FreshLanDiv: A Global Database of Freshwater Biodiversity Across Different Land Uses

Minghua Shen, Roel van Klink, Alban Sagouis, Danielle K. Petsch, Deborah Atieno Abong'O, Janne Alahuhta, Salman Abdo Al-Shami, Laura Cecilia Armendáriz, Mi-jung Bae, Tiago Octavio Begot, et al.

Global Ecology and Biogeography

WILEY

Global Ecology and Biogeography — A Journal of Macroecology

DATA ARTICLE OPEN ACCESS

FreshLanDiv: A Global Database of Freshwater Biodiversity Across Different Land Uses

Minghua Shen[1,2] | Roel van Klink[1,2] | Alban Sagouis[1,2] | Danielle K. Petsch[3] | Deborah Atieno Abong'o[4] | Janne Alahuhta[5] | Salman Abdo Al-Shami[6] | Laura Cecilia Armendáriz[7] | Mi-Jung Bae[8] | Tiago Octavio Begot[9] | Jerome Belliard[10] | Jonathan Peter Benstead[11] | Francieli F. Bomfim[12] | Emile Bredenhand[13] | William R. Budnick[14] | Marcos Callisto[15] | Lenize Batista Calvão[9] | Claudia Patricia Camacho-Rozo[16] | Miguel Cañedo-Argüelles[17] | Fernando Geraldo Carvalho[18,19] | Jacqueline Chapman[20] | Lauren Chapman[21] | Qiuwen Chen[22] | Barry Chernoff[23,24] | Luciana Cibils-Martina[25] | Gerard Patrick Closs[26] | Juliano J. Corbi[27] | Erlane José Cunha[19] | Almir Manoel Cunico[28] | Patricio De los Rios-Escalante[29,30] | Sylvain Dolédec[31] | Barbara Dunck[32] | Augustine Ovie Edegbene[33,34] | Augustin C. Engman[35] | Tibor Erős[36] | Katharina Eichbaum Esteves[37] | Ruan Carlos Pires Faquim[38] | Ana Paula Justino Faria[39] | Claudia Maris Ferreira[40] | Márcio Cunha Ferreira[9,41] | Pablo Fierro[42] | Pâmela V. Freitas[43] | Vincent Fugère[44] | Thiago Deruza Garcia[45,46] | Xingli Giam[47] | Gabriel Murilo Ribeiro Gonino[48] | Juan David González-Trujillo[49] | Éder André Gubiani[50] | Neusa Hamada[51] | Roger John Haro[52] | Luiz Ubiratan Hepp[53] | Guido A. Herrera-R[47] | Matthew J. Hill[54] | A. Nurul Huda[55] | Carlos Iniguez-Armijos[56] | Aurélien Jamoneau[57] | Micael Jonsson[58] | Leandro Juen[12] | Wilbert T. Kadye[59,60] | Kahirun Kahirun[61] | Aventino Kasangaki[62] | Chad A. Larson[63] | Alexandre Leandro Pereira[28] | Thibault Leboucher[64] | Gustavo Figueiredo Marques Leite[65] | Dunhai Li[66] | Ana Luiza-Andrade[67] | Sarah H. Luke[68,69] | Matthew Joseph Lundquist[70] | Daniela Lupi[71] | Jorge Machuca-Sepúlveda[72] | Messias Alfredo Macuiane[73,74,75] | Nestor Javier Mancera-Rodriguez[76] | Javier A. Márquez[25] | Renato Tavares Martins[51] | Frank O. Masese[77] | Marcia S. Meixler[78] | Thaisa Sala Michelan[12] | María José Monge-Salazar[79] | Joseph L. Mruzek[80] | Hernan Diego Mugni[81] | Hilton Garikai Taambuka Ndagurwa[82,83] | Augustine Niba[84] | Jorge Nimptsch[42] | Rodolfo Novelo-Gutiérrez[85] | Hannington Ochieng[86] | Rodrigo Pacheco-Díaz[87] | Young-Seuk Park[88] | Sophia I. Passy[89] | Richard G. Pearson[90] | Alexandre Peressin[91] | Eduardo Périco[92] | Mateus Marques Pires[92] | Helen Poulos[93] | Romina E. Principe[25] | Bruno S. Prudente[94] | Blanca Ríos-Touma[95] | Renata Ruaro[96] | Juan J. Schmitter-Soto[87] | Fabiana Schneck[97] | Uwe Horst Schulz[98] | Chellappa Selvakumar[99] | Chhatra Mani Sharma[100] | Tadeu Siqueira[101,102] | Marina Laura Solis[103] | Raniere Garcez Costa Sousa[104] | Emily H. Stanley[105] | Csilla Stenger-Kovács[106,107,108] | Evelyne Tales[10] | Fabrício Barreto Teresa[109] | Ian Thornhill[110] | Juliette Tison-Rosebery[57] | Thiago Bernardi Vieira[111] | Sebastián Villada-Bedoya[112] | James C. White[113] | Paul J. Wood[114] | Zhicai Xie[67] | Catherine M. Yule[115] | João Antonio Cyrino Zequi[116] | Jonathan M. Chase[1,2]

Correspondence: Minghua Shen (minghua.shen@idiv.de)

Received: 18 March 2024 | **Revised:** 23 July 2024 | **Accepted:** 11 September 2024

Handling Editor: Fabien Leprieur

Funding: This work was supported by China Scholarship Council (Grant 202104910063), German Research Foundation (Grant FZT 118), National Research, Development and Innovation Office through the following NKFIH project (Grant K137950), Brazilian National Council for Scientific and Technological Development (CNPq) (Grant 308970/2019-5), CNPq (Grants 380592/2022-3, 382557/2023-9), FAPEAM—Amazonas State Research Foundation and CNPq funded field sampling in the Amazon (Grants 465540/2014-7, 062.1187/2017), BIODIVERSA/FAPEAM and Universal/CNPq (Grant 403758/2021-1), and Ministry of Sciences, Technology and Innovation of Colombia, No. 860 from 2019, and Graduate School of the University of Tennessee.

Keywords: abundance | data sharing | land-use categories | lentic ecosystems | lotic ecosystems

ABSTRACT

Motivation: Freshwater ecosystems have been heavily impacted by land-use changes, but data syntheses on these impacts are still limited. Here, we compiled a global database encompassing 241 studies with species abundance data (from multiple

biological groups and geographic locations) across sites with different land-use categories. This compilation will be useful for addressing questions regarding land-use change and its impact on freshwater biodiversity.
Main Types of Variables Contained: The database includes metadata of each study, sites location, sample methods, sample time, land-use category and abundance of each taxon.
Spatial Location and Grain: The database contains data from across the globe, with 85% of the sites having well-defined geographical coordinates.
Major Taxa and Level of Measurement: The database covers all major freshwater biological groups including algae, macrophytes, zooplankton, macroinvertebrates, fish and amphibians.

