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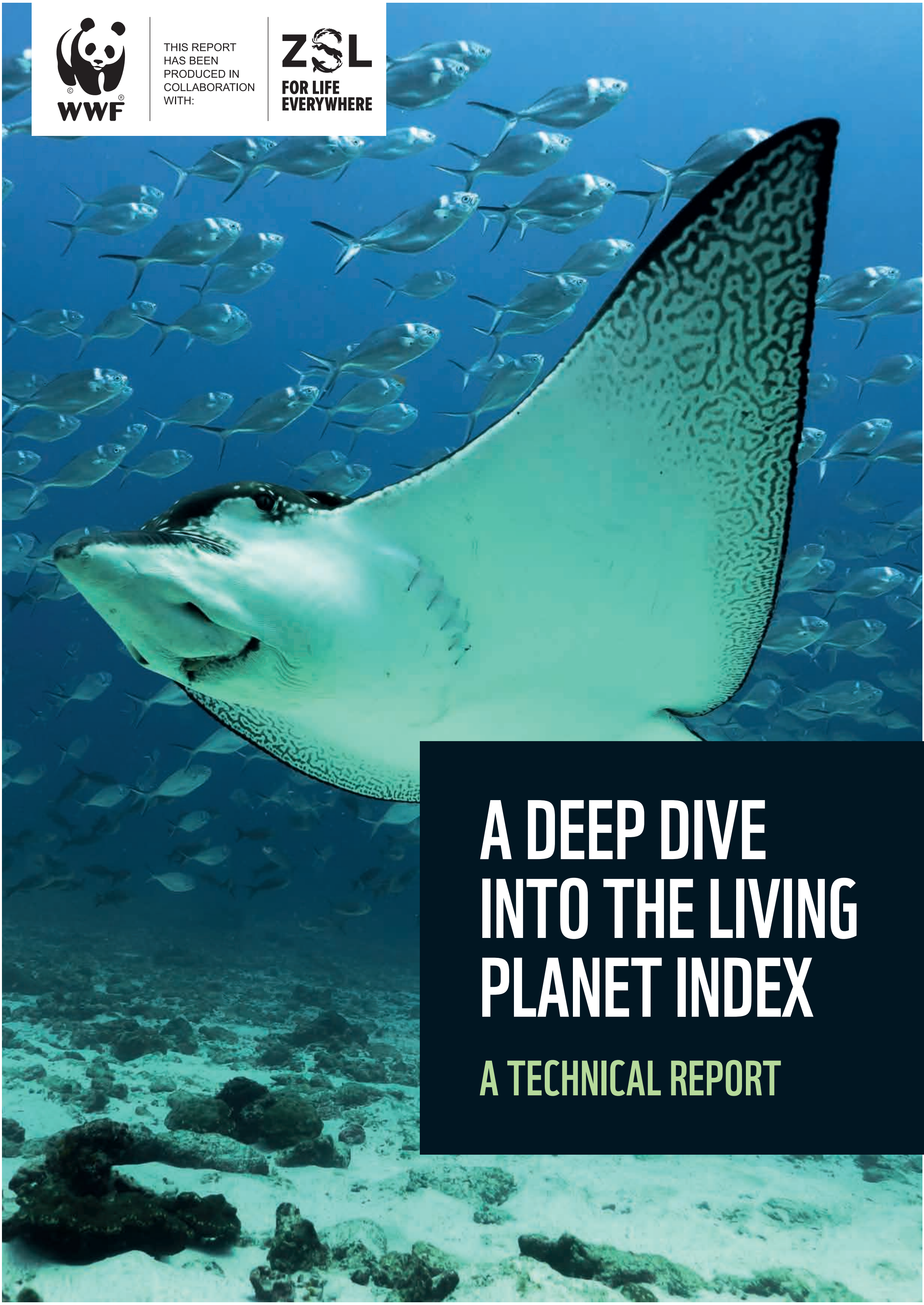

A DEEP DIVE INTO THE LIVING PLANET INDEX

A TECHNICAL REPORT

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WWF is an independent conservation organisation, with more than 35 million followers and a global network active through local leadership in over 100 countries. WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which people live in harmony with nature, by conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

ZSL (Zoological Society of London) Institute of Zoology
ZSL is a global science-led conservation organisation helping people and wildlife live better together to restore the wonder and diversity of life everywhere. It is a powerful movement of conservationists for the living world, working together to save animals on the brink of extinction and those which could be next.

ZSL manages the Living Planet Index in a collaborative partnership with WWF.

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Spotted eagle ray (*Aetobatus narinari*) swimming near the ocean floor near Darwin Island, Galapagos Islands.

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THE LIVING PLANET INDEX: AN EARLY WARNING INDICATOR

This year's *Living Planet Report* is filled with ground-breaking figures, with most of the indicators describing a tremendous decline in ecosystem health. The calculation of the Living Planet Index shows an average **69%** decline in population sizes of monitored mammals, birds, amphibians, reptiles and fish since the year 1970 (Figure 1). Just as the R-number in epidemiology describes a virus's ability to spread, and gross domestic product (GDP) reflects a country's economic growth or decline, the Living Planet Index is a multifaceted metric that indicates the state of biodiversity on our planet.

This metric is calculated by compiling extensive datasets on animal population sizes from all over the globe – and it reveals that populations, on average, are less than one-third of the size they were in 1970. Here, we tell the story behind the development and results of the Living Planet Index and dive deeper into the features of this unique biodiversity indicator.

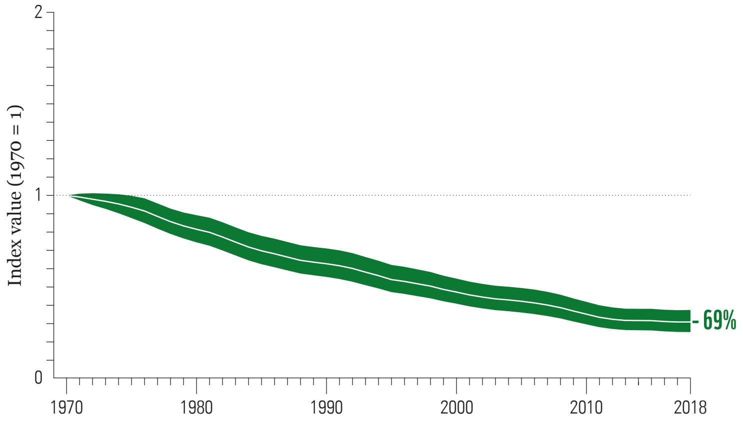


Figure 1: The global Living Planet Index (1970 to 2018)
The average change in relative abundance of 31,821 populations, representing 5,230 species monitored across the globe, was a decline of 69%. The white line shows the index values and the shaded areas represent the statistical certainty surrounding the trend (95% statistical certainty, range 63% to 75%). Source: WWF/ZSL (2022)[1].

Key

Global Living Planet Index

Confidence limits

Common cranes (*Grus grus*) looking for food.

WHY THE LIVING PLANET INDEX?

THE ABILITY IT GIVES US TO SEE POPULATION TRENDS OVER THE PAST 50 YEARS IS WHAT MAKES THE LPI EXTREMELY VALUABLE – THIS 'EARLY WARNING SYSTEM' SHOWS US IF SPECIES ARE THRIVING OR FADING, BOTH LOCALLY AND GLOBALLY, AND GIVES US KNOWLEDGE ON WHERE TO ACT.

To help protect nature, we need to understand the patterns of increase and decrease in animal diversity and abundance that occur over time and in different places.

