantan | 1997-2014 | 49,467 | 34,673 | 870 (2.51%) | 47,512 | 1,536 (SD ±942) | 2.54% | Voigt et al. (2018); 2017-2019 extrapolation from Sherman et al. (2022) |
| | | 2007-2019 | 86,778 | 60,351 | 2,202 (2.58%) | | | | Utami-Atmoko et al. (2017); GIS model |
| | East Kalimantan | 1997-2014 | 30368 | 22847 | 442 (1.94%) | 14,091 | 303 (SD ±197) | 2.05% | Voigt et al. 2018; 2017-2019 extrapolation from Sherman et al. 2022 |
| | | 2007-2019 | 7294 | 5335 | 163 (2.16%) | | | | Utami-Atmoko et al. (2017); GIS model |
| | West Kalimantan | 1997-2014 | 46,510 | 32,494 | 824 (2.54%) | 25,079 | 813 (SD ±16) | 2.87% | Voigt et al. (2018); 2017-2019 extrapolation from Sherman et al. (2022) |
| | | 2007-2019 | 27,291 | 17,663 | 802 (3.21%) | | | | Utami-Atmoko et al. 2017; GIS model |
| Sumatra[3] | Sumatra (*Pongo abelii* and *Pongo tapanuliensis*) | 2010-2014 | 14,613 | 10,637 | 398 (3.74%) | 11,861 | 242 (SD ±147) | 2.17% | Wich et al. (2016); multi-model estimate scenario 1; 1 km barrier |
| | | 2010-2014 | 14,613 | 13,085 | 153 (1.17%) | | | | Wich et al. (2016); multi-model estimate scenario 2; 1 km barrier |
| | | 2010-2014 | 13,938 | 10,637 | 330 (3.10%) | | | | Wich et al. (2016); design estimate scenario 1; 5 km barrier |
| | | 2010-2014 | 13,938 | 13,085 | 85 (0.65%) | | | | Wich et al. (2016); design estimate scenario 2; 5 km barrier |

1. Estimated annual declines = initial population size – latest population size/years.
2. Borneo figures based on population estimates from: 1) Santika et al. (2017), Supplementary materials Figure 3, Voigt et al. (2018) estimates per province used in Sherman et al. (2022), and the GIS model estimates by province in Utami-Atmoko et al. (2017).
3. Sumatra estimates are based on the outcome of deforestation scenarios in Wich et al. (2016), using both the 1 km and 5 km dispersal barriers using an initial population per the mean from the multi-model and design estimates, respectively. 2020 populations are based on the estimated numbers for island-wide populations in Wich et al. (2016), Table 3 numbers for "Total abundance".

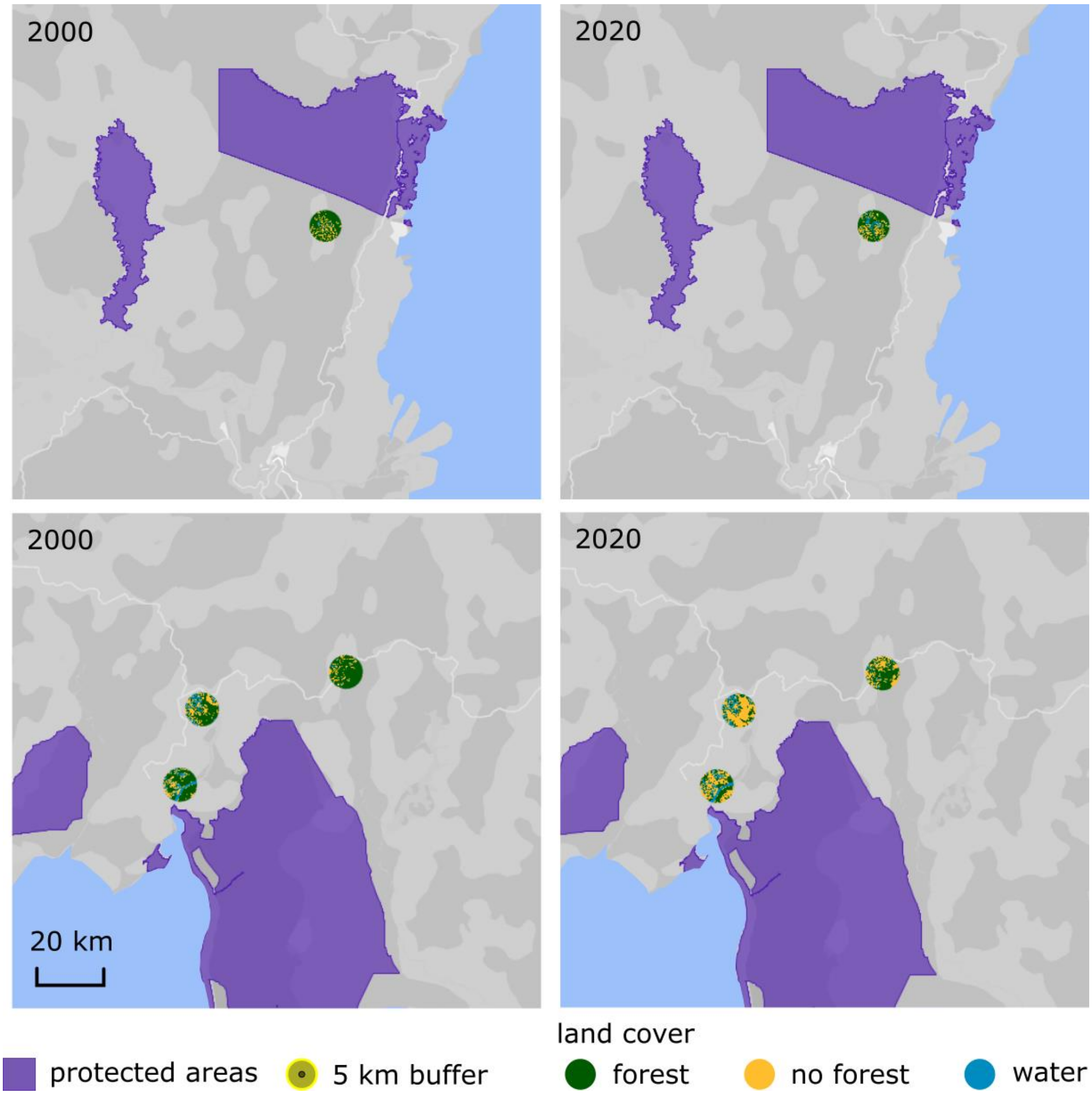
**Table S5. Village administrative units (*desa*) where 7 or more orangutans were reported as captured for wild-to-wild translocation between 2005 and 2022 (Kalimantan) and 2012 to 2022 (Sumatra).** Data on *desa* locations was available for 528 of the 988 reported captures during the study period. F= female, M = male. Estimated age classes are: infant (I) 0-6 years, juvenile/adolescent (J) 7-12 years, adult (A) 15 or more years, and unknown (U). Unknown sex or age means these data were not available in the records we reviewed. Age and sex data may have been collected but not made available in the records we were able to access.

