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LPR 2024 Technical Supplement

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1. The Living Planet Index

1.1 What is the Living Planet Index?

To be able to protect nature, we need to understand environmental change over time and in different places. The Living Planet Index (LPI) was developed in 1997 to measure the changing state of the world's biodiversity by examining the patterns of increase and decrease in animal diversity and abundance. It tracks trends in the sizes of a large number of populations (defined here as a group of animals of the same species consistently monitored in the same location over a same period of time) of vertebrate species in much the same way that a stock market index tracks the value of a set of shares, or a retail price index tracks the cost of a basket of consumer goods. Because population-level extinction is the prelude to species-level extinction, the LPI can thus act as an early warning indicator of the potential loss of ecosystem function and resilience, and of increasing extinction risk.

The data used to construct the LPI comprise a variety of different measures that indicate how the number of individuals of a population has changed over time. In addition to direct counts of individuals, the LPI can also use density (population size per unit area) or a proxy of abundance (e.g. the number of nests or breeding pairs). The trends presented in the Living Planet Report 2024 (WWF 2024) are based on time-series data for 34,836 populations of 5,495 species of mammals, birds, reptiles, amphibians considered native in the location where they were monitored and fish from around the globe (including 5,005 time-series that were provided to the LPI team under the agreement that they would be kept confidential). Using a method developed by ZSL and WWF (Loh et al. 2005; Collen et al. 2009; McRae et al. 2017), these species population trends are aggregated and weighted to produce the different Living Planet Indices, focusing not just on the global trend but also on change in different systems or regions of the world. In addition, the LPI can be used to describe trends in different countries when sufficient data are available (see for example the Canadian species index - Canada.ca) or along different themes, e.g. the Forest Specialist Index (Green et al. 2020). Trends can be further examined in relation to body size, habitat and environmental variables and threats (Spooner et al. 2018; Green et al. 2020; Cornford et al. 2023) and conservation actions (Craigie et al. 2010; Costelloe et al. 2016; Ledger et al. 2022; Barnes et al. 2016).

1.2 The Living Planet Database: the building blocks of the LPI

The Living Planet Database is continually evolving as we add data for an increasing number of species and regions every year (Figure 1). By collecting additional information alongside species population trends – such as the taxonomic group of the species monitored, or where it lives – we can increase the value of the LPI data beyond the statistics, producing a more in-depth view of the changes in species around the world. The data and the methodology used to calculate the LPI have been increasingly used in a variety of scientific outputs to look at population trends in different taxa, regions and groups of species. For a full list of publications about the LPI from the LPI team, please visit https://livingplanetindex.org/publications.

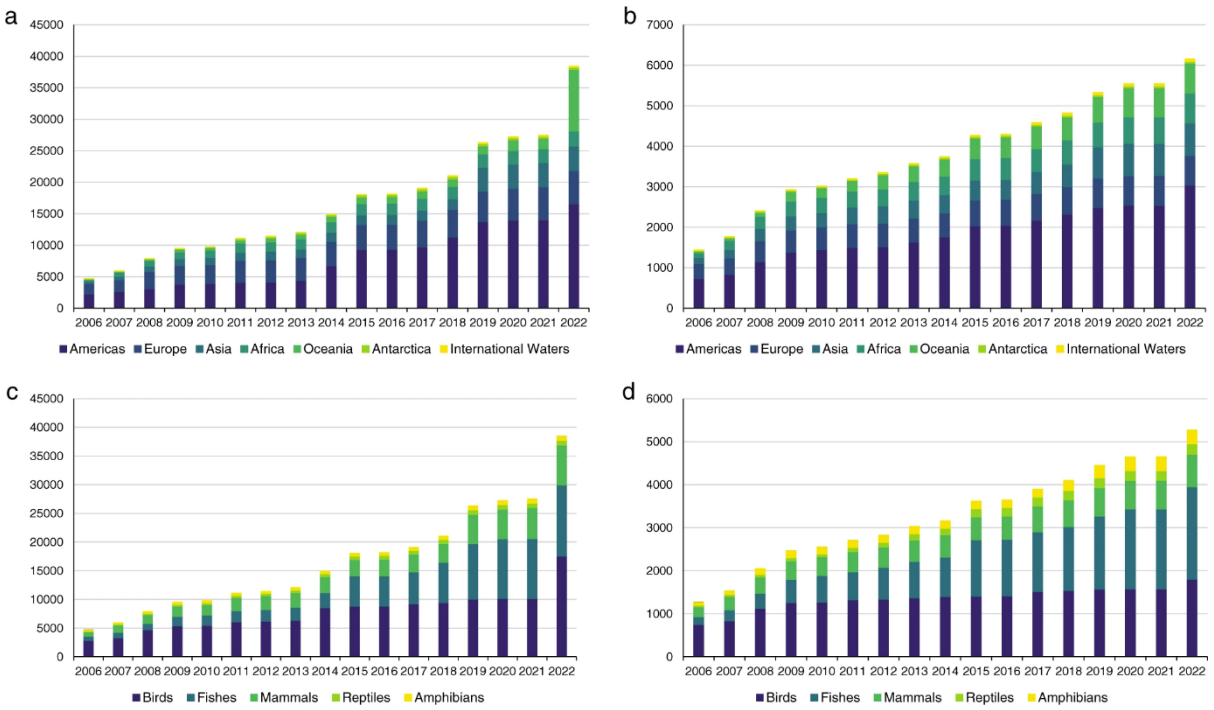


Figure 1. Growth in number of populations and species in the Living Planet Database (LPD) by region and taxa. The cumulative number of new **a)** populations and **b)** species entered by region, and the cumulative number of **c)** populations and **d)** species entered by taxon. Please note 2b adds up to more than the individual number of species as some species occur in more than one region. From Ledger et al. (2023).

1.3 The LPI as a policy tool

The LPI was one of a suite of global indicators used to monitor progress towards the Aichi biodiversity targets agreed by the Convention on Biological Diversity (CBD) in 2010 (Secretariat of the Convention on Biological Diversity 2010). These targets required nations to take effective and urgent action to halt the loss of biodiversity and ensure that ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being and poverty eradication. Following the failure to meet the Aichi targets, we are now in the next phase of international policy commitments to address biodiversity loss. The LPI has been included as a component and complementary indicator in two goals and four targets of the Kunming-Montreal Global Biodiversity Framework (UNEP (United Nations Environment Programme) 2022). More information about the role of the LPI in policy can be found in McRae et al. (In review). In the Living Planet Report, other global CBD indicators including the IUCN Red List Index and Biodiversity Intactness Index are presented to provide context for the LPI and to show that a number of different tools paint a very similar picture of trends in biodiversity.

1.4 Why should we use the LPI?

The LPI is based on abundance data collected in the field – examples of some of the populations included can be seen in the Living Planet Report 2024 on page 32-33. It has functioned as a talking point for public engagement events held for everyone from children to scientists, to engage people in conversations about the natural world and how to conserve it. Apart from aggregating LPI abundance information into a global indicator, provided there are

enough data, LPIs can also be calculated at smaller spatial scales such as regions or countries, for different taxonomic groups or along different schemes, making it a useful tool for national and conservation monitoring. The LPI is a useful resource for student training at undergraduate and postgraduate level, through both formal teaching and independent research projects. There are also several additional reasons why the LPI can be a useful tool for tracking biodiversity trends and therefore helpful for policymakers:

- It is the largest available repository for vertebrate population abundance data.
- It includes primary data, collected in the field at known locations.
- The dataset is long-term, continuously updated and expanding.
- It includes an increasing proportion of research and publications in languages other than English, which can help improve the representation of data from biodiverse regions where English is not widely spoken.
- Because the data are publicly available, they can support research.
- The method is peer-reviewed.
- The index is sensitive to annual changes.
- The trends are consistent year after year, even with the addition of more data.
- The method is designed to limit the impact of taxonomic and geographic bias.
- The index is relatively simple to communicate.

1.5 Interpretation of the LPI

1.5.1 The basics

Living Planet Indices – whether the global index or those for a specific realm or species group – show the average rate of change over time across a set of species populations. Although the resulting figures appear very simple, their interpretation requires the understanding of certain important terms, as depicted in Figure 2.

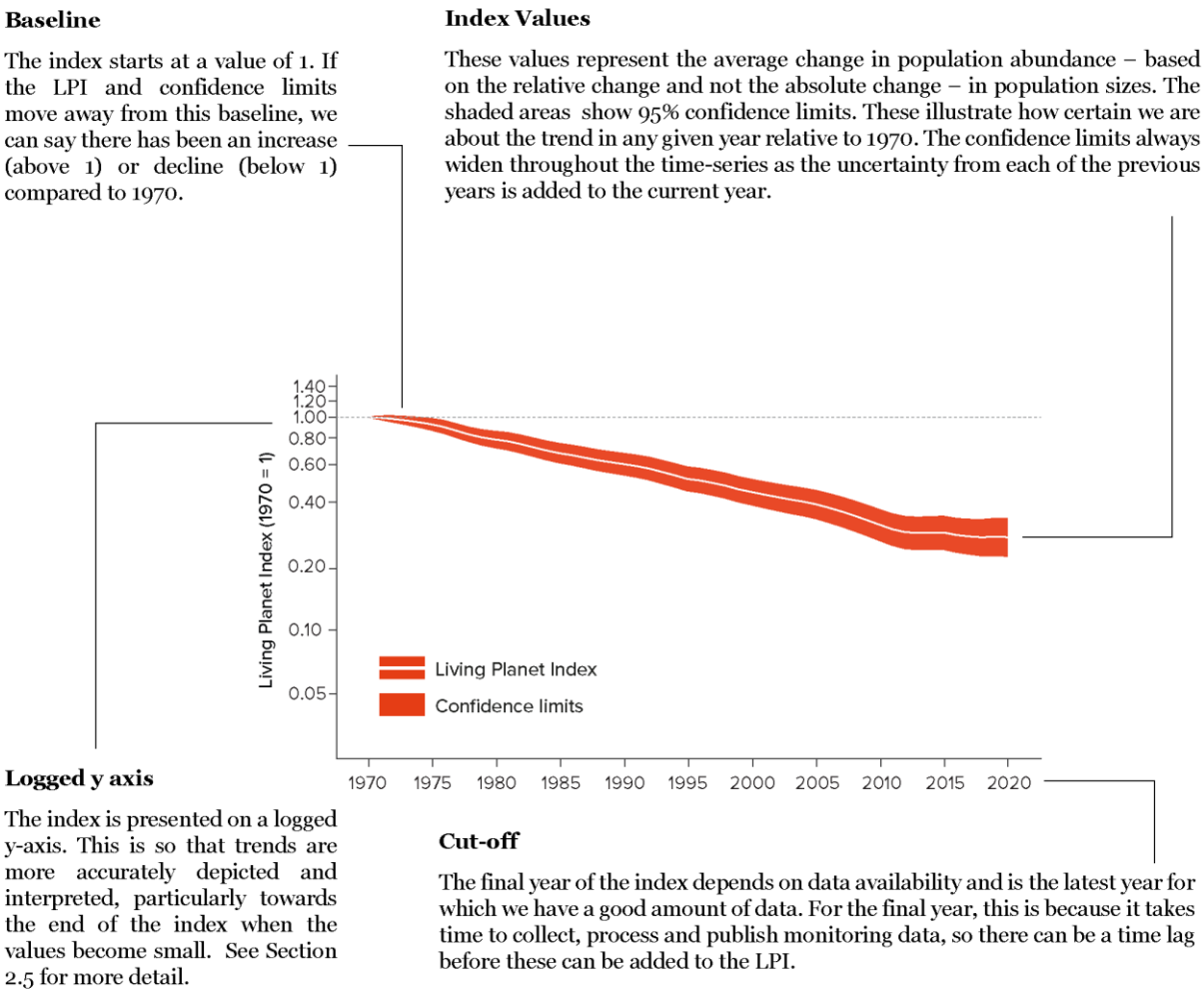


Figure 2. Explanation of the basic terms necessary for the interpretation of the LPI.

