Pathways linking biodiversity to human health: A conceptual framework

Supplementary Literature

# 

## Melissa R. Marselle1,2,3, Terry Hartig4,5, Daniel T. C. Cox6, Siân de Bell7, Sonja Knapp8, Sarah Lindley9, Margarita Triguero-Mas10-13, Katrin Böhning-Gaese2,14,15, Matthias Braubach16, Penny A. Cook17, Sjerp de Vries18, Anna Heintz-Buschart2,19, Max Hofmann2,20,21, Katherine N. Irvine22, Nadja Kabisch23,24, Franziska Kolek25, Roland Kraemer23,26, Iana Markevych27,Dörte Martens28, Ruth Müller29, 30, Mark Nieuwenhuijsen31-34, Jacqueline M. Potts35, Jutta Stadler36, Samantha Walton37, Sara L. Warber7,38, & Aletta Bonn1,2,3

## Affiliations:

1 Helmholtz Centre for Environmental Research - UFZ, Department of Ecosystem Services, Permoserstraße 15, 04318 Leipzig, Germany

2 German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Deutscher Platz 5e, 04103 Leipzig, Germany.

3 Institute of Biodiversity, Friedrich Schiller University Jena, Dornburger Straße 159, 07743 Jena, Germany

4 Institute for Housing and Urban Research, Uppsala University, Box 514, SE-75120 Uppsala, Sweden

5 Department of Psychology, Uppsala University, Box 1225, SE-75142 Uppsala, Sweden

6 Environment and Sustainability Institute, University of Exeter, Penryn, Cornwall, TR10 9FE, United Kingdom

7 European Centre for Environment and Human Health, University of Exeter, Truro, Cornwall, TR1 3HD, United Kingdom

8 Helmholtz Centre for Environmental Research - UFZ, Department of Community Ecology, Theodor-Lieser-Str. 4, 06120 Halle, Germany

9 Department of Geography, School of Environment, Education and Development, University of Manchester, Oxford Road, Manchester, M13 9PL, United Kingdom

10 Universitat Autònoma de Barcelona, Barcelona, Spain

11 Institute for Environmental Science and Technology, Barcelona, Spain

12 IMIM (Hospital del Mar Medical Research Institute), Barcelona, Spain

13 Barcelona Lab for Urban Environmental Justice and Sustainability, Barcelona, Spain

14 Senckenberg Biodiversity and Climate Research Centre (SBiK-F), Senckenberganlage 25, 60325 Frankfurt (Main), Germany

15 Goethe University Frankfurt am Main, Institute for Ecology, Evolution & Diversity, Max‑von‑Laue‑Str. 13, 60439 Frankfurt (Main), Germany

16 WHO Regional Office for Europe, European Centre for Environment and Health, Platz der Vereinten Nationen 1, 53113 Bonn, Germany

17 School of Health and Society, University of Salford, Salford, M6 6PU, United Kingdom

## 18 Cultural Geography, Wageningen Environmental Research, Wageningen University & Research, P.O. Box 47, 6700 AA Wageningen, The Netherlands

19 Helmholtz Centre for Environmental Research - UFZ, Department of Soil Ecology, Theodor-Lieser-Str. 4, 06120 Halle, Germany

20 Institute of Biology, Martin Luther University Halle-Wittenberg, Am Kirchtor 1, 06108 Halle (Saale), Germany

21 Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Theodor-Lieser- Strasse 2, 06120 Halle (Saale), Germany

## 22 Social, Economic and Geographical Sciences Department, The James Hutton Institute, Aberdeen AB15 8QH, United Kingdom

23 Humboldt-Universität zu Berlin, Geography Department, Unter den Linden 6, 10099 Berlin, Germany

24 Helmholtz Centre for Environmental Research-UFZ, Department of Urban and Environmental Sociology, Leipzig, Germany

25 Chair and Institute of Environmental Medicine, UNIKA-T, Technical University of Munich and Helmholtz Zentrum München, Germany - German Research Centre for Environmental Health, Augsburg, Germany