| Village (Desa) name[1] | Province | Island | # of Orangutans captured 2005-2022[2] | Sex and estimated age class of captured orangutans | Year(s) of capture |
|---|---|---|---|---|---|
| Ujung Padang | Aceh | Sumatra | 15 | F: A = 6, J = 1<br>M: A = 4, I = 4 | 2014-2018 |
| Rimba Sawang | Aceh | Sumatra | 9 | F: A = 7, I = 1<br>M: I = 2 | 2012 |
| Sei Serdang | North Sumatra | Sumatra | 18 | F: A = 9, J = 2<br>M: A = 2, J = 2, I = 3 | 2012-2018 |
| Tumbang Mangkutup | Central Kalimantan | Borneo | 106 | F: A = 20, I = 4<br>M: A = 11, J = 1, I = 10<br>7 Adults unknown sex<br>4 Infants unknown sex<br>49 unknown age class + sex | 2005(1), 2015-2019 |
| Baambang Barat | Central Kalimantan | Borneo | 52 | F: A = 14, J = 9, I = 7, U = 3<br>M: A = 10, J = 3, I = 4, U =2 | 2006-2007 |
| Dadahup | Central Kalimantan | Borneo | 14 | F: A = 2, J = 4, I = 3<br>M: A = 2, J = 2, I = 1 | 2006 |
| Jahitan | Central Kalimantan | Borneo | 12 | F: A= 2, J= 5, I= 2<br>M: A = 1, J= 1, I = 1 | 2006 |
| Pundu | Central Kalimantan | Borneo | 20 | F: A = 2, J = 4, I = 5<br>M: A = 4, J = 3, I = 1, U = 1 | 2005-2013 |
| Sangkulirang | East Kalimantan | Borneo | 20 | Age class + sex unknown | 2012-2015 |
| Telen | East Kalimantan | Borneo | 20 | Age class + sex unknown | 2011-2015 |
| Pematang Gadung | West Kalimantan | Borneo | 7 | F: A =1<br>M: A= 2<br>1 Infant unknown sex<br>3 unknown age class + sex | 2013-2015 |