1.5.2 What does the LPI tell us?

LPI results are calculations of average trends in population size over time per chosen area and/or species group. In the case of the global LPI, this means that some populations and species are faring worse than the average decline reported, whereas others are not declining as much or are increasing compared to the chosen baseline of 1970. In fact, approximately half the populations show a stable or increasing trend, and half show a declining overall trend (Figure 3). Depending on how the existing data are grouped – per region, per ecosystem, per species – we can see trends with different directions and magnitude.

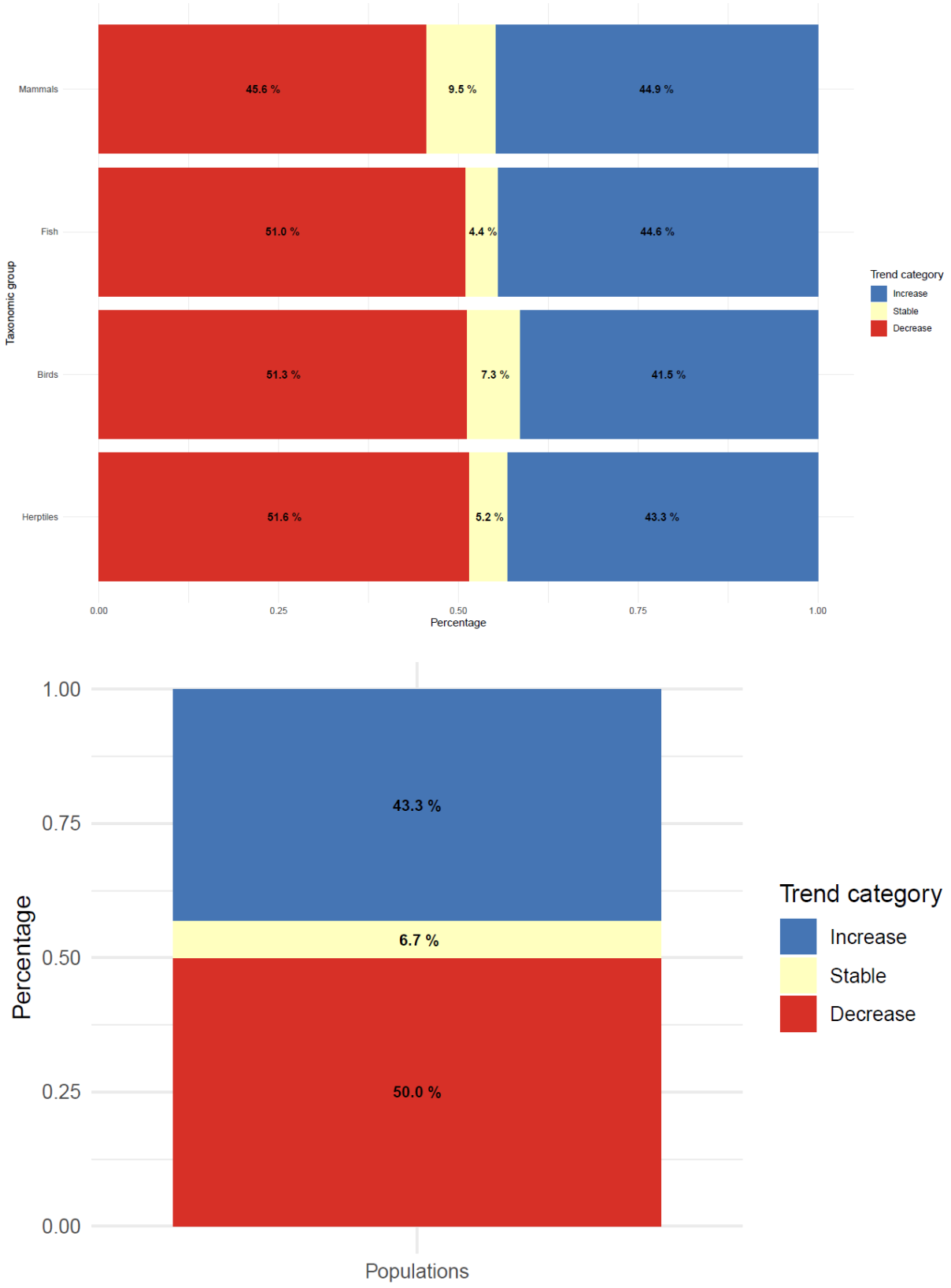


Figure 3. The proportion of decreasing, increasing and stable populations (based on the total change during the course of the time-series) a) by taxonomic group and b) in the dataset as a whole. Stable populations are defined as populations that change by less than 5% over the study period.

Figure 4 illustrates what the overall average percentage change of the LPI represents. In the example, the average trend across the three example species is -50%, but the percentage change for each species is more or less than that. In addition, looking at the total number of animals in the three combined populations, the table shows we have not lost 50% of animals.

	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%

Figure 4. An illustration of how the average percentage change of the trend differs from the change in total number of animals lost. From the 2022 Living Planet Report (WWF 2022).

The LPI combines different abundance measures from a large number of populations and species into one simple graph, but there are details behind the index that are necessary to understand. Below is a table putting right some common misconceptions about what the LPI does and does not show.

What the LPI shows	***What the LPI does not show***
• The LPI indicates the average rate of change in animal population sizes of native species. • Species and populations in the LPI show increasing, declining and stable trends. • About half of the populations we have in the LPI show an average decline in population trend. • The reported decline is the average change in population size since 1970. • The LPI includes data for threatened and non-threatened species – if a species is monitored consistently over time, it is included in the dataset.	• A declining global LPI doesn't mean that all species and populations are in decline. • The LPI doesn't show numbers of individuals lost or extinctions, although some populations do decline to local extinction. • The LPI statistic does not mean that the same proportion of all species or populations worldwide are in decline, nor that the same number of populations or individual animals have been lost. • 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.

1.5.3 Why the final value changes, and why it is not recommended to compare to previous reports

The global LPI has consistently shown a declining trend in different editions of the Living Planet Report. However, the final value of the global LPI and its subsets have changed in each edition of the report. The reasons for this are twofold.

Firstly, the database is continually evolving and for each Living Planet Report a larger dataset is available for analysis (see Figures 1 and 5). Data for the LPI are gathered from a variety of sources, such as journals, online databases and government reports, that contain time-series of vertebrate populations spanning any number of years between 1970 and 2020. The addition of new data changes the overall composition of species and populations in any given year, meaning that the average value of each global LPI can change as a result.

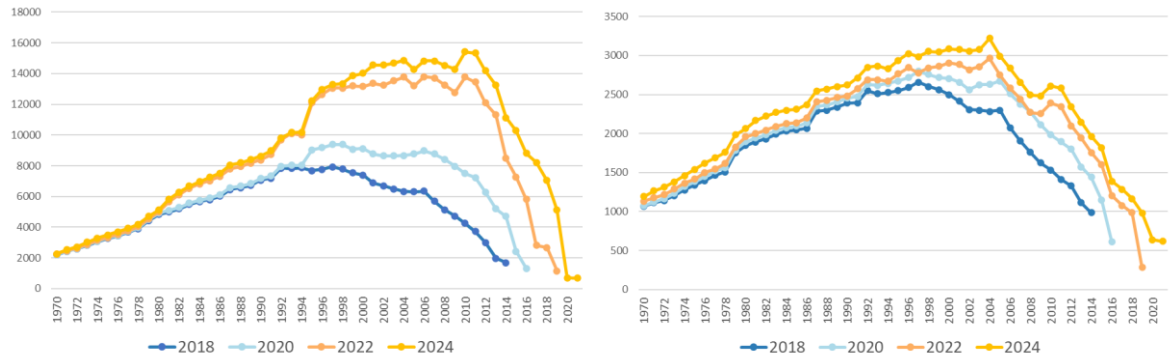


Figure 5. Number of a) populations and b) species with data available in each year for the global trends presented in each edition of the Living Planet Report from 2018 to 2024.

Secondly, some of these new data will add information from more recent monitoring, so that existing indices may be extended by two years for each new edition of the Living Planet Report. This new information might reflect similar trends (e.g. -2% per year) for existing species or populations, but as they include more years, the overall changes to these populations will differ, resulting in different overall changes in the global dataset.

Overall, the new final value generally stays within or close to the range of previous results (as measured by the confidence limits) so there are similar overall trends even if the final percentage value is different.

1.5.4 Caveats and limitations of the LPI

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 indicate a trend in vertebrate population sizes. Below, we clarify some of the remaining challenges that accompany the precision and the interpretation of the LPI.

- The dataset does not include invertebrates or plants. This is currently being addressed through a series of collaborations to explore the population trends of specific groups of invertebrates and plants.
- The method of aggregating the LPI can be sensitive to strong population declines and fluctuations, or short and sparse time-series. More detail on this in section 4.2.

- The starting years for individual populations within the overall database differ as not all population studies in the LPI start in 1970 and end in 2020.
- The dataset is biased towards well-studied species groups and regions. This is common in many biodiversity datasets, where species that are charismatic, threatened or easier to observe tend to be better represented (Donaldson et al. 2017, Troudet et al. 2017).
- The global LPI masks the different trends seen amongst taxonomic groups and regions. This is addressed through the IPBES regional analysis and showing the proportion of increasing, decreasing and stable population trends in this document (see section 3.4).

2. The Living Planet Report

2.1 Change in the number of populations and species

The 2022 Living Planet Report used data from 31,821 populations of 5,230 species for the period 1970 to 2018. For this year's report, the index has been extended by two years to 2020, and it is now based on 34,836 populations of 5,495 species. There are more species and populations from three of the IPBES regions in the 2024 index compared to the 2022 index, with the largest increases seen in the number of species in Africa and Latin America & Caribbean, and in the number of populations in Africa, and Asia & the Pacific (Table 1). Searches for data published in Portuguese continued, which further increased the data set for Brazil. New data were included from African countries such as data on declines in raptor species across the continent. There was also a focus on boosting data on freshwater migratory fish for a recent report; this included a study on trends in freshwater fish in the Mekong.

Table 1. Changes in the number of populations and species in each IPBES region for the 2022 (WWF 2022) **and 2024** (WWF 2024) **Living Planet Reports.**

	LPR 2022		LPR 2024		Difference	
	Populations	Species	Populations	Species	Populations	Species
North America	2,535	952	2,449	935	-3%	-2%
Latin America & the Caribbean	3,680	1,261	3,936	1,362	7%	8%
Europe & Central Asia	4,680	627	4,615	619	-1%	-1%
Africa	1,587	510	2,304	552	45%	8%
Asia & the Pacific	3,581	729	4,622	768	29%	5%

Although this year's index includes 265 more species and 3,015 more populations compared to the last Living Planet Report, this is not necessarily the amount of data that has been added in the interval between the two reports. In fact, the datasets for two IBPES regions have actually decreased a little. The difference in datasets is due to a number of reasons.

