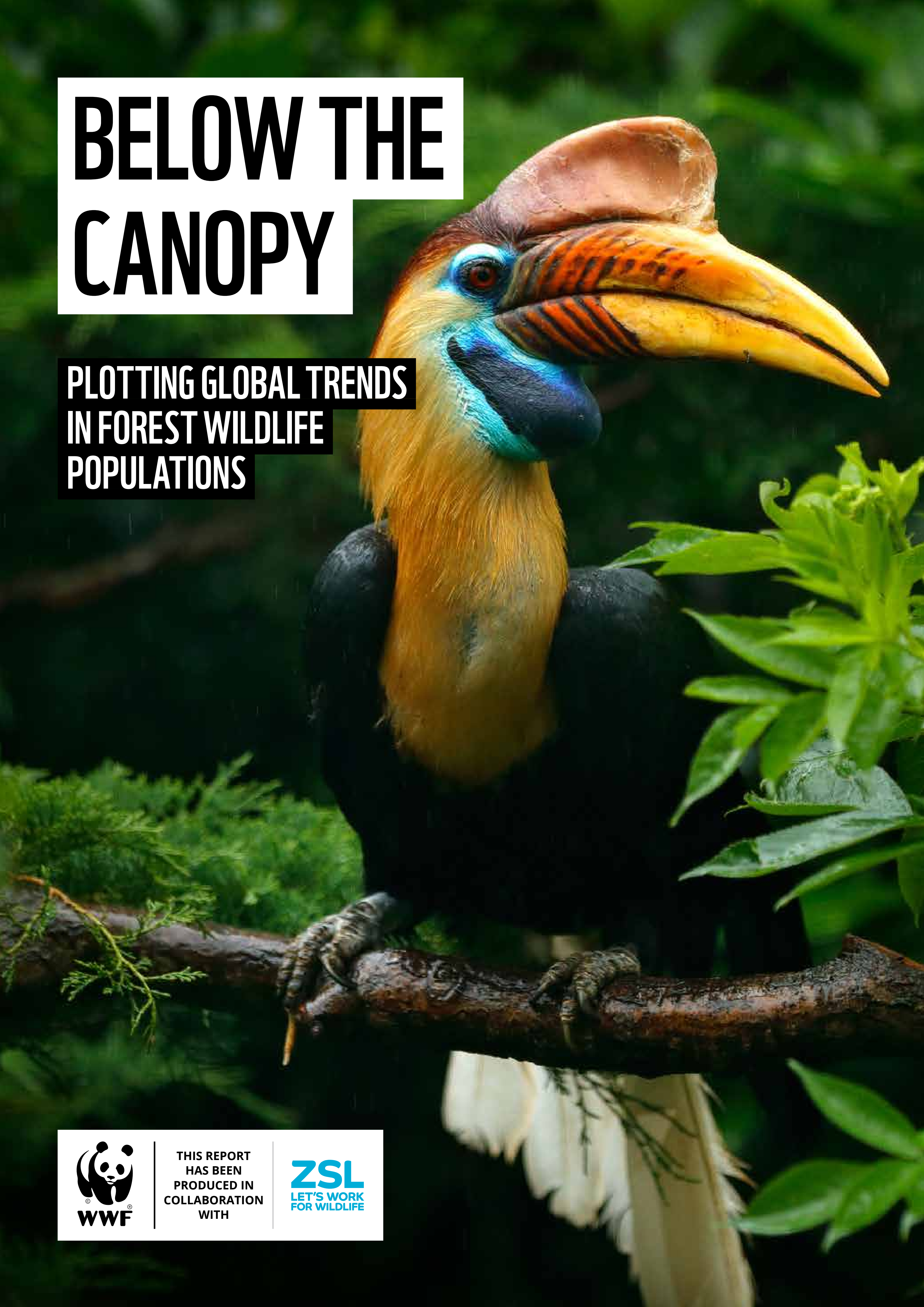
BELOW THE CANOPY

PLOTTING GLOBAL TRENDS IN FOREST WILDLIFE POPULATIONS



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LET'S WORK FOR WILDLIFE

Written by
Elizabeth Green (UNEP-WCMC), Louise McRae (ZSL), Mike Harfoot, Samantha Hill, Will Simonson (UNEP-WCMC), and Will Baldwin-Cantello (WWF-UK).

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CONTENTS

KEY FINDINGS

FOREST VERTEBRATE POPULATIONS MORE THAN HALVED BETWEEN 1970 AND 2014, ON AVERAGE.

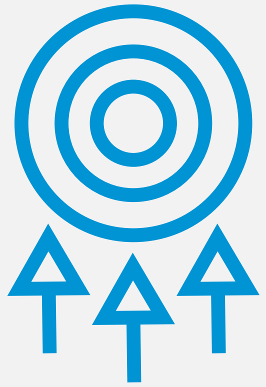
Using the Living Planet Index methodology, an index for wildlife that lives only in forests was created. It showed that monitored populations of these vertebrate species declined by 53% on average over the period. This decline has serious consequences for forest integrity and climate change because of the roles that wildlife play in forest regeneration and carbon storage.

DEFORESTATION IS A MAJOR DRIVER OF THIS LOSS BUT ALONE IT DOES NOT EXPLAIN THIS LEVEL OF DECLINE.

Even though habitat degradation or change accounted for 60% of the threats to forest specialists, changes in tree cover did not always reflect changes in populations of forest animals. Forest animals face multiple threats in addition to habitat loss and degradation, such as overexploitation, invasive species, climate change and disease. Tackling deforestation and increasing forest cover are essential but on their own insufficient to restore forest biodiversity. In order to reverse the decline of forest biodiversity it is crucial to address the multiple pressures on forest species.

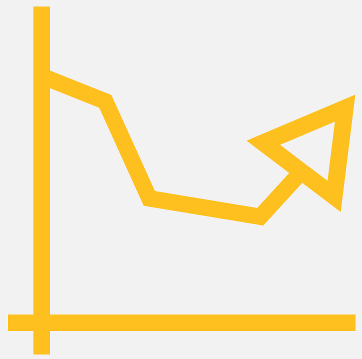
IN 2020 WE HAVE AN OPPORTUNITY TO ADDRESS THIS DECLINE AS PART OF THE NEW DEAL FOR NATURE AND PEOPLE.

Forests are home to well over half the world's land-based species and are one of our most important carbon sinks. If we are to reverse the decline in biodiversity worldwide and avoid dangerous climate change then we need to safeguard the species that live in forests and keep them healthy.



A DIRECT MEASURE OF FOREST BIODIVERSITY SHOULD BE INCLUDED ALONGSIDE FOREST COVER IN THE POST-2020 BIODIVERSITY FRAMEWORK AND THE FOREST SPECIALIST INDEX IS RECOMMENDED TO FILL THIS GAP.

This report shows that tree cover does not provide a good indication of the status of biodiversity below the canopy. A post-2020 global biodiversity framework and all future global forest assessments should consider forest quality as well as quantity and including a direct measures of forest biodiversity alongside forest cover change would enable it to do that. The Forest Specialist Index developed in this research offers a tool to do so by tracking the status of the world's forest specialist vertebrate populations.



SUCCESS STORIES SHOW THAT WITH THE RIGHT CONSERVATION STRATEGIES, FOREST VERTEBRATE POPULATIONS CAN RECOVER.

Despite this global decline there are signs of hope, places where forest specialist populations have rebounded. This requires taking a multi-pronged approach to tackle the multiple pressures on forest animals including enabling natural regeneration of forests, working with communities to address overexploitation of wildlife, and tackling invasive species. to address the multiple pressures on forest species.

GAPS IN MONITORING IN SOME OF THE MOST BIODIVERSE FORESTS OF THE WORLD REMAIN, AND NEED TO BE FILLED.

Our index includes data from all corners of the world, covering 268 species and 455 populations. However, we need to do far more repeated, on-the-ground monitoring in important biodiversity hotspots like the Amazon or we risk being blinded to the loss of wildlife in years to come. In order to fill this gap and inform conservation strategies in these regions, greater investment must be made towards long-term, systematic forest biodiversity monitoring.

EXECUTIVE SUMMARY

THE 2020 OPPORTUNITY AND A NEW DEAL FOR NATURE AND PEOPLE

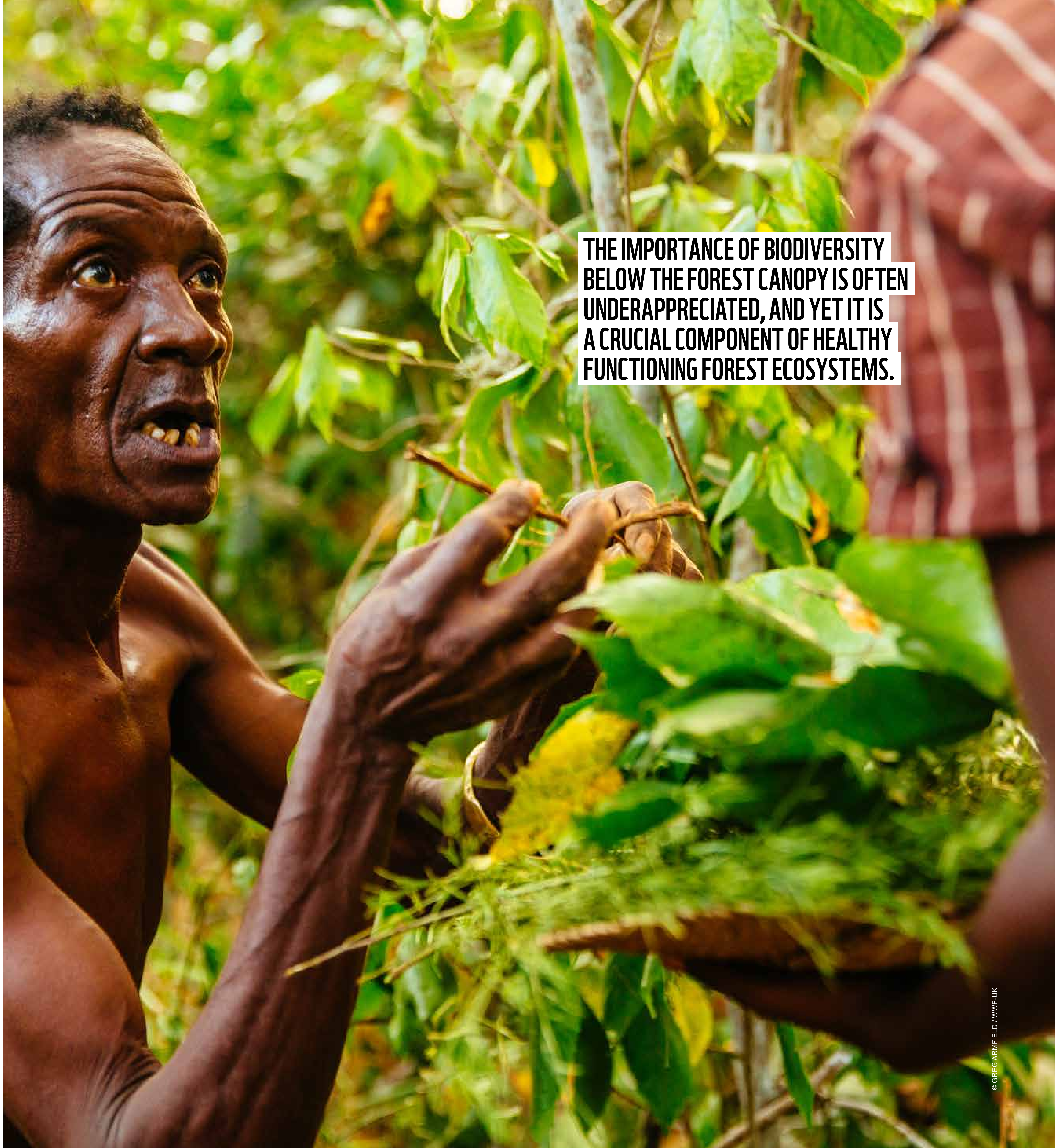
The year 2020 is a milestone year for taking action to protect and restore the health of our planet. As the Paris Agreement on climate change meets its first milestone for delivery and upgrading of national commitments, and several Sustainable Development Goals (SDGs) reach deadlines, and it is expected that governments will agree on a new global biodiversity framework through the UN biodiversity conference. Ambitious action taken towards all these agendas could combine to be a “New Deal for Nature and People.”