26 Helmholtz Centre for Environmental Research – UFZ, Department of Monitoring and Exploration Technologies, Permoserstraße 15, 04318, Leipzig, Germany

27 Institute of Psychology, Jagiellonian University, Ingardena 6, 33-332 Krakow, Poland

28 Eberswalde University for Sustainable Development, Faculty of Landscape Management and Nature Conservation

29 Unit Entomology, Institute of Tropical Medicine, Nationalestraat 155, 2000, Antwerp, Belgium

30 Institute of Occupational Medicine, Social Medicine and Environmental Medicine, Theodor-Stern-Kai 7, 60596, Goethe University, Frankfurt am Main, Germany

31 ISGlobal, Barcelona, Spain

32 Universitat Pompeu Fabra (UPF), Barcelona, Spain

33 CIBER Epidemiología y Salud Pública (CIBERESP), Madrid, Spain

34 Mary MacKillop Institute for Health Research, Melbourne, Australia

35 Biomathematics and Statistics Scotland, Craigiebuckler, Aberdeen, AB15 8QH, United Kingdom

36 German Federal Agency for Nature Conservation (BfN)

## 37 Department of English Literature, Bath Spa University, Bath, United Kingdom

38 Department of Family Medicine, University of Michigan, Ann Arbor, Michigan, USA

Disclaimer:

**The authors alone are responsible for the views expressed in this article and they do not necessarily represent the views, decisions or policies of the institutions with which they are affiliated.**

### Supplementary Table 1. Definitions of biodiversity variables and examples of actual biodiversity measurement. For simplicity, examples refer to the biodiversity tier *species*, while variables apply also to genetic and ecosystem biodiversity.

|  |  |  |
| --- | --- | --- |
| **Biodiversity variable** | **Definition** | **Examples of actual biodiversity indicators or measurements** |
| Individual organism/traits | Characteristics shared between individuals of a species, e.g. physical (e.g. body size, appearance, colouration, sound, scent), behavioural (e.g. movement, interactions with people), phenological (e.g. seasonal activity), biochemical (e.g., nutritional value, allergenic content), or ecological (e.g. trophic level, type of trophic interaction, pathogens, vector for veterinary and human diseases) | Taxonomic identification e.g. for plants ([www.try-db.org](https://www.try-db.org/TryWeb/Home.php)), birds (birdlife.org) (Elton traits, Wilman et al. 2014), or corals (coraltraits.org).  Physical traits, e.g. bird song; birds of prey; behavioural (e.g. mammals that are active during the day); phenological, mass seasonal flowering; biochemical, release of spores; genotype, morphotype; biting activity of disease vectors, vector competence, host preference |
| Abundance of individuals | Number of organisms present at a given time at a site | Counts of individuals combined with statistical techniques to estimate true abundance; Systematic recordings mostly with observations, but also e-DNA, remote sensing, radar, etc. |
| Species richness | Number of different species in a site | Systematic recording with observations, traps, AI records or e-DNA. Next to in-situ sampling, species records are available (e.g., gbif.org), taxon atlases, non-governmental organisations and administrative agencies and citizen science records. Richness depends on sampling intensity. |