- Firstly, there have been taxonomic changes following revisions in naming conventions, which will have had an impact on the overall species count. This is especially the case if previously distinct species are grouped under one name, or a distinct species is split into two or more species names.

- Secondly, to better align with Goal A of the CBDs Global Biodiversity Framework ("…the abundance of native wild species is increased to healthy and resilient levels…"), the decision was made to exclude non-native species from this year's dataset for the first time, which may have contributed to a decrease in the number of populations and species for some regions. The impact of the exclusion of these species is shown in Figure A1 in the Appendix.
- Lastly, when the global LPI is calculated, any population surveys that overlap with others (so-called "replicates") are filtered out and excluded from analysis. To decide which of the overlapping populations to keep, we consider the area or number of individuals represented by that population (tending towards larger-scale studies) as well as the quality of the data (tending towards higher-quality data, i.e. longer and fuller time-series). For example, if there is a population survey for Blackbirds in the UK and one for the whole of Europe and both cover the same time period, we keep the Europe population in the global LPI and exclude the UK one. The UK population stays in the data portal, however, as it could be useful for smaller scale studies. As we collect new population data, we often need to adjust the tagging of replicates in the database, and this can reduce the total number of populations for a given species that is included in the global LPI. If one new population was monitored at a larger-scale and overlaps with existing smaller-scale populations in the database then the latter will be tagged as replicates and not count towards the population total for the global LPI, leading to fewer populations overall.

2.2 Representation

The global LPI included in this year's Living Planet Report has been calculated for 34,836 populations of 5,495 native species, which have been extracted from the Living Planet Database. This time-series information has been collated from more than 4,200 individual data sources such as published scientific literature, online databases and grey literature.

While an LPI can be calculated using data from any species, the current approach focuses only on vertebrate species (i.e. birds, mammals, fish, amphibians and reptiles) because these are groups that have been monitored more consistently and for longer. Figure 6 shows the number of species included in the current global index for each taxonomic group compared to the number of species that are known to exist. It shows that the current index represents between 2% and 16% of known species within vertebrate taxonomic groups, with mammals and birds being the best represented.

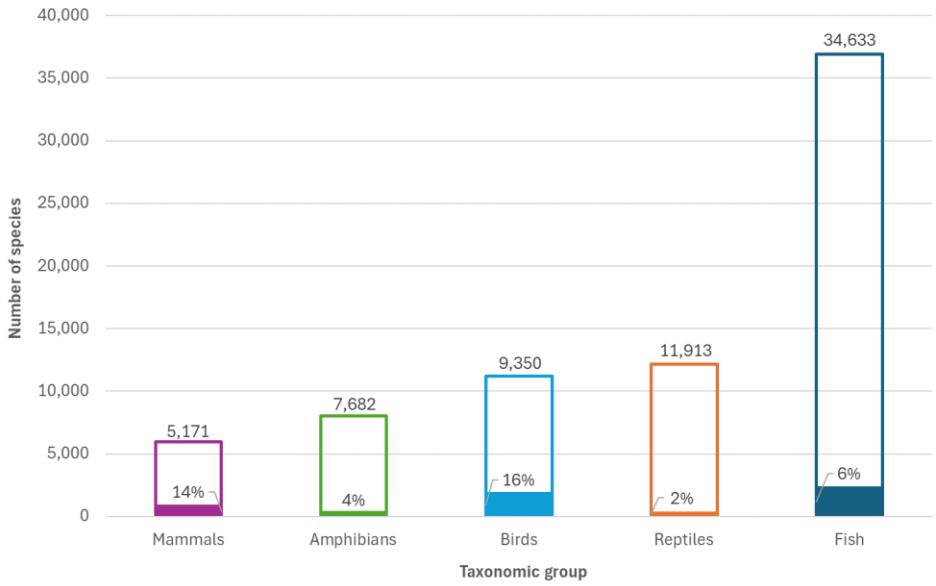


Figure 6. The number of species included in the LPI for each taxonomic group compared to the number of species known to exist.

In terms of geographic representation, Figure 7 shows the distribution of populations included in the global LPI. It is clear from the map that there are more data from regions with a longer history of monitoring and publishing data, such as North America and Europe. Larger gaps tend to be in more remote, tropical areas. Despite this, the tropical species count has been improving over the past few reports, so representation of the more species-rich tropical regions is also improving. Representation can be boosted further by searching for data published in languages other than English or in local journals. For example, a collaboration with in-country researchers collecting data in Portuguese helped to rapidly expand the data set for Brazil, trebling the number of species represented to over 1,000 in a few months for the Living Planet Report 2022 (WWF 2022). There is also preliminary evidence that local journals contain data from different locations within an under-represented country compared to international journals (Serrano et al. In prep). Future data searches would therefore benefit from closer collaboration with research groups and institutions within under-represented regions or countries to expand geographic coverage by tapping into local publications.

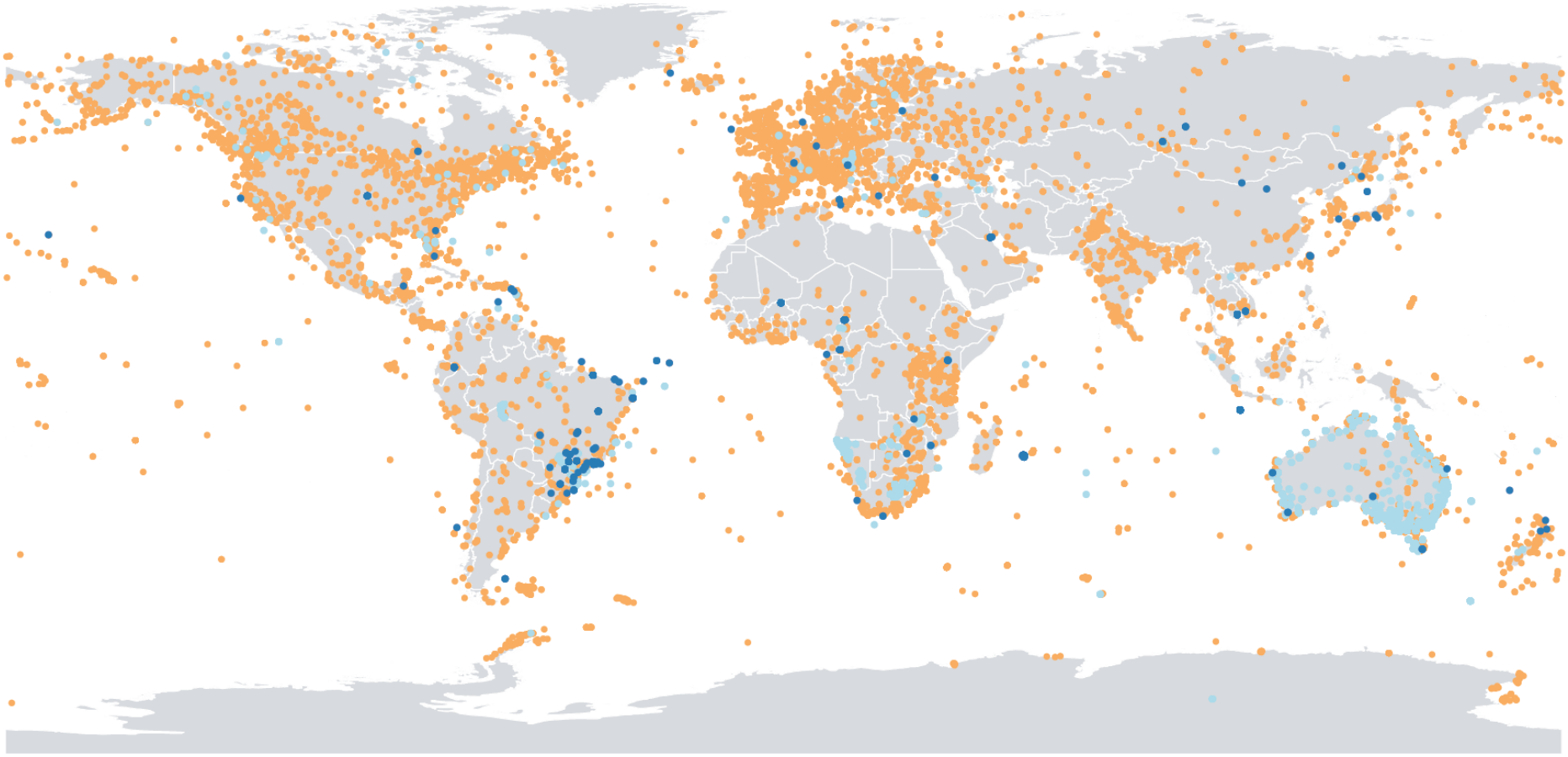


Figure 7. Locations of animal populations used to calculate the 2024 Living Planet Index. Light blue dots indicate locations of populations that were added since the Living Planet Report 2022, and dark blue dots indicate locations of new species added. Populations previously included in the Living Planet Report 2022 are marked in orange.

2.3 Main trends in the LPR 2024

The main trends from this year's Living Planet Report, based on a dataset of 34,836 populations of 5,495 species, are presented in Table 2. It shows the results for each of the system and IPBES region LPIs. The global LPI for 2024 indicates an average decline of 73% in species population relative abundance between 1970 and 2020.

Table 2. The results from the Living Planet Report 2024. 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. From (WWF 2024).

		Number of species	Percentage change 1970-2020	95% confidence limits (Lower/Upper)	
Global	Global	5,495	-73%	-78%	-67%
Systems	Freshwater	1,472	-85%	-90%	-77%
	Terrestrial	2,519	-69%	-79%	-55%
	Marine	1,816	-56%	-66%	-43%
IPBES regions	North America	935	-39%	-57%	-14%
	Latin America & the Caribbean	1,362	-95%	-97%	-90%
	Europe & Central Asia	619	-35%	-53%	-10%
	Africa	552	-76%	-89%	-49%
	Asia & the Pacific	768	-60%	-76%	-36%

2.4 The IPBES LPIs - changes to the data and trends

The Intergovernmental Science- Policy Platform on Biodiversity and Ecosystem Services (IPBES) divides the world into different geographic regions to help assess and monitor nature. In recent years, the LPR has presented trends for terrestrial and freshwater species for each of these regions. This year, the overall percentage change for some of them differed from those published in 2022. Whilst, as explained in section 1.5.3, LPIs from different years should not be compared directly, the following explanation describes how the data set has changed and how this has influenced the new results for 2024.

There has been a 45% increase in the number of populations and 8% in the number of species added to the Africa LPI, including raptor trends across Africa, freshwater migratory fish in Reunion, and mammals in Cameroon, Mozambique and South Africa. The addition of data for new locations and species is responsible for the more negative trend in the LPR 2024 version compared to the LPR 2022 version. The previous Africa LPI showed a small uptick in the final year of the index, and this has disappeared with the addition of new data. The mammal trend stabilised in the LPR 2022 index and this time it continues to decline. There are also an additional 5 years of trend data now for fish, which show a continuous decline. With the addition of new data, the bird trend is now less positive on average than in LPR 2022.

