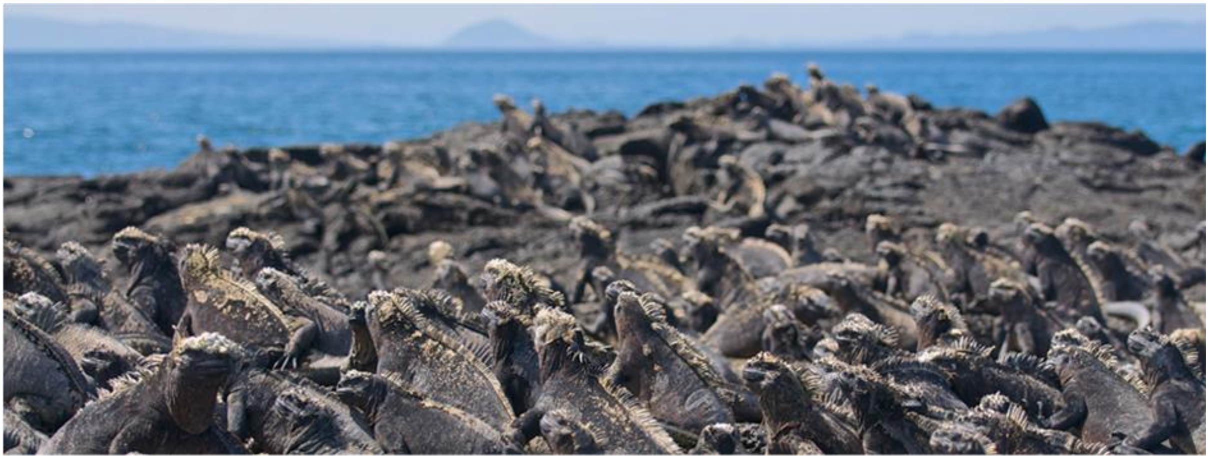

Living Planet Index

Guidance for national and regional use Version 1.2

10/18/2021

ZSL
Valentina Marconi, Louise McRae

Contents

What is the Living Planet Index and how is it used?

The Living Planet Index (LPI) is an indicator of global biodiversity based on change in population abundance of vertebrate species from all around the world. Biodiversity is perhaps most widely understood at the species level, so as a measure of trends in species abundance the LPI has a high degree of resonance with decision makers and the public and links clearly to ecological process and ecosystem function.

The Living Planet Index uses vertebrate (amphibian, bird, fish, mammal, and reptile) population trend data from 1970 until the present day, combining these trends into a measure that can be plotted over time to visualise and track any changes. The database underlying the indicator currently includes over 27,000 population time-series for over 4,500 species. The original LPI methodology has been described by Loh et al. (2005) and Collen et al. (2009). McRae et al. (2017) introduced a new weighting procedure to give a better representation of global vertebrate diversity and to correct for a bias towards well studied species from Europe and North America.

Living Planet Index trends at the global level have been published every two years in the Living Planet Report since 1996. The most recent report was launched in September 2020. The global LPI presented in the report showed a 68% decline from 1970 to 2016 meaning that on average, vertebrate populations have declined in abundance over this 46-year period. The LPI has also been used in the past to look at biodiversity trends at a different scale rather than the global one. In 2008, the indicator formed the basis for an assessment of the change in population abundance in wetlands across the Mediterranean region. In 2021, the Living Mediterranean Report (Galewsky et al. 2021), a comprehensive synthesis of biodiversity trends of vertebrates in the Mediterranean region since 1993 was published. The LPI project has also had a long-standing collaboration with the Conservation of Arctic Flora and Fauna (CAFF), the biodiversity working group of the Arctic Council. This has resulted in a number of reports, such as the Arctic Species Trend Index (ASTI) in 2010 (McRae et al. 2010) and an update in 2011 (Gill et al. 2011), which focused particularly on marine populations, and a more recent report on Arctic migratory birds (Deinet et al. 2015). The LPI method can also be used to calculate national indicators provided that enough in-country data is available. This document provides some guidance on the process of collating data and calculating trends at the national level.