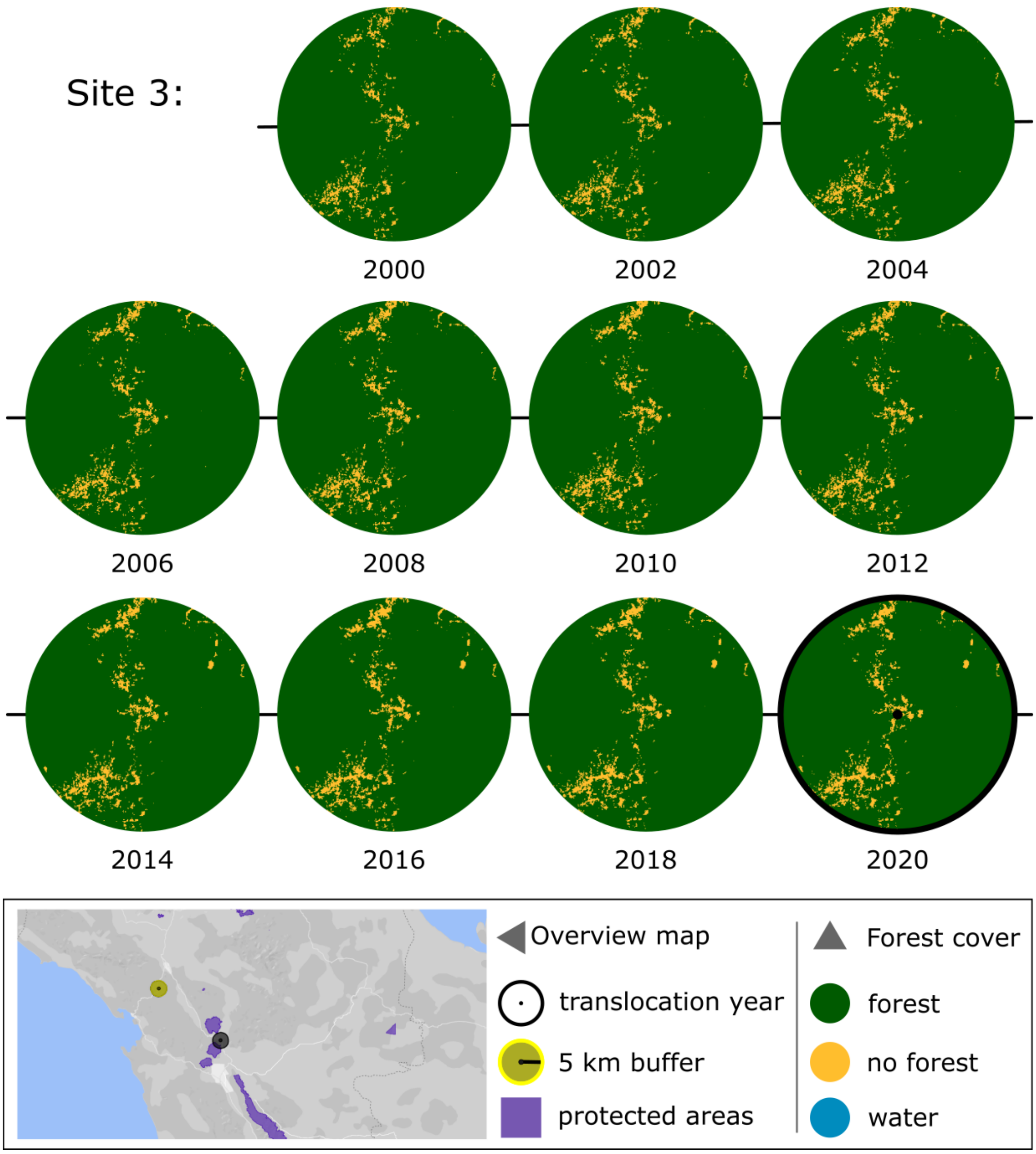
1. D*esa* are administrative units designated by the Indonesian government. Each *desa* has unique boundaries, geographic extent, biophysical characteristics, and human impacts. Orangutan habitats and populations thus vary among *desa*.
2. Numbers are an underestimate of orangutans captured for translocation as they are based on available records collected for this study. Not all captures for translocation are reported, and not all records were available to authors. Figures for Sumatra represent data from 2012-2022, as no records of captures were available for prior years.