In the Asia and the Pacific LPI, the total number of populations increased by 29%. Many of these came from the Threatened Species Index data set from Australia (www.tsx.org.au), where we also updated existing data. New data also came for freshwater fish in the Mekong and mammal trend data from Cambodia and Laos. The LPR 2024 result is broadly similar in trajectory to LPR 2022, and the underlying taxonomic trends are not very different. The new fish data provided 5 more years of data, which show a decreasing trend. Previously the mammal trend showed an uptick in the final year, and this has now disappeared.

There was a net decrease in the number of populations and species in the North American data set by 3% and 2% respectively due to the exclusion of non-native species and some taxonomic changes. New data were added – some new birds from the United States Geological Survey (USGS) breeding bird survey, freshwater turtles in Canada and mammals monitored in a boreal region of Canada. The overall index for North America in LPR 2022 showed an uptick in the last few years and this since disappeared. This is due to changes in two taxonomic groups where this increase was seen – herptiles (reptiles and amphibians) and mammals. The trend stabilised (herptiles) and declined (mammals) after the addition of new data which caused the decrease in the North America LPI to continue in LPR 2024.

There was an increase in the data set for Latin America & Caribbean of 7% in populations and 8% in species. Much of this was for Brazil where our collaborators continued searches for data published in Portuguese. Another new data set entered was for insectivorous bird species from the Ecuadorian Amazon. The trend for LPR 2024 is very similar to LPR 2022 with few changes to the underlying taxonomic trends. Average declines are seen across all taxonomic groups with herptiles and fish showing more negative trends than birds and mammals.

The Europe and Central Asia region also saw a net decrease in numbers of populations and species, also due to the removal of non-native species. New data added were for migratory fish species in various countries, bats in central Europe and rodents in Russia. The index for LPR 2024 showed a similar shape of trend but overall, it is more negative than the index for LPR 2022. This is due to the mammal trend showing a slower increase compared to LPR 2022 (but it is still showing an increase on average). It is also due to a more negative average trend for fishes, especially after 2000. Both differences are primarily due to the removal of non-native species and the recent addition of new data. Other taxonomic trends for birds and herptiles are very similar to the trend in LPR 2022.

2.5 Presenting the LPI on logarithmic vs arithmetic axes

For this year's report, a choice was made to present all LPI indices on a logarithmic scale. This has the effect of spacing out the lower values on the y axis, so that trends are more accurately depicted, particularly towards the end of the index when the values become very small. On the arithmetic scale it looks like the trend is almost flattening towards the end, whereas on the logged scale the flattening is less pronounced (Figure 8), showing that the decline is still ongoing. Plotting on the arithmetic scale could lead to misinterpretations of the index, as readers might assume that the decline has stopped. This way of presenting indices is most important for trends that decline to very small values, such as the Freshwater LPI, or the LPI for Latin America and the Caribbean, but it is appropriate for all LPIs.

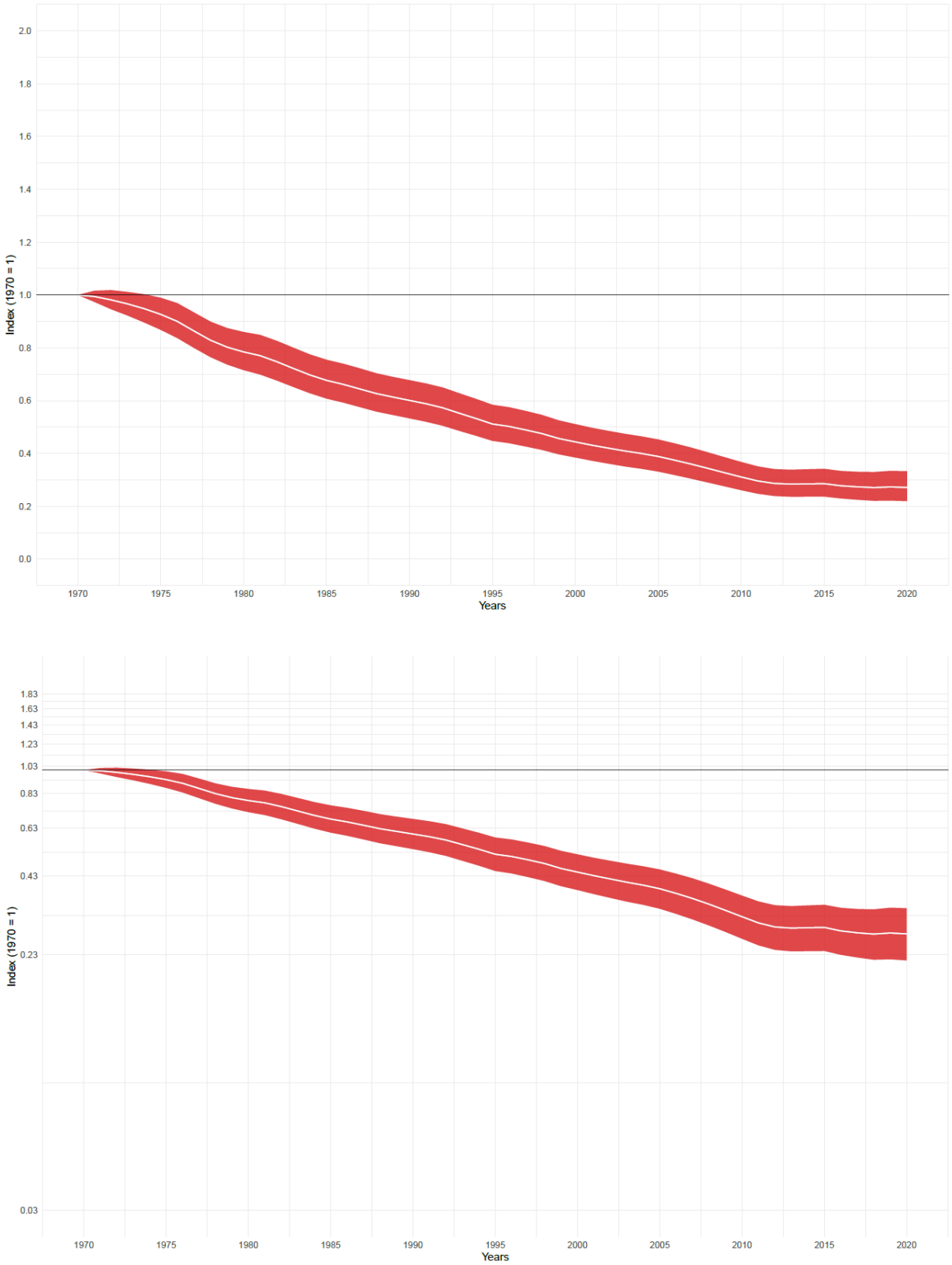


Figure 8. Comparison of plotting the 2024 global LPI on an arithmetic scale (top) vs logarithmic scale (bottom).

3. The Living Planet Index method

3.1 Step-by-step guide

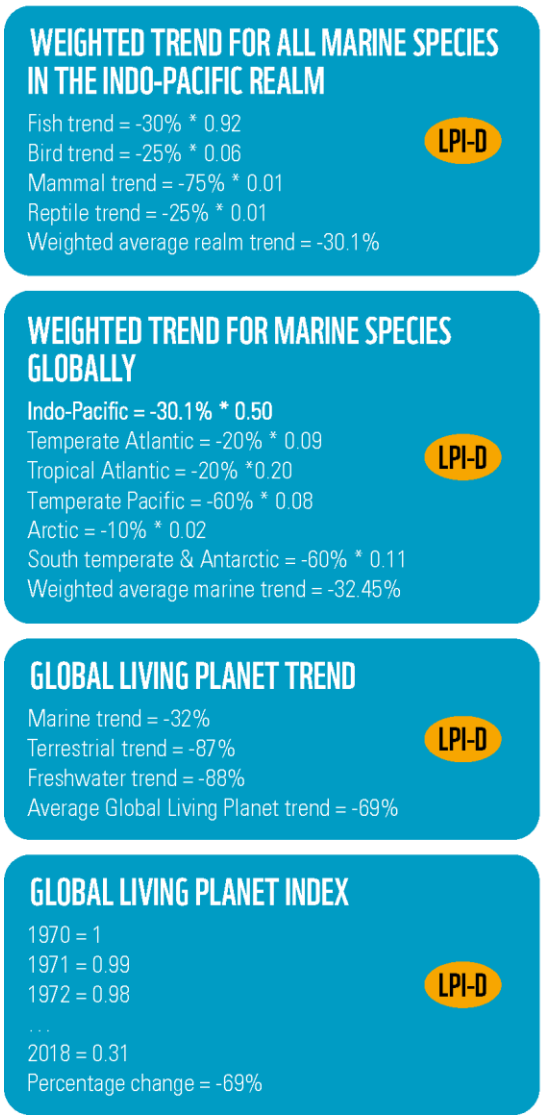
To calculate a simple LPI, i.e. one without any weighting applied (see below for more information on weightings), the rate of change from one year to the next is calculated for each population. If the available data are from only a few (less than 6), non-consecutive years, a constant annual rate of change 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 Generalised Additive Modelling (GAM). Average annual rates of change in populations of the same species are then aggregated to the species level and then to higher levels (e.g. taxonomic group and biogeographic realm; see Figure 9). This method is used for smaller subsets of data such as the LPI for migratory freshwater fish (Deinet et al. 2024). For illustrative purposes, the arithmetic mean is used in the calculations in Figures 9 and 10, although we use the geometric mean for the calculation of the LPI.

Figure 9. A step-by-step guide to calculating an LPI using the unweighted method. Please note that all numbers in this calculation of an index for marine fish in the Indo-Pacific biogeographic realm are fictional. From Westveer et al. (2022).

3.2 Weightings – how and why they are used

There is no 'perfect' LPI which has data for all species from everywhere in the world. The challenge therefore is to represent all 68,700 described vertebrate species using those for which data are available. One way we try to address this problem is to collect more data and continue to improve the taxonomic and geographic coverage of the dataset. Data searches are ongoing, and the database is continuously augmented, particularly for taxa and regions that are underrepresented. But in 2012 we made the choice to address the remaining bias in the data set, thus making the indicator more representative of vertebrate biodiversity, by changing the methodology to account for the estimated diversity of species globally.

As described in section 3.1, the rate of change from one year to the next is calculated and aggregated to the species level and then higher levels (e.g. per taxonomic group). For the global and IPBES LPIs, weightings (listed in Tables 3 and 4) 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 represent. This is to account for certain geographic and taxonomic biases in the dataset (McRae et al. 2017). This method is called the "LPI-D" (=diversity-weighted; Figure 10), and it is normally used for larger subsets. For other smaller LPIs, such as the freshwater migratory fish LPI from the Living Planet Report 2022 (WWF 2022), the "LPI-U" method (=unweighted) is applied, where no weightings are used so each species counts equally when the LPI is aggregated (Figure 9).



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 weighting factor for marine fish in the Indo-Pacific is 0.92 because they represent 95% of vertebrate species in this realm.

STEP 6

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

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.

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 10. A step-by-step guide to calculating an LPI with weightings. This method is used for larger subsets and the global LPI and incorporates a weighting score according to the estimated number of known species in the world within each species group and realm. Please note that all numbers in this calculation are fictional. From (Westveer et al. 2022).

Table 3. Terrestrial and freshwater weightings applied to taxa/realm when calculating a global LPI. From McRae et al. (2017). Please note that weightings have been rounded to three decimal places.