National trends and their relevance

Although administrative boundaries are not biologically significant and species often move across borders (and international conservation efforts are therefore also essential to species survival), conservation intervention is often initiated at the local or national level. Being able to monitor species at this level is useful for a range of reasons:

- it gives an indication of management effectiveness including conservation efforts;
- can provide an early warning of threats as changes in populations are often a forerunner of extinctions/loss;
- from a policy perspective, it can help tracking progress towards biodiversity targets and with respect to the goals of the Ramsar Convention, the Convention on Migratory Species and CITES, as well as other international processes and agreements, such as those addressing forests and marine systems.

Since the ratification of the CBD in 1992, much effort has been put into the development of indicators at the national level. In 2011, the Biodiversity Indicator Partnership, the global initiative to promote and coordinate development and delivery of biodiversity indicators in support of several international conventions and agreements, published guidelines for National Biodiversity Indicator Development and Use (Stanwell-Smith et al. 2011). According to these guidelines, the requirements for the development of an indicator at the national level are as follows:

- That it is scientifically valid. There has to be an accepted theory of the relationship between the indicator and its purpose, with agreement that change in the indicator does indicate change in the issue of concern. Furthermore, the data used are reliable and verifiable.
- That it is based on available data so that the indicator can be produced over time. The amount and quality of the data represent constraints that shape the development of the indicator.
- That it is responsive to change in the issue of interest.
- That it is easily understandable both conceptually (how the measure relates to the purpose) and in its presentation (it is easy to interpret the data). As biodiversity is of interest for several groups of stakeholders and relevant policies are scattered through a variety of sectors, it is important to develop an indicator that can be used to communicate issues on biodiversity to a wide and diverse range of people.
- That it is relevant to user's needs. This is of fundamental importance, if the indicator is to be used to support informed and effective decision making and action for biodiversity conservation and sustainable use of resources.

The Living Planet Index is based on a peer reviewed method (Loh et al. 2005, Collen et al 2009, McRae et al. 2017), it uses readily available data and produces a final indicator that is sensitive to annual changes and is easy to communicate to a range of audiences. The use of the LPI has been reliably tested at the global, regional and national level (Ledger et al., in prep.). The data included in the Living Planet Database (LPD) is publicly available, unless data were shared with the Zoological Society of London under the agreement that they would be kept confidential.

Data collection and selection

The first step to constructing a national-level LPI is to collate a dataset of abundance time series for populations of species occurring within the country of interest to supplement the existing data for the target country in the LPI database. Before starting to directly collect data, it is useful to gather data on the number and taxonomic spread of the species occurring in the country.

The principal constraint in using LPI approaches at national scale is the availability of enough appropriate population time series data to be representative of the systems of interest within a single country. Unless a comprehensive and structured national monitoring programme has been implemented where appropriate data are available, they are likely to be geographically clustered into well-studied areas and to focus on particular taxa for which there is national expertise and/or interest. In this case, results might not be necessarily representative of large-scale population trends in the area of interest, but they will still provide the starting point for an informative national scale index, which can be built upon.

The time required for data collection will vary depending on how many species occur in the country and the availability of data. If the reference list is long, it is likely that a line will need to be drawn on data collection at some point, although there might be other data that haven't been processed.

Creating a reference list

A **reference list of all vertebrate species occurring within the country of interest** could be available if the country has a National Red List, or through other national-specific sources. Where possible, the list should include regularly occurring species. As it is unlikely that there will be data available for species that do not occur regularlyin the country, these species should not be targeted during the data collection process.

Also, a decision should be made at an early stage on whether **invasive species will be included in the** national LPI trend. An increase in abundance in these species does not necessarily represent a positive signal for biodiversity. Data available for these species could still be collected, but the time-series should be marked as invasive (depending on data availability, it might be possible to calculate a separate index for invasive species) or they could be excluded altogether.

To make consistent decisions on whether a species is to be included in the dataset, taxonomic authorities should be selected early on and adhered to. If these don't match the ones used by the reference list (if known), there will most likely be some taxonomic discrepancies to be resolved.