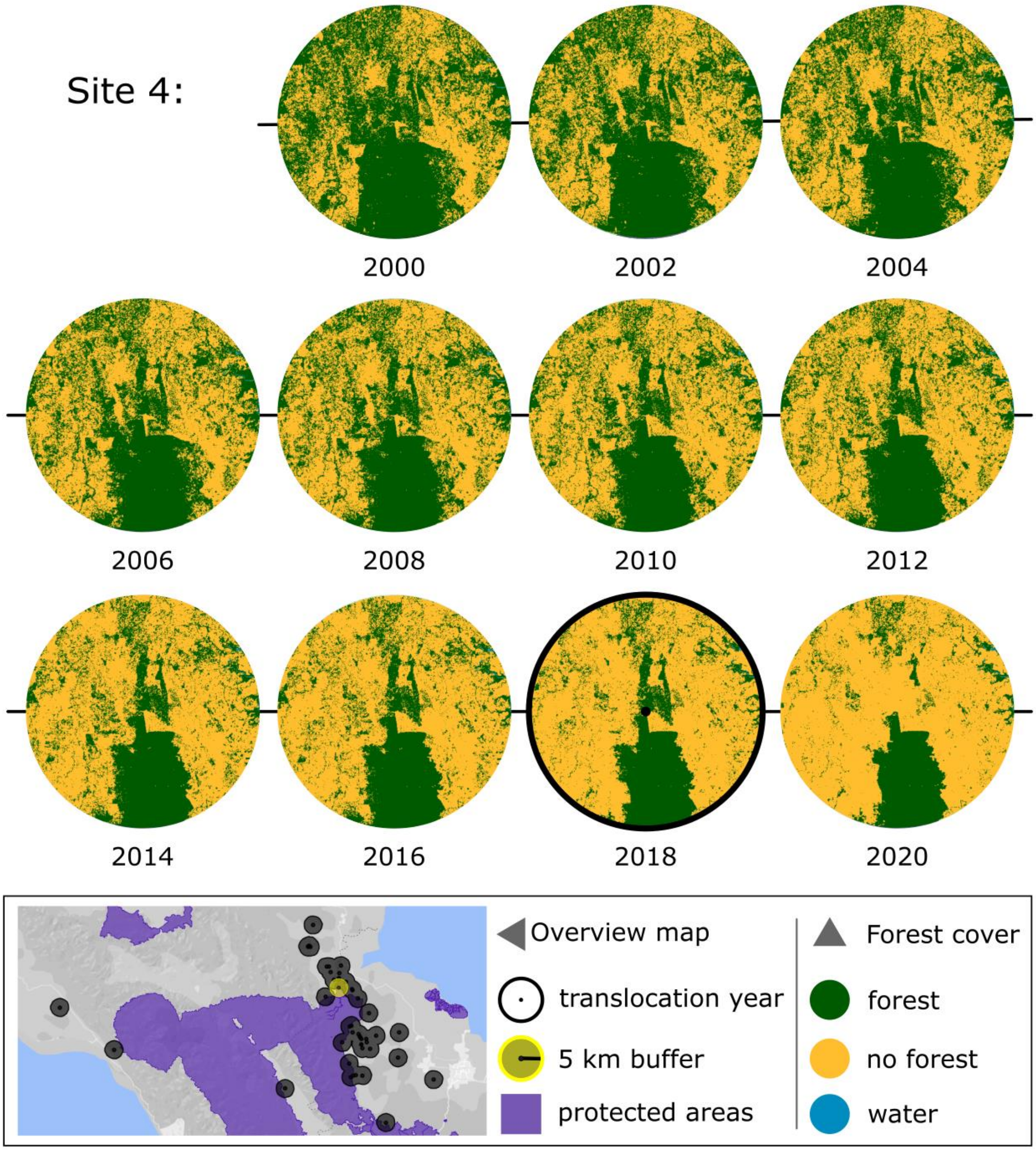

**S1 Fig. Overview of land cover changes around orangutan capture sites in Sumatra, 2000–2022.** Depicted areas cover a 5-km buffer around GNSS coordinates of sites where 99 orangutans were captured for translocation between 2000 and 2022. Intact tropical moist forest, degraded tropical moist forest, and regrowth from Vancutsem et al. (2021) were combined into a single forest class (green) to visualize forested areas available to orangutans. Several captures were reported within the same areas and thus have overlapping buffers. Protected areas (purple): UNEP-WCMC and IUCN (2023). Forest map: EC JRC. Basemap: Google Earth Engine.