1 | Introduction

Freshwater ecosystems cover only 0.8% of Earth's surface but play an outsized role in maintaining biodiversity, which in turn provides valuable ecosystem functions and services (Cardinale et al. 2012; Dudgeon et al. 2006). However, intensive anthropogenic pressures can reduce freshwater biodiversity and shift species composition (Feio et al. 2023; Feld et al. 2016; Petsch et al. 2021; Tickner et al. 2020). Therefore, it is urgent to improve our understanding of how freshwater biodiversity responds to anthropogenic changes. Such knowledge would be invaluable for freshwater ecosystem restoration and conservation (Barouillet et al. 2023; Maasri et al. 2022; Reid et al. 2019; Rumschlag et al. 2023).

Land-use is widely regarded as one of the major anthropogenic drivers of biodiversity loss (Dudgeon et al. 2006; Jaureguiberry et al. 2022; McKeon et al. 2023). However, large-scale to global biodiversity assessments have primarily focused on terrestrial ecosystems (Hudson et al. 2014; Newbold et al. 2015), with limited attention given to freshwater ecosystems (Budnick et al. 2019; Tickner et al. 2020; Wilkinson et al. 2018). Land-use practices involving activities such as agriculture, urban expansion, logging and mining (Allan et al. 2015; Foley et al. 2005) can have major effects on freshwater ecosystems, changing flow patterns, water temperature, river morphology and water chemistry, which in turn can alter freshwater biodiversity (Allan, Erickson, and Fay 1997; Cooper et al. 2012; Dala-Corte et al. 2020; Feld et al. 2016; Foley et al. 2005; Petsch et al. 2021).

Many small-scale studies showed that different land-use practices have demonstrable effects on freshwater biodiversity. For example, insect communities in urban and agricultural streams tend to experience transitions from disturbance-sensitive taxa to more disturbance-tolerant taxa (Kasangaki, Chapman, and Balirwa 2008; Rumschlag et al. 2023). Fish communities can also be affected by changes in water quality and other habitat disturbances caused by urbanisation and agricultural runoff (Januchowski-Hartley et al. 2016). Other biological groups, such as freshwater algae (Heino et al. 2009) and macrophytes (Bomfim et al. 2023) can be strongly influenced by changes in land-use, such as forestry. Likewise, mining activities can alter patterns of species richness and abundance of invertebrates, fish and amphibians (Giam, Olden, and Simberloff 2018).

Here, we develop a globally distributed database of species-level data from freshwater assemblages. We compile from existing studies on land-use effects on freshwater biodiversity to provide a comprehensive resource for uncovering general patterns and their variation across systems, geographic regions and biological groups. A comparable database is already available for the effects of land use on terrestrial biodiversity (Hudson et al. 2014, 2017), and has led to a number of important insights (Leclère et al. 2020; Millard et al. 2021; Newbold et al. 2015). Providing species-level data (rather than derived metrics) in a comprehensive database will allow the calculation of multiple metrics of biodiversity (e.g., richness, evenness, abundance), determination of species composition and measurement of their changes across spatial scales (Chase et al. 2018). This is necessary for achieving a deeper understanding of the response of ecological communities in response to changes in land use. Our database explicitly includes species-level abundance data across different land-use categories, encompasses studies on all major freshwater biological groups and ecosystems, and will facilitate the investigation on freshwater biodiversity change in the Anthropocene.

2 | Methods

2.1 | Data Acquisition

We conducted a systematic literature search to identify primary studies on land-use effects on freshwater systems in November 2021. We started with 25 studies compiled by Petsch et al. (2021) to address a similar question of land-use effects on freshwater biodiversity. We then employed 'Litsearchr' (Grames et al. 2019), an R package designed to complete the search term coverage, to generate the search terms (refer to Supporting Information) related to 'land-use effects on freshwater using data from "Web of Science"'. This search identified 10,453 potentially useful articles.

For refining these results, we scanned through the title, abstract and full-text to filter the papers based on two criteria: (1) the title and abstract indicated that the study was on freshwater biodiversity across different land-use categories; (2) the data incorporated species abundance of multiple species within a consistent sampling method in each study. In all, our search resulted in 100 studies fitting our criteria. We next used the R package 'citationchaser', and by performing forward and backward citation chasing from these 100 studies (Haddaway, Grainger, and Gray 2022), we identified an additional 40 studies that met our criteria. We also obtained 22 studies that were originally not in our search results from the recommendations of our co-authors. For each study, we extracted data from tables, figures and/or supplemental documents and repositories.

When data were not available in the publication or associated repositories (met the criteria 1 only), we contacted authors to determine whether the data were available and could be included in this compilation. In total we contacted authors of 227 potentially relevant studies, and received 54 studies, which we make public for the first time here. In total, we compiled 241 studies with metadata regarding data source, site information, land-use categories and species-level information (further described in the database); the complete list can be found in the Supporting Information. The database is accessible on Dryad, saved in xlsx format.

2.2 | Quality Control

2.2.1 | Land-Use Categories

We recorded the land-use information used by the authors of the paper, which we then grouped into five broader categories: natural vegetation, forestry, agriculture, urban and mining. Most of the studies had a comparison to reference land use, which we defined as natural vegetation. We also included areas adjacent to dams due to their significant impact on freshwater ecosystems (Table 1) (Grill et al. 2019).

If the author provided several land-use categories for a given site, we chose the dominant land-use category. All the author-defined land-use information is available in the database, along with the land-use categories we defined.

2.2.2 | Taxonomy

We standardised all taxon names using the 'bdc' (v. 1.1.4) and 'rgbif' (v.3.7.7.2) packages in R (Chamberlain 2017; Ribeiro et al. 2022), which used the GBIF (Global Biodiversity Information Facility) taxonomic backbone (Secretariat 2023) to match the scientific name, and obtain the scientific classification. Names without a match in GBIF were checked for potential spelling errors, corrected when needed and checked again against GBIF. We maintained the original name as there is still no match in GBIF. Whenever a species name was modified, the original name was also kept to ensure name traceability.

2.2.3 | Geographical Coordinates

For most studies, we obtained geographical coordinates from the paper or directly from the authors. For some studies where geographical coordinates were not immediately available, we were able to extract geographical coordinates from published maps using WebPlotDigitizer (version 4.6). We transformed geographical coordinates into the World Geodetic System 1984 (WGS84) geographical coordinate reference system. When the authors did not report geographical coordinates in the paper, or we could not otherwise obtain them, these values were considered missing in the database, and omitted.

2.2.4 | Sampling Methods

We recorded the specifics of the sampling method and the sample area, followed by standardisation in accordance with the author's instructions.

3 | Results

The database consists of 200,124 records from 4716 sites, covering all major freshwater biological groups, including algae, macrophytes, zooplankton, macroinvertebrates, fish and amphibians, across both lotic and lentic ecosystems. These records are from 241 studies spread across 42 countries, from 1972 to 2019. The spatial distribution shows a sampling bias towards South America (58% studies), with the lowest proportion in Oceania (3%); the remaining continents contain 8%–14% of the data (Figure 1, Figure S1).

The database includes 138 studies on macroinvertebrates, 77 on fish, 12 on algae, 7 on zooplankton, 4 on amphibians and 3 on macrophytes. Our database includes 6078 species from 2464 genera, 710 families and 216 orders. In our database, 45% of the species are macroinvertebrates, 22% are fish and 24% are algae. All other biological groups comprised < 5% of the species in the database (Table 2, Figure 2A).

TABLE 1 | Land-use categories and definitions.