Forests need to be front and centre of this New Deal for Nature and People because of their importance for biodiversity conservation, climate change mitigation and the provision of ecosystem services, such as water and air purification, nutrient cycling, soil erosion control, and supplies of food, wood and other products. Despite this importance, forest loss and degradation continues apace, driven primarily by clearance for commodity production, unsustainable logging, shifting agriculture and wildfires. This heavily compromises our ability to prevent the world entering dangerous levels of climate change and breaching other planetary boundaries.

This report highlights the status of forest biodiversity worldwide and provides evidence to inform the discussions and negotiations around the development of the New Deal and the synergies between the new framework on biodiversity, the Paris Agreement and the SDGs.

FOREST WILDLIFE MATTERS IN THE FIGHT AGAINST CLIMATE CHANGE

The importance of biodiversity below the forest canopy is often underappreciated, and yet it is a crucial component of healthy functioning forest ecosystems. A growing body of scientific evidence shows how forest animals are essential components of natural, healthy forests and maintaining the services they provide to people. They perform pollination, seed dispersal, herbivory and other crucial roles that affect natural regeneration and, importantly, carbon storage. Notably, in the vast forests of South America and Africa, the carbon locked in forests would decline if large birds and primates, in particular, were lost. These animals ensure that the seeds of the most carbon-dense trees are dispersed and without them the less carbon-dense trees would dominate. When animals are lost from forests these vital functions are lost with them, with severe implications for forest health, the climate, and more than a billion humans who depend on forests for their livelihoods.



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FOREST SPECIALIST INDEX: FILLING A GAP IN MONITORING OF FOREST BIODIVERSITY GLOBALLY

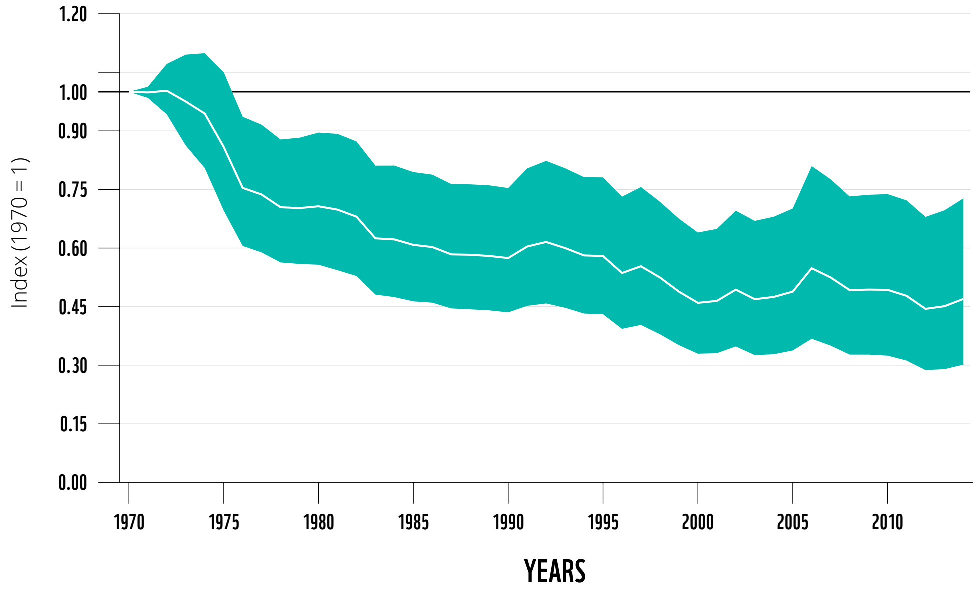
Remarkably little is known about the state of forest biodiversity globally. In the absence of a direct global measure of forest biodiversity, forest area has often been used as a proxy indicator. However, until now, the suitability of forest cover as a proxy for forest biodiversity had never been assessed.

This report presents the Forest Specialist Index (Fig A), developed following the Living Planet Index methodology, as a way of improving our ability to assess the global state of forest biodiversity. The focus on specialist species, which depend entirely on forests, means this indicator provides a good representation of forest ecosystem health.

We found that, on average, monitored populations of forest specialists more than halved between 1970 and 2014.

These trends vary by region and taxa. The overall decline is driven mostly by declines in tropical species which made up 75% of the data, while species in temperate areas tended to have more positive trends over time, albeit starting from a reduce baseline due to historical losses. For mammals, amphibians and reptiles, more species had negative trends than positive trends, whereas the opposite was true for bird species. Overall, these findings tell us that many forest species are in serious trouble.

FIG A.
FOREST SPECIALIST INDEX FOR 268 FOREST SPECIALIST SPECIES (455 POPULATIONS) FROM 1970 TO 2014.



Note: Solid line shows the weighted index values and shaded region shows the 95% confidence for the index

THE NEED FOR TARGETS AND INDICATORS THAT LOOK BELOW THE CANOPY

To understand what is driving these trends in forest biodiversity, we explored the drivers of changes in forest vertebrate populations (including generalist and specialist species). These investigations showed that forest vertebrate populations are responding to multiple pressures, including habitat loss and degradation, overexploitation, climate change and invasive species. They also showed that, globally, forest animals are not responding to tree cover change in a consistent manner.

This important finding demonstrates that changes in tree cover do not always reflect changes in the populations of animals below the canopy, and that forest area is therefore a poor proxy for assessing global forest biodiversity. A focus on forest area alone neglects the many important factors that determine whether standing forests retain their wildlife or whether newly planted or regenerated forests become rich in biodiversity – restoring trees is important, but alone it is not enough. It is therefore essential that the monitoring of forest biodiversity is improved. The Forest Specialist Index provides a solution to these challenges in the form of a direct measure of the state of forest vertebrate populations.

MAINTAINING FOREST BIODIVERSITY REQUIRES ADDRESSING MULTIPLE THREATS

What is clear is that new commitments and action pledged in 2020 should not only halt and reverse tree cover loss but also tackle the multiple other threats to forest biodiversity, such as overexploitation, climate change and invasive species. To support this, greater investment should be made towards on-the-ground monitoring of forest wildlife. Only then can we identify and address the many threats facing forest biodiversity below the canopy.

THE TREND CAN BE REVERSED: THERE ARE BEACONS OF HOPE WHERE FOREST WILDLIFE HAS RECOVERED

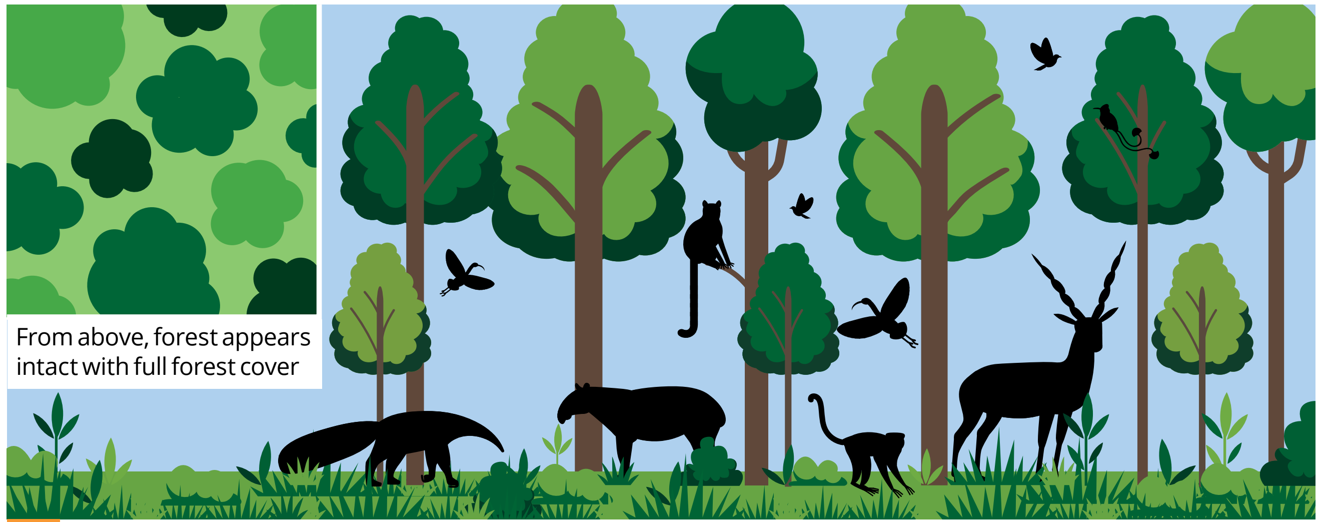
While the findings of the Forest Specialist Index paint a gloomy picture of the state of forest biodiversity, conservation success stories show us that forest-dwelling animals can recover with the right interventions. From monkeys in Costa Rica to gorillas in central Africa we find that, by releasing forest animals from the direct pressures they face, their populations can thrive. We must learn from these successes and seize 2020 as a pivotal moment to start reversing the decline in forest species, protecting the long-term health and integrity of our forests for nature and people.

53%

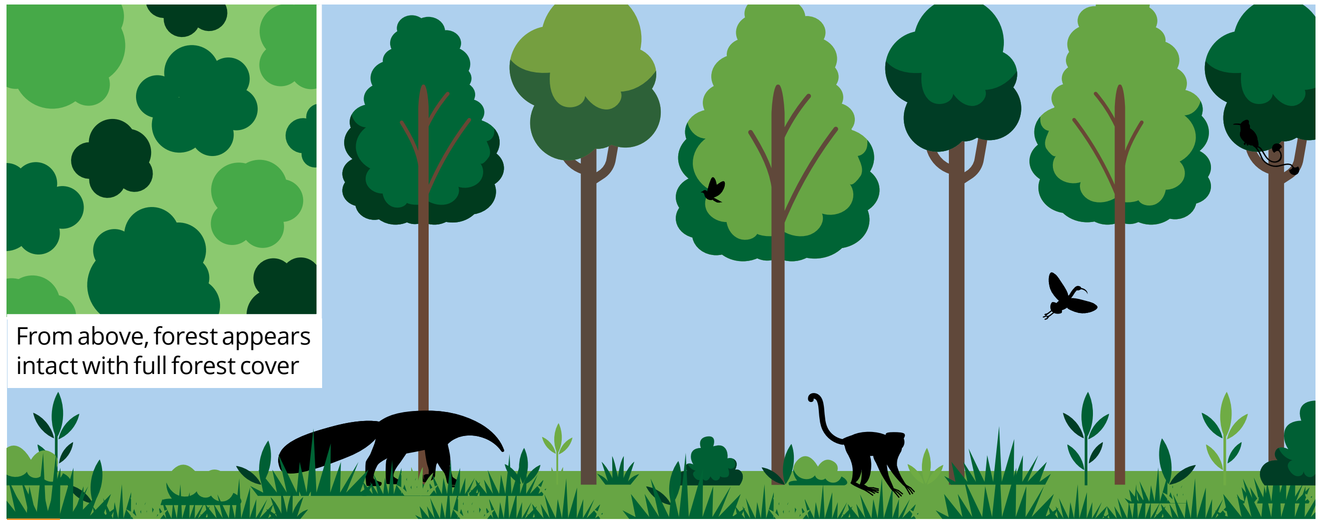
DECLINE IN SIZE OF FOREST WILDLIFE POPULATIONS SINCE 1970

THE IMPORTANCE OF LOOKING BELOW THE CANOPY

From above, both forests appear intact with full forest cover. By looking below the canopy, changes in the forest fauna community can be identified; in the longterm, loss of large-bodied vertebrates can lead to a reduction in carbon-dense trees.



A Intact forest fauna community: large-bodied vertebrates still present



B Fauna community degraded, large-bodied vertebrates lost; large seeds of carbon-dense trees stop being dispersed

INTRODUCTION

Forests are essential for meeting global goals on conserving biodiversity, combating climate change and achieving sustainable development. Forests are important sinks and stores of carbon, and tropical forests are some of the most biodiverse habitats, supporting over half the world's land-based species[1]. Forests provide other vital ecosystem services too, including food, medicines, materials, water purification, erosion control and nutrient recycling, while over a billion people depend upon forests for their livelihoods.[2]

Reversing the decline in biodiversity, keeping global warming from reaching dangerous levels, and eradicating poverty and inequality, cannot be achieved without protecting and restoring the world's forests.