		Afrotropical	Nearctic	Neotropical	Palearctic	Indo-Pacific
Terrestrial groups	Birds	0.387	0.376	0.387	0.433	0.396
	Mammals	0.197	0.249	0.127	0.249	0.172
	Herptiles	0.414	0.373	0.484	0.316	0.431
Freshwater groups	Fishes	0.590	0.565	0.584	0.592	0.493
	Birds	0.192	0.203	0.107	0.211	0.176
	Mammals	0.009	0.013	0.010	0.015	0.008
	Herptiles	0.207	0.217	0.298	0.179	0.321

Table 4. Marine weightings applied to taxa/realm when calculating a global LPI. Updated since McRae et al. (2017) to reflect changes in the source of marine species estimates (Ocean Biodiversity Information System). Please note that weightings have been rounded to three decimal places. There are no marine amphibian species.

	Arctic	Atlantic North Temperate	Atlantic Tropical & Subtropical	Pacific North Temperate	Tropical & Subtropical Indo-Pacific	South Temperate & Antarctic
Fishes	0.754	0.833	0.895	0.880	0.932	0.918
Birds	0.205	0.144	0.094	0.090	0.056	0.056
Mammals	0.041	0.021	0.008	0.028	0.006	0.024
Reptiles	0	0.003	0.002	0.001	0.006	0.002

3.3 Calculating the global LPI

The global LPI is a weighted index, and it is calculated following the steps presented in Figure 10, through a hierarchical weighting process that is illustrated in Figure 11.

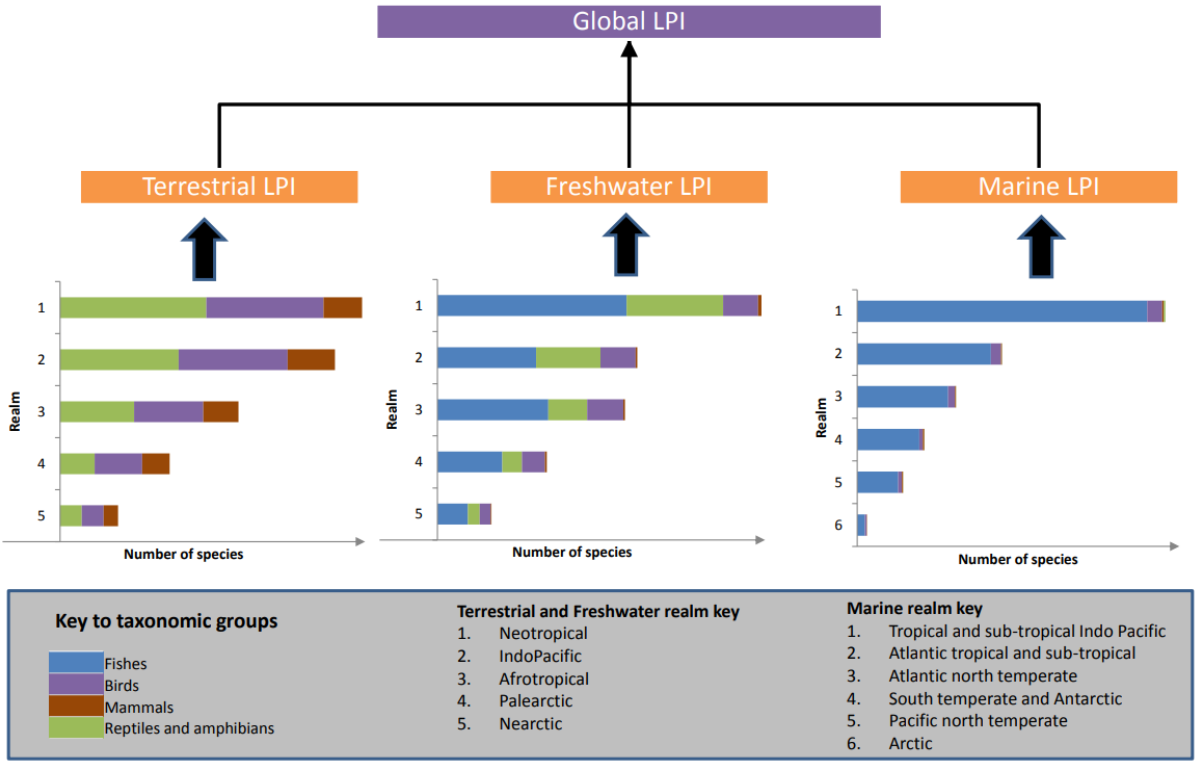


Figure 11. Schematic of the weighting process. Systems (Terrestrial/Freshwater/Marine) are weighted equally. Within each system, the proportion of species found across the realms that compose that system (the length of the bars above) is used to proportionally weight each realm index. Within each realm, the diversity of species is used to weight taxonomic indices (the relative size of the sections of the bars above). From McRae et al. (2017).

However, calculating this global indicator and its subsets requires a series of additional steps. These ensure that the dataset is as representative of what we currently know about biodiversity trends as possible, and therefore most useful to policymakers.

- Whenever data for a new species is entered into the LPD, the species name is checked against specific taxonomic authorities to ensure consistent naming. All population trends for one species can then be averaged together to form a single species trend when needed, even if the original source assigns a different species name to a trend. In addition to this, all populations are marked as native or non-native in the location where the population was monitored. This is important, as often national and international commitments to protect biodiversity focus on native species. This is the case for the GBF goals, and that is why the decision was made to include only native species in the 2024 global LPI (see Figure A1 in the Appendix).
- Before data are added to the LPD, the quality of the data source is carefully assessed, so as to ensure that all sources in the database are deemed robust, and they are

referenced and traceable. However, in some cases a single population can have an undue effect on the overall trend, meaning that their exclusion will cause a noticeable shift in the trend trajectory (usually over a short period) or final value of the global or realm-level trends. This is routinely checked as part of the tests we carry out during the LPR analysis. These populations are removed, not because they are low quality or the trends are not valid per se, but because we want LPI trends to be representative of a broad set of species, and not to be driven by individual populations. These populations are marked with a 1 in the "Exclude" column in the public dataset, which will be published on the Living Planet Index website.

- As described in more detail in section 2.1, populations for the same species monitored in the same location over the same period of time are considered "replicates". Only one of them is ever used in the global LPI calculations, to avoid potentially double-counting individuals. Replicates that are excluded in the global analysis are marked as 1 in the "Replicate" column in the public dataset.
- In the calculation of the LPI, as a way to ensure the robustness of the index, interannual change values are capped to 10-fold increases or declines, to limit changes deemed less likely biologically.
- Finally, index values are smoothed using a 3-year running average but keeping the first and final index values fixed. The difference between the smoothed and unsmoothed global trend is shown in Figure A2 in the Appendix.

3.4 The effects of weighting the LPI by species richness

Applying taxon-realm level weightings to the LPI means that, if strong declines occur in taxonomic groups or areas that are rich in species, more weight will be attributed to these, resulting in an overall negative weighted average. Figure 3 shows the proportion of populations that are increasing, decreasing or stable. This categorisation is based on the total or overall change i.e. how much the population has changed over the whole monitoring period.

This is one way to describe the change occurring in that particular population or species. Another is to consider the average annual change, i.e. how much the population or species changes each year, on average. Figure 12 shows the proportion of populations for each taxonomic group (mammals, birds, fish, and herptiles) in five categories of trends (Strongly or moderately increasing or declining and those showing little change). While the trends are relatively balanced, we generally see more strongly decreasing than strongly increasing trends. Figures 13, 14 and 15 show a more in-depth breakdown of these patterns. Note how some of the largest proportions of strongly declining populations occur in highly biodiverse – and therefore heavily weighted groups) – such as Neotropical herptiles among terrestrial species, and Afrotropical fish among Freshwater species.

It is important to note that within an LPI, individual populations trends are never considered in isolation. Indices like the LPI are composite, meaning that population trends are averaged with other trends. The time period when an increase or decline occurs within a time-series can differentially impact the overall trajectory of the trend, as does how many species and populations contribute to the trend at that point in time. For example, when data are scarcer (e.g. towards the earlier or later years of an index) steep declines or sharp increases can have stronger impacts on the overall trend, as there may be fewer population time-series contributing at that time. This will also be reflected in the estimated confidence intervals of the index highlighting the uncertainty caused by lower amounts of data.

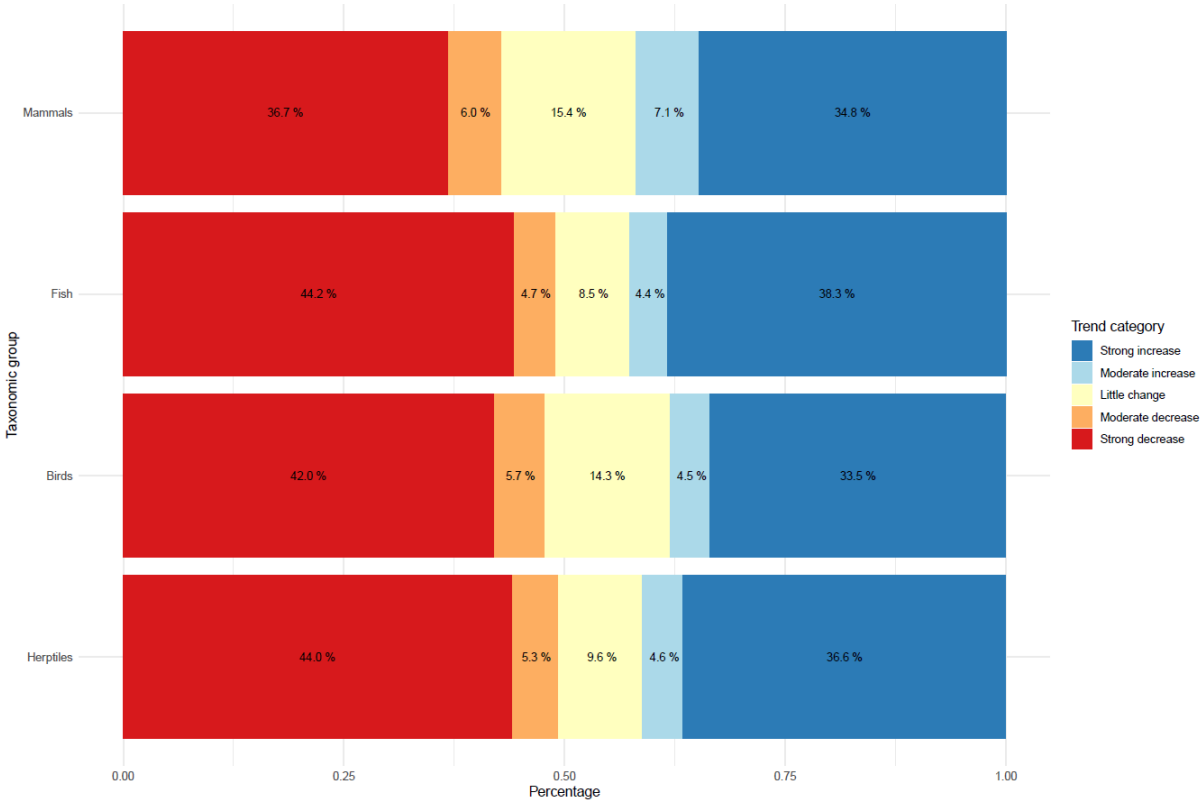


Figure 12. The proportion of species population trends by taxonomic group showing a strong or moderate increase or decreasing, or little change. Categories are based on Burns et al. (2023) and describe an annual change greater than or equal to +2.81% (Strong increase), between +1.16% and +2.81% (Moderate increase), between -1.14% and +1.16% (Little change), between -2.73% and -1.14% (Moderate decrease), and less than or equal to -2.73% (Strong decrease)**.** Inset percentages highlight the proportion of trends within each taxonomic group in the shown categories.