Land-use	Definition
Natural vegetation	Little evidence of disturbance on the vegetation, including forest, grassland or what the author simply called 'vegetation'
Forestry	Defined as managed (human-impacted) forest, including deforestation, tree plantations and reforestation
Agricultural	Agricultural activities (sometimes mixed with some human settlement). This category included cropland, pasture, rural and mixed agricultural activities
Urban	Sites located in cities. Impervious surfaces were also regarded as urban
Mining	Mining activities in or near water bodies
Impounded	Reservoir or impounded water bodies
Unimpounded	Unimpounded water bodies or control sites (upstream of reservoir/dam and control streams)
Downstream	Downstream of the dam

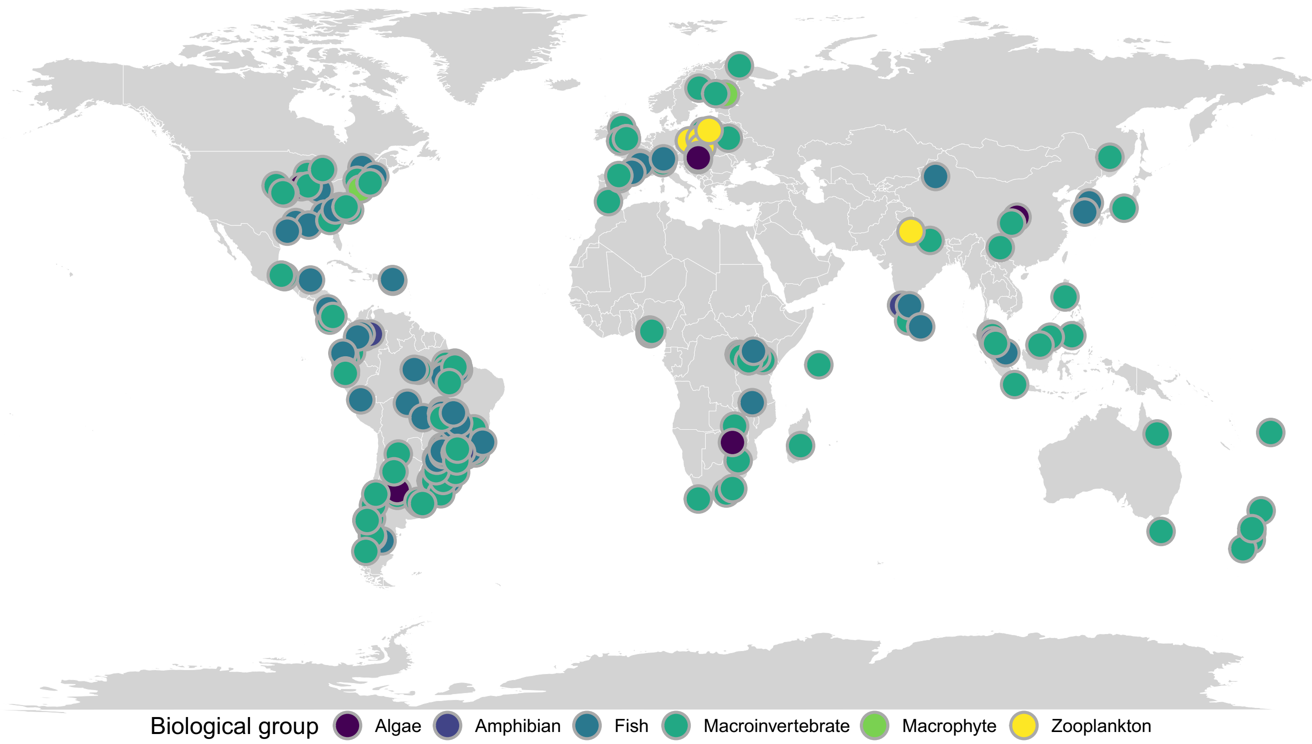

FIGURE 1 | Geographical distribution of studies by biological group. The study locations represent the central geographical coordinates (average latitude and longitude) of their sites. In cases of missing geographical coordinates, we placed studies at the geographical centre of their respective province/state or country, based on the most detailed information we had.

TABLE 2 | Number of taxa and records estimated by biological groups.

Biological group	Orders	Families	Genera	Species	Records
Macroinvertebrates	85	392	1466	2782	122,106
Fish	30	99	502	1314	24,850
Algae	55	100	253	1438	46,368
Zooplankton	14	48	105	295	2791
Macrophytes	30	56	97	171	3387
Amphibians	2	15	41	78	622

Our literature search included both lotic and lentic ecosystems, with 93% being from lotic systems (streams and rivers) and 7% from lentic systems (wetlands, ponds and lakes). Within lotic systems (224 studies), 163 studies were on streams (Figure 2B). The ecosystem type was recorded according to the author's description.

Each study encompassed a minimum of two land use or land cover categories. Most studies provided comparisons between water bodies adjacent to natural vegetation with water bodies adjacent to agriculture (117 studies), forestry (47) or urban (46). Other frequent comparisons include comparisons between agricultural and urban sites (51 studies; Figure 3) (dams are not included in this comparison).

Diverse sampling methods, land-use buffers, taxonomic precision and the measure of 'abundance' were used across studies, but they remained consistent within each study. Each site in a study was labelled with details of sampling methodology, including sampled area. The term 'land-use buffer' denotes the size of the identified land-use category surrounding each site, with the buffer size of each study being recorded in the database. Precision in species identification varied among taxa, particularly for macroinvertebrates, with certain studies identifying individuals only to family or genus. The measure of 'abundance' varied across studies, alongside diverse sampling and recording methodologies. It could mean the total number of individuals and mean density. The majority of studies (73%) use total abundance.

4 | Discussion

Our database is the largest compilation to incorporate the abundance data of freshwater biota across different land-use