FORESTS AND A NEW DEAL FOR NATURE AND PEOPLE

As the landmark year of 2020 approaches, and with forest loss and degradation still rampant across many parts of the globe, the importance of forest conservation to biodiversity, climate and societal goals has never been more apparent. We will fall far short of the target set in 2010 through the UN biodiversity conference to halve the rate of loss of forests and other natural habitats[3]. So what now? 2020 is a pivotal moment of scrutiny under the UN's climate change convention and must see increases in the ambition of national climate change pledges under the Paris Agreement to be consistent with 1.5°C. A new global biodiversity framework is expected to be agreed at the 15th Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) in late 2020. Around the same time, the Sustainable Development Goals (SDGs) will reach their fifth anniversary, with 21 of the SDG targets expiring that year. Between these policy processes, a step-change needs to be delivered in more coherent, concerted and coordinated action for forests by governments, businesses and civil society, balancing the needs of both people and wildlife. A New Deal for Nature and People, drawing together a new global biodiversity framework with reinvigorated action under the Paris Agreement and SDGs, is an unmissable opportunity to forge such an alliance of action for forests. In 2021, we will also enter the UN-declared decade of ecosystem restoration, so WWF and others are calling on the global community to set our sights on the global recovery of nature and biodiversity.

1 Groombridge and Jenkins, 2003
2 Vira, 2015
3 Aichi biodiversity target 5, Convention on Biological Diversity

WHAT IS THE NEW DEAL FOR NATURE AND PEOPLE?

WWF and others are calling for world leaders and citizens around the world to back a New Deal for Nature and People in 2020. The New Deal would be made up of a coordinated set of agreements and actions to tackle biodiversity loss, climate change and to advance sustainable development for all. It would be a deal that makes it socially, politically and economically unacceptable to sit back and watch the destruction of nature. A deal focused on tackling the underlying root causes of nature's decline. And a deal that not only stops the catastrophic loss of nature, but leads to a collective global programme of recovery. It would recognise that a healthy planet is indespensible for human development.

We need a New Deal for Nature and People to unite world leaders behind the biggest issue of our generation and catalyse a new movement that can and will save our planet. As well as a commitment from heads of state and government, it must galvanise momentum so that urgent actions are taken by businesses. It must represent the views of our youth, indigenous people and civil society.

For forests, the deal should accelerate progress towards reducing deforestation and restoring forests, address the decline in forest biodiversity, and uphold the importance of forests for people, ensuring the benefits forests provide are maintained or enhanced.

THE IMPORTANCE OF FOREST VERTEBRATES FOR CLIMATE CHANGE

The policy interlinkages between biodiversity, society and climate that would be embodied in a New Deal should represent the interlinkages between the very components of forests themselves. Trees are of course defining of forests, creating carbon reserves, habitats, microclimates, timber and non-timber forest products. But they are only half the story. Below the canopy, forest-dwelling species provide vital functions for keeping forests healthy and productive. They contribute to the maintenance and regulation of key processes associated with forest regeneration and carbon storage, such as seed dispersal, pollination, herbivory and the production of soil organic matter[4].

In temperate areas, large predators such as wolves control the abundance of herbivorous prey species like moose, regulating the level of herbivory and maintaining forest tree biomass[5]. In some tropical regions, the loss of large fruit-eating animals from forests can lead to a reduction in the biomass and carbon stored in forests, because only they can disperse the large seeds of carbon-dense trees[6]. The targeting of such animals for bushmeat among other factors leads to so-called 'empty forests': forests which appear intact but have in fact been emptied of large animals and, with them, many of the underlying ecological processes that maintain forests and their carbon stocks[7].

4 Sobral et al., 2017; Schmitz et al., 2018
5 Schmitz et al., 2018
6 Poulson et al., 2013; Bello et al., 2015; Osuri et al., 2016
7 Redford, 1992

THE OVEREXPLOITATION AND LOSS OF LARGE FRUIT EATING ANIMALS SUCH AS PRIMATES FROM TROPICAL FORESTS SHOULD BE REGARDED AS A SIGNIFICANT THREAT TO FOREST CARBON STORAGE

For this reason, implementing the New Deal will require reliable monitoring information on the state of biodiversity below the canopy. How well is this monitoring challenge being addressed already? Every five years the Food and Agriculture Organization of the United Nations (FAO) assesses the global status of forests and publishes its findings in the Global Forest Resources Assessment (FRA). The FRA reports how much land across the world is classed as forest, what kind of management (if any) it is under, what carbon is likely to be stored in it and what socioeconomic benefits it might be delivering. The most recent assessment included three proxy indicators on forest biodiversity: the area of primary forest, the area of forest designated for the conservation of biodiversity and forest area within protected areas[8]. However, these indicators give little information about the ecosystem condition of that forest or its inhabitants. Further, all three indicators focus on forest area, but the suitability of forest area as a proxy indicator for forest biodiversity has not been assessed – until now.

GROUND-BREAKING RESEARCH

This report sets out ground-breaking research commissioned by WWF to inform the development of the new global biodiversity framework and the wider New Deal for Nature and People. In particular, it provides advice and solutions regarding global forest assessments and how we measure progress towards forest biodiversity targets. The research, which has been detailed in a scientific paper[9], tackled three questions relating to forest-dwelling vertebrates (mammals, amphibians, reptiles and birds), for which most data is available:

Question 1
What are the global status and trends of forest vertebrate populations?

Question 2
Are changes in these populations associated with changes in tree cover? In other words, is tree cover a good proxy indicator of forest biodiversity?

Question 3
What other threats do forest vertebrate populations face?

We introduce the Forest Specialist Index, a new indicator that provides the first ever global assessment of trends in forest vertebrates, and take a closer look at one group of species that are particularly important for forest health: primates. We then explore the relationship between populations of forest vertebrates and changes in tree cover. We reflect on information from the scientific literature regarding threats to forest-dwelling animals, and present case studies that not only give insight into drivers of forest biodiversity decline but also demonstrate how successful conservation interventions can support population recovery. We discuss the implications of the findings for forest health and climate change, biodiversity conservation and forest policy: what is taking place below the canopy, and why does it matter?

8 FAO, 2015
9 Green et al., 2019

STATUS AND TRENDS IN FOREST VERTEBRATE POPULATIONS

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268

SPECIES OF BIRDS, MAMMALS, REPTILES AND AMPHIBIANS ARE INCLUDED IN THE INDEX

DEVELOPMENT OF A FOREST SPECIALIST INDEX

Forest specialists comprise species which live only in forest habitat whereas forest generalists live in forests but also occupy one or more other habitats. Living in a single habitat, specialists are reliant on healthy forests to thrive and are likely to be important species within the ecosystem. A Forest Specialist Index was developed based on this definition of forest specialists and the method for the Living Planet Index (LPI), an indicator of global biodiversity. The LPI tracks the average change in the abundance of thousands of populations of mammal, bird, amphibian, reptile and fish species from around the world. By extracting and analysing only the data for forest specialists from the LPI, an indicator of trends from below the canopy was produced. Alongside the data already in the LPI database, new data for tropical forest species was collected and added to improve the database and get the best picture possible of trends in forest species (see Green et al., 2019 for full details).

In total, data was available for 268 species of birds, mammals, reptiles and amphibians that were identified as forest specialists. Forest species data in the index covers all regions of the world (Fig 1) and different types of forest biomes – temperate, tropical, boreal and Mediterranean. The data available allowed trends for forest specialists to be calculated from 1970 to 2014 at a global scale, as well as a comparison between tropical and temperate regions and a glimpse at trends among taxonomic groups.

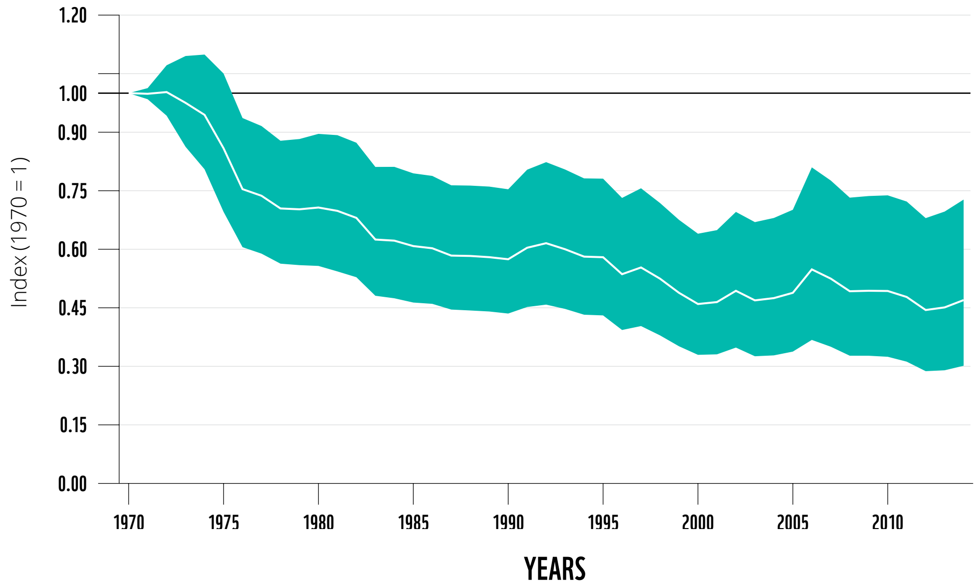
FIGURE 1:
THE DISTRIBUTION OF FOREST SPECIALIST POPULATIONS INCLUDED IN THE FOREST SPECIALIST INDEX

Note: Some locations had data for multiple species.

FINDINGS OF THE FOREST SPECIALIST INDEX

The Forest Specialist Index declined by 53% between 1970 and 2014 (Fig 2: Index value 0.47; range 0.30-0.73). This indicates that 455 monitored populations of forest specialists more than halved in number on average over the period, at an annual rate of decline of 1.7%. The decline in the index was steepest between 1970 and 1976 after which the decline continued at a slower rate; in the final two years of the index, the number of increasing species exceeded the number of declining species. It is not possible to say at this stage whether the latest upturn in the Forest Specialist Index is a sign of a significant long-term improvement in the abundance of forest specialists as there have been previous instances of positive years in the index but these have all been followed by a subsequent decline.

FIGURE 2:
FOREST SPECIALIST INDEX FOR 268 FOREST SPECIALIST SPECIES (455 POPULATIONS) FROM 1970 TO 2014.

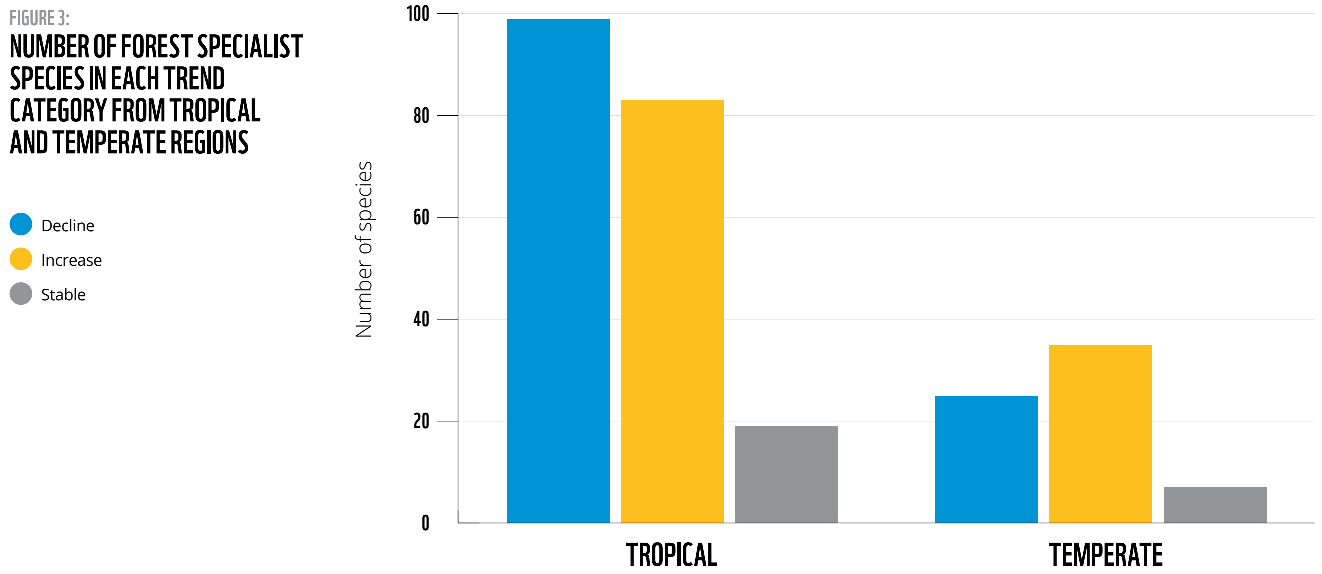


Note: Solid line shows the weighted index values and shaded region shows the 95% confidence for the index

REGIONAL COMPARISONS

Of the species studied, 75% were from tropical forests, reflecting the fact that these are the most biodiverse forests in the world. Species showed a mixture of positive, stable and negative trends in both tropical and temperate forests (Fig 3). In tropical forests, negative species trends outweighed the positive trends while in temperate forests, the opposite was found. The more rapid rates of forest loss in tropical regions over this period[10] could be a factor but as seen in the following section (Drivers of forest vertebrate population trends), the picture is more complex.

