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LIVING PLANET REPORT 2020

BENDING THE CURVE OF BIODIVERSITY LOSS

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Citation
WWF (2020) *Living Planet Report 2020 -*
Bending the curve of biodiversity loss.
Almond, R.E.A., Grooten M. and Petersen, T. (Eds).
WWF, Gland, Switzerland.

Design and infographics by: peer&dedigitalesupermarkt

Cover photograph: © Jonathan Caramanus / Green Renaissance / WWF-UK
Farmer Nancy Rono with a chameleon on her sleeve, Bomet County, Mara River Upper Catchment, Kenya.

ISBN 978-2-940529-99-5

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Special thanks
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LIVING PLANET REPORT 2020

BENDING THE CURVE OF BIODIVERSITY LOSS

8 BILLION REASONS TO SAFEGUARD NATURE


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At a time when the world is reeling from the deepest global disruption and health crisis of a lifetime, this year's *Living Planet Report* provides unequivocal and alarming evidence that nature is unravelling and that our planet is flashing red warning signs of vital natural systems failure. The *Living Planet Report 2020* clearly outlines how humanity's increasing destruction of nature is having catastrophic impacts not only on wildlife populations but also on human health and all aspects of our lives.

This highlights that a deep cultural and systemic shift is urgently needed, one that so far our civilisation has failed to embrace: a transition to a society and economic system that values nature, stops taking it for granted and recognises that we depend on nature more than nature depends on us.

This is about rebalancing our relationship with the planet to preserve the Earth's amazing diversity of life and enable a just, healthy and prosperous society – and ultimately to ensure our own survival.

Nature is declining globally at rates unprecedented in millions of years. The way we produce and consume food and energy, and the blatant disregard for the environment entrenched in our current economic model, has pushed the natural world to its limits. COVID-19 is a clear manifestation of our broken relationship with nature. It has highlighted the deep interconnection between nature, human health and well-being, and how unprecedented biodiversity loss threatens the health of both people and the planet.

It is time we answer nature's SOS. Not just to secure the future of tigers, rhinos, whales, bees, trees and all the amazing diversity of life we love and have the moral duty to coexist with, but because ignoring it also puts the health, well-being and prosperity, indeed the future, of nearly 8 billion people at stake.

The *Living Planet Report 2020* shows that there is an opportunity to heal our relationship with nature and mitigate risks of future pandemics but this better future starts with the decisions that governments, companies and people around the world take today. World leaders must take urgent action to protect and restore nature as the foundation for a healthy society and a thriving economy.

We still have a chance to put things right. It's time for the world to agree a New Deal for Nature and People, committing to stop and reverse the loss of nature by the end of this decade and build a carbon-neutral and nature-positive economy and society. This is our best safeguard for human health and livelihoods in the long term, and to ensure a safe future for our children and children's children.

Marco Lambertini,

Director General
WWF International

EXECUTIVE SUMMARY

The global Living Planet Index continues to decline. It shows an average 68% decrease in population sizes of mammals, birds, amphibians, reptiles and fish between 1970 and 2016. A 94% decline in the LPI for the tropical subregions of the Americas is the largest fall observed in any part of the world.

Why does this matter?

It matters because biodiversity is fundamental to human life on Earth, and the evidence is unequivocal – it is being destroyed by us at a rate unprecedented in history. Since the industrial revolution, human activities have increasingly destroyed and degraded forests, grasslands, wetlands and other important ecosystems, threatening human well-being. Seventy-five per cent of the Earth's ice-free land surface has already been significantly altered, most of the oceans are polluted, and more than 85% of the area of wetlands has been lost.

Species population trends are important because they are a measure of overall ecosystem health. Measuring biodiversity, the variety of all living things, is complex, and there is no single measure that can capture all of the changes in this web of life. Nevertheless, the vast majority of indicators show net declines over recent decades.

That's because in the last 50 years our world has been transformed by an explosion in global trade, consumption and human population growth, as well as an enormous move towards urbanisation. Until 1970, humanity's Ecological Footprint was smaller than the Earth's rate of regeneration. To feed and fuel our 21st century lifestyles, we are overusing the Earth's biocapacity by at least 56%.

These underlying trends are driving the unrelenting destruction of nature, with only a handful of countries retaining most of the last remaining wilderness areas. Our natural world is transforming more rapidly than ever before, and climate change is further accelerating the change.

Tigers, pandas and polar bears are well-known species in the story of biodiversity decline, but what of the millions of tiny, or as-yet-undiscovered, species that are also under threat? What is happening to the life in our soils, or in plant and insect diversity? All of these provide fundamental support for life on Earth and are showing signs of stress.

Biodiversity loss threatens food security and urgent action is needed to address the loss of the biodiversity that feeds the world. Where and how we produce food is one of the biggest human-caused threats to nature and our ecosystems, making the transformation of our global food system more important than ever.

The transformation of our economic systems is also critical. Our economies are embedded within nature, and it is only by recognising and acting on this reality that we can protect and enhance biodiversity and improve our economic prosperity.

We can estimate the value of 'natural capital' – the planet's stock of renewable and non-renewable natural resources, like plants, soils and minerals – alongside values of produced and human capital – for example, roads and skills – which together form a measure of a country's true wealth. Data from the United Nations Environment Programme shows that, per person, our global stock of natural capital has declined by nearly 40% since the early 1990s, while produced capital has doubled and human capital has increased by 13%.

But too few of our economic and financial decision-makers know how to interpret what we are hearing, or, even worse, they choose not to tune in at all. A key problem is the mismatch between the artificial 'economic grammar' which drives public and private policy and 'nature's syntax' which determines how the real world operates.

Together this evidence shows that biodiversity conservation is more than an ethical commitment for humanity: it is a non-negotiable and strategic investment to preserve our health, wealth and security.

Can we reverse these trends of decline? WWF co-founded a new research initiative – the Bending the Curve Initiative – that has developed pioneering modelling, providing a 'proof of concept' that we can halt, and reverse, terrestrial biodiversity loss from land-use change. And the models are all telling us the same thing: that we still have an opportunity to flatten, and reverse, the loss of nature if we take urgent and unprecedented conservation action and make transformational changes in the way we produce and consume food.

2020 was billed as a 'super year' of climate, biodiversity and sustainable development meetings in which the international community had great plans to take the reins of the Anthropocene. The COVID-19 pandemic has meant that most of these conferences are now scheduled for 2021, and has provided a stark reminder of how nature and humans are intertwined.

Until now, decades of words and warnings have not changed modern human society's business-as-usual trajectory. Yet in times of rapid upheaval and disruption new ideas, creativity, processes and opportunities for transformation can arise. The future is always uncertain but perhaps the COVID-19 pandemic will spur us on to embrace this unexpected opportunity and revolutionise how we take care of our home.

AT A GLANCE

An SOS for nature

CHAPTER 1

- Serious declines in species population trends are a measure of overall ecosystem health, and our planet is flashing red warning signs.
- The 2020 global Living Planet Index shows an average 68% fall in monitored vertebrate species populations between 1970 and 2016.
- The 94% decline in the LPI for the tropical subregions of the Americas is the largest fall observed in any region.
- In addition to mammals, birds, reptiles, amphibians and fish, this chapter also uncovers trends from the tiniest creatures to the canopy, looking at soil biodiversity, insects and – for the first time – plants.

Our world in 2020

CHAPTER 2

- Global economic growth since WWII has driven exponential human improvements, yet this has come at a huge cost to the stability of Earth's operating systems that sustain us.
- Humans are now overusing the Earth's biocapacity by at least 56%.
- Land-use change due to where and how we produce food, is one of the biggest threats humans pose to biodiversity.
- Our ocean is also in hot water, with overfishing, pollution, coastal development and climate change causing a growing spectrum of adverse effects across marine ecosystems.

People and nature are intertwined

CHAPTER 3

- The alteration of the world's natural systems threatens to undo the extraordinary gains in human health and well-being of the past century.
- Urgent action is needed to address the loss of the biodiversity that feeds the world.
- There is a fundamental mismatch between artificial 'economic grammar' and 'nature's syntax' which determines how the real world operates.
- It is now becoming ever clearer that biodiversity is a non-negotiable and strategic investment to preserve our health, wealth and security.

Imagining a roadmap for people and nature

CHAPTER 4

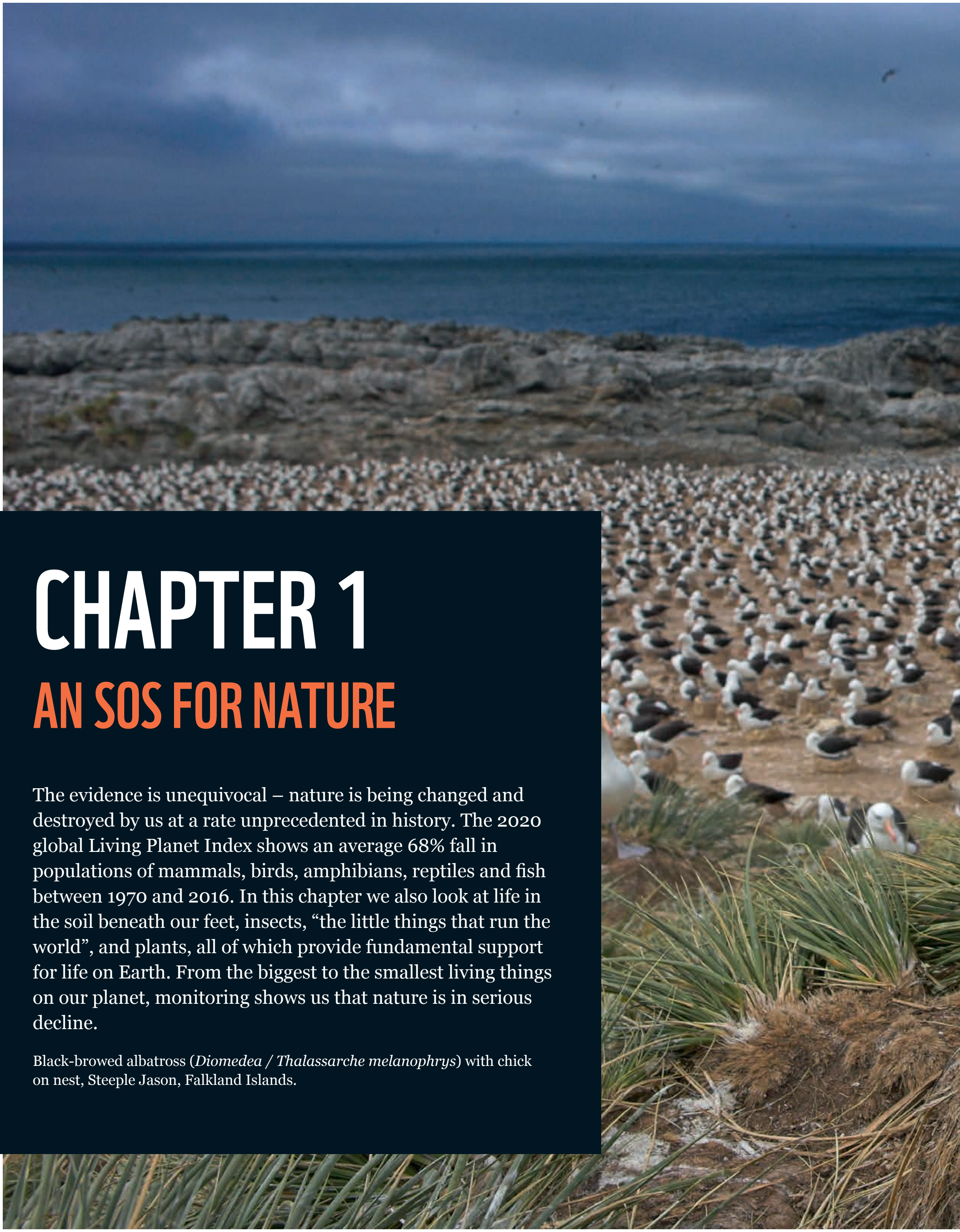
- Pioneering biodiversity modelling helps us to imagine the future, asking 'What if humanity takes different pathways?'
- The Bending the Curve Initiative has provided 'proof of concept' that we can halt, and reverse, the loss of nature while feeding a growing population.
- Bending the curve of biodiversity loss is technologically and economically possible, but it will require truly transformational change in the way we produce and consume food and in how we sustainably manage and conserve nature.

EXPLORE MORE

- **Freshwater deep dive:** Freshwater ecosystems are some of the world's most vulnerable. This deep dive explores freshwater status and trends, drivers of change and an outlook for recovery.
- **Climate deep dive:** Climate change is already affecting biodiversity, and this deep dive explores its current and future impacts.
- **Voices for a Living Planet:** A special supplement complementing the LPR story brings together a collection of short opinion essays – written by thinkers and practitioners from different countries and cultures around the globe – on how to build a resilient and healthy planet for people and nature.

CHAPTER 1
AN SOS FOR NATURE

The evidence is unequivocal – nature is being changed and destroyed by us at a rate unprecedented in history. The 2020 global Living Planet Index shows an average 68% fall in populations of mammals, birds, amphibians, reptiles and fish between 1970 and 2016. In this chapter we also look at life in the soil beneath our feet, insects, “the little things that run the world”, and plants, all of which provide fundamental support for life on Earth. From the biggest to the smallest living things on our planet, monitoring shows us that nature is in serious decline.



Black-browed albatross (*Diomedea / Thalassarche melanophrys*) with chick on nest, Steeple Jason, Falkland Islands.


© naturepl.com / Andy Rouse / WWF

BIODIVERSITY ON THE BRINK: WE KNOW IT IS CRASHING

Biodiversity as we know it today is fundamental to human life on Earth, and the evidence is unequivocal – it is being destroyed by us at a rate unprecedented in history.

Sir Robert Watson, Tyndall Centre for Climate Change Research

Since the industrial revolution, human activities have increasingly destroyed and degraded forests, grasslands, wetlands and other important ecosystems, threatening human well-being. Seventy-five per cent of the Earth's ice-free land surface has already been significantly altered, most of the oceans are polluted, and more than 85% of the area of wetlands has been lost. This destruction of ecosystems has led to 1 million species (500,000 animals and plants and 500,000 insects) being threatened with extinction over the coming decades to centuries, although many of these extinctions are preventable if we conserve and restore nature[1].

The most important direct driver of biodiversity loss in terrestrial systems in the last several decades has been land-use change, primarily the conversion of pristine native habitats (forests, grasslands and mangroves) into agricultural systems; while much of the oceans has been overfished. Since 1970, these trends have been driven in large part by a doubling of the world's human population, a fourfold increase in the global economy, and a tenfold increase in trade.

The challenge is to transform agricultural and fishing practices, many of which are unsustainable today, into ones that produce the affordable and nourishing food we need while protecting and conserving biodiversity. For agriculture, this means using sustainable agroecological practices, reducing the use of chemicals, fertilisers and pesticides, and protecting our soils and pollinators.

Globally, climate change has not been the most important driver of the loss of biodiversity to date, yet in coming decades it is projected to become as, or more, important than the other drivers. Climate change adversely affects genetic variability, species richness and populations, and ecosystems. In turn, loss of biodiversity can adversely affect climate – for example, deforestation increases the atmospheric abundance of carbon dioxide, a key greenhouse gas.

Therefore, it is essential that the issues of biodiversity loss and climate change are addressed together.

While the Paris Agreement is an important step towards limiting human-induced climate change, the current pledges from its signatories are totally inadequate to achieve its targets, with global emissions projected to be about the same in 2030 as they are today. Global temperatures could reach the 1.5°C aspirational target by the early to mid-2030s, and the 2°C threshold by 2050-2070. Without additional actions to reduce greenhouse gas emissions we are on a pathway to a rise of 3-4°C, which will have devastating effects on biodiversity and human well-being.

The loss of biodiversity is not only an environmental issue but a development, economic, global security, ethical and moral one. The continued loss of biodiversity will undermine the achievement of most of the UN Sustainable Development Goals, including poverty alleviation and food, water and energy security. Biodiversity has significant economic value, which should be recognised in national accounting systems; it is a security issue insofar as the loss of natural resources, especially in poor developing countries, can lead to conflict; it is an ethical issue because loss of biodiversity hurts the poorest people who depend on it, further exacerbating an already inequitable world; and it is a moral issue because we humans should not destroy the living planet.

It is also a self-preservation issue. Biodiversity plays a critical role in providing food, fibre, water, energy, medicines and other genetic materials; and is key to the regulation of our climate, water quality, pollution, pollination services, flood control and storm surges. In addition, nature underpins all dimensions of human health and contributes on non-material levels – inspiration and learning, physical and psychological experiences, and shaping our identities – that are central to quality of life and cultural integrity.

In 2019, drawing on almost 15,000 references and the expertise of more than 150 natural and social scientists from more than 50 countries, **the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)** published its first global assessment on the state of the Earth's biodiversity, the *Global Assessment Report on Biodiversity and Ecosystem Services*[1]. Established in Panama City in 2012 by 94 governments, IPBES is an independent intergovernmental body established to strengthen the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development.

THE LIVING PLANET INDEX: AN EARLY WARNING INDICATOR ON THE HEALTH OF NATURE

Species population trends are important because they are a measure of overall ecosystem health. Serious declines are a proxy for the unravelling of nature and our planet is flashing red warnings signs of systems failure.

Louise McRae, Stefanie Deinet, Valentina Marconi, Kate Scott-Gatty and Robin Freeman (ZSL)

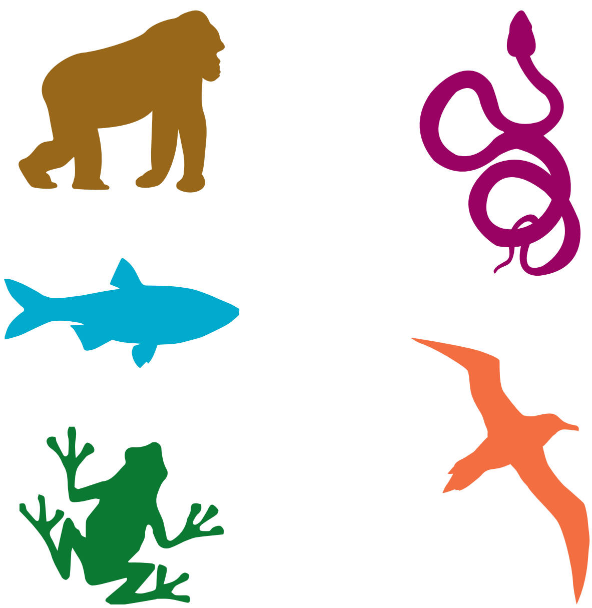
The Living Planet Index (LPI) now tracks the abundance of almost 21,000 populations of mammals, birds, fish, reptiles and amphibians around the world. For two decades it has used the trends that emerge as a measure for changes in biodiversity. The building blocks for this indicator are wildlife population datasets gathered from almost 4,000 sources. The majority of these are publicly available and are found in scientific literature or in online repositories of wildlife census data such as the African elephant database [2] and the Australian Threatened Species Index data portal [3].

The collection of population trend data is often time-consuming and can be challenging. Increasingly, citizen scientists are volunteering their time to count species, from birds to butterflies. One of the longest-running bird surveys, the Audubon Christmas Bird Count [4], has thousands of people counting the birds of North America every year, and similar projects are expanding all over the globe. Another example is the first *State of India's Birds* report that has been published using sightings data from birdwatchers [5]. The LPI is missing data for some species or places that are challenging to monitor; however advancing technology is set to change that as datasets are compiled in increasingly sophisticated and varied ways. We now use audio devices to monitor insect sounds [6], environmental DNA to track populations of specific species like polar bears [7], and drones to count wildlife more precisely [8]. Future editions of the LPI will be able to incorporate this trend data as it emerges.

Thousands of population trends are brought together in the LPI to calculate the average percentage change in population sizes since 1970 using an index (Figure 1). The percentage doesn't represent the number of individual animals lost but reflects the average proportional change in animal population sizes tracked over 46 years.

Since the last Living Planet Report (2018) the number of species represented has improved for the majority of regions and taxonomic groups, with the biggest boost being to amphibian species. New ways to discover and extract this data are under development, including the automatic identification of relevant data sources using artificial intelligence. At present the LPI contains data only for vertebrate species as, historically, these have been better monitored; but efforts to incorporate data on invertebrates are underway as we try to broaden our understanding of changes in wildlife populations. These efforts are starting with insects, including a European grassland butterfly LPI.

Understanding how species populations may change in years to come is another huge challenge, and new techniques – such as predictive modelling and machine learning – are starting to help us see how wildlife might respond to projected future changes in climate and land use (see the scenarios in Chapter 4).



At a population level: in 2020 what does the Living Planet Index show?

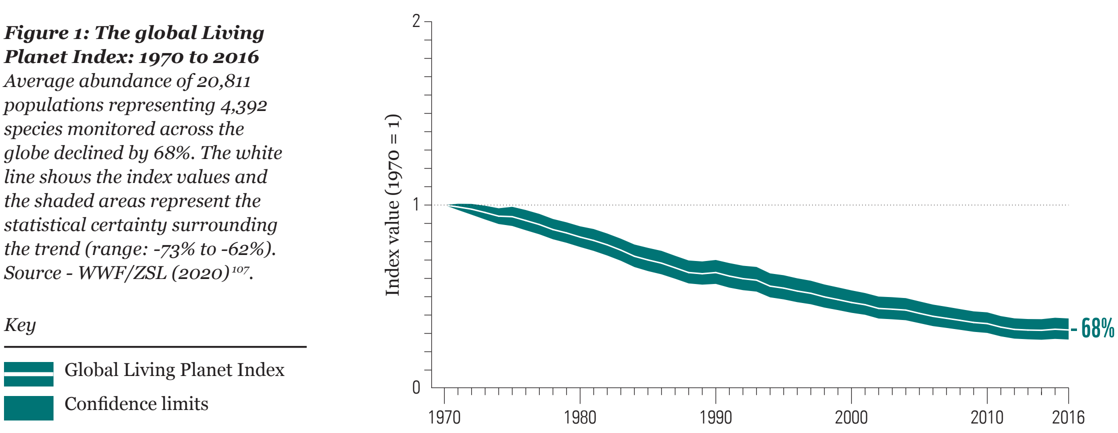
The 2020 global Living Planet Index shows an average 68% decrease in monitored vertebrate species populations between 1970 and 2016.

Using the data from 20,811 populations of 4,392 species, the 2020 global LPI shows an average 68% decline in monitored populations between 1970 and 2016 (range: -73% to -62%).

This year's index includes 400 new species and 4,870 new populations. The representation of neotropical amphibians has increased the most as we try to fill data gaps for tropical species. Adding new data and taxa into the Living Planet Database, the collection of population trends that are the key components of the LPI, helps to make the index a better reflection of trends in biodiversity. Adding these new data updates all of the annual LPI values and accounts for the differences seen between each version of the LPI (see technical supplement).

The 2020 global LPI runs from 1970 to 2016, starting at a value of 1 in 1970. This was set as a common starting year for many indicators because not enough earlier information is available; and it ends in 2016 to reflect the latest year for which there is a good amount of data and the time lag in collecting, processing and publishing it.

Figure 1: The global Living Planet Index: 1970 to 2016
Average abundance of 20,811 populations representing 4,392 species monitored across the globe declined by 68%. The white line shows the index values and the shaded areas represent the statistical certainty surrounding the trend (range: -73% to -62%). Source - WWF/ZSL (2020)[107].



The LPI explained

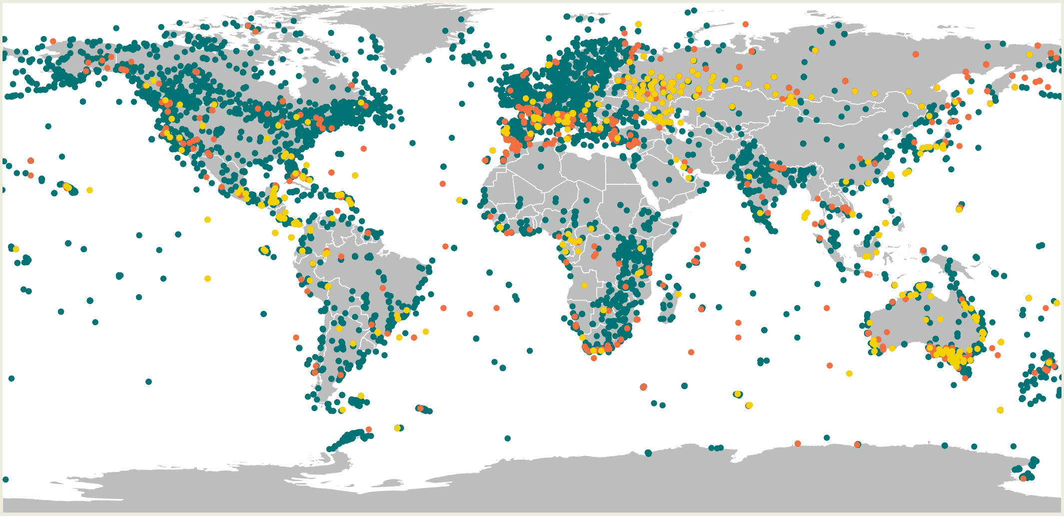


Figure 2: Locations of Living Planet Index species populations

Locations of Living Planet Index species populations. Map showing the locations of the monitored populations in the LPI. Newly added populations since the last report are highlighted in orange or in yellow for species new to the LPI. Source: WWF/ZSL (2020)[107].

Key

- New species
- New populations
- Existing data

How to read the Living Planet Index

- In 2020, the LPI shows an average rate of decline in population size of 68% between 1970 and 2016.
- The LPI now tracks the abundance of almost 21,000 populations of mammals, birds, fish, reptiles and amphibians around the world.
- The LPI includes data for threatened and non-threatened species – if it's monitored consistently over time, it goes in!
- Species and populations in the LPI are increasing, declining or stable.
- About half of the species in the LPI show an average decline in population size.

What the LPI does not tell us

- The LPI doesn't show numbers of species lost or extinctions.
- It does not mean that X% of species or populations are declining.
- Or that X% of populations or individuals have been lost.

Biodiversity is declining at different rates in different places

The global LPI does not give us the entire picture – there are differences in abundance trends between regions, with the largest declines in tropical areas.

In 2019, the landmark IPBES global assessment on the state of biodiversity divided the world into different geographic regions (Figure 3) in order to complete regular and timely assessments of biodiversity, ecosystem services, their linkages, threats, and the impacts of these at regional and sub-regional levels[1]. Using a smaller spatial scale of regions and sub-regions, rather than a global approach, also allows for a more focused way of monitoring progress towards targets developed under the Convention on Biological Diversity,

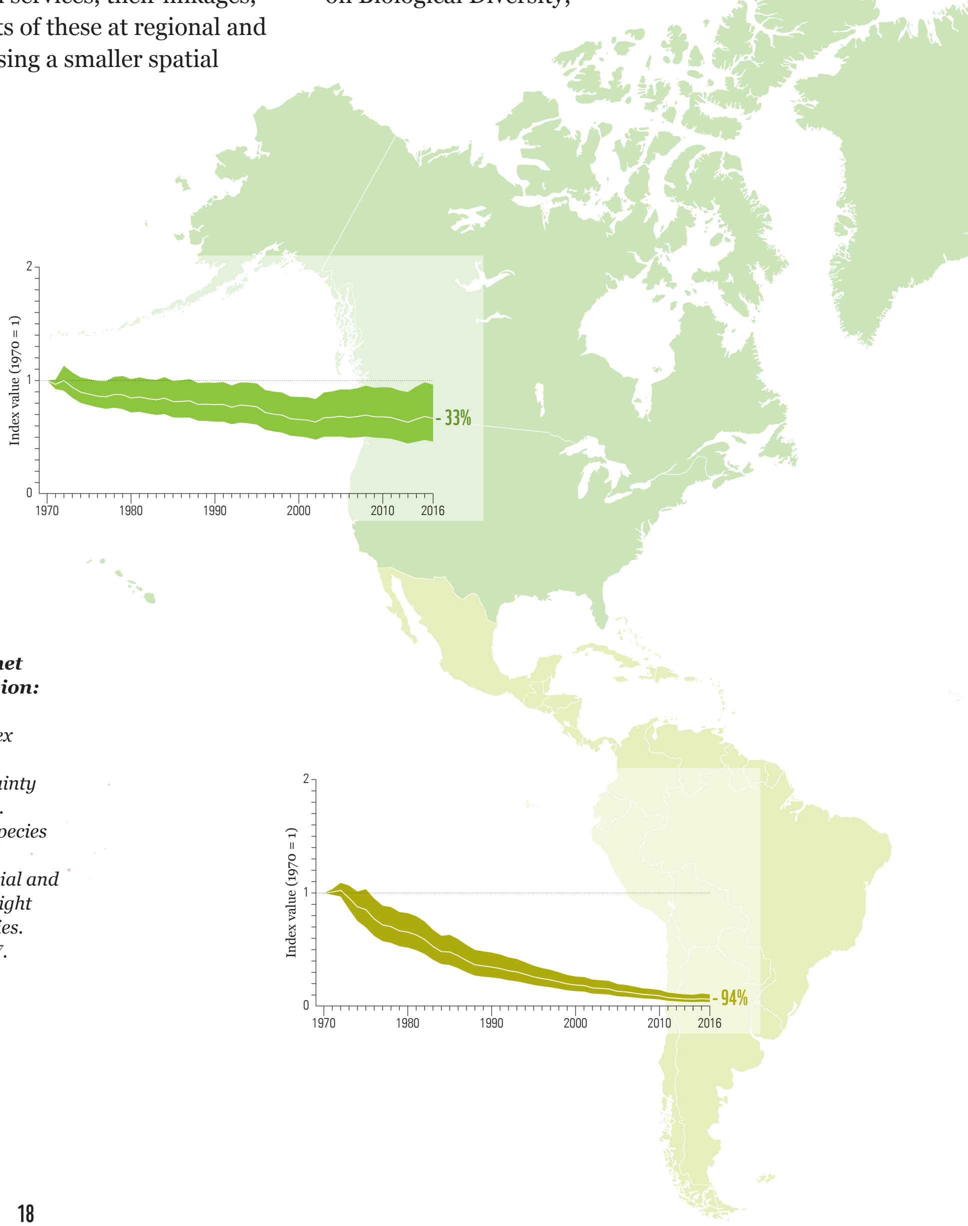
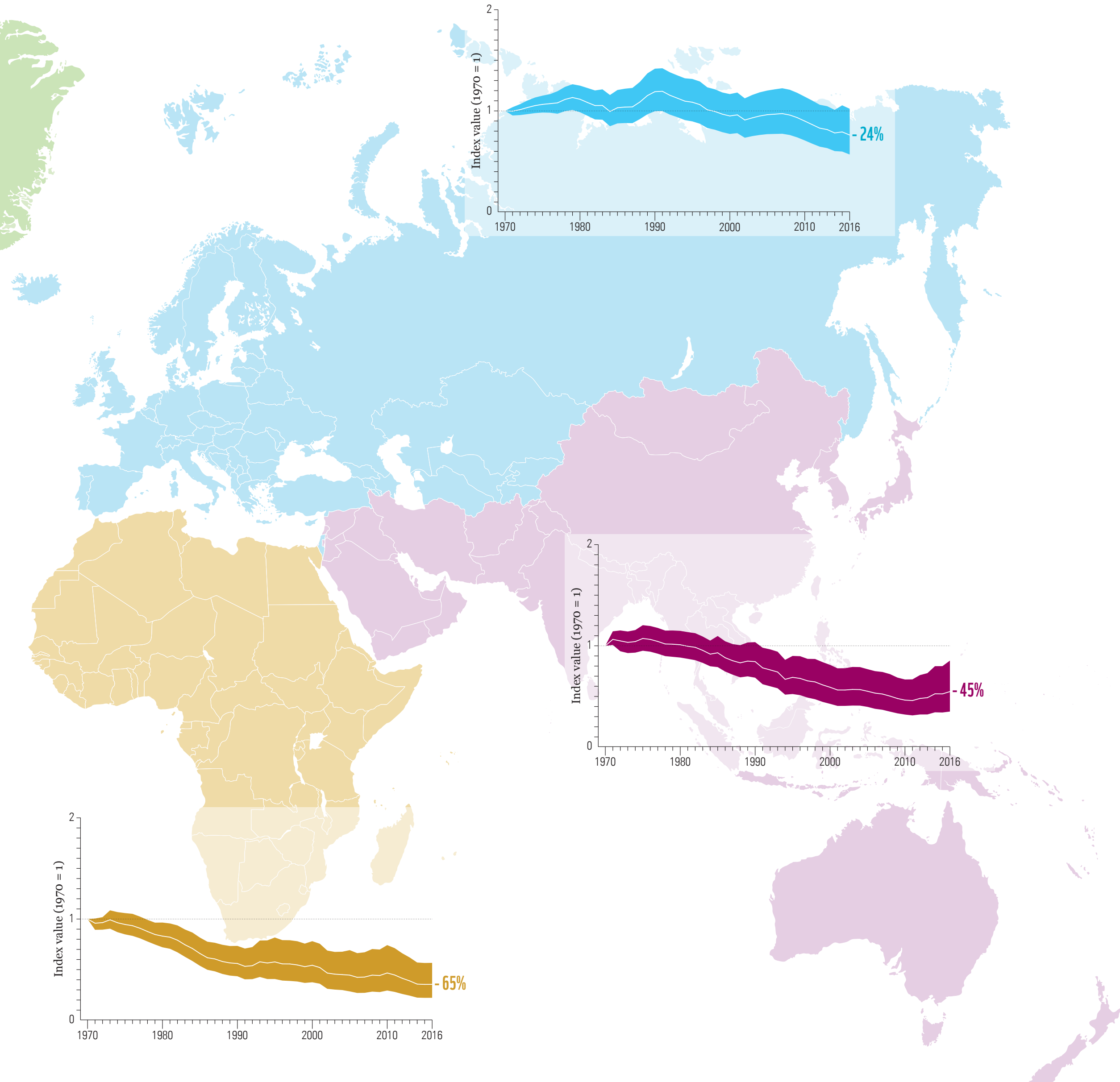


Figure 3: The Living Planet Index for each IPBES region: 1970 to 2016 [9]
The white line shows the index values and the shaded areas represent the statistical certainty surrounding the trend (95%). All indices are weighted by species richness, giving species-rich taxonomic groups in terrestrial and freshwater systems more weight than groups with fewer species. Source - WWF/ZSL (2020)[107].

including the Aichi Biodiversity Targets, Sustainable Development Goals, and National Biodiversity Strategies and Action Plans. In 2020, in order to align with IPBES, regional Living Planet indices have been divided slightly differently to previous years. Following the regional classifications in Figure 3, all terrestrial and freshwater populations within a country were assigned to an IPBES region. In the case of the Americas, this region was further subdivided in two: North America, and Latin America and the Caribbean (Mesoamerica, the Caribbean and South America combined). Trends for each species group are weighted according to how many species are found in each IPBES region. Threats to populations in each region are shown on page 21, and detail behind the trends can be found in the technical supplement.