The Living Planet Index (LPI) was developed in 1997 to get a grasp on environmental change[2], with the primary aim of measuring the changing state of the world's biodiversity over time. To do so, the LPI uses wildlife population data from multiple years to calculate average rates of change in a large number of species, in terrestrial, freshwater and marine systems. It is currently based on data from the year 1970 until 2018 for a total of 31,821 populations of 5,230 species from around the globe.

Compiling the data for all populations in the LPI worldwide shows a decreasing trendline, with an average decline of 69% in population sizes between 1970 and 2018. However, separating the data into different regions and ecosystems shows more detail – in some years and in some regions, we see small increases in population sizes, while other regions show stronger and faster declines in population size.

Using a formula developed by the Zoological Society of London (ZSL) in collaboration with WWF, the trends in species population sizes are combined to produce the LPI[3].

In this years' *Living Planet Report*, the index is divided into five regions following the geopolitical boundaries of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) – namely Africa; North America; Latin America and the Caribbean; Asia and the Pacific; and Europe and Central Asia. The IPBES division is geared towards an efficient assessment of whole continents, and is made to strengthen the science-policy interface at a large scale[4].

Besides these five IPBES regions, the LPI data can be separated in many different ways. For example, the 2022 *Living Planet Report* shows index values for sharks and migratory fish species, which allows us to see group-specific population trends. But the LPI data can also be subdivided into biogeographic realms, ecosystems, specific habitats and many other categories. This gives us a better and more detailed understanding of how biodiversity is changing in different parts of the world.

What is the Living Planet Index?

The LPI is basically a 'tool' that serves a purpose – a purpose that was defined 30 years ago. In 1992, the United Nations' Convention on Biological Diversity was adopted and many government leaders pledged to promote sustainable development and the preservation of biological diversity[12]. Specific targets were set, and countries translated these into national biodiversity strategies and action plans. To monitor progress towards these 'Aichi' biodiversity targets[13], established during the last Convention of the Parties in Japan in 2010, a number of new and existing indicators were used – of which the LPI is one[14].

Each indicator reflects a specific trend or status and is a useful instrument for understanding how animals and ecosystems are affected by human pressures, and how to prioritize conservation efforts. While the LPI measures the relative abundance of thousands of vertebrate populations around the world, other indices measure, for example, extinction risk or include other taxonomic groups. These indicators all have one thing in common: they all show that biodiversity has declined over recent decades[15].

The most recent time period for achieving agreed global biodiversity targets ran from 2011 until 2020, yet none of the targets were fully met[16]. The preparations for the next assessment – 'the post-2020 global biodiversity monitoring framework' – are in full swing and will be finalized during the UN Biodiversity Conference in Canada at the end of this year. The LPI is, once again, one of the indicators that will be used to monitor progress towards new global biodiversity targets.

Key definitions

The LPI is created based on multiple time-series of population size, density, and abundance (or a proxy of abundance) in order to reveal changes in biodiversity. To interpret the results of the LPI correctly, let's define these commonly used terms.

Biodiversity[17]**:** biological diversity – or biodiversity – is the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Species: a group of similar individuals that are capable of reproducing fertile offspring. For example, all whale sharks (*Rhincodon typus*) belong to the same species. There are exceptions to this definition, as some species can breed with other species and create offspring while still being considered separate species based on dissimilarities in their genetics.

Population (definition as is used to calculate the LPI): a population is a group of animals who belong to the same species, living at the same place at a certain time where they have been surveyed over time. There can be multiple populations of one species, based on where they live. For example, whale sharks that live in the Indian Ocean belong to a different population than whale sharks that live in the Caribbean Sea.

Population size: population size can be the total number of individuals per unit area or volume. It is often very difficult to catch or count 100% of the population in a natural environment; in these cases a sample number of individuals are counted and extrapolated to a larger area.

Population density: population density is determined by the average number of individuals of one species per specific unit of area (e.g. 0.1 whale shark per square mile). Population density is often used to describe the location, growth and migration of animals. A high population density means there are many individual animals together in an area, while a low population density means there are few individual animals in one area. Average population densities differ across species.

Abundance: population abundance is the number of counted individuals per sample. For example, three whale sharks per area of monitored ocean. By counting the number of individuals of a species at a given study site, and extrapolating based on habitat suitability for that species, it can give a relative representation of a species' population size in a particular ecosystem.

Proxy of abundance: a proxy is a feature created by an animal that gives an indication of its presence, which can be used to count animal abundance instead of seeing the actual animal. For example, a bird's nest instead of the bird, or the excrements of a tiger instead of the tiger itself.

Relative abundance: relative abundance refers to the rate at which wildlife populations are changing over time on average. Some of these populations may contain many individuals, some very few, but it is the average relative change that we are trying to measure, rather than the total change in absolute numbers of individual animals.

Confidence intervals: these are calculated each time an index value is produced. A technique called 'bootstrapping' is used to resample the species trends in each LPI and produce an upper and lower estimate of the index calculation. This illustrates the amount of variation in the underlying species trends: wider confidence intervals represent more variation.

RESULTS OF THE NEW LIVING PLANET INDEX

We want to see what trends are visible in wildlife populations across the globe, and the magnitude of these trends – and this is exactly what the LPI shows. Let's zoom in to the results of the population trends per IPBES region (Table 1).

Terrestrial and freshwater populations are used to calculate the five regional LPIs. The original IPBES assessment is based on four regions, considering the Americas as a whole, but we have split these continents into two groups – one for North America, and one for Latin America and the Caribbean – due to large differences in population trends per subregion.

Table 1: The results from the 2022 global Living Planet Index
For this year's index values, the LPI database is divided into several subsets. Each subset contains a different number of species and shows a different average percentage of change in population size over time. Source: WWF/ZSL (2022)[1].

		Number of species	Percentage change 1970 - 2018	95% confidence limits	
				Lower	Upper
Global	Global	5,230	-69%	-75%	-63%
Systems	Freshwater	1,398	-83%	-89%	-74%
IPBES regions	Africa	510	-66%	-84%	-27%
	North America	952	-20%	-43%	13%
	Latin America and the Caribbean	1,261	-94%	-96%	-89%
	Asia and the Pacific	729	-55%	-73%	-26%
	Europe and Central Asia	627	-18%	-40%	13%
Freshwater migratory fish		247	-76%	-88%	-53%

Europe and Central Asia

The Europe and Central Asia LPI shows an average population decline of 18% from 1970 to 2018. This is the smallest decline of all the IPBES regions, but it is important to remember the context of the 1970 baseline – nature had been transformed to a large degree prior to 1970, so the LPI shows trends for many species that were already in a depleted state. Fortunately, some populations are recovering and this year's LPI shows more positive trends among bird and mammal populations. However, on average, the amphibian, reptile and freshwater fish populations are declining.

Asia and the Pacific

The Asia and the Pacific LPI shows a near continuous decline between 1970 and 2018, with an average decline in monitored populations of 55%. Average declines across all taxonomic groups in this region are observed.

Africa

The Africa LPI shows a decline of 66% between 1970 and 2018. The decreasing trend is consistent throughout the time period, with stronger declines on average for mammals and freshwater fishes. The wider confidence intervals (i.e. estimated statistical accuracy) are due to the inclusion of more freshwater fish data. Fish population trends can be quite variable, due in large part to fluctuating population sizes which can 'boom and bust' from year to year.