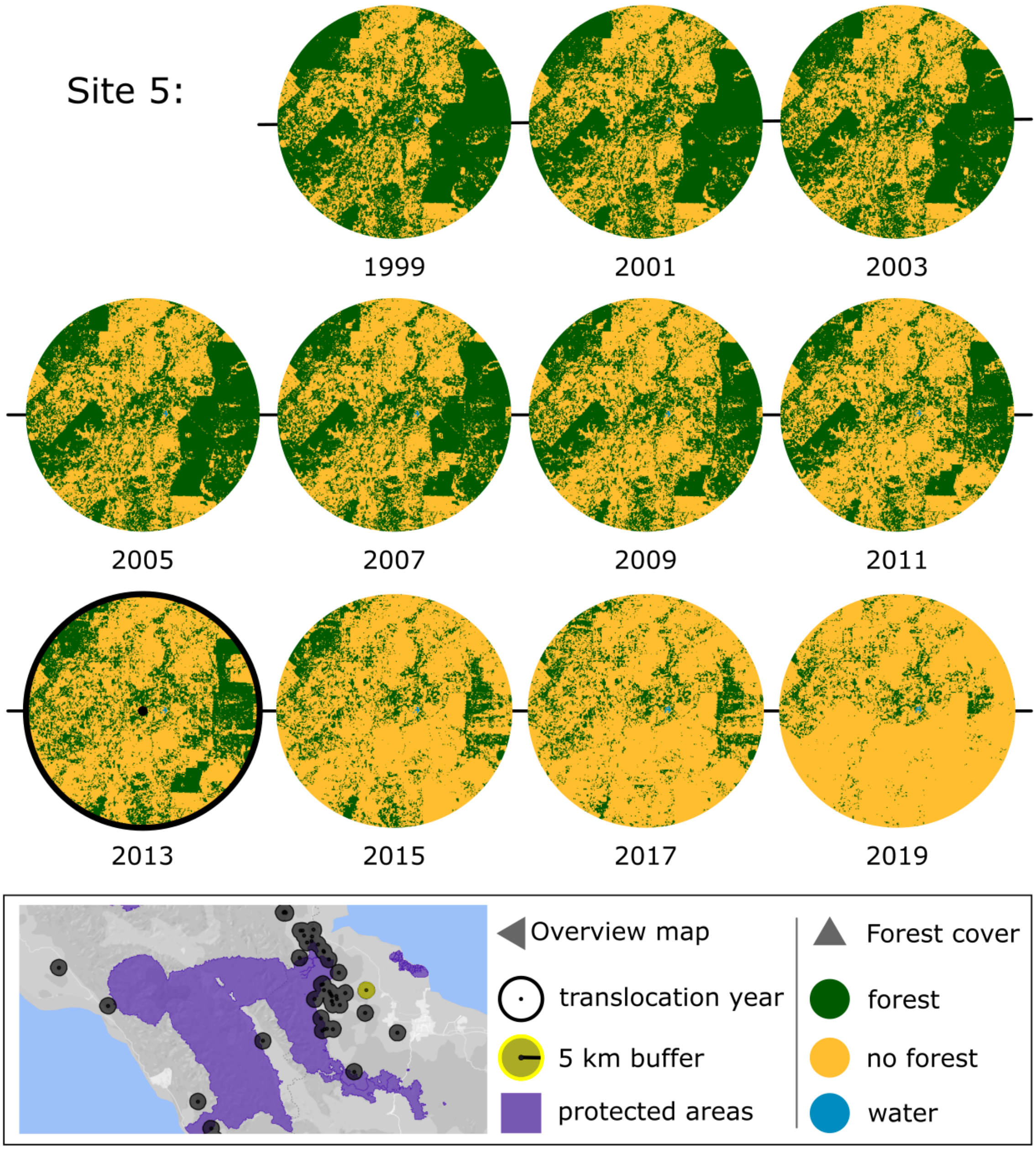

**S2 Fig. Overview of land cover changes around orangutan capture sites in Kalimantan.** Land cover changes are shown for a 5-km buffer around GNSS coordinates of four sites where five orangutans were captured for translocation between 2000 and 2022. Top panels show one capture site in East Kalimantan. Bottom panels show three capture sites in Central Kalimantan. Intact tropical moist forest, degraded tropical moist forest, and regrowth from Vancutsem et al. (2021) were combined into a single forest class (green) to visualize forested areas available to orangutans. Protected areas (purple): UNEP-WCMC and IUCN (2023). Forest map: EC JRC. Basemap: Google Earth Engine.



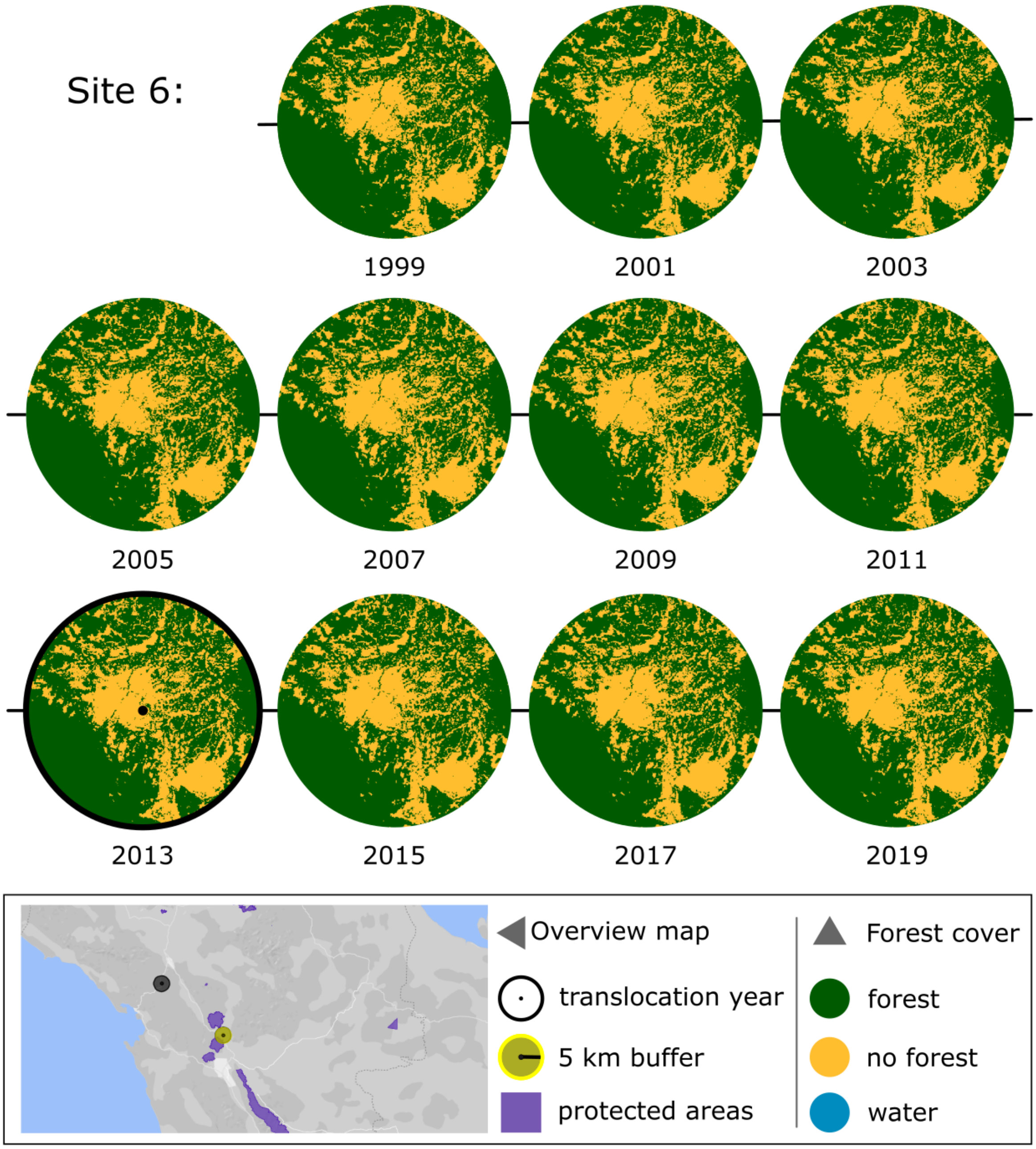

**S3 Fig. Forest change in area surrounding orangutan capture for translocation site 2.** Recapture of a healthy Tapanuli adult male originally captured and translocated in 2019. He had returned to the original capture area and was seen alongside a road. Year of capture (2020) is indicated with a thick black bordered circle. Intact tropical moist forest, degraded tropical moist forest, and regrowth are combined into a single forest class (green). The map inset at the bottom is the location of the specific capture site and buffer (yellow) along with remaining locations where 1 other orangutan was captured for translocation (black). Basemap: Google Earth Engine. Forest map: EC JRC. Protected areas (purple): UNEP-WCMC and IUCN (2023).