FIGURE 3:
NUMBER OF FOREST SPECIALIST SPECIES IN EACH TREND CATEGORY FROM TROPICAL AND TEMPERATE REGIONS



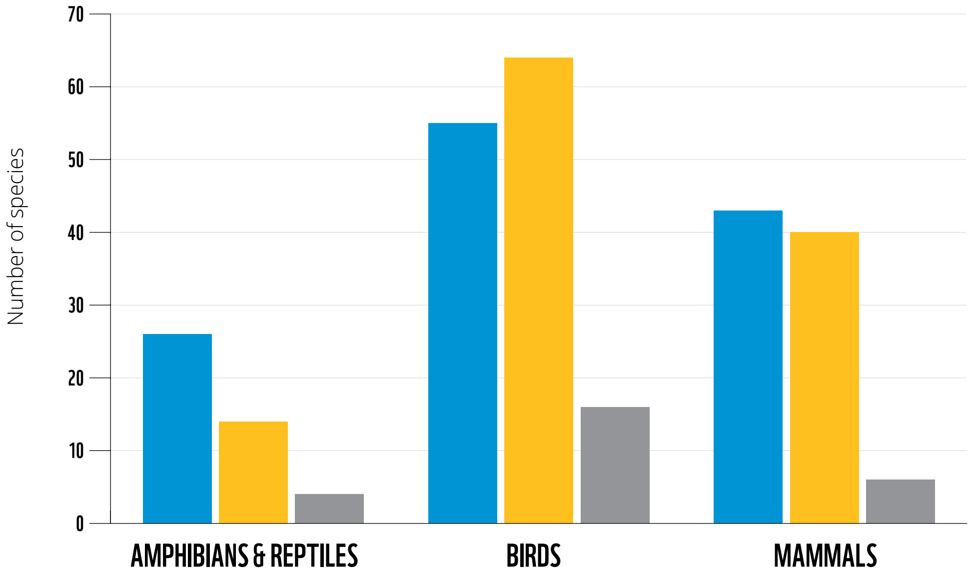
10 FAO, 2015

DIFFERENCES AMONG TAXA

The decline observed in the Forest Specialist Index was consistent among mammals, reptiles and amphibians but less so among birds, especially from temperate forests. The analysis revealed that there were more years with an average negative trend than there were positive among species of mammals, reptiles and amphibians; the reverse was true for birds. This was also seen when categorising the average trend for each species over the whole time period as an increase, a decline or a stable trend (Fig 4).

FIGURE 4:
NUMBER OF FOREST SPECIALIST SPECIES IN EACH TREND CATEGORY FROM EACH TAXONOMIC CLASS

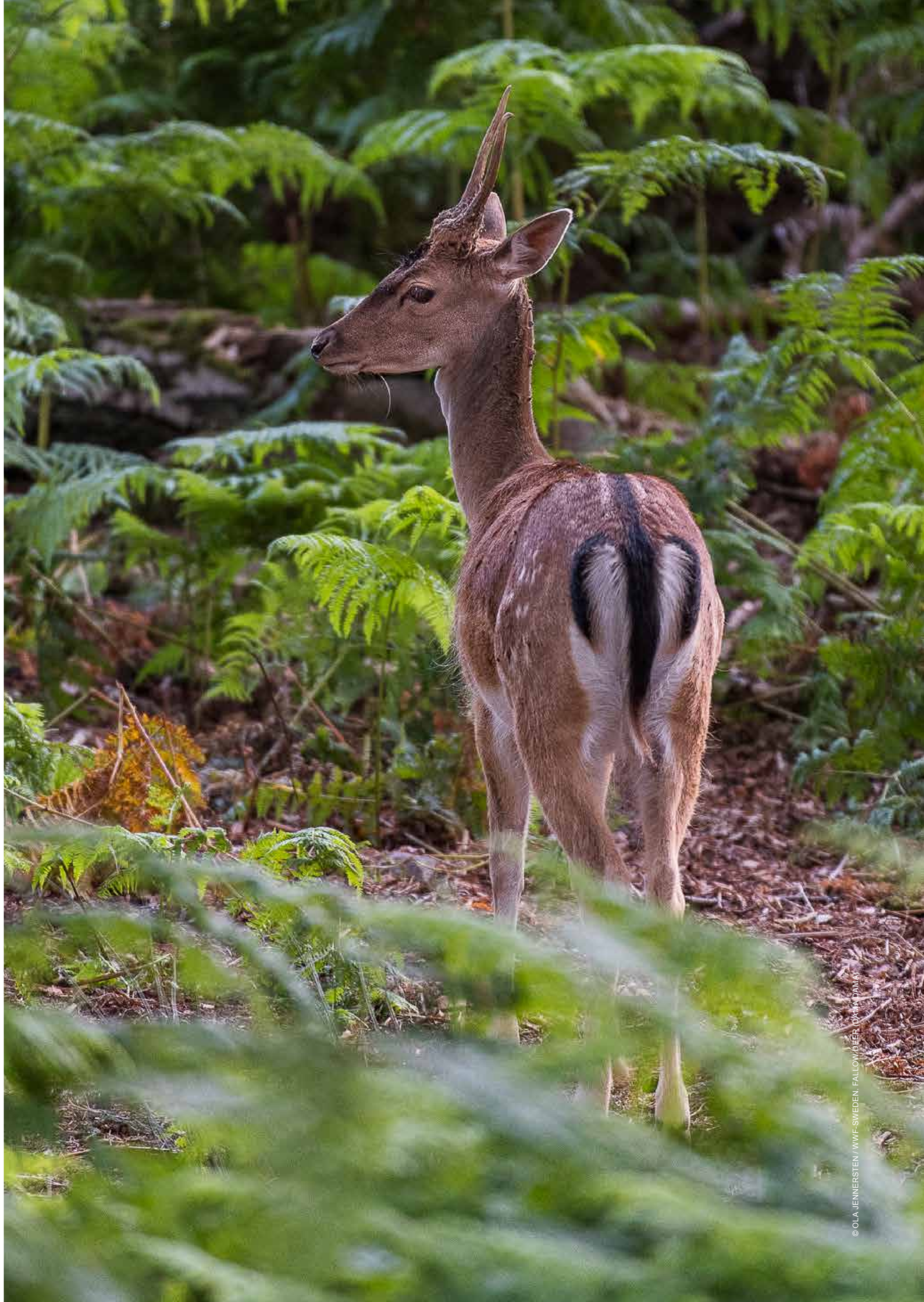
Decline
Increase
Stable



GLOBAL REPRESENTATION

Assessing the geographical coverage of the data for forest specialists, species are represented from all regions of the world (Fig 1); however, some forest ecosystems, such as in West and Central Africa, the Amazon and Southeast Asia, were not well represented by the data. Over half of the species in the index are from the Americas, while the number of African species was the lowest. Forest specialist birds and mammals from Europe and North America had the highest proportion of known species represented in the index; all species groups from other regions were represented by less than 10% of known species.

As an indicator for forest specialists, this index highlights trends in broad taxonomic groups and regions and provides a valuable complement to indices of forest cover, but more data from some important forest areas is now needed to understand if the global picture reflects trends in these underrepresented regions.



 FALLOW DEER (DAMA DAMA)

CASE STUDY 1

TEETERING ON THE BRINK: THE JAVAN RHINO

The Javan rhinoceros *Rhinoceros sondaicus* used to be fairly common throughout the forests of Southeast Asia, with three subspecies occupying eastern India, Bangladesh, southern China, Laos, Vietnam, Cambodia, Thailand, Myanmar, Malaysia and Indonesia. Intensive hunting began in the mid-nineteenth century causing the species to decline rapidly and become increasingly rare throughout its range. While the decline was driven primarily by hunting, habitat loss is likely to have contributed as populations became increasingly fragmented and accessible to hunters.

By the mid-twentieth century one subspecies (*R. s. inermis*) was extinct and another (*R. s. annamiticus*), previously widespread in Thailand, Cambodia, Laos and Vietnam, was presumed extinct. However, a small population was rediscovered in 1988 when an individual was killed by a poacher in Cat Loc, a forest block in southern Vietnam. Cat Loc had experienced high human population growth and deforestation in the 1970s following an influx of people from northern Vietnam and conversion of the lowland forest, primarily to cashew plantations. Field surveys in 1989 indicated a population of just 10-15 rhinos remained in the area[11].

The forest was designated as a rhinoceros sanctuary in 1992 and later merged with other nearby reserves to form Cat Tien National Park. However, the reserves were disconnected due to agricultural encroachment and human settlements in the intervening habitat. Despite the establishment of targeted conservation projects, monitoring and patrols within the park were infrequent[12]. A lack of law enforcement and ineffective management of the national park allowed the continuation of illegal forest conversion, road development and human occupation in the rhino conservation area. By 2007, it was believed that just two rhinos remained, and when dung samples were collected in 2009-2010 these were identified as coming from a single individual[13,14]. The extinction of the subspecies was confirmed in April 2010 when the last rhino was found dead, with a shot wound and its horn removed.

The third and only surviving subspecies of Javan rhino, *R. s. sondaicus*, is restricted to a single population in Ujung Kulon National Park in Indonesia. This subspecies has also suffered a massive range reduction and population decline, with around 68 individuals remaining[15]. In Ujung Kulon the population is being effectively protected by rhino protection units and appears to be stable. However, it appears the population is at carrying capacity and will not increase without conservation intervention. The single location combined with the small population size also makes the species incredibly vulnerable to extreme events such as disease or natural disasters. It is therefore crucial to establish a second viable population elsewhere in Indonesia. WWF is working to achieve this and continuing to enhance the protection of the remaining rhinos and their habitat in Ujung Kulon to prevent the species' global extinction.