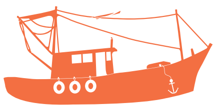


Threats to biodiversity

Changes in land and sea use, including habitat loss and degradation

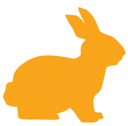
This refers to the modification of the environment where a species lives, by complete removal, fragmentation or reduction in quality of key habitat. Common changes in use are caused by unsustainable agriculture, logging, transportation, residential or commercial development, energy production and mining. For freshwater habitats, fragmentation of rivers and streams and abstraction of water are common threats.

Species overexploitation



There are both direct and indirect forms of overexploitation. Direct overexploitation refers to unsustainable hunting and poaching or harvesting, whether for subsistence or for trade. Indirect overexploitation occurs when non-target species are killed unintentionally, for example as bycatch in fisheries.

Invasive species and disease

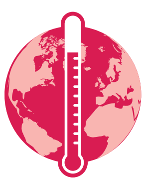


Invasive species can compete with native species for space, food and other resources, can turn out to be a predator for native species, or spread diseases that were not previously present in the environment. Humans also transport new diseases from one area of the globe to another.

Pollution

Pollution can directly affect a species by making the environment unsuitable for its survival (this is what happens, for example, in the case of an oil spill). It can also affect a species indirectly, by affecting food availability or reproductive performance, thus reducing population numbers over time.

Climate change

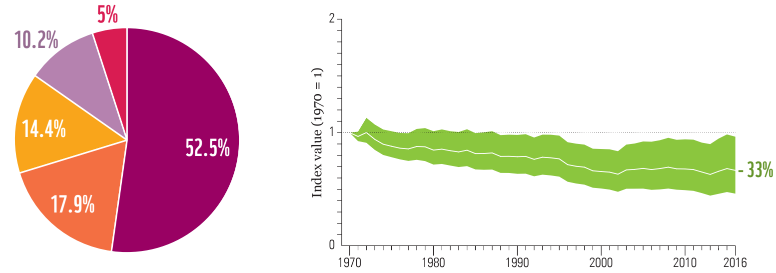


As temperatures change, some species will need to adapt by shifting their range to track a suitable climate. The effects of climate change on species are often indirect. Changes in temperature can confound the signals that trigger seasonal events such as migration and reproduction, causing these events to happen at the wrong time (for example misaligning reproduction and the period of greater food availability in a specific habitat).

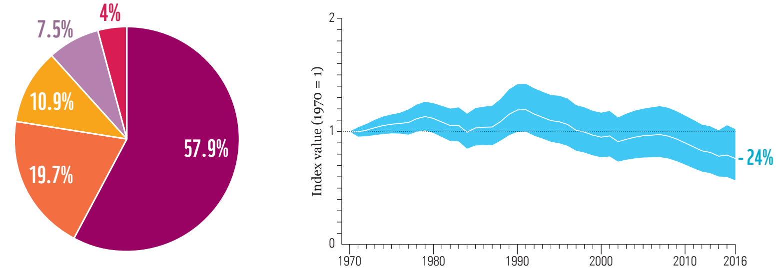
Figure 4: Different threat types in the Living Planet Database
Descriptions of the major threat categories used in the Living Planet Database. This classification reflects the direct drivers with the largest global impact as identified by IPBES[1]; it is also followed by the IUCN Red List and is based on the original classification by Salafsky, N. et al. (2010)[10]. Source WWF/ZSL (2020)[107].

Figure 5: The proportion of threats recorded in each category for populations in each IPBES region[9]
The number of populations with threat data available is shown next to the pie chart[107]. The colour of each section refers to the colour for each threat category on the opposite page.

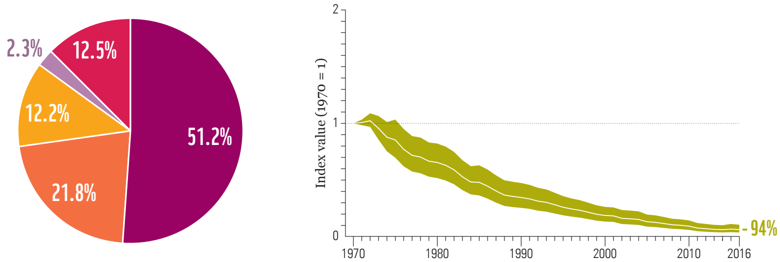
Regional threats to populations in the LPI



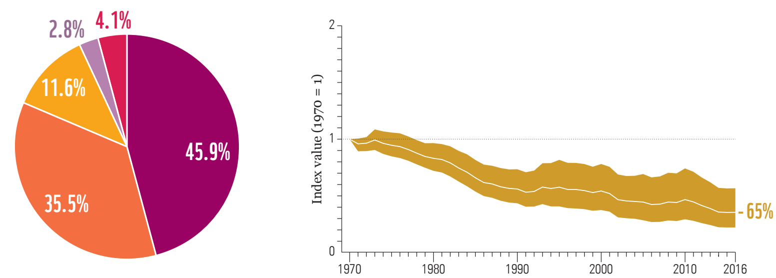
NORTH AMERICA



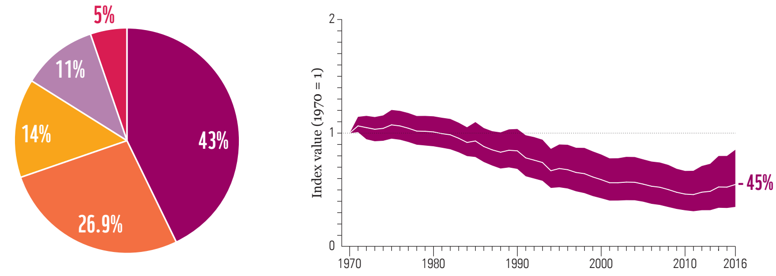
EUROPE AND CENTRAL ASIA



LATIN AMERICA & CARIBBEAN



AFRICA



ASIA PACIFIC

Zooming in on Latin America and the Caribbean

The 94% decline in the LPI for the tropical subregions of the Americas is the most striking result observed in any region. The conversion of grasslands, savannahs, forests and wetlands, the overexploitation of species, climate change, and the introduction of alien species are key drivers.

Stefanie Deinet and Louise McRae (ZSL), Paula Valdujo (WWF-Brazil) and Marcio Martins (Universidade de São Paulo)

Much of the overall decline in the 2020 Latin America and Caribbean LPI is driven by very negative trends in reptiles, amphibians and fish – groups which, according to our data, are each affected by a different cocktail of threats. For reptiles, these include land-use change and overexploitation. Freshwater fish are affected most by overexploitation in this dataset; however, habitat fragmentation due to hydropower development is already severely impacting populations in this region [11] and is predicted to pose an even greater threat in the future [12].

For amphibians, disease and habitat loss are the biggest threats. The Atlantic Forest in Brazil has lost 87.6% of its natural vegetation since 1500, mostly during the last century, which has led to at least two amphibian extinctions and 46 species threatened with extinction [13]. The infection rate of the chytrid fungus, which is impacting amphibians worldwide, is high among Atlantic Forest amphibians [14]; and this, combined with climate change and land-use change, might have an even more dramatic impact on their populations in the coming decades.

More than 2,000 species of amphibian are threatened with extinction [15], the highest current estimate among vertebrate groups. For amphibians in the LPI, disease is the main recorded threat. In El Copé in the highlands of central Panama, the chytrid fungus caused mass mortality, leading to the loss of 30 amphibian species and severely reducing the diversity of the local amphibian community [16].

Tree frog in the rain, Manu National Park, Peru.

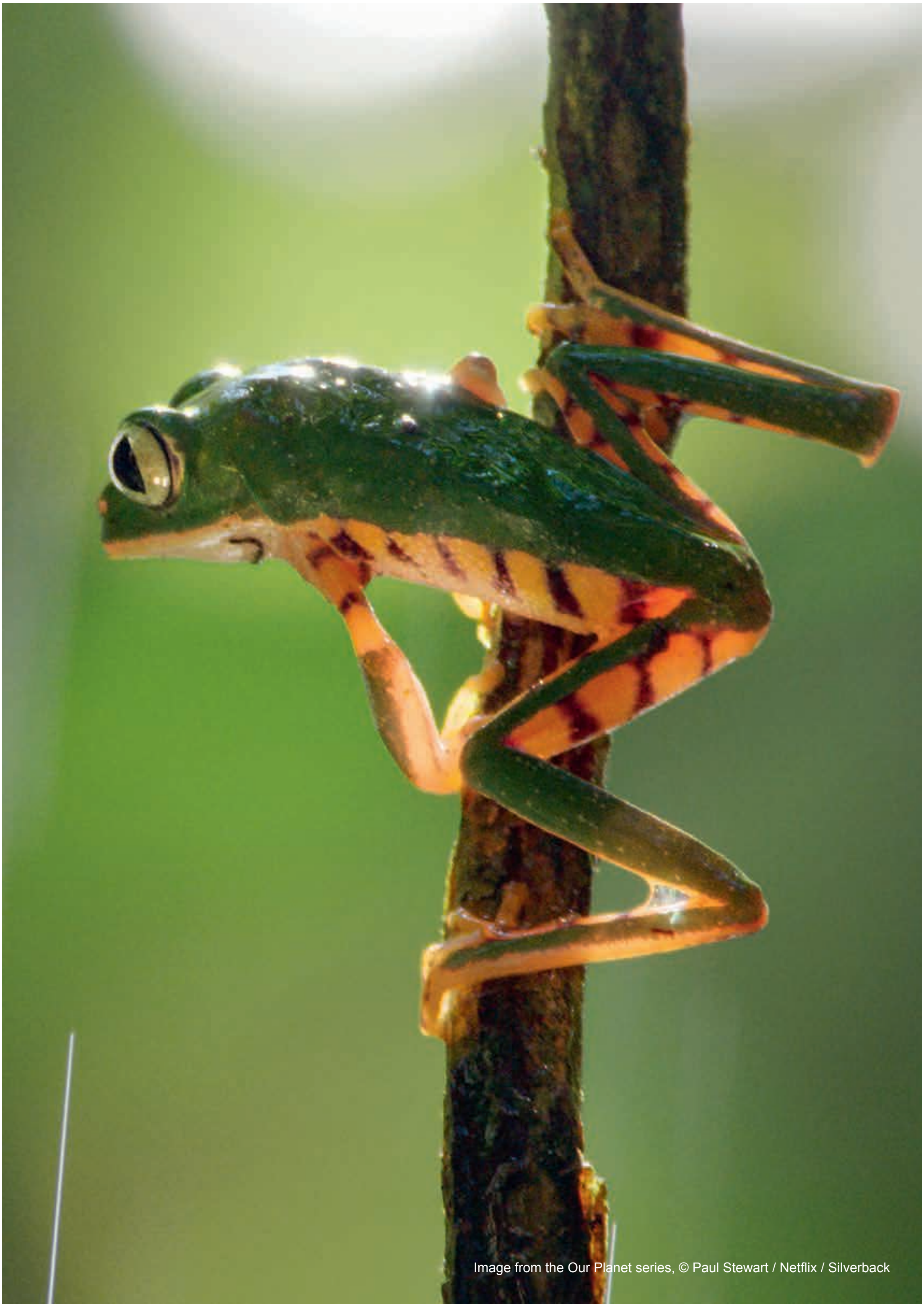


Image from the Our Planet series, © Paul Stewart / Netflix / Silverback

The Freshwater Living Planet Index

On average, population trends for monitored freshwater species appear to be falling steeply, with megafauna particularly at risk.

Louise McRae, Stefanie Deinet, Valentina Marconi, Kate Scott-Gatty and Robin Freeman (ZSL)

Almost one in three freshwater species are threatened with extinction, with all taxonomic groups showing a higher risk of extinction in the freshwater, compared to the terrestrial, system [106]. If we look at population trends using the Living Planet Index, a similar story emerges.

The 3,741 monitored populations – representing 944 species of mammals, birds, amphibians, reptiles and fishes – in the Freshwater Living Planet Index have declined by an average of 84% (range: -89% to -77%), equivalent to 4% per year since 1970. Most of the declines are seen in freshwater amphibians, reptiles and fishes; and they're recorded across all regions, particularly Latin America and the Caribbean (see page 22).

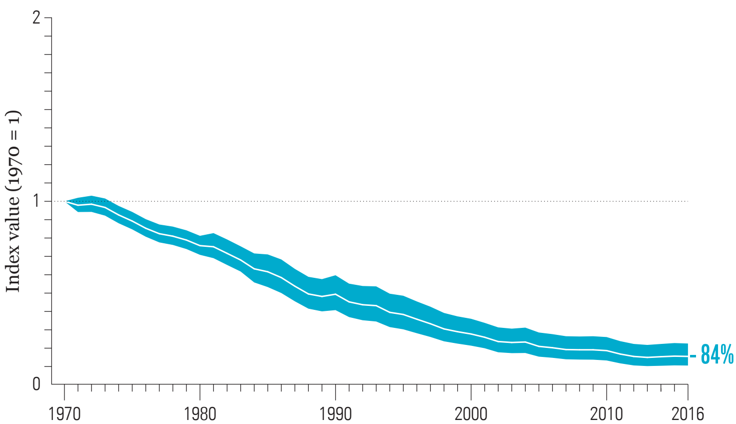
Habitat degradation through pollution or flow modification, overexploitation, invasive species [108] and sand mining in rivers [109] is among the threats affecting freshwater species. Conservation action often fails to target freshwater species or habitats [110-112], partly because the protection of freshwater environments often requires large-scale, multi-sectoral efforts [113].

Figure 6: The Freshwater Living Planet Index: 1970 to 2016
The average abundance of 3,741 freshwater populations, representing 944 species, monitored across the globe declined by 84% on average. The white line shows the index values and the shaded areas represent the statistical certainty surrounding the trend (range: -89% to -77%) [107].

Key

Freshwater Living Planet Index

Confidence limits



The bigger the size, the bigger the threats

Species with a larger body size compared with other species in the same taxonomic group are sometimes referred to as 'megafauna'. Across the world, these species are particularly at risk [114]: they tend to be less resilient to changes in the environment because they generally require complex and large habitats, reproduce at a later stage in life and have fewer offspring [115].

In the freshwater system, megafauna are species that grow to more than 30kg, such as sturgeon and Mekong giant catfish, river dolphins, otters, beavers and hippos. They are subject to intense anthropogenic threats [116], including overexploitation [114], and strong population declines have been observed as a result [117]. Mega-fishes are particularly vulnerable. Catches in the Mekong river basin between 2000 and 2015, for example, have decreased for 78% of species, and declines are stronger among medium- to large-bodied species [118]. Large fishes are also heavily impacted by dam construction, which blocks their migratory routes to spawning and feeding grounds [116, 119].

Large-scale cross-boundary collaboration is required to effectively protect freshwater species [113], and some persistent conservation efforts have proved successful. The Eurasian beaver (*Castor fiber*), for instance, has now been reintroduced into many countries from which it had disappeared, including Czechia, Estonia, Finland, Sweden and the UK [120].

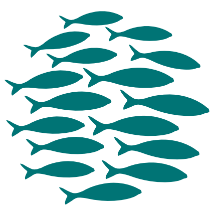
Close up of the head of a West Indian manatee (*Trichechus manatus*) under water, Crystal River, Florida.


© WWF / Vincent Kneefel

The Living Planet Index is one indicator among many showing severe declines or changes in recent decades

Humanity's influence on the decline of nature is so great that scientists believe we are entering a new geological epoch, the Anthropocene. Yet, measuring biodiversity, the variety of all living things, is complex, and there is no single measure that can capture all of the changes in this web of life. Nevertheless, the vast majority of indicators show net declines over recent decades.

Piero Visconti (IIASA), Robin Freeman (ZSL)

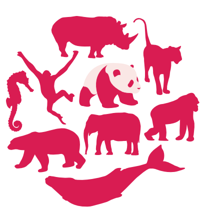


ABUNDANCE

The LPI measures the population abundance of thousands of vertebrate species around the world. Other indices measure different things, or have broader taxonomic breadth, giving us different information about how biodiversity is responding to human pressures, as well as conservation interventions. Indicators of the extent and structural condition of ecosystems, of the composition of ecological communities, and of species populations overwhelmingly show net declines over recent decades [17]. In this report we have included the IUCN Red List Index that tracks extinction risk; the Mean Species Abundance Index and Biodiversity Intactness Index that look at changes in species community composition; and the Species Habitat Index that measures changes in species distribution.

Extinction risk: the IUCN Red List Index

Stuart Butchart (BirdLife International), Craig Hilton-Taylor (IUCN)



EXTINCTION RISK

Humans have driven at least 680 species of vertebrates, the best studied taxonomic group, to extinction since 1500 [1]. This equates to ~1% of species in these groups. Many other species are now at elevated risk of extinction owing to human impacts. The IUCN Red List represents the most comprehensive and objective system for assessing the relative risk of extinction of species [15]. Over 100,000 species have now been evaluated using information on life-history traits, population and distribution size and structure, and their change over time to assign each species into one of eight categories (Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern or Data Deficient). For five groups in which all species have been assessed at least twice, the Red List Index (RLI) shows trends over time in their relative survival probability based on these Red List categories. Baseline RLI values are available for a range of additional groups that have only been assessed once. These data shows that cycads (an ancient group of plants) are most threatened, while corals are declining fastest.

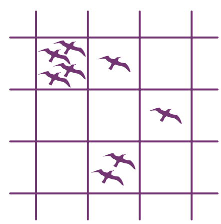
Community composition: the Mean Species Abundance Index and Biodiversity Intactness Index

Andy Purvis (Natural History Museum)

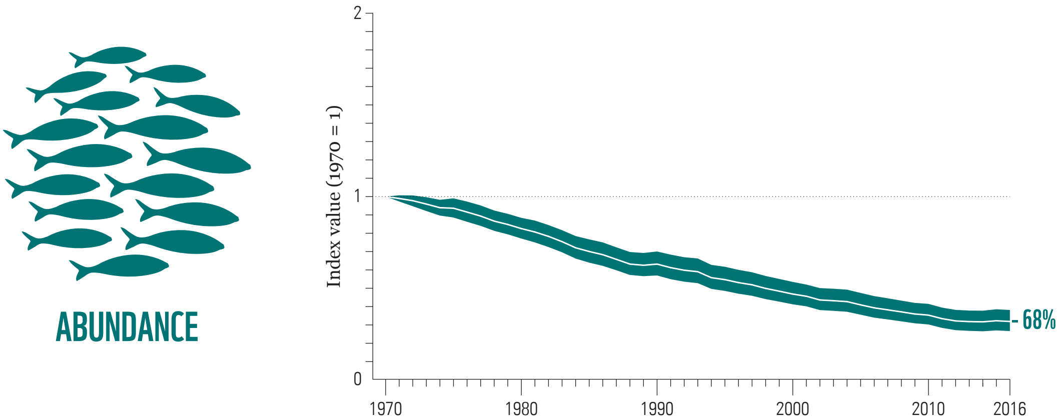
Biological communities can change fundamentally as a result of human pressures compared to what they would have been in pristine conditions, even without any species going locally extinct. Tracking community composition – the species that are present and their local abundances – can give an indication of both the intactness and functioning of ecosystems. The Mean Species Abundance (MSA) Index [18] and Biodiversity Intactness Index (BII) [19], are two modelled indices that estimate the intactness of animal and plant communities spatially. The indices range from 100-0%, with 100 representing an undisturbed natural environment with little to no human footprint. The MSA Index has fallen to 66% of its pre-impact value and is falling by 1.1% per decade, whereas the BII has fallen to 79% of its pre-impact value and is declining by 0.8% per decade [1]. Both the MSA and BII are projected to continue to decline under business-as-usual socio-economic trends.

Species distribution: the Species Habitat Index

Walter Jetz (Yale University)

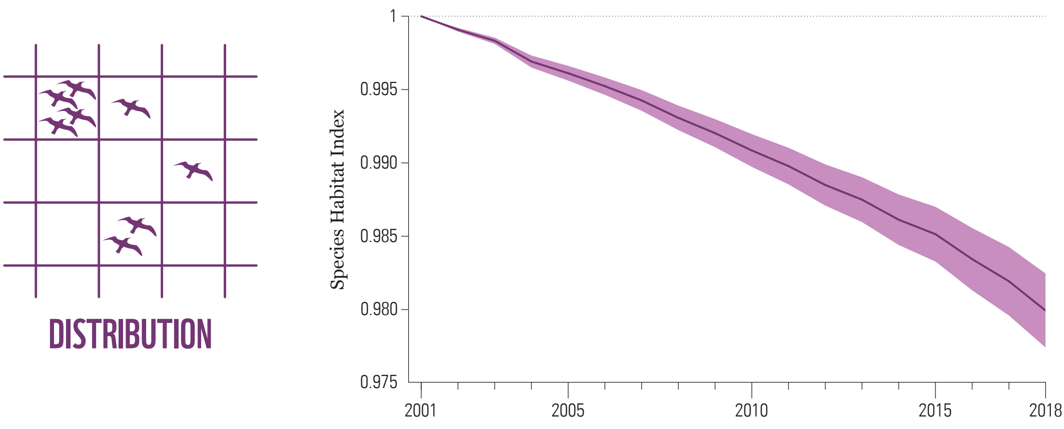


Species distributions are dynamic by nature, with local populations constantly adapting to the environment. The magnitude of these dynamics has, however, been greatly altered by human pressures, especially those that have caused the loss of habitats. The Species Habitat Index captures changes in species range and incorporates information about species habitat preferences with observed or modelled data on habitat loss and restoration, habitat fragmentation and climate change. This index has fallen by 1% per decade since 1970 [20] and, on average, the geographic distribution of terrestrial mammals, the only group for which baseline distribution could be estimated, has been reduced to 83% of pre-impact values [21].



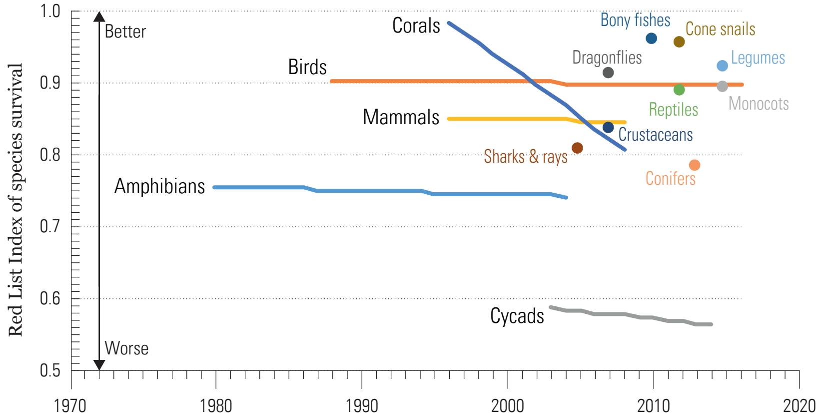
Living Planet Index

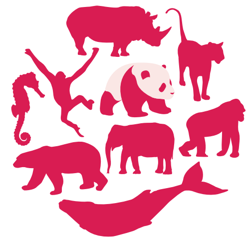
The Living Planet Index (LPI) now tracks the abundance of almost 21,000 populations of mammals, birds, fish, reptiles and amphibians around the world[107]. Using the data from 20,811 populations of 4,392 species, the 2020 global LPI shows an average 68% decline in monitored populations between 1970 and 2016 (range: -73% to -62%). The percentage change in the index doesn't represent the number of individual animals lost but reflects the average proportional change in animal population sizes tracked over 46 years.



Species Habitat Index

Human land-use change, and increasingly climate change, are altering landscapes worldwide. Remotely sensed monitoring and model-based projections offer an increasingly strong and near-global capture of these changes to the land cover. The Species Habitat Index (SHI) quantifies the resulting implications for species populations[24, 25]. For thousands of species with validated habitat associations worldwide the index measures the losses in habitat-suitable range from observed or modelled habitat change[26]. Between 2000 and 2018 the index has fallen by 2%, indicating a strong and general downward trend in habitat available to species. For select regions and species the SHI decrease is much steeper, with double-digit percentage losses suggesting extensive contractions in total population sizes and thus the ecological roles provided by species.

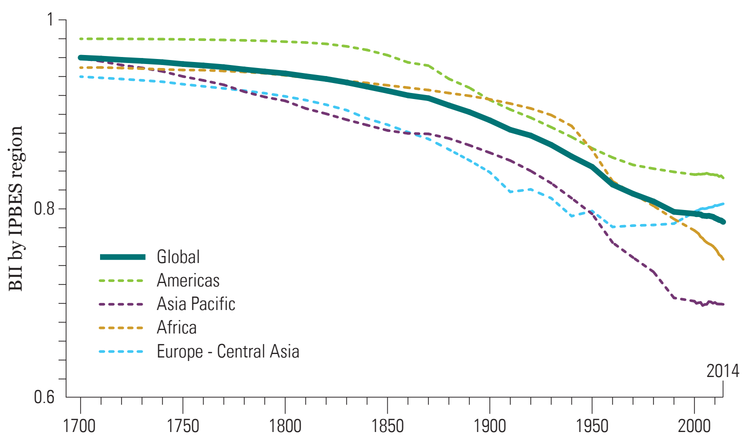




EXTINCTION RISK

Red List Index

The Red List Index, based on data from the IUCN Red List of Threatened Species [15], shows trends in survival probability (the inverse of extinction risk) over time [22]. A Red List Index value of 1.0 equates to all species within a group qualifying as Least Concern (i.e. not expected to become Extinct in the near future [22]). An index value of 0 equates to all species having gone Extinct. A constant value over time indicates that the overall extinction risk for the group is unchanged. If the rate of biodiversity loss were reducing, the index would show an upward trend. A decline in the index means that species are being driven towards extinction at an accelerating rate.



COMPOSITION

Biodiversity Intactness Index

The Biodiversity Intactness Index (BII) estimates how much originally present biodiversity remains on average across the terrestrial ecological communities within a region. It focuses on the effects of land use and related pressures, which have so far been the dominant drivers of biodiversity loss [27,1]. Because it is estimated across a very large set of ecologically diverse animal and plant species, the BII is a useful index of ecosystems' ability to provide benefits to people (ecosystem services). For this reason, it is used in the Planetary Boundaries framework as an indicator of biosphere integrity [28]. The global average BII (79%) is well below the proposed lower safe limit (90%) and continues to fall, especially in Africa [19] (note the steep decline in the brown line above), suggesting that the world's terrestrial biodiversity is already dangerously compromised. The BII is very low in some regions, such as Western Europe, that have a long history of intensive use of the landscape (for a global BII map, see the technical supplement).

Uncovering trends from the tiniest creatures to the canopy

From the biggest to the smallest living things on Earth, monitoring tells us that nature is under serious pressure. Tigers and polar bears are well-known poster species in the story of biodiversity decline, but what of the billions of tiny or as-yet-undiscovered species that are also under threat? What is happening to the life in our soils, biodiversity that plays a critical role in the ecosystem services on which we depend? Or to insects in tropical regions in light of studies in North America and Europe that may represent an early warning for the rest of the world?

For the first time this *Living Planet Report* also investigates the status of plants, which provide fundamental support for life on Earth and are the basis of virtually all terrestrial ecosystems. The number of documented terrestrial plant extinctions is twice as high as for mammals, birds and amphibians combined.

Leaf-cutter bee (*Megachile* sp) and milkweed, Highmore, South Dakota, USA.


© WWF-US / Clay Bolt

SOIL BIODIVERSITY: SAVING THE WORLD BENEATH OUR FEET

Soil is a critical component of the natural environment – yet most people are totally unaware of, or underestimate, the vital role that soil biodiversity plays in the ecosystem services on which we depend.

Monica Kobayashi and Ronald Vargas (FAO/GSP)

Soil hosts one of the largest reservoirs of biodiversity on Earth: up to 90% of living organisms in terrestrial ecosystems, including some pollinators, spend part of their life cycle in soil habitats [29]. The variety of soil components, filled with air and water, create an incredible diversity of habitats for a myriad of different soil organisms that underpin our life on this planet.

Besides food production, soil biodiversity provides a vast range of ecosystem functions and services, including soil formation, the retention and purification of water, nutrient cycling, the degradation of some soil contaminants and the regulation of greenhouse gases, as well as sustaining plant, animal and human health.

Without soil biodiversity, terrestrial ecosystems may collapse. We now know that above- and belowground biodiversity are in constant collaboration [30-32], and an improved understanding of this relationship will help to better predict the consequences of biodiversity change and loss.

The Status of the World's Soil Resources [33] concluded that the loss of soil biodiversity is considered one of the major soil threats in many regions of the world. Some responses to bend the curve of biodiversity loss include sustainable use of soil genetic resources and improved soil management to safeguard soil biota as well as its multiple functions [34]. Future agricultural systems may need to combine traditional practices, nature-based solutions and novel technologies such as artificial intelligence, DNA sequencing and microbiome-based precision farming.

Additionally, policies on land use, agriculture, ecosystems restoration, climate change mitigation and adaptation, pollution remediation and urban planning should highlight the importance of healthy soils in order to reduce threats to soil biodiversity and people.