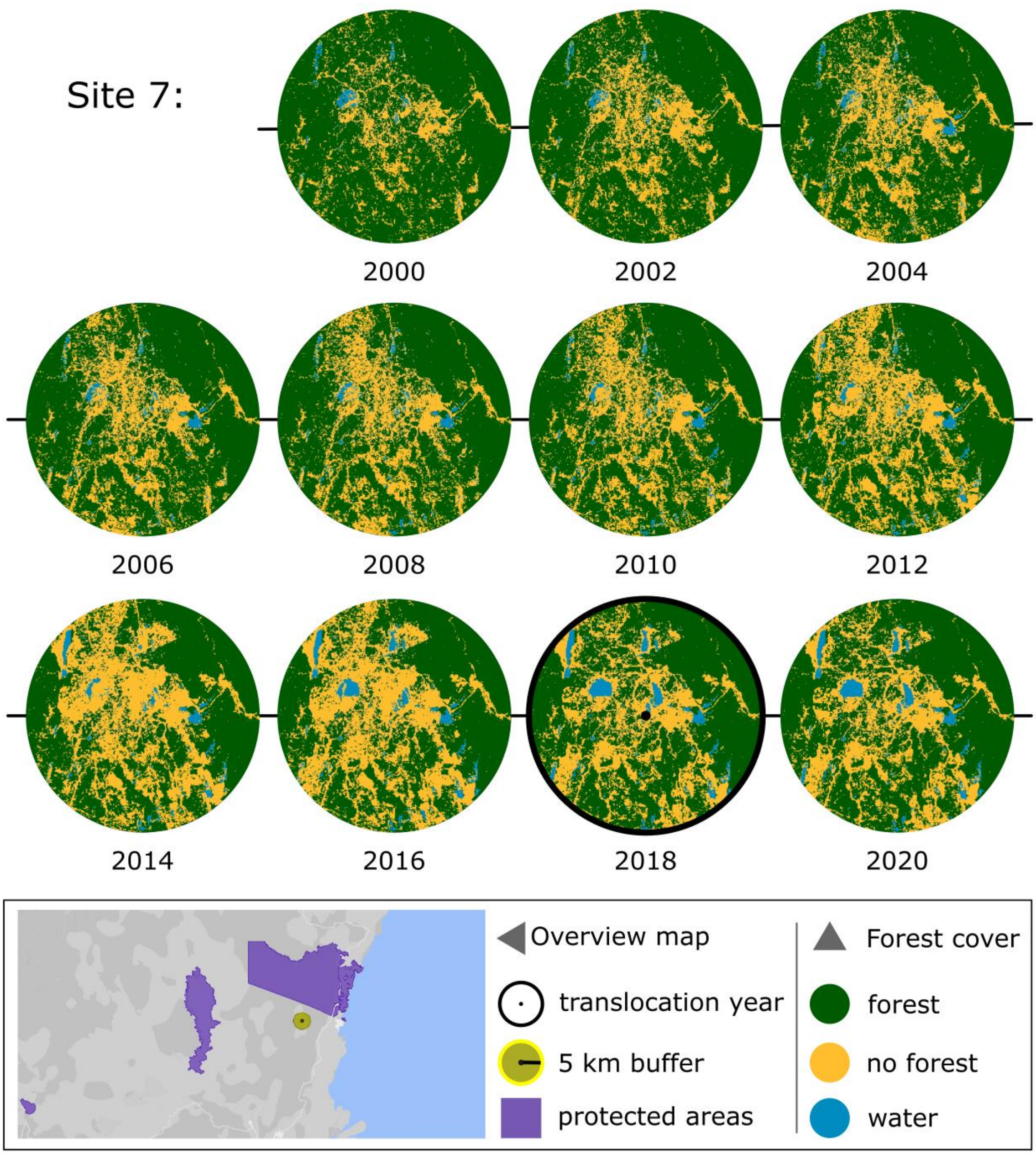

**S4 Fig. Forest change in areas surrounding orangutan capture for translocation in site 4.** An injured Sumatran adult male reported as seasonally foraging in durian (*Durio* sp.) and langsat (*Lansium parasiticum*) gardens at the edge of protected forest. Year of capture (2018) is indicated with thick black bordered circle. Intact tropical moist forest, degraded tropical moist forest, and regrowth are combined into a single forest class (green). The map inset at the bottom is the location of the specific capture site and buffer (yellow) along with remaining locations where 98 other orangutans were captured for translocation (black). Basemap: Google Earth Engine. Forest map: EC JRC. Protected areas (purple): UNEP-WCMC and IUCN (2023).