Data storage

The data need to be in a specified format for analysis (a csv file) but the data can be stored in other formats (for example, a database). Data could also be provided to the LPI team at ZSL (see contact information) and stored in the LPD. This has the advantage of being maintained in a secure database which is regularly backed up. Data provided to ZSL can be are kept confidential, so that they can be used in large-scale analysis but never shown individually nor made publicly available. A bibliographic software or service would also be useful for labelling and storing the data sources, as it's important that the data are references and traceable. Back up of both the data and the sources should be carried out regularly.

Data already available

An **initial dataset** can be compiled with the data in the LPI database, if any are available for the area of interest. These data have been collected over a number of years as part of other LPI projects and can be downloaded from the portal or are available from the LPI team upon request. LPI data are subject to a Data use policy, which can be found here.

Gap analysis

It is good practice to compare the number of species in the dataset with the number of species in the reference list within each taxon at various stages of the data collection project. A simple comparison will produce a list of species currently missing from the dataset that can be targeted in the data collection. Alternatively, the estimated proportion of species from each taxonomic group occurring in the country could be compared with the proportions of species for that taxon found in the dataset through binomial tests of proportions (see McRae et al 2017). Bonferroni corrections should be applied to all multiple tests, as done by Saha *et al*. This can highlight species or groups of species to focus on during data collection, and can be repeated at different stages throughout the data collection process to check if any of the **gaps** have been filled in. This also helps identifying data gaps in monitoring data and highlighting taxonomic groups and areas on which monitoring should focus at the national level, as well as providing an assessment of taxonomic representation. Data collection can also be informed by an analysis of the **temporal spread** of the data.

Contact list

Data collection could also be carried out by contacting local organizations (government departments, NGOs and scientific institutions) or individuals that work in the country and might have greater knowledge of data availability or access to unpublished monitoring reports. This might require putting in place an agreement or Memorandum of Understanding. Keeping a list of contacts will be useful, especially for any future updates of the index.

Data searches

A protocol for timed data searches is available from the Living Planet Index team upon request. Data can be collected from a range of sources including published scientific literature, online databases and government reports, directly from researchers and institutions, and from grey literature. Ideally, in order to make the trends as robust as possible, peer-reviewed data sources should be prioritised, although they might not always be available.

Data inclusion criteria

To be included in the Living Planet Database, data must adhere to strict data **quality criteria**:

- Data have to be for a single species
- At least two years of data (they don't need to be consecutive)
- Known geographic location
- Known method (standard across monitoring period)

Different types of data can be included in the dataset to calculate LPI trends as long as these data can be used to gauge change in abundance over time. These include full population counts, estimates, density measures, indices, proxies such as the number of breeding pairs or nests, measures per unit of effort or biomass. Landings or harvest data are not suitable for inclusion in an LPI unless there they are accompanied by a measure of effort. Time-series could be for the whole of a national population of a particular species or for individual local populations

Generally, the data are entered in the LPI database in the format they are found in in the data source (rather than being modelled before entering). For instance, density estimates from camera trapping data could be used, but it's best to rely on density estimates already provided by the source. When multiple abundance estimates are provided for each year, e.g. monthly/seasonal counts, counts using several methods, or counts of different sexes, age classes or lengths, the most appropriate annual count should be used. This could be an average or a total, or a peak month count. Detailed information about the data entry process is available here.

Adding data tags

Provided there are enough data available, LPI trends can be disaggregated in many ways, based on taxonomic groups, geographic area, etc. These disaggregated indices are based on the tags added to the data. As much as possible, these tags should be added at the time of data entry, using the information available in the data source as per the data entry manual document on the Supporting document page of the LPI website. Location-specific tags could also be relevant to the analysis (e.g. for the Canadian dataset, the province or territory the data had been collected in was recorded to allow for disaggregation at the administrative division level). External sources (databases, maps etc) used to add tags should be recorded and referenced in any outputs for future reference.

Spatial data

In the LPI database, time series are recorded as point locations (they are assigned a latitude and longitude value, usually corresponding to the midpoint of the area covered by the study). However, as more spatial data become available (for example on threats, such as forest loss, land use change etc.) it becomes more and more important to store detailed spatial information on where the data were collected, as this will allow a more precise coupling of population trends with their potential drivers. If possible, information on the area where the data were collected should be recorded (for example, in well-known text format - WKT). In the case of estimates for a large area (e.g. an entire country), use the midpoint of the intersection between the country and the species distribution range as spatial information. This prevents cases where the spatial coordinates for a specific record fall outside the actual distribution range of the species. For instance, if we have a national-level time-series for Canada for a species that only occur in the southern provinces, the midpoint of Canada would fall outside the species' distribution range. Species distribution information for mammals, amphibians, reptiles and fish can be collated from the IUCN Red List of Threatened Species, whilst information on bird distribution ranges can be downloaded from Birdlife website.

