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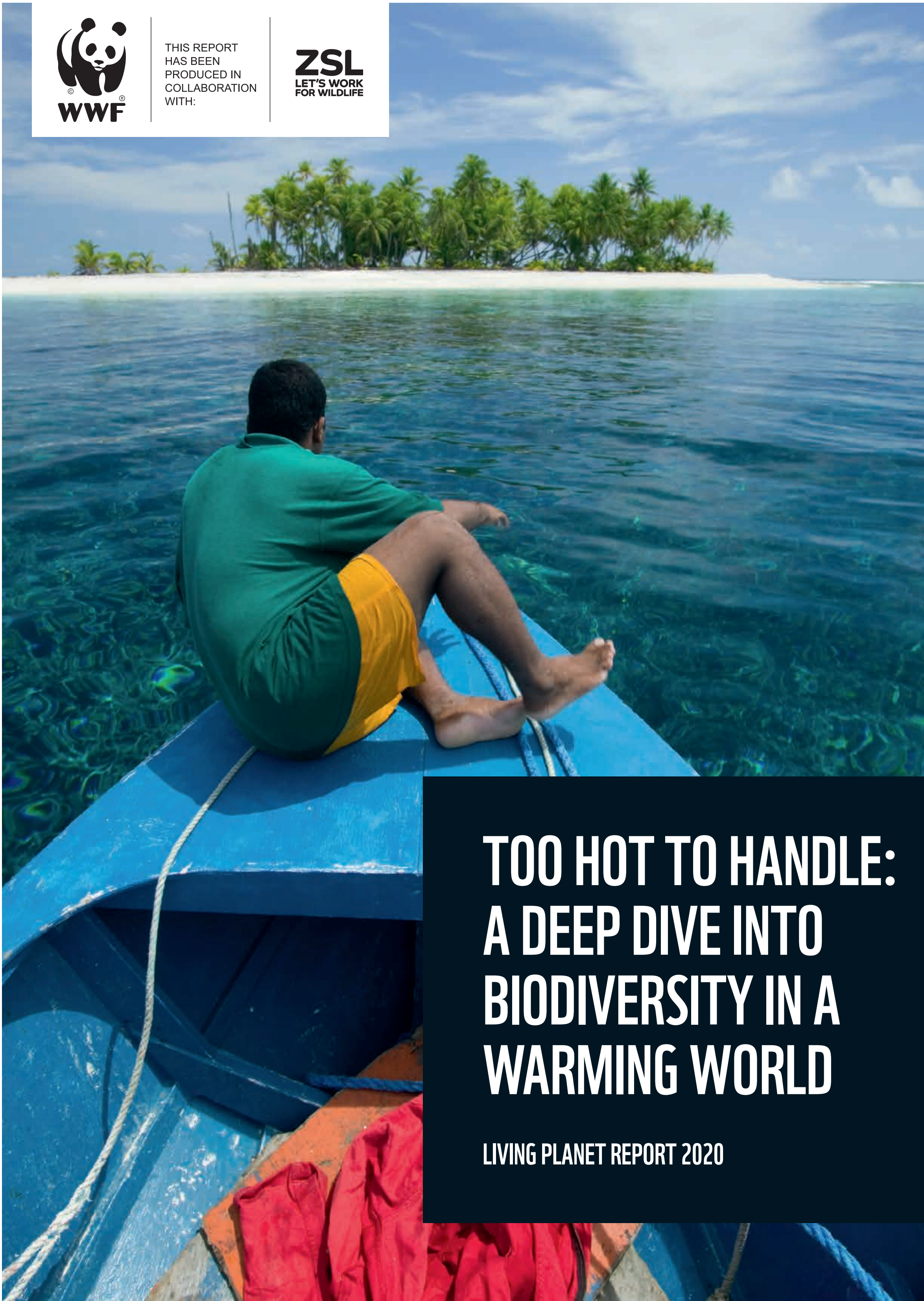

TOO HOT TO HANDLE: A DEEP DIVE INTO BIODIVERSITY IN A WARMING WORLD

LIVING PLANET REPORT 2020

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Cover photograph: © Global Warming Images / WWF
Funafuti atol, Tuvalu, is on the front line of the battle against global warming. Only 15 feet above sea level at the highest point, rising sea levels are increasingly putting the island population of 10,000 Tuvaluans at risk. It seems likely that this island nation will be the first country to disappear completely as a result of climate change and global warming.

TOO HOT TO HANDLE: A DEEP DIVE INTO BIODIVERSITY IN A WARMING WORLD

LIVING PLANET REPORT 2020

THE GROWING CLIMATE THREAT

Adrienne Etard, Jessica J. Williams and Tim Newbold (University College London) and Sarah Cornell (Stockholm Resilience Centre)

