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DATA ARTICLE

The Zooplankton International Geospatial dataset: A global repository of spatiotemporal freshwater zooplankton community composition data from lakes and reservoirs to support ecological research

Stephanie E. Figary,[1,2*] Michael F. Meyer,[3] Rachel M. Pilla,[4] Warren J. S. Currie,[5] Javier Alcocer,[6] María Belén Alfonso,[7] Caitlin M. Andrews,[8] Orlane Anneville,[9] Ana M. Antão-Geraldes,[10] Shelley E. Arnott,[11] Syuhei Ban,[12] Arnab Banerjee,[13] Gábor Bernát,[14] Jessica E. Beyer,[15] Kätlin Blank,[16] Kelly L. Bowen,[5] Christer Brönmark,[17] Rosalie Bruel,[18,19] Sarah H. Burnet,[20] Tyler J. Butts,[21] Cayelan C. Carey,[22] Rossana Caroni,[23] Moitreyee Chakrabarty,[24] Sudeep Chandra,[25] Kirsten S. Christoffersen,[26] Alicia Cortés,[27] Maria Cristina Crispim,[28] Elvira de Eyto,[29] Luciana De Souza Cardoso,[30] Bridget R. Deemer,[8] Curtis L. DeGasperi,[31] Braden C. DeMattei,[32] Jianming Deng,[33] Jean-Pierre Descy,[34] Inta Dimante-Deimantovica,[35,36] Nadia Diovisalvi,[37] Renata Dondajewska-Pielka,[38] Jonathan P. Doubek,[39] Tvrtko Dražina,[40] Hilary A. Dugan,[21] Zorka Dulić,[41] Ashley A. Dunker,[42] Gaël Dur,[43] Brie A. Edwards,[44] Jolanta E. Ejsmont-Karabin,[45] Mariam Elmarsafy,[5] Zeynep Ersoy,[46,47] Rocio Fernandez,[6] Heidrun Feuchtmayr,[48] Maria Soledad Fontanarrosa,[49] Elena Forasacco,[50] László G.-Tóth,[14] Evelyn E. Gaiser,[51] Gideon Gal,[52] Anita Galir,[53] Javier R. Garcia de Souza,[54] Scott F. Girdner,[55] Ryszard Goldyn,[38] K. David Hambright,[15] David P. Hamilton,[56] Lars-Anders Hansson,[17] Susan P. Hendricks,[57] Huihuang Chen,[58] Pascal M. Isumbisho,[59] Stéphan Jacquet,[9] Jun Yang,[58] Martin J. Kainz,[60] Maciej Karpowicz,[45] Samiullah Khan,[61] Katarzyna Kowalczewska-Madura,[38] Natalia Kuczyńska-Kippen,[38] Silke Langenheder,[62] Sarah D. Lawhun,[1] Barbara Leoni,[63] Fabio Lepori,[64] Shuqi Lin,[65] Arni H. Litt,[66] Eleanor B. Mackay,[48] Marina M. Manca,[23] Shin-ichiro S. Matsuzaki,[67] Blake Matthews,[68] Linda May,[69] Yvonne R. McElarney,[70] Christopher J. McLimans,[15] Rosemberg F. Menezes,[71] Ewa Merz,[72] Evangelia Michaloudi,[73] S. Jannicke Moe,[74]

*Correspondence: sef92@cornell.edu

†Deceased

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Dörthe C. Müller-Navarra,[75] Manuel E. Muñoz-Colmenares,[76] Kayden C. Nasworthy,[1] Veronica Nava,[63] Jens C. Nejstgaard,[77] Ulrike Obertegger,[78] David A. Ortiz,[21] Luis A. Oseguera,[6] Michael J. Paterson,[79] Maria Cintia Piccolo,[80,81] Lorena Pinheiro-Silva,[82] Roberta Piscia,[23] Francesco Pomati,[72] Serena Rasconi,[9] Brian L. Reid,[83] Leonardo L. Ribeiro,[84] Florencia M. Rojas Molina,[85] Joanna Rosińska,[86] Lars G. Rudstam,[1] James A. Rusak,[11,87] Olga O. Rusanovskaya,[88] Nico Salmaso,[78] Jouko Sarvala,[89] S. Geoffrey Schladow,[27] Anna G. Schmidt,[2] Anne E. Scofield,[90] Facundo Scordo,[25,91] Jaromír Sed'a,[92] Katie J. Senft,[27,93] Kirill Shchapov,[94] Svetlana V. Shimaraeva,[88] Eugene A. Silow,[88] Maria Špoljar,[39] Dietmar Straile,[95] Silva M. Sundberg,[2] Jon N. Sweetman,[96] Celia C. Symons,[97] Andrew J. Tanentzap,[98] Barbara Tartarotti,[99] Stephen J. Thackeray,[48] Jan-Erik Thrane,[74] Maxim A. Timofeyev,[88] Jörg Tittel,[100] Pablo Urrutia-Cordero,[101] Piet Verburg,[102] Danielle Machado Vieira,[103] Heather L. Wander,[22] Shohei Watanabe,[27,93] James M. Watkins,[1] David S. White,[57†] Sabine Wollrab,[77] Vivian Yorojo Moreno,[54] Horacio E. Zagarese,[37] Matiss Zagars,[35,104] Petr Znachor[92]