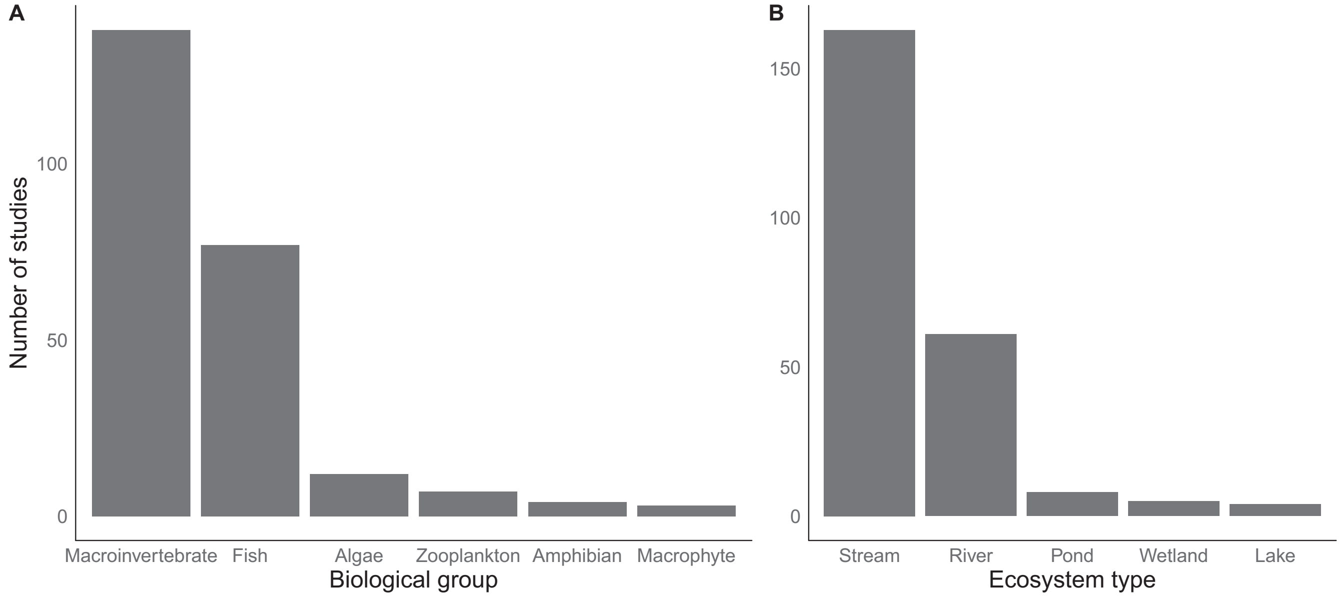

FIGURE 2 | Number of studies per biological group (A) and ecosystem type (B).

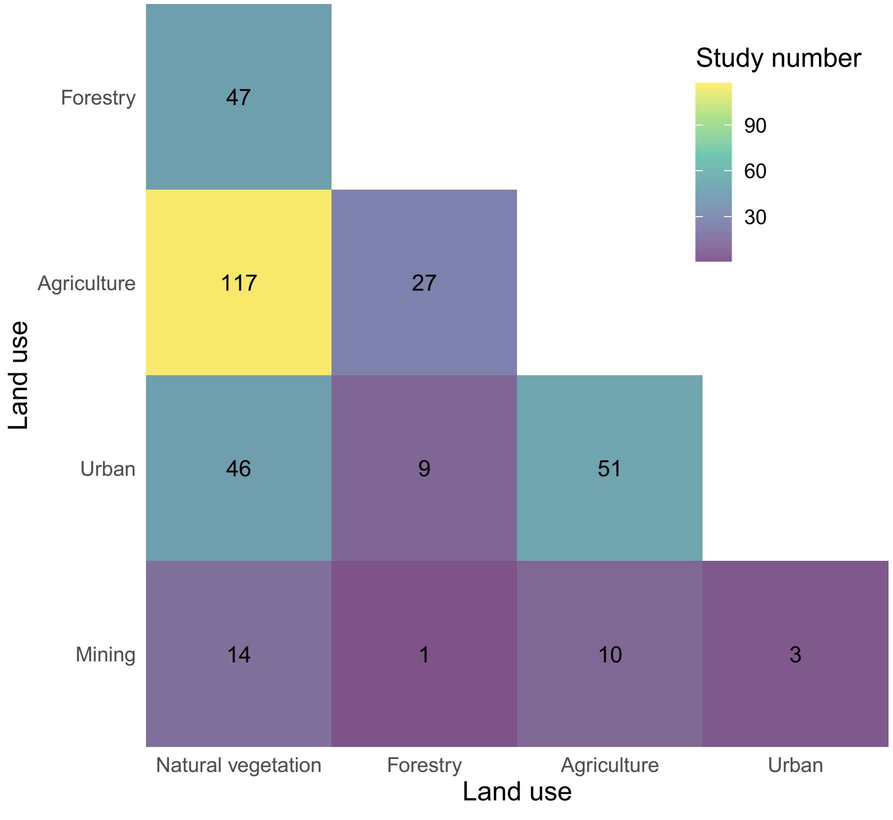

FIGURE 3 | Cumulative land-use comparisons recorded in the database. Each number within the grid indicates the count of study occurrences for the comparison of two land-use categories plotted on the respective axes.

categories. It builds on previous efforts (Petsch et al. 2021), but includes six times more data. By compiling all major freshwater biological groups and ecosystems in the database, this collation will facilitate the exploration of numerous aspects of freshwater ecology and land-use impacts, including changes to species abundance distributions (Blowes et al. 2022; McGill et al. 2007), biodiversity across scales (Chase et al. 2018), shifts in species composition (Blowes et al. 2024; Rumschlag et al. 2023) and related questions. As such, this data compilation can support both basic and applied ecological research (Spake et al. 2022).

About one-half of the studies in our database originate from South America, encompassing all of the biodiversity hotspots in this continent. This bias may suggest South America has growing scientific activities on this topic, particularly concerning vast freshwater resources threatened by land-use changes driven by economic development (Barletta et al. 2010; Campuzano et al. 2014). Conversely, other continents show a comparatively lower number of studies, showing an important knowledge gap. For example, regions in southwest Australia and the Horn of Africa are under-represented in our database, are currently experiencing rapid urbanisation (Güneralp et al. 2017; Myers et al. 2000; Pettit et al. 2015). Further work is needed to expand access to studies concerning the response of freshwater biodiversity to land-use change in these regions.

The biases regarding biological groups and ecosystem types largely reflect known patterns in ecological research globally. Macroinvertebrates comprise approximately 60% of our database and are widely used as indicators in stream and river monitoring. Different macroinvertebrate groups exhibit diverse responses to changes in habitat and water quality, and particularly sensitive taxa are useful for gauging the effects of land use on freshwater ecosystems (Chang et al. 2014; Juvigny-Khenafou et al. 2021). Among freshwater ecosystems, lotic systems—particularly streams—emerge as the most extensively studied within our records. As our database requires land-use data across varying intensities, most studies have utilised 'natural vegetation' as reference, which is more prevalent in headwater streams (Colvin et al. 2019; Encalada et al. 2019).

In conclusion, our database stands as the largest and most comprehensive compilation on the distribution and abundance of a broad range of freshwater biological groups across various land-use categories. Data on freshwater ecosystems need to be accessible, understandable, unambiguous and available to all those working on practical conservation projects (Barouillet et al. 2023). As such, this database can help in the development and implementation of effective management plans. Such plans require recognition of the vast diversity of freshwater habitats and species, as well as a systematic assessment of how scientific information can be translated into action at local, regional and global scales.

Author Contributions

M.S., R.v.K., J.M.C. contributed to project design. M.S. collected the data with support from R.v.K. and J.M.C. Data were validated by M.S. and A.S. All authors contributed their data to the database except M.S., R.v.K., A.S. and J.M.C. M.S. wrote the first draft of the manuscript. All authors contributed to revisions.