11 Schaller et al., 1990

12 Brook et al., 2014

13 Brook et al., 2012

14 PPID, 2019

15 Setiawan et al., 2018

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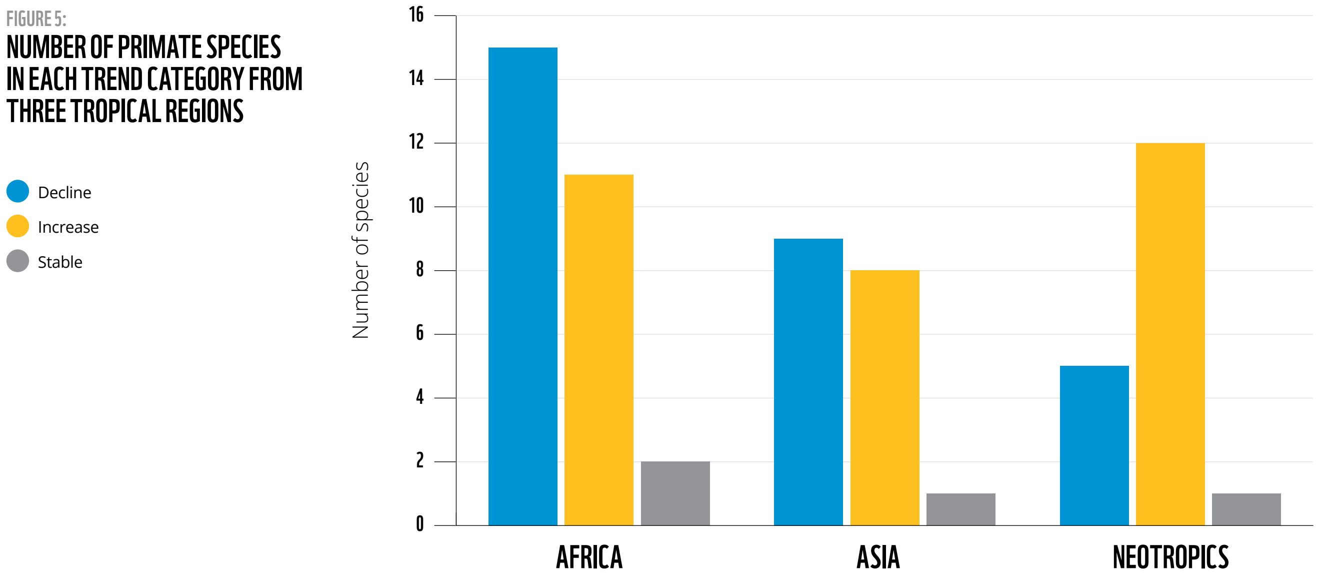
PRIMATES

Given the importance of many primate species to regeneration of carbon-dense trees as seed dispersers in forests[16], a closer look was also taken at the trends in these species. For successful maintenance and enhancement of forest carbon stocks – as called for in the Paris Agreement – having a healthy population of primates matters greatly.

Nearly half of the mammal species in the Forest Specialist Index are primates and, given the importance of this group for forests, the focus for analysis was extended to include generalists. Population trend data for primates was available for 66 species and from all regions in which they are found: the Neotropics (Central and South America), Africa and Asia. Of these 66 primate species, 42 are considered forest specialists, including great apes such as mountain gorillas and orang-utans, gibbons, lemurs and monkeys. Across all of the primates we found that roughly half had increasing species trends on average and half declining. The regional analysis included all 66 species and found that on average the majority of primates in the Neotropics had increased and the majority in Africa had declined. Primate species in Asia revealed slightly more species declining on average than increasing.

The trend found in the Neotropics is unexpected as the IUCN Red List[17] assessment of how threatened primates are revealed that more than half of these species have declining population trends[18]. The contradiction can be explained by a few outliers in the data, such as the recovery of two species as a result of forest regeneration in the Santa Rosa National Park in Costa Rica (Case study 3: From farmland to forest). The trend data shown in Fig 5 for 18 Neotropical primates (out of a total of 171 primate species that live in the Neotropics) is not representative of the region as a whole, but has allowed examples of pathways to recovery to be highlighted.

FIGURE 5:
NUMBER OF PRIMATE SPECIES IN EACH TREND CATEGORY FROM THREE TROPICAL REGIONS



16 Gardner et al., 2017

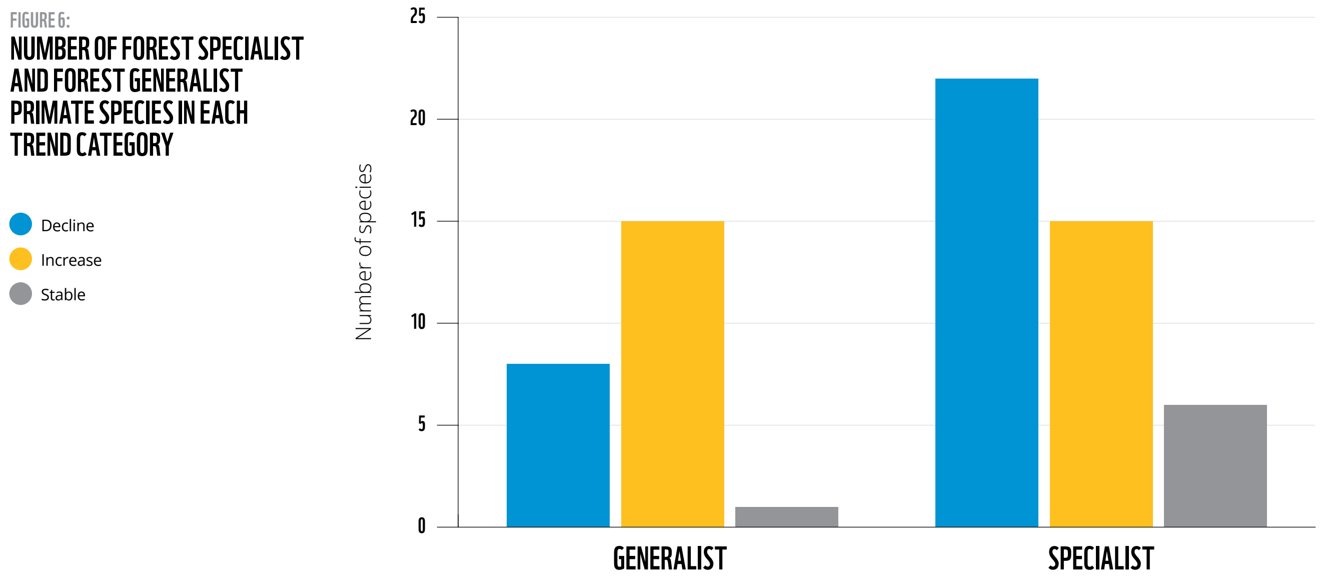
17 The International Union for Conservation of Nature (IUCN) Red List of Threatened Species is the world's most comprehensive information source on the global conservation status of animal, fungi and plant species.

18 Estrada et al., 2017

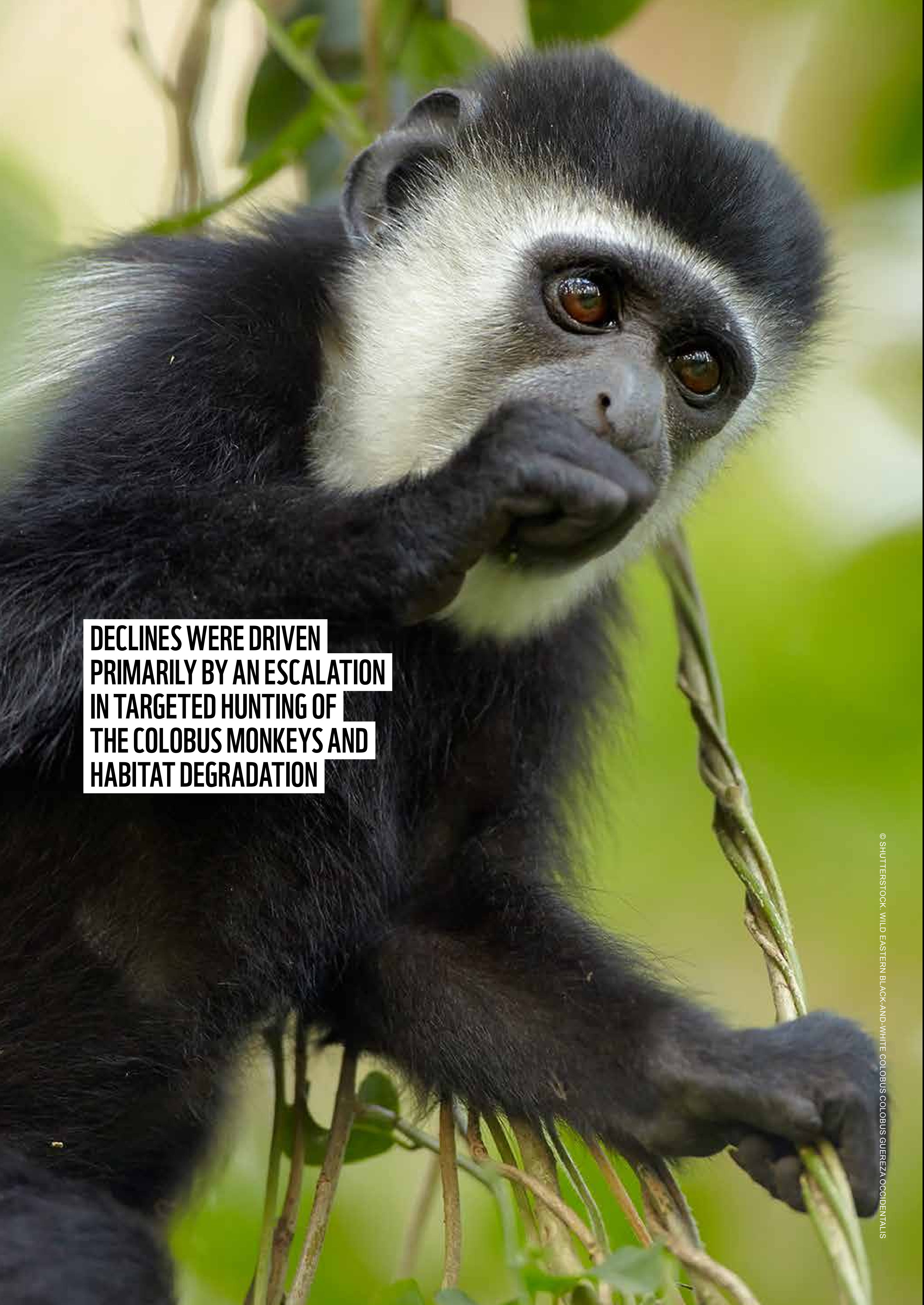
Conversely, the proportion of declining species trends from Africa reported here is slightly greater than reported in the IUCN Red List assessment for primates. Over half of all forest species in this report threatened by overexploitation are African primates which highlights the impact that targeted hunting can have (Case study 2: Colobus monkeys in Tanzania).

Of the primates that are forest specialists, over half of the species showed a declining trend. This was more than for forest generalists (Fig 6). An ability to use alternative or human-modified habitats may explain why generalist primates are faring better; research also shows that generalist primates are less likely to be threatened with extinction[19]. Primates that are forest specialists are wholly reliant on forest habitat for their persistence which means they are more sensitive to changes or loss of habitat than generalist species. In turn these specialists often play vital roles in the functioning of the ecosystem, such as seed dispersal and herbivory, so their fate can also impact the health of the forest.

FIGURE 6:
NUMBER OF FOREST SPECIALIST AND FOREST GENERALIST PRIMATE SPECIES IN EACH TREND CATEGORY



19 Galán-Acedo et al., 2019



DECLINES WERE DRIVEN PRIMARILY BY AN ESCALATION IN TARGETED HUNTING OF THE COLOBUS MONKEYS AND HABITAT DEGRADATION

CASE STUDY 2

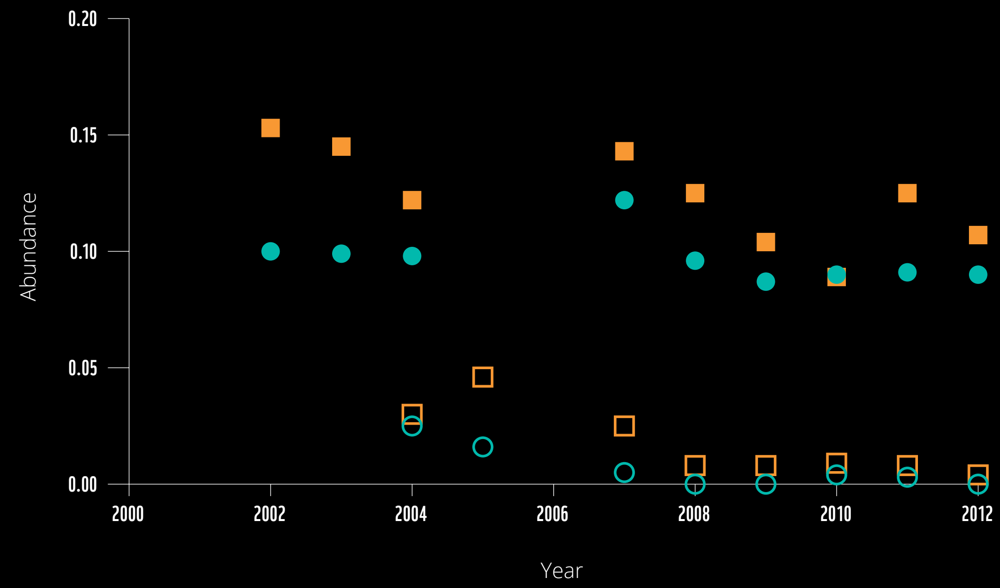
COLOBUS MONKEYS IN TANZANIA

An area of particular importance for primate endemism and richness are the Udzungwa Mountains of Tanzania, home to 13 primate species including the Critically Endangered kipunji, two colobus monkeys and various species of bushbabies[20].