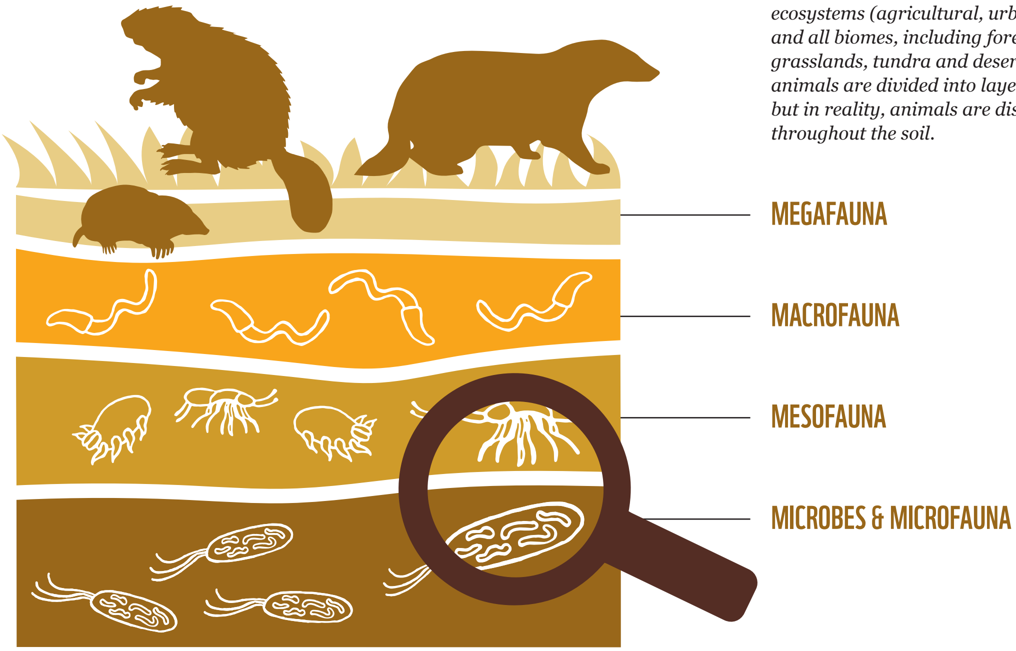


Figure 7: Soil communities
Soil biodiversity underpins terrestrial ecosystems (agricultural, urban, nature and all biomes, including forests, grasslands, tundra and deserts). Here, animals are divided into layers by size but in reality, animals are distributed throughout the soil.

Soil organisms vary from 20nm to 20-30cm and are traditionally divided into four size classes [121, 122, 123].

***Megafauna** (20mm+) vertebrates (mammalia, reptilia and amphibia). They create spatial heterogeneity on the soil surface and in its profile through movement.*

***Macrofauna** (2mm-20mm) are large soil invertebrates (earthworms, enchytraeids, woodlice, myriapods, insect larvae). They are ecosystem engineers, moving through the soil, thus perturbing the soil and increasing water permeability, soil aeration, and creating new habitats for smaller organisms. Their faeces are hotspots for microbial diversity and activity.*

***Mesofauna** (0.1-2mm) are soil microarthropods (mites, apterygota, small larvae of insects). They live in soil cavities filled with air and form coprogenic microaggregates; increase the surface of active biochemical interactions in the soil; participate in the transformation of soil organic matter.*

***Microbes** (viruses, bacteria, archaea, fungi; 20nm-10um) and **Microfauna** (soil protozoa and nematodes; 10um - 0.1mm) mostly live in soil solutions in gravitational, capillary and hygroscopic water; they participate in decomposition of soil organic matter, as well as in the weathering of minerals in the soil. Their diversity depends on the conditions of microhabitats and on the physicochemical properties of soil horizons.*

Soil biodiversity and agricultural ecosystems

Soil biodiversity keeps us alive, so we need to ensure that we stop destroying it. With this in mind, the European Commission's Joint Research Centre is carrying out genetic analyses of the soils of the European Union to measure how their diversity is related to specific land uses and the presence of pollutants.

Monica Kobayashi and Ronald Vargas (FAO/GSP) and Alberto Orgiazzi and Arwyn Jones (JRC)

The State of the World's Biodiversity for Food and Agriculture report [35] concluded that many species living in and around production systems, particularly microorganisms and invertebrates, have never been documented. In many cases, the contributions of specific biodiversity components to production systems are poorly understood. Increasing soil organisms' diversity is linked to an increase in soil functions and the provision of services. This includes support to plant growth as well as higher nutrient use efficiency [36]. Soil biota also help to build resilience and to control, prevent or suppress pests and diseases [37]. Diversification of agricultural systems and improved tree cover can also contribute to enhancing below- and aboveground biodiversity and, as a result, the ecosystem services it provides [38]. Understanding and promoting these soil dynamics could help not only to protect plants, animals and humans; it could also help us to live in harmony with nature.

In addition to agriculture, the European Commission's Joint Research Centre (JRC) has identified the key drivers of pressures on soil organisms. These include climate change (both temperature and precipitation have significant effects on soil-dwelling communities), land-use change (especially the sealing of soil by impervious layers such as asphalt or concrete), habitat fragmentation, intensive human exploitation, soil organic matter decline, pollution (including industrial emissions), and the introduction and diffusion of invasive alien species [39].

Researchers are starting to better understand the complexity of soil biodiversity which is composed of microorganisms, macro- and megafauna. Some threats, like pesticides, may potentially impact only a single entity of soil-dwelling organisms, and at different levels of intensity. However, the loss of a single element may cause the collapse of the entire food web. Other threats, such as erosion or soil-sealing, can result in the complete – and in some cases irreversible – loss of habitat [40].

For this reason, the JRC is currently conducting an assessment of soil biodiversity across the European Union as part of the Land Use and Coverage Area frame Survey (LUCAS)[41]. Through genomic analysis, the diversity of soil organisms will be measured in relation to specific land uses (e.g. different farming systems) and the presence of pollutants, such as metals and pesticide residues.

A two-pronged bristletail (Order Diplura) in Ithica, NY.

PLANT DIVERSITY IS IN SERIOUS DECLINE

Plants are the structural and ecological foundation of virtually all terrestrial ecosystems and provide fundamental support for life on Earth. They are vital to human health, food and well-being [42].

Eimear Nic Lughadha (Royal Botanic Gardens, Kew), Alexandre Antonelli (Royal Botanic Gardens, Kew and Gothenburg Global Biodiversity Centre) and Aelys M Humphreys (Stockholm University)

On average, more than 2,000 plant species continue to be described as new to science each year [43], adding to the total number of known vascular plant species, estimated to be between 340,000 to 390,000 [44, 45]. Yet, despite their importance to life on Earth, the status and trends of the world's plants remain poorly understood compared to vertebrates, and they are usually omitted from global analyses of biodiversity [46]. Geographic, genetic and trait information for plants, including their uses for humankind and function in ecosystems, is even more incomplete [47]. For example, about half of the world's plant species lack detailed distribution data [48], in contrast to the range maps available for most vertebrates [15].

Plant diversity loss: documented and predicted

Only 10% of plants have been assessed for the global IUCN Red List and current coverage is biased, with trees and threatened species more likely to have been assessed [49]. However, assessment of a sample of thousands of species representing the taxonomic and geographic breadth of global plant diversity showed that one in five (22%) are threatened with extinction, most of them in the tropics [50]. Plant extinction risk is comparable to that of mammals and higher than for birds.

The number of documented plant extinctions is twice as many as for mammals, birds and amphibians combined [51]. Documenting actual plant extinctions is more challenging than assessing extinction risk because plants may live for years without being detected and may therefore be erroneously declared extinct (see page 38). Examples include many tropical plants that are naturally rare [52] with small populations, and plants that are inconspicuous or present only as seeds in the soil.

Conversely, plant species may be prominent in the landscape but no longer regenerating and therefore functionally extinct, so they are erroneously omitted from counts of extinct plants [53, 54]. Half of plant extinctions reported to have occurred since 1750 have been subsequently refuted (due to rediscovery or redefinition of species) but those unrefuted indicate that seed plant extinctions are occurring up to 500 times faster than in pre-industrial times [51].

Small-ranged species have long been understood to be particularly susceptible to global extinction, because impacts are more likely to affect their entire range [55]. The loss of these relatively rare species, even at the local scale, results in biotic homogenisation [56]. Indeed, range size is the strongest predictor of extinction risk in plants, followed by measures of human impact, such as population density or the Human Footprint Index (explored in Chapter 2,) [57, 58]. Analysis of global Anthropocene extinctions shows high rates on islands, in the tropics, of woody plants, and among those known to have only narrow geographical ranges [51].

Causes of plant diversity loss

Agriculture, including expansion or intensification of crop or livestock farming, plantations and aquaculture, is the most frequently identified threat to plants in IUCN Red List assessments. Consistent with these assessments, habitat destruction and land-use changes, mainly urbanisation and agriculture-related, are the major causes reported for plant extinctions [59]. However, for most plant extinctions, the cause remains unknown.

The threat to plants presented by climate change is, as yet, scarcely detectable on the Red List, with just 4% of assessments citing climate change or severe weather. The recent categorisation of wild Arabica coffee as Endangered based on projected climate change impacts, when it would otherwise have been assessed as Least Concern [60], suggests that the Red List currently underestimates the impact of future climate change. The relative importance of climate versus land-use change will have practical implications for conservation planning over time [61].

If the dismal prospect of an increasingly uniform natural world is not sufficient to win converts to the plant conservation cause, then the importance of plants to other life on Earth, including animals and humans, needs to be more widely understood.

Plants that are extinct in the wild

Ex situ conservation, which preserves species outside their natural habitat, provides us with options to prevent plant extinctions and to restore wild populations.

Colin Clubbe
(Royal Botanic Gardens, Kew)

The IUCN Red List categorises a plant as Extinct in the Wild when it exists only in cultivation, or as a naturalised population well outside its past range [62, 63]. This category is only applied when there is no reasonable doubt that the last individual in the wild has died [63]. However, proving extinction in the field is challenging and rediscoveries do occur, as was the case with the endemic Ascension Island parsley fern *(Anogramma ascensionis)*. Last seen on the volcanic island in the South Atlantic Ocean in 1958 [64], the parsley fern was listed as Extinct on the 2003 IUCN Red List. However, a 2009 survey rediscovered four plants on the island's Green Mountain. Spores were collected and cultured *in vitro* at the Royal Botanic Gardens, Kew, where a living collection is maintained [65]. Plants have been reintroduced on Ascension and the species reassessed as Critically Endangered [66].

Nymphaea thermarum, illustrated here, became Extinct in the Wild in 2008 when the last known plant died at its only known location in Rwanda [67]. Yet, a recent comprehensive review suggests there may still be hope for the future of some plants: it documents 431 species, once declared to be globally Extinct or Extinct in the Wild, that have since been rediscovered [51]. The IUCN Red List documents 118 vascular plant species that are Extinct and 35 that are Extinct in the Wild, while a recent review reports nearly 600 seed plant species to have gone globally Extinct or Extinct in the Wild [51, 68].

The causes of extinction are varied but are largely driven by anthropogenic activities including invasive species, agricultural intensification, and habitat loss and fragmentation. *Ex situ* conservation encompasses a wide range of techniques to preserve species outside their natural habitat, including seed-banking and cryopreservation (the use of very low temperatures to preserve structurally intact living cells). These techniques provide us with options for the future, and global efforts such as the Millennium Seed Bank Partnership [69] have extensive seed-collecting programmes in more than 100 countries and territories to provide this interim protection of species.

Nymphaea thermarum, the world's smallest waterlily, known only from the damp mud created by the overflow from a single hot spring in Rwanda. The last plant desiccated and died when the stream feeding the hot spring was diverted for local agriculture in 2008. An *ex situ* collection is being maintained at the Royal Botanic Gardens Kew: in the hope of a possible reintroduction if this fragile habitat can be restored.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Useful plants: providers in peril

Ongoing plant diversity loss not only threatens plants and their ecosystems, but also the invaluable spectrum of services that plants provide to people and the planet.

Serene Hargreaves and Jack Plummer (Royal Botanic Gardens, Kew)

Plants provide a remarkable array of services, vital in maintaining the health of the natural world and sustaining the demands of an increasingly anthropogenic planet. However, relentless human population growth is putting a damaging strain on the world's plant diversity, and many with medicinal properties, nutritional value and ornamental appeal are now under threat of extinction.

Useful plants are susceptible to the drivers causing biodiversity loss globally. For example, habitat loss, driven by agricultural land conversion, has restricted the Madagascar banana to just three individuals in the wild [70]. Indian belladonna, possessing similar medicinal properties to the related deadly nightshade, is threatened by deforestation, and overharvesting of its leaves and roots for use by the pharmaceutical industry and in traditional medicine systems [71-73]. Climate change is projected to sharply reduce the suitable habitat for indigenous Arabica coffee. From healthcare to food security, and construction materials to your morning coffee, a heightened extinction risk for these plants has negative implications reaching far beyond their local ecosystems.

Arabica coffee (*Coffea arabica*) is the world's most popular coffee bean. An extinction risk assessment which incorporated the likely effects of climate change categorised *C. arabica* as Endangered, with a predicted loss of more than half its natural population by 2088 [74].

Tracking trees: building a picture of their global status

The first Global Tree Assessment will cover all 60,000 known tree species across the planet to give us a complete picture of the conservation status of the world's trees.

Malin Rivers and Emily Beech (Botanic Gardens Conservation International)

The Global Tree Assessment is coordinated by Botanic Gardens Conservation International and the IUCN/SSC Global Tree Specialist Group[75]. It works through an extensive global collaborative partnership with national Red List organisations, botanic gardens, NGOs, forestry institutes, universities, herbaria and taxonomic experts. Its goal is to produce a conservation assessment for every known tree species to identify and prioritise conservation action for trees of greatest conservation concern.

First, a list of the world's trees had to be collated. In April 2017, GlobalTreeSearch – a checklist of 60,000 unique tree species and their distribution – was completed[76]. This list is continually updated with new species, new distributions and taxonomic changes. Second, a conservation assessment, using the IUCN Red List categories and criteria, is needed for each of the 60,000 tree species to evaluate their risk of extinction. In addition, information on distribution, population trends, threats and conservation actions is gathered.

The Global Tree Assessment will give us a complete picture of the conservation status of the world's trees. Beyond trees the results will also be vital for other biodiversity and ecosystems that depend on trees for their survival, to guide conservation action and ensure that biodiversity is managed, restored and saved from extinction.

Terminalia acuminata, commonly known as Guarajuba, is an Endangered tree endemic to Brazil. Previously thought to be Extinct in the Wild, it was rediscovered when reassessed for the Global Tree Assessment.


© Malin Rivers

ARE "THE LITTLE THINGS THAT RUN THE WORLD" DISAPPEARING?

There is evidence of recent, rapid declines in insect abundance, diversity and biomass, but the picture is complex and most evidence comes from a few taxa and a few countries in the northern hemisphere.

Lynn Dicks
and Edgar Turner
(University of Cambridge)

Insects dominate the animal kingdom in their sheer number of species. More than a million have been described, but the latest estimates suggest there may be as many as 5.5 million insect species altogether, with most in the tropics [77]. Insects carry out essential roles in all terrestrial ecosystems, including pollinating plants, regulating pests, processing nutrients in soil and providing food for other animals, leading E.O. Wilson to famously describe them as "the little things that run the world" [78].

In Western Europe and North America, insect monitoring schemes and long-term studies show startlingly rapid, recent and ongoing declines in insect numbers, distributions or collective weight (biomass).

A recent analysis of wild bee and hoverfly records, collected by UK naturalists, shows a net loss of 11 species (4 bees and 7 hoverflies) per 1km^2 between 1980 and 2013 [79], the result of a third of species reducing their range. The total abundance of large moths declined in the UK by 31% between 1969 and 2016 [80], while three-quarters of UK ground beetle species declined in abundance between 1994 and 2008, with half showing reductions of more than 30% [81].

There have been dramatic range declines in some North American bumblebee species [82]. In Germany, insect abundance declined by 78% and biomass by 67% between 2008 and 2017 in grassland sites [83]; and in a different set of sites overall insect biomass declined by 76% between 1989 and 2016 [84].

The most comprehensive global review of long-term insect declines in abundance and biomass to date, released earlier this year, confirms widespread losses of terrestrial insects since 1925, with a mean global loss of 8.8% per decade. However, the study also found a mean increase of 11.3% per decade for freshwater insects over the same time period, which may reflect recovery from past degradation due to policies that have reduced water pollution in North America and Europe [85]. A general pattern is that habitat specialists or rarer species are declining, while a subset of common generalists are stable or even increasing [86-88, 79].

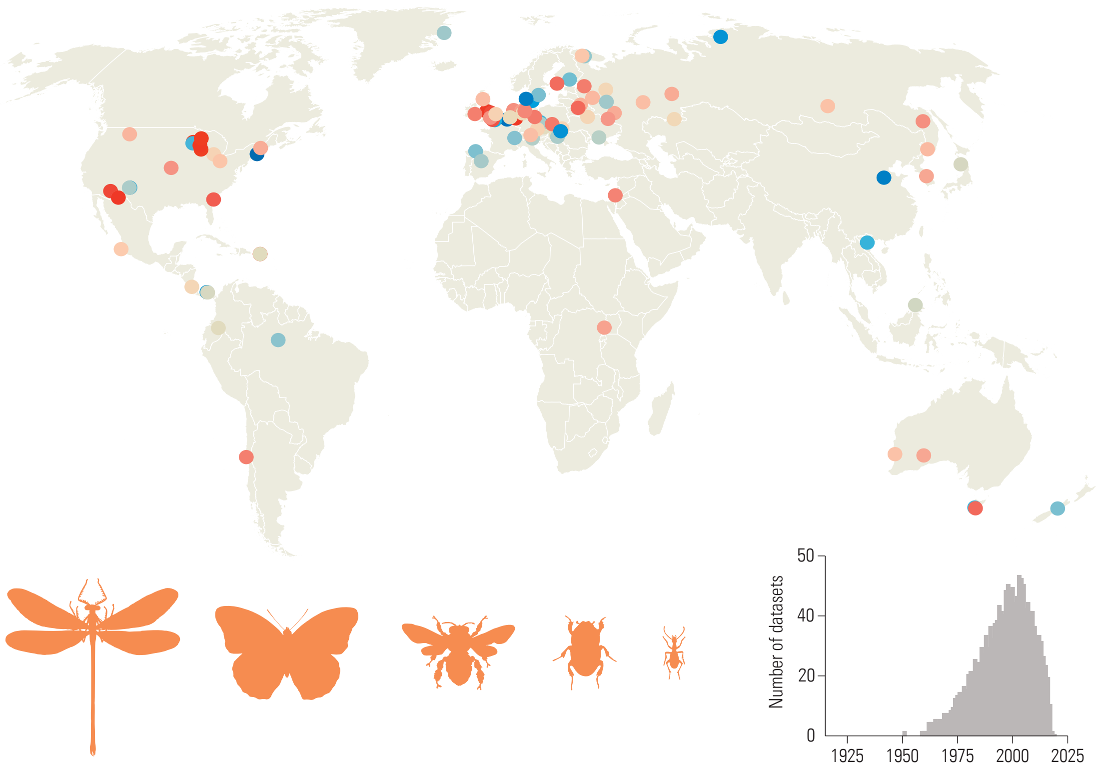


Figure 8: Estimates of long-term change in terrestrial insect numbers (abundance or biomass), *from 103 studies reviewed by Van Klink et al (2020)[85]. Three-quarters of the studies (77/103) are from Europe and North America, with very few from Africa (1), Asia (5, excluding Russia and the Middle East) or South America (3). The inset shows a histogram of the number of datasets with at least one data point for each year.*

Key

A focus on European butterflies: the 2020 Butterfly Living Planet Index

Louise McRae and Monika Böhm (ZSL) and Butterfly Conservation in Europe, European Butterfly Monitoring Schemes and the Assessing Butterflies in Europe Consortium

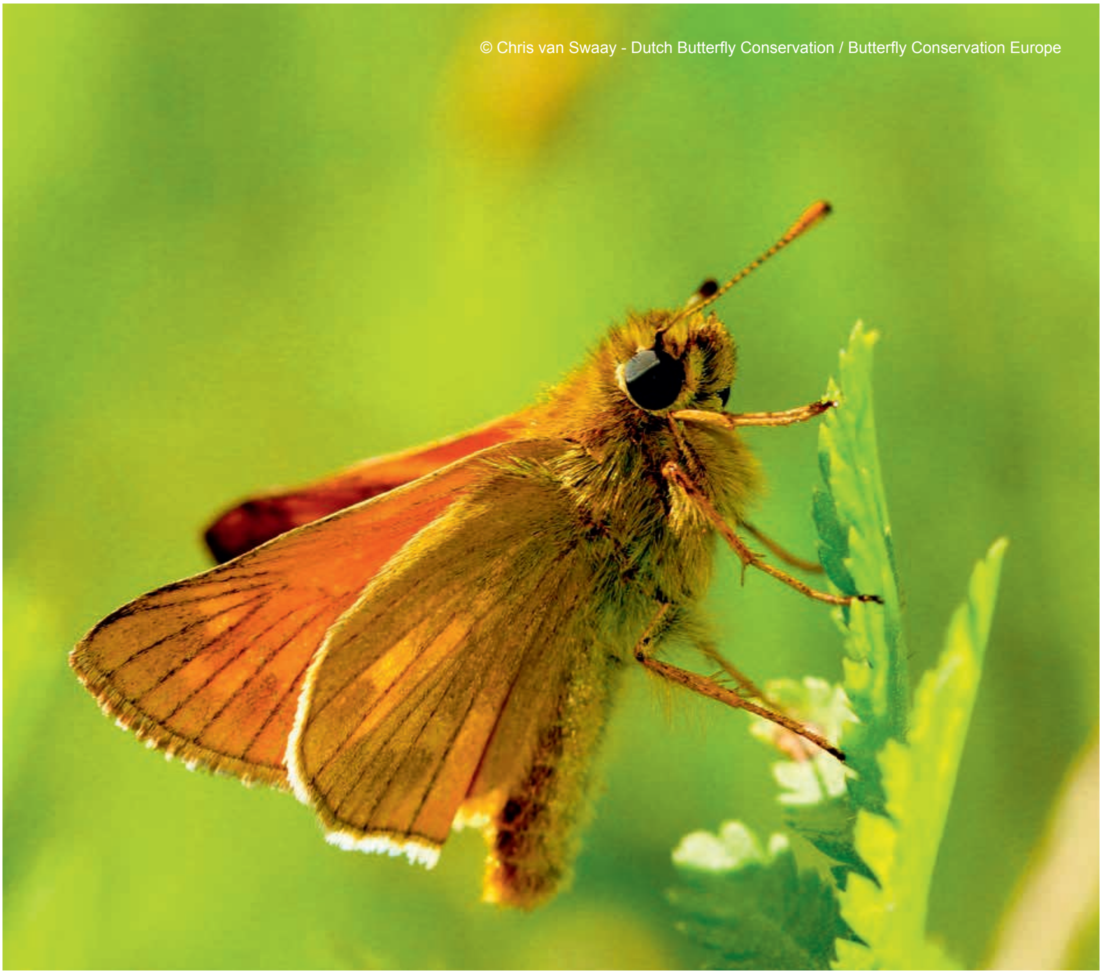
Globally, butterflies are still very poorly represented on the IUCN Red List of Threatened Species, with only 978 of the ~20,000 described species currently assessed. Of these assessed species, 173 (~18%) are listed as threatened [15].

Although globally underrepresented, butterflies are one of the easier insect groups to monitor as they are active during the day and are usually fairly conspicuous. As a result they have been monitored long-term, and on a national scale, in many countries in Europe [89].

While there are challenges in establishing schemes to regularly collect data in a consistent manner, one way is to harness the combined effort of trained professionals and volunteers who walk a set route under specific weather conditions and record the number of each butterfly species seen. The latest results show trends in 17 typical grassland butterfly species for 16 European countries over 28 years. The index shows a decline of 49% (range -71% to -13%) between 1990 and 2017 (Figure 9). Six of the 17 species show a decline, seven are stable and four are increasing.

The decline in the butterfly index is largely attributed to the intensification of agriculture in Northwest Europe and the abandonment of grasslands in other areas [90]. In Europe these environmental pressures have existed for longer than the 1990 baseline shown here, therefore it's possible that the populations of these butterfly species are in a poorer state than the results suggest. For example, in the Netherlands, an estimated 84% decline, on average, occurred between 1890 and 2017 for 71 butterfly species [91]. Protection and restoration of grasslands are needed to reverse the trends and allow grassland butterfly populations to recover.

What is known about butterflies in the rest of the world? Regular butterfly counts in Ohio, USA show numbers declining at 2% per year, with a 33% reduction in numbers between 1996 and 2016 [92]. An ongoing assessment of the extinction risk of the world's swallowtails – large, colourful butterflies in the Papilionidae family – has so far shown that ~14% of the 36 birdwing butterfly species, the largest butterflies in the world, are threatened with extinction.



The large skipper butterfly (*Ochlodes sylvanus*) is a widespread grassland species within Europe and has shown a moderate decline in abundance of around 25% between 1990 and 2017.

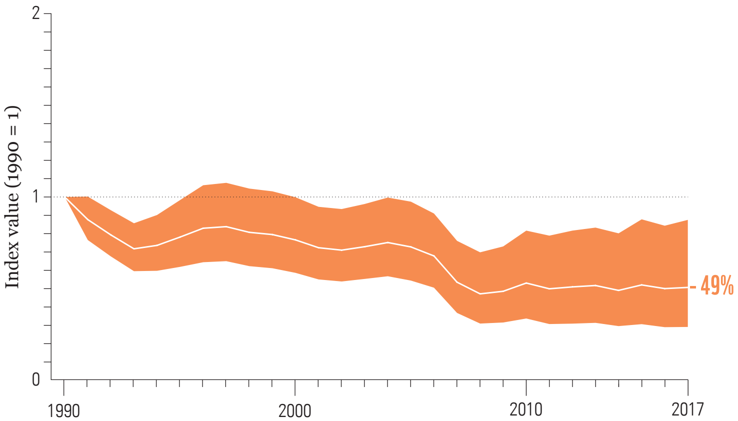


Figure 9: The Living Planet Index for European grassland butterflies: 1990 to 2017
The abundance of 17 grassland butterfly species declined by 49% on average. The white line shows the index values and the shaded areas represent the statistical certainty surrounding the trend (range: -71% to -13%). Data contributed by Butterfly Conservation in Europe, European Butterfly Monitoring Scheme, Assessing Butterflies in Europe Consortium [89]. The LPI method differs slightly to other analyses of the data [89] but the ranges overlap, meaning that the results are statistically similar.

Key

- LPI for European grassland butterflies
- Confidence limits

Building a better picture of the insect world

Insect populations are plummeting, but much more data is needed to better understand these trends around the world. Two initiatives are underway to add to our current knowledge base.

Lynn Dicks and Edgar Turner
(University of Cambridge),
Eliza Grames
(University of Connecticut),
Graham Montgomery
(University of California Los Angeles)
and Neal Haddaway
(Stockholm Environment Institute)

There are few analyses of long-term insect datasets from the tropics or the southern hemisphere [85]. Some of these datasets show less change than temperate studies. For example, fruit-feeding butterflies fluctuated in abundance in eastern Ecuador between 1994 and 2004 [94], and in a forest in Uganda between 2000 and 2011 [95], but with no obvious decline over time in either case. Orchid-bees in Panama showed very high variability between years, but no overall change in abundance between 1979 and 2000 [96]. In contrast, a rainforest study in Puerto Rico found a very large drop in both canopy and ground arthropod biomass between surveys carried out in 1976 and 2012 [93].

Given that the spread of intensive agriculture occurred earlier in Western Europe and North America than in other regions [97], it seems likely that the insect losses being observed there provide a forecast of global insect losses if anthropogenic disturbance and land-use change continue worldwide. Initiating long-term and large-scale monitoring is key to understanding current and future levels of insect population change [96].

An example of such a scheme in the tropics is the ForestGEO Arthropod Initiative [98]. Having now been underway for just over a decade, this long-term project is monitoring change in the abundance and composition of tropical insects at seven Forest Global Earth Observatory (ForestGEO) tropical sites [99].

Because insects are capable of rapid population increases, and are heavily influenced by the environment, insect numbers and biomass usually fluctuate strongly over time [96, 81, 94, 95, 100]. Long-term studies are vital to understand the true level of loss [96], and all analyses of insect datasets must take careful account of the potential pitfalls in interpreting insect monitoring data [101]. For example, this includes ensuring that representative sets of sites are surveyed in the same way for long enough to pick up trends, and that unusual years with particularly high or low numbers aren't used as a baseline or final year in analysed trends.

Even in areas with more datasets that have been analysed, such as Europe and North America, our understanding of insect population trends is hampered because evidence is stored in myriad places – from government reports on agricultural pests, to ecology journals, to unpublished data on prey availability for organisms that eat insects. A second effort, the Entomological Global Evidence Map project, or EntoGEM, was designed to tackle this challenge and is producing a global map of insect status and trends.

EntoGEM is using rigorous methods to identify published and unpublished datasets documenting multiyear insect population trends [102, 103]. These studies are systematically mapped by factors like location, duration of study and taxonomic group to identify knowledge clusters and gaps. This will enable a global community of researchers to analyse what is known, prioritise future research efforts, and make evidence-based policy and management recommendations to help to conserve insects around the world.

To address global insect declines, it is clear that a multi-pronged effort is urgently needed to identify their primary causes and inform conservation. Robust monitoring programmes, comprehensive synthesis and evaluation of evidence on insect population trends, and conservation action based on the evidence that is currently available are all needed to reduce insect declines [104, 105].

Leaf cutter ants in Costa Rica.

© naturepl.com / Bence Mate / WWF

CHAPTER 2

OUR WORLD IN 2020

In the last 50 years our world has been transformed by an explosion in global trade, consumption and human population growth, as well as an enormous move towards urbanisation. These underlying trends are driving the unrelenting destruction of nature, with humanity now overusing our natural capital at an unprecedented rate. Only a handful of countries retain most of the last remaining wilderness areas. As a result of our 21st century lifestyles our natural world is transforming more rapidly than ever before, and climate change is further accelerating the change.

This collection of red plastic is just a small selection of the plastic pollutants collected by the Rame Peninsula Beach Care Group in Whitsand Bay, Cornwall.


© Sam Hobson / WWF-UK

OUR WORLD IN 2020

Global economic growth in the last half century has changed our world unrecognisably, driving exponential health, knowledge and standard-of-living improvements. Yet this has come at a huge cost to nature and the stability of the Earth's operating systems that sustain us.