Affiliations

[1]German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Leipzig, Germany | [2]Department of Computer Science, Martin Luther University Halle-Wittenberg, Halle (Saale), Germany | [3]Department of Biological Sciences, Faculty of Sciences and Letters (FCL), São Paulo State University (UNESP), Assis, Brazil | [4]Department of Chemistry, Faculty of Science & Technology, University of Nairobi, Nairobi, Kenya | [5]Geography Research Unit, University of Oulu, Oulu, Finland | [6]Department of Biology, Wilfrid Laurier University, Waterloo, Ontario, Canada | [7]Laboratorio Bentos, Instituto de Limnologia "Dr. Raúl Ringuelet" (CONICET-FCNyM, UNLP-CIC), La Plata, Argentina | [8]Freshwater Biodiversity Research Bureau, Nakdonggang National Institute of Biological Resources (NNIBR), Sangju, South Korea | [9]Laboratório de Ecologia e Conservação, Universidade Federal do Pará, Belém, Brazil | [10]University of Paris-Saclay, INRAE, HYCAR Hydrosystems Under Changes, Antony, France | [11]Department of Biological Sciences, University of Alabama, Tuscaloosa, Alabama, USA | [12]Instituto de Ciências Biológicas (ICB), Universidade Federal do Pará (UFPA), Belém, Brazil | [13]Department of Zoology and Entomology, University of the Free State, Phuthaditjhaba, South Africa | [14]Department of Fisheries and Wildlife, Michigan State University, East Lansing, Michigan, USA | [15]Departamento de Genética, Ecologia e Evolução, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil | [16]Departamento de Ecología y Territorio, Facultad de Estudios Ambientales y Rurales, Pontificia Universidad Javeriana, Bogota, Colombia | [17]Institute of Environmental Assessment and Water Research (IDAEA), CSIC, Barcelona, Spain | [18]Programa de Pós-graduação em Ecologia, Universidade Federal Do Pará, Belém, Brazil | [19]Instituto Tecnológico Vale, Belém, Brazil | [20]Department of Biology, Carleton University, Ottawa, Ontario, Canada | [21]Department of Biology, McGill University, Montreal, Quebec, Canada | [22]Nanjing Hydraulic Research Institute, Nanjing, China | [23]Bailey College of the Environment, Wesleyan University, Middletown, Connecticut, USA | [24]Department of Biology, Department of Earth & Environmental Sciences, Wesleyan University, Middletown, Connecticut, USA | [25]Departamento de Ciencias Naturales, Instituto de Ciencias de la Tierra, Biodiversidad y Ambiente (ICBIA), Universidad Nacional de Río Cuarto—CONICET, Río Cuarto, Argentina | [26]Department of Zoology, University of Otago, Dunedin, New Zealand | [27]Department of Hydraulics and Sanitation, University of São Paulo, São Carlos, Brazil | [28]Departamento de Biodiversidade, Laboratorio de Ecologia, Pesca e Ictiologia, Universidade Federal Do Paraná, Palotina, Brazil | [29]Departamento de Ciencias Biológicas y Químicas, Facultad de Recursos Naturales, Universidad Católica de Temuco, Temuco, Chile | [30]Núcleo de Estudios Ambientales, UC Temuco, Temuco, Chile | [31]LEHNA UMR 5023, CNRS, ENTPE, Université Claude Bernard Lyon 1, Villeurbanne, France | [32]Instituto Socioambiental e dos Recursos Hídricos (ISARH), Universidade Federal Rural da Amazônia (UFRA), Belém, Brazil | [33]Department of Biological Sciences, Federal University of Health Sciences, Otukpo, Nigeria | [34]Institute of Global Health and Health Security (Climate Change and Health), Federal University of Health Sciences, Otukpo, Nigeria | [35]School of Natural Resources, University of Tennessee, Knoxville, Tennessee, USA | [36]HUN-REN Balaton Limnological Research Institute, Tihany, Hungary | [37]Centro de Pesquisa em Recursos Hídricos e Pesqueiros, Fisheries Institute—APTA/SAA, São Paulo, Brazil | [38]Universidade Estadual de Goiás, Anapolis, Brazil | [39]Núcleo de Pesquisa em Insetos Aquáticos, Universidade Estadual Do Piauí, Campo Maior, Brazil | [40]Fisheries Institute—APTA—SAA, Sao Paulo, Brazil | [41]Grupo de Pesquisa Ecologia e Manejo de Organismos e Ambientes Aquáticos—EMOA, Universidade Do Estado Do Amapá—UEAP, Macapá, Brazil | [42]Facultad de Ciencias, Instituto de Ciencias Marinas y Limnologicas, Universidad Austral de Chile, Valdivia, Chile | [43]Faculdade de Educação do Campo, Universidade Federal do Pará, Cametá, Brazil | [44]Département des Sciences de l'environnement, Université du Québec à Trois-Rivières, Trois-Rivières, Québec, Canada | [45]Centro Universitário de Ourinhos (UNIFIO), Ourinhos, Brazil | [46]Universidade Estadual de Londrina (UEL), Londrina, Brazil | [47]Department of Ecology and Evolutionary Biology, The University of Tennessee, Knoxville, Tennessee, USA | [48]Instituto Federal Catarinense—IFC, Ibirama, Brazil | [49]Departamento de Biología, Facultad de Ciencias, Universidad Nacional de Colombia, Sede Bogotá, Colombia | [50]Laboratório de Ictiologia e Estatística Pesqueira, Centro de Engenharias e Ciências Exatas, Universidade Estadual Do Oeste Do Paraná, Toledo, Brazil | [51]Coordenação de Biodiversidade, Instituto Nacional de Pesquisas da Amazônia, Manaus, Brazil | [52]Northern Arizona University, Flagstaff, Arizona, USA | [53]Laboratório de Indicadores Ambientais, Universidade Federal de Mato Grosso Do Sul, Três Lagoas, Brazil | [54]Department of Life and Environmental Sciences, Bournemouth University, Dorset, UK | [55]Department of Plant Science, Kulliyyah of Science, International Islamic University Malaysia, Kuantan, Malaysia | [56]Laboratorio de Ecología Tropical y Servicios Ecosistémicos, Departamento de Ciencias Biológicas y Agropecuarias, Universidad Técnica Particular de Loja, Loja,