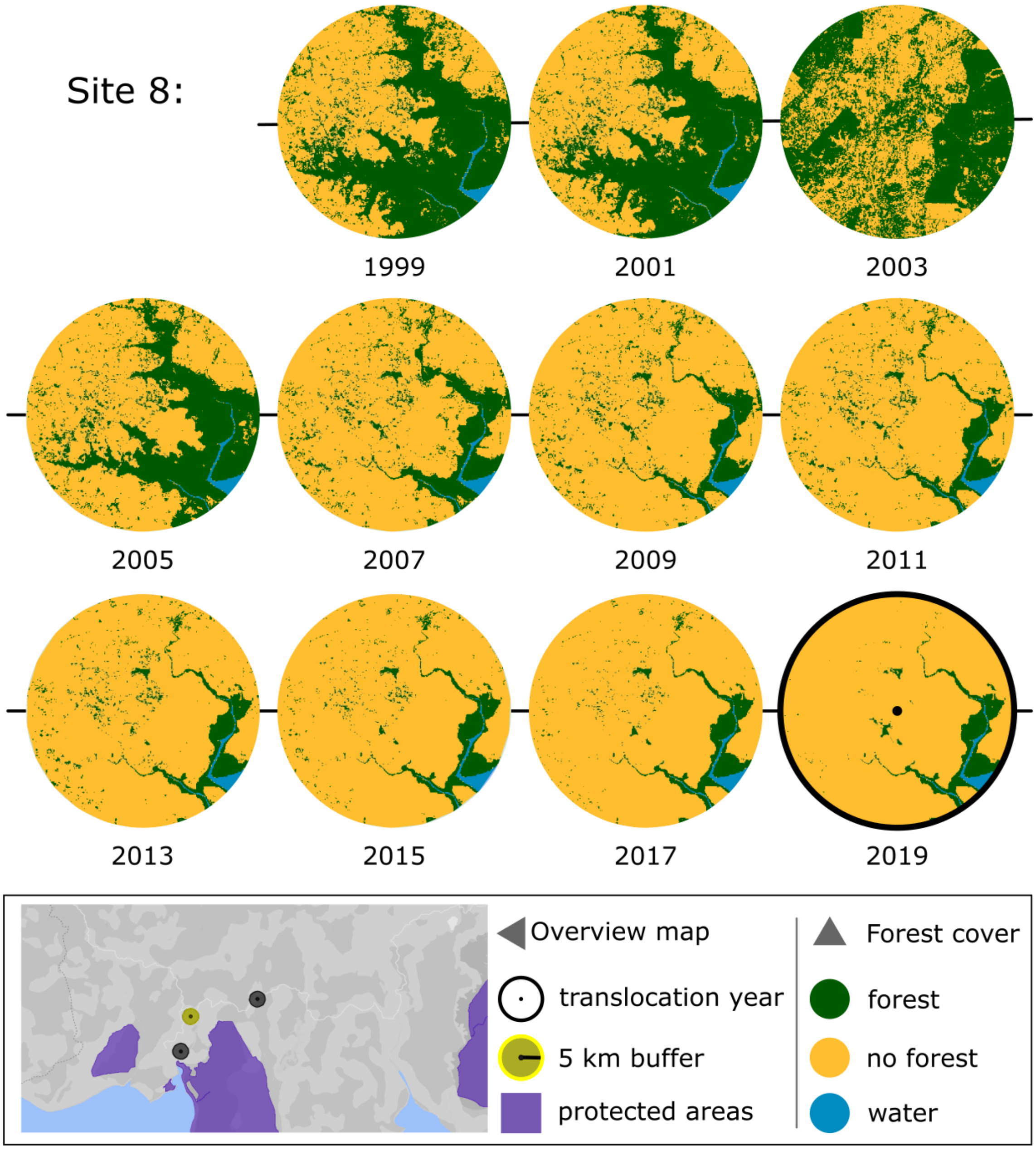

**S5 Fig. Forest change in area surrounding orangutan capture for translocation in site 5.** A Sumatran orangutan population reported as isolated in area considered at risk for deforestation; two healthy adult females were translocated from this site. Year of capture (2013) is indicated with thick black bordered circle. Intact tropical moist forest, degraded tropical moist forest, and regrowth are combined into a single forest class (green). The map inset at the bottom is the location of the specific capture site and buffer (yellow) along with remaining locations where 97 other orangutans were captured for translocation (black). Basemap: Google Earth Engine. Forest map: EC JRC. Protected areas (purple): UNEP-WCMC and IUCN (2023).