**Supplementary Table 2.** Non-exhaustive list of available biodiversity data, health and well-being data, as well as data on potential mediating pathways among these. Spatial scale, type of dataset, type of data (point, line, area), data resolution and examples are provided.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Spatial scale** | **Type of dataset** | **Example** |
| **Biodiversity** | Local | Cadastre/Point-data | * [London, England street tree cadastre](https://data.london.gov.uk/dataset/local-authority-maintained-trees) * [Leipzig, Germany street tree cadastre](https://opendata.leipzig.de/dataset/strassenbaumkataster) |
| Species’ occurrence data (single sites/plots) | Biodiversity count surveys (bird watching, insect counts)   * [eBird](https://ebird.org/about) * [sPlot](https://www.idiv.de/en/splot.html) |
|  | Environmental Impact Assessments (EIA) |
| Habitat maps | Habitat and land-use types |
| Regional | Habitat maps | Habitat and land-use types (e.g. [The Biotope Type and Land Use Maps (BTLNK) of Saxony](https://www.natur.sachsen.de/biotoptypen-und-landnutzungskartierung-btlnk-22282.html)) |
| National | Species’ occurrence data (e.g. regular grids (Atlas), range maps), taxonomic guides | * [Atlas of German Breeding Birds (Gedeon et al., 2014)](https://www.dda-web.de/downloads/adebar/files/assets/basic-html/index.html#1) * [German Atlas of flowering plants and ferns](https://deutschlandflora.de/dflor/en) * [German Mosquito Atlas](https://mueckenatlas.com/about/) * [Atlas of Living Australia](https://www.ala.org.au/) * [Observational data of birds in Germany and Luxembourg](https://www.ornitho.de/index.php?m_id=1) |
| Continental | Species’ occurrence and remotely sensed data | * [Copernicus Land Cover](https://land.copernicus.eu/pan-european/high-resolution-layers) * [European breeding bird atlas](https://www.ebba2.info/data-availability/) |
| Global | Species’ occurrence (mostly range maps) and remotely sensed data, taxonomic guides | * [Global Biodiversity Information Facility, (GBIF)](https://www.gbif.org/) * [IUCN Red List of Threatened Species](https://www.iucnredlist.org/resources/spatial-data-download) * [IUCN Red List of Ecosystems](https://www.iucn.org/resources/conservation-tools/iucn-red-list-ecosystems) * [IUCN World Database on Key Biodiversity Areas](https://www.iucn.org/resources/conservation-tools/world-database-of-key-biodiversity-areas) * [IUCN World Database on Protected Areas](https://www.iucn.org/resources/conservation-tools/protected-planet) * Global [Species Richness Grid Maps for mammals and amphibians](https://sedac.ciesin.columbia.edu/data/collection/species/maps/services) * [Copernicus global land services (e.g. water, vegetation)](https://land.copernicus.eu/global/) * G[lobal land cover (time series](http://maps.elie.ucl.ac.be/CCI/viewer/) data from 1992 to 2015) * Spatial [Heterogeneity](https://www.earthenv.org/texture) of [Global Habitat](https://www.earthenv.org/texture) * Taxonomic identification e.g. for [plants,](http://www.try-db.org) mammals and [birds](http://birdlife.org) (Elton traits, Wilman et al., (2014)), or [corals](http://coraltraits.org) * [Census of Marine Life](http://www.coml.org/about-census/) * [Long-Term Ecological Research (LTER) Data](https://lternet.edu/using-lter-data/) * [Algae Database](https://www.algaebase.org/about/) |
| **Health and well-being** | Local | Cadastre/Point-data | * Children & adult cohort studies (e.g. [LIFE Health Study](https://life.uni-leipzig.de/en/life_health_study.html) on [adults](https://life.uni-leipzig.de/en/adults.html) or [pregnant women, children and adolescents](https://life.uni-leipzig.de/en/children_adolescents_and_pregnant_women.html)) |
| Vital statistics, survey data | * [USA City Health Dashboard](https://www.cityhealthdashboard.com/) * German school enrolment examinations (*Einschulungsuntersuchung)* * Children & adult cohort studies * [United Kingdom Biobank](https://www.ukbiobank.ac.uk/researchers/) * Medical records from doctors’ surgeries * Health Systems Medical records * Mortality records |
| Regional | Vital statistics, survey data | * Quality of Life (e.g. [Eurobarometer](https://www.gesis.org/en/eurobarometer-data-service/home)) * Environment related disease statistics (lyme, borreliosis, poisoning, etc) * Regional health surveys (e.g. [USA Centre for Disease Control National Health Interview Survey](https://www.cdc.gov/nchs/nhis/about_nhis.htm)) |