Ecuador | [57]INRAE, UR EABX, Cestas, France | [58]Department of Ecology and Environmental Science, Umeå University, Umeå, Sweden | [59]Department of Ichthyology and Fisheries Science, Rhodes University, Makhanda, South Africa | [60]South African Institute for Aquatic Biodiversity, Makhanda, South Africa | [61]Department of Environmental Science, Faculty of Forestry and Environmental Sciences, Universitas Halu Oleo, Kendari, Indonesia | [62]Department of Biological Sciences, Faculty of Science Kabale University, Kabale, Uganda | [63]Washington State Department of Ecology, Olympia, Washington, USA | [64]Laboratory for Continental Environments, National Scientific Research Center, University of Lorraine, Metz, France | [65]Colégio Militar de Brasília, Clube de Estudos Ambientais, Brasília, Brazil | [66]Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan, P. R. China | [67]Laboratório de Biodiversidade e Conservação - LABICON, Departamento Acadêmico de Biologia, Fundação Universidade Federal de Rondônia - Porto Velho, Rondônia, Brazil | [68]School of Biosciences, University of Nottingham, Nottingham, UK | [69]Department of Zoology, University of Cambridge, Cambridge, UK | [70]Marymount Manhattan College, New York, New York, USA | [71]Department of Food, Environmental and Nutritional Sciences, University of Milan, Milan, Italy | [72]Doctoral Program on Natural Resources Sciences, Universidad de La Frontera, Temuco, Chile | [73]Escola de Ciências Marinhas e Costeiras da Universidade Eduardo Mondlane, Quelimane, Mozambique | [74]Independent Consultant in Fisheries and Aquaculture, Quelimane, Mozambique | [75]Fundo de Desenvolvimento da Economia Azul, IP, Quelimane, Mozambique | [76]Departamento de Ciencias Forestales, Universidad Nacional de Colombia, Sede Medellin, Medellín, Colombia | [77]Department of Fisheries & Aquatic Science, University of Eldoret, Eldoret, Kenya | [78]Rutgers University, New Brunswick, New Jersey, USA | [79]University of Costa Rica, San José, Costa Rica | [80]Center for Fisheries, Aquaculture, and Aquatic Sciences, Southern Illinois University, Carbondale, Illinois, USA | [81]Instituto de Limnología, Dr.-Raúl A. Ringuelet (ILPLA, CCT-La Plata CONICET, UNLP), La Plata, Argentina | [82]Department of Geospatial Science, Faculty of Environmental Science, National University of Science and Technology, Bulawayo, Zimbabwe | [83]School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg, South Africa | [84]Walter Sisulu University, Mthatha, South Africa | [85]Instituto de Ecología, A.C., red de Biodiversidad y Sistemática, Xalapa, Mexico | [86]Department of Biology, Faculty of Science and Education, Busitema University, Tororo, Uganda | [87]Departamento de Sistemática y Ecología Acuática, El Colegio de la Frontera Sur, Chetumal, Mexico | [88]Department of Biology, College of Sciences, Kyung Hee University, Seoul, Republic of Korea | [89]Department of Biology, University of Texas at Arlington, Arlington, Texas, USA | [90]College of Science and Engineering, and TropWater, James Cook University, Townsville, Queensland, Australia | [91]Centro de Ciências da Natureza, Universidade Federal de São Carlos (UFSCar), Buri, Brazil | [92]Universidade Do Vale Do Taquari—Univates, Lajeado, Brazil | [93]Department of Earth and Environmental Sciences, Bailey College of the Environment, Wesleyan University, Middletown, Connecticut, USA | [94]Universidade Federal Rural da Amazônia (UFRA), Capitão Poço, Brazil | [95]Grupo de Investigación en Biodiversidad, Medio Ambiente y Salud (BIOMAS), Facultad de Ingenierías y Ciencias Aplicadas, Ingenuería Ambiental, Universidad de las Américas, Quito, Ecuador | [96]Departamento de Química e Biologia, Universidade Tecnológica Federal Do Paraná, Curitiba, Brazil | [97]Universidade Federal do Rio Grande—FURG, Rio Grande, Brazil | [98]Tropical Water Research Alliance—TWRA, Novo Hamburgo, Brazil | [99]Department of Zoology, The Madura College (Autonomous), Madurai, India | [100]Central Department of Environmental Science, Institute of Science and Technology, Tribhuvan University, Kirtipur, Nepal | [101]School of Biological Sciences, University of Canterbury, Christchurch, New Zealand | [102]Instituto de Biociências, Universidade Estadual Paulista, UNESP, Rio Claro, Brazil | [103]ILPLA (CONICET_CCT La Plata), UNLP Instituto de Limnología "Dr. Raúl A. Ringuelet", La Plata, Argentina | [104]Rondônia Federal University, Porto Velho, Brazil | [105]Center for Limnology, University of Wisconsin-Madison, Madison, Wisconsin, USA | [106]Limnology Research Group, University of Pannonia, Veszprém, Hungary | [107]HUN-REN Limnoecology Research Group, Veszprém, Hungary | [108]National Laboratory for Water Science and Water Security, University of Pannonia, Veszprém, Hungary | [109]Universidade Estadual de Goiás, Anápolis, Brazil | [110]School of Environment, Education and Development (SEED), University of Manchester, Manchester, UK | [111]Universidade Federal do Pará - UFPA, Altamira, Brazil | [112]Neuroecology Lab, Facultad de Psicología, UNAM, Mexico City, Mexico | [113]School of Geography, Earth & Environmental Sciences, University of Birmingham, Birmingham, UK | [114]Geography and Environment, Loughborough University, Loughborough, UK | [115]University of the Sunshine Coast, Sippy Downs, Queensland, Australia | [116]State University of Londrina, Londrina, Brazil

Acknowledgements

We thank Sonja Jähnig for help with land-use classification and Tsun Fung Yau for help with the data collection. We thank Jiefeng Yu, Jie Yang and Beatriz Prado Bastos Monteiro for help with the revision. We thank the Biodiversity Synthesis group at iDiv for feedback on the database. We thank researchers who collected the data and made it available in the papers, including A. E. Ogbeibu, A. E. Siegloch, A. Martínez, A. S. Niba, Abraham Addo-Bediako, Agnieszka Pociecha, Alan Herlihy, Albert Chakona, Alesandra Martins Dias, Alison Haynes, Allison H. Roy, Alonso Aguilar Ibarra, Ana Emilia Siegloch, András Weiperth, Ani Suryanti, Antonio Ruiz-García, Ariel Hernán Paracampo, Arunachalam Manimekalan, Barbara C. G. Gimenez, Benson Mwangi, Berit H. Bojsen, Carlos A. Cultid-Medina, Carolina Costa Pera, Christine Weber, Christopher M. Lorion, Claudia Eiko Yoshida, Cláudia Maris Ferreira, Cláudia P. D. Silva, Claus Haetinger, Craig Paukert, Cristina Natalia Horak, D. F. Baptista, David R. Lenat, Diego Córdoba Rojas, Fabiana Schneck, Francisco Gerson Araújo, Fred Van Dyke, Glenn R. Matlack, Gomez Daniela, Graciela Vázquez, Gregory J. Knothe, Haitao Wu, Híngara Leão, Hugo Marques, I. Jabłońska-Barna, Iain A. Fraser, Ihn-Sil Kwak, Izumi Katano, J. P. A. Pagotto, J. T. Betts, Jayakody A. Sumith, Jeffrey D. Muehlbauer, John M. Quinn, Jolanta Ejsmont-Karabin, Joshuah S. Perkin, Juan Martín Paredes del Puerto, Juan Victor Tomailla Tenazoa, Julián Chará, K. L. Smalling, Karen Shearer, Karina Dias-Silva, Kwang-Guk An, Laís L. Jacob, Leonardo Antunes Pessoa, Leticia M. Mesa, Lilian Casatti, Luis Vargas-Chacoff, Ma Yanwu, María Laura Miserendino, María Natalia Marrochi, Mariele P. Camargo, Mateus Marques Pires, Matt R. Whiles, Michael H. Paller, Michael K. Stone, Nicelly B. Araújo, Nitin Kamboj, Nyakeya Kobingi, Oliver Konopik, Omar Pérez-Reyes, P. D. Armitage, Pedro Jiménez Prado, Pedro Sartori Manoel, R. H. Norris, Raymond P. Morgan, Robert Czerniawski, S. C. Escarpinati, S. Karim Mousavi, S. N. Krishna, Samuel Leberg, Saúl Prada Pedreros, Sebastián Villada-Bedoya, Suhaila Ab Hamid, Talitha Zanini, Tau Bere, Tiago R. N. Bertaso, V. S. Uieda, Wakhid, William Aino Shivoga and Wojciech Jurasz. Open Access funding enabled and organized by Projekt DEAL.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

FreshLanDiv can be downloaded from Dryad https://doi.org/10.5061/dryad.nvx0k6f06 and the code associated with the data paper is available at https://doi.org/10.5281/zenodo.13866691.