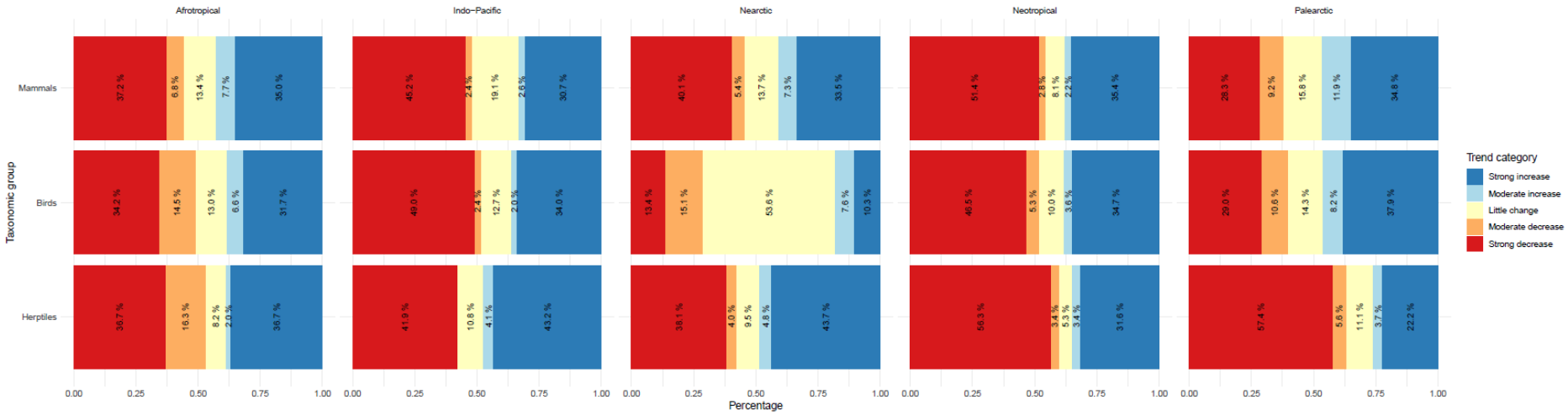


Figure 13. The proportion of species population trends by taxonomic group and biogeographic realm in the terrestrial system showing a strong or moderate increase or decrease, or little change. Categories are based on Burns et al. (2023) and describe an annual change greater than or equal to +2.81% (Strong increase), between +1.16% and +2.81% (Moderate increase), between -1.14% and +1.16% (Little change), between -2.73% and -1.14% (Moderate decrease), and less than or equal to -2.73% (Strong decrease)**.** Inset percentages highlight the proportion of trends within each taxonomic group in the shown categories.

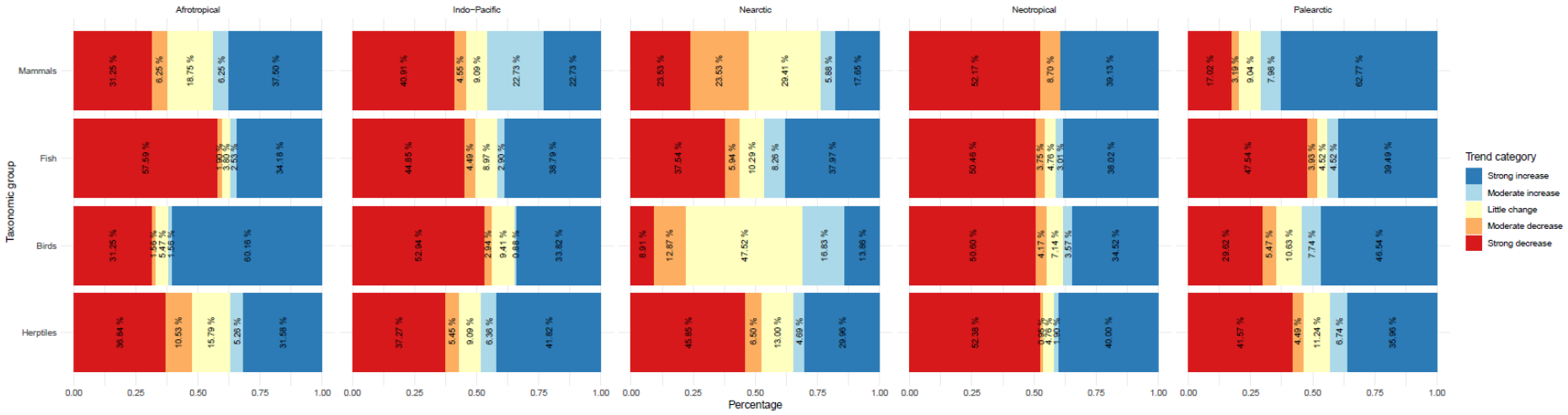


Figure 14. The proportion of species populatio trends by taxonomic group and biogeographic realm in the freshwater system showing a strong or moderate increase or decrease, or little change. Categories are based on Burns et al. (2023) and describe an annual change greater than or equal to +2.81% (Strong increase), between +1.16% and +2.81% (Moderate increase), between -1.14% and +1.16% (Little change), between -2.73% and -1.14% (Moderate decrease), and less than or equal to -2.73% (Strong decrease)**.** Inset percentages highlight the proportion of trends within each taxonomic group in the shown categories.

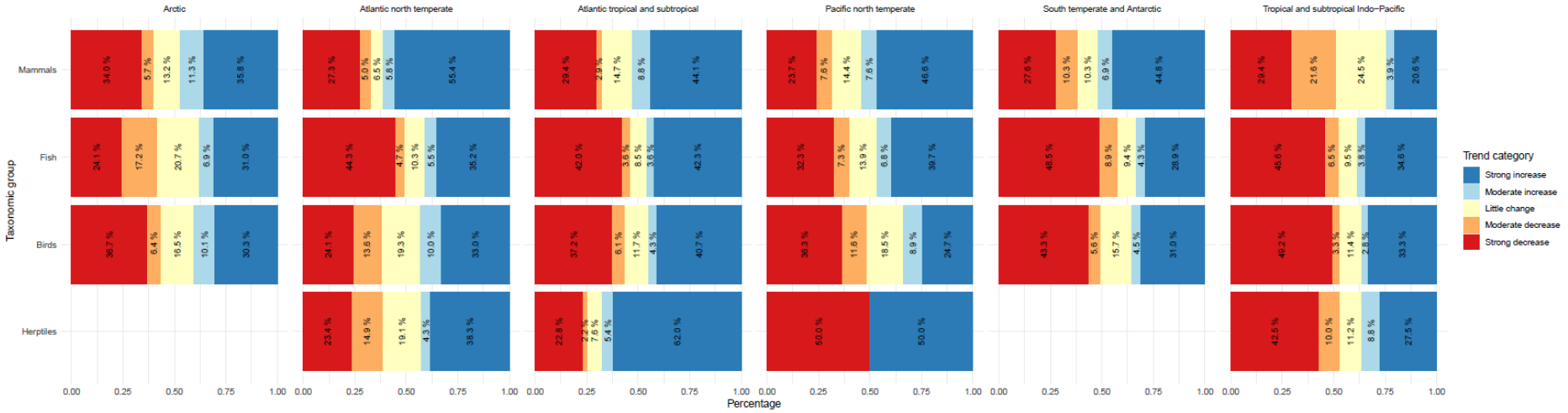


Figure 15. The proportion of species population trends by taxonomic group and ocean in the marine system showing a strong or moderate increase or decrease, or little change. Categories are based on Burns et al. (2023) and describe an annual change greater than or equal to +2.81% (Strong increase), between +1.16% and +2.81% (Moderate increase), between -1.14% and +1.16% (Little change), between -2.73% and -1.14% (Moderate decrease), and less than or equal to -2.73% (Strong decrease)**.** Inset percentages highlight the proportion of trends within each taxonomic group in the shown categories.

4. Stress-testing the LPI

Measuring how and why nature is changing is critical, but also difficult. Biodiversity data are patchy and biased towards certain regions and taxonomic groups. All indicators that track the state of nature at a global scale measure different facets of biodiversity, and they all show a decline. Each indicator, including the LPI, comes with its own set of caveats and sensitivities, which have been described in the scientific literature. To ensure each iteration of the LPI is as robust as it can be, the index is stress-tested, as reported here and on the LPI website (www.livingplanetindex.org). Please note that the trends presented in this section are all unsmoothed (included the global trend) to allow for comparison between direct outputs of the sensitivity tests presented.

4.1 Sensitivity to outliers

A recent paper highlighted that the underlying statistic of the LPI can be sensitive to both extreme population increases and declines (Leung et al. 2020). With each Living Planet Report, we test the index by recalculating it excluding the most declining populations, excluding the most increasing ones, and both sets of populations together. This is to ensure the accuracy of the statistics, and to confirm that it is not driven by extreme declines or increases in species or populations. The populations removed during this stress-testing are not necessarily the same as those identified as having undue noticeable effects on system or realm indices such as sudden short-term shifts in the trend trajectory (the latter are described in section 3.3). Outliers are not automatically removed from the trends as they represent valid data (as assessed through the checks carried out during data entry) and because they often come from underrepresented regions and taxonomic groups.

The results of the tests on the removal of extreme trends are presented in Figure 16. This shows that the removal of 2.5% and 5% of the populations with the most positive and the most negative trends has a small positive effect on the global LPI. The removal of 10% of the most positive and the most negative trends among the LPI populations reduces the overall change in the LPI from -73% to -61%. The removal of values at both extremes lessens the decline for two reasons: firstly, the magnitude of the most negative trends exceeds the opposite magnitude of the most positive trends. Secondly, it is affected by the realms and taxonomic groups that the extreme trends occur in – if more of the negative trends are found in the higher weighted groups, and the most positive trends in the lower weighted groups, the net effect of removing extremes will also be a positive shift in the index. Figures 13, 14 and 15 show how the magnitude of population trends varies by taxonomic group and biogeographic realm. For a more in-depth explanation of these tests, see also this blog on the ZSL website which addresses this point (but please note that this was written in 2020 and is based on an older version of the LPI dataset).