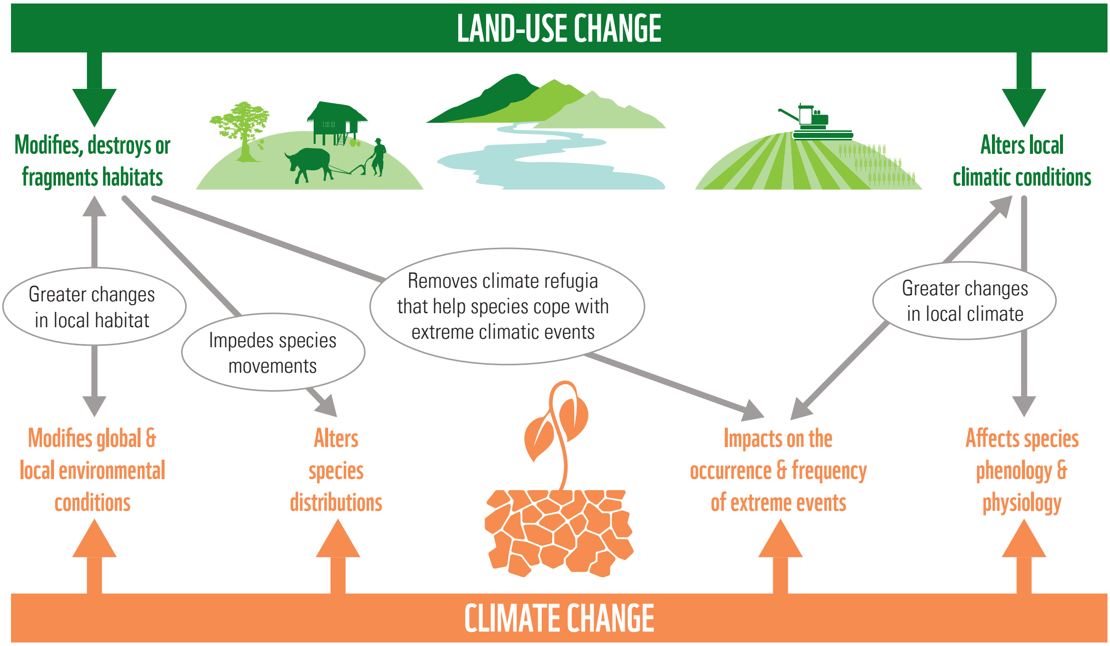
Environmental changes are occurring at a global scale. We know that the drivers affecting terrestrial biodiversity are not happening in isolation, and the interactions between them can be multipliers of change. In particular, climate change has the potential to interact with many other drivers of change. What we are starting to grasp, but still requires much attention, is how the drivers of biodiversity change are interacting and where this will have the greatest negative impacts on nature.

When two or more pressures occur simultaneously, their effects can accumulate and potentially interact. Synergistic interactions, where the combined impact of two biodiversity loss drivers is greater than the impact expected if the two were acting independently, pose the greatest concern. The rapid acceleration of global climate change has led to growing unease that it will interact synergistically with land-use change. For example, land-use change can lead to the fragmentation of habitats, making it harder for some species to move as the climate changes [1, 2]. In addition, changes in the way land is used can result in changes in local climate conditions. Within agricultural landscapes, cropland areas tend to be hotter and drier than surrounding areas [3]. This may lead to biodiversity having to face greater changes in temperature and precipitation regimes compared to the effects of the global climatic trend alone [4]. Other ways in which climate change and land-use change interact are explored more in the next section and in Figure 1.

As our natural systems begin to shift, getting to the roots of change takes more than just identifying the drivers, like climate change. We also need to assess how these drivers interact and cascade across global, regional and local scales. Understanding how, and where, these are likely to impact global biodiversity will be key to creating a world where both people and nature can thrive.

Figure 1:
Examples of ways in which land-use and climate change may interact synergistically [2, 4]. Grey circles indicate mechanisms by which one pressure may affect the impact of another pressure and lead to larger impacts on biodiversity than if these pressures acted independently.

The green leaves of a huge plantation of soy (*Glycine max*) seem to extend into the horizon, Rondonópolis, Brazil.



DOUBLE THE TROUBLE: LAND-USE CHANGE WITH CLIMATE CHANGE, AN INCREASING CHALLENGE

Climate change is growing as a threat to nature with recent analysis showing that, across every biodiversity indicator tested, the combined effect of climate change and land-use change is much worse than that of land-use change alone.

Moreno Di Marco (Sapienza University of Rome), Henrique Pereira (Martin Luther University, German Centre for Integrative Biodiversity Research – iDiv) and David Leclère (IIASA)

The overexploitation of natural resources and unsustainable changes in land use were the dominant drivers of global biodiversity loss in the 20th century [5]. Land-use change, in particular, affects every aspect of terrestrial biodiversity, with the risk of pushing species loss to a level where essential planetary functions might become compromised [6]. It is estimated that thousands of species have declined or disappeared since 1900 due to the impact of land-use change [7].

Establishing quantitative relationships between land-use change and observed biodiversity decline has allowed scientists to make predictions on the global biological impact of land-use change from the past to the future [8]. Additionally, by knowing the potential impact of land use on biodiversity, scientists have developed scenarios of sustainable socio-economic development which are compatible with international commitments to halt biodiversity decline [9]. This demonstrates that it is possible to satisfy essential human demands from land while preserving the biodiversity of our planet.

Yet, climate change is predicted to drastically affect every aspect of life on Earth, from human to natural systems [10]. The climate is changing at a rate with no precedent in recent millennia [11], and the pace of climate change may surpass that of land-use change [12, 13]. This represents a crucial risk to biodiversity because climate change is a recognised driver of species decline [14].

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) expert group on scenarios and models used a representative set of biodiversity and ecosystem service models to test scenarios of land-use change and climate change [15]. The analysis showed that, by 2050, across every biodiversity indicator tested, the combined effect of climate change and land-use change is much worse than that of land-use change alone. This is especially the case under scenarios of high carbon emissions, as was already found in works based on single biodiversity indicators [16, 7]. When looking at ecosystem services, there was a general increase in services such as food production and a general decrease in those such as coastal resilience, which decline rapidly under intense fossil fuel use or high land-use change [17].

It is important to clarify that these predictions come with uncertainties. First, the predicted magnitude of effects of climate versus land-use change relies on scenario settings. These represent possible future conditions, because the decisions that societies will make cannot be predicted with certainty. Second, while much evidence exists on the direct effect of land-use change on biodiversity, less is known about the impact of climate change and the ability of species to adapt to new climatic conditions (i.e. different from present conditions). Nevertheless, these results represent an important warning that acting on land-use change alone, without addressing climate change, might not be sufficient to halt future biodiversity decline, potentially imperilling hundreds of thousands of species with extinction [18].