References

Allan, D., D. Erickson, and J. Fay. 1997. "The Influence of Catchment Land Use on Stream Integrity Across Multiple Spatial Scales." *Freshwater Biology* 37, no. 1: 149–161. https://doi.org/10.1046/j.1365-2427.1997.d01-546.x.

Allan, E., P. Manning, F. Alt, et al. 2015. "Land Use Intensification Alters Ecosystem Multifunctionality via Loss of Biodiversity and Changes to Functional Composition." *Ecology Letters* 18, no. 8: 834–843. https://doi.org/10.1111/ele.12469.

Barletta, M., A. J. Jaureguizar, C. Baigun, et al. 2010. “Fish and Aquatic Habitat Conservation in South America: A Continental Overview With Emphasis on Neotropical Systems.” *Journal of Fish Biology* 76, no. 9: 2118–2176. https://doi.org/10.1111/j.1095-8649.2010.02684.x.

Barouillet, C., J. D. González-Trujillo, J. Geist, et al. 2023. “Freshwater Conservation: Lost in Limnology?” *Aquatic Conservation: Marine and Freshwater Ecosystems* 34, no. 1: e4049. https://doi.org/10.1002/aqc.4049.

Blowes, S. A., G. N. Daskalova, M. Dornelas, et al. 2022. “Local Biodiversity Change Reflects Interactions Among Changing Abundance, Evenness, and Richness.” *Ecology* 103: e3820. https://doi.org/10.1002/ecy.3820.

Blowes, S. A., B. McGill, V. Brambilla, et al. 2024. “Synthesis Reveals Approximately Balanced Biotic Differentiation and Homogenization.” *Science Advances* 10, no. 8: eadj9395. https://doi.org/10.1126/sciadv.adj9395.

Bomfim, F. F., A. L. B. Fares, D. G. L. Melo, E. Vieira, and T. S. Michelan. 2023. “Land Use Increases Macrophytes Beta Diversity in Amazon Streams by Favoring Amphibious Life Forms Species.” *Community Ecology* 24, no. 2: 159–170. https://doi.org/10.1007/s42974-023-00139-5.

Budnick, W. R., T. Leboucher, J. Belliard, et al. 2019. “Local and Regional Drivers of Taxonomic Homogenization in Stream Communities Along a Land Use Gradient.” *Global Ecology and Biogeography* 28, no. 11: 1597–1609. https://doi.org/10.1111/geb.12976.

Campuzano, C., A. M. Hansen, L. De Stefano, P. Martínez-Santos, D. Torrente, and B. A. Willaarts. 2014. *Water for Food and Wellbeing in Latin America and the Caribbean. Social and Environmental Implications for a Globalized Economy*. Oxon and New York: Routledge.

Cardinale, B. J., J. E. Duffy, A. Gonzalez, et al. 2012. “Biodiversity Loss and Its Impact on Humanity.” *Nature* 486, no. 7401: 59–67. https://doi.org/10.1038/nature11148.

Chamberlain, S. 2017. *Rgbif: Interface to the Global ‘Biodiversity’ Information Facility ‘API’*. R package version 0.9.8. https://CRAN.R-project.org/package=rgbif.

Chang, F. H., J. E. Lawrence, B. Rios-Touma, and V. H. Resh. 2014. “Tolerance Values of Benthic Macroinvertebrates for Stream Biomonitoring: Assessment of Assumptions Underlying Scoring Systems Worldwide.” *Environmental Monitoring and Assessment* 186, no. 4: 2135–2149. https://doi.org/10.1007/s10661-013-3523-6.

Chase, J. M., B. J. McGill, D. J. McGlinn, et al. 2018. “Embracing Scale-Dependence to Achieve a Deeper Understanding of Biodiversity and Its Change Across Communities.” *Ecology Letters* 21, no. 11: 1737–1751. https://doi.org/10.1111/ele.13151.

Colvin, S. A. R., S. M. P. Sullivan, P. D. Shirey, et al. 2019. “Headwater Streams and Wetlands Are Critical for Sustaining Fish, Fisheries, and Ecosystem Services.” *Fisheries* 44, no. 2: 73–91. https://doi.org/10.1002/fsh.10229.

Cooper, S. D., P. S. Lake, S. Sabater, J. M. Melack, and J. L. Sabo. 2012. “The Effects of Land Use Changes on Streams and Rivers in Mediterranean Climates.” *Hydrobiologia* 719, no. 1: 383–425. https://doi.org/10.1007/s10750-012-1333-4.

Dala-Corte, R. B., A. S. Melo, T. Siqueira, et al. 2020. “Thresholds of Freshwater Biodiversity in Response to Riparian Vegetation Loss in the Neotropical Region.” *Journal of Applied Ecology* 57, no. 7: 1391–1402. https://doi.org/10.1111/1365-2664.13657.

Dudgeon, D., A. H. Arthington, M. O. Gessner, et al. 2006. “Freshwater Biodiversity: Importance, Threats, Status and Conservation Challenges.” *Biological Reviews of the Cambridge Philosophical Society* 81, no. 2: 163–182. https://doi.org/10.1017/S1464793105006950.

Encalada, A. C., A. S. Flecker, N. L. Poff, et al. 2019. “A Global Perspective on Tropical Montane Rivers.” *Science* 365, no. 6458: 1124–1129. https://doi.org/10.1126/science.aax1682.

Feio, M. J., R. M. Hughes, S. R. Q. Serra, et al. 2023. “Fish and Macroinvertebrate Assemblages Reveal Extensive Degradation of the world's Rivers.” *Global Change Biology* 29, no. 2: 355–374. https://doi.org/10.1111/gcb.16439.

Feld, C. K., S. Birk, D. Eme, et al. 2016. “Disentangling the Effects of Land Use and Geo-Climatic Factors on Diversity in European Freshwater Ecosystems.” *Ecological Indicators* 60: 71–83. https://doi.org/10.1016/j.ecolind.2015.06.024.

Foley, J. A., R. DeFries, G. P. Asner, et al. 2005. “Global Consequences of Land Use.” *Science* 309, no. 5734: 570–574. https://doi.org/10.1126/science.1111772.

Giam, X., J. D. Olden, and D. Simberloff. 2018. “Impact of Coal Mining on Stream Biodiversity in the US and Its Regulatory Implications.” *Nature Sustainability* 1, no. 4: 176–183. https://doi.org/10.1038/s41893-018-0048-6.

Grames, E. M., A. N. Stillman, M. W. Tingley, C. S. Elphick, and R. Freckleton. 2019. “An Automated Approach to Identifying Search Terms for Systematic Reviews Using Keyword Co-Occurrence Networks.” *Methods in Ecology and Evolution* 10, no. 10: 1645–1654. https://doi.org/10.1111/2041-210x.13268.

Grill, G., B. Lehner, M. Thieme, et al. 2019. “Mapping the World's Free-Flowing Rivers.” *Nature* 569, no. 7755: 215–221. https://doi.org/10.1038/s41586-019-1111-9.