North America

The North America LPI shows a declining trend from 1970 to 2000. After this time, the trend stabilizes and there is an increasing trend from 2014 to 2018, resulting in an average 20% decline over the 48-year time period. While it is too early to say that species numbers are significantly increasing, it is an encouraging sign that there may be some population recoveries in North America. It is important to note that the 1970 baseline refers to a time when wildlife abundances in North America had already been impacted by human activities for many decades. Bird trends are the most stable of the taxonomic groups, whereas mammals, freshwater fishes, and amphibians and reptiles show more negative trends, although a recent increase in the latter two groups has been seen.

Latin America and the Caribbean

The trend in the Latin America and Caribbean LPI is the strongest decline among all the regions – a 94% decrease between 1970 and 2018 which is sustained throughout the entire time period. Average declines are seen across all taxonomic groups but are most profound in freshwater fishes, reptiles and amphibians.

Population trends by region

It is important to note that the LPIs for IPBES geographic regions should not be directly compared with each other, since a) the regional trends are based on different sets of species and the amount of data available for each region varies; and b) we consider the year 1970 as a baseline for the LPI trends, but this provides a different starting point in biodiversity and population sizes for each region.

For some regions, pressures had been impacting species and habitats for many decades prior to 1970 – so while the declines in these regions are not as steep, it doesn't mean that populations aren't declining. Conversely, other regions started with more biodiversity and larger populations in 1970 but are now experiencing more rapid changes to their ecosystems.

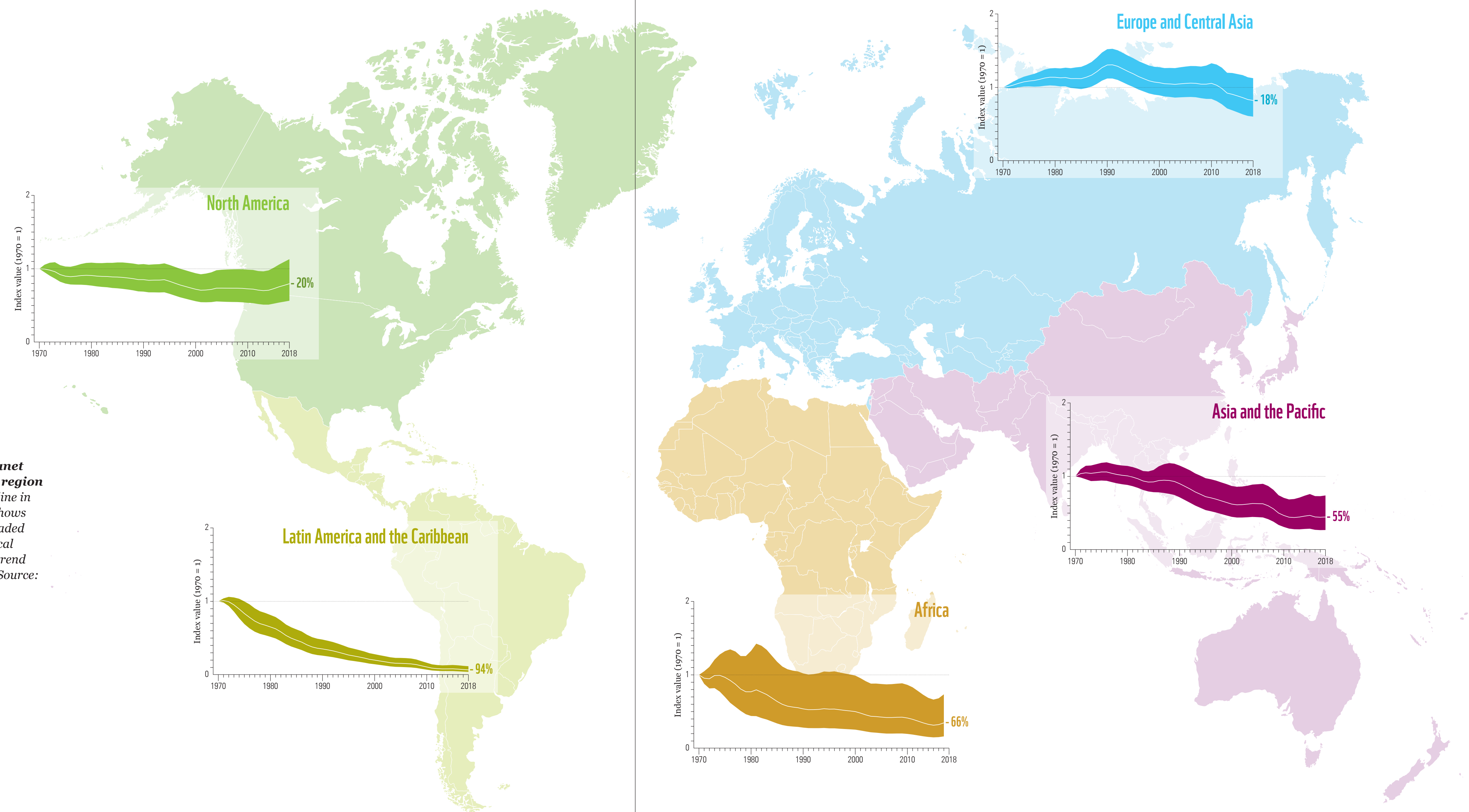


Figure 2: The Living Planet Indices for each IPBES region
For each region, the white line in the LPI graphs on the left shows the index values and the shaded areas represent the statistical certainty surrounding the trend (95% confidence interval). Source: WWF/ZSL (2022)[1].

Population threats by region

There are many types of threats that can affect species, and by investigating the relationships between population trends and threats we can start to understand which species are most vulnerable and where. The LPI data has been used to explore five different threats that have been recorded for some of the terrestrial and freshwater populations in each region (Figure 4).

Habitat degradation and loss is most commonly recorded as the main threat to populations in each IPBES region, and *species overexploitation* is the second most recorded threat.

Africa shows almost equal proportions for habitat degradation and overexploitation as the reason for population change. The impact of *invasive species and disease* is also frequently reported, with the highest numbers recorded in Asia and the Pacific and North America. Other common threats in each region are *environmental pollution* and *climate change*.

Data on the most prevalent threats is only available for a subset of the populations within each region (some populations face no threats, and for others we have no information on what they may be threatened by), so the information here represents an indication of what the main threats are.

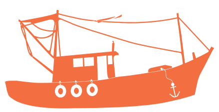
Loggerhead turtle hatchlings (*Caretta caretta*) emerge after 47-66 days of incubation and head out to sea.

Regional threats to populations in the LPI

Habitat loss and degradation

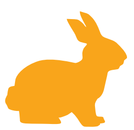
This refers to changes in land or water use in the area where a species lives, leading to complete removal, fragmentation or reduction in quality of its key habitat. Common changes in land use are caused by unsustainable agriculture, logging, transportation, urban development, energy production and mining. 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 be predators of native species; or can 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 shift their home 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 by having offspring in a time of scarce food availability in a specific habitat).

Figure 3: 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[5]; it is also followed by the IUCN Red List and is based on the original classification by Salafsky, N. et al.(2010)[6]. Source: WWF/ZSL (2022)[1].