Mitigating future changes in climate will therefore be key to reducing biodiversity loss. However, some solutions proposed to meet Paris Agreement targets for climate change mitigation could pose large risks to ecosystems. For example, the massive deployment of intensive woody plantations for bioenergy and large-scale afforestation, both leading to carbon capture and sequestration, could significantly increase threats to biodiversity through the alteration of natural ecosystem structures [19, 20].

Conversely, the conservation and restoration of key ecosystems could provide nature-based solutions for ambitious climate mitigation [21] which also serve the purpose of biodiversity conservation [22]. This shows that reversing biodiversity declines will require carefully designed contributions from land to ambitious climate mitigation [23], and a closer integration of biodiversity and climate objectives is a prerequisite for bending the curve of biodiversity loss.

The secret world beneath our feet: some surprising connections with climate

Monica Kobayashi and Ronald Vargas (FAO/GSP)

The advent of new technology means that we now know that hotspots of high above- and below-ground biodiversity are not always in the same place [24]. This means that measures to protect terrestrial biodiversity may not necessarily conserve soil biodiversity. Terrestrial biodiversity distribution is primarily shaped by climatic conditions (increasing diversity from the poles to the tropics), whereas the distribution of soil biota is governed by other key drivers, such as the characteristics of the soil [25] and biogeographical patterns [26, 27].

Cameron et al. highlighted the global areas of mismatch between aboveground and soil biodiversity [24]. For instance, temperate forests often show high aboveground biodiversity but low soil biodiversity, while tundra forests show the opposite trends [28, 24, 29]. Likewise, contrary to aboveground patterns, the largest belowground carbon stocks and soil microbial diversity are found in cold conditions [24]. The activities of microorganisms combined with the environmental conditions lead to soils either absorbing carbon or contributing to the emission of greenhouse gases. Therefore, the influence of soil biota on climate change cannot be underestimated.

Farm owner Marcio de Oliveira Santos plants a seedling, Socorro, São Paulo, Brazil.


© Adriano Gambarini / WWF-US

Below the canopy: a Living Planet Index for forest specialist species

A new indicator developed to improve forest biodiversity assessments shows monitored forest animals have declined by over half, on average, since 1970. Because they often perform crucial roles in the ecosystem, such as pollination, seed dispersal and herbivory, their loss may have knock-on impacts on forest regeneration and carbon storage, vital to combatting climate change.

Louise McRae and Robin Freeman (ZSL), Elizabeth Green, Samantha Hill, Mike Harfoot and Will Simonson (UNEP-WCMC) and William Baldwin-Cantello (WWF)

Deforestation, through the conversion of land for agriculture, is one of the main causes of land-use change [30], and this loss of habitat is the main cause of species decline [31]. As such, we would expect to see declines in forest-dwelling species wherever forest habitat has been altered – however, a recent study found that the relationship between tree cover and population trends in forest species is not quite so straightforward [32, 33]. For example, some forests may appear intact but are lacking in wildlife as a result of other threats such as over-hunting [34].

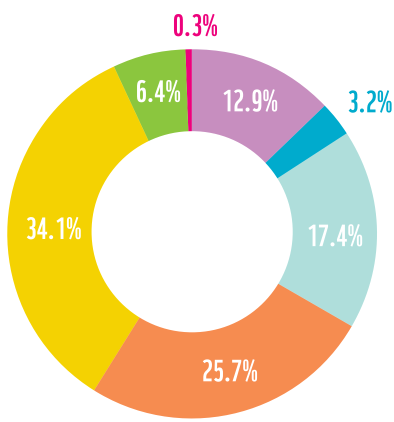
As the change in forest area does not always correspond to trends below the canopy, a complementary measure focused on wildlife is needed. Using LPI data, we can monitor changes in population abundance for forest specialist species and also reveal that they can be affected by different threats (Figure 2).

The global trend for 455 monitored populations of 268 bird, mammal, reptile and amphibian species that only live in forests shows an average decline of 53% (range: -70% to -27%) between 1970 and 2014 (Figure 4).

Figure 2:
Types of threats as a percentage of all threats faced by forest specialist species, based on population-level information in the Living Planet Index database [35]. Figure reproduced from Green, E. et al. (2019) [32].

Key

- Climate change
- Disease
- Exploitation
- Habitat degradation/change
- Habitat loss
- Invasive spp/genes
- Pollution