Güneralp, B., S. Lwasa, H. Masundire, S. Parnell, and K. C. Seto. 2017. “Urbanization in Africa: Challenges and Opportunities for Conservation.” *Environmental Research Letters* 13, no. 1: 015002. https://doi.org/10.1088/1748-9326/aa94fe.

Haddaway, N. R., M. J. Grainger, and C. T. Gray. 2022. “Citationchaser: A Tool for Transparent and Efficient Forward and Backward Citation Chasing in Systematic Searching.” *Research Synthesis Methods* 13, no. 4: 533–545. https://doi.org/10.1002/jrsm.1563.

Heino, J., J. Ilmonen, J. Kotanen, et al. 2009. “Surveying Biodiversity in Protected and Managed Areas: Algae, Macrophytes and Macroinvertebrates in Boreal Forest Streams.” *Ecological Indicators* 9, no. 6: 1179–1187. https://doi.org/10.1016/j.ecolind.2009.02.003.

Hudson, L. N., T. Newbold, S. Contu, et al. 2014. “The PREDICTS Database: A Global Database of How Local Terrestrial Biodiversity Responds to Human Impacts.” *Ecology and Evolution* 4, no. 24: 4701–4735. https://doi.org/10.1002/ece3.1303.

Hudson, L. N., T. Newbold, S. Contu, et al. 2017. “The Database of the PREDICTS (Projecting Responses of Ecological Diversity in Changing Terrestrial Systems) Project.” *Ecology and Evolution* 7, no. 1: 145–188. https://doi.org/10.1002/ece3.2579.

Januchowski-Hartley, S. R., L. A. Holtz, S. Martinuzzi, et al. 2016. “Future Land Use Threats to Range-Restricted Fish Species in the United States.” *Diversity and Distributions* 22, no. 6: 663–671. https://doi.org/10.1111/ddi.12431.

Jaureguiberry, P., N. Titeux, M. Wiemers, et al. 2022. “The Direct Drivers of Recent Global Anthropogenic Biodiversity Loss.” *Science Advances* 8, no. 45: eabm9982. https://doi.org/10.1126/sciadv.abm9982.

Juvigny-Khenafou, N. P. D., J. J. Piggott, D. Atkinson, et al. 2021. “Impacts of Multiple Anthropogenic Stressors on Stream Macroinvertebrate Community Composition and Functional Diversity.” *Ecology and Evolution* 11, no. 1: 133–152. https://doi.org/10.1002/ece3.6979.

Kasangaki, A., L. J. Chapman, and J. Balirwa. 2008. “Land Use and the Ecology of Benthic Macroinvertebrate Assemblages of High-Altitude Rainforest Streams in Uganda.” *Freshwater Biology* 53, no. 4: 681–697. https://doi.org/10.1111/j.1365-2427.2007.01925.x.

Leclère, D., M. Obersteiner, M. Barrett, et al. 2020. “Bending the Curve of Terrestrial Biodiversity Needs an Integrated Strategy.” *Nature* 585, no. 7826: 551–556. https://doi.org/10.1038/s41586-020-2705-y.

Maasri, A., S. C. Jahnig, M. C. Adamescu, et al. 2022. "A Global Agenda for Advancing Freshwater Biodiversity Research." *Ecology Letters* 25, no. 2: 255–263. https://doi.org/10.1111/ele.13931.

McGill, B. J., R. S. Etienne, J. S. Gray, et al. 2007. "Species Abundance Distributions: Moving Beyond Single Prediction Theories to Integration Within an Ecological Framework." *Ecology Letters* 10, no. 10: 995–1015. https://doi.org/10.1111/j.1461-0248.2007.01094.x.

McKeon, C. M., R. Kelly, L. Börger, A. De Palma, and Y. M. Buckley. 2023. "Human Land Use Is Comparable to Climate as a Driver of Global Plant Occurrence and Abundance Across Life Forms." *Global Ecology and Biogeography* 32: 1618–1631. https://doi.org/10.1111/geb.13713.

Millard, J., C. L. Outhwaite, R. Kinnersley, et al. 2021. "Global Effects of Land-Use Intensity on Local Pollinator Biodiversity." *Nature Communications* 12, no. 1: 2902. https://doi.org/10.1038/s41467-021-23228-3.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca, and J. Kent. 2000. "Biodiversity Hotspots for Conservation Priorities." *Nature* 403, no. 6772: 853–858. https://doi.org/10.1038/35002501.

Newbold, T., L. N. Hudson, S. L. Hill, et al. 2015. "Global Effects of Land Use on Local Terrestrial Biodiversity." *Nature* 520, no. 7545: 45–50. https://doi.org/10.1038/nature14324.

Petsch, D. K., S. A. Blowes, A. S. Melo, and J. M. Chase. 2021. "A Synthesis of Land Use Impacts on Stream Biodiversity Across Metrics and Scales." *Ecology* 102, no. 11: e03498. https://doi.org/10.1002/ecy.3498.

Pettit, N. E., R. J. Naiman, J. M. Fry, et al. 2015. "Environmental Change Prospects for Conservation and Agriculture in a Southwest Australia Biodiversity Hotspot." *Ecology and Society* 20, no. 3: 16.

Reid, A. J., A. K. Carlson, I. F. Creed, et al. 2019. "Emerging Threats and Persistent Conservation Challenges for Freshwater Biodiversity." *Biological Reviews of the Cambridge Philosophical Society* 94, no. 3: 849–873. https://doi.org/10.1111/brv.12480.

Ribeiro, B. R., S. J. E. Velazco, K. Guidoni-Martins, et al. 2022. "bdc: A Toolkit for Standardizing, Integrating and Cleaning Biodiversity Data." *Methods in Ecology and Evolution* 13: 1421–1428. https://doi.org/10.1111/2041-210x.13868.

Rumschlag, S. L., M. B. Mahon, D. K. Jones, et al. 2023. "Density Declines, Richness Increases, and Composition Shifts in Stream Macroinvertebrates." *Science Advances* 9, no. 18: eadf4896. https://doi.org/10.1126/sciadv.adf4896.

Secretariat, G. 2023. GBIF Backbone Taxonomy. Checklist Dataset https://doi.org/10.15468/39omei Accessed via GBIF.org on 2024-02-28. https://www.gbif.org/dataset/d7dddbf4-2cf0-4f39-9b2a-bb099caae36c.

Spake, R., R. E. O'Dea, S. Nakagawa, et al. 2022. "Improving Quantitative Synthesis to Achieve Generality in Ecology." *Nature Ecology & Evolution* 6, no. 12: 1818–1828. https://doi.org/10.1038/s41559-022-01891-z.

Tickner, D., J. J. Opperman, R. Abell, et al. 2020. "Bending the Curve of Global Freshwater Biodiversity Loss: An Emergency Recovery Plan." *Bioscience* 70, no. 4: 330–342. https://doi.org/10.1093/biosci/biaa002.

Wilkinson, C. L., D. C. J. Yeo, H. H. Tan, A. H. Fikri, and R. M. Ewers. 2018. "Land-Use Change Is Associated With a Significant Loss of Freshwater Fish Species and Functional Richness in Sabah, Malaysia." *Biological Conservation* 222: 164–171. https://doi.org/10.1016/j.biocon.2018.04.004.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.