[1]Ashley School of Global Development and the Environment, Cornell University, Ithaca, New York, USA; [2]Rubenstein Ecosystem Science Laboratory, University of Vermont, Burlington, Vermont, USA; [3]U.S. Geological Survey, Portland, Oregon, USA; [4]Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA; [5]Great Lakes Laboratory for Fisheries and Aquatic Sciences, Fisheries and Oceans Canada, Burlington, Ontario, Canada; [6]Grupo de Investigación en Limnología Tropical, Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México, Mexico City, Mexico; [7]Research Institute for Applied Mechanics, Kyushu University, Kasuga, Japan; [8]Southwest Biological Science Center, Grand Canyon Monitoring and Research Center, U.S. Geological Survey, Flagstaff, Arizona, USA; [9]Université Savoie Mont Blanc, INRAE, CARRTEL, Thonon-les-bains, France; [10]CIMO, LA SusTEC, Instituto Politécnico de Bragança, Braganca, Portugal; [11]Department of Biology, Queen's University, Kingston, Ontario, Canada; [12]Department of Ecosystem Studies, University of Shiga Prefecture, Hikone, Japan; [13]Department of Zoology, Sikkim University, Gangtok, India; [14]HUN-REN Balaton Limnological Research Institute, Tihany, Hungary; [15]School of Biological Sciences, University of Oklahoma, Norman, Oklahoma, USA; [16]Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, Tartu, Estonia; [17]Department of Biology, Lund University, Lund, Sweden; [18]Service EcoAqua, Direction de la Recherche et de l'Appui Scientifique, Office français de la biodiversité, Thonon-les-bains, France; [19]Pôle R&D ECLA, Thonon-les-bains, France; [20]Department of Fish and Wildlife Sciences, University of Idaho, Moscow, Idaho, USA; [21]Center for Limnology, University of Wisconsin-Madison, Madison, Wisconsin, USA; [22]Department of Biological Sciences, Virginia Tech, Blacksburg, Virginia, USA; [23]Consiglio Nazionale delle Ricerche, Istituto di Ricerca sulle Acque (CNR IRSA), Verbania, Italy; [24]Department of Conservation Biology, Durgapur Government College, Durgapur, India; [25]Tahoe Institute for Global Sustainability & Biology Department, University of Nevada Reno, Reno, Nevada, USA; [26]Department of Biology, University of Copenhagen, Copenhagen, Denmark; [27]Department of Civil and Environmental Engineering, University of California Davis, Davis, California, USA; [28]Department of Ecology and Systematics, Universidade Federal da Paraiba (UFPB), João Pessoa, Brazil; [29]Fisheries and Ecosystem Advisory Services, Marine Institute, Newport, Ireland; [30]Instituto de Biociencias, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil; [31]King County Water and Land Resources Division, Seattle, Washington, USA; [32]Biosphere Sciences & Engineering, Carnegie Science, Pasadena, California, USA; [33]State Key Laboratory of Lake and Watershed Science for Water Security, Nanjing Institute of Geography & Limnology, Chinese Academy of Sciences, Nanjing, China; [34]FOCUS, Unversité de Liège, Liège, Belgium; [35]Latvian Institute of Aquatic Ecology, Riga, Latvia; [36]Institute of Food Safety, Animal Health and Environment "BIOR", Riga, Latvia; [37]Laboratorio de Ecología Acuática, Instituto Tecnológico de Chascomús (CONICET-UNSAM), Escuela de Bio y Nanotecnologías (UNSAM), Chascomús, Buenos Aires, Argentina; [38]Department of Water Protection, Faculty of Biology, Adam Mickiewicz University, Poznan, Poland; [39]School of Natural Resources and Center for Freshwater Research and Education, Lake Superior State University, Sault Ste. Marie, Michigan, USA; [40]Department of Biology, Faculty of Science, University of Zagreb, Zagreb, Croatia; [41]University of Belgrade, Faculty of Agriculture, Belgrade, Serbia; [42]Fisheries Research and Development, Norton Sound Economic Development Corporation, Nome, Alaska, USA; [43]Creative Science Unit, Faculty of Science, Shizuoka University, Shizuoka City, Japan; [44]Biomonitoring and Inland Waters Section, Ontario Ministry of the Environment, Conservation and Parks, Sudbury, Ontario, Canada; [45]Department of Hydrobiology, University of Bialystok, Bialystok, Poland; [46]Área de Biodiversidad y Conservación, Departamento de Biología, Universidad Rey Juan Carlos (URJC), Madrid, Spain; [47]Instituto de Investigación en Cambio Global (IICG-URJC), Universidad Rey Juan Carlos, Madrid, Spain; [48]Aquatic Ecosystems Group, UK Centre for Ecology & Hydrology, Bailrigg, Lancaster, UK; [49]Consejo Nacional de Investigaciones Cientificas y Tecnicas (CONICET), Tandil, Buenos Aires, Argentina; [50]Early Career Researcher Institute, Imperial College London, London, UK; [51]Institute of Environment and Department of Biological Sciences, Florida International University, Miami, Florida, USA;