Patricia Balvanera (Universidad Nacional Autónoma de México), Alexander Pfaff (Duke University), Leticia Merino (Universidad Nacional Autónoma de México), Zsolt Molnár (Centre for Ecological Research, Hungary) and Andy Purvis (Natural History Museum, UK)

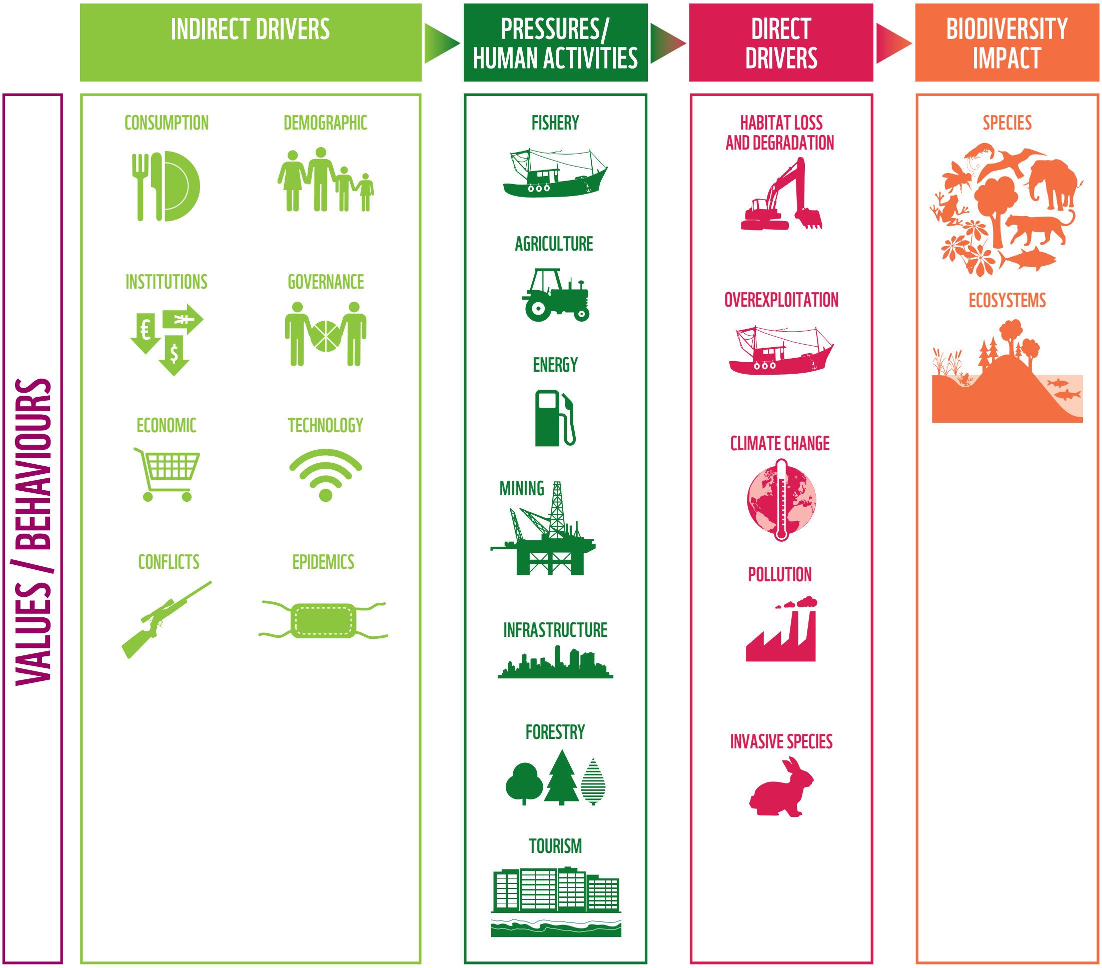
Social and economic globalisation are undoubtedly the most important forces shaping contemporary societies. Since 1970, total gross domestic product (GDP) has increased four times, the extraction of living materials from nature has tripled and, in total, the global human population has doubled [1, 2], along with an enormous trend towards urbanisation [2].

People living in cities now account for 50% of the global population [1, 2]. In the last 50 years this number has increased more rapidly, by 30%, in developing and least developed countries [1, 2] where many live in slums lacking resources and access to public services [3, 2]. Yet, in the same time period, child mortality decreased overall, more sharply in least developed countries (350% decrease) [4, 1, 2]; and caloric intake increased globally by 20%, even though many people in least developed countries are still below the thresholds recommended by the World Health Organization [5, 1, 2].

Migration has also changed the face of our planet. More than 260 million migrants have entered other countries since 1970, mainly developed countries [1, 2], and this migration occurs increasingly in precarious conditions [6]. The global movement of people across regions increased at an unprecedented pace during this period, producing profound economic gaps.

Indeed, trade has exploded with the value of exports rising 200-fold from 1970 to 2017, with the largest increases in developed countries (1,200-fold) [7]. This boom has enabled higher-income countries to increase their consumption even though nature, within their own boundaries, is relatively well protected; much of the added consumption is of nature's contributions imported from lower-income countries, which are sometimes surrendered for little economic growth [8, 2]. Supply chains that depend heavily on nature are often dominated by large corporations [9, 2], and when their, and others', amassed capital is funnelled through tax havens it can

Threats to nature and the drivers and pressures behind them



be difficult to regulate the financing of activities that damage the planet's natural systems [10].

Further, a number of economic policies currently provide incentives to degrade nature – such as direct and indirect subsidies to use fossil fuels, as well as those related to fisheries and agriculture [11, 2]. While eliminating this form of incentive is not impossible, the political complexities and constraints are vast [8, 2]. However, increasingly, some policies offer incentives to reflect the value of nature's contributions within individual behaviours, as do some private incentives, for example through certified supply chains [12, 13, 2]. Nations also create protected areas, including different types in recognition that empowering local interests in conservation is critical [14, 2].

Figure 10: Threats to nature and the drivers and pressures behind them
Values underpin changes in societies, which lead to the way human activities are undertaken defining the direct drivers on nature. Habitat loss and degradation is the major direct driver on land and overexploitation the major one in the oceans [15].

© Global Warming Images / WWF

Colour dyes outside a shop in Kathmandu, Nepal.

These patterns of production, consumption, finance and governance, alongside population, migration and urbanisation demographics, are indirect drivers of biodiversity loss as they underlie land-use change and habitat loss, the overexploitation of natural resources, pollution, the spread of invasive species and climate change – the direct drivers of the destruction of terrestrial, freshwater and marine ecosystems [2].

Indeed, one-third of the terrestrial land surface is now used for cropping or animal husbandry, while of the total amount of water that people withdraw from available freshwater resources, 75% is used for crops or livestock [15].

In marine ecosystems, the direct exploitation of organisms, mainly in fishing, has expanded geographically and into deeper waters, and now covers over half the surface of the oceans [16, 2]. With shipping accounting for 90% of world trade [17] to destinations all over the globe, our oceans are also a conduit for the spread of invasive alien species that often 'hitchhike' to new places – for instance in ballast water, as fouling organisms attached to the hulls of ships [18], or in packing materials, living plants or soils [19]. The rate of new introductions of invasive species has increased steeply since 1950, and a recent study found that 37% of all recorded alien species were introduced between 1970 and 2014 [20]. In parallel, the impacts of these introductions on biodiversity and human livelihoods are increasing worldwide [21].

Climate change is accelerating, leading to the increased frequency and intensity of extreme weather events and sea level rise [22], putting further pressure on ecosystems and biodiversity.

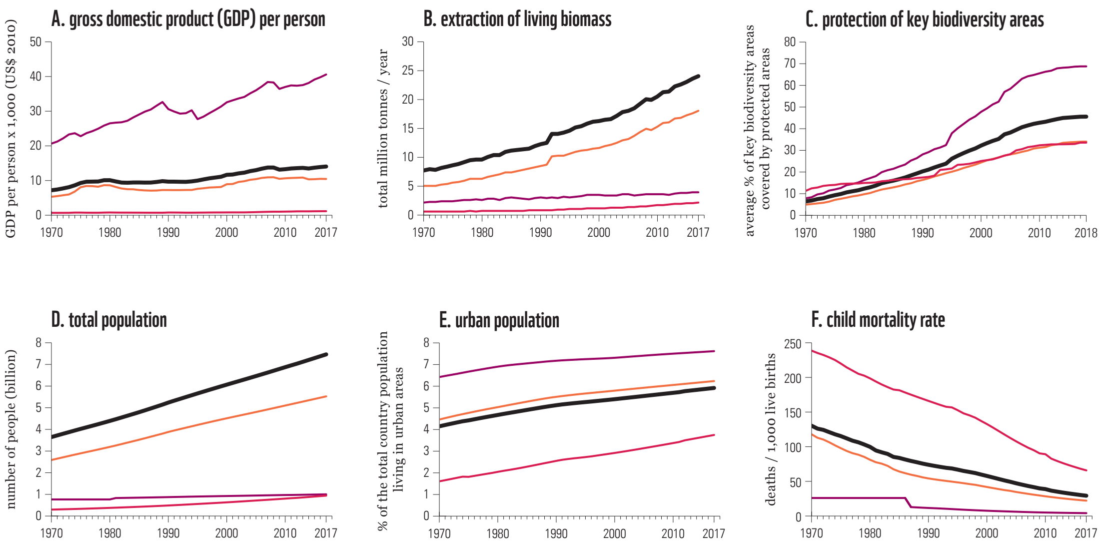


***Figure 11:* Development pathways since 1970 have featured unequal benefits and burdens that differ across countries**

The lowest increases in GDP have occurred in the currently least developed countries (a), while increased consumption in more developed countries has increased extraction of living materials from nature that largely come from developing countries (b) and protection of key biodiversity areas has been highest in developed countries (c). Total human population has increased more rapidly in developing countries (d) while urban population is largest in developed countries and increasing fastest in least developed countries (e). Child mortality has sharply decreased globally, though challenges remain for least developed countries (f). In all these graphs, countries are classified according to the UN World Economic Situation and Prospects [25]. Sources: Modified from World Bank (2018) [27], IPBES (2019) [26].

Key

- Developed economies
- Developing economies
- Least developed economies
- World

HUMANITY NOW OVERSPENDS ITS BIOLOGICAL BUDGET EVERY YEAR

Since 1970, our Ecological Footprint has exceeded the Earth's rate of regeneration. This overshoot erodes the planet's health and, with it, humanity's prospects.

Mathis Wackernagel, David Lin, Alessandro Galli and Laurel Hanscom (Global Footprint Network)

Biocapacity, the ability of our planet's ecosystems to regenerate, is the underlying currency of all living systems on Earth. Everything depends on it. Ecological Footprint accounting measures both the biocapacity available as well as the demand people put on it through all of our activities: from food and fibre production to the absorption of excess carbon emissions [23-29].

This ecological balance sheet allows us to contrast biocapacity with all the human demands that compete for biologically productive areas [26-29]. The common measurement unit is global hectares: biologically productive hectares with world average productivity [23, 30, 28, 29]. Thanks to this common measurement unit, countries, regions, cities, individuals and products can be compared across the world and over time [23, 25, 29].

Through changes in technology and land management practices, global biocapacity has increased by about 28% in the past 60 years [30, 31]; however this may be an overestimate because the UN statistics used undercount losses such as soil erosion, groundwater depletion and deforestation. Still, this increase has not kept pace with growth in aggregate consumption: humanity's Ecological Footprint, also estimated from UN statistics, has increased by about 173% over the same time period [25, 30, 29, 31] and now exceeds the planet's biocapacity by 56%.

This means that the human enterprise currently demands 1.56 times more than the amount that Earth can regenerate [31]. It is like living off 1.56 Earths. As with the 2008 economic crash, this year's lockdowns due to COVID-19 have reduced humanity's demand by nearly 10% [31]. However, since this reduction was not caused by structural change the gains are unlikely to last, and may even delay action on climate change and biodiversity loss [32, 33].

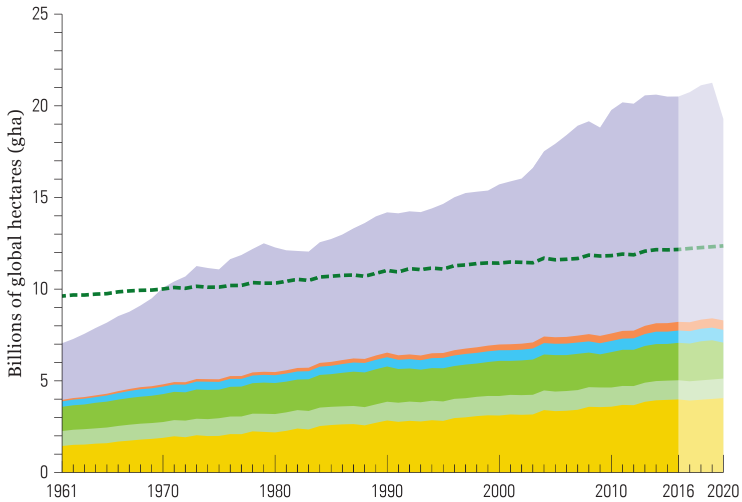
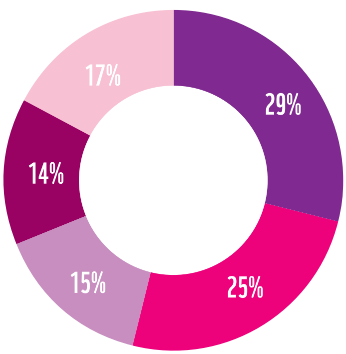


Figure 12: Humanity's Ecological Footprint against Earth's biocapacity in global hectares, 1961-2020
Global overshoot, starting in the early 1970s, has increased since. The COVID-19 related footprint contraction - in lighter colours from 2016 onwards - is an estimate[30, 31].

Key

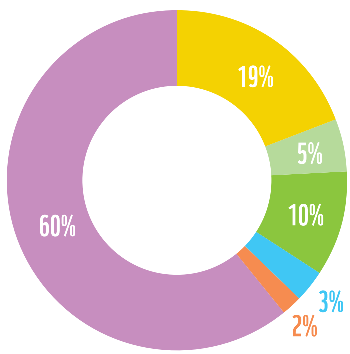
- **Carbon footprint**[34] for absorbing emissions from fossil fuel burning and cement production
- **Built-up land footprint** for accommodating roads and buildings
- **Fishing grounds footprint** for wild and farmed seafood from oceans and freshwater
- **Forest product footprint** for fuel wood, pulp and timber
- **Grazing land footprint** for meat, dairy, leather and wool
- **Cropland footprint** for food, fibre, oil and feed crops, including rubber
- World biocapacity



Humanity's Ecological Footprint by activities

Key

- Food
- Housing
- Personal transportation
- Goods
- Services



Humanity's Ecological Footprint by land use

Key

- Cropland footprint
- Grazing land footprint
- Forest product footprint
- Fishing grounds footprint
- Built-up land footprint
- Carbon footprint

Figure 13: Humanity's Ecological Footprint by land use and by activities
The Ecological Footprint measures how much demand human consumption places on the biosphere and compares it to what ecosystems can renew. In 2020, the world average Footprint amounts to 2.5 global hectares per person, compared to 1.6 global hectares of biocapacity. It can be broken down by area categories (outer circle) or, using Multi-Regional Input-Output Assessments, by activity fields (inner circle)[35, 30, 29, 36].

Consumption around the world

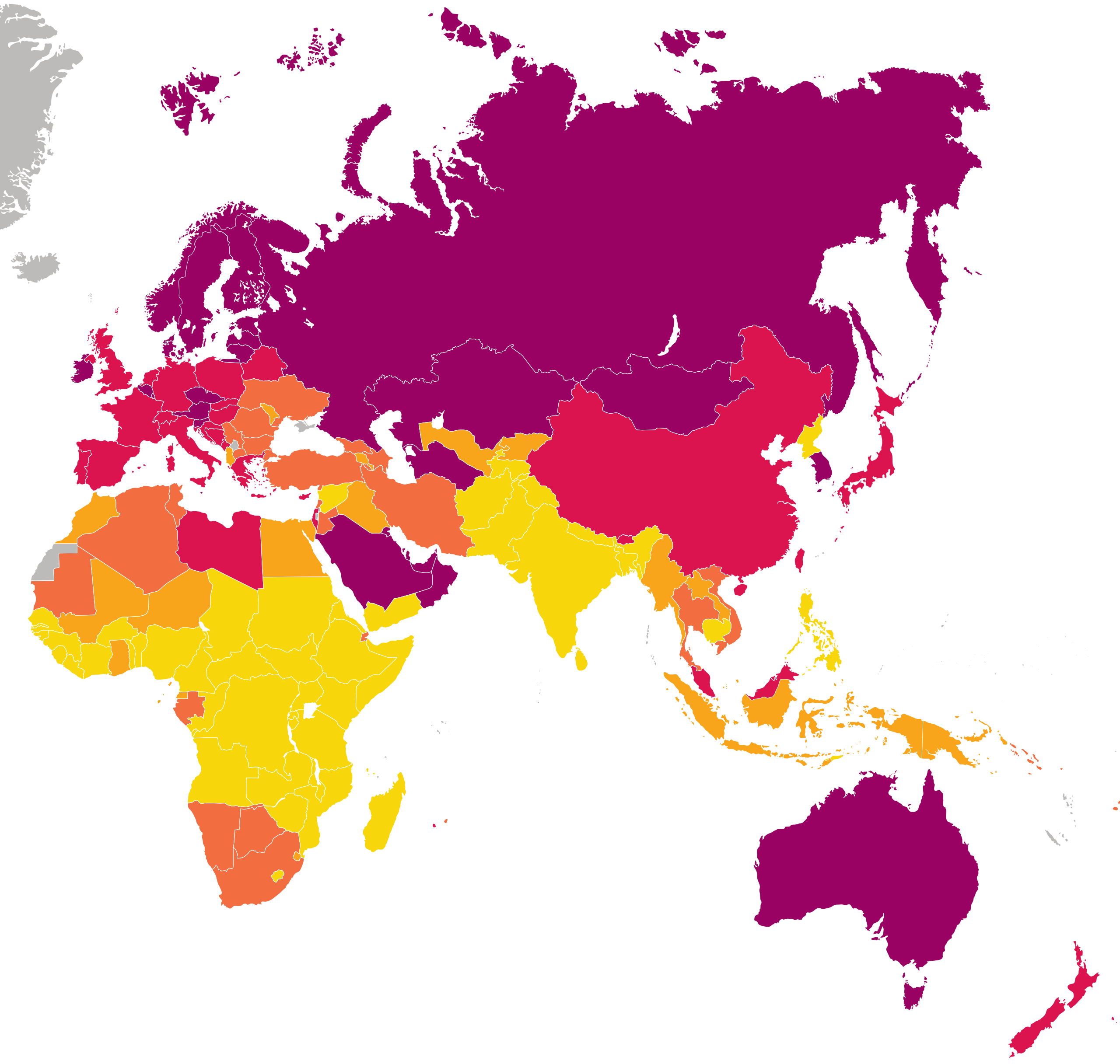
Both human demand and natural resources are unevenly distributed across the Earth. The pattern of human consumption of these resources differs from resource availability, since resources are not consumed at the point of extraction. The Ecological Footprint per person, across countries, provides insights into countries' resource performance, risks and opportunities[37, 38, 29].

Figure 14: Global map of the Ecological Footprint of consumption per person in 2016
The Ecological Footprint per person is a function of both total population and rates of consumption within a country. A country's consumption includes the Ecological Footprint it produces, plus imports from other countries, minus exports[31].

Key

- > 5 gha/person
- 3.5 - 5 gha/person
- 2 - 3.5 gha/person
- 1.6 - 2 gha/person
- < 1.6 gha/person
- Insufficient data

Varying levels of Ecological Footprint are due to different lifestyles and consumption patterns, including the quantity of food, goods and services residents consume, the natural resources they use, and the carbon dioxide emitted to provide these goods and services.



THE TRUE COST OF FOOD

We cannot feed the world without agriculture yet where and how we produce food is one of the biggest human-caused threats to biodiversity and our ecosystems. This makes the transformation of our global food system more important than ever.

Sarah Doornbos and Natasja Oerlemans (WWF)

Today, most of the world's ecosystems are influenced by humans and any landscape is likely to have a mosaic of land uses along a spectrum of intensity, from relatively undisturbed, native habitat at the one end to cities and industrial agricultural production systems, with little biodiversity, at the other. Agri-food production systems – that is, where and how we produce food – play a key role as a major land use and are also now widely acknowledged as one of the largest threats to biodiversity and ecosystems [39, 15, 40].

Obvious as it may seem, feeding a growing and increasingly affluent global population is the primary goal of our food system, and we cannot feed the world without agriculture. Yet agriculture is the primary force behind the transgression of the Planetary Boundaries for nitrogen, phosphorus, climate change, biosphere integrity, land-system change and freshwater use [41, 101, 102]. Many of these issues are interlinked, aggravating the challenge. Agriculture is a significant driver of climate change, and climate change, in turn, adds further stress to land systems, worsening existing risks – for example of land degradation and biodiversity loss [15, 40]. Mitigating the negative impacts of agriculture on nature and biodiversity is therefore more important than ever.

At the same time, the potential of agricultural systems to provide habitats, and vegetation corridors for species to move between these habitats, enhancing rather than eroding ecosystem services and landscape resilience, has started to become more recognised [42-44, 100]. Some agricultural systems and specific components within them – from riparian corridors, hedges, woodland patches and clearings in forests, to waterways, ponds or other biodiversity-friendly features of the production environment – can provide habitat for specific species [45, 44].

At a landscape scale, crop and livestock farming can add diversity to the 'mosaic' of habitat types present, and such diversified agricultural landscapes can support much more biodiversity than was initially thought [44]. Agricultural systems can also be managed in such a way that they facilitate, rather than constrain, species dispersal through corridors and along migratory routes, which is especially important considering climate change [46, 47].

Biodiversity is also of crucial importance for food production itself. It has been amply documented that biodiversity underpins key ecosystem functions that help determine food production and security [48]. A high degree of diversity among species, varieties, breeds, populations and ecosystems can help to create and maintain healthy soils, pollinate plants, purify water, provide protection against extreme weather events, or any of a range of other vital services [49, 48, 39].

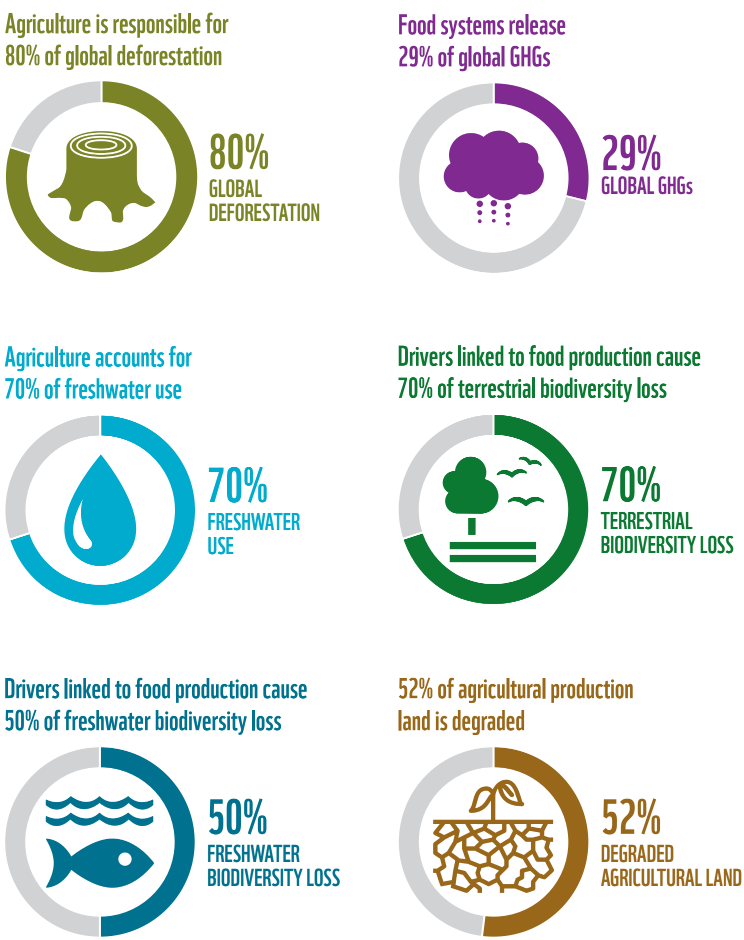


Figure 15: The environmental impacts of food production
Sources: Adapted from CBD (2014) [98], GSDR (2019) [99] and ELD Initiative (2015) [103].

WASTE NOT, WANT NOT: WHY NO FOOD SHOULD BE LEFT BEHIND

Globally, more than 820 million people face hunger or food insecurity, while staggering quantities of food loss and waste result in US$1 trillion in economic costs, around US$700 billion in environmental costs and around US$900 billion in social costs [104, 105].

Pete Pearson and Amanda Stone (WWF)

Reducing food loss and waste represents a critical opportunity to relieve environmental pressure on our planet. An estimated one-third of the food produced for human consumption is lost or wasted globally – this amounts to about 1.3 billion tonnes every year [52]. This means that around one-quarter of the calories the world produces are never eaten: they're spoiled or spilled in supply chains, or are wasted by retailers, restaurants and consumers [53]. In a multiplier effect, when food loss and waste occurs along the supply chain, all the land, water, energy, seeds, fertiliser, labour, capital and other resources that went into its production also go to waste.

Food loss and waste also contributes to climate change. It is responsible for at least 6% of total global greenhouse gas emissions [54], three times more than the global emissions from aviation [55, 56]. Almost a quarter - 24% - of all emissions from the food sector comes from food that is lost in supply chains or wasted by consumers [57, 54].

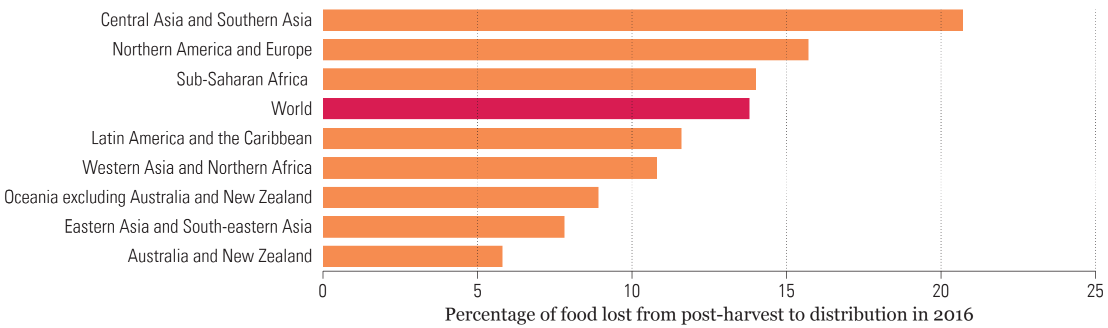
***Figure 16: Food Loss Index from post-harvest to distribution by region (2016)* [60]**
Agenda 2030 Sustainable Development Goal 12 aims to "ensure sustainable consumption and production patterns". It includes target 12.3: "by 2030, halve the per capita global food waste at the retail and consumer level, and reduce food losses along production and supply chains including post-harvest losses." Progress towards this goal will be measured by two separate indices – the Food Loss Index, led by FAO; and the Food Waste Index, led by UN Environment. This figure shows the Food Loss Index which focuses on food losses that occur from production up to (but not including) the retail level in each region. The index is calculated by measuring the changes in percentage losses for a basket of 10 main commodities in each country, compared to a base period [60, 61].

Almost two-thirds of this (15% of food emissions) comes from losses across the supply chain, resulting from poor storage and handling techniques, a lack of refrigeration, or spoilage in transport and processing. The other 9% comes from food thrown away by retailers and consumers [57].

The COVID-19 crisis has exposed many weaknesses in our global food system [58, 59]. One is the complexity of supply chains, including the general lack of data transparency and real-time market information that means food systems are unable to quickly adapt and shift food distribution. Within weeks of the COVID-19 crisis beginning, traditional food outlets and markets were shuttered, leaving distribution channels ill-prepared to fully utilise food stores and establish new channels for farmers, further exacerbating food waste.

In general, waste happens for a variety of reasons at different points along the supply chain. In developing or emerging markets, food is most often lost post-harvest due to a lack of infrastructure, such as storage or cold chain logistics, or ready access to markets. In developed economies like the US or EU, food is more often wasted further along the supply chain, in consumer-facing industries such as hospitality, food service, grocery retail, restaurants, and in homes. However, there is unmeasured consumer waste in developing countries, and there is unmeasured in-field and post-harvest loss in developed countries. Because loss and waste quantification is still largely only estimated, measurement must be prioritised across global value chains if we are to improve (Figure 16).

Like climate change, food loss and waste can be characterised as a multiplier of environmental, social and economic impacts. By setting national food-waste targets and policies and introducing supply chain and operational practices to encourage widespread change, we can ease pressure on land and natural habitats, ensuring that every calorie counts.



BIODIVERSITY'S CATASTROPHIC COLLAPSE ON LAND

Land-use change is currently the most important direct driver of biodiversity loss on land, with climate change, overexploitation, pollution and invasive species not far behind.

Adrienne Etard,
Jessica J. Williams &
Tim Newbold
(University College London)

Human activities are altering natural habitats and reshaping life on Earth's surface. Terrestrial biodiversity is mainly impacted by five direct drivers: land-use change, climate change, overexploitation, pollution and the introduction of invasive species [62].

These drivers, alone and in combination, have had dramatic impacts on terrestrial biota. The latest Living Planet Index shows that vertebrate populations have declined by 68%, on average, since 1970 (Chapter 1). Impacts vary in different parts of the world, with the hyper-diverse tropical areas – that are critical to global biodiversity conservation – being particularly sensitive to anthropogenic threats [63].

Despite the increasing impact of a changing climate, three-quarters of all the plant and vertebrate species that have gone extinct since the year 1500 were harmed by overexploitation and/or agricultural activity (with invasive species also a predominant threat) [64, 62]. Indeed, about one-third of the total land surface is used for agricultural purposes. Energy, transportation and housing also contribute to land conversion; built-up areas cover about 1% of the total land surface. The land surface covered by agricultural and built-up areas nearly doubled between 1900 and 2016 [65].

Land-use change has profound impacts on local biodiversity. When humans modify habitats, many species can't persist in the new conditions. Fragmented habitats, comprising remnant habitat patches surrounded by human-disturbed land, may not be large enough to sustain viable populations. Remaining species are those able to cope in altered conditions; as such, global land-use change favours ecological generalists at the expense of rare and specialist species [66-68].

Species richness – that is, the number of species occurring in an ecological community, landscape or region – is estimated to decrease by a global average of 13.6% in human-modified habitats compared to intact habitats [69], although the effects are geographically uneven. Mediterranean and tropical biodiversity has been found to be the most sensitive to land-use change [70]. Land-use change also has indirect negative effects on biodiversity, for example through roadkills and human-wildlife conflicts.

Looking ahead to 2050, global land-use model projections show that, without changes in diet, food production and food loss and waste, agricultural areas will have to expand in order to meet increased food demand. Future projections indicate that, by 2050, cropland areas may have to be 10 to 25% larger than in 2005 [71]. Associated biodiversity losses may have negative effects on the delivery of ecosystem services, such as pollination and pest control, a situation compounded by the changing climate [72]. This makes reconciling global food production with biodiversity conservation one of the major challenges of the 21st century.

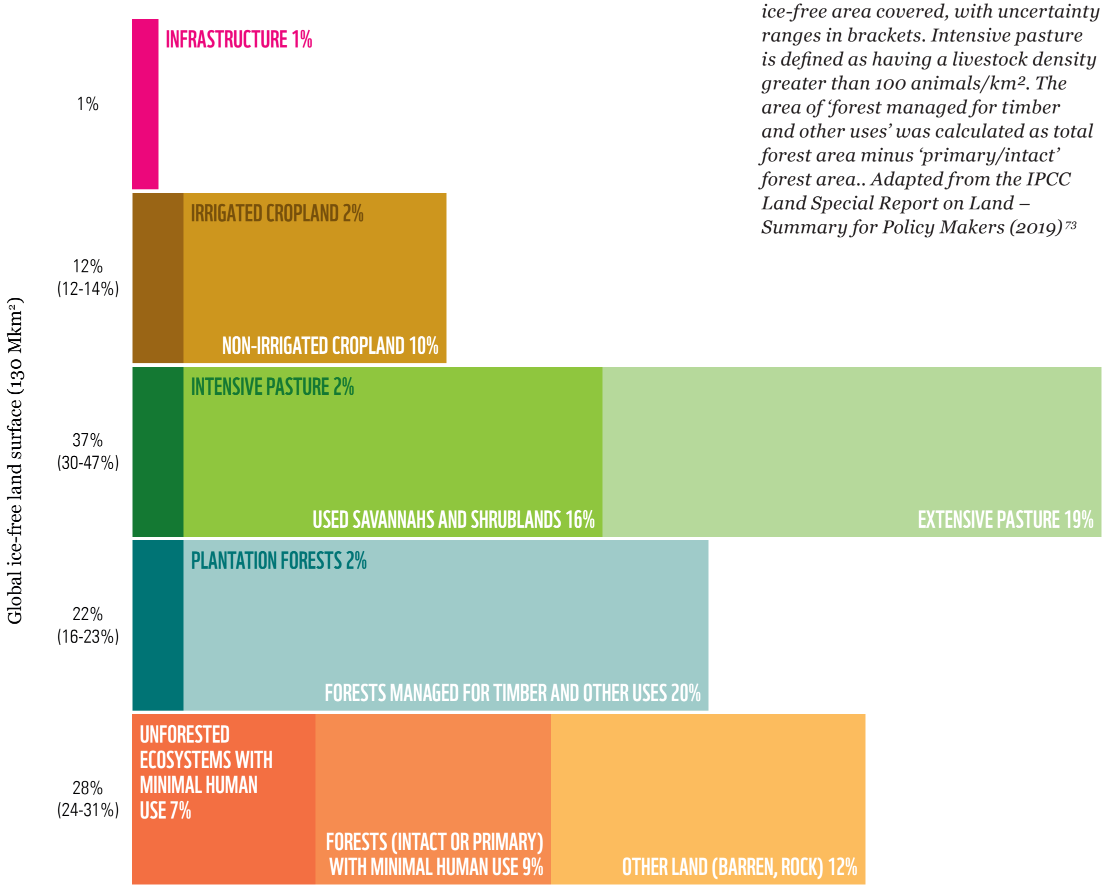


Figure 17: Global land use in circa 2015
The bar chart depicts shares of different uses of the global ice-free land area for approximately the year 2015. Bars are ordered along a gradient of decreasing land-use intensity from left to right. Each bar represents a broad land cover category; the numbers on top are the total percentage of the ice-free area covered, with uncertainty ranges in brackets. Intensive pasture is defined as having a livestock density greater than 100 animals/km². The area of 'forest managed for timber and other uses' was calculated as total forest area minus 'primary/intact' forest area.. Adapted from the IPCC Land Special Report on Land – Summary for Policy Makers (2019) [73]

MAPPING THE LAST WILDERNESS AREAS ON EARTH

Advances in satellite technology allow us to visualise how the Earth is changing in real time. Human footprint mapping then shows where we are and aren't impacting land on Earth. The latest map reveals that just a handful of countries – Russia, Canada, Brazil and Australia – contain most of the places without a human footprint, the last remaining terrestrial wilderness areas on our planet[74].