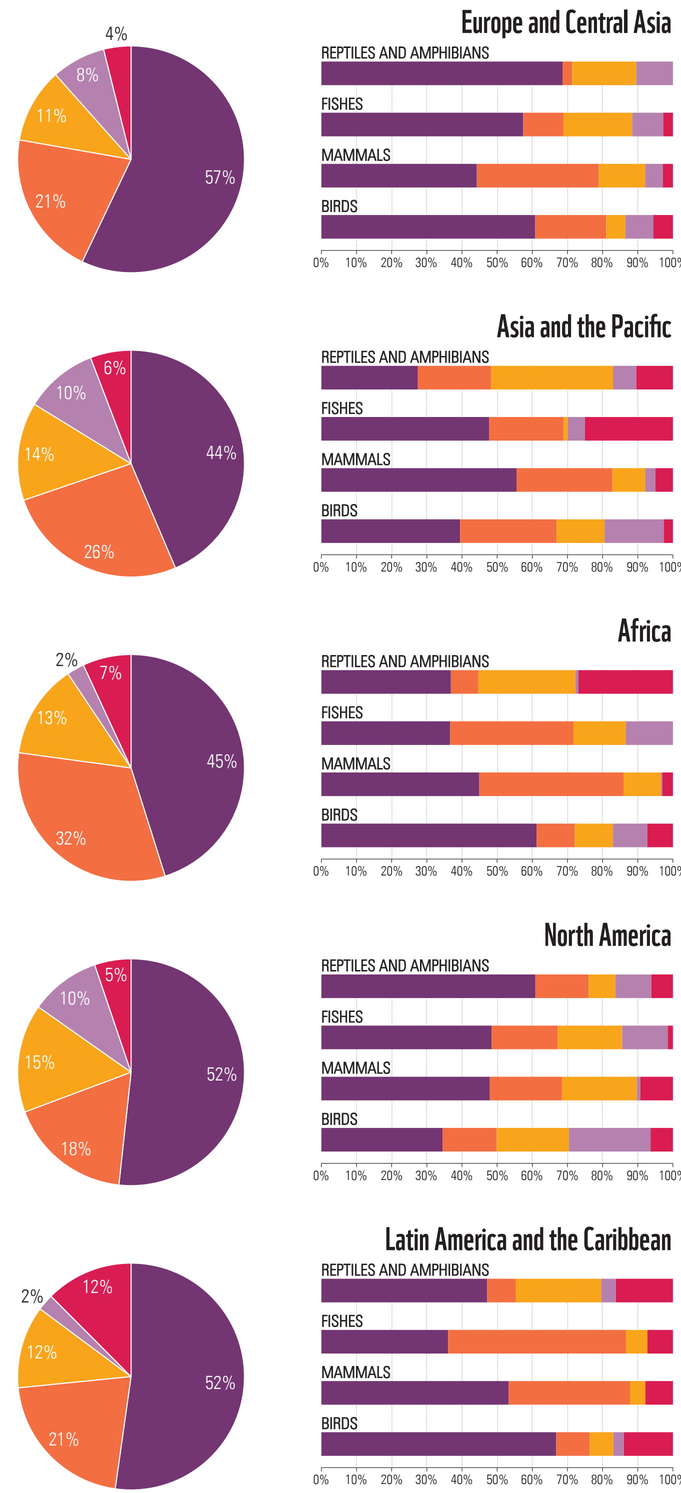


Figure 4: Relative frequency of major threats by taxonomic group
Threat data is available for 2,785 populations in the global LPI database. Each of these populations could be associated with up to three different threats. There were 4840 threats recorded in all . The pie chart shows threats to populations in each region as a whole. The bar charts break down these threats per taxa. Source: WWF/ZSL (2022)[1].

Key

- Habitat degradation/loss
- Overexploitation
- Invasive species and disease
- Pollution
- Climate change

INTERPRETING THE LIVING PLANET INDEX CORRECTLY

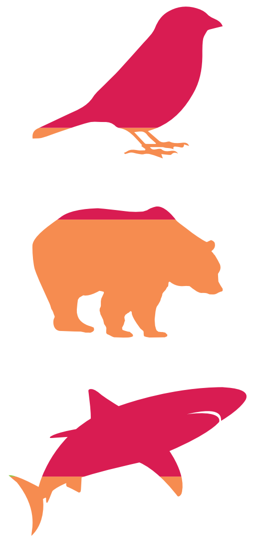
LPI results are calculations of average trends in population size over time. In the case of the global LPI, this means that some populations and species are faring worse than the average 69% decline, whereas others are not declining as much or are increasing (Figure 5). In fact, approximately half the populations show a stable or increasing trend, and half show a declining trend.

Depending on how the existing data are grouped – per region, per ecosystem, per species – we can see trends with different directions and magnitude.

The LPI indicates the average trend in population size over time per chosen area and/or species group. In other words, it shows if there is an average increase or decrease overall in populations of one species or several species compared to data from 1970, the year that was established as a baseline for population sizes.

The tables below show that although the average percentage change of the trend represented is 50%, the total number of animals in the three combined populations has not declined by this much, so we haven't lost 50% of animals.

Figure 5: Does the trend in the global LPI mean we have lost roughly two-thirds of all animals?
An illustration of how the average percentage change of the trend differs from the change in total number of animals lost (in percentage). WWF/ZSL (2022)[1].



	Bird population	Bear population	Shark population
Initial population size	25	50	20
Final population size	5	45	8
Number of animals lost	20	5	12
Percentage change	-80%	-10%	-60%

Initial population size (total)	95
Final population size (total)	58
Number of animals lost (total)	37
Number of animals lost (%)	39%
Percentage change (average)	-50%

What does the index tell us?

Grasping the concept of global population declines is complex, especially when it lumps a large number of species together. Yet this is exactly what the LPI is for – calculating global average population declines. But what does this actually mean? Below is a table of index features which corrects common misconceptions: what the LPI *does* and *does not* show.

What the LPI shows

- The LPI shows the average rate of change in animal population sizes.
- Species and populations in the LPI show increasing, declining and stable trends.
- About half of the species we have in the LPI show an average decline in population trend.
- The average change in population size in the LPI is a decline of 69%.
- The LPI represents the monitored populations included in the index.
- The LPI includes data for threatened and non-threatened species – if it's monitored consistently over time, it's included in the dataset.

What the LPI does not show

- The LPI doesn't show numbers of individuals lost or extinctions, although some populations do decline to local extinction.
- A declining global LPI doesn't mean that all species and populations are in decline.
- The LPI statistic does not mean that 69% of all species or populations worldwide are in decline.
- The LPI statistic does not mean that 69% of populations or individual animals have been lost.
- The LPI doesn't necessarily represent trends in other populations, species or biodiversity as a whole.
- The species in the LPI are not selected based on whether they are under threat, but on whether there is robust population trend data available.

Strengths and weaknesses of the Living Planet Index

Tracking the world's biodiversity over time is a challenging task. Many elements of the LPI have been improved over time in order to fulfil its primary aim: to show a clear trend in vertebrate population sizes. Here we clarify some of the strengths and remaining challenges that accompany the precision and the interpretation of the LPI [2].

Strengths

- Largest available repository for vertebrate population abundance data.
- Long-term, continuously updated and expanding dataset.
- Includes an increasing proportion of research and publications in languages other than English.
- Publicly available data to support research.
- Method is peer-reviewed.
- Sensitive to annual changes.
- Trends are consistent year after year.
- Method is designed to limit the impact of taxonomic bias.
- Relatively simple to communicate.

Weaknesses

- Does not include invertebrates or plants.
- The method of aggregating the LPI can be sensitive to strong population declines and fluctuations.
- Baseline values differ as not all population studies in the LPI start in 1970 and end in 2018.
- The dataset is biased towards well-studied species groups and regions.