[52]Kinneret Limnological Institute, Israel Oceanographic & Limnological Research, Migdal, Israel; [53]Department of Biology, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia; [54]Laboratorio de Ecología de Peces, Instituto de Limnología "Dr. Raúl A. Ringuelet," La Plata, Buenos Aires, Argentina; [55]Department of Lake Ecology, Crater Lake National Park, Crater Lake, Oregon, USA; [56]Australian Rivers Institute, Griffith University, Queensland, Australia; [57]Hancock Biological Station, Murray State University, Murray, Kentucky, USA; [58]Aquatic EcoHealth Group, Fujian Key Laboratory of Watershed Ecology, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen, China; [59]Department of Biology, LEMA, ISP-Gombe, Kinshasa, Democratic Republic of Congo; [60]Aquatic Lipid and Ecotoxicology Research Group, WasserCluster - Biological Station Lunz, Lunz am See, Austria; [61]Resource Science Unit, Otago Regional Council, Dunedin, New Zealand; [62]Department of Ecology and Genetics/Limnology, Uppsala University, Uppsala, Sweden; [63]Department of Earth and Environmental Sciences, University of Milano-Bicocca, Milan, Italy; [64]Department of Environment Constructions and Design, University of Applied Sciences and Arts of Southern Switzerland, Mendrisio, Switzerland; [65]Environmental Research and Modelling Directorate, Environment and Climate Change Canada, Burlington, Ontario, Canada; [66]School of Aquatic and Fishery Sciences, University of Washington, Seattle, Washington, USA; [67]Biodiversity Division, National Institute for Environmental Studies, Tsukuba, Ibaraki, Japan; [68]Department of Fish Ecology and Evolution, Eawag, Luzern, Switzerland; [69]Aquatic Ecosystems Group, UK Centre for Ecology & Hydrology, Penicuik, Midlothian, UK; [70]Fisheries and Aquatic Ecosystems Branch, Agri-Food and Biosciences Institute, Belfast, Northern Ireland; [71]Departamento de Fitotecnia e Ciências Ambientais, Universidade Federal da Paraíba (UFPB), Centro de Ciências Agrárias, Areia, Brazil; [72]Department of Aquatic Ecology, Swiss Federal Institute of Aquatic Science and Technology, Duebendorf, Switzerland; [73]School of Biology, Aristotle University of Thessaloniki, Thessaloniki, Greece; [74]Ecotoxicology and Risk Assessment, Norwegian Institute for Water Research, Oslo, Norway; [75]Department of Biology, University of Hamburg, Hamburg, Germany; [76]Cavanilles Institute of Biodiversity and Evolutionary Biology, University of Valencia, Valencia, Spain; [77]Department of Plankton and Microbial Ecology, Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), Stechlin, Germany; [78]Research and Innovation Centre, Fondazione Edmund Mach, S. Michele all'Adige, Trento, Italy; [79]International Institute for Sustainable Development Experimental Lakes Area, Winnipeg, Manitoba, Canada; [80]Instituto Argentino de Oceanografia, CONICET-UNS, Bahia Blanca, Argentina; [81]Departamento de Geografia y Turismo, Universidad Nacional del Sur (UNS), Bahia Blanca, Argentina; [82]Horn Point Laboratory, University of Maryland Center for Environmental Science, Cambridge, Maryland, USA; [83]Centro de Investigacion en Ecosistemas de la Patagonia (CIEP), Coyhaique, Chile; [84]Campus Prof Ariston Dias Lima, Universidade Estadual do Piaui, Sao Raimundo Nonato, Brazil; [85]Department of Plankton, Instituto Nacional de Limnologia, Santa Fe, Argentina; [86]Department of Ecology and Environmental Protection, Poznan University of Life Sciences, Poznan, Poland; [87]Dorset Environmental Science Centre, Ontario Ministry of the Environment, Conservation and Parks, Dorset, Ontario, Canada; [88]Institute of Lake Baikal Biology, Irkutsk State University, Irkutsk, Russia; [89]Department of Biology, University of Turku, Turku, Finland; [90]Great Lakes National Program Office, U.S. Environmental Protection Agency, Chicago, Illinois, USA; [91]Instituto de Investigaciones en Biodiversidad y Medioambiente (CONICET—UNCOMA), San Carlos de Bariloche, Argentina; [92]Institute of Hydrobiology, Biology Centre CAS, České Budějovice, Czechia; [93]Tahoe Environmental Research Center University of California, Davis, California, USA; [94]River and Lake Ecology Team, Cawthron Institute, Nelson, New Zealand; [95]Limnological Institute, Department of Biology, University of Konstanz, Konstanz, Germany; [96]Department of Ecosystem Science and Management, Penn State University, University Park, Pennsylvania, USA; [97]Department of Ecology and Evolutionary Biology, University of California, Irvine, Irvine, California, USA; [98]Ecosystems and Global Change Group, School of the Environment, Trent University, Peterborough, Ontario, Canada; [99]Department of Ecology, University of Innsbruck, Innsbruck, Austria; [100]Department of Lake Research, Helmholtz-Centre for Environmental Research—UFZ, Magdeburg, Germany; [101]Department of Aquatic Ecology and Biotechnology, IMDEA Water, Madrid, Spain; [102]School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand; [103]Instituto Machado & Estrela pos-graduacao em Saude, Bairro dos Estados, Brazil; [104]University of Latvia, Riga, Latvia