Analysis

Baseline and end year

Usually, LPI trends are calculated with a baseline set at 1970, as this is when a lot of monitoring schemes were set up so more data are available from that year onwards. That could be changed depending on data availability for the country of interest. It might be difficult to establish the most appropriate baseline for the trends until data collection has been completed, so initially it is probably worth collecting and storing all data. Also, data from before the baseline year can still be useful, especially if the available data points span the baseline year itself. Annual values will be derived for all years between the start and the end year of the time series through the modelling process (see analysis section) so, although they might not be used in their entirety, time-series that span the baseline year will contribute useful data to the first few years of the trend.

Similarly, data availability often drops in recent years as there is a lag between when data is collected and when it is published. This will most likely determine when trends should be cut as data availability becomes too low. The number of populations or species available in the baseline year could be used as an arbitrary threshold. As mentioned for the baseline year, collecting data that go beyond the chosen end year is still useful to increase the number of interpolated data points over the last few years of the trend and for any future updates of the trends.

Replicates and data quality

Two populations of the same species that were monitored in the same location over the same period of time are considered replicates, as the two time-series could include counts of the same individuals. Within the LPI database, we consider replicates time-series with an overlap of at least three years (of interpolated rather than actual data points). For example, if a time-series has data points in 1970, 1974 and 1978, and another time-series for the same species has data for 1968 and 1972, the two time-series will be considered replicates as – after modelling – interpolated data points will be available for both of them for an overlapping period of three years (1970-1972). Replicates can be useful in case of trend disaggregation (e.g. if there are two time-series for a species, one time-series that covers a smaller area and one at the national level, the local-level one might be marked as replicate but then be used if we calculate regional-level LPIs for which we can't use national estimates).

There are a few factors that come into play when deciding which one out of two (or more) time-series should be marked as replicate. It could be a good idea to calculate a quality score for each time-series, for example based on the length (years between first and last data point), fullness (number of data points between the first and last year), geographic scale, data type, variation and data source and then mark as replicate the time-series with the lowest quality score. Collen et al. (2009) and Marconi et al. (2021) used a similar system to classify time-series included in the respective studies.

When two time-series for the same species monitored over the same area overlap for over three years, but extend for long period of times beyond the period of overlap the years that overlap within the lowest-quality time-series could be deleted. Deleting part of a time-series is not something that is done for the global dataset, but it might make sense when the objective is to get the best temporal coverage for a specific country, rather than contributing to a global database where it is best to have sources entered in full for consistency and clarity.

Variation in the data includes looking for outliers that are far removed from the mass of data, and which may be detected when the data is graphed. Outliers should be investigated carefully. Often they contain valuable information about the population under investigation or the data gathering and recording process. Before considering the possible elimination of these points from the data, one should try to understand why they appeared and whether it is likely similar values will continue to appear. Of course, outliers may be bad data points. In almost all cases there will be a trade-off between data quality and data availability. Too stringent an application of data quality criteria will mean that the number of usable data sets may become vanishingly small. Too relaxed an approach will mean that the indicators produced will be difficult to defend and therefore lose much of their impact.

Zero values

Another issue to consider before calculating LPI trends for the area of interest is how to treat the zero values included in the dataset.

Zero values usually occur in time series for a few different reasons:

- Population declines to local extinction;
- Boom and bust populations – especially those which are just sampled rather than a total population count;
- Sampling approaches such as trapping can result in zero values without the population actually having declined to zero;

- Rare species or ones that occur in low numbers in the sampled area may persist as a population but not always found when the annual sampling is conducted;

- Migratory species whose arrival times to breeding (or overwintering) grounds might differ from year to year (monitoring programmes that target several species might not necessarily be timed perfectly for all target species).