The LPI is based on a considerable amount of data, and new data are continually added and updated to provide the most complete and accurate picture possible of relative trends in population sizes. The LPI shows consistent downward trends each time it is calculated, for each region and ecosystem, which indicates that as new data are added there is greater certainty in the LPI trend after each update.

Some existing indicators of biodiversity trends rely on publicly available data and are prone to bias towards well-studied species groups and regions. This can give misleading estimates of biodiversity trends. To minimize this error, the LPI uses an approach [18] to tackle taxonomic and geographic bias by accounting for the estimated number of species within biogeographical realms, and the relative diversity of species within them.

Extra effort was made this year to include population data from publications written in languages other than English. There is a wealth of scientific literature in other languages which can help improve the representation of data from biodiverse regions in the LPI. As a result of the first phase of this new approach, the latest LPI includes 3,269 populations for 1,002 Brazilian species (575 of which are new to the database).

However, it is important to keep in mind that the LPI does not detect extinctions and can be sensitive to strong declines or increases in population sizes [19, 20]. Another weakness is that not every population size study starts in 1970 and ends in 2018, which means that the amount of population data we have for any given year varies. Unfortunately, only data on vertebrates is included in the current LPI. Once sufficient time-series of invertebrate and plant populations are available, these could also be included in the LPI.

When it comes to animal population studies, we only have information from the species and locations scientists can monitor. This is never every single individual on the planet, so it inevitably leads to some assumptions on how many animals there actually are (and are lost or gained) – and this affects the LPI, which can only tell us something about populations that have actually been monitored. However, predictive versions of the LPI are being developed to help estimate trends in species and regions which are not currently monitored.

From the field: how are the raw data collected?

At the core of the LPI is a large amount of data, which is reliant on the work of very dedicated scientists, conservationists and volunteers who count animals. But not every animal can be seen easily, especially species that live underwater or in extremely remote and inaccessible areas. In order to correctly calculate population sizes over time, various methods were used.

For example, to determine the population size of whale sharks in the Gulf of Mexico, small aeroplanes fly low above the water in a straight line and all observed whale sharks are counted [21]. The area surveyed is calculated as the length of the flight path inside each zone multiplied by the width of the strip surveyed visually (500 m on either side of the aircraft). The total area sampled by year is calculated by multiplying the surveyed area of each zone by the number of flights made per year. This protocol allows for an estimate of whale sharks by year in each zone as an index of relative abundance (sightings per unit effort).

Other examples of how data are collected involve counting animals from camera trap photographs or seen with the naked eye, counting nests of birds in treetops or cliffs, counting the number of excrements along a trail, or any other sign, or *proxy*, that indicates how many animals are present in a specific habitat.

WWF and ZSL have compiled the most reliable peer-reviewed datasets into one integrated, interactive map, which can be found at www.livingplanetindex.org. Here you can click on the different regions with different species, and find the published data on population size, methodology, trends and original authors.

After collecting the data in the field, scientists analyse and publish the results in scientific journals, government reports, online databases, or books, after which WWF and ZSL obtain the data. The populations in the LPI database consist of a minimum of two population estimates (or proxies) in time.

Why we can't compare Living Planet Indices from previous years

One rule in science is that to make a correct comparison between one dataset and another, the data have to be uniform. To compare the 2020 LPI to this year's LPI, the aggregated dataset would have had to stay the same, with exactly the same monitored populations and species, but recounted for two more years. This is not the case, since data from about 11,000 populations and 900 species from various years were added. This makes the 2022 LPI trend more solid and representative of the actual population changes worldwide, which is the ultimate goal of the LPI.

The global 69% average decrease in population sizes is always in comparison to the initial year of the trendline: the year 1970. Since more data is continuously added to the entire LPI dataset, including historical data, the certainty of the LPI is continuously improving. This makes this year's LPI the most comprehensive index value to date. More knowledge brings a more detailed picture of wildlife trends, yet it also means that results from subsequent reports are not completely comparable while using this method.

HOW MANY SPECIES AND POPULATIONS ARE THERE IN THE LIVING PLANET INDEX?

The 2020 Living Planet Report used data from 1970 through to 2016, including 20,811 populations of 4,392 species. That year's LPI showed an average 68% decrease in global population sizes, with the most significant population decreases in Latin America and the Caribbean and the Freshwater habitat. This year's LPI uses data from 1970 through to 2018, with 31,821 populations of 5,230 species (Table 2). There are more species and populations from each taxonomic group in the 2022 index compared to the 2020 index, with the largest increase seen in the number of fishes (regarding species) and birds (regarding populations).

A couple of noteworthy additions to the database have been made since the previous *Living Planet Report*. For the Asia and Pacific region, the number of species has increased by a quarter since the last report[22]. The Africa region database achieved a 37% increase in the number of species, with notable increases in species coverage for amphibians, birds and freshwater fishes.

A few new bird and freshwater fish species were added to the North America dataset. But the biggest expansion of the LPI dataset takes place in the Latin America and the Caribbean region – a huge 66% rise in recorded terrestrial and freshwater species. This is in large part down to the collaboration of WWF-Brazil and the University of São Paulo, which helped boost the monitoring data from Brazil.

Taxonomic groups	LPR 2020		LPR 2022		% added	
	Populations	Species	Populations	Species	Populations	Species
Birds	6,666	1,586	12,995	1,802	95%	14%
Mammals	4,422	658	6,171	751	40%	14%
Fishes	8,412	1,635	11,282	2,116	34%	29%
Reptiles and amphibians	1,311	513	1,373	561	5%	9%

Table 2: Species and populations in the LPI
Changes in the number of populations and species for different taxonomic groups between LPR 2020 and 2022. WWF/ZSL (2022)[1].

Population-level trends

The numbers and trend lines from the LPI are based on a massive amount of data from actual wildlife populations. Being able to see trends at a population level helps us to understand what the overall change means for different species populations.

Populations in decline

- In the Mamirauá Sustainable Development Reserve in the Brazilian state of Amazonas, there was a 65% decline in populations of the Amazon pink river dolphin or boto (*Inia geoffrensis*) between 1994 and 2016, due to increased targeting by fisheries as well as pressures imposed by a rapidly growing human population in the region[7].
- In South and West Australia there was a 64% decline in Australian sea lion (*Neophoca cinerea*) pup numbers between 1977 and 2019, due to hunting as well as pups being caught in fishing gear or other marine debris, or dying of disease[8].

Populations defying the declining global trend

- The number of loggerhead turtle (*Caretta caretta*) nests increased by 500% along the coastline of Chrysochou Bay, Cyprus, between 1999 and 2015, due to targeted conservation efforts including using cages to protect turtle nests from foxes and relocating nests from areas which were under heavy tourist pressure or too close to the sea[9].
- In the UK, the common crane (*Grus grus*) fell into extinction as a breeding bird around 1600 due to hunting and loss of habitat. However, a small breeding population was re-established in Norfolk in 1979 and a reintroduction programme was launched in Somerset in 2010. 2021 was the most successful year for cranes since the 17th century; the total population is now thought to stand at more than 200 individuals[10].
- Despite years of civil unrest in the region where mountain gorillas (*Gorilla beringei beringei*) live, conservation efforts have found success. In the Virunga Mountains along the northern border of Rwanda, the Democratic Republic of Congo and Uganda, populations of mountain gorillas have grown to 604 individuals, up from 480 individuals in 2010[11].

Where is the current data coming from?