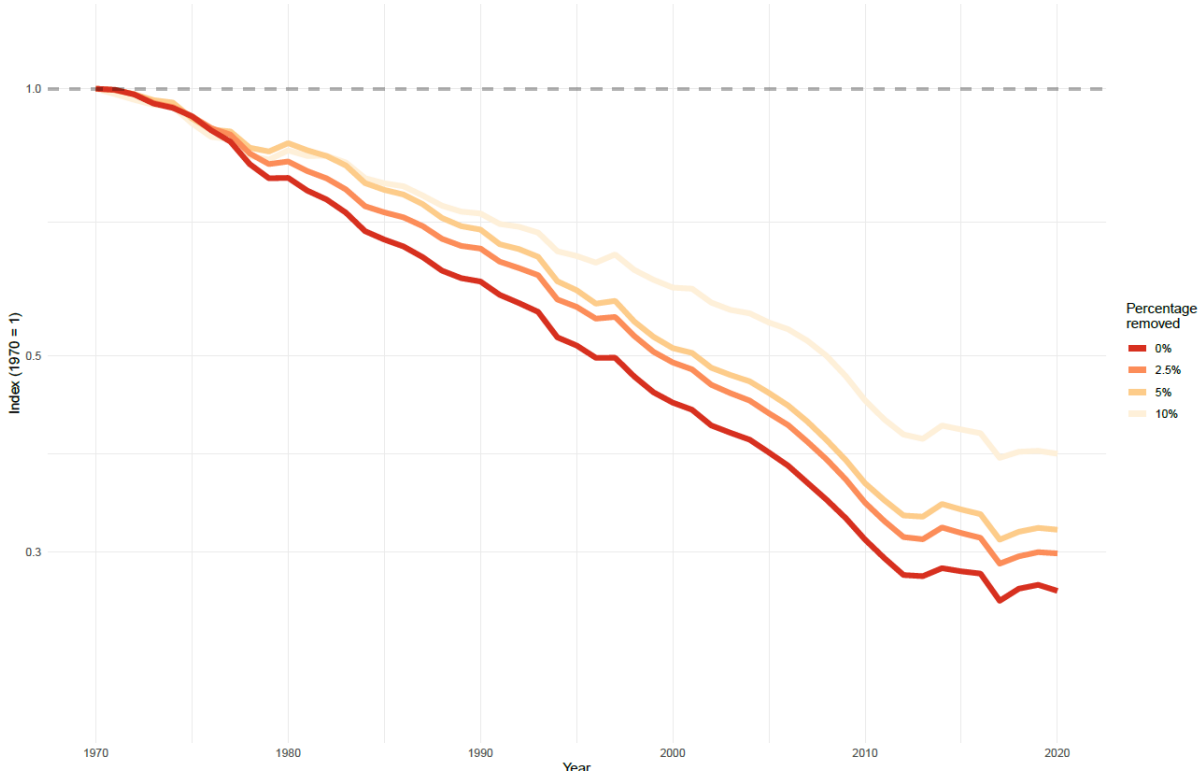


Figure 16. Removing extreme trends on the global Living Planet Index. The global Living Planet Index after removing a proportion of the most declining and increasing trends in the dataset. The three lines show the effect of removing populations beyond the 2.5%, 5% and 10% thresholds. The global LPI (0% of the dataset removed) is shown in red for reference.

4.2 Why we include short and sparse time-series

The data included in the LPD are gathered from a variety of sources and collected at different scales. The time-series included in these data are therefore characterised by varying lengths (i.e. the interval between the first and the last observation) and fullness (number of observations in the time-series). While most birds and some mammals have – at least in some areas of the world – been monitored for longer as part of baseline monitoring programmes, for other species or groups only shorter time-series are available. Placing a strict threshold on the minimum length of the time-series or the minimum number of data points could therefore disproportionately impact some taxonomic groups, and often those that are already less well represented in the LPI (Marconi et al. 2021). Amphibians, for example, are mostly represented in the database by shorter time-series (Figure 17). Disregarding this information could potentially lead to missing declines, which are important from a conservation perspective.

A study comparing known long-term trends in bird abundance with samples of these complete time-series (Wauchope et al. 2019) found 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. It remains to be tested if these results can be expanded to other taxonomic groups and types of data, but this nonetheless points to the fact that a decline detected in a short time-series is probably worth investigating to confirm the trend and potentially avoid further decline.

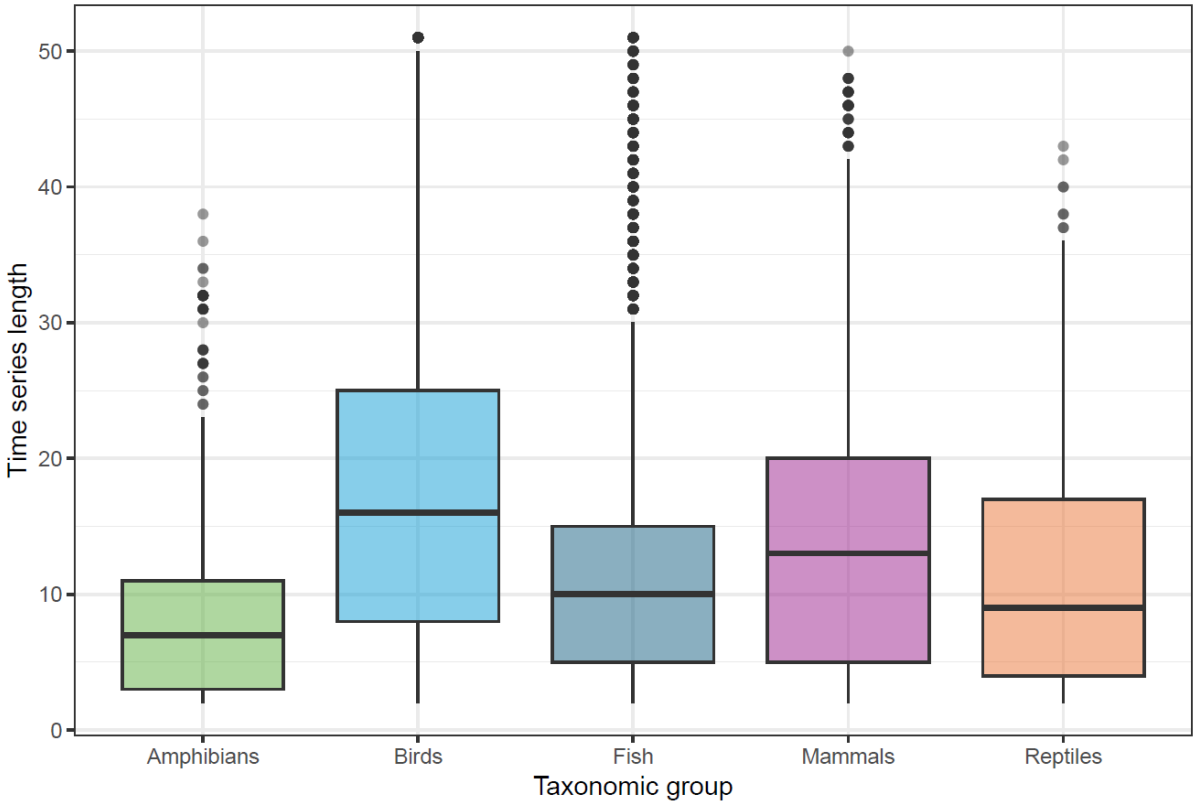


Figure 17. Time-series length by taxonomic group.

To gauge the impact of shorter time-series and sparser time-series on the results of the global LPI, as highlighted by a recent study (Toszogyova et al. 2024), we recalculated the trend excluding these (Figures 18 and 19). While the removal of a part of the dataset will inevitably result in a change in the overall trend, the removal of shorter time-series does not have a strong influence on the global LPI (Figure 18). The confidence intervals for trends calculated excluding time-series spanning less than 5 and 10 years generally overlap with the confidence intervals around the global trend, and the final index values differ from the final value of the global trend by 7 and 4 percentage points respectively (the trend which excludes time-series covering less than five years shows an uptick in the last three years). The removal of sparse time-series (irrespective of the length of the time period they cover) has a stronger impact on the trend. Setting the minimum number of data points for a time-series to be included to 3, 5 or 10 years leads to 21%, 39% and 59% of the dataset being removed respectively in the trends presented in Figure 19.

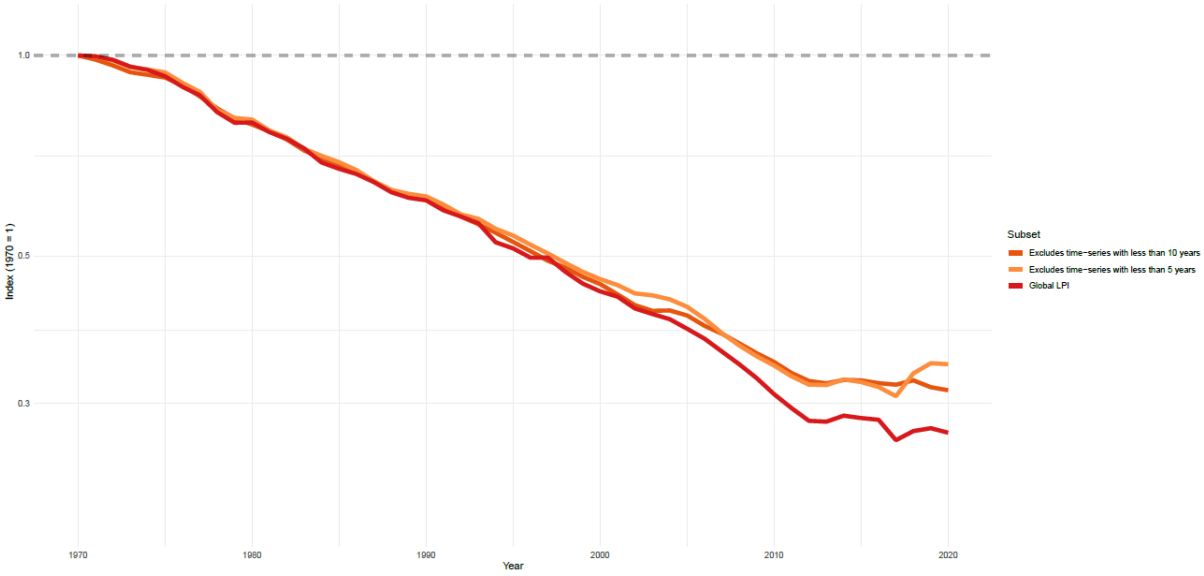


Figure 18. Indices of abundance for vertebrate species monitored between 1970 and 2020, calculated excluding time-series with data covering less than 5 years (light orange) and 10 years (dark orange). The global LPI trend is provided for comparison (in red).