As data sources often do not include information on the reason why a zero value was observed, it might be difficult to establish whether a zero corresponds to an actual local extinction or is just the result of a mismatch between the survey timing and the species arrival, for example. However, it is useful to inspect zero values in the dataset; if they mostly occur in the middle of the time-series (rather than at the end) the population has not gone extinct locally. Similarly, if the data mostly come from long-term monitoring programmes that look at multiple species at the same time, it is likely that the survey might not be perfectly timed to record the presence of all species. Based on these or similar considerations, the treatment of zero values that fits most of the time-series should be chosen.

Within the global LPI, zero values are kept in the dataset and substituted with a small value (corresponding to 1% of the average of all values in the time-series) in the analysis process (as in Collen *et al*., 2009). This step is necessary in order to be able to log all values in the time-series, a step necessary to calculate geometric mean abundance, the metric the LPI methodology is based on. The transformation of zero values as just described is included in the LPI code as the default option. If zero values are excluded and treated as missing, some short time-series that contained zero values might no longer have sufficient data (more than two years of non-zero data) to be included in the analyses.

Trends calculation

Code

There is an R package for using the LPI method on GitHub and details on the method are in Collen et al. 2009 and McRae et al 2017. A tutorial manuscript, with a more detailed description of the many parameters and options that are available within the code, will be available in the future.

Method

LPI data analysis follows a robust and peer reviewed method (Loh *et al*, 2005 and Collen *et al*, 2009 for the unweighted version; McRae *et al*, 2017 for the diversity-weighted version). Change in abundance is calculated between the baseline year and the end year using a two-stage modelling process, using mgcv 1.8-0 (Wood, 2011) package in R (R Development Core Team 2021), to obtain annual time-series level trends. Long time-series are modelled through a Generalised Additive Modelling (GAM) framework. For short time series (less than 6 data points) and time series that fail the GAM the chain method is used. Annual time series are aggregated geometrically following a standardised method to produce the final index. Within the indices calculated using the unweighted approach, each population carries equal weight within each species and each species carries equal weight within the overall trend. Unless otherwise specified, all populations of a species are weighted equally, and an average value is calculated for a species with more than one population within the data set. This means that species represented by several populations within the data set will have the same influence on the trend as species with only one population within the data set. If using weightings, a file specifying what weightings should be used will need to be provided to the code (examples are provided in the Github repository).

Presenting and interpreting trends

Description of representation of the dataset alongside results

To be representative of broader trends within the country of interest, national LPI trends should track a randomly selected representative subset of taxa stratified within the country of interest. However, these data are not usually available. As a consequence, we cannot measure how well the indices we calculate match the “real” trends but understanding the composition of the data is essential when interpreting the trends. It is always advised to present LPI trends alongside a description of the dataset, of its taxonomic and geographic representation and of its temporal coverage. The number of species and populations contributing to the index in a given year, for example, can be shown alongside the trends. The total number of contributing species and populations should always be mentioned when interpreting trends.

It is also useful to show the scale of the studies the data come from. Within the indices, species represented by several populations will have the same influence on the trend as species represented by one population only. Populations can vary from national or regional abundance measures to small scale, local measures and all carry equal weight within a species trend. Finally, the data collected will most likely come from a range of sources and will have been collected for different reasons. As a consequence, there will be differences in the methods, the time frame over which data were collected, the frequency of measurements and the units used. All these factors have to be taken into account when interpreting an index, so presenting about the quality of the data will help the readers/audience understand how representative the trends are of broader trends within the country.

Disaggregation

One of the advantages of LPI trends is that they can be disaggregated in many ways using the additional information described above (see section Adding data tags). Subsets can be created based on taxonomic, geographic or administrative criteria to provide results that are informative for scientists and policy makers. However, creating subsets of the original data set means that the number of populations within some subsets can be quite low and, as a result, indices with wide or no confidence intervals are generated that might be worth mentioning but not showing in an output.

Confidence intervals

LPI trends are generally presented with 95% bootstrapped confidence intervals, calculated by bootstrapping species lambdas and calculating an index for each of the 10,000 subsamples. When we look at the index value in the final year, the confidence intervals around the final year tell us something about the population value in relation to the baseline year. The CIs around that year’s value will in this case represent the uncertainty around the whole trend, as CIs calculated using this method are multiplicative. Each indexed year’s confidence interval is the previous year’s indexed confidence interval multiplied by the underlying variability in the rate of change.