Scientists have collected data on animal populations around the globe for a number of years, sometimes decades. Each dot on this map represents a study on a specific species or group of species over time that fits the requirements to be included in the LPI database. Here, we highlight some examples of data from around the world.

This map shows the populations in the LPI, monitored in specific locations around the globe. Green dots indicate populations that were already included in the last Living Planet Report, yellow dots represent newly added populations since the last report, and orange dots indicate species new to the LPI.

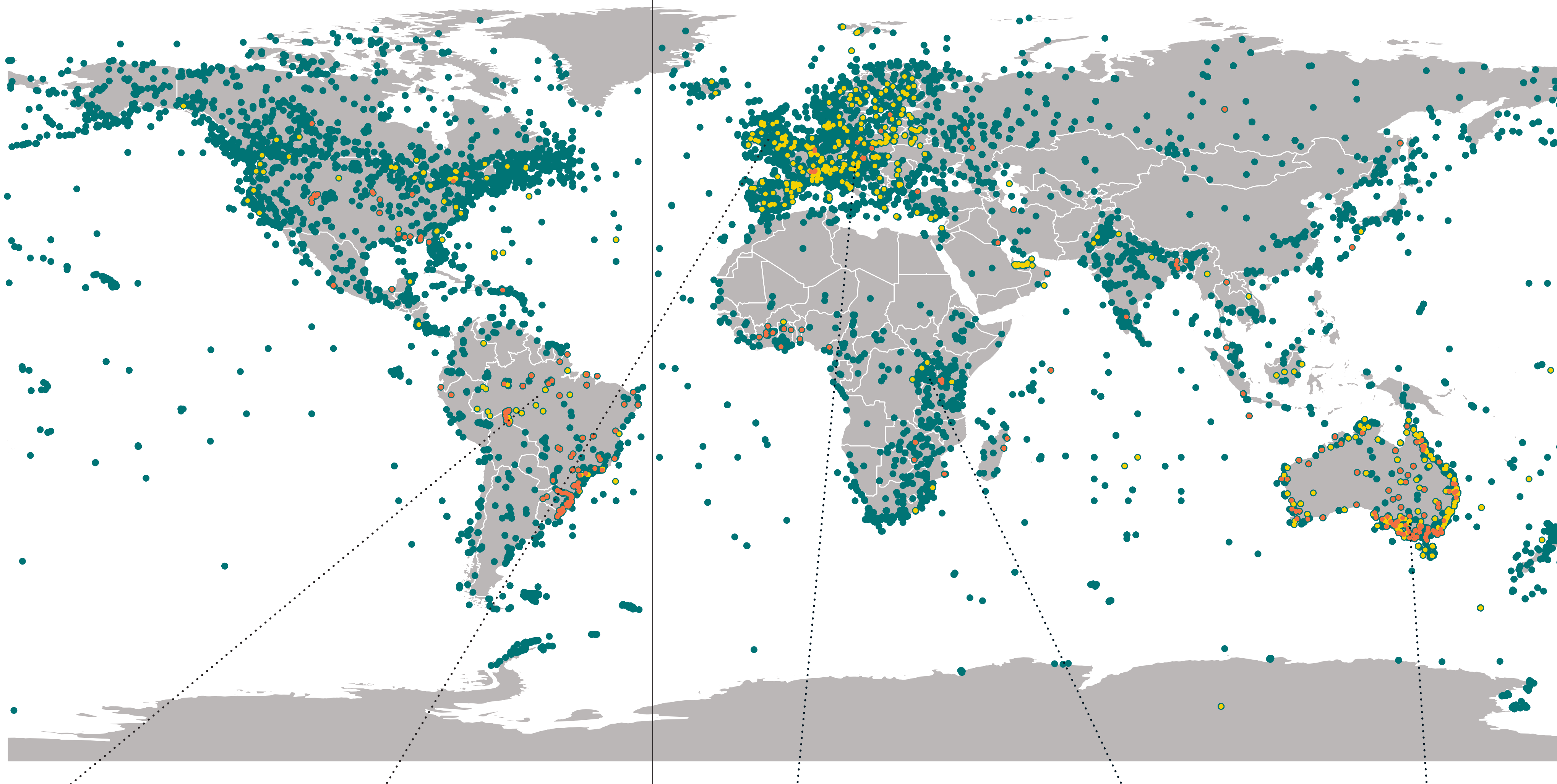


Figure 6: Locations of animal populations used for the Living Planet Index
WWF/ZSL (2022)[1].

Key

- New populations
- New species
- Existing data

LATIN AMERICA (BRAZIL)
Amazon pink river dolphins (*Inia geoffrensis*) in the Mamirauá Sustainable Development Reserve declined by 65% between 1994 and 2016[7].

EUROPE (UNITED KINGDOM)
The common crane (*Grus grus*) has increased from zero breeding pairs in the UK in 1981 to 72 pairs in 2021[10].

EUROPE (CYPRUS)
The number of loggerhead turtles (*Caretta caretta*) nests along the coastline of Chrysochou Bay, Cyprus increased by 500% between 1999 and 2015[9].

AFRICA (RWANDA)
In the Virunga mountains, the number of mountain gorillas (*Gorilla beringei beringei*) has increased by 25% between 2010 and 2013[11].

ASIA AND THE PACIFIC (AUSTRALIA)
The population of Australian sea-lions has declined by 64% between 1977 and 2019[8].

HOW TO CALCULATE THE LIVING PLANET INDEX

For each population, the rate of change from one year to the next is calculated. If the available data are from only a few, non-consecutive years, a constant annual rate of change in the population is assumed between each data year. Where data are available from many years (consecutive or not) a curve is plotted through the data points using a statistical method called generalized additive modelling. Average annual rates of change in populations of the same species are aggregated to the species level and then higher levels (e.g. per taxonomic group).

For the global and IPBES LPIs, weightings are applied as these trends are aggregated to higher levels, based on how much of the world's vertebrate biodiversity the species in the LPI represents. This is to account for certain geographic and taxonomic biases in the dataset [26]. This method is called the 'LPI-D', which stands for 'diversity-weighted'. For other LPIs, such as the freshwater migratory fish LPI, no weightings are used so each species counts equally when the LPI is aggregated. This method is called the 'LPI-U' method, where the U stands for 'unweighted'. Smaller subsets of data used to calculate a local or species-specific LPI use the LPI-U method, while larger subsets always use the LPI-D method.

The annual average trend is calculated in a similar way to how loan interest rates are calculated. The reason that we don't divide the percentage decline of the LPI by the number of years is that we are reporting the rate at which the LPI is declining each year and this value depends on the previous year's value. This is the same way that when calculating interest, that interest is added based on the percentage of an original sum of money plus interest already accrued and not based on the original sum of money alone.

From counting whale sharks to calculating the global LPI – here we give an example of a simplified LPI calculation from start to finish. All numbers in this calculation are fictional.

One of three Iberian Lynx cubs (*Lynx pardinus*) born in the Ciudad Real province, Spain.

A step-by-step guide to calculating a Living Planet Index

This fictional calculation shows how the input of raw data – in this case, monitored whale shark populations in the Indian Ocean – eventually leads to the output of the global Living Planet Index value, following a number of mathematical steps to model missing data, apply weight factors and average values per taxonomic groups, biogeographic realms and systems.

THE UNWEIGHTED LPI METHOD

This method is used for smaller subsets of data such as the LPI for freshwater migratory fish.

WHALE SHARKS IN THE INDIAN OCEAN

LPI-U

1999: 1300 individuals
2000: 1156 individuals
2001: 957 individuals
2002: 756 individuals
2003: missing data
2004: 613 individuals
2005: 559 individuals

STEP 1

Collect data on a single population over time.