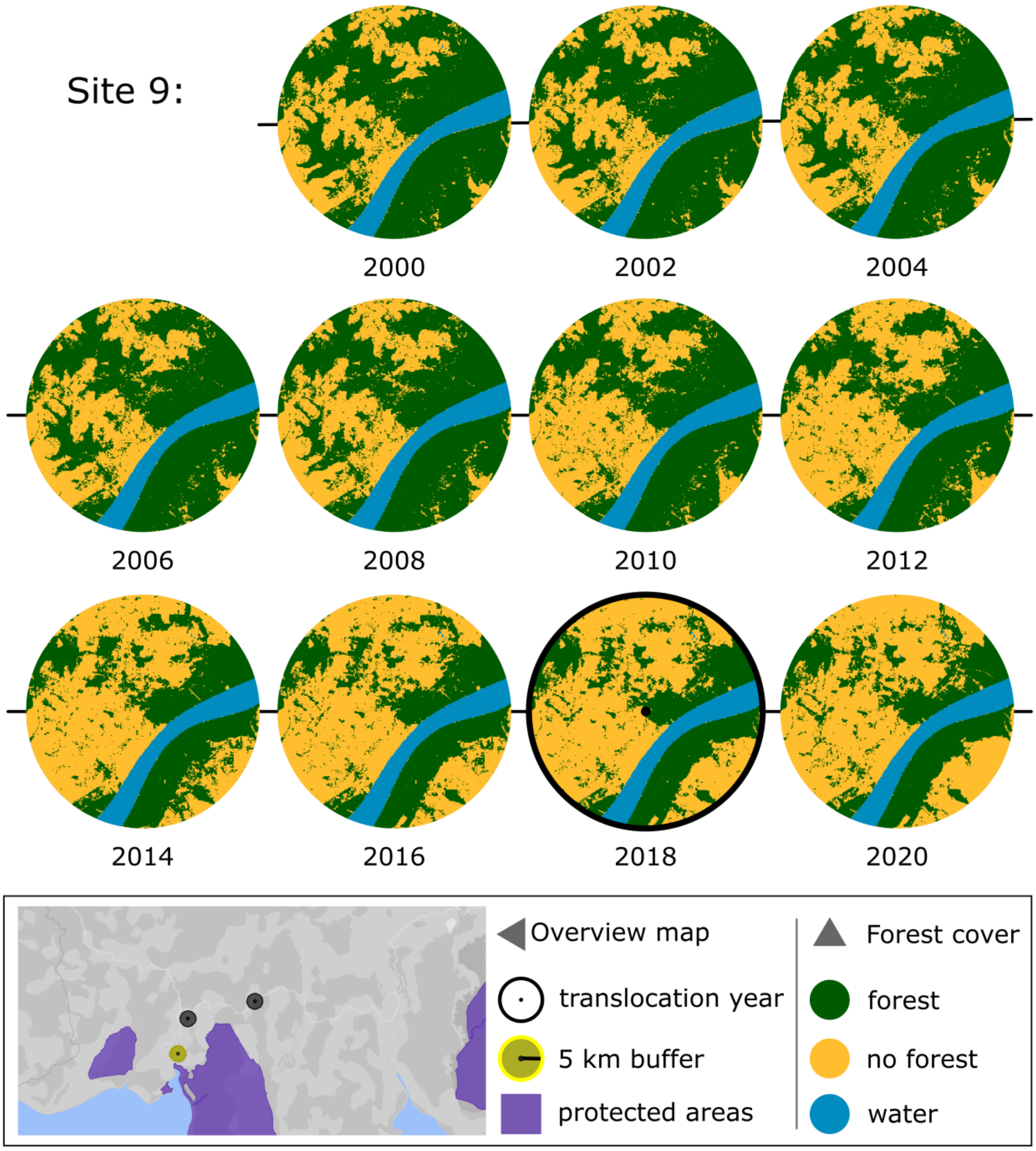

**S6 Fig. Forest change in area surrounding orangutan capture for translocation in site 6.** An injured Tapanuli adult male in a salak fruit (*Salacca zalacca*) plantation. Year of capture (2013) is indicated with thick black bordered circle. Intact tropical moist forest, degraded tropical moist forest, and regrowth are combined into a single forest class (green). The map inset at the bottom is the location of the specific capture site and buffer (yellow) along with remaining locations where 1 other orangutan was captured for translocation (black). Basemap: Google Earth Engine. Forest map: EC JRC. Protected areas (purple): UNEP-WCMC and IUCN (2023).




**S7 Fig. Forest change in area surrounding an orangutan capture for translocation in site 7.** A gravely injured juvenile male Bornean orangutan, previously thought to have been foraging in a local pineapple garden within Kutai National Park. Year of capture (2018) is indicated with thick black bordered circle. Intact tropical moist forest, degraded tropical moist forest, and regrowth are combined into a single forest class (green). The map inset at the bottom is the location of the specific capture site and buffer (yellow). Basemap: Google Earth Engine. Forest map: EC JRC. Protected areas (purple): UNEP-WCMC and IUCN (2023).




**S8 Fig. Forest change in area surrounding orangutan capture for translocation site 8**. Healthy Bornean adult male reported to be staying in and "disturbing" a local durian garden. Year of capture (2019) is indicated with thick black bordered circle. Intact tropical moist forest, degraded tropical moist forest, and regrowth are combined into a single forest class (green). The map inset at the bottom is the location of the specific capture site and buffer (yellow) along with remaining locations where three other orangutans were captured for translocation (black). Basemap: Google Earth Engine. Forest map: EC JRC. Protected areas (purple): UNEP-WCMC and IUCN (2023).




**S9 Fig. Forest change in area surrounding orangutan capture for translocation site 9.** Healthy Bornean adult male seen in APL (non-forest) land near a power plant and uninsulated electrical wires. Year of capture (2018) is indicated with thick black bordered circle. Intact tropical moist forest, degraded tropical moist forest, and regrowth are combined into a single forest class (green). The map inset at the bottom is the location of the specific capture site and buffer (yellow) along with remaining locations where three other orangutans were captured for translocation (black). Basemap: Google Earth Engine. Forest map: EC JRC. Protected areas (purple): UNEP-WCMC and IUCN (2023).

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