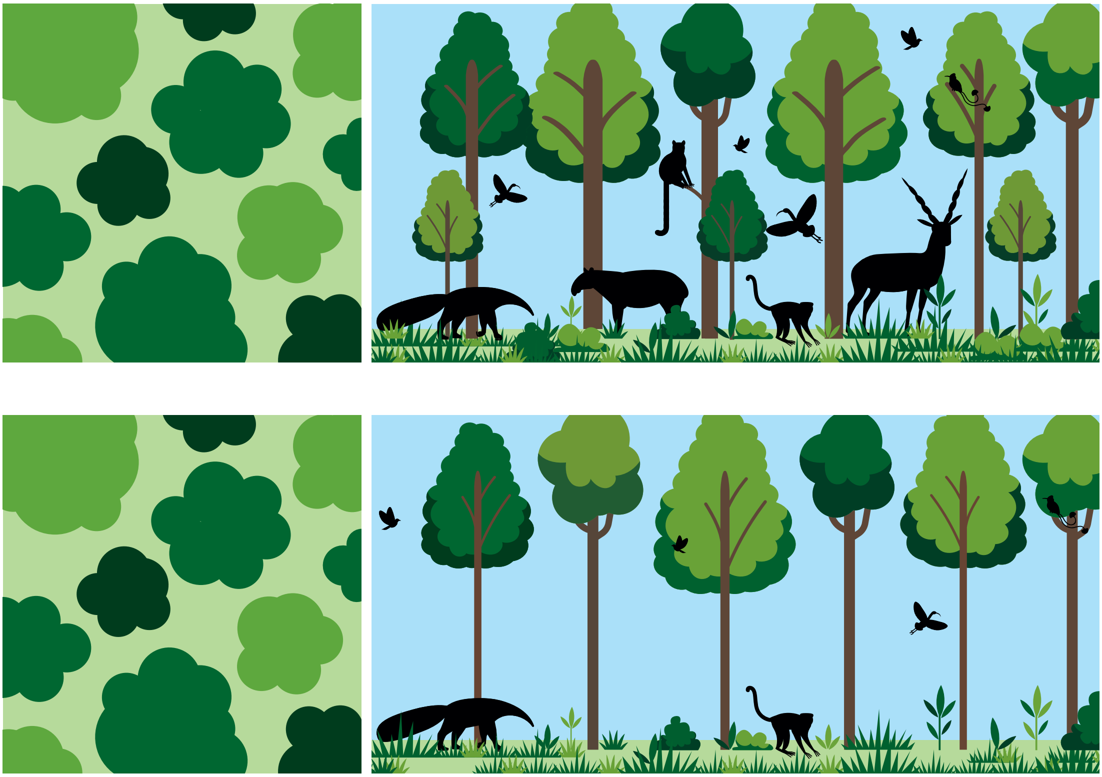


Figure 3:
The importance of looking below the canopy. From above, both forests appear intact with full forest cover. By looking below the canopy, changes in the forest fauna community can be identified; in the long term, loss of large-bodied vertebrates can lead to a reduction in carbon-dense trees. Figure reproduced from Green, E. et al. (2019)[32].

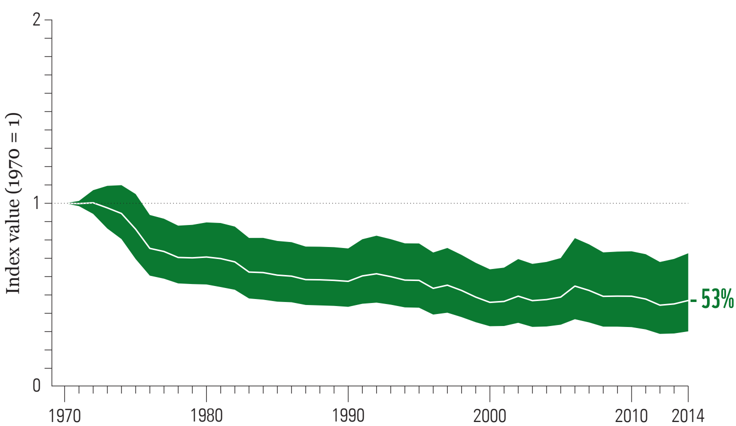


Figure 4: The Forest Specialist Index: 1970 to 2014
The average abundance of 455 populations representing 268 forest specialist species monitored across the globe declined by 53% on average[32, 33]*. The white line shows the index values and the shaded areas represent the statistical certainty surrounding the trend (range -70% to -27%). Sourced from WWF/ZSL (2020)*[35].

Key

Forest Specialist Living Planet Index

Confidence limits

CLIMATE CHANGE RISKS TO BIODIVERSITY

Up to one-fifth of wild species are at risk of extinction this century due to climate change alone, even with significant mitigation efforts, with some of the highest rates of loss anticipated in biodiversity hotspots.

Guy Midgley
(Stellenbosch University)

Greenhouse gas emissions from the human burning of fossil fuel for energy generation and transport, and land use and land cover change have already been responsible for about 1°C of warming in the Earth's lower atmosphere since the industrial revolution[36]. The surface waters of the ocean have also warmed significantly, absorbing almost 90% of the total additional warming caused by these activities since the 1970s[37]. Together, these changes are influencing weather patterns around the world[38], thus tending to raise the intensity and frequency of extreme heatwaves and floods, lengthen dry spells and enhance conditions conducive to wildfires.

The rising atmospheric CO_2 is also already causing ecological changes. Ocean acidification has resulted in a pH drop of 0.1 units[39], with potential adverse effects on shell-constructing organisms, such as shellfish and corals, and calcareous plankton communities[40]. The combined effects of warming and acidification on these organisms have been shown to weaken and even collapse marine food webs[41]. On land, rising atmospheric CO_2 has been enhancing plant carbon uptake by photosynthesis (so-called CO_2 fertilisation)[42]. This vital ecosystem service is estimated to be absorbing about 30% of emissions annually, significantly mitigating the rate of anthropogenic global warming[43].

There is high confidence that climate change is already affecting species, communities and ecosystems globally[45]. IPBES recently assessed the risks of climate change in the context of multiple risks, and found that climate change is reducing the geographic ranges of almost 50% of terrestrial non-flying mammals and 25% of birds classified as 'threatened' due to other adverse human impacts[18]. Separately, observation-based evidence clearly demonstrates that species, communities and ecosystems have begun to respond to climate change over the past few decades[47].

Estimates of the risk of extinction by 2100 due to climate change alone, under credible mitigation policies, is in the range of up to 20% of wild terrestrial species. Local-scale risks may be far higher (up to ~40% of endemic species) depending on the ecosystem and endemism rates [48].

Studies of climate risks to biodiversity may have been biased towards areas of high species endemicity and richness [49]. Such areas may well be more vulnerable to biodiversity loss under climate change because the rare species, with more limited geographic ranges, are less likely to shift geographic range successfully [50]. Biodiversity hotspots on land, and in the ocean, also appear to be concentrated in regions that have shown high climate stability for several million years, suggesting that they may be particularly at risk of rapid anthropogenic climate change. Indeed, some of the highest rates of biodiversity loss under climate change are anticipated in biodiversity hotspots [51, 52].