Situated within the Udzungwa National Park is the Mwanihana Forest, home to stable populations of both the Angolan and Udzungwa red colobus monkeys. Both species are forest specialists that have benefited from on-the-ground protection from hunting and habitat loss[21]. Yet outside the national park law enforcement is lacking and human disturbance is high. In the unprotected Udzungwa Scarp Forest Reserve, for instance, populations of Angolan colobus and Udzungwa red colobus declined markedly between 2004 and 2012. These declines were driven primarily by an escalation in targeted hunting of the colobus monkeys and habitat degradation.

FIGURE 7:
COLOBUS MONKEY POPULATIONS IN THE PROTECTED MWANIHANA FOREST (MF) AND THE UNPROTECTED UDZUNGWA SCARP FOREST RESERVE (USF), BOTH IN THE UDZUNGWA MOUNTAINS OF TANZANIA[20,21]

- Angolan colobus, MF
- Udzungwa red colobus, MF
- Angolan colobus, USF
- Udzungwa red colobus, USF



20 Rovero et al., 2009

21 Rovero et al., 2015

CASE STUDY 3

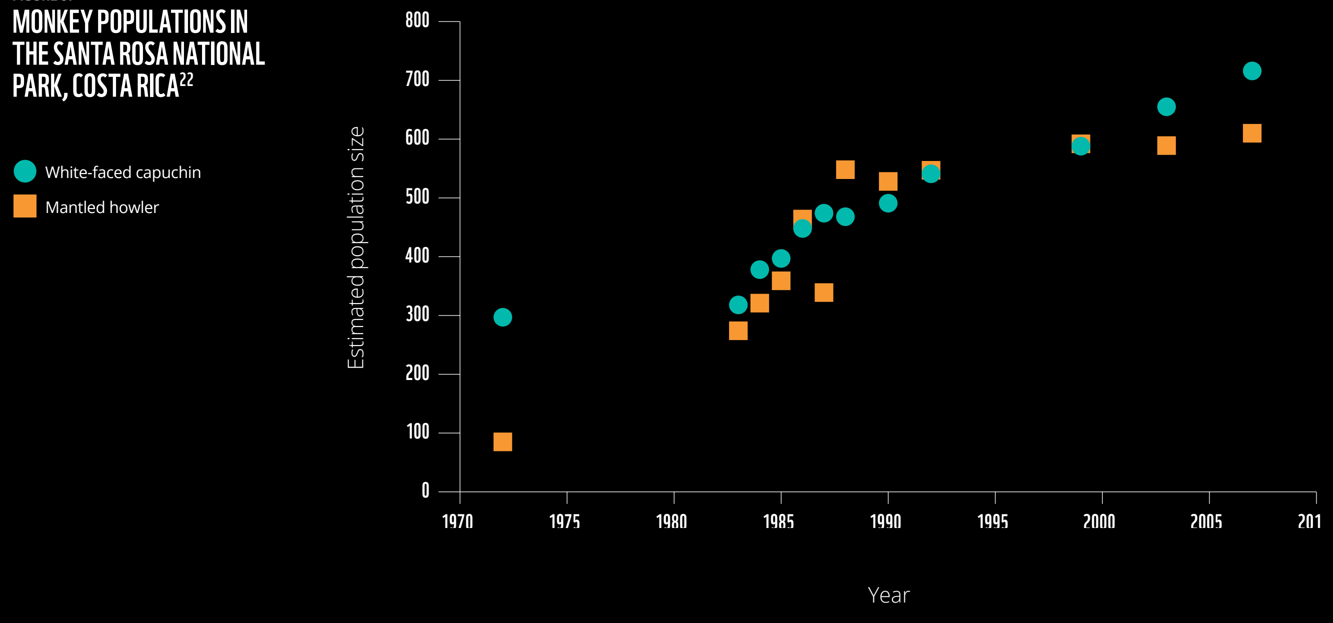
FROM FARMLAND TO FOREST IN COSTA RICA

Habitat loss and degradation is the most common threat facing forest specialists. However, some areas that have been deforested and degraded are, with the right management and protection, being restored to forest.

The Santa Rosa National Park in Costa Rica was established in 1971 on reclaimed ranch lands. Before the establishment of the park, much of the Santa Rosa forests had been cleared for cattle pasture, selectively logged, damaged by anthropogenic fires or impacted by hunting. Since being designated as a national park almost 50 years ago the forests have been protected from hunting, human disturbance and logging, and the former pasturelands are regenerating to forest.

As the forests have begun to recover, so have the resident monkey populations: long-term monitoring of mantled howler monkeys and white-faced capuchins has shown an increase in both populations since the park's establishment[22]. However, the speed of recovery of different forest species varies in relation to species-specific characteristics such as body size, diet and behavioural ecology. Capuchins can inhabit fairly young forest patches, and the most recent survey at Santa Rosa showed the population had grown continuously since the 1980s[23]. Howler monkeys prefer forests at least 60 years old, and a population plateau since the 1990s suggests the population has reached its current carrying capacity in the national park. Although spider monkeys are also found in Santa Rosa they are only found in large old-growth patches of forest at least 100-200 years old. Therefore, while forests may regenerate relatively quickly in terms of tree cover, it may take many decades for the vertebrate communities that inhabit them to fully recover.

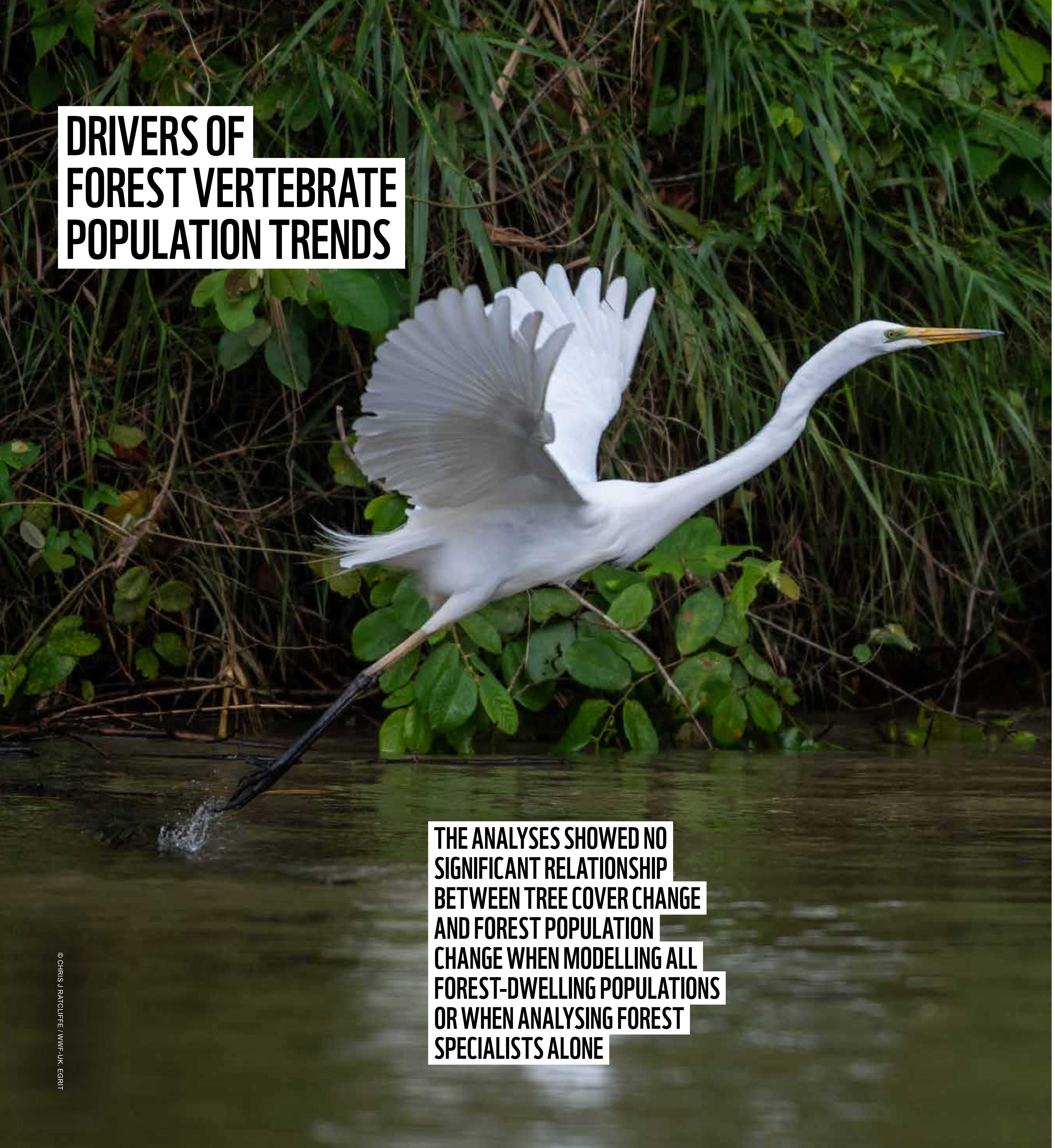
FIGURE 8:
MONKEY POPULATIONS IN THE SANTA ROSA NATIONAL PARK, COSTA RICA[22]



22 Fedigan and Jack, 2012

WHILE FORESTS MAY REGENERATE RELATIVELY QUICKLY IN TERMS OF TREE COVER, IT MAY TAKE MANY DECADES FOR THE VERTEBRATE COMMUNITIES THAT INHABIT THEM TO FULLY RECOVER.

DRIVERS OF FOREST VERTEBRATE POPULATION TRENDS



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THE ANALYSES SHOWED NO SIGNIFICANT RELATIONSHIP BETWEEN TREE COVER CHANGE AND FOREST POPULATION CHANGE WHEN MODELLING ALL FOREST-DWELLING POPULATIONS OR WHEN ANALYSING FOREST SPECIALISTS ALONE

RELATIONSHIP BETWEEN FOREST VERTEBRATES AND TREE COVER CHANGE

The Forest Specialist Index shows us that forest specialist populations have declined globally since the 1970s. Here, an investigation into the drivers of that decline using forest species population abundance data from the Living Planet Database (LPD) is presented.

Abundance datasets of forest vertebrates from survey sites across the world were used to assess whether changes in forest species populations were associated with pressures in the surrounding area (within a 5km radius of the survey site). Populations were included if the survey covered at least a five-year period, to minimise the influence of short-term fluctuations, and if they were surveyed in a discrete area such as a national park. They were excluded if from national or regional surveys which contain data from many sites. The analyses included population data for all forest-dwelling vertebrate species (generalists and specialists; 1,668 populations) and were repeated including only forest specialists (175 populations), as these species are restricted to forests and are more likely to show a strong relationship with tree cover change. For each site with forest vertebrate data, satellite imagery was used to assess tree cover change over the survey period (see Green et al., 2019 for full details). The tree cover data reflected changes in both natural and planted forests, which currently cannot be differentiated using satellite imagery.

In order to identify global drivers of forest vertebrate populations, relationships were assessed between forest vertebrate population change and tree cover change, species body size (to investigate the effect of species traits), human population density, accessibility to the site, road density and overexploitation threat (based on ancillary population-level information held in the LPD). If the models showed a positive relationship between forest vertebrate populations and tree cover change this would indicate that the greatest population declines were happening in areas that had lost the most tree cover and that populations were increasing in areas gaining tree cover, supporting the use of forest area as a proxy indicator of forest biodiversity.