As traditional LPI CIs don’t give us any information about the uncertainty around the rate of change from a specific year to the previous one, the plot of mean annual lambda values (average annual change from the previous year) with the associated standard error could be presented alongside a trend. These plots provide a useful indication of the variation in the data underlying the index. Mean annual lambda plots reflect the confidence in the data to produce the index trend shown, not in its representation of the actual trends or in the individual variability for each population estimate.

Y-axis scale

In public-facing reports, LPI trends are usually presented with linear-scale Y-axis as this is considered easier to understand. However, some of the national-level applications of the LPI (for example, the Canadian Species Index) have chosen to present trend on a logarithmic Y-axis, as a more appropriate scale for rate of change. This also means that increases and decreases are being represented evenly.

Diagnostics

Once trends have been calculated, it is always advised to have a closer look at them to try and understand if most species are behaving consistently within the trend or there are some species who are having a stronger influence the trend (for example because there is more data available for them). Any sharp changes in trajectory or blips in the trend should also be investigated to establish if they represent genuine changes in the trend, or data effects. For example, a large number of time-series with similar trajectory entering the trend at the same point in time might be causing a change in the shape of the trend. There are different ways to investigate patterns within a trend.

Disaggregation

Breaking down a trend down into smaller subsets can be useful, for example, to see if all taxa within the country or region of interest show similar or diverging trends, or if species belonging to the same taxon but occurring within different systems (terrestrial vs marine mammals, for instance) show similar or different trends. The smaller the subset of populations included in a trend the more likely it is that one single time-series or a small number of time-series might have a strong influence on the overall trend.

The rate of change over time for each species can also be inspected in order to detect outliers. Where a specific species or group of species is found to show very fast rates of increase/decrease within an index, the index can be re-calculated excluding the specific populations to see whether this exclusion has an effect on the overall index. If is causes marked changes in the index, this is stated in the comments, and sometimes the modified trend is shown alongside the original one to highlight differences.

Temporal coverage of trends

One other aspect that is important to take into account is the temporal coverage. The number of species and populations contributing to the trend in each year and the number of years of data available for each species and populations can be calculated using the "summarise_lpi" function of the rlpi R package. If the number of species and populations suddenly increases or decreases at some point in the trend, the index could be recalculated from that particular point in time, in order to have a trend with a relatively even coverage. For instance, it can happen that a trend appears to be above baseline level for the whole of the considered time-frame, but the first few years of the trend are only based on a small number of populations, and the index is actually decreasing from the point when most time-series come into the trend.

Drivers of trends

The Living Planet Index and its derived indicators are designed to detect broad-scale long-term trends in biodiversity data. As data availability increases, our ability to estimate trends for particular subsets improves. This, together with the diagnostic techniques highlighted above, may help resolve the influence of particular habitats, geographic areas or groups of species on the overall trends. The LPI database also includes information on threats to specific populations based on the information included in the original data source. This threat information is useful to create data summaries on what the most frequently mentioned threat to species in that particular area or group are. However, links between trends and drivers are currently speculative and rely on external research. At this stage, we cannot reliably say that a specific LPI trend is definitely caused by a certain threat even though that specific threat is mentioned in relation to most of the time-series used to calculate the trend. It is important to consider this when discussing species trends.

Case studies

The process of creating a national version of the Living Planet Index can vary widely, depending on who is responsible for it, what the index is going to be used for, and what output is expected from the project. In this section we present a few examples of how the process has worked in the past.

In September 2017 and September 2020 WWF Canada published two editions of the **Living Planet Report for Canada**. The data collection and analysis for these reports were done by WWF Canada, with ZSL's involvement for data-quality control, and for the review of the final draft of the report.