Recent modelling work projects that the anticipated adverse effects of climate change on ecological communities and ecosystems could be abrupt because changing climate conditions will breach the tolerance limits of most species in a community roughly simultaneously. Abrupt thresholds could be reached in tropical oceans within a decade under a high-emissions scenario (representative concentration pathway 8.5), spreading to tropical forests and reaching higher latitudes by mid-century. Up to 15% of ecological communities would be exposed to this threshold if global warming exceeds 4°C, but fewer than 2% if global warming is kept below 2°C [53].

Figure 5:
Climate change-driven pressures on biodiversity, showing those originating from abiotic (physical), biotic (living components of ecosystems) and human responses (Figure adapted from Foden, W.B. et al. (2018) [44]).

Examples

Changes in:
Carbon dioxide
Methane
Nitrous oxide
Water vapour

Changes in:
Stream oxygen
Ocean acidity
Sea level
Glacial extent
Storm surges
Fire frequency

Changes in:
Land use e.g. agriculture
Greenhouse gas emissions
Hard infrastructure e.g. dams
Existing threats e.g. over-harvesting

Changes in:
Community composition
Ecological type transition

Changes in:
Drought frequency
Temperatures
Precipitation
Extreme weather
Seasonality

SPECIES LOSS AND EXTINCTION THROUGH A CLIMATE LENS

Thirty years ago, climate change impacts on species were extremely rare but today they are commonplace. Recent climate change impacts on flying foxes and the Bramble Cay melomys show how quickly climate change can lead to drastic population declines, and warn of unseen damage to less conspicuous species.

Wendy Foden and Nicola van Wilgen
(South African National Parks)

The 1999 discovery that Edith's checkerspot butterfly, in North America, was shifting its range pole-ward and to higher elevations marked the first documented impact of climate change on nature [54]. Just two decades later, climate change impacts are widespread, including the extinction of the Bramble Cay melomys [55, 56], a small Australian rodent, and the mass die-off of tens of thousands of flying foxes in a single heatwave. At least 83% of biological processes have been impacted by climate change, at scales from genes and populations to species, ecosystems and their services to humans [10]. These impacts span terrestrial, freshwater and marine biomes.

Some species are relatively buffered from changes (e.g. deep-sea fishes), but others (e.g. Arctic and tundra species) already face enormous climate change pressures. Such pressures impact species through various mechanisms including direct physiological stress, loss of suitable habitat, disruptions of interspecies interactions (such as pollination or interactions between predators and prey), and the timing of key life events (such as migration, breeding or leaf emergence) (Figure 6) [44].

Each impact mechanism may have positive, negative or a combination of impacts on species' survival. Some species have biological traits and life histories that may make them less sensitive, and better able to withstand these impacts [57].

Others have the capacity to adapt by dispersing to more suitable areas (i.e. range shifts), changing gene expression or rapidly evolving [44]. Ultimately, these pressures, mechanisms and characteristics interact with species' historic pressures in unique and sometimes unexpected ways, to determine each species' fate.

Every species currently on Earth is the survivor of a fiercely competitive, treacherous and arduous natural selection contest spanning millennia. The extinction of the Bramble Cay melomys marks the tragic end of a distinct evolutionary lineage and demonstrates how drastically and unexpectedly climate change can operate. Actions that reduce greenhouse gas emissions, and aid biodiversity adaptation, are clearly urgently needed and are vital for nature's survival.

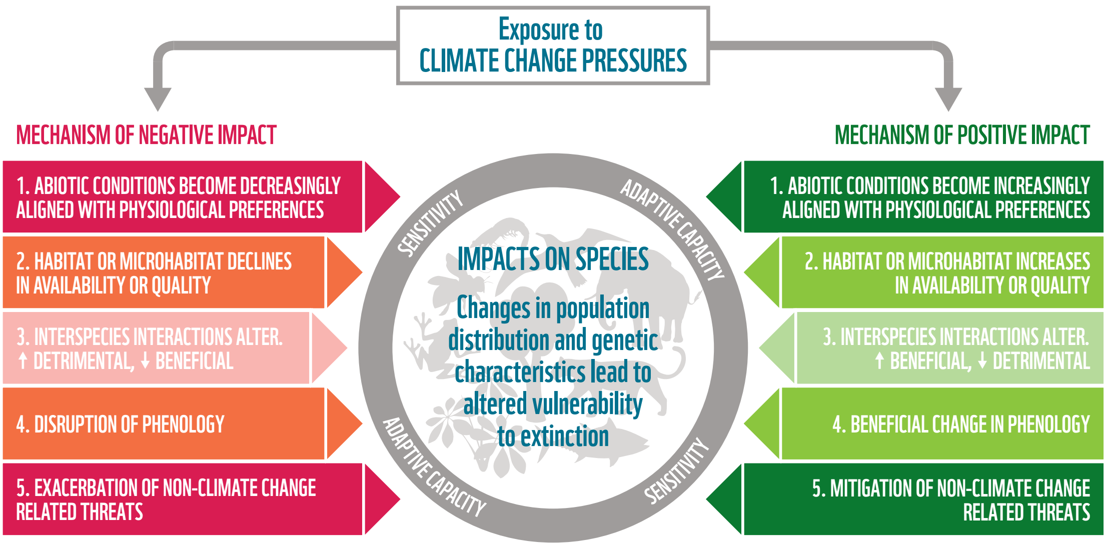


Figure 6: Species exposed to climate change pressures may be impacted through five mechanisms, in positive, negative or combined ways

Each species' sensitivity and adaptive capacity to these impacts is influenced by its unique biological traits and life history. Together, these pressures, mechanisms, sensitivities and adaptive capacity affect each species' vulnerability to extinction. (Figure adapted from Foden et al. (2018) [44]).

The first mammal extinction from climate change

The Bramble Cay melomys (*Melomys rubicola*), the first mammal extinct due to anthropogenic climate change, Bramble Cay, Torres Strait Islands, Australia.