James Watson (University of Queensland and WCS), Brooke Williams (University of Queensland) and Oscar Venter (University of Northern British Columbia)

In the last two decades increasingly powerful computing, which aims to track human pressure across Earth using a network of satellites combined with bottom-up census and crowd-sourced data[75], allows us to quantify and locate even sparse human settlements, low-intensity agricultural farming and road construction, and other forms of human pressure[76, 74].

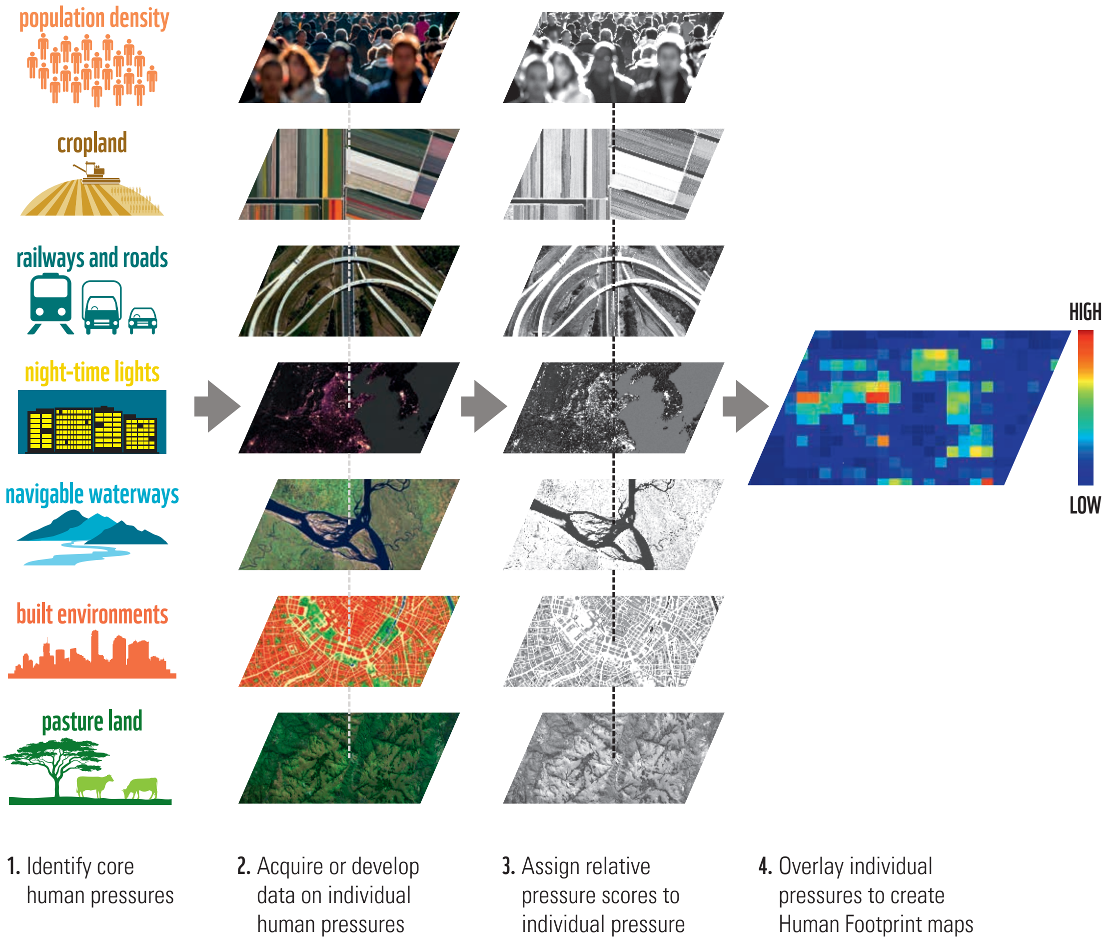
The new field of 'cumulative human pressure mapping' has helped to integrate this data to provide a new view of the terrestrial biosphere and humanity's role in shaping its patterns and processes (Figure 18). The latest human footprint map clearly shows the spatial extent of humanity's environmental footprint, with 58% of the land's surface under intense human pressure (Figure 19). Since 2000, 1.9 million km^2, an area the size of Mexico of ecologically intact land – that is, ecosystems that remain free from significant direct human pressure – has been lost, with most losses occurring within the world's tropical and subtropical grasslands, savannah and shrubland ecosystems, and the rainforests of Southeast Asia. It also illustrates that only 25% of terrestrial Earth can be considered 'wilderness' (i.e. areas having no human footprint score), and that most of this is contained in just a small number of nations – Russia, Canada, Brazil and Australia.

Polar regions represent some of Earth's last wilderness areas: Ilulissat, Greenland.


© Elisabeth Kruger / WWF-US

This most recent assessment shows that Earth's remaining ecologically intact places are in the throes of the same extinction crisis as is being faced by species. These places are disappearing in front of our eyes. Like species extinction, the erosion of these intact ecosystems is essentially irreversible and has profound impacts on species', and our own, ability to adapt to a rapidly changing climate[77].

Figure 18:
The broad methodological framework used to create a map of cumulative human pressure – adapted from Watson and Venter (2019)[75]

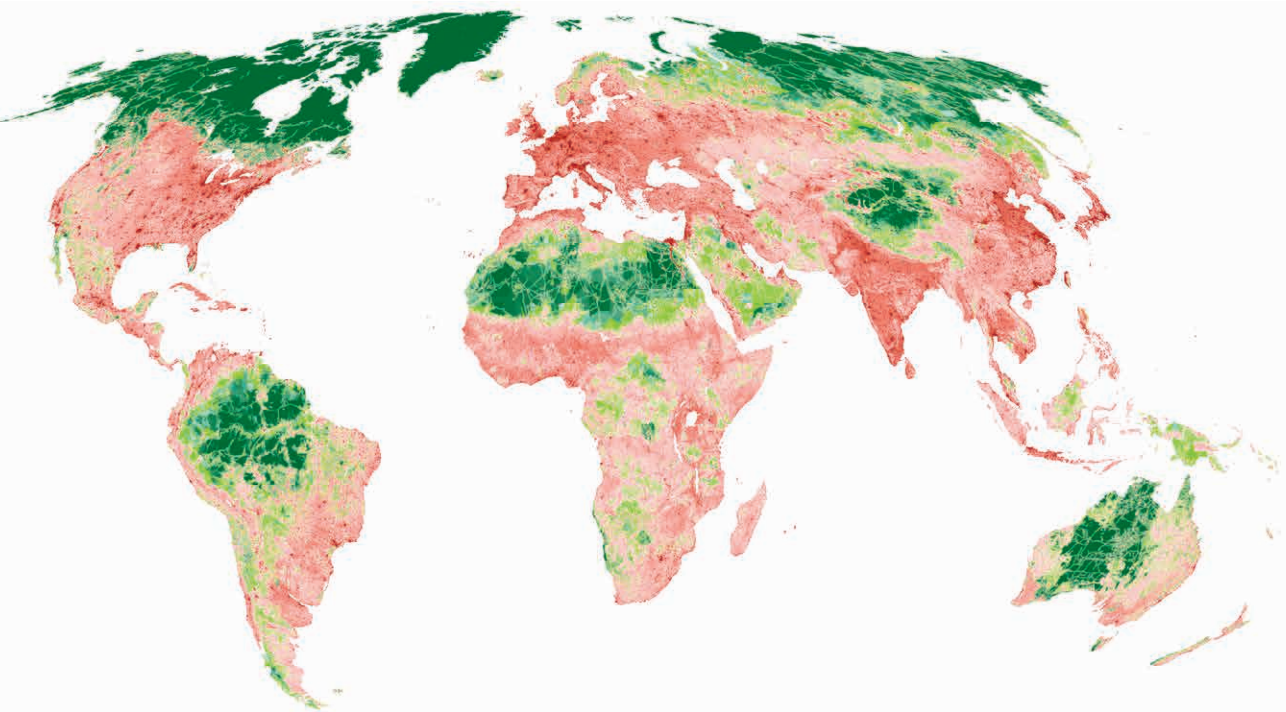


Once it has been eroded, an intact ecosystem and its many values can never be fully restored[78]. Our enhanced ability to use technology to map and monitor the land needs to go hand in hand with commitments to prevent Earth's intact ecosystems from disappearing completely, allowing them to fulfil their critical role in abating both the biodiversity and climate crises.

Key

Damaged	Intact	Wilderness
High: 50	High: 1	High: 0
Low: 4	Low: 4	Low: 1

Figure 19:
The proportion of each terrestrial biome (excluding Antarctica) considered wilderness (dark green, human footprint value of <1), intact (light green, human footprint value of <4), or highly modified by humanity (red, human footprint value of > or equal to 4)[74].



OUR OCEAN IS IN 'HOT WATER'

Overfishing, pollution and coastal development, among other pressures, have impacted the entire ocean, from shallow waters to the deep sea, and climate change will continue to cause a growing spectrum of effects across marine ecosystems.

Derek P. Tittensor
(Dalhousie University)

Nowhere in the ocean is entirely unaffected by humans[79]: only 13% of its area is considered to be wilderness[80], waste and marine litter are found even in deep ocean trenches[81], and human pressures are increasing over time[82]. The negative effects of these impacts threaten the goods and services – such as food provision, climate regulation, carbon storage and coastal protection – that marine ecosystems provide to human society, and upon which we all depend.

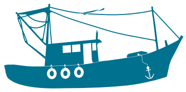
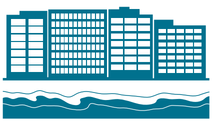
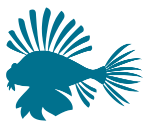
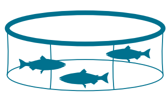
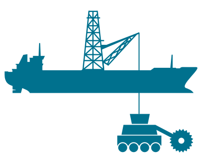
The UN FAO estimates that fish consumption (including freshwater) provides more than 3.3 billion people with at least 20% of their animal protein intake, and that the fisheries and aquaculture sectors provide direct employment for 59.5 million people[83]. Nearly 200 million people depend on coral reefs to help protect them from storm surges and waves[84].

Fishing for human consumption is considered to have the greatest impact on ocean biodiversity[2], causing one in three fish stocks assessed to be considered overfished[85] and leading to the unintended bycatch of species such as sharks, seabirds and turtles[86].

In addition to fishing, numerous other impacts – such as pollution, including plastic pollution, and coastal development – affect our oceans through a variety of mechanisms (Figure 20). Climate change will increasingly interact with these stressors. It has already altered marine ecosystems[87]), and climate impacts will only continue to grow in future. These will include causing species to shift their ranges as the ocean warms[88], coral bleaching[89] and the additional challenges posed by ocean acidification for these and other calcifying organisms, an increase in extreme weather events, changes in interactions between species, and reduced productivity and animal biomass[90].

As climate change continues, it will present serious challenges to management and conservation approaches [91]. For example, it may alter where large ocean fauna (like whales) feed, potentially bringing them into conflict with hazards like shipping [92]; cause range shifts that can move fish stocks across national boundaries and outpace regulations and governance [93]; affect nutrient cycles and productivity [94]; increase the risk of species invasions [95]; and change the potential for marine aquaculture production [96].

Dead Southern bluefin tuna (*Thunnus maccoyii*) caught in a tuna pen, Port Lincoln, South Australia.

DRIVER OF CHANGE		POTENTIAL NEGATIVE IMPACTS
Fishing		Overexploitation, bycatch of non-target species, seafloor habitat destruction from seafloor trawling, illegal, unregulated, and unreported (IUU) fishing, gathering of organisms for the aquarium trade.
Climate change		Warming waters, ocean acidification, increased oxygen minimum zones, more frequent extreme events, change in ocean currents.
Land-based pollution		Nutrient run-off, contaminants such as heavy metals, micro- and macro-plastics.
Ocean-based pollution		Waste disposal, fuel leaks and dumping from ships, oil spills from offshore platforms, noise pollution.
Coastal development		Destruction of habitats, increased pressure on local shorelines, increased pollution and waste.
Invasive alien species		Invasive species accidentally (e.g. through ballast water) or deliberately introduced; more climate-driven invasions likely.
Offshore infrastructure		Physical disturbance of the seafloor, creation of habitat structure.
Shipping		Vessel strikes, pollution from dumping.
Mariculture (aquaculture of marine organisms)		Physical presence of aquaculture facilities, pollution.
Deep-sea mining		Seafloor destruction, settlement plumes on seabed, potential for leakages and chemical spills, noise pollution.

EXAMPLES OF ECOLOGICAL CONSEQUENCES

Reduced population sizes, ecosystem restructuring and trophic cascades, reductions in body size, local and commercial extinction of species, 'ghost-fishing' due to lost or dumped fishing gear.

Reef die-off through bleaching, species moving away from warming waters, changes in ecological interactions and metabolism, changes in interactions with human activities (e.g. fishing, vessel strikes) as organisms alter their location and space use, changes in ocean circulation patterns and productivity, changes in disease incidence and the timing of biological processes.

Algal blooms and fish kills, accumulation of toxins up the food web, ingestion of and entanglement in plastic and other debris.

Toxic impacts on marine organismal physiology, noise pollution impacts on marine animal behaviour.

Reduction in area of habitats such as mangroves and seagrasses, limits the ability of coastal habitats and organisms to shift, and migrate, to adapt to climate change.

Invasive species can outcompete native species, disrupt ecosystems and cause local or global extinctions.

Local seafloor habitat destruction, provision of structures for organisms to colonise and aggregate around.

Impacts on population sizes of endangered marine mammals hit by vessels, physiological and physical impacts of pollution.

Potential for nutrient build-up and algal blooms, disease, antibiotic use, escape of captive organisms and impacts on local ecosystem, indirect impact of capture fisheries to source fishmeal as foodstuff.

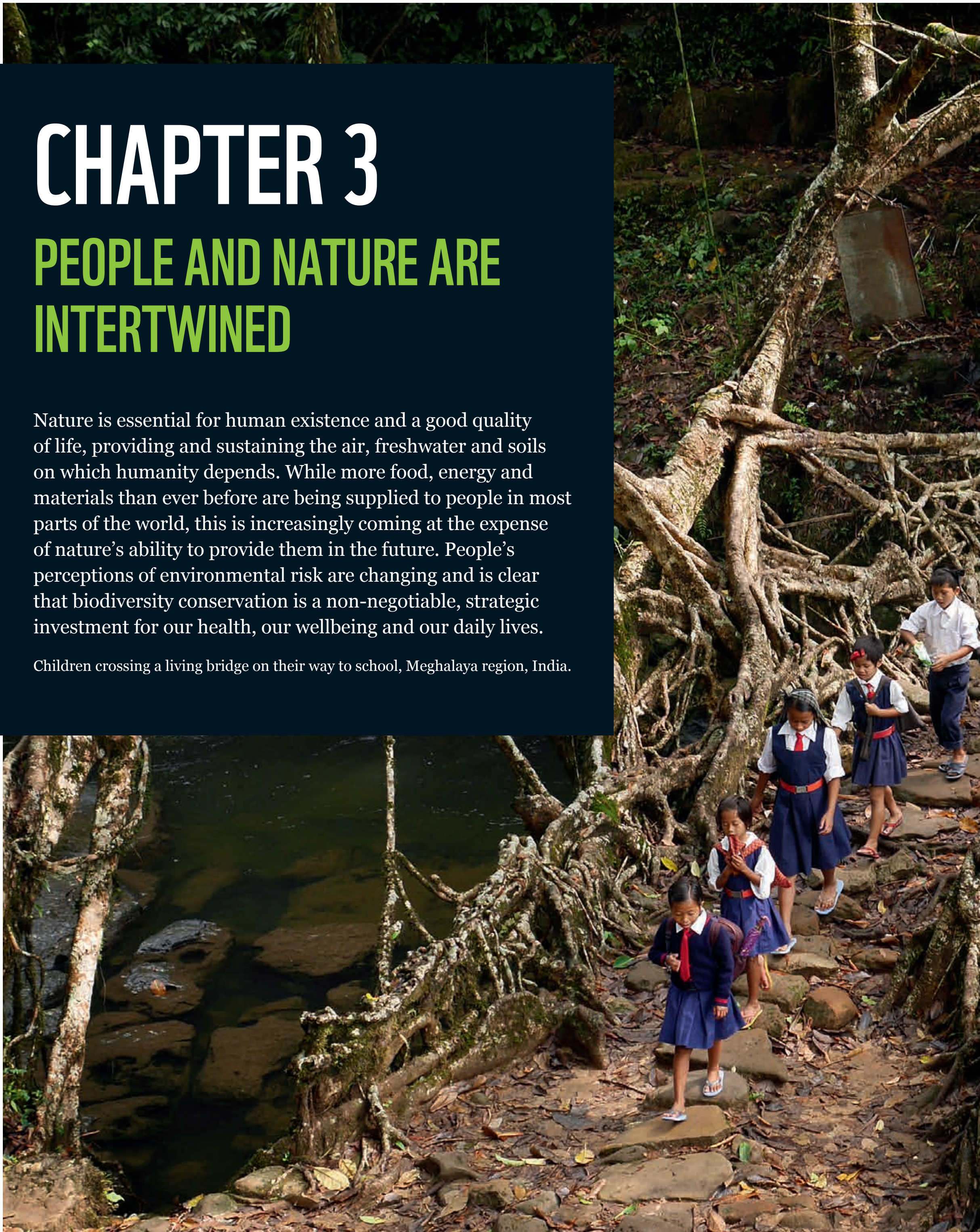
Destruction of physical habitat (e.g. cold-water corals) and benthic layer, potential smothering of organisms by settlement plumes.

Figure 20:
Anthropogenic drivers of change in marine ecosystems, types of negative impact that can arise from them, and examples of potential ecological consequences. It is important to recognise that negative impacts can be mitigated and must be weighed against societal benefits in some cases. For deep-sea mining, impacts are projected since it is not yet applied at scale. Note that impacts for individual drivers can vary from very local to global scales. Sourced from IPBES (2019)[2] and references therein.

CHAPTER 3

PEOPLE AND NATURE ARE INTERTWINED

Nature is essential for human existence and a good quality of life, providing and sustaining the air, freshwater and soils on which humanity depends. While more food, energy and materials than ever before are being supplied to people in most parts of the world, this is increasingly coming at the expense of nature's ability to provide them in the future. People's perceptions of environmental risk are changing and is clear that biodiversity conservation is a non-negotiable, strategic investment for our health, our wellbeing and our daily lives.



Children crossing a living bridge on their way to school, Meghalaya region, India.


© Amos Chapple

GLOBAL CHANGE IS ALREADY IMPACTING OUR HEALTH, WEALTH AND SECURITY

Recently, a series of catastrophic events have shaken the world's environmental conscience, showing that biodiversity conservation is more than an ethical commitment for humanity: it is a non-negotiable and strategic investment to preserve our health, wealth and security.

Moreno Di Marco
(Sapienza University of Rome)

The human enterprise relies fundamentally on goods and services that are contributed and regulated by biodiversity, including food, clean water, climate mitigation and cultural connections [1]. Nevertheless, our impact on biodiversity has been pervasive since prehistoric times, and environmental degradation has rapidly accelerated in recent decades [2].

In 2019, Africa had its largest outbreak of desert locusts in decades. It originated in the southern Arabian Peninsula, where climate change caused two cyclones with unusually heavy rainfall in 2018 [3]. These conditions created perfect breeding grounds for the locusts, which migrated to East Africa and South Asia causing widespread crop devastation. Also in 2019, an exceptionally hot and long heatwave led to extreme droughts in India and Pakistan, forcing tens of thousands to abandon their homes and causing an as-yet-unknown death toll [4].

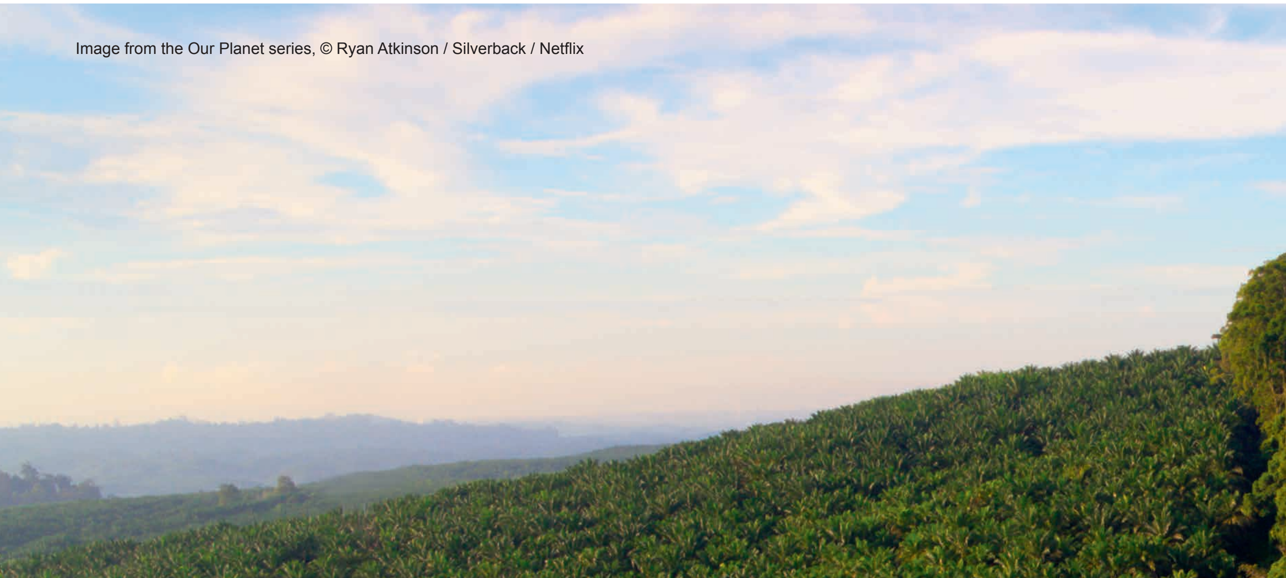


Image from the Our Planet series, © Ryan Atkinson / Silverback / Netflix

Just a few months later, Australia was impacted by one of the most intense bushfire seasons ever recorded, with over 10 million hectares, an area the size of Iceland, burnt and more than 10 million people exposed to thick smoke [5]. This crisis was exacerbated by unusually low rainfall and record high temperatures; as well as excessive logging that has created drier and more flammable understorey vegetation [6].

More globally, 2020 will be remembered in the history books for something else, as the outbreak of a previously unknown coronavirus generated a pandemic that held the world hostage. In just its first six months, hundreds of thousands of people died, millions were infected, and society was confronted with a long-lasting economic impact in the order of trillions of US dollars.

Although the origins of COVID-19 remain uncertain, 60% of emerging infectious diseases come from animals, and nearly three-quarters of these from wild animals [8, 23]. The emergence of these diseases correlates with high human population density and high wildlife diversity, and is driven by anthropogenic changes such as deforestation and the expansion of agricultural land, the intensification of livestock production, and the increased harvesting of wildlife [8, 9]. This was the case for Nipah in Malaysia in 1998, SARS in China in 2003, Ebola in West Africa in 2013-16, and many others [10]. Mitigating the underlying drivers of disease emergence risk will therefore require consideration of multiple dimensions of socio-economic development targeting a diverse range of societal issues [11].

What is now clear is that the social and economic consequences of environmental degradation are catastrophic, and safeguarding human health, wealth and security is intrinsically linked to safeguarding environmental health.

Pristine Asian rainforest alongside an oil palm plantation.

STRETCHING OUR SAFETY NET ALMOST TO BREAKING POINT

Berta Martin-Lopez (Leuphana University, Lüneburg) and Sandra Díaz (CONICET and Córdoba National University, Argentina and IPBES Global Assessment Co-Chair)

Nature is essential for human existence and a good quality of life, providing and sustaining the air, freshwater and soils on which humanity depends. It also regulates the climate, provides pollination and pest control, and reduces the impact of natural hazards. While more food, energy and materials than ever before are being supplied to people in most parts of the world, this is increasingly coming at the expense of nature's ability to provide them in the future, with the overexploitation of plants and animals frequently undermining nature's many other contributions [13, 99]. Within the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) conceptual framework, these contributions are referred to as 'Nature's Contributions to People' [13, 99]. This table was included in the IPBES Summary for Policymakers and it presents the global trends for some of these contributions from 1970 to the present day: we explore these concepts in more detail in the final section of this chapter.

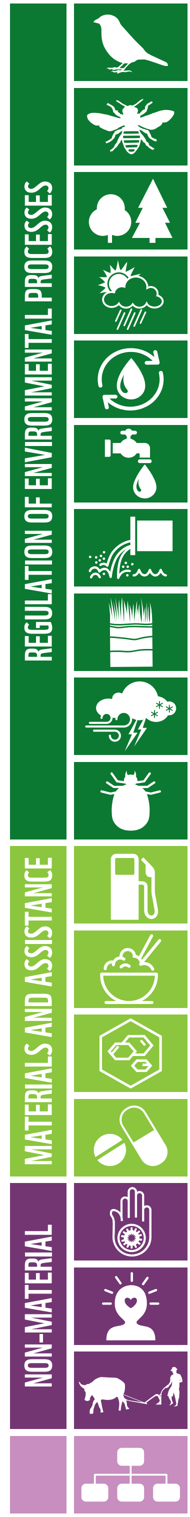
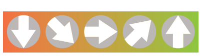


Figure 21: *Global trends from 1970 to the present of the 18 categories of Nature's Contributions to People: 14 of the 18 categories analysed have declined since 1970* [13, 99]*. (Figure adapted from Díaz, S. et al. (2019)* [99]*, IPBES (2019)* [13]*)*

Key

Global trends

Decrease  Increase

Levels of certainty

- Well established
- Established but incomplete
- Unresolved

NATURE'S CONTRIBUTION TO PEOPLE	50-YEAR GLOBAL TREND	SELECTED INDICATOR
HABITAT CREATION AND MAINTENANCE	↓	Extent of suitable habitat
	↓	Biodiversity intactness
POLLINATION AND DISPERSAL OF SEEDS AND OTHER PROPAGULES	↓	Pollinator diversity
	↓	Extent of natural habitat in agricultural areas
REGULATION OF AIR QUALITY	↘	Retention and prevented emissions of air pollutants by ecosystems
REGULATION OF CLIMATE	↘	Prevented emissions and uptake of greenhouse gases by ecosystems
REGULATION OF OCEAN ACIDIFICATION	→	Capacity to sequester carbon by marine and terrestrial environments
REGULATION OF FRESHWATER QUANTITY, LOCATION AND TIMING	↘	Ecosystem impact on air-surface-ground water partitioning
REGULATION OF FRESHWATER AND COASTAL WATER QUALITY	↘	Extent of ecosystems that filter or add constituent components to water
FORMATION, PROTECTION AND DECONTAMINATION OF SOILS AND SEDIMENTS	↘	Soil organic carbon
REGULATION OF HAZARDS AND EXTREME EVENTS	↘	Ability of ecosystems to absorb and buffer hazards
REGULATION OF DETRIMENTAL ORGANISMS AND BIOLOGICAL PROCESSES	↓	Extent of natural habitat in agricultural areas
	↘	Diversity of competent hosts of vector-borne diseases
ENERGY	↗	Extent of agricultural land – potential land for bioenergy production
	↘	Extent of forested land
FOOD AND FEED	↗	Extent of agricultural land – potential land for food and feed production
	↓	Abundance of marine fish stocks
MATERIALS AND ASSISTANCE	↗	Extent of agricultural land – potential land for material production
	↘	Extent of forested land
MEDICINAL, BIOCHEMICAL AND GENETIC RESOURCES	↘	Fraction of species locally known and used medicinally
	↓	Phylogenetic diversity
LEARNING AND INSPIRATION	↓	Number of people in close proximity to nature
	↓	Diversity of life from which to learn
PHYSICAL AND PSYCHOLOGICAL EXPERIENCES	↘	Area of natural and traditional landscapes and seascapes
SUPPORTING IDENTITIES	↘	Stability of land use and land cover
MAINTENANCE OF OPTIONS	↓	Species' survival probability
	↓	Phylogenetic diversity

Intrinsically interlinked: healthy planet, healthy people

The past century has seen extraordinary gains in human health and well-being. This is rightly celebrated, but it has been partially achieved through the exploitation and alteration of the world's natural systems, which threatens to undo these successes.

Thomas Pienkowski and Sarah Whitmee (University of Oxford)

There have been tremendous gains in human health in the past 50 years. For instance, child mortality among under-5s has halved since 1990 [15], the share of the world's population living on less than $1.90 a day fell by two-thirds over the same period [16], and life expectancy at birth is around 15 years higher today than it was 50 years ago [17].

These trends are positive, but they have in part been achieved through the exploitation and alteration of the world's natural systems. Current levels of environmental change undermine the capacity of these natural systems to continue to benefit humanity, and also create new threats to health [18]. Nature's contributions to health are diverse, from traditional medicines and pharmaceuticals derived from plants to water filtration by wetlands (see our accompanying "deep dive" into freshwater) [19, 20]. As such, the loss of nature threatens to slow and, in some cases, reverse these positive health and well-being trends.

In recognition of this, in 2015 the Rockefeller Foundation–Lancet Commission introduced the concept of 'Planetary Health', defining it as "the health of human civilization and the state of the natural systems on which it depends", recognising that nature and human well-being are deeply linked [21].

An example of this is the emergence of zoonotic diseases driven, in part, by environmental degradation [22]. The global coronavirus pandemic has caused incredible human suffering and social and economic upheaval. Although the origins of COVID-19 remain uncertain, 60% of emerging infectious diseases come from animals, and nearly three-quarters of these from wild animals [8, 23].

A mothers' meeting is led by a community health volunteer in Bardia, Nepal.


© James Morgan / WWF-US

These diseases can spill over into humans in a variety of ways, sometimes through direct contact with wild animals, but often through intermediary hosts such as domestic animals [24].

The rate of infectious disease emergence has drastically increased over the last 80 years [8], with one study suggesting that diseases originating in animals cause 2.5 billion cases of illness, and nearly 3 million deaths, each year [25]. Given that many of these diseases come from wildlife, preventing the next pandemic might depend on understanding how humanity's relationship with nature contributes to the emergence of these diseases.