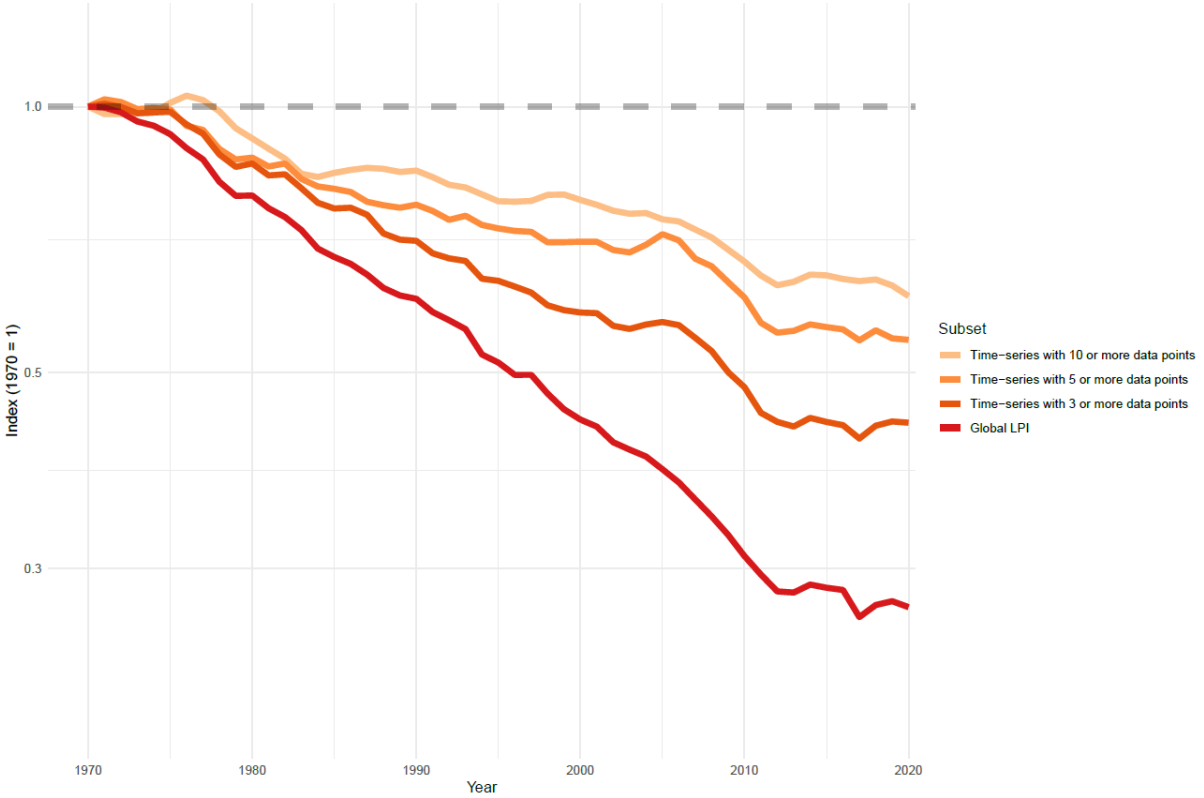


Figure 19. Indices of abundance for vertebrate species monitored between 1970 and 2020, calculated excluding time-series with less than 3, 5 and 10 data points. The global LPI trend is provided for comparison (in red).

However, there are important considerations behind the methodological decision to include shorter and sparser time-series in the database and global analysis (based on discussions and testing during the over 25+-year lifetime of the LPI). These time-series are included in the LPI as they capture important information about population trends, often in underrepresented taxonomic groups. For example, a recent paper highlighting the decline in African savanna raptors (Shaw et al. 2024) would have to be removed if population trends with two data points were automatically discounted – but this would take out an important insight into what is happening to 42 bird species in Africa, and the Africa LPI would lack key trends as a result. So, once the data quality checks described above (see section 3.3) have been carried out, the LPI team take a conservative approach to removing population data from the LPI, as a good justification is needed for excluding valuable data from the final index.

4.3 Handling missing counts and extinctions

Zero values occur in monitoring data for a variety of reasons; they can be missing counts, a sign of a population crashing to local extinction, or a pre-cursor to new immigration. During data entry into the LPD, we make sure that a value is entered as a zero only if monitoring was carried out and no individuals of that particular species were found. If no survey was carried out in a particular year, this will appear as a missing value in an LPI time-series. Although zero values are meant to indicate that the species was not observed in a specific year, this can also be the result of a missing observations. For example, failure to detect a species can result from very low abundance, or when a multi-species monitoring programme is not timed to the migration patterns of all species. Ideally, we would want to know the reason behind each zero value, and would treat zeros differently depending on what they represent. However, the information provided in the data source is not always sufficient to establish this with absolute certainty.

As the LPI calculation starts from the computation of an interannual growth rate $\log_{10}(N_{year+1}/N_{year})$, and this cannot be calculated if the population size is zero in one of the two years, zeros are replaced with a small value (1% of the population mean is added to all values within a time-series containing zeros). During the development stage of the LPI, tests were carried out to decide how to most appropriately deal with zeros values, and this was the best identified approach (Loh et al. 2005). This conservative approach assumes that the population is indeed changing by two orders of magnitude, to ensure large increases and decreases in abundance are captured by the index, as they are important from a conservation perspective.

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6. Appendix

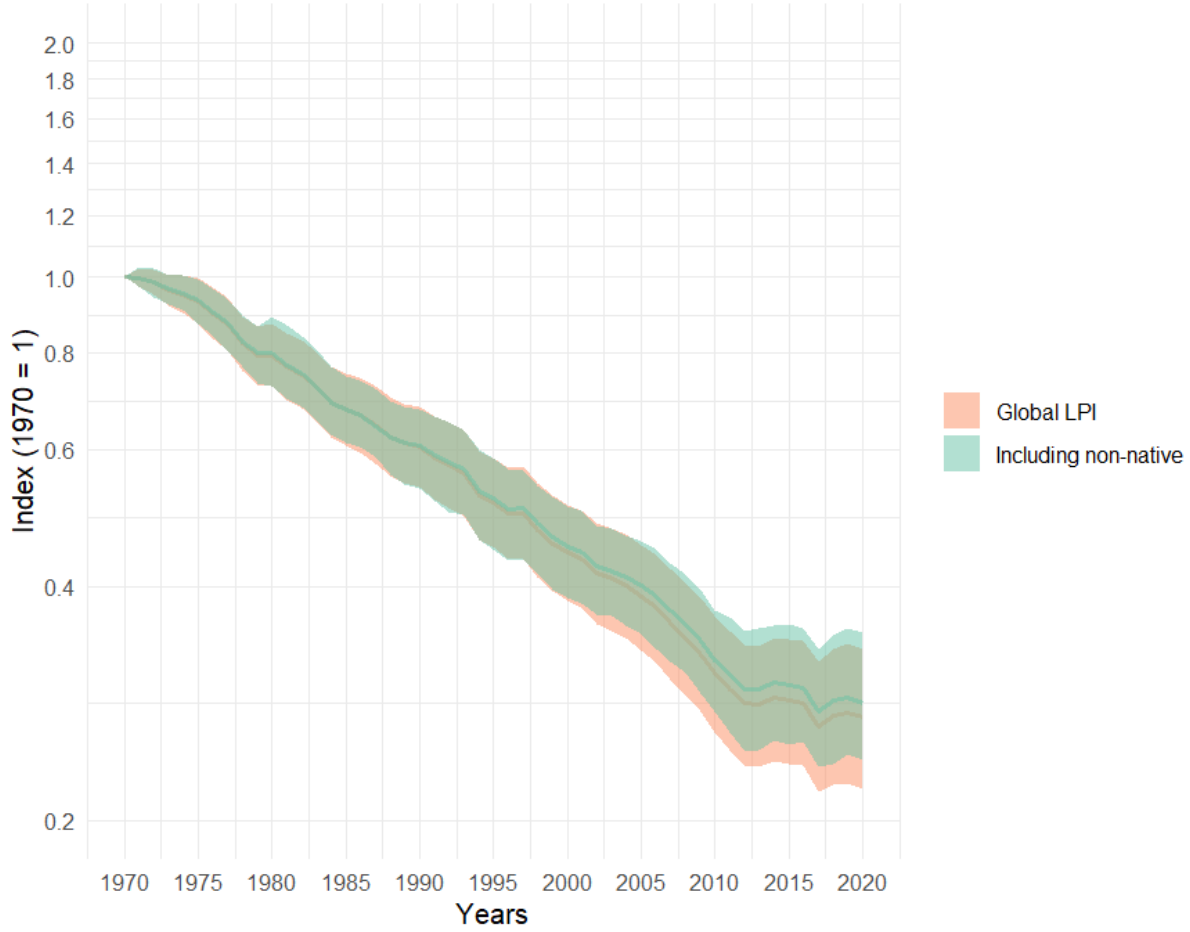

Figure A1. The global LPI 2024 with and without the inclusion of non-native species.

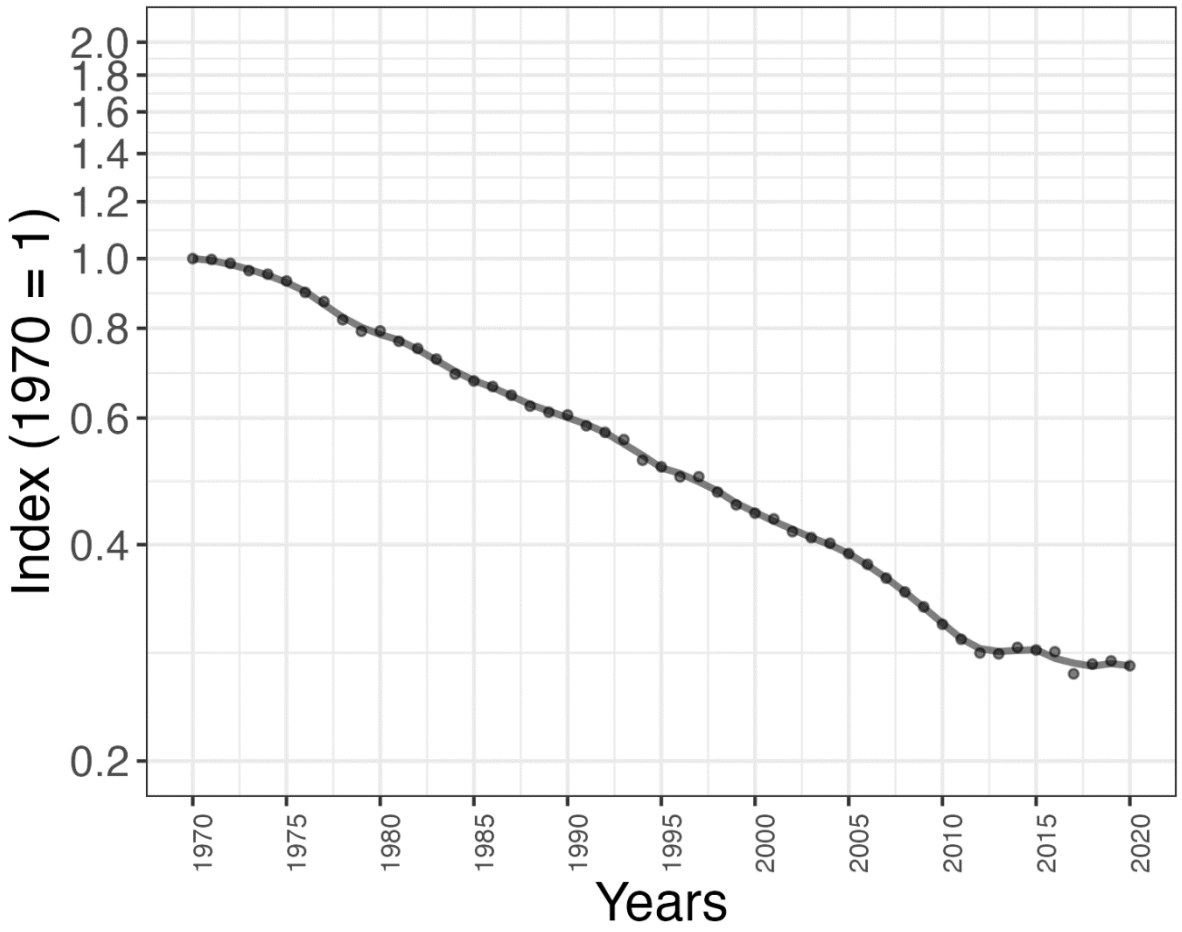

Figure A2. The global LPI 2024 smoothed (line) and unsmoothed (points).