The Bramble Cay melomys, *Melomys rubicola*, made headlines in 2016 when it was declared extinct following intensive surveys of the 5-hectare coral cay in Australia's Torres Strait where the species lived. It is the first known mammal extinction to be linked directly to climate change[56]. The population had declined from several hundred in the 1970s to around 90 by the late 1990s, likely due to an episodic decline in vegetation cover, and the death of individuals, as a result of storm surges. Changes in wind strength and rising sea levels, both linked to climate change, have resulted in an increasing intensity and frequency of storm surges. The local impacts of these changes meant that by 2014 there was almost no vegetation cover or associated food resources left on the small island[56]. This rodent has been lost. It will, however, remain immortalised as a stark reminder that the time to act on climate change is now[58].

Temperatures rise, bats fall

Flying foxes (genus *Pteropus*) have long been of conservation concern due to human persecution and mass die-offs during cyclones [59]. But a severe new threat is emerging: these bats are not physiologically capable of tolerating temperatures above 42°C [60]. At these temperatures, their usual coping behaviours – such as shade-seeking, hyperventilation and spreading saliva on their bodies (they can't sweat) – are insufficient to keep them cool and they begin to clump together in a frenzy to escape the heat. As they drop from the trees, many are injured or become trapped and die. Between 1994 and 2007, more than 30,000 flying foxes from at least two species, from a global population of less than 100,000, are thought to have died during heatwaves [60]. In 2018, in the Australian state of Queensland, one heatwave alone killed an estimated third of the global spectacled flying fox population [61].

Because lactating females have greater thermoregulatory needs and pups are highly susceptible, heatwaves in early summer are particularly devastating. Flying foxes also demonstrate the complex evolutionary challenges posed by climate change. One species, *Pteropus alecto*, has expanded its range southward over the last century, likely in response to less frost occurrence in winter. However, this species is particularly intolerant of heatwaves and now faces a much greater threat in its new range, where heatwaves are much more common. Scientists caution that flying foxes should serve as a warning [62]. Their tendency to roost in large colonies means that mass die-offs are easily observed; we see the dramatic images of wheelbarrows of dead bats. But what of species that live solitary, hidden lives?

A spectacled flying fox (*Pteropus conspicillatus*) colony leaving roost at sunset, Australia. Flying foxes roost en masse, making detection of population-level impacts of extreme events easier than for solitary species.

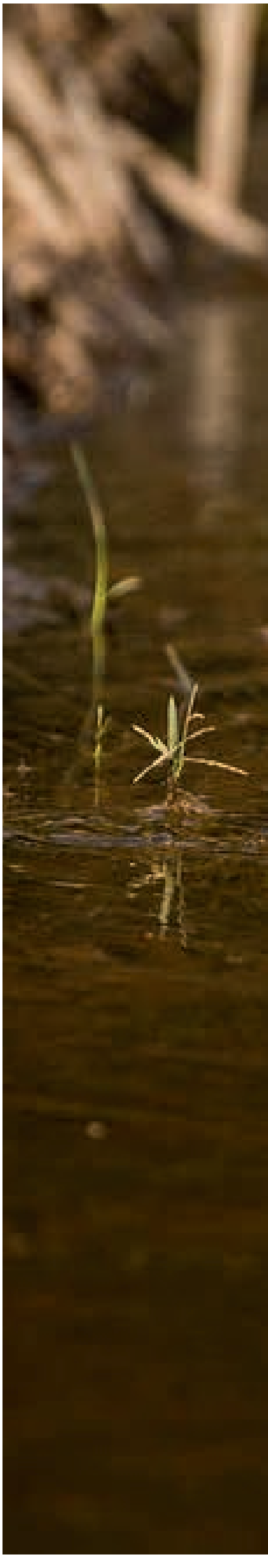
Faster climate change driving population declines: investigating Living Planet Index trends in birds and mammals

Faster climate warming is associated with stronger declines in terrestrial bird and mammal populations.

Robin Freeman
(ZSL)

Understanding the processes that drive population trends in the Living Planet Index is critical for focusing conservation efforts. Wildlife populations face an ongoing combination of anthropogenic threats including habitat loss and degradation, and climate change.

A recent study by Spooner, F.E.B. *et al*. (2018)[63] compared population trends of 981 populations of 480 terrestrial bird and mammal species from the Living Planet Index to rates of climate warming and changes in anthropogenic land use (farming, urbanisation). They found that the rate of climate warming had a much stronger effect than anticipated. In locations where average temperatures had increased more rapidly, population abundance was found to be declining more. This was particularly true for bird populations, which may be more sensitive to changes in the timings of annual temperature cycles for optimum breeding and migration conditions. Understanding how the rate of climate warming may interact with other threats such as land-use change and habitat degradation is critical to identifying those species populations that are most vulnerable to these impacts and may benefit most from protection and conservation efforts.



A black-tailed godwit (*Limosa limosa*), in its winter plumage, Ranthambhore, Rajasthan.


© Ola Jennersten / WWF-Sweden

Hot and bothered: tracking reptile trends and threats

A recent increase in reptile research efforts has revealed that one in five species are threatened with extinction, and population trends have declined on average by over 30% since 1970. The usual threats are to blame for this; but there is also a concern that many species are vulnerable to climate change, which could exacerbate pressure on reptiles in the near future.

Monika Böhm and Louise McRae (ZSL)

In terms of species, reptiles are the most numerous terrestrial vertebrate group after birds, with more than 11,000 described species[64]. Largely overlooked on the conservation agenda until recently, this balance has begun to be redressed over the past decade by studies highlighting the status and trends of reptiles, and the threats impacting them around the globe.