We do know that nearly half of all new emerging infectious diseases from animals are linked to land-use change, agricultural intensification and the food industry [26]. Agricultural and industrial expansion into natural areas often disrupts ecological systems that regulate pathogenic risk, particularly in the biodiverse tropics [27, 28]. This can lead to close contact between wildlife, livestock and people, increasing the chance that a disease will spill over into humans [29].

There are also concerning examples of diseases emerging through the use and trade of wildlife, such as HIV/AIDS linked to chimpanzee consumption, SARS connected to markets containing wildlife, and Ebola linked to the hunting of great apes [30-32]. These examples illustrate the complex links and trade-offs between nature, health and other aspects of human well-being. For instance, terrestrial wild meats make vital contributions to the health and livelihoods of millions of people globally [33, 34].

Diseases like COVID-19, originating from animals, are one of the many connections between the health of people and the planet. Other kinds of environmental change, such as climate change and biodiversity loss, also pose serious threats to human health in the near future. However, there are solutions within reach which can benefit both people and the planet. How humanity chooses to recover from the COVID-19 pandemic, and how it addresses the looming threats from global environmental change, will influence the health of generations to come.

Rosy periwinkle (*Catharanthus roseus*) is valued for medicinal uses especially in the treatment of juvenile leukemia and other cancers, Madagascar.


© Olivier Langrand / WWF

Nature underpins human health and well-being

The links between **BIODIVERSITY** and **HEALTH** are diverse, from traditional medicines and pharmaceuticals derived from plants to water filtration by wetlands[13, 19, 20].

HEALTH is *"A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition."* The World Health Organization, WHO (1948)[107].

BIODIVERSITY is *"The fruit of billions of years of evolution, shaped by natural processes and, increasingly, by the influence of humans. It forms the web of life of which we are an integral part and upon which we so fully depend. It also encompasses the variety of ecosystems such as those that occur in deserts, forests, wetlands, mountains, lakes, rivers, and agricultural landscapes. In each ecosystem, living creatures, including humans, form a community, interacting with one another and with the air, water, and soil around them."* The Convention on Biological Diversity, CBD (2020)[108].

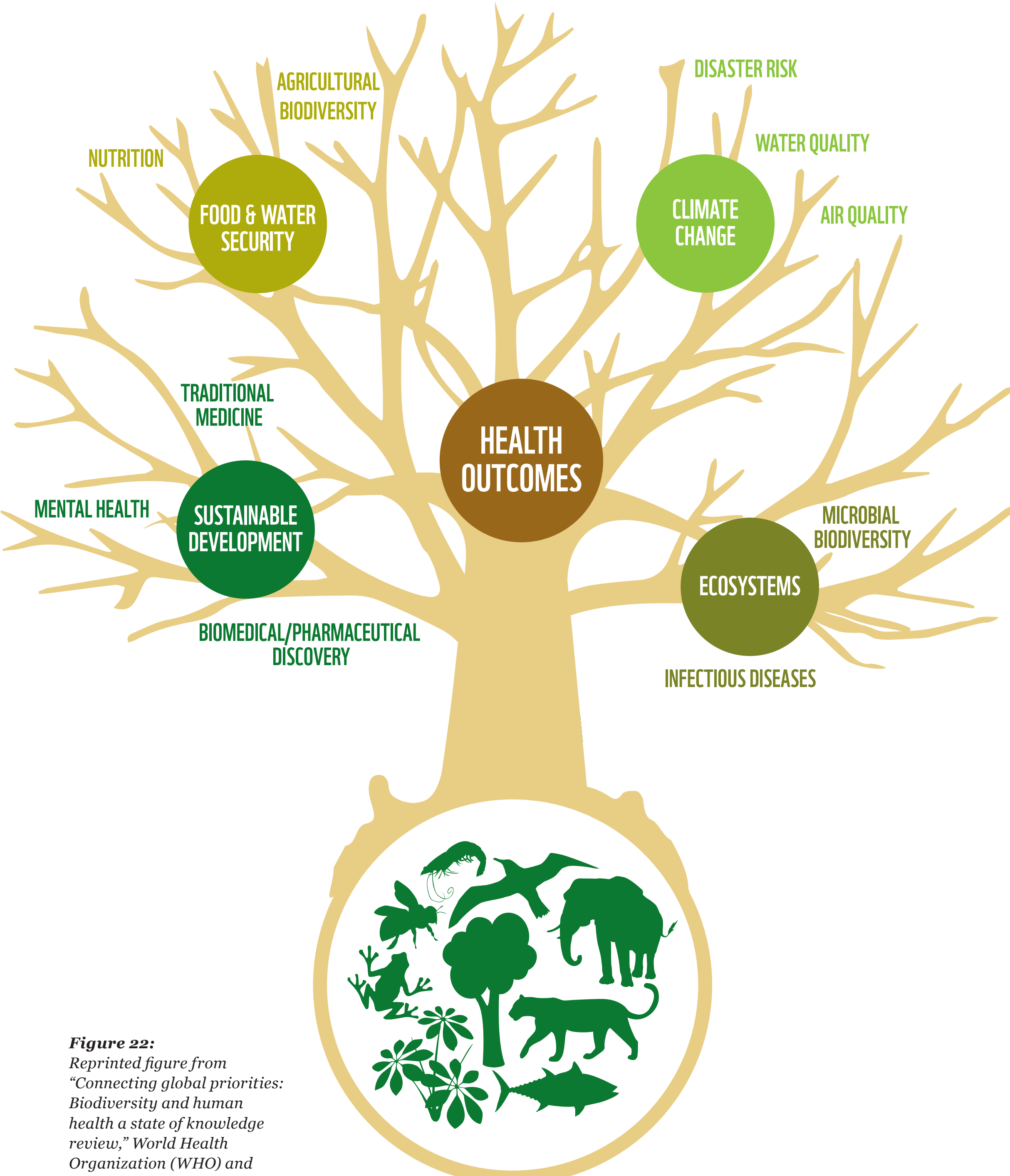


Figure 22:
Reprinted figure from "Connecting global priorities: Biodiversity and human health a state of knowledge review," World Health Organization (WHO) and Secretariat of the Convention on Biological Diversity (CBD),Copyright (2015)[14].

It's better being green: health and well-being in cities

A growing body of evidence confirms that it is good for everyone's health and well-being to be able to engage with green and natural spaces near to home. Good access to such natural places can help reduce health inequalities.

Catharine Ward Thompson (OPENspace research centre, University of Edinburgh)

Links between access to green space and the health and well-being of urban residents have been recognised throughout history and were one of the driving forces behind the urban parks movement of the 19th century in Europe and North America [35]. However, until recently, many of the mechanisms behind such links were poorly understood or lacked rigorous scientific evidence. Recently, new research techniques have provided opportunities to study what lies behind associations between green space and health with increasing sophistication. This is demonstrating associations between access to green or natural environments and a range of health outcomes, including lower probabilities of cardiovascular disease [36], obesity [37], diabetes [38], asthma hospitalisation [39], mental distress [40] and, ultimately, mortality [41] among adults; and lower risks of obesity [42] and myopia [43] in children. More green space in the neighbourhood is also associated with better self-reported health [44, 45, 43], subjective well-being [46] in adults, improved birth outcomes [47-49], and cognitive development in children [45]. Recent epidemiological studies have revealed that access to urban green space may have lifelong effects on health, with childhood access to green space, for example, predicting cognitive health and mental well-being in people aged 70 years or more [50-52].

Current evidence linking green space and health is predominantly from the Global North. Urban green space might also bring ecosystem disservices to some cities globally, including fostering the spread of infectious diseases and problematic interactions with wildlife, yet there is nonetheless an argument for urban green space as a fundamental element of sustainable, healthy and liveable cities, including in the Global South [53]. Investing in environmental interventions, such as extending the amount of urban green space and improving its quality and connectedness, has the potential to offer multiple ecosystem services while supporting better and more equitable human health [54].

Norway maple (*Acer platanoides*)
in the Royal National City Park, Sweden.

© WWF-Sweden / Germund Sellgren

Sowing the seeds to connect with nature

New research is beginning to show how children's experiences of nature have long-term effects in the ways they value, and take action for, nature as adults.

Riyan van den Born
(Radboud University Nijmegen)

What motivates people to act for nature?

We know that people act for nature because it has *instrumental value*, that is, it improves our income or health; for *moral value*, for instance its intrinsic right to exist; and because of its *relational value*, for example connectedness and living a meaningful life [55, 56]. In seven European countries we studied people who were committed activists for nature and found that the desire to live a meaningful life was the primary energising force of committed action [57]. Other studies have demonstrated that living a meaningful life "is a fundamental component of human well-being" [58], and therefore a basic human motivation.

Recognising the importance of feeling connected to nature raises the question of how this connection is developed and can be strengthened. Studies show that in order to establish a connection to nature, it is first important to be in contact with nature in early childhood; and having intense, and autonomous, childhood experiences in nature is crucial as well [59]. This makes children's access to nature of vital importance, especially since more and more children are growing up in urban areas where nature experiences can be scarce. Our work confirms that intense encounters with nature without supervision [60] are vital for building this connectedness [61] which is a key condition for commitment to, and action for, nature conservation in later life.

Salima Gurau picks vegetables from the gardens of the homestay her family runs in Nepal.


© Karine Aigner / WWF-US

BIODIVERSITY IS FUNDAMENTAL TO FOOD SECURITY

Urgent action is needed to address the loss of the biodiversity that feeds the world.

Julie Bélanger and Dafydd Pilling
(Food and Agriculture Organization of the United Nations FAO)

Food security is considered to exist "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" [62]. With the number of undernourished people in the world at about 820 million, and increasing in recent years, and more than 2 billion people estimated not to have regular access to safe, nutritious and sufficient food [63], global food security is far from being achieved. Major changes are needed if Sustainable Development Goal 2: Zero Hunger (targeting the end of hunger and all forms of malnutrition by 2030) is to be met. Better management of biodiversity has an important role to play in this.

FAO's global assessment of biodiversity for food and agriculture [64], on which this section draws, provides an analysis of the multiple ways in which biodiversity contributes to food security (see Figure 23 overleaf). Thousands of species of wild and domesticated plants, animals, fungi and micro-organisms are consumed as food. Among domesticated species, thousands of different plant varieties, livestock breeds and aquaculture strains have been developed. All this diversity adds to the options available to food producers and increases the range of foods available. It allows food to be produced in a wide variety of environments and helps provide people with diverse and balanced diets. Millions of livelihoods are supported by the farming or harvesting of a wide variety of food, feed, fuel and fibre-producing species.

Beyond the species that we eat, a vast range of others – as well as whole ecosystems – are essential to food production. These include the pollinators that enable many important crop species to reproduce, the natural enemies that protect crops from pests and reduce the need for harmful pesticides, the micro-organisms and invertebrates that enrich soils, the grassland ecosystems that provide food for livestock, and the mangroves, coral reefs and seagrass beds that provide habitats for fish.

Many ecosystems contribute in multiple ways to providing the conditions needed for food production, for example by regulating water flows or providing protection against storms.

Biodiversity – at genetic, species and ecosystem levels – makes production systems and livelihoods better able to withstand shocks and respond to environmental, social and economic changes. Genetic diversity allows populations to adapt over time via natural selection. In the case of domesticated species, it provides the basis for breeding programmes aimed at increasing production or improving the capacity of crops, trees, livestock or farmed aquatic organisms to cope with challenges such as high temperatures or the presence of diseases or parasites.

The potential benefits of biodiversity for food security are far from being fully realised. Species that are richer in micronutrients and vitamins, or better adapted to local conditions, are often underused. Among plants for example, only nine species (sugar cane, maize, rice, wheat, potatoes, soybeans, cassava, sugar beet and oil palm) account for 67% of all crop production [65]. There are also many ways in which the indirect contributions of biodiversity to food security could be increased, for example by protecting soils, or providing habitats for pollinators or the natural enemies of pests, in and around production systems.

Many species and ecosystems of importance to food and agriculture are in decline, and genetic diversity within species is often decreasing. Major threats include destructive changes in land and water use and management, including in the food and agricultural sector, climate change, and the overexploitation of wild species used for food. Reversing these negative trends and addressing these threats will be essential to the future of global food security.

In 2019, FAO launched the first report on **The State of the World's Biodiversity for Food and Agriculture** [64]. Five years in the making, the report was prepared under the guidance of FAO's Commission on Genetic Resources for Food and Agriculture through a participatory, country-driven process, engaging over 175 authors and reviewers, who based their analysis on 91 country reports prepared by over 1,300 contributors. It details the many benefits that biodiversity brings to food and agriculture, examines how farmers, pastoralists, forest dwellers, fishers and fish farmers have shaped and managed biodiversity, identifies major drivers of trends in the status of biodiversity, and discusses trends in the use of biodiversity-friendly production practices.

LIVELIHOODS

FOOD SECURITY

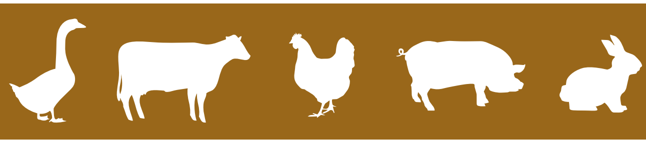
DIRECT: BIODIVERSITY USED AS FOOD

Domesticated

TERRESTRIAL PLANTS

Around 6000 species[71] of which 9 account for 2/3 of crop production[77]

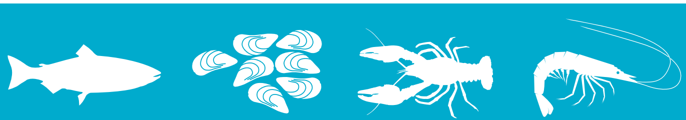
Thousands of varieties, landraces and cultivars (exact numbers unknown)[67] - some 5.3 million samples are stored in gene banks[76]



TERRESTRIAL ANIMALS

About 40 species of birds and mammals, of which 8 provide more than 95% of the human food supply from livestock[69]

About 8800 breeds (distinct within-species populations)[75]



AQUATIC ANIMALS AND PLANTS

Almost 700 species used in aquaculture, of which 10 account for 50% of production[74]

Few recognised strains (distinct within-species populations)[74]

MICRO-ORGANISMS AND FUNGI

Thousands of species of fungi and micro-organisms essential for food processes such as fermentation[64]

Around 60 species of edible fungi commercially cultivated[70]

INDIRECT: BIODIVERSITY THAT CREATES THE COND

GENES, SPECIES AND ECOSYSTEMS

Thousands of species of pollinators, soil engineers, natural enemies of pests, nitrogen-fixing bacteria, and wild relatives of domesticated species.

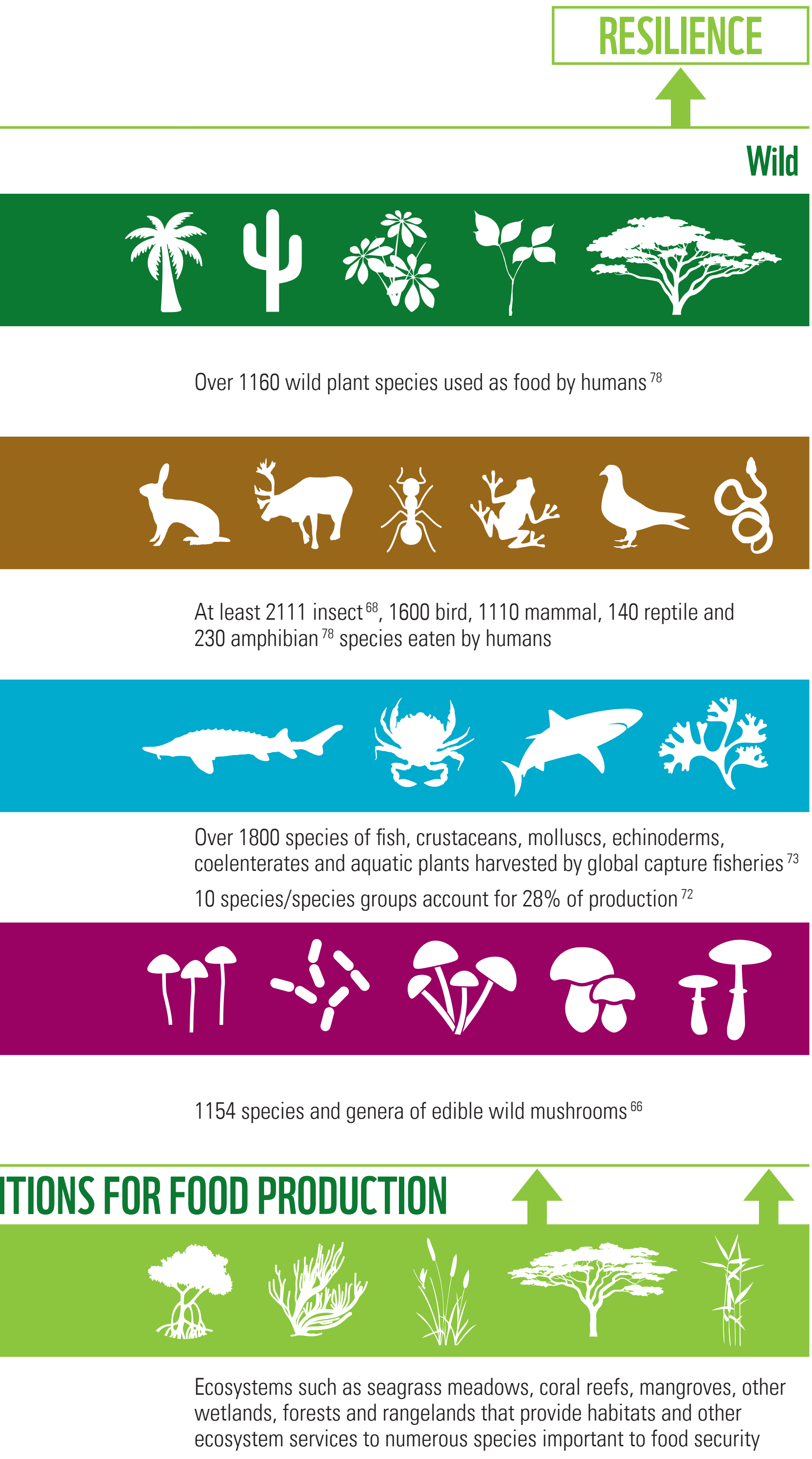


Figure 23: Key direct and indirect contributions of biodiversity to food security
Information for this figure was drawn from a number of sources [66 - 73, 64, 74-78].

A planetary health diet spares land for biodiversity and saves lives

Healthy eating can help to save biodiversity and tackle diet-related disease risk – the leading cause of premature mortality globally.

Fabrice DeClerck (EAT)

What food we produce and consume, how and where we produce that food, and how much is lost or wasted will determine whether we can provide a healthy diet, within environmental limits, for a global population of 10 billion people by 2050 [79-82].

For far too long we have been presented with a trade-off between food security or conservation, with 'feed the world' narratives presented as over-riding those to do with conservation. In the age of the Anthropocene this is finally changing, with the realisation that food is failing society both on health and environment grounds. Diet-related disease risk is the primary driver of premature mortality globally, and food production is the primary driver of biodiversity loss and water pollution. It also accounts for 20-30% of greenhouse gas emissions.

Many models suggest that food security, nutritional security, climate security, environmental security and livelihood security are possible, and that innovative solutions emerge when these goals are considered as equally non-negotiable [81, 82]. These are the five 'ands' of the *And*thropocene.

Overconsumption in general, and more specifically overconsumption of meat, has important impacts on both human and planetary health. The planetary health diet [82] is one that retains significant flexibility of choice among major food groups while providing guidance which, if followed, would make it possible to feed a global population of 10 billion while halting the conversion of intact ecosystems, and help reduce premature deaths by 11 million each year [79-81]. It starts with the assumption that all people, irrespective of wealth, are entitled to a sufficient (±2,500 kcal per day) and diverse diet with a balanced proportion of protective foods – that is, foods that are rich in vitamins and minerals that provide immunity, and significantly protect our body from various diseases and infections. These include whole grains, fruits, nuts, vegetables, beans and pulses; and fish, eggs, dairy and other animal-sourced meats in moderation where desired.

The terraces of the garden in the Municipal School PA Sapiquá are built with reused plastic bottles to promote a circular economy as part of a water conservation project implemented by local NGOs, Brazil.


© Jaime Rojo / WWF-US

The second rise of the humble potato: buffering against hunger and climate change

Andean native potatoes comprise a wealth of biodiversity that could contribute to the food security of an increasingly crowded, climate-stressed world. Conserving them is essential.

Ginya Truitt Nakata
(International Potato Center)

Since the first tubers were taken from South America to Europe in the 16th century the potato has spread across the globe and is now the world's third most consumed crop. However, it is highly susceptible to disease, as Ireland's Great Famine proved, and vulnerable to the weather extremes exacerbated by climate change.

The Andes region is the birthplace of the potato and is home to at least 4,500 types of native tuber cornucopia, including more than 100 wild potato species. Local farmers grow and eat an array of native potatoes that together provide relatively high levels of zinc, iron, potassium, vitamin C and antioxidants, and are fundamental to the health of Indigenous communities.

Adaptable and highly productive, the potato has saved millions from hunger. Yet one study has estimated that climate-induced weather extremes could drive 13 wild potato species to extinction by 2055 – and we know that the loss of just one species could be catastrophic. In 2007 one of many unexpected frosts wiped out the entire potato harvest in Peru's Huancavelica region, except for yana. This single variety came between local families and extreme hunger.

The Andes' potato agrobiodiversity remains key to strengthening the resilience of farming communities and is used by scientists to breed nutritious, disease-resistant potato varieties for the world. The International Potato Center recognises biodiversity's fundamental contribution to human and planetary health, and works with Andean farmers to maintain potato diversity. Just one of these varieties could hold the key to alleviating the next global hunger crisis [83].

A selection of potato varieties within a market in Huancayo, Peru.

© Ginya Truitt Nakata / The International Potato Center (CIP)

HUMAN WEALTH DEPENDS ON NATURE'S HEALTH

Our economies are embedded within nature, and it is only by recognising and acting on this reality that we can protect and enhance biodiversity and improve our economic prosperity.

Sir Partha Dasgupta
(Lead Reviewer of the Dasgupta Review and the University of Cambridge)

Inger Andersen
(Executive Director, UN Environment Programme)

COVID-19 is nature sending us a message. In fact, it reads like an SOS signal for the human enterprise, bringing into sharp focus the need to live within the planet's 'safe operating space'. The environmental, health and economic consequences of failing to do so are disastrous.

Now more than ever before, technological advances allow us to listen to such messages and better understand the natural world. We can estimate the value of 'natural capital' – the planet's stock of renewable and non-renewable natural resources, like plants, soils and minerals – alongside values of produced and human capital – for example, roads and skills – which together form a measure of a country's true wealth.

Data from the United Nations Environment Programme shows that, per person, our global stock of natural capital has declined nearly 40% since the early 1990s, while produced capital has doubled and human capital has increased by 13% [84].

But too few of our economic and finance decision-makers know how to interpret what we are hearing, or, even worse, they choose not to tune in at all. A key problem is the mismatch between the artificial 'economic grammar' which drives public and private policy and 'nature's syntax' which determines how the real world operates.

The result is that we miss the message.

In recent decades we've heard repeatedly that we've 'never had it so good'. Since the mid-20th century, humanity has prospered at an unprecedented rate. The average person today enjoys a far higher income, is less likely to be in absolute poverty, and lives significantly longer than their ancestors. These are tremendous achievements.

But these successes have come hand in hand with a profound degradation of the biosphere, and extensive biodiversity loss. This extreme contradiction is unsustainable. Simple estimates of our total impact on nature now suggest that maintaining the world's current living standards with our current economic systems, fuelled by unsustainable production and consumption, would require 1.75 Earths (see Chapter 2).

One truly worrying result of our over-demand is that critical ecosystems are reaching tipping points. Ocean heatwaves have already destroyed half of the shallow-water corals on Australia's Great Barrier Reef. As the IPCC reported in 2018, scientists have projected that a 2°C global temperature rise will result in the almost complete eradication (a 99% loss) of coral reefs globally[85]. The economic impacts will be devastating. Large numbers of people depend on coral reef fisheries for livelihoods and nutrition, particularly in developing countries. Reef tourism and recreation bring significant economic benefits.

Meanwhile, scientists have also shown that deforestation of our tropical forests is pushing them dangerously close to tipping points that would see rainforest switch to savannah. This could have enormous consequences for the water cycle and cause major climatic disruption.

So, if the language of economics is failing us, how and where do we begin to find better answers? Unlike standard models of economic growth and development, placing ourselves and our economies within nature helps us to accept that our prosperity is ultimately bounded by that of our planet. This new grammar is needed everywhere, from classrooms to boardrooms, and from local councils to national government departments. It has profound implications for what we mean by sustainable economic growth, helping to steer our leaders towards making better decisions that deliver us, and future generations, the healthier, greener, happier lives that more and more of us say we want.

The importance of being guided by the science when taking decisions has become all the more apparent in recent months. While we still have more to learn about the epidemiology and effects of COVID-19, the link between biodiversity loss and the emergence and spread of infectious disease is well established. As discussions about the recovery gather pace, economic and financial decisions must be guided by the science too.

From now on, protecting and enhancing our environment must be at the heart of how we achieve economic prosperity.

The Dasgupta Review on the Economics of Biodiversity

The Dasgupta Review explores the sustainability of our engagements with nature: what we take from it; how we transform what we take from it and return to it; why we have disrupted nature's processes; and what we must urgently do differently to enhance our collective wealth and well-being, and that of our descendants.

Emily McKenzie, Ant Parham, Mark Anderson and Haroon Mohamoud (Dasgupta Review Team)

The Dasgupta Review is an independent, global review on the economics of biodiversity commissioned by HM Treasury – the UK's economic and finance ministry – in 2019 [86]. In its framing, the Review shows how humanity, and our economies, are embedded within – rather than external to – nature, helping us to recognise the limits nature places on the economy and, in so doing, reshape our understanding of sustainable economic growth.

A number of central economic and scientific concepts underpin the Review's work. These include the need to recognise that biodiversity is an essential characteristic of nature, playing an important role in the provision of ecosystem services on which our economies rely; to view nature as an asset, just as produced and human capital are assets, and acknowledge that we are failing to manage our assets efficiently; to understand that the loss of nature is an asset management problem; to assess how our total demand on nature outstrips its ability to supply goods and services on a sustainable basis; and to accept that addressing the supply-demand imbalance means confronting difficult questions, including questions about what and how we consume, how we manage our waste, and the role family planning and reproductive health can play.

Villa Leppefisk salmon farm, Vestnes, Norway.

© Jo Benn / WWF

THE LOSS OF NATURE IS A MATERIAL RISK FOR ECONOMIC DEVELOPMENT AND HUMAN WELL-BEING

In 2020 climate change, biodiversity loss, extreme weather, natural disasters and other human-made environmental disasters lead an annual World Economic Forum survey of economic and business risks – the first time the top five risks have all been environmental.

Dominic Waughray
and Akanksha Khatri
(World Economic Forum)

Each year the World Economic Forum presents a global risks landscape in the annual *Global Risks* report, based on the outcomes of a Global Risks Perception Survey completed by about 1,000 members of the Forum's multi-stakeholder community. For the first time in the 15-year history of the survey, the top five risks are all environmental, indicating a higher-than-average perception of both the likelihood and the impact of these environmental risks affecting the global economy, and society, within the next 10 years [87]. Figure 24 overleaf shows the global risks landscape of 2019.

The most pressing environmental challenges identified are extreme weather, climate action failure, biodiversity loss, natural disasters and other human-made environmental disasters.

© Adriano Gambarini / WWF-Brazil

The survey result is a wake-up call to remind us that a stable environment and planetary health underpin human civilization, prosperity and growth and there are clear interconnections that can be drawn between them. Over the past year, multiple natural disasters have cost billions of dollars globally, and it is now widely accepted that physical climate risks are not priced properly in today's global economic system. For instance, Munich Re, the world's largest reinsurance firm, cited climate change for US$24 billion of losses in the California wildfires [88]. In 2019, a severe drought in Australia drove farmers to sell their feedstock and shut down farm operations as they were unable to keep up with water prices. In 2019-20, the Australian government announced a drought stimulus package worth more than AU$500 million, with a regional government offering an additional AU$170 million [89].

All economic activities are either directly or indirectly dependent on nature. The *Nature Risk Rising* report found that more than half the world's GDP – US$44 trillion – is highly or moderately dependent on nature and its services [109]. Agriculture and food supply are where the loss of nature and biodiversity become most critical. A case in point is the prevalence of monoculture production: for example, 60% of the world's coffee varieties are in danger of extinction due to climate change, disease and deforestation [90]. If this were to happen, global coffee markets – a sector with retail sales of US$83 billion in 2017 – would be significantly destabilised, affecting the livelihoods of many smallholder farmers [91].

Tackling interconnected nature risks to secure a resilient economy and society will require multi-stakeholder collaborations, as no single group can resolve this systemic challenge alone. Post COVID-19, the urgency of the challenge facing us today also provides a unique opportunity to reset humanity's relationship with nature to ensure a nature-positive economy.

A landscape of a dry, cracked soil, Maranhão, Brazil.

TOP 5 GLOBAL RISKS IN TERMS OF LIKELIHOOD

	2010	2011	2012	2013	2014	2015
1st	Asset price collapse	Storms and cyclones	Income disparity	Income disparity	Income disparity	Interstate conflict
2nd	China economic slowdown	Flooding	Fiscal imbalances	Fiscal imbalances	Extreme weather	Extreme weather
3rd	Chronic diseases	Corruption	Greenhouse gas emissions	Greenhouse gas emissions	Unemployment	Failure of national governance
4th	Fiscal crises	Biodiversity loss	Cyberattacks	Water crises	Climate action failure	State collapse or crisis
5th	Global governance gaps	Climate change	Water crises	Population ageing	Cyberattacks	Unemployment

TOP 5 GLOBAL RISKS IN TERMS OF IMPACT

	2010	2011	2012	2013	2014	2015
1st	Asset price collapse	Fiscal crises	Financial failure	Financial failure	Fiscal crises	Water crises
2nd	Deglobalization (developed)	Climate change	Water crises	Water crises	Climate action failure	Infectious diseases
3rd	Oil price spikes	Geopolitical conflict	Food crises	Fisca imbalancesl	Water crises	Weapons of mass destruction
4th	Chronic diseases	Asset price collapse	Fiscal imbalances	Weapons of mass destruction	Unemployment	Interstate conflict
5th	Fiscal crises	Energy price volatility	Energy price volatility	Climate action failure	Infrastructure breakdown	Climate action failure

A "global risk" is defined as an uncertain event or condition that, if it occurs, can cause significant negative impact on several countries or industries within the next 10 years

Note: Global risks may not be strictly comparable across years, as definitions and the set of global risks have evolved with new issues emerging on the 10-year horizon. For example, cyberattacks, income disparity and unemployment entered the set of global risks in 2012. Some global risks have been reclassified: water crises and income disparity were recategorised as societal risks in the 2015 and 2014 Global Risks Reports, respectively[93, 94].

2016	2017	2018	2019	2020
Involuntary migration	Extreme weather	Extreme weather	Extreme weather	Extreme weather
Extreme weather	Involuntary migration	Natural disasters	Climate action failure	Climate action failure
Climate action failure	Natural disasters	Cyberattacks	Natural disasters	Natural disasters
Interstate conflict	Terrorist attacks	Data fraud or theft	Data fraud or theft	Biodiversity loss
Natural catastrophes	Data fraud or theft	Climate action failure	Cyberattacks	Human-made environmental disasters

2016	2017	2018	2019	2020
Climate action failure	Weapons of mass destruction	Weapons of mass destruction	Weapons of mass destruction	Climate action failure
Weapons of mass destruction	Extreme weather	Extreme weather	Climate action failure	Weapons of mass destruction
Water crises	Water crises	Natural disasters	Extreme weather	Biodiversity loss
Involuntary migration	Natural disasters	Climate action failure	Water crises	Extreme weather
Energy price shock	Climate action failure	Water crises	Natural disasters	Water crises

Figure 24: The evolving risks landscape. Top five perceived global risks in terms of likelihood and impact, according to the World Economic Forum (2020)
The Global Risks Perception Survey is the World Economic Forum's source of original risks data, harnessing the expertise of the Forum's extensive network of business, government, civil society and thought leaders. For each of the 30 global risks, respondents were asked to assess: (1) the likelihood of each global risk occurring over the course of the next 10 years, and (2) the severity of its impact at a global level if it were to occur, both on a scale from 1 to 5. This figure was adapted from World Economic Forum (2020)[92] and full definitions of each risk can be found in the appendix of the report. Source - World Economic Forum (2020)[92].