Scientific Significance Statement

In aquatic ecosystems, zooplankton transfer substantial energy from primary producers to higher trophic levels. Aquatic scientists seek to understand how and why zooplankton community compositions vary spatially and temporally, as well as how those changes propagate throughout the food web. However, synthesizing zooplankton community patterns across datasets is challenging because individual sampling efforts often use program-specific data curation practices, nomenclatures, and taxonomies. To address this challenge, we present the Zooplankton International Geospatial (ZIG) dataset: a grassroot initiative creating a harmonized, quality assessed, and compiled zooplankton and waterbody dataset of 311 inland waterbodies spanning 37 countries and 60 yr. With an emphasis on preserving data integrity and documenting sample comparability, ZIG is a robust tool for analyzing drivers and processes of inland waterbodies worldwide.

Abstract

Zooplankton transfer substantial energy in aquatic food webs and are used as indicators of environmental change. Syntheses of zooplankton community dynamics globally require datasets that span a wide range of environmental gradients; however, these datasets are limited due to methodological differences across programs, taxonomic inconsistencies, and a lack of standardized metadata. To reconcile these challenges, we created the Zooplankton International Geospatial (ZIG) dataset, which includes original zooplankton, water physical and chemical variables, and lake morphometric data from 311 inland lakes and reservoirs. ZIG includes waterbodies ranging in size from 0.005 to 82,100 km^2 and spanning broad latitudinal (−47.26 to 64.90) and longitudinal ranges (−165.04 to 176.53). Temporal coverage for individual waterbodies ranges between 1 and 60 yr with sampling frequency ranging from annually to weekly. With its extensive coverage and content, we consider ZIG to be a cornerstone for future investigations of global scale lake biodiversity change.

Background and motivation

Inland lakes and reservoirs (hereafter "lakes") provide vital ecosystem services (Dudgeon et al. 2006; Declerck and de Senerpont Domis 2023). In these systems, zooplankton are a major conduit for carbon and nutrients to flow bottom-up to higher trophic levels, providing a critical link in supporting ecosystem services and functions (Dudgeon et al. 2006; Declerck and de Senerpont Domis 2023). In this role, zooplankton experience top-down control by higher trophic levels and exert top-down control on phytoplankton through grazing (Lampert et al. 1986; Jeppesen et al. 2000, 2003; Rogers et al. 2020). Many studies from individual waterbodies and regions have extensively documented relationships between zooplankton community structure and composition in response to various natural and anthropogenic environmental factors such as lake productivity, planktivory, harmful algal blooms, invasive species, and disturbances (Brooks and Dodson 1965; Mills et al. 1987; Whitman et al. 2004; Mitra and Flynn 2006; Caroni and Irvine 2010; Jeppesen et al. 2011; Ger et al. 2019; Carrozzo et al. 2020; Pinheiro-Silva et al. 2020). Hence, zooplankton are useful indicators of ecosystem conditions (Choi et al. 2023). However, choosing appropriate zooplankton metrics and biotic indices to detect multivariate environmental change remains difficult, especially considering zooplankton indices developed on a subset of lakes might not be appropriate for global-scale questions (Caroni et al. 2025). Unifying temporally and geographically disparate zooplankton datasets to understand their responses and related ecosystem consequences is therefore critical to leveraging novel insights in a time of rapid and widespread environmental and ecological change (Adrian et al. 2009; O'Reilly et al. 2015).