Reptiles play vital roles in our ecosystems, for example as predators, prey, grazers and seed dispersers, yet only relatively recently have they entered the conservation stage. Over the past decade, extensive work has been carried out to assess the conservation status of reptiles at global and regional levels[65-69], map their global distribution[70], identify the most phylogenetically distinct and threatened species[71], and investigate their long-term vulnerability to climate change[72]. This means that, for the first time, we can assess the impact of human pressures on reptiles globally. To date, 70% of described reptile species have had their extinction risk assessed for the IUCN Red List of Threatened Species, with 18% assessed as threatened[73].

The LPI for reptiles, the first in-depth analysis of a taxonomic group using the LPI, gives us an initial estimate of global population trends for reptiles[74]. The latest results, with new data added, show an average decline of 31% for 672 monitored populations representing 227 species between 1970 and 2016 (Figure 7). The main threats identified for these populations are land-use change and overexploitation, but around 10% of populations are threatened by climate change, pollution or invasive species. Looking into the future, the prevalence of these threats may shift as preliminary assessments of the climate change vulnerability of reptiles have identified 80% of species as highly sensitive to predicted temperature changes[72].

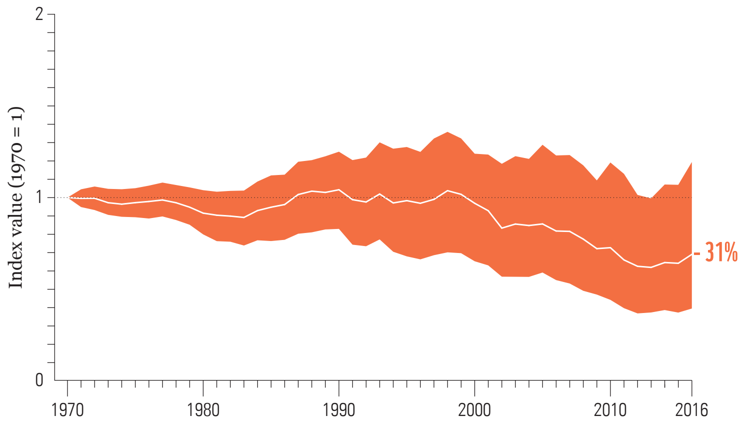


Figure 7: The Living Planet Index for reptiles: 1970 to 2016
The average abundance of 672 populations, representing 227 species, monitored across the globe declined by 31% on average. The white line shows the index values and the shaded areas represent the statistical certainty surrounding the trend (range -61% to +19%). Sourced from WWF/ZSL (2020)[35]. There is still comparatively little data on reptiles in the Living Planet database, compared to birds, mammals and fish, with available data biased towards well-studied groups such as crocodiles, turtles and tortoises[74].

Key

Reptiles Living Planet Index

Confidence limits

While we often think of reptiles as associated with extreme habitats, such as deserts, many species are highly specialised in their habitat use and the climatic conditions they require for day-to-day functioning. In many environments, reptiles may exist at, or close to, their thermal limits, and temperature increases may restrict the time available for vital activities such as foraging[75]. This is why reptiles are likely to be highly climate-sensitive[72]. A recent study on reptiles in Tanzania showed that while agriculture and overexploitation were the main current threats, between 31% (best-case scenario) and 91% (worst-case scenario) of species assessed were vulnerable to future climate change[76].

The Australian continent, particularly its hot and arid interior, holds the highest lizard species richness in the world[70]. While climate change was one of the lesser threats in a recent extinction risk assessment of Australian lizards and snakes, fires were identified as a major one[69]. The unprecedented fire season experienced in eastern Australia in 2019/20 suggests that changes to the 'natural' fire regime are starting to take effect at a grand scale[77], showing how climate change will exacerbate threats to the natural world.

NATURE-BASED APPROACHES TO REDUCING CLIMATE RISKS

Nature has an important role to play in protecting people and communities from the impacts of a changing climate, but climate change is already impacting nature and may undermine its capacity to provide these protective services.

Bruce A. Stein
(National Wildlife Federation)

Climate adaptation is an emerging field of practice that focuses on preparing for, and adjusting to, climate-related changes in ways that reduce climate vulnerabilities and risks – or, more rarely, take advantage of new opportunities [45]. Ecosystem-based adaptation specifically refers to the use of biodiversity and ecosystem services to help people adapt to the adverse effects of climate change [79, 80]. As climate change fuels increasingly severe and costly natural disasters, including intensified typhoons, droughts and wildfires, natural systems can play a key role in disaster risk reduction [81].

Marshes, dunes and coral reefs, for example, can decrease the height and energy of storm surges, and reduce coastal flooding, while upland forests and riparian (streamside) vegetation are critical for sustaining water supplies, particularly during times of drought. During Hurricane Sandy, which caused massive destruction along the east coast of the US in 2011, coastal wetlands are estimated to have reduced flooding-related property damage in adjacent communities by more than US$625 million [82]. Natural defences to protect people and property can include the protection of intact natural systems, the restoration of degraded ecosystems, and even the construction of engineered systems that mimic natural features and functions [83, 84]. Such natural, and nature-based, features can offer adaptation benefits to people wherever they live, whether in rural agricultural settings or in densely populated urban areas [85].

Natural ecosystems also play a major role in combatting the underlying problem of climate change by sequestering and storing carbon, and there is a growing recognition of the importance of natural climate solutions to achieve global climate mitigation goals [86]. Conservation, restoration and improved management of natural systems can all contribute to increasing carbon sequestration and storage, and avoiding the release of greenhouse gases [87].

Unfortunately though, climate change is also threatening many natural ecosystems, undermining their capacity not only to provide traditional ecosystem services – such as water, food and fibre – but also their ability to provide a buffer to human communities from intensifying climate impacts. Indeed, without an explicit focus on climate adaptation for nature – or *biodiversity-focused adaptation* – these systems will suffer significant deterioration, leading to continued species declines and extinctions, as well as a loss of critical services on which people depend.