POPULATION TREND FOR WHALE SHARKS IN THE INDIAN OCEAN

LPI-U

1999-2000: -15%
2000-2001: -16%
2001-2002: -15%
2002-2003: -13%
2003-2004: -11%
2004-2005: -10%
Overall modelled population trend = -58%

STEP 2

Use generalized additive modelling or log-linear interpolation to insert numbers for missing data years, then calculate annual population trends by comparing population size in any year to population size in the previous year.

WHALE SHARKS IN THE INDO-PACIFIC REALM

LPI-U

Indian Ocean: - 58%
South Pacific Ocean: -80%
Average realm population trend = - 69%

STEP 3

Average the interannual change across all populations of a species to give an average annual change and an overall trend and for that species in its biogeographic realm.

AVERAGE POPULATION TREND FOR MARINE FISH IN THE INDO-PACIFIC REALM

LPI-U

Whale shark – 69%
Yellowfin tuna -25%
Clown fish +0.5%
Average marine fish change = -30%

STEP 4

Average the interannual change across all species in the group to produce an overall trend for the species group in its biogeographic realm.

THE DIVERSITY-WEIGHTED LPI METHOD

This extended method is used for larger subsets and the global LPI and it incorporates a weighting score according to the estimated number of known species in the world within each species group and realm.

WEIGHTED TREND FOR ALL MARINE SPECIES IN THE INDO-PACIFIC REALM

LPI-D

Fish trend = -30% * 0.92
Bird trend = -25% * 0.06
Mammal trend = -75% * 0.01
Reptile trend = -25% * 0.01
Weighted average realm trend = -30.1%

STEP 5

Apply weight factor to each taxonomic trend, depending on system, taxonomic group and biogeographic realm. Weight factor is determined by how much of the world's vertebrate biodiversity the species group represents within the realm. For example, the weight factor for marine fish in the Indo-Pacific is 0.92 because they represent 92% of vertebrate species in this realm.

WEIGHTED TREND FOR MARINE SPECIES GLOBALLY

LPI-D

Indo-Pacific = -30.1% * 0.50
Temperate Atlantic = -20% * 0.09
Tropical Atlantic = -20% *0.20
Temperate Pacific = - 60% *0.08
Arctic = - 10% * 0.02
South temperate & Antarctic = - 60% * 0.11
Weighted average marine trend = - 32.45%

STEP 6

Include all marine biogeographic realm trends to calculate average system trend of population change. Apply weight factor, depending on biogeographic realm.

GLOBAL LIVING PLANET TREND

LPI-D

Marine trend = -32%
Terrestrial trend = -87%
Freshwater trend = -88%
Average Global Living Planet trend = -69%

STEP 7

Include all weighted average system trends to calculate average global trend. The averaging and weighting is done separately for populations occurring in the three systems (terrestrial, freshwater and marine), which are then equally weighted to obtain one set of interannual change values.

GLOBAL LIVING PLANET INDEX

LPI-D

1970 = 1
1971 = 0.99
1972 = 0.98
. . .
2018 = 0.31
Percentage change = -69%

STEP 8

Set baseline global index value to 1 in 1970 and calculate all other index values based on the interannual change values from Step 7.

Figure 7: *Step-by-step Living Planet Index calculation example.*

How sensitive is the LPI to outliers?

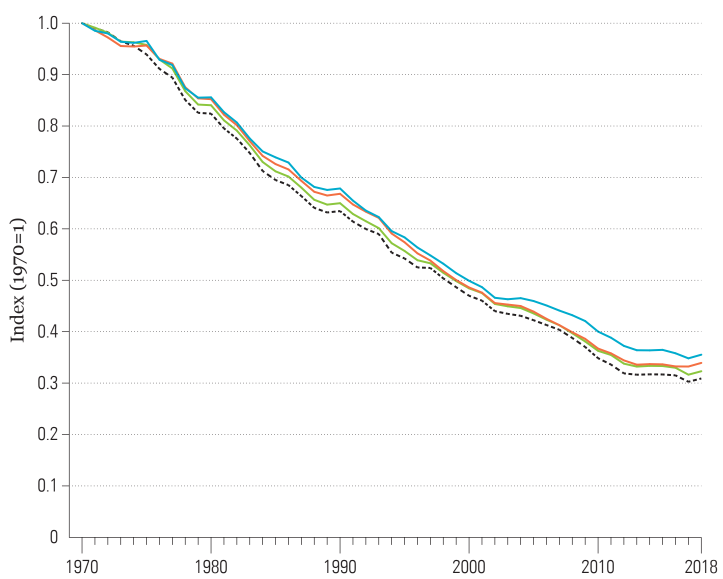
The geometric mean, the metric on which the LPI is based, can be sensitive to extreme values and outliers both positive and negative. It is useful to identify the populations that are most in decline, and excluding these from the remaining populations is complex, yet sometimes necessary to see trends in underlying data. For this year's LPI calculations, we tested the sensitivity of the analysis to extreme increases and declines in individual populations[23].

A recent study identified clusters of extreme decline or increase in population size that differ statistically from the majority of population trends[24]. In order to test whether these extreme trends have a disproportionate impact on the trends shown by the global LPI, we removed them from the dataset and then recalculated the global index (Figure 8). We tested different proportions of the dataset to show what happens when 2.5%, 5% and 10% of the data containing both extreme declines and increases are removed. The results show that while we get slightly different results for the global LPI with each of the tests, the overall trend remains very similar in each one. This demonstrates that extreme declines and increases are not significantly driving the trend in the global LPI.

Figure 8: The effect of removing outliers on the global Living Planet Index
The global Living Planet Index after removing a proportion of the most declining and increasing trends in the dataset. The three lines show the effect of removing 2.5%, 5% and 10% of the dataset. WWF/ZSL (2022)[1].

Key

- 10% removed
- 5% removed
- 2,5% removed
- The global LPI



What influence do short time-series have on the LPI trend?

The LPI database contains data gathered from different sources and collected at different scales, and not explicitly for the purpose of the analyses presented in the *Living Planet Report*. It therefore consists of time-series of varying lengths (interval between the first and the last observation) and fullness (number of observations during the time-series). For some species/groups, only shorter time-series are available. While time-series for birds and mammals are longer, amphibians are almost exclusively represented in the database by shorter time-series. If we only collected and used long-term data, which is often available for species/groups that are doing relatively well, we could potentially miss declines in other species, which are important signals from a conservation perspective. Also, a recent study comparing known long-term trends in bird abundance with samples of these complete time-series[25] suggests that if a significant trend is detected in the sample it is likely to reliably describe the direction (positive or negative) of the complete trend. Although it remains to be tested if these results can be expanded to other taxonomic groups and types of data, this might suggest that a decline detected in a short time-series is worth investigating to confirm the trend and potentially avoid further decline.

To gauge whether the inclusion of these shorter time-series might be skewing the results of the global LPI, we recalculated the trend excluding short time-series. Overall, the removal of shorter time-series appears to have little influence on the overall trend. The confidence intervals for trends calculated excluding time-series with less than 5 and 10 years of data overlap for the most part with the confidence intervals around the global trend, and the final index values differ from the final value of the global trend by 2% and 5% respectively.

FUTURE PERSPECTIVE

The LPI is currently used to monitor global biodiversity targets by quantifying population trends over time. But can this biodiversity indicator have an even larger impact in the future? With these four prospective improvements [2] the LPI can assist scientists and policymakers even better in measuring and understanding biodiversity change.