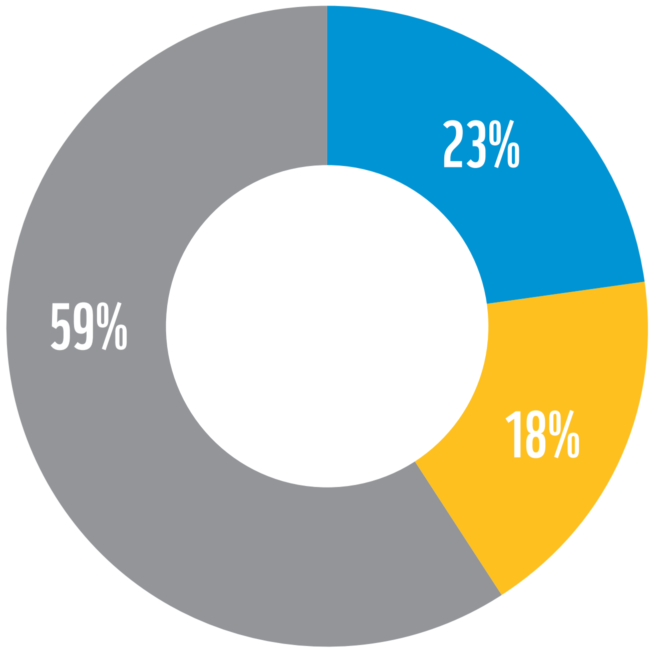
The analyses showed no significant relationship between tree cover change and forest population change when modelling all forest-dwelling populations or when analysing forest specialists alone.

The absence of a relationship is important because it shows that, at a global scale, forest species are not responding in a consistent manner to tree cover change in the surrounding area. Areas that have gained tree cover are not necessarily seeing a recovery of forest biodiversity, and there are additional pressures driving forest species declines that are not associated with tree cover loss. The importance of additional pressures is supported by the finding that overexploitation has a significant negative effect on forest specialist populations. Overexploitation includes unsustainable hunting, persecution, indirect killing or collection of wild individuals for trade. However, this is based on a small number of populations – only 12 forest specialist populations were threatened primarily by overexploitation compared to 163 populations with alternative threats or for which no threats were reported. Interestingly, all exploited forest specialist populations included in these analyses were mammals, and more than half were primates in Africa, such as guenons (e.g. the moustached monkey), colobus monkeys and gorillas. As noted earlier, the loss of frugivorous species such as primates has consequences for the carbon storage potential of forests[23]. There were no significant relationships between any other pressures and forest species population change.

While we did not find evidence of a globally consistent relationship between forest species population change and tree cover change, at the local scale we were able to observe individual occurrences of this relationship. The correlation between annual abundance values of individual forest specialist populations and annual tree cover in the surrounding area was investigated to identify populations correlated with tree cover (Fig 9). Time-lags between tree cover change and population change were allowed for, as forest vertebrates may take some years to respond to habitat changes. Of the 175 forest specialist populations included in our analyses, 40 were found to be positively correlated with tree cover, while others were negatively correlated or uncorrelated with tree cover.

FIGURE 9:
PERCENT OF FOREST SPECIALIST POPULATIONS INCLUDED IN THE ANALYSES THAT WERE POSITIVELY, NEGATIVELY OR UNCORRELATED WITH TREE COVER CHANGE

- Positively correlated
- Negatively correlated
- Uncorrelated



23 Osuri et al., 2016; Gardner et al., 2017

>60%
OF THREATENED FOREST SPECIALIST POPULATIONS FACE MORE THAN ONE THREAT

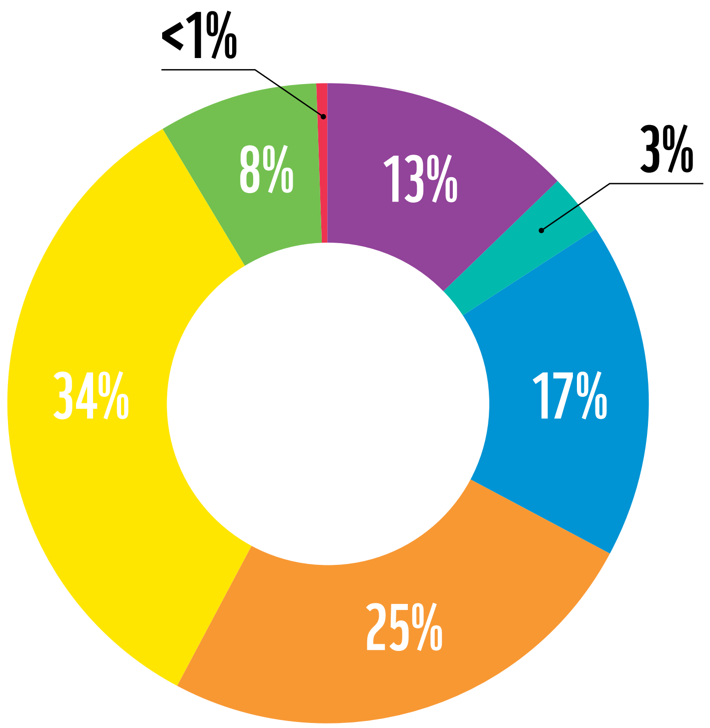
THREATS TO FOREST VERTEBRATES

The absence of a consistent relationship between forest vertebrate populations and tree cover change does not mean that protecting our remaining forests is not crucial for forest biodiversity; indeed, the most frequent threat listed in the LPD for forest specialist populations is habitat loss and degradation/change. Rather, it points to a more complex situation where forest vertebrate populations are responding to multiple context-specific drivers and indicates that focusing on tree cover alone is not enough to protect forest biodiversity. On-the-ground monitoring and local knowledge of the study area can provide a more comprehensive view of threats below the canopy.

Habitat loss and habitat degradation/change account for almost 60% of threats to forest specialists in the LPD (Fig 10). Clearance for commodity production, forestry, shifting agriculture and wildfires were the major drivers of forest loss between 2000 and 2015[24]. Exploitation is the second most frequent driver of forest population decline after habitat loss and degradation: 17% of threats recorded for forest specialist populations were due to overexploitation (excluding populations with no threat information available). Primates are particularly threatened by hunting: of the 112 forest-dwelling primate populations (generalist or specialist) in the LPD with known threat status, 40 were threatened by overexploitation. Climate change was the third most frequent threat to forest specialist populations, listed as a threat to 43% of amphibian populations, 37% of reptile populations, 21% of bird populations but only 3% of mammal populations (although this was based on a small number of amphibian and reptile populations). More than 60% of threatened forest specialist populations faced more than one threat.

FIGURE 10:
TYPES OF THREAT AS A PERCENT OF ALL THREATS FACED BY FOREST SPECIALIST SPECIES, BASED ON POPULATION-LEVEL INFORMATION IN THE LIVING PLANET DATABASE

- Climate Change
- Disease
- Explotation
- Habitat degradation/change
- Habitat loss
- Invasisve species/genes
- Pollution



24 Curtis et al., 2018

UNDERSTANDING POPULATION DECLINES AND CONSERVATION SUCCESS STORIES

To extract more information on the drivers of forest population change and to understand why some populations were responding to tree cover change but others were not, the source literature of forest specialists positively or negatively correlated with tree cover was examined (Table 1).

This subset of the forest specialist dataset included various examples of pressures driving forest population declines, including the extinction of a rhino subspecies in response to poaching and habitat loss (Case study 1), the hunting of monkeys in Africa (Case study 2), an association between increasing intensity of La Niña and a decline in birds in the Amazon (Case study 5), and disease affecting amphibians in Puerto Rico. Other studies gave examples of forest species populations recovering after successful conservation initiatives, such as forest regeneration on former ranch lands (Case study 3), intensive population protection for mountain gorillas (Case study 4) and the eradication of introduced rats from islands. These studies show that, in order for forest biodiversity to recover, we need to not only protect forest area but also identify and address the multiple other threats forest species face. Moreover, the significant negative impact of overexploitation on forest specialist populations and the multiple other threats identified here highlight the importance of on-the-ground multi-year monitoring of forest animals and the local pressures they face. Without such monitoring, below-canopy threats such as hunting, invasive species and disease cannot be identified and addressed.

IN ORDER FOR FOREST BIODIVERSITY TO RECOVER, WE NEED TO NOT ONLY PROTECT FOREST AREA BUT ALSO IDENTIFY AND ADDRESS THE MULTIPLE OTHER THREATS FOREST SPECIES FACE.

TABLE 1:
FOREST UTILISATION, DRIVERS OF FOREST COVER CHANGE AND DRIVERS OF POPULATION CHANGE.

Category	Observation	No. of populations	Countries	Correlation of populations with tree cover
Forest utilisation	Hunting in forest (not necessarily targeting the species being monitored)	14	Brazil, Canada, Ecuador, Ghana, Madagascar, Spain, Tanzania, Uganda	11/14 populations negatively correlated with tree cover
	Logging	9	Brazil, Ghana, Madagascar, Tanzania, Uganda, USA	6/9 populations negatively correlated with tree cover
Drivers of forest cover change	Regeneration (including managed regeneration of native tree species and natural regeneration)	10	Antigua and Barbuda, Costa Rica, New Zealand, USA, Venezuela	All populations positively correlated with tree cover
	Extreme events (fire, storm damage)	3	Cook Islands, USA, Russian Federation	All populations positively correlated with tree cover
Specified drivers of population change	Poaching	5	Ghana, Indonesia, Tanzania	All populations negatively correlated with tree cover
	Habitat change	8	Cook Islands, Costa Rica, Indonesia, USA, Venezuela, Vietnam	5/8 populations positively correlated with tree cover
	Food availability	4	Argentina, Canada, Nigeria, Venezuela	3/4 populations positively correlated with tree cover
	Disease	4	Ecuador, Puerto Rico, Venezuela	3/4 populations negatively correlated with tree cover
	Climate	11	Ecuador, Panama, Puerto Rico, Sweden	10/11 populations negatively correlated with tree cover
	Increased predation	3	Argentina, Madagascar, Spain	2/3 populations negatively correlated with tree cover
	Invasive species control	4	Antigua and Barbuda, Cook Islands	All populations positively correlated with tree cover

Note *Based on a review of the source literature for 71 forest specialist populations in the LPD that were identified as positively or negatively correlated with tree cover change within a 5km radius of the survey location. Calculated using a global dataset of tree and bare ground cover (Song et al., 2018).*

CASE STUDY 4

JOURNEY OF RECOVERY FOR THE MOUNTAIN GORILLA

Gorillas are the largest of the great apes and share 98.3% of their DNA with humans. Like humans they have a slow reproduction rate which makes it particularly difficult for them to recover following population declines.

Habitat loss, due to logging, agricultural expansion and mining operations, is a major threat to gorillas, as are hunting for the bushmeat trade and the spread of diseases such as Ebola. Many populations are found in areas experiencing civil unrest, making law enforcement weak and conservation interventions dangerous. Faced with this onslaught of threats, the Critically Endangered western gorilla (*Gorilla gorilla*) and the lowland subspecies of the eastern gorilla (*Gorilla beringei graueri*) continue to decline[25]. And yet there is cause for cautious optimism for another subspecies.