| National | Vital statistics, survey data | * Prescription data ([England](https://openprescribing.net/)) * Index of multiple deprivation ([England](https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019)) * National Census (e.g. [United K](https://www.ons.gov.uk/census)ingdom; [US](https://www.census.gov/topics/health/surveys.html)A) * Public Health surveys (e.g. [Indonesia Demographic and Health Survey](https://microdata.worldbank.org/index.php/catalog/3477); [German Socio-Economic Panel](https://www.diw.de/en/diw_02.c.222518.en/research_data_center_of_the_soep.html); [Bhutan Gross National Happiness](https://ophi.org.uk/policy/national-policy/gross-national-happiness-index/)) * Malaria data * Hospitalisation records |
| Continental | Vital statistics, survey data | * Health surveys (e.g. [European Health Interview Survey (EHIS)](https://ec.europa.eu/eurostat/web/microdata/european-health-interview-survey) or the [European Community Household Panel (ECHP](https://ec.europa.eu/eurostat/web/microdata/european-community-household-panel))) * Hospitalization records and insurance records related to indicator diseases (e.g. Zoonosis) |
| Global | Vital statistics, survey data | * [WHO Malaria Threats Map](https://www.who.int/malaria/maps/threats-about/en/) * [WHO Global Health Observatory](https://www.who.int/data/gho) * [Open Flu data base](http://openflu.vital-it.ch/about.php) * [World Happiness Report](https://worldhappiness.report/ed/2020/) |
| **Pathway domains** | Local | Environmental/pollution maps | Mitigating harm pathway   * [Environmental Atlas of Berlin](https://stadtentwicklung.berlin.de/umwelt/umweltatlas/edua_index.shtml) |
| Vital statistics | Building capacities pathway   * Physical activity data in Child or Adult cohort studies or the [City Health Dashboard](https://www.cityhealthdashboard.com/) |
| Regional | Environmental and biological data | Mitigating harm pathway   * Medicinal plants   Causing harm pathway   * Human microbiome (as part of health cohorts, e.g. [Belgian Flemish Gut Flora Project](https://www.nature.com/articles/s41564-018-0337-x)) * [Allergenic pollen and spore counting stations across the USA](https://www.aaaai.org/global/nab-pollen-counts/about-the-nab) |
| National | Environmental, social survey and biological data | Mitigating harm pathway   * Medicinal plants databases (e.g. [Prelude Medicinal Plants Database](https://www.gbif.org/dataset/49c5b4ac-e3bf-401b-94b1-c94a2ad5c8d6))   Restoring and Building Capacities pathways   * [Monitor of Engagement with the Natural Environment (MENE), United K](https://www.gov.uk/government/collections/monitor-of-engagement-with-the-natural-environment-survey-purpose-and-results)ingdom * [Scotland People and Nature Survey (SPANS)](https://www.nature.scot/professional-advice/land-and-sea-management/managing-access-and-recreation/increasing-participation/measuring-participation)   Causing harm pathway   * [Allergenic pollen and spore counting stations across the USA](https://www.aaaai.org/global/nab-pollen-counts/about-the-nab) |
| Continental | Environmental and biological data | Mitigating harm pathway   * [Air pollution](https://www.eea.europa.eu//themes/air/dc) in Europe * [EU Noise maps](https://noise.eea.europa.eu/) * [Copernicus European Atmosphere Monitoring Service](https://atmosphere.copernicus.eu/) * [Local Climate Zones](http://www.wudapt.org/continental-lcz-maps/) (continental maps)   Causing harm pathway   * European Centre for Disease Prevention [mosquito](https://www.ecdc.europa.eu/en/disease-vectors/surveillance-and-disease-data/mosquito-maps) and [tick](https://www.ecdc.europa.eu/en/disease-vectors/surveillance-and-disease-data/tick-maps) distribution maps * [European Aeroallergen Network Pollen Database](https://ean.polleninfo.eu/Ean/) * [1000 Ag genome project (mosquitos)](https://www.malariagen.net/projects/ag1000g) |
| Global | Environmental and biological data | Mitigating harm pathway   * [World Water Quality](https://www.eomap.com/world-water-quality/) * [Copernicus Global Atmosphere Monitoring Service](https://atmosphere.copernicus.eu/) * [WHO Global Ambient Air Quality Database](https://www.who.int/airpollution/data/en/)   Causing harm pathway   * [Global Invasive Species Database](http://www.iucngisd.org/gisd/) |