While 'ecosystem-based adaptation' emphasises nature's value to people, biodiversity-focused adaptation is explicitly designed to reduce climate risks to species and ecosystems themselves [88]. Fortunately, techniques for carrying out climate-smart conservation are available and increasingly being put into practice [89], and growing numbers of natural resource managers are re-evaluating and adjusting traditional conservation goals and strategies in light of changing climatic conditions [90].

Nature has an increasingly vital role to play in buffering people from intensifying climate impacts and in helping communities adapt to changing conditions. For nature to provide such ecosystem-based adaptation functions, however, society will need to dramatically scale up its efforts to help nature itself cope with, and adapt to, the intensifying impacts of climate change.

Rich invertebrate life including corals, tunicates and sponges covers the underwater portions of red mangrove roots (Rhizophora mangle), Tunicate Cove, Belize.

The role of forests in a changing climate

The ecosystem services that forests provide can buffer against climate change by enhancing ecological processes and supporting biodiversity across landscapes.

Jaboury Ghazoul
(ETH Zurich)

We know that forests have an important role to play in climate mitigation through carbon sequestration and storage, but the climate adaptation opportunities they provide are equally important for creating a liveable future environment.

In most agricultural lands, climatic changes will detrimentally affect crops and livestock, and deplete soil organic matter, a major contributor to soil fertility [91]. Trees and woodlands in these agricultural systems protect livestock from inclement weather; while leaf litter from trees provides nutrient and organic inputs into agricultural soils, maintaining soil fertility [92]. In turn, leaf litter cover protects soils from erosion [92]. Additionally, forests enhance natural pest control and pollination by supporting arthropod and vertebrate biodiversity [93].

In mountain regions that are vulnerable to climate change, threatening both infrastructure and people, forests act as slope stabilisers and protect against rock falls [94]. If managed appropriately they slow water flows and provide flood abatement benefits. In lowland regions, riparian woodland networks also protect riverbanks from erosion following extreme rainfall events, while the shade of riverbank trees reduces stream water temperatures, providing more favourable and oxygen-rich aquatic habitats that better support invertebrates and fish [95]. Moreover, the landscape connectivity these woodlands provide enhances terrestrial biodiversity [96].

Forests play a critical role in our increasingly urbanised world. Trees and woodlands help to regulate urban climates, improving the mental and physical health of urban citizens who make up more than half the world's population. Urban woodlands also reduce the energy demands for cooling during periods of high temperatures [97, 98].

Matécho forest near Saül in the center of French Guiana.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PUSHING PLANETARY BOUNDARIES: BEYOND EARTH'S 'SAFE OPERATING SPACE' FOR HUMANS

As the coronavirus pandemic, insect plagues and wildfires reach global crisis dimensions, people are seeing environmental changes in a new light.

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Quite simply, the impacts of our modern, 21st century lifestyles mean that people are not just 'passengers' in today's changing world. Human activities are driving large-scale changes in how our planet functions and this impacts all life on Earth. Individually and collectively we contribute to land-use change, overfishing, habitat fragmentation, excessive emissions of nutrients and greenhouse gases in our pursuit of more food, bigger homes and greater livelihoods. Many of us do not even perceive the ecosystem changes that we are causing because the impacts are often 'over there' and far removed from our daily lives.

One way of tracking the effects of these connections is the planetary boundaries approach[99, 100]. It highlights nine critical environmental processes where human activities are driving global changes in ways that increase risks of large-scale ecosystem shifts. The planetary boundaries for biosphere integrity, climate change, biogeochemical flows and land-system change have already long been breached[101]. Pressure is also rising on the planetary boundaries for ocean acidification[39] and freshwater use[102]. For two processes – atmospheric aerosol loading and pollution by novel entities – a global quantification has not been established, but their current global trends are also reasons for concern[103].

These boundaries mark out Earth's 'safe operating space' for humanity. The closer the world's societies remain to the planetary boundaries, the greater the opportunities will be for social systems to continue flourishing together with the ecosystems they are part of.

Figure 8: Human activities increase pressure on the planetary boundaries
The inter-linked Planetary Boundary processes affect the fundamental interactions and feedbacks between biosphere integrity and climate. In turn, human pressures on biosphere integrity and climate change reduce the safe operating space for other processes[101].

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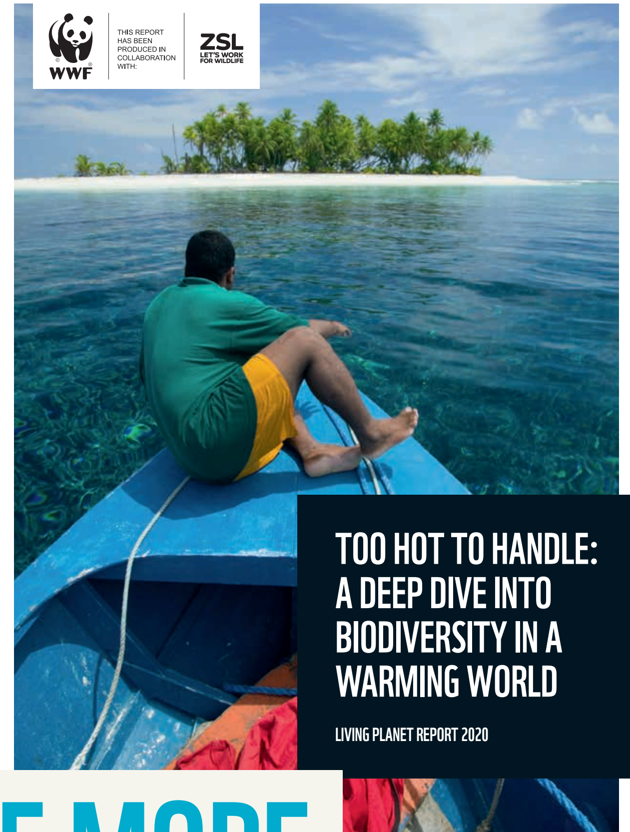

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