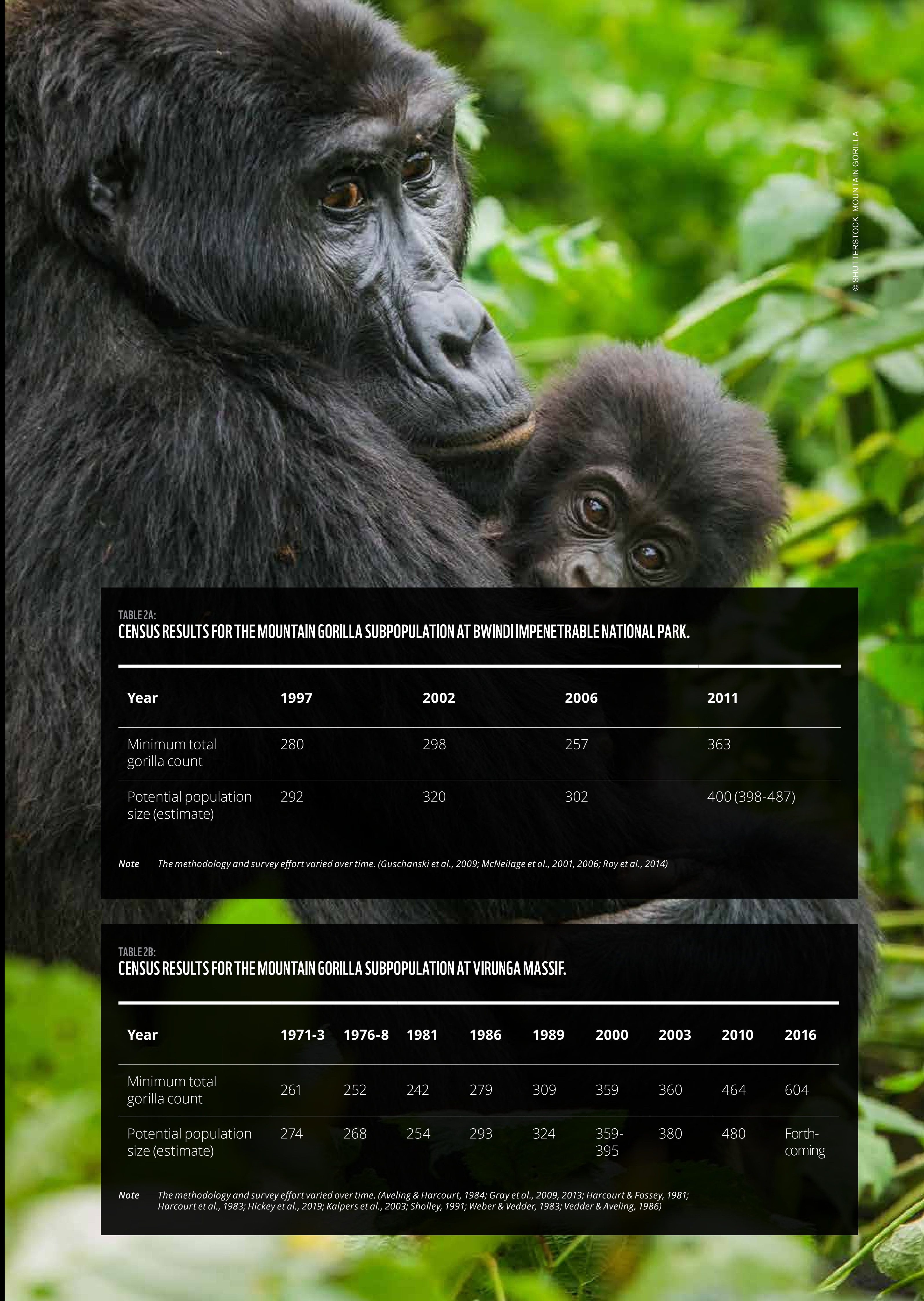
98.3%

OF GORILLA DNA IS SHARED WITH HUMANS

Thanks to intensive conservation efforts in Virunga massif and Bwindi Impenetrable National Park the mountain gorilla (*Gorilla b. beringei*) population is believed to be increasing, with the most recent estimates putting the global population at 1,004 individuals[26]. Taking into account changing methods, the results from the last three decades of surveys suggest that mountain gorillas are the only subspecies of great ape that is not declining in numbers. There is evidence that both populations have in fact been growing over this same period (Table 2A and B). It is important to note that techniques for detecting individual mountain gorillas and verifying unique individuals have been improving over time, as well as the level of survey effort. Direct comparisons, therefore, are not scientifically sound, but give the best indication of how the population is faring – and this is believed to be positive. The success at these sites is down to tackling the multitude of threats facing the subspecies, achieved through engagement with the local community, daily anti-poaching and anti-snare patrols, veterinary care, regulated ecotourism and effective law enforcement.

25 Plumptre et al., 2015; Strindberg et al., 2018

26 Greater Virunga Transboundary Collaboration, 2018



© SHUTTERSTOCK, MOUNTAIN GORILLA

TABLE 2A:

CENSUS RESULTS FOR THE MOUNTAIN GORILLA SUBPOPULATION AT BWINDI IMPENETRABLE NATIONAL PARK.

Year	1997	2002	2006	2011
Minimum total gorilla count	280	298	257	363
Potential population size (estimate)	292	320	302	400 (398-487)

Note *The methodology and survey effort varied over time. (Guschanski et al., 2009; McNeilage et al., 2001, 2006; Roy et al., 2014)*

TABLE 2B:

CENSUS RESULTS FOR THE MOUNTAIN GORILLA SUBPOPULATION AT VIRUNGA MASSIF.

Year	1971-3	1976-8	1981	1986	1989	2000	2003	2010	2016
Minimum total gorilla count	261	252	242	279	309	359	360	464	604
Potential population size (estimate)	274	268	254	293	324	359-395	380	480	Forth-coming

Note *The methodology and survey effort varied over time. (Aveling & Harcourt, 1984; Gray et al., 2009, 2013; Harcourt & Fossey, 1981; Harcourt et al., 1983; Hickey et al., 2019; Kalpers et al., 2003; Sholley, 1991; Weber & Vedder, 1983; Vedder & Aveling, 1986)*

CASE STUDY 5

THE AMAZON UNDER THREAT

The future of Amazon rainforest will be a litmus test of whether we have adequately responded to the climate emergency.

The Amazon is a major carbon store and natural sink of atmospheric carbon, but our impact on the rainforest is causing huge amounts of emissions through deforestation and degradation. At the same time, the Amazon rainforest is itself highly vulnerable to climate change, and if we continue on our 'business as usual' path then two-thirds of the species that live here will be under threat.[27] The Amazon is so vast that the effect of climate change on the rainforest will vary across its range, from wetter to drier areas. There are many uncertainties and complexities, but past experiences of increased rainfall levels and incidences of fire give us some glimpses into a future we hope to avoid for this most valuable of ecosystems.

For example, data used in this report found that increased levels of rainfall in the western Amazon in Ecuador were linked to a decline in populations of a range of bird species over the period 2001-2014[28]. Bird populations were monitored in a forest area considered stable and not directly disrupted by human activity, but the numbers of birds identified by researchers in 2014 had almost halved compared to 2001 levels. Over this period the region experienced stronger La Niña[29] events than previous years, which are associated with increased rainfall at this site. The higher levels of rainfall over several years is thought to have reduced the birds' reproductive success and survival. La Niña and its opposite, El Niño, are normal occurrences in this region but due to climate change their patterns are changing. Some models suggest we can expect greater intensities of each event and that they will impact a much wider area of South America in future[30].

In contrast, the central, eastern and southern portions the Amazon rainforest are expected to experience drier conditions due to climate change in the future and are at increased risk of fires as a result. Although not caused by climate change themselves, the severe fires experienced in the Tapajos landscape in the central Amazon in 1997-98 offer insights into the impact such fires have on wildlife. Researchers surveyed bird populations on both burned and nearby unburned sites one year, three years and ten years after the fire event and, again, their data is integrated into the Forest Specialist Index. Species richness – the number of different species in the defined area – fell immediately after the fire at the burned sites, then experienced an increase at the three-year juncture (reflecting new habitat niches and plant species) before stabilising at a similar level to the unburned sites after 10 years[31]. However, in terms of population sizes of each bird species, of the 30 most abundant species in this forest area, 12 were still recovering in the burned areas even after 10 years. Those still in recovery tended to be the forest specialists, whose fate is most closely tied to that of the forest.

The threat of climate change to the Amazon is also worsened by deforestation and degradation as this leaves the rainforest less resilient and more exposed. Indeed, some scholars have argued that we are close to an irreversible transformation of the Amazon as a whole: we have already cleared around 20%, and a tipping point is thought to lie between 20-25% clearance that would see the southern and eastern portions of the rainforest dry out and transform into a savannah[32]. For species in the Amazon to survive and thrive it is vital that we halt deforestation and restore forests, keep global temperature rise well below 1.5°C and ensure wildlife is able to disperse across connected forest areas towards those places where the climate remains suitable for them.[27, 32]

27 WWF, 2018
28 Blake et al., 2015
29 According to the US National Oceanic and Atmospheric Administration, "El Niño and La Niña are opposite phases of what is known as the El Niño-Southern Oscillation (ENSO) cycle. The ENSO cycle is a scientific term that describes the fluctuations in temperature between the ocean and atmosphere in the east-central Equatorial Pacific". See https://oceanservice.noaa.gov/facts/ninonina.html (viewed 22/05/19).
30 Perry et al., 2017
31 Mestre at al., 2013
32 Lovejoy & Nobre, 2018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CONCLUSIONS AND RECOMMENDATIONS

> **WE MUST NOT LET A FOREST FULL OF TREES FOOL US INTO BELIEVING ALL IS WELL**
>
> – Kent Redford

- **Monitored forest vertebrate populations declined substantially between 1970 and 2014.** The results suggest that temperate forest birds may be faring better than tropical birds, mammals, reptiles and amphibians. The decline in forest specialist vertebrates has serious consequences for forest integrity and climate change because of the roles that particular vertebrates play in forest regeneration and carbon storage. To ensure the future health and carbon storage potential of our forests, strategies must be adopted to ensure the decline in forest vertebrates is reversed. This should be a priority for policy-makers and funders working to enhance forest carbon stocks and reduce emissions from deforestation and forest degradation.

- **Changes in tree cover – deforestation or reforestation – did not alone explain the changes in wildlife populations.** Our analysis found no consistent global relationship between forest vertebrate population change and tree cover change. In other words, changes in tree cover do not always reflect changes in populations of forest animals. Equally, wildlife populations could change with no apparent change in tree cover, one way or the other. Gains in tree cover do not necessarily signal a reduction in other pressures, and at a global level will include a large proportion of planted forests, which may not provide suitable habitat for forest wildlife. In addition, populations in some areas are declining without a corresponding decline in tree cover, responding instead to other pressures – such as overexploitation, invasive species, climate change and disease – that are acting independently of tree cover change.

  Critically, this does not mean that protecting forest area is not important for biodiversity – indeed, habitat degradation/change accounted for 60% of the threats to forests specialists in the LPD. It does, however, mean that the current focus on forest area as a proxy indicator of forest biodiversity in many international agreements is insufficient. Satellite-derived tree cover datasets have undoubtedly improved our ability to assess changes in forest cover, but they should be complemented by site-level information on local conditions and threats to forest species populations when assessing the state of forest biodiversity. The global decline in forest vertebrates and the lack of a relationship with tree cover change builds on other evidence that suggests a shift towards 'empty forests'. In the words of Kent Redford, who coined the term in 1992: "We must not let a forest full of trees fool us into believing all is well".

- **Conservation success stories show us that forest vertebrate populations can recover with the right strategies.** Tackling deforestation and increasing forest cover are essential but on their own insufficient to restore forest biodiversity. In order to reverse the decline of forest biodiversity it is crucial to address the multiple pressures on forest species. Research from areas that have employed a multi-pronged conservation approach, such as coupling habitat restoration with effective community engagement towards anti-poaching strategies, shows that the recovery of forest species populations is possible.

- **A direct measure of forest biodiversity should be included alongside forest cover in the post-2020 biodiversity framework and supporting global forest assessments. The Forest Specialist Index is recommended to fill this gap.** Until now, the monitoring of progress towards global biodiversity targets associated with forests has been hampered by a lack of information on forest biodiversity. As we move forward with a new global biodiversity framework it will be important to ensure there are targets and indicators that relate to forest quantity and quality. The Forest Specialist Index offers a tool to do so by providing a direct measure of the state of the world's forest vertebrate populations. We recommend that this indicator is adopted as a measure of the global status of forest biodiversity and considered in conjunction with indicators of forest cover.

- **More long-term systematic monitoring of forest species, particularly in the most biodiverse tropical forests in Asia, Africa, and the Amazon, is needed.** Moreover, there is lack of consistency in data collection methodologies across studies and over time, making it difficult to compare and synthesise results. There are massive opportunities to fill the gap in knowledge on vertebrate trends over time, improve the representation of the Forest Specialist Index, identify threats to forest species and inform conservation strategies to reverse the decline in forest vertebrates. Advancement in technologies, such as big data analytics, ubiquitous cell phones and emerging techniques of environmental DNA detections, has dramatically improved our ability to collect biodiversity data at scale. More research funding could be directed towards making new monitoring technologies cheaper and more accessible, while encouraging collaborations between researchers, forest managers, citizens and forest community members on data collection.

60%

OF THREATS TO FOREST SPECIALISTS IN THE LPD IS MADE UP OF HABITAT DEGREDATION OR CHANGE

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