Increasing taxonomic representation in the Living Planet Index
Incorporating invertebrate and plant species into the LPI is likely to be challenging given the scarcity of long-term studies, but it is key to attaining broader understanding of the world's environmental change. These developments in the dataset will be realized through the use of emerging techniques to incorporate unstructured data, such as that collected through citizen science initiatives [27], and capitalizing on growing technology for monitoring biodiversity such as eDNA, satellite monitoring and AI-assisted counting of species, provided they can be transformed into usable metrics of abundance.

Streamlining data collation and data access
Finding and extracting data continue to be significant bottlenecks for the development of the LPI database. Working with publishers, data holders, government institutions and research funding bodies to automate the process of identifying and extracting data from articles would be beneficial, particularly if a standardized data extraction method is developed. It is also important that the LPI database is made as accessible as possible, both through simple, downloadable, tidy data formats and the development of application programming interfaces (APIs) to allow the data to interoperate with other resources such as the IUCN Red List, Protected Planet and GBIF. Visit www.livingplanetindex.org to access the current dataset.

Better models to link population trends with drivers
The LPI continues to highlight that global biodiversity is in trouble, and understanding (and predicting) which regions and species are likely to decline most in the future is useful. As such, models to better predict wildlife abundance trends for species and regions where we have poorer data are critical. Understanding the quality and utility of these models will allow us to make concrete and valuable predictions.

Increasing the utility of the Living Planet Index for policy
From a policy perspective, an emphasis on developing LPIs at the national level is needed to expand its use as a communication and reporting tool. National LPIs would serve a dual purpose of providing countries with a sensitive indicator for reporting while boosting data representation for the global index. Disaggregations of the LPI on themes such as use, trade, migration and wetlands should continue to be developed, so that these are available for reporting against other multilateral environmental agreements such as the Ramsar Convention on Wetlands, CITES and the CBD.

REFERENCES

1 WWF/ZSL. (2020). The Living Planet Index database. <www.livingplanetindex.org>.

2 Ledger, S., McRae, L., Loh, J., Almond, R., Böhm, M., Christopher, F. *et al.* (2022). Past, present, and future of the Living Planet Index. *bioRxiv*. doi: https://doi.org/10.1101/2022.06.20.496803

3 Collen, B., Loh, J., Whitmee, S., McRae, L., Amin, R. et al. (2009). Monitoring change in vertebrate abundance: The Living Planet Index. *Conservation Biology* **23**:317-327. doi: 10.1111/j.1523-1739.2008.01117.x.

4 IPBES. (2015). Regional/subregional assessments on biodiversity and ecosystem services. <https://ipbes.net/regional-assessments>.

5 IPBES. (2019). *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES secretariat, Bonn, Germany.

6 Salafsky, N., Salzer, D., Stattersfield, A. J., Hilton-Taylor, C., Neugarten, R., *et al.* (2008). A standard lexicon for biodiversity conservation: Unified classifications of threats and actions. *Conservation Biology* 22(4):897-911. doi: 10.1111/j.1523-1739.2008.00937.x

7 Silva, V.M.F., Freitas, C.E.C., Dias, R.L. & Martin, A.R. (2018). Both cetaceans in the Brazilian Amazon show sustained, profound population declines over two decades. *PloS one*, 1–12. https://doi.org/10.1371/journal. pone.0191304

8 Goldsworthy, S.D., Shaughnessy, P.D., Mackay, A.I., Bailleul, F., Holman, D. *et al.* (2021). Assessment of the status and trends in abundance of a coastal pinniped, the Australian sea lion *Neophoca cinerea*. *Endangered Species Research* 44: 421-437.

9 Casale, P. *et al.* (2020). *Sea Turtles in the Mediterranean Region: MTSG Regional Report 2020*. IUCN-SSC Marine Turtle Specialist Group.

10 The Great Crane Project, UK. (2021). <https://www.rspb.org.uk/our-work/conservation/projects/great-crane-project/>

11 Gray, M., Roy, J., Vigilant, L., Fawcett, K., Basabose, A. *et al.* (2013) Genetic census reveals increased but uneven growth of a critically endangered mountain gorilla population. *Biological Conservation* **158**:230-8.

12 Convention on Biological Diversity. (2022). History of the Convention. <https://www.cbd.int/history/>

13 Convention on Biological Diversity. (2022). Aichi Biodiversity Targets. <https://www.cbd.int/sp/targets/>

14 Biodiversity Indicator Partnership. (2022). Browse global indicators under the BIP. <https://www.bipindicators.net>

15 Secretariat of the Convention on Biological Diversity (2020) Global Biodiversity Outlook 5. Montreal, Canada.

16 Convention on Biological Diversity. (2022). Global Biodiversity Outlook 5. <https://www.cbd.int/gbo5>

17 Convention on Biological Diversity. (2022). Article 2, Use of Terms. <https://www.cbd.int/convention/articles/?a=cbd-02>

18 McRae L., Deinet S. & Freeman R. (2017). The Diversity-Weighted Living Planet Index: Controlling for Taxonomic Bias in a Global Biodiversity Indicator. *PloS one* **12**: 1–20. https://doi.org/10.1371/journal.pone.0169156

19 Leung, B., Hargreaves, A.L., Greenberg, D.A. *et al.* (2020). Clustered versus catastrophic global vertebrate declines. *Nature* **588**: 267–271. doi.org/10.1038/s41586-020-2920-6

20 Buschke, F.T., Hagan, J.G., Santini, L. *et al.* (2021) Random population fluctuations bias the Living Planet Index. *Nature Ecology & Evolution* **5**, 1145–1152. https://doi.org/10.1038/s41559-021-01494-0

21 Cárdenas-Palomo, N., Herrera-Silveira, J., Velázquez-Abunader, I., Reyes, O. & Ordoñez, U. (2015). Distribution and feeding habitat characterization of whale sharks *Rhincodon typus* in a protected area in the north Caribbean Sea. *Journal of Fish Biology* **86**: 668-686. doi.org/10.1111/jfb.12589

22 Threatened Species Index of Australian birds and mammals. (2022).<www.tsx.org.au>

23 Freeman, R. (2020). The Living Planet Index – data analysis, clusters and biodiversity loss. ZSL website <https://www.zsl.org/blogs/science/the-living-planet-index--data-analysis-clusters-and-biodiversity-loss>

24 Leung, B., Hargreaves, A.L., Greenberg, D.A. *et al.* (2020). Clustered versus catastrophic global vertebrate declines. *Nature* **588**: 267–271. doi.org/10.1038/s41586-020-2920-6

25 Wauchope, H.S., Amano, T., Sutherland, W.J. & Johnston, A. (2019). When can we trust population trends? A method for quantifying the effects of sampling interval and duration. *Methods in Ecology and Evolution* **10**:2067-2078. doi: 10.1111/2041-210x.13302.

26 McRae, L., Deinet, S. & Freeman, R. (2017). The Diversity-Weighted Living Planet Index: Controlling for taxonomic bias in a global biodiversity indicator. *PLOS ONE* **12**: e0169156. doi: 10.1371/journal.pone.0169156.

27 Pocock, M.J.O., Logie, M.W., Isaac, N.J.B., Outhwaite, C.L. & August, T. (2019). Rapid assessment of the suitability of multi-species citizen science datasets for occupancy trend analysis. *bioRxiv*, 813626, doi:10.1101/813626

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