Key

- Economic
- Environmental
- Geopolitical
- Societal
- Technological

Seed banks as a safety net and insurance policy

Seed banks worldwide hold around 7 million crop samples, helping to safeguard biodiversity and global nutritional security.

Luigi Guarino
(Crop Trust)

In the past few decades hundreds of local, national, regional and international seed banks have been established, complementing on-farm and in situ plant conservation, much as some zoos are part of the mosaic of animal species conservation [67]. At their heart are cold stores holding a worldwide total of approximately 7 million seed samples of crops, including forage and fodder plants, and their wild relatives. Perhaps the most well-known seed bank, the Svalbard Global Seed Vault in Norway, provides a back-up service for when things go wrong in other seed banks.

For species that either do not produce seeds or whose seeds cannot be stored at low temperatures, conservation takes place with live plants in the field or in tissue culture in labs. Seed banks are used by researchers and plant breeders to develop new, improved crop varieties. They have also provided farmers with varieties they have lost. The International Treaty for Plant Genetic Resources for Food and Agriculture provides the rules under which crop diversity in seed banks is accessed, and benefits shared. Target 2.5 of the UN Sustainable Development Goals explicitly links the work of seed banks to global nutritional security.

A view of the front of the Svalbard Global Seed Vault, Svalbard archipelago, Norway.


© Svalbard Global Seed Vault / Riccardo Gangale

A PARADIGM SHIFT IN THE WAY WE ASSESS NATURE

People value nature in many different ways, and bringing these together can be used to shape policies that will create a healthy and resilient planet for people and nature.

Berta Martin-Lopez
(Leuphana University, Lüneburg)
and Sandra Díaz
(CONICET and Córdoba
National University, Argentina and
IPBES Global Assessment Co-Chair)

Nature's Contributions to People refers to all the contributions, both positive and negative, that nature makes to people's quality of life [1]. Building on the ecosystem service concept popularised by the Millennium Ecosystem Assessment [95], the Nature's Contributions to People concept includes a wide range of descriptions of human dependence on nature, such as ecosystem goods and services and nature's gifts. It recognises the central role that culture plays in defining all links between people and nature. It also elevates, emphasises and operationalises the role of indigenous and local knowledge [1, 100].

Until recently, the conceptualisation of, and practical work on, ecosystem services have focused on assessing and valuing those service flows with biophysical and economic approaches coming from natural sciences and economics respectively. This approach has largely failed to engage a range of perspectives from social sciences, humanities [96], or those of local actors including Indigenous peoples and local communities [1].

The Nature's Contributions to People approach explicitly recognises that a range of views of nature exist. At one extreme, humans and nature are viewed as distinct; at the other, humans and non-human entities are interwoven in deep relationships of kinship and reciprocal obligations [97, 98]. It uses two lenses to assess how people relate to nature: *generalising* and *context-specific* perspectives.

The **generalising perspective** is typical of the natural sciences and economics and is fundamentally analytical in purpose; it seeks a universally applicable set of categories that define flows from nature to people. IPBES identified and assessed 18 of these categories and organised them in three partially overlapping groups: regulating, material and nonmaterial contributions [1, 13]. Trends in these categories and their indicators are explored more earlier in this chapter on pages 78-79. These are defined according to the type of contribution they make to people's quality of life.

- **Material contributions** are substances, objects or other material elements from nature that directly sustain people's physical existence and material assets. For example, this includes when organisms are transformed into food, energy or materials for ornamental purposes.

- **Nonmaterial contributions** are nature's effects on subjective or psychological aspects underpinning people's quality of life, both individually and collectively. Examples include forests and coral reefs providing opportunities for recreation and inspiration, or particular animals and plants being the basis of spiritual or social-cohesion experiences.

- **Regulating contributions** frequently affect quality of life in indirect ways. They are the functional and structural aspects of organisms and ecosystems that modify environmental conditions experienced by people, and/or regulate the generation of material and nonmaterial contributions. For example, people directly enjoy useful or beautiful plants but only indirectly benefit from the soil organisms that are essential for the supply of nutrients to such plants.

Culture permeates through and across all three groups rather than being confined to an isolated category.

The **context-specific perspective** is the perspective typical of, but not exclusive to, local and indigenous knowledge systems. Providing space for context-specific perspectives recognises that there are multiple ways of understanding and categorising relationships between people and nature.

Although presented as extremes, these two perspectives are often blended and interwoven – therefore recognising both these approaches leads to a richer understanding of how biodiversity contributes to people's quality of life and reveals solutions for the sustainable management of nature and the many contributions it makes to our lives [99, 100].

Looking ahead: a different way to imagine our future with nature

Putting nature at the centre of global biodiversity scenario development recognises the fundamental role it plays in human well-being and may help to inspire transformative change.

Carolyn Lundquist (National Institute of Water and Atmospheric Research, New Zealand, and the University of Auckland), Henrique Pereira (Martin Luther University and German Centre for Integrative Biodiversity Research – iDiv), HyeJin Kim (Martin Luther University and German Centre for Integrative Biodiversity Research – iDiv) and Isabel Rosa (Bangor University)

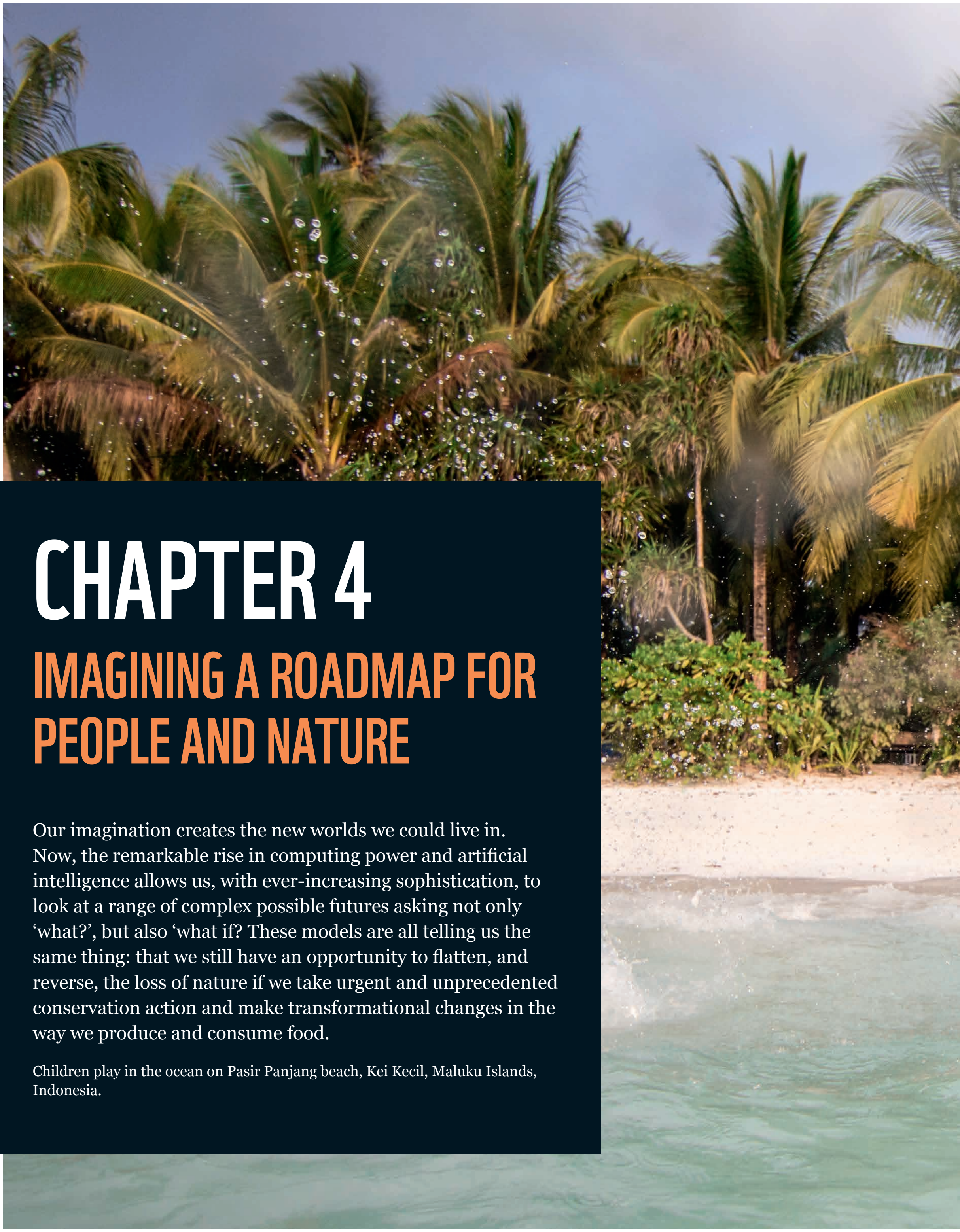
Our values, as humans, influence the choices we make and these underpin the development of a new approach to environmental scenarios, catalysed by the IPBES Task Force on Scenarios and Models. The Nature Futures Framework builds on the different ways in which people experience and value nature [101, 102]:

'Nature for Nature', where people value nature for its intrinsic and existence values; ***'Nature for Society'***, which views nature as provider of direct and indirect benefits to society; and ***'Nature as Culture'*** where people and nature are connected and the sense of identity derived from cultural landscapes and relational values dominates [103]. These human-nature relationships are being used to develop scenarios that explore different socioeconomic development pathways, where one or more of these perspectives dominates, identifying potential trade-offs and co-benefits across the three perspectives.

The Nature Futures Framework is designed to be adaptable across the diversity of local and regional societal, cultural, policy and governance contexts [104], adding new perspectives to the diversity of human values, relationships with nature, and how these can motivate society to act to bend the curve of biodiversity loss [105].

Close up of a Madagascan dwarf chameleon (*Brookesia micra*), the world's smallest chameleon, endemic to Nosy Hara archipelago in Madagascar.


© Nick Riley / WWF-Madagascar



CHAPTER 4

IMAGINING A ROADMAP FOR PEOPLE AND NATURE

Our imagination creates the new worlds we could live in. Now, the remarkable rise in computing power and artificial intelligence allows us, with ever-increasing sophistication, to look at a range of complex possible futures asking not only 'what?', but also 'what if? These models are all telling us the same thing: that we still have an opportunity to flatten, and reverse, the loss of nature if we take urgent and unprecedented conservation action and make transformational changes in the way we produce and consume food.

Children play in the ocean on Pasir Panjang beach, Kei Kecil, Maluku Islands, Indonesia.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CHOICE OR CHANCE: COUNTDOWN TO THE FUTURE

Will 2020 go down in history as the year in which COVID-19 served as the catalyst to completely alter our future relationship with nature? Cutting-edge new modelling shows that with urgent action it is still possible to halt loss and reverse the trend of nature's decline.

Michael Obersteiner
(The Environmental Change Institute,
University of Oxford and IIASA)

Our imagination creates the new worlds we could live in. Building digital twins of our living planet allows us to better imagine many possible future states of life on planet Earth. The in-silico twins of the Earth are created in computer models of the Earth system and its biodiversity. Modelling is used around the world every day, to predict the weather, to plan traffic, forecast population growth areas to understand where to build schools – and, in conservation, to understand, how to most effectively manage for better biodiversity outcomes with least costs. Now, the remarkable rise in computing power and artificial intelligence allows us, with ever-increasing sophistication, to look at a range of complex possible futures asking not only 'what?', but also 'what if?'

There is no better case in point than COVID-19, which has propelled scenario modelling to the forefront of our daily lives. In a real-time global experiment, mathematicians and epidemiologists have used specialised software and complex programming code to take what they measured and know about the virus, then used simulations to test different control strategies, such as social distancing and lockdowns, and compared them against results projected from business as usual. Based on this scenario modelling, politicians have made difficult decisions on paths of action, with trade-offs between public health and economic consequences.

This *Living Planet Report* – like others before it, as well as an overwhelming body of other scientific literature – sets out a grim diagnosis for our natural world, and consequently for the human enterprise. For more than 30 years, since the Brundtland Commission's *Our Common Future* report in 1987, scientists, environmentalists and many others have called for dramatic changes to how we produce, consume and protect our world. Now, today's computing power has been used to develop a proof of concept to do just this – to bend the curve of biodiversity loss.

This pioneering effort started in 2018, when WWF began a collaboration with a consortium of almost 50 partners to launch the Bending the Curve Initiative. For the first time, multiple models have been integrated to help us understand how we can reverse the loss of nature, save millions of species from extinction, and guard humans against a risky future. And the models are all telling us the same thing: that we still have an opportunity to flatten, and reverse, the loss of nature if we take urgent and unprecedented conservation action and make transformational changes in the way we produce and consume food.

Yet an important question remains. It is not, 'What kind of future world do we want?' – this seems evident: one in which humanity not only survives but thrives, which means a planet on which nature also survives and thrives.

WHAT IF? SCENARIOS EXPLORING HOW TO BEND THE CURVE OF BIODIVERSITY LOSS

Pioneering modelling has provided the first ‘proof of concept’ that we can halt, and reverse, terrestrial biodiversity loss from land-use change. With an unprecedented and immediate focus on both conservation and a transformation of our modern food system, the Bending the Curve Initiative gives us a roadmap to restore biodiversity and feed a growing human population.

David Leclère (IIASA)

We know that nature is being changed and destroyed by us at a rate unprecedented in history, driven largely through the conversion of natural habitats for agriculture and forestry. While many conservation efforts have been locally successful, they have not been able to stop this global trend: the land demand for food, animal feed and energy provision is increasing, and already impacting the ecosystem services that we depend upon.

Some conservation groups have proposed ambitious targets to save nature, such as conserving half of the Earth. However, there is no evidence as to whether these targets can be achieved, and they would inevitably involve trade-offs – for example, with providing for people’s basic needs such as food [45] and livelihoods [46], as well as with addressing climate change to keep warming below the target of 1.5°C.

The Bending the Curve Initiative [47] used multiple state-of-the-art models and scenarios to investigate whether we can reverse terrestrial biodiversity declines – and if so, how. Building on pioneering work that modelled pathways to achieve sustainability objectives [48] and recent efforts by the scientific community for the Intergovernmental Panel on Climate Change (IPCC) and IPBES [49-51], seven future what-if scenarios were developed.

The reference what-if scenario is based on the IPCC's 'middle-of-the-road' scenario (SSP2 in Fricko, O. *et al.* (2017)[52]) and assumes a business-as-usual future, with limited efforts towards conservation and sustainable production and consumption. In this scenario, human population peaks at 9.4 billion by 2070, economic growth is moderate and uneven, and globalisation continues. In addition to the reference scenario, six additional what-if scenarios were developed to explore the potential effects of different actions.

Just as with modelling for climate change, or indeed COVID-19, interventions to determine possible future pathways were broken into action 'wedges'. These include measures around increased conservation as well as reducing the impact of our global food system on terrestrial biodiversity, in terms of both production and consumption.

Three of the scenarios picture single types of interventions aimed at bending the curve:

1. **The increased conservation efforts (C) scenario included an increase in the extent and management of protected areas, and increased restoration and landscape-level conservation planning**. It assumed an extension of protected areas in 2020 to all areas currently covered by the World Database on Protected Areas, the World Database of Key Biodiversity Areas, and Wilderness Areas. These areas were assumed to be efficiently managed so that no land-use change detrimental to biodiversity is allowed. In addition, in all areas managed for production activities, financial incentives encouraging both restoration and land-use planning for better biodiversity outcomes are implemented from 2020, starting with low incentives and increasing towards mid-century.

2. **The more sustainable production (supply-side efforts or SS) scenario included higher and more sustainable increases in both agricultural productivity and trade of agricultural goods.** It assumed that the yield of domestic crops and the productivity of livestock activities will rise slightly more strongly than in the reference scenario at the global scale, with crop yields increasing more rapidly in developing countries so they converge towards the level seen in higher yielding, developed countries. Trade in agricultural commodities across the globe is facilitated, assuming a more globalised economy and reduced trade barriers. For both aspects, assumptions follow those of the IPCC's 'sustainability' scenario (SSP1, van Vuuren, D.P. *et al.* (2017)[53], instead of SSP2).

3. **The more sustainable consumption (demand-side efforts or DS) scenario included reduced waste of agricultural goods from field to fork and a diet shift to a lower share of animal calories in high meat-consuming countries.** It assumed that total loss throughout the food supply chain (losses in harvest, processing, distribution and final household consumption) will decline linearly between 2020 and 2050, culminating in a 50% reduction in loss by 2050. Dietary preferences evolve linearly towards 50% less meat consumption by 2050 compared to the reference scenario (animal calories are replaced by vegetal calories), except in regions with a low share of meat in current diets like the Middle East, Sub-Saharan Africa, India, Southeast Asia and other Pacific Islands, where dietary preferences for meat follow the reference scenario.

The three other scenarios modelled different combinations of these increased efforts:

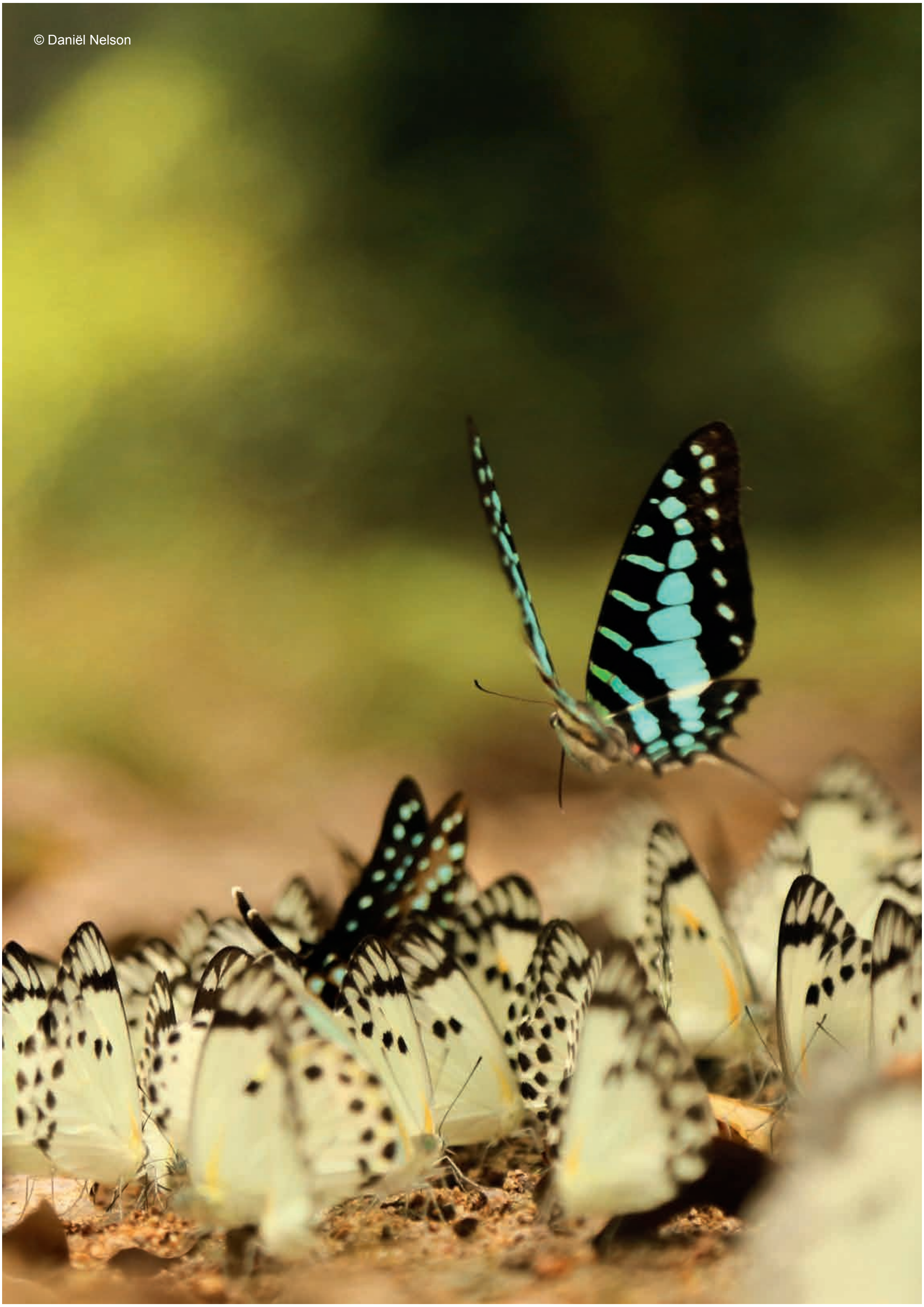
4. The fourth looked at **conservation and sustainable production (C+SS scenario).**

5. The fifth combined **conservation and sustainable consumption (C+DS).**

6. The sixth scenario investigated interventions in all three sectors at once. This was known as the **'integrated action portfolio' of interventions, or IAP scenario.**

Four land-use models [54] translated each scenario into future maps of the share of land occupied by 12 land uses, from built-up areas to primary forests, on a grid of ca. 50km resolution, every 10 years throughout the 21st century. Biodiversity models translated these land-use maps into global and regional biodiversity outcomes. Using eight models allowed the modelling to not only capture uncertainties, but also to grasp five facets of biodiversity: the extent of suitable habitat, wildlife abundance, compositional intactness of ecological communities, and regional and global species extinctions.

Butterflies in a clearing in Messok-Dja National Park, Republic of Congo.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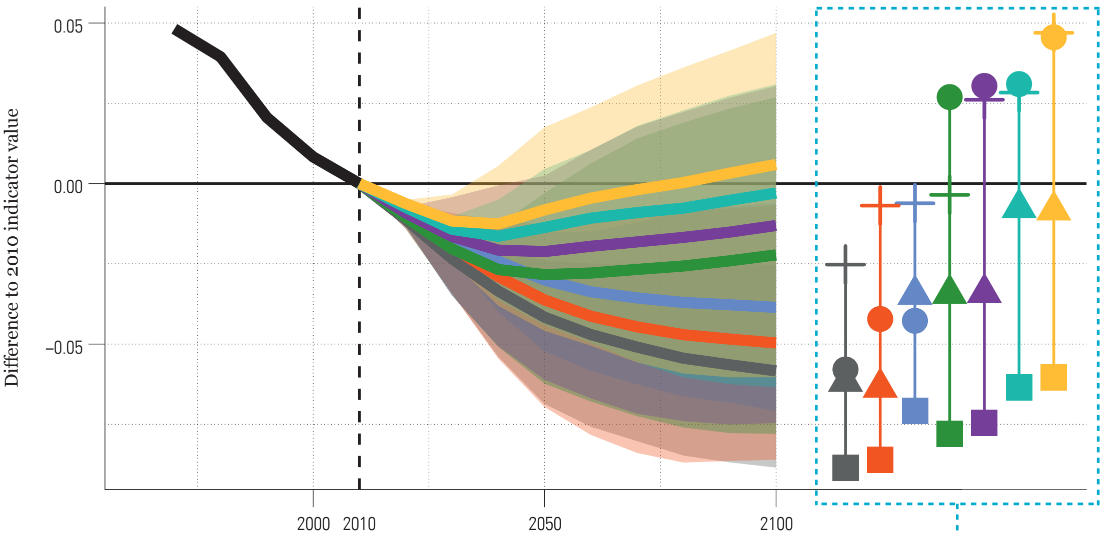
Bending the curve



The projected change in biodiversity under each land-use change model in 2100

Scenario (mean & range across land use change models)

Key

- Historical
- Baseline (BASE)
- Supply-side efforts (SS)
- Demand-side efforts (DS)
- Inc. conservation efforts (C)
- Inc. conservation & supply-side efforts (C+SS)
- Inc. conservation & demand-side efforts (C+DS)
- Integrated action portolio (IAP)

2100 values for individual land-use change

- AIM
- GLOBIOM
- IMAGE
- MAgPIE

Figure 25: Projected contributions of various efforts to reverse biodiversity trends from land-use change
Sourced from Leclère et al. (2020)[47]. This illustration uses one biodiversity indicator to show how future actions to reverse biodiversity trends have varying results across the seven scenarios indicated by different colours. The line and shaded area for each scenario represent the average and range of the projected relative changes across four land-use models (compared to 2010). This graph shows the projected response of one of the biodiversity indicators – mean species abundance, or MSA – using one of the biodiversity models (GLOBIO – more details about all the biodiversity indicators and models can be found in the technical supplement). Biodiversity trends differ between the indicators. Figure 27 provides an overview the main outcomes projected under each combination of scenarios.

The thick coloured lines on the graph show how biodiversity is projected to respond under each scenario. As four land-use models were used, this shows the average value across all of them.

The grey line shows that in the reference baseline ‘business-as-usual’ scenario, global biodiversity trends continue declining throughout the 21st century, with a speed similar to recent decades until 2050.

Single interventions:
- The red line shows the effect of putting in place sustainable production measures alone.
- The blue line shows the effect of putting in place sustainable consumption interventions alone.
- The green line shows the effect of putting in place more ambitious conservation measures alone.

Integrated interventions combine these three in different ways:
- The purple line shows how biodiversity is projected to respond if increased conservation measures are combined with more sustainable production efforts.
- The light blue line shows how biodiversity is projected to respond if increased conservation measures are combined with more sustainable consumption efforts.
- The yellow line shows how biodiversity responds under the ‘integrated action portfolio’ that combines all three single interventions: increased conservation measures and more sustainable production and consumption efforts.

Conservation is critical but not enough – we must also transform food production and consumption patterns

This research shows that bolder conservation efforts are key to bending the curve: more than any other single type of action, increased conservation was found to limit further biodiversity losses in the future and to set global biodiversity trends on a recovery trajectory. Yet, if implemented alone, these efforts could lead to increases in the price of agricultural products, thereby increasing risks of hunger (Figure 27). Results show this trade-off could be strongly reduced by additional actions related to sustainable production and consumption such as closing yield gaps, reducing waste, or favouring healthier and more sustainable diets. Taking these additional actions would also mean a much larger share of future biodiversity losses would be avoided than with increased conservation efforts alone, and recovery would begin earlier (see Figure 26 for more information).

These findings make it clear that only an integrated approach, combining ambitious conservation with measures targeting the drivers of habitat conversion – such as sustainable production or consumption interventions, or preferably both – will succeed in bending the curve of biodiversity loss. It is only under these scenarios that the biodiversity trends from habitat conversion might still be reversed by 2030, whilst also avoiding an increase in food prices. These points are explored in detail in Figure 27.

Bending curves for people and nature

The study also looked at the concept of 'peak loss' of biodiversity. Peak loss has two components to it – when recovery begins and how much is lost before then. The date of peak loss is the year when a biodiversity indicator – like the Living Planet Index – reaches its minimum, before 'bending' upwards. This date combined with the rate at which biodiversity is lost determines the overall size of peak loss for each scenario. In reality, some of these losses might be irreversible – once a species of animal or plant becomes extinct, it cannot return. Minimising future peak loss is therefore critically important.

Figure 26 illustrates when, and how much, peak loss occurs under each scenario. Bold conservation measures – in green – is the most efficient 'single action' scenario. However, it cannot guarantee to either bend the curve or fully avoid future biodiversity losses by 2050. In contrast, combining conservation measures with sustainable consumption or production interventions – or both, as illustrated in the IAP scenario, in yellow – simultaneously bends the curve before 2050 and avoids a large share of the potential biodiversity losses by then.

THE BIODIVERSITY CURVE STARTS TO BEND UPWARDS AT A DIFFERENT TIME UNDER EACH SCENARIO - WHEN AND HOW DEPENDS ON WHICH ACTIONS ARE TAKEN

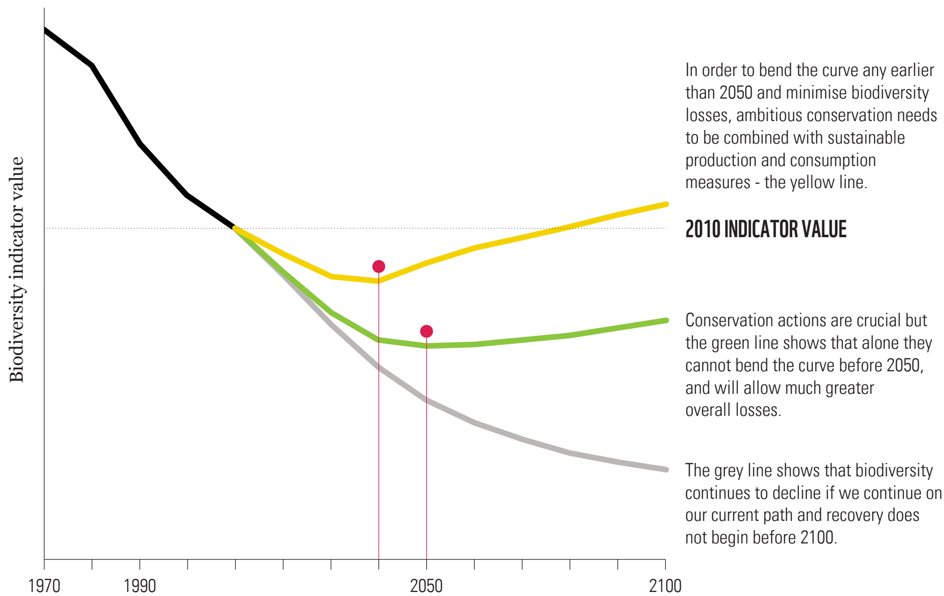


Figure 26:
What bending the curve means for biodiversity, and how to get there. This illustration uses one biodiversity indicator (Mean species abundance, MSA) for one biodiversity model (GLOBIO), averaged across the four land use models, to explain what the different scenarios mean for projected biodiversity trends and what this tells us about how to bend the curve. Adapted from Leclère et al. (2020)[47].

Scenario
(mean across land-use change models)

- Historical
- Baseline
- Increased conservation efforts
- Integrated Action Portfolio
- The date when recovery begins

Combining sustainable production or sustainable consumption interventions – or preferably both – with bolder conservation measures will represent a deep transformation of our food system. Yet such a transformation would also provide large co-benefits for the environment, through reduced greenhouse gas emissions, fertiliser application and irrigation water consumption (Figure 27). As other studies show, it would also provide significant co-benefits in terms of improved health[56]. An integrated action portfolio would therefore not only reduce the trade-offs between conservation and agricultural production, but would also embark us upon a transformation that is more consistent with the wider sustainable development agenda and balances the needs of people and nature.