Global assessments of biodiversity change rely on comprehensive analyses of community dynamics across time, space, and taxonomic scales. In marine and terrestrial ecosystems, many spatially extensive time series have been assembled (O'Brien 2010; Edwards et al. 2010; Magurran et al. 2010; Dornelas et al. 2018; Maureaud et al. 2024), enabling assessments of how and why biodiversity in these ecosystems has changed over time. By comparison, freshwater ecosystems remain underrepresented in global assessments, although they contain a high proportion of the Earth's at-risk species and have experienced extensive biodiversity losses (Maasri et al. 2022). For example, while only occupying 1% of the Earth's surface, freshwater ecosystems are home to over 25% of all vertebrates and over 50% of all fish species (WWF 2022). The Living Planet Index, which measures global biodiversity trends across habitats, shows that the decline of inland water populations continues to outpace those of marine or terrestrial ecosystems (Reid et al. 2019; Tickner et al. 2020; WWF 2022). Additionally, while global-scale declines in freshwater biodiversity have been documented (Collen et al. 2014), these assessments focus heavily on vertebrate populations and often ignore important invertebrate members of the food web, such as zooplankton. Moreover, zooplankton are rarely included as a component of water quality and biological health assessments, which is the case in the European Union Water Framework Directive (Caroni and Irvine 2010; Jeppesen et al. 2011). Large expert groups have recognized the need to enhance the taxonomic, ecological, and genomic knowledge of aquatic invertebrates and increase monitoring across space and time (Maasri et al. 2022).

While global-scale marine zooplankton data have supported important biodiversity studies (Irigoien et al. 2004), datasets of zooplankton communities and associated environmental variables from lakes that are analysis-ready, multiyear, and macroscale are lacking at a global scale. However, national-scale lake zooplankton datasets, such as the U.S. Environmental Protection Agency's National Lakes Assessment (Pollard et al. 2018) and LakePulse (Huot et al. 2019) have improved our understanding of the factors regulating biodiversity (Schartau et al. 2022; Paquette et al. 2022), of emerging ecosystem states and subsequent food web implications (Leech et al. 2018), and of differences in energy transfer across eutrophication gradients (Yuan and Pollard 2018). These national efforts forged a path for standardizing macroscale limnological data, and these programs predominantly collect samples in a coordinated manner, but a wealth of zooplankton community data exist among individual sampling programs that each curate data according to their own objectives and protocols. Likely due to the considerable energy needed to harmonize data across individual sampling efforts and programs, no globally harmonized zooplankton dataset for inland lakes exists. For example, the largest assemblage-level time-series database, BioTIME (Dornelas et al. 2018), contains only 28 datasets for freshwater ecosystems out of 382 total datasets (< 8%). Instead, global scale inferences about lake zooplankton have largely relied on meta-analysis or systematic reviews (Merrix-Jones et al. 2013; Pearson and Duggan 2018; Dexter and Bollens 2020; Dos Santos et al. 2024). The absence of a comprehensive global zooplankton dataset restricts our ability to understand drivers of zooplankton communities across a gradient of limnological, geographical, and ecological contexts, and limits our capacity to predict zooplankton responses to future environmental changes.

A major challenge to the compilation of biological datasets is the need to harmonize often disparate methodologies, taxonomies, and metadata across sampling programs to make the individual data streams interoperable (Wilkinson et al. 2016). Building a harmonized dataset across large spatial scales is more tenable when crowdsourcing data directly from providers (e.g., the community science model where mobile applications like eBird [https://ebird.org/home] or PurpleAir [https://www2.purpleair.com] ask for data in consistent formats). Operationally, harmonizing individual datasets into a common structure is challenging because different datasets can be limited in temporal or spatial scope or have different structures, use different vocabulary, data storage practices, methods, and taxonomy, thereby limiting their comparability. Compiling and ensuring reusability of these individual datasets as a unified dataset requires significant time and effort; however, once created unified datasets enable new opportunities for synthesis and analysis of different aspects of freshwater community ecology (Soranno and Schimel 2014).

As a foundational step towards addressing this collective need, we present the Zooplankton International Geospatial (ZIG) dataset to facilitate and empower global zooplankton community analysis of inland lakes. ZIG is a harmonized community dataset in a standardized format covering 311 lakes with up to 60 yr of data from each waterbody. ZIG was initiated at the 2019 Global Lake Ecological Observatory Network (GLEON; Weathers et al. 2014) meeting with plans to explore the role of zooplankton as indicators of environmental change (Figary et al. 2022). The data call was focused on crustacean zooplankton abundances, common water chemistry variables (surface temperature, chlorophyll *a*, nutrients, Secchi depth), and lake characteristics but also welcomed additional data of rotifer abundance, zooplankton biomass and length, and ancillary water property variables (such as dissolved oxygen, hypolimnetic temperature, or additional water chemistry). Due to the sharing of zooplankton data from researchers worldwide, ZIG soon developed into a much larger undertaking. This global zooplankton dataset creates new opportunities for researchers to investigate global zooplankton biodiversity and community composition trends, thereby providing critical insights into ecosystem functioning and freshwater biodiversity. Further, ZIG enables the identification of drivers governing zooplankton dynamics such as thermal region, nutrient variability, and other natural and anthropogenic stressors. With an emphasis on Findable, Accessible, Interoperable, and Reusable (FAIR) data principles (Wilkinson et al. 2016), ZIG represents a new approach to the macroscale synthesis of freshwater ecosystems. This effort provides a roadmap for other researchers interested in aggregating and harmonizing crowdsourced datasets and a data template for future published zooplankton data for easy integration into ZIG.

Data description

The ZIG dataset was created by compiling existing zooplankton community composition and abundance, waterbody characteristics, physical, and chemical data from 311 waterbodies provided by more than 120 data contributors worldwide (Fig. 1). ZIG includes data across global thermal regimes, covering all nine lake thermal regions described in Maberly et al. (2020), a classification system that broadly groups lakes into thermal regimes that are important for physical, chemical, and biological processes. The waterbodies are principally lakes (88%) but also include reservoirs (12%). Sampling periods for each waterbody range from 1 to 60 yr (median of 4 yr), and 37% of the waterbodies have been monitored for 10 or more years. The approximate sampling frequencies, primarily during the ice-free season, were as follows: 3% of waterbodies were sampled weekly, 24% biweekly, 37% monthly, and the remaining 36% were sampled sporadically within a year (Fig. 2).

The creation of the ZIG dataset was a years-long endeavor, with the original data call using a standardized template being distributed January 2021, culminating in a completed dataset January 2025. Each data submission was individually harmonized, quality-checked, and quality-assessed before being added to the ZIG dataset, and the entire dataset went through similar quality review processes (described below in Technical validation section). Gathering, harmonizing, and compiling the dataset was a collaborative effort by a designated data harmonization team. The ZIG dataset is interoperable with data from HydroLAKES (Messager et al. 2016), which is among the largest compendiums of worldwide lake locational data, a database of 1.42 million lakes of at least 0.1 km^2 in surface area. ZIG has a similar spatial distribution across latitudes as in the HydroLAKES database (Fig. 3; Messager et al. 2016), with 78% of ZIG waterbodies having a corresponding unique

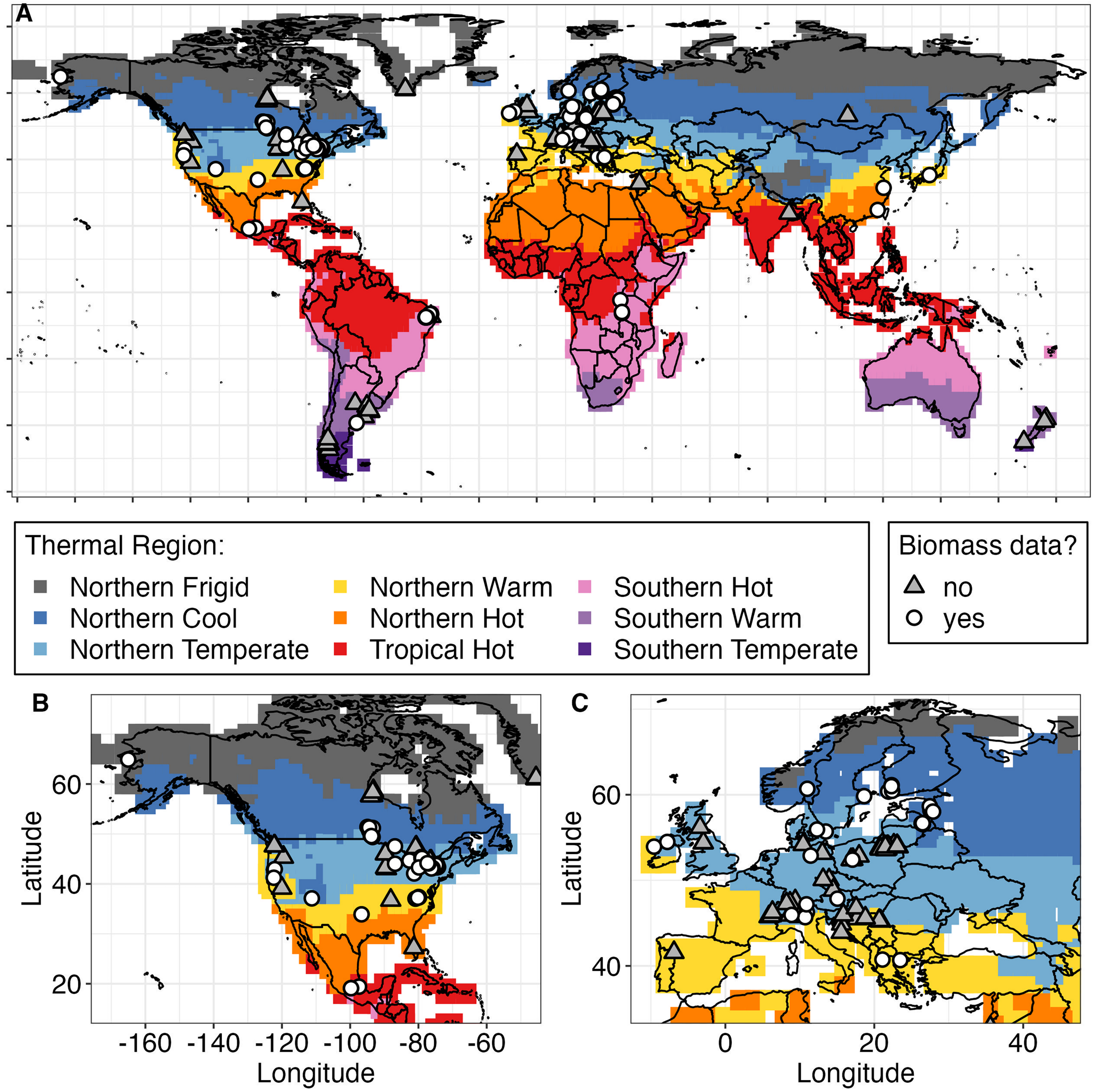

Fig. 1. Locations of the 311 waterbodies in the ZIG dataset across global thermal regions (Maberly et al. 2020) (**A**), with insets highlighting lake-dense regions in North America (**B**) and Europe (**C**). White circles indicate lakes with zooplankton biomass data in addition to abundance data, while gray triangles indicate lakes that only have zooplankton density data.

HydroLAKES identifier (i.e., Hylak_id). The full ZIG dataset can be accessed via the Environmental Data Initiative (Figary et al. 2026).

The ZIG dataset comprises seven comma-separated value (CSV) files in a tabular format (Table 1). Three files include descriptive information about the waterbodies (waterbodies.csv), sampling locations (stationid.csv), and timelines (waterbody_timeline.csv). Three files contain the core data on water physical, chemical, and biological measurements (hereafter referred to as "water chemistry" in the text; water_chemistry.csv), zooplankton abundance (zooplankton_abundance.csv), and zooplankton length (zooplankton_length.csv), where each row is a unique waterbody-station-timepoint combination. The last file is a crosswalk of taxonomic

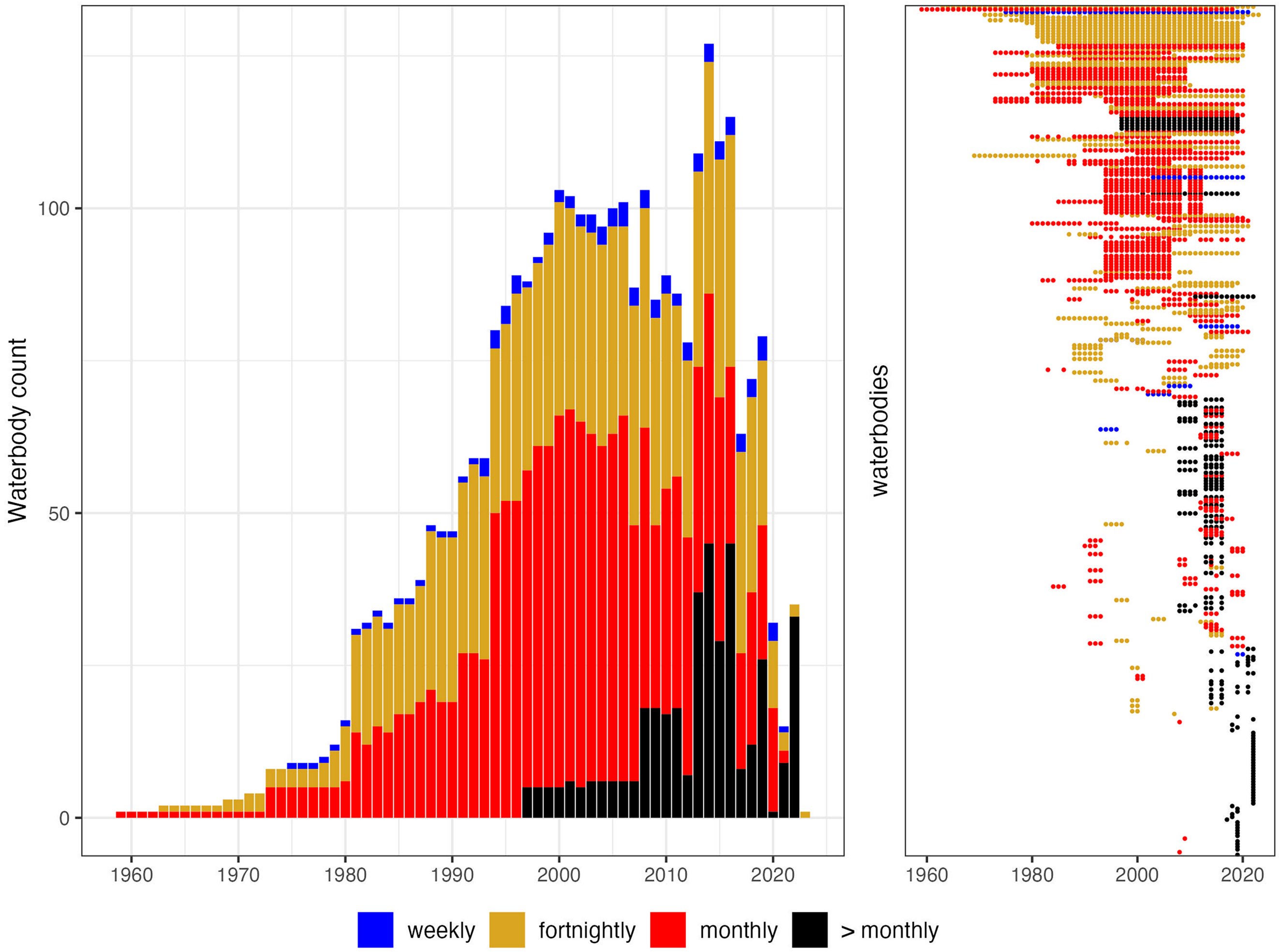

Fig. 2. Sampling frequency of waterbodies contained in the ZIG dataset from 1963 to 2023 by (**A**) year, and (**B**) span of data across years for each waterbody.

information between the user-provided taxa and current accepted taxonomic nomenclature with reference links to an external taxonomic database (taxa_list.csv; Fig. 4). The six files with waterbody-specific data (i.e., excluding taxa_list.csv) can be seamlessly linked using the "zig_id" column in all files and the "stationid" column in those containing sampling event data.

Waterbody and sampling station information tables include geographic and morphometric parameters (e.g., maximum and mean depth, surface area) and watershed characteristics (e.g., area and land use). Waterbody morphology varies significantly, with maximum depths ranging from 0.5 to 1642 m and surface areas ranging from 0.005 to 82,100 km^2 (Fig. 5).

The "water_chemistry.csv" data include sampling event information along with sampling depth and water physical, chemical, and biological variables. The variables include alkalinity (mg L^{-1}), chlorophyll *a* (μg L^{-1}), chloride (mg L^{-1}), conductivity (μS cm^{-1}), dissolved inorganic carbon (mg L^{-1}), dissolved oxygen (mg L^{-1}), dissolved organic carbon (mg L^{-1}), dissolved phosphorus (μg L^{-1}), hardness (mg L^{-1}), nitrate + nitrite (mg L^{-1}), pH, Secchi disk depth (m), soluble reactive silica (mg L^{-1}), soluble reactive phosphorus (μg L^{-1}), water temperature (°C), thermocline depth (m), total Kjeldahl nitrogen (mg L^{-1}), total nitrogen (mg L^{-1}), total phosphorus (μg L^{-1}), and turbidity (NTU). Not all waterbodies have data for all variables. The most frequently supplied water physical and chemical data, per the