In February 2018, the Canadian Species Index (CSI), a biodiversity indicator based on the Living Planet Index methodology, was released by Environment and Climate Change Canada as part of the Canadian Environmental Sustainability Indicators (CESI), which provides data and information to track Canada's performance on key environmental sustainability issues such as climate-change, air-quality, water quality and availability, and nature protection. These indicators are used to measure progress of the Federal Sustainable Development Strategy and respond to commitments to report on the state of the environment. The Canadian Government and the Zoological Society of London had been working collaboratively on the CSI project since 2013, gathering data for over 50% of Canadian vertebrate species. The method and dataset behind the indicator are described in Marconi et al. 2021. An update to the indicator was published in 2020.

Originally established by the National Environmental Science Program's Threatened Species Recovery Hub, The University of Queensland and Birdlife Australia, the Threatened Species Index was first produced in 2018 and is based on the LPI methodology. It provides reliable and robust measures of changes in the relative abundance of Australia's threatened and near-threatened species at national, state and regional levels. The project is now managed by the NCRIS-funded TERN project at The University of Queensland and supported by the Australian Government Department of Agriculture, Water and the Environment (DAWE).

References and resources

- 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): e0169156.
- Collen B, Loh J, McRae L, Whitmee S, Amin R, & Baillie JEM. (2009) **Monitoring change in vertebrate abundance: the Living Planet Index**. *Conservation Biology*, 23: 317-327.
- Deinet S, Zöckler C, Jacoby D, Tresize E, Marconi V, McRae L, Svoboda M, & Barry T (2015). **The Arctic Species Trend Index: Migratory Birds Index.** Conservation of Arctic Flora and Fauna, Akureyri, Iceland.
- Galewski T., Segura L., Biquet J., Saccon E. & Boutry N. **Living Mediterranean Report – Monitoring species trends to secure one of the major biodiversity hotspots**. Tour du Valat, 2021. France.
- Ledger S, McRae L, Loh J, Almond R, Böhm M, Clements C, Currie J, Deinet S, Galewski T, Grooten M, Marconi V, Painter B, Scott-Gatty K, Young L and Freeman R. **Past, present, and future of the Living Planet Index**. Manuscript in preparation.

- Loh J, Green RE, Ricketts T, Lamoreux JF, Jenkins M, et al. (2005) **The Living Planet Index: using species population time series to track trends in biodiversity**. *Philosophical Transactions of the Royal Society of London B*, 360: 289-295.
- Marconi V, McRae L, Müller H, Currie J, Whitmee S, Gadallah F (ZuZu), Freeman R. 2021 **Population declines among Canadian vertebrates: But data of different quality show diverging trends**, Ecological Indicators, 130.
- McRae L, Zockler C, Gill M, Loh J, Latham J, Harrison N, Martin J, & Collen B (2010) **Arctic Species Trend Index 2010: Tracking trends in Arctic wildlife**. CAFF CBMP Report No. 20.
- Gill MJ, Zöckler C, McRae L, Loh J, & Collen B. (2011) **The Arctic Species Trend Index: A barometer for Arctic wildlife in: State of the Arctic Coast 2010: scientific review and outlook** (ed. Forbes DL), International Arctic Science Committee, Land-Ocean Interactions in the Coastal Zone, Arctic Monitoring and Assessment Programme, International Permafrost Association, Germany.
- R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.
- Saha A, McRae L, Dodd, CK Jr., Gadsden H, Hare KM, Lukoschek V, Böhm M. (2018) **Tracking Global Population Trends: Population Time-Series Data and a Living Planet Index for Reptiles**. Journal of Herpetology, 52(3), pp. 259-268.
- Stanwell-Smith, Damon & Bubb, Philip & almond, rosamunde & chenery, anna & Kapos, Valerie & Jenkins, Martin. (2011). Guidance for National Biodiversity Indicator Development and Use. UNEP World Conservation Monitoring Centre.
- Wood, S. N. (2011). **Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models**. In *Journal of the Royal Statistical Society (B)* (Vol. 73, Issue 1, pp. 3–36

Useful contacts

To notify the Living Planet Index team at the Zoological Society of London of your intention to work on national-level LPI trends and discuss options for collaboration, you can contact Louise McRae (louise.mcrae@ioz.ac.uk), the Living Planet Index Project Manager. For any general queries on the data or the code, you can also contact the other members of the Living Planet Index team at livingplanetindex@ioz.ac.uk.