			OUTCOMES PROJECTED BY THE MODELS				
				Trends in other sustainability dimensions of land use			
					Other environmental impacts by 2050		
			Global biodiversity trends	Market price of crops by 2050	GHG emissions	Water use	Nitrogen application as fertilizer
INTERVENTION SCENARIOS	Limited efforts	Reference	decline until last quarter of 21st century	↘	↗	↗↗	↗↗↗↗
	Targeted efforts	Increased supply-side efforts	slightly more moderate decline until last quarter of 21st century	↘↘	↘	↗↗	↗↗↗↗
		Increased demand-side efforts	slightly more moderate decline until last quarter of 21st century	↘↘↘	↘↘↘	↗↗	↗↗↗
		Increased conservation efforts	slightly more moderate decline until about 2050, followed by moderate recovery	↗	-	↗↗	↗↗↗↗
	Integrated combined efforts	Increased conservation and supply-side efforts	small decline followed by faster recovery starting before 2050	↘	↘↘	↗↗	↗↗↗↗
		Increased conservation and demand-side efforts	small decline followed by faster recovery starting before 2050	↘↘	↘↘↘	↗↗	↗↗↗
		Integrated action portfolio (all efforts combined)	small decline followed by faster recovery starting before 2050	↘↘	↘↘↘	↗	↗↗↗

Key	*Biodiversity*	*Price trends*	*GHG emissions*	*Water use*	*Nitrogen application as fertilizer*
(red)	decline	-	increase	very strong (>50%) increase	strong (>20%) increase
(orange)	slightly lower decline	strong (>20%) decline or increase	stable	strong increase (>20%)	moderate increase (10%-20%)
(yellow)	slightly lower decline followed by moderate recovery	moderate (10-20%) decline	small (<10%) to moderate (10-20%) decrease	moderate increase (<20%)	small increase (<10%)
(green)	small decline followed by faster recovery	small decline (< 10%)	strong (>20%) decline	decrease	decrease

rationale:	biodiversity	colour qualifies distance from target = bending the curve
	price	colour qualifies distance from target = decline (from a food security perspective) but not too strong (from a producer perspective)
	other envtl impacts	colour indicates whether or not pressures are transgressing (red), within uncertainty range (orange) or below planetary boundary (green)

Looking ahead

The Bending the Curve Initiative shows that bold conservation efforts and food system transformation are central to an effective post-2020 biodiversity strategy. They are also essential components of a roadmap towards building a resilient future where both people and nature thrive.

It is important to note that these models focus on the strongest driver of terrestrial biodiversity loss, land-use change. Ongoing research is making this roadmap more complete. Threats not included in this analysis, like climate change or invasive species, will also become more important in the future. While work is already underway to investigate how to tackle these threats, it is clear that leaving them unaddressed could jeopardise chances to bend the curve. Bending the curve could, therefore, require even more ambitious action than is anticipated here.

Global modelling also needs to be implemented at a national and local level. Global networks of national research teams are using models and scenarios to support the design of integrated and concrete national-level policies. These will contribute towards both national and global sustainability targets. One of these initiatives – the Food, Agriculture, Biodiversity, Land-Use and Energy (FABLE) Consortium – is explored later in this chapter.

Figure 27: Summary of the main outcomes projected for the various scenarios

Rows denote scenarios: the reference scenario (top row), and additional efforts as previously described. Higher levels of integration and ambition are towards the bottom of the table. Columns display the outcomes projected by the ensemble of models for each scenario, including trends in both future global biodiversity and sustainability aspects such as crop prices and other environmental impacts of agriculture. For the latter trends, arrows denote the direction and amplitude of relative change projected from 2010 to 2050. Colour codes indicate a sustainability assessment, picturing the distance to target for biodiversity (bending the curve) and crop prices (small decline to reduce food insecurity while limiting pressure on producers) and positioning with respect to planetary boundaries for other environmental impacts (above boundary for red colours, within uncertainty range for yellow, and below boundary for green), inspired from Figure 2 of Springmann et al. (2018)[55].

DIFFERENT WAYS TO GET TO THE FUTURE WE WANT

Complementing the roadmap emerging from the Bending the Curve Initiative, other new modelling has evaluated the effectiveness of two contrasting conservation planning strategies, each combined with measures to meet global climate and food security targets. Both are able to bend the curve of biodiversity loss, but this is only possible when combined with strong climate mitigation.

Jelle Hilbers
(Institute for Water and Wetland Research, Radboud University, Nijmegen, The Netherlands)

Before COVID-19 stopped the world in its tracks, 2020 was being hailed as a 'super-year for nature' with three major conferences set to determine the pathway for action on climate and biodiversity over the next decade. At the UN Climate Change Conference (COP26) in Glasgow, countries were to submit their new long-term emission reduction goals; the UN Convention on Biological Diversity was to meet in Kunming in China to agree a new framework and targets; and a Leader's Biodiversity Summit was planned for October in New York as part of the UN's 75th anniversary celebrations.

Most of these conferences have been pushed into 2021, but much of the work helping to underpin the decision-making has been done. This included new scenario projections with the IMAGE-GLOBIO framework that explored the ability of two contrasting conservation planning strategies to bend the curve of biodiversity loss, while incorporating measures to safeguard global food security and limit global warming to well below 2°C. By looking at these goals simultaneously, some of the potential trade-offs from climate mitigation could be addressed while exploring the full mitigation potential of land-based measures.

The IMAGE-GLOBIO modelling framework [16, 17] was used to explore the effectiveness of these two contrasting strategies under the assumptions of a business-as-usual trend for population growth and socio-economic development (SSP2). It also aimed to achieve climate change mitigation and food security goals in 2050[18].

Newly threshed rice ready to be brought to a milling area for husk removal, Camarines Sur, Bicol, Philippines.


© Jürgen Freund / WWF

The first of these high-profile conservation strategies – the 'half-Earth' scenario – calls for the expansion of the world's protected areas to cover half of the Earth [9-13]. This strategy is based on the belief that it is best to separate human pressures from nature to bend the curve of biodiversity loss. It relies on what's known as 'land-sparing': that is, promoting wilderness through restoration and the extension of protected and conservation areas.

In contrast, the second conservation strategy – the 'sharing the planet' scenario – aims to support biodiversity while providing goods and services for humanity [14, 15]. This strategy takes the view that it is best to live with and through nature, connecting biodiversity targets with the achievement of a good quality of life. It relies on 'land-sharing' or integrating biodiversity conservation within the agricultural landscape.

In the 'half Earth' scenario, 50% of each ecoregion in the world was protected for biodiversity conservation, while the other 50% was used to sustain human needs. To safeguard food security, this scenario also included the sustainable intensification of agricultural production by, for example, efficient nutrient use, pest management and genetic modification.

The 'sharing the planet' scenario focused on conserving areas that support and enhance the provisioning of various ecosystem services (such as carbon storage, pollination and pest control) by adding high-carbon forests, riparian zones, water towers, peatlands and urban green spaces to current protected areas and key biodiversity areas, covering up to 30% of the global terrestrial area. This scenario relied on agricultural production from advanced agroecology, organic farming, agroforestry and diversified farming systems.

It was found that both conservation strategies have the potential to reverse the trend of biodiversity loss, but only in combination with a broader set of sustainability measures aimed at mitigating climate change and safeguarding food security. These include production measures in agricultural and energy systems (e.g. increasing agricultural productivity) as well as consumption-based measures (such as reducing food waste and animal product consumption). With this full package of measures, losses in local compositional biodiversity intactness (as measured by the mean species abundance indicator) were reversed in 2030 and numbers increased to similar or higher values in 2050 compared to 2015, while the number of people at risk of hunger decreased and the global temperature increase was kept well below 2°C.

Modelling like this can help us to understand the effectiveness and potential trade-offs of different actions and to make choices on the pathway forwards. The ‘half Earth’ strategy slightly outperformed the ‘sharing the planet’ strategy in terms of biodiversity restoration, while ‘sharing the planet’ was more beneficial in terms of ecosystem service provisioning, food prices and food security. These results suggest a need to combine both conservation strategies, such that areas strictly protected for biodiversity conservation are surrounded by human-used land that is managed favourably for biodiversity and ecosystem services provisioning [15].

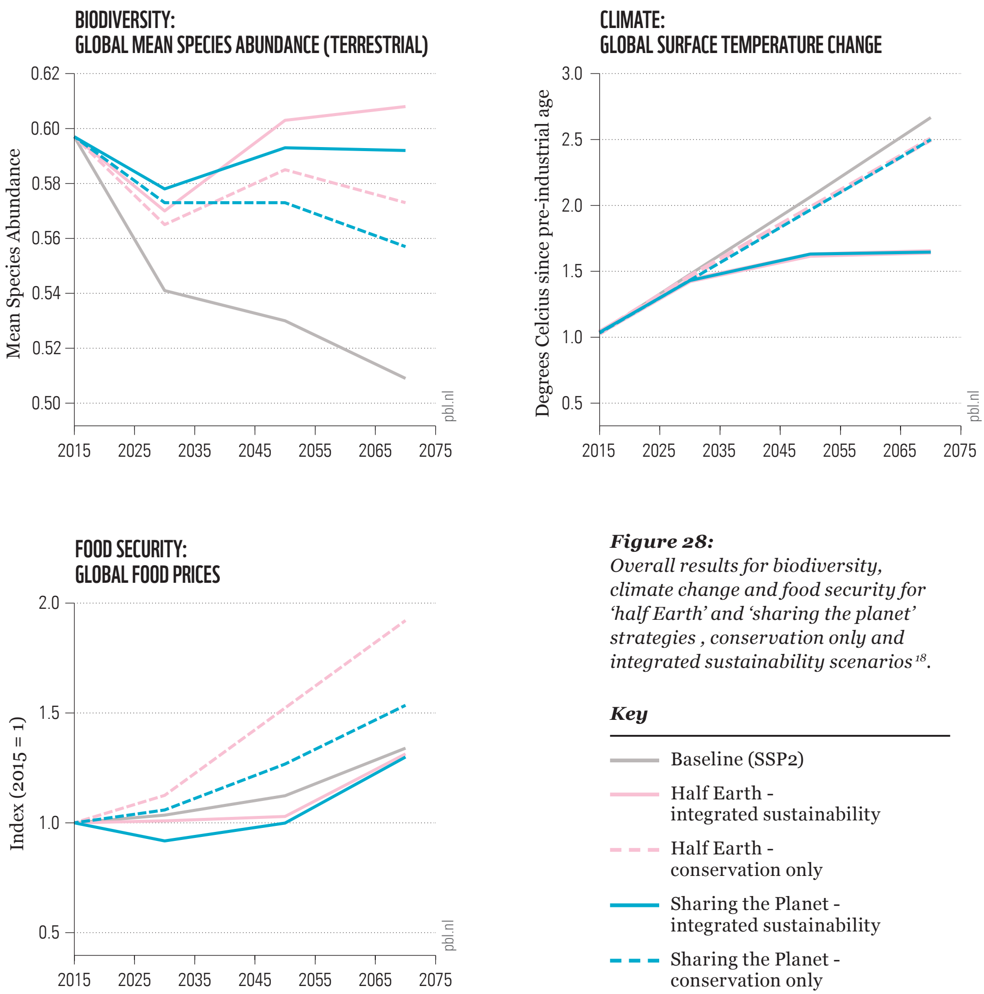


Figure 28:
Overall results for biodiversity, climate change and food security for ‘half Earth’ and ‘sharing the planet’ strategies , conservation only and integrated sustainability scenarios [18].

The future predicted rise of biological invasions

In contrast to other major drivers of global biodiversity loss, the lack of models and scenarios of biological invasions severely hampers the evaluation of ongoing and future rises in invasive alien species numbers.

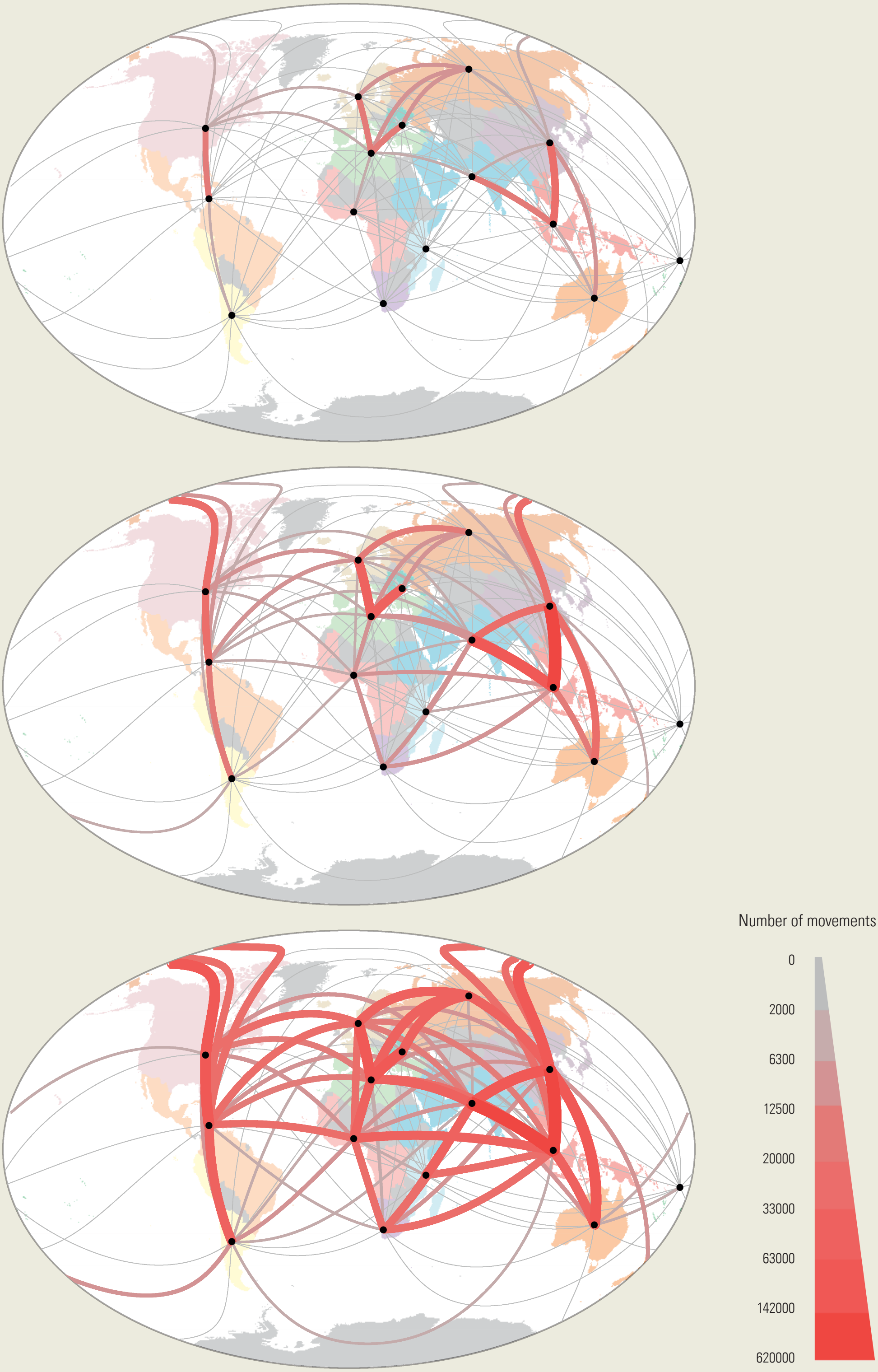
Bernd Lenzner, Guillaume Latombe and Franz Essl (University of Vienna), Hanno Seebens (Senckenberg Biodiversity and Climate Research Centre) and Brian Leung (McGill University)

Alien species numbers are rising unabatedly, having increased by 37% since 1970 without signs of saturation [1]. Invasive alien species pose major threats to global biodiversity [2], ecosystem services [3] and human livelihoods [4]. Consequently, there is an urgent need to project and evaluate future trajectories of their accumulation, abundances and impacts, which are currently absent from global biodiversity modelling initiatives [5].

The AlienScenarios consortium is currently developing the first qualitative and quantitative global scenarios of biological invasions until 2100 [6] and investigating the effect of different drivers. For instance, global shipping – which today accounts for 90% of world trade [7] – will increase by up to >1,200% under alternative scenarios (Figure 29) [8]. This may result in a three- to twentyfold increase in marine invasions and highlights the importance of international policies to bend the curve. Other socio-ecological drivers need comparable analyses in the context of invasive alien species, and these scenarios will provide crucially needed insights for policy and management.

Figure 29: Current and projected future global shipping network under two different Shared Socioeconomic Pathways scenarios [8]

Shipping networks in 2014 (top), in 2050 under the lowest-case traffic growth (SSP3 – the Regional Rivalry pathway, middle) and under the highest-case traffic growth (SSP5 – the Fossil-fuelled Development pathway, bottom). The predicted change illustrates the potential future risk of invasive alien species introductions from shipping alone.


Number of movements
0
2000
6300
12500
20000
33000
63000
142000
620000

ZOOMING IN: COUNTRY-LED MODELLING TO ACHIEVE LONG-TERM SUSTAINABILITY IN FOOD AND LAND-USE SYSTEMS

Global modelling needs to be implemented at a local level. Country-led analyses indicate that reversing biodiversity decline is possible after 2020 with targeted national strategies, ranging from dietary changes to restrictions on land conversion.

Aline Mosnier (Sustainable Development Solutions Network), Sarah Jones (Bioversity International, Parc Scientifique Agropolis II), Jordan Poncet (Sustainable Development Solutions Network) and the FABLE Consortium

Many governments are currently revising the ambition of their climate and biodiversity strategies. To be effective, these will need to include measures to support a transformation towards sustainable land-use and food systems, and consider the impacts of international trade. Yet most countries lack the integrated analytical models to understand and address the complex synergies and trade-offs involved.

The Food, Agriculture, Biodiversity, Land-Use, and Energy Consortium (FABLE) is a knowledge network of national institutions from 20 countries aiming to fill this gap by preparing integrated, long-term pathways that describe options for achieving mid-century sustainability objectives at the national level [19, 20].

FABLE's 2019 and preliminary 2020 results [19, 20] suggest that substantial progress can be made towards achieving targets on biodiversity conservation, greenhouse gas emissions reductions from agriculture and land-use change, and food security by 2050. These results incorporate nationally based assumptions on the feasibility of transformation, including assumptions on dietary shifts, the evolution of productivity, and afforestation targets.

Our 2019 results show that at least 50% of the Earth's terrestrial area could be managed to support biodiversity conservation by 2050. This target for biodiversity conservation could be achieved while also ensuring food security, reducing carbon emissions, and supporting reforestation initiatives. Major caveats are that we do not consider biodiversity supported by habitat on agricultural land, the management intensity of grassland, or uncertainties related to rates and levels of biodiversity reestablishment on afforested and abandoned agricultural land.

Achieving these objectives by 2050 will require spatially explicit national actions, such as establishing effective protected areas [21, 22], reforested land [23], and multifunctional working landscapes [24, 15]. FABLE, in collaboration with the Nature Map Initiative [25], local experts and other stakeholders, is developing a methodology to prioritise areas for future protection and restoration as part of each national pathway.

Pathways for sustainable food and land-use systems in Ethiopia

The long-term pathway for Ethiopia draws heavily from the country's Climate Resilient Green Economy strategy, its Growth Transformation Plan II, the Agricultural Growth Program, and targets from the Bonn Challenge, a global effort to restore 350 million hectares of the world's deforested and degraded lands by 2030. Using the FABLE Calculator [26], our 2019 results show that more than 60% of Ethiopia's land could support biodiversity in 2050 [27]. Higher demand for animal products leads to pasture expansion but a strong increase in crop productivity frees some cropland area after 2030, which becomes available for afforestation and natural vegetation regeneration. We used these findings as a basis to engage with national stakeholders and experts to further refine our model and pathway for Ethiopia for the 2020 FABLE Report.

MODELS AND SCENARIOS SHOW A SEA CHANGE ON THE WAY

As with land-based projections, marine modelling scenarios show that climate change and other human activities are posing serious risks to the conservation of marine life and the sustainability of fisheries in the 21st century and beyond.

William W. L. Cheung
(Institute for the Oceans and Fisheries, The University of British Columbia)

Relative to pre-industrial times, sea levels around the globe are rising and our oceans are warmer, more acidic and losing oxygen. These changes are linked to greenhouse gas emissions from human activities and are predicted to continue into the 21st century[28].

More specifically, based on an ensemble of 10 Earth system models, net primary production from phytoplanktons is projected to decrease by 4-11% by the end of this century relative to 2006-2015 under the no mitigation, high greenhouse gas emissions scenario[29]. Given that this net primary production is the ultimate source of energy supporting most marine food webs in the open ocean, including deep-sea ecosystems, its decrease would reduce ecosystem productivity and impact ecosystem functions. In coastal regions, for example, in a 2°C warmer world relative to pre-industrial levels[29], warming and sea level rise are projected to put sensitive ecosystems – like coral reefs, seagrass beds and kelp forests, that support a vast diversity of marine life and important ecosystem services such as fisheries – at a high to very high risk of negative impacts.

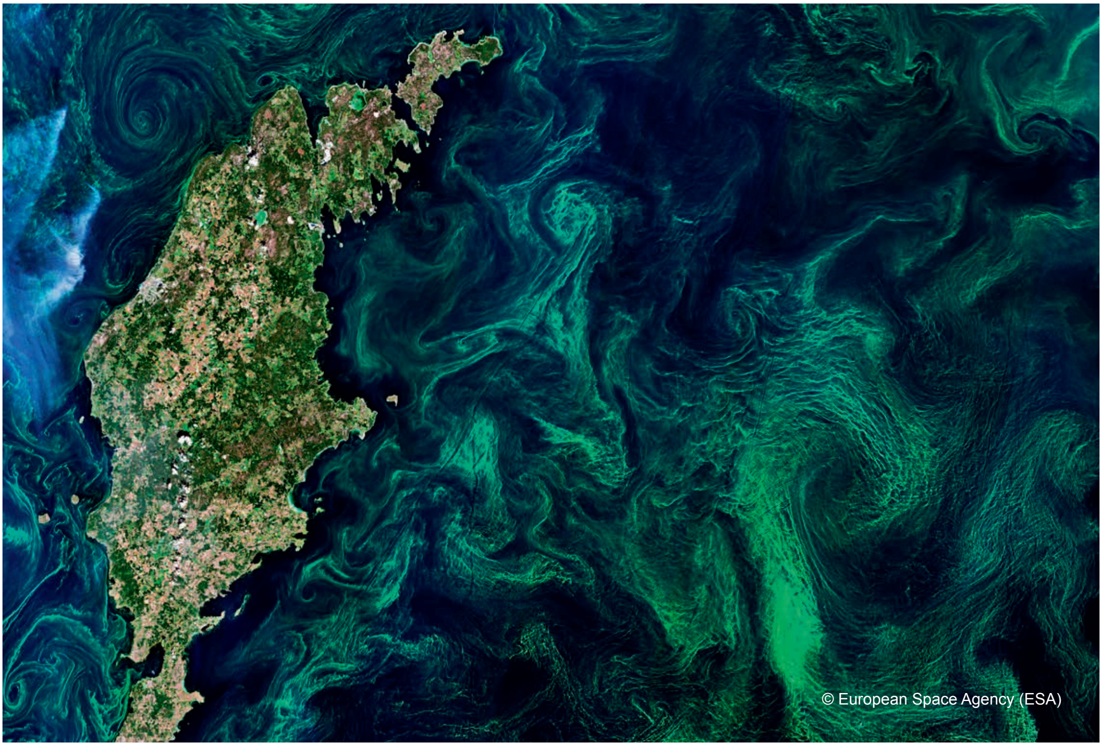
Climate change will impact the distribution and abundance of fishes and invertebrates as their biology is closely related to environmental conditions such as temperature and oxygen level, challenging the long-term conservation of marine biodiversity. Exposed to multiple climatic and non-climatic hazards in the ocean, many marine fishes and invertebrates, including those that are already under threat, are projected to be at risk of local, and potentially global, extinction[30]. Multiple marine species and ecosystem models project that the global biomass of marine invertebrates, fishes and non-fish vertebrates will decrease by around 4.3% under a strong mitigation, low greenhouse gas emissions scenario and 15% under a no mitigation, high emissions scenario by the end of this century relative to 1986-2005[31];

with species also shifting their distributions by hundreds to thousands of kilometres from their current ranges.

Global decreases in ocean productivity, the falling biomass of fishes and invertebrates, and shifts in species distributions result in the high risk of impacts on many fisheries in the future. Global fisheries models project large decreases in maximum fisheries catch potential (a proxy of maximum sustainable yield) of 20-24% by 2100 relative to 1986-2005, with more widespread declines in the tropics, under the no mitigation scenario. Changes in the availability of fishes under climate change are projected to have substantial ramifications for the economy, seafood security and livelihoods of dependent human communities; translating, for example, into a global decrease in seafood workers' incomes and an increase in households' seafood expenditure [32]. Increasing human population, economic wealth and consumption will drive a further increase in demand for seafood, putting additional pressure on fish stocks and fisheries.

Models and scenarios for the sea highlight the importance of climate mitigation and the reduction of other human stressors like overfishing and plastic pollution, accompanied by local adaptation, to secure the long-term conservation of marine biodiversity and the sustainability of fisheries.

An algal bloom in the Baltic sea captured by the Copernicus Sentinel-2 mission satellites.



MAKING CONNECTIONS FROM LAND TO SEA

We need an integrative understanding of land-sea interactions to capture missing feedbacks and trade-offs in human impact scenarios.

Julia Blanchard (University of Tasmania), Duncan Cameron (University of Sheffield) and Richard Cottrell (University of California Santa Barbara)

Land and sea ecosystems are intrinsically connected, but these links are often ignored in scenario modelling that looks at a range of possible futures of land-use change. It's true that state-of-the art global land and sea use models both use complex combinations of 'big data', often with shared input sources like remote sensing and Earth system models. However, scenario modelling of changes in human activities, in the sea and on land, is largely carried out separately, with limited feedbacks to the connected ecosystems that underpin them [33, 34].

We know that food production systems are major drivers of biodiversity loss, both on land and in the sea, exemplifying these hidden interconnections [35] – two examples are agricultural runoff into coastal and marine ecosystems, and the use of wild-capture fisheries for fertilisers and feed on land. Climate change creates feedbacks among these linkages, as food production produces emissions that impact the climate system, which in turn alters the environment, habitats and biodiversity that support resilient food production.

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Shifting diets from land-based to more environmentally efficient ocean-based protein has been proposed as one leverage point for climate mitigation [36]. Scenarios shifting towards marine diets, via aquaculture growth, have been shown to spare land and marine feed resources compared to business-as-usual practices [37]. However, the broader impacts of changes in food demand on marine ecosystems are not well understood. Given the threats to biodiversity already present in the ocean, care needs to be taken to ensure any shift would not create perverse biodiversity outcomes or create inequities in food and nutrition [33, 38].

There are growing attempts to bridge these knowledge gaps; however, much of the work addressing the land-sea interface has, as yet, only been carried out at regional catchment scales [39, 40]. Developments in global modelling of nutrient flows from a variety of human activities on land to coastal systems [41] are promising, but the links to ecosystem responses across the land-ocean continuum are still missing. These critical gaps need to be accounted for if we are to understand and predict the consequences and trade-offs of changing human activities for the planet.

Climate change projections show that food production shocks across sectors are increasing, and are likely to worsen as extreme events such as marine heatwaves and drought become the 'new normal' [42]. What this means for the overall food system, and underlying biodiversity and ecosystem processes, is not yet well understood. Scaling up assessments of the environmental impacts of food systems [43], by mapping synergies and trade-offs of biodiversity protection on human well-being, could help us to better understand the influence of feedbacks on sustainability pathways [44].

An aerial view of the Atlantic coastline in Gabon.

THE PATH AHEAD

The *Living Planet Report 2020* is being published at a time of global upheaval, yet its key message is something that has not changed in decades: nature – our life-support system – is declining at a staggering rate. We know that the health of people and that of our planet are increasingly intertwined; the devastating forest fires of the past year and the ongoing COVID-19 pandemic have made this undeniable.

The Bending the Curve modelling tells us that, with transformational change, we can turn the tide of biodiversity loss. It is easy to talk about transformational change, but how will we, living in our complex, highly connected modern society, make it a reality? We know that it will take a global, collective effort; that increased conservation efforts are key, along with changes in how we produce and consume our food and energy. Citizens, governments and business leaders around the globe will need to be part of a movement for change with a scale, urgency and ambition never seen before.

We want you to be part of this movement. For ideas and inspiration, we invite you to explore our *Voices for a Living Planet* supplement. We have invited thinkers and practitioners from a range of fields in many countries to share their views on how to bring about a healthy planet for people and nature.

Voices for a Living Planet complements the themes of the *Living Planet Report 2020* by reflecting a diversity of voices and opinions from all over the globe. Covering ideas ranging from human rights and moral philosophy to sustainable finance and business innovation, it provides a starting point for hopeful conversations, food for thought and ideas for a future in which people and nature can thrive.

We hope it will inspire you to be part of the change.

Children walking in the Forest Landscape Restoration HQ and nursery in Rukoki Sub-County, Kasese District, Rwenzori Mountains, Uganda.

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Chapter 3: People and nature are intertwined

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Chapter 4: Imagining a roadmap for people and nature

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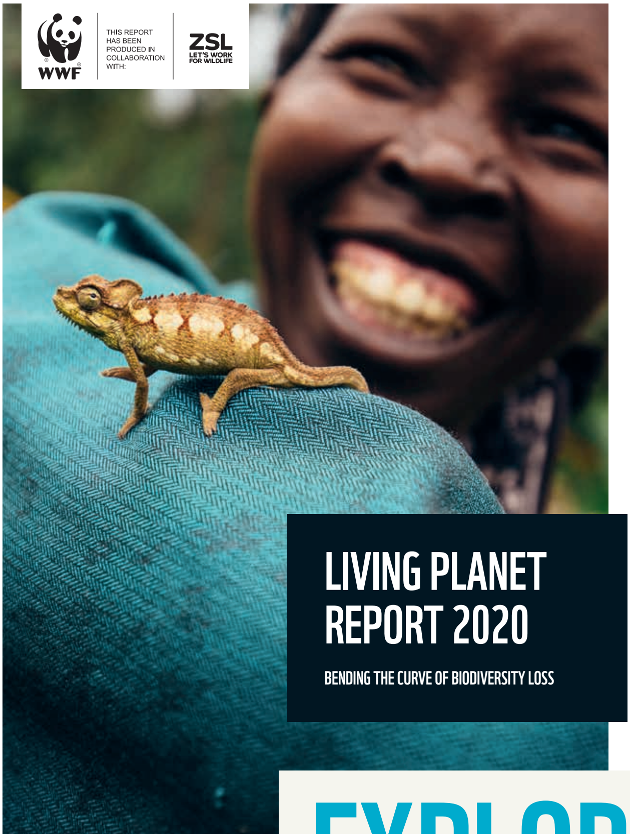

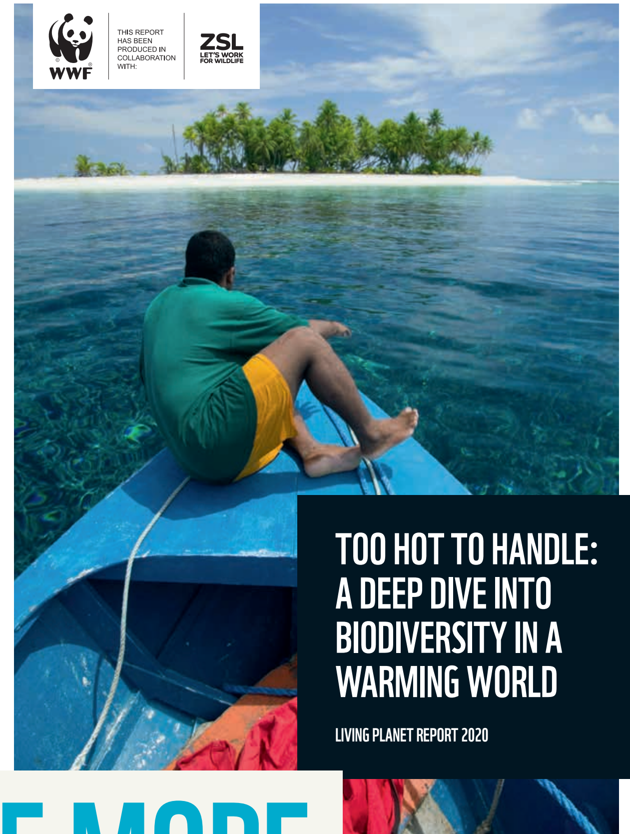

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Publication details

Published in September 2020 by WWF – World Wide Fund for Nature (Formerly World Wildlife Fund), Gland, Switzerland ("WWF").

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Recommended citation:

WWF (2020) *Living Planet Report 2020 - Bending the curve of biodiversity loss.* Almond, R.E.A., Grooten M. and Petersen, T. (Eds). WWF, Gland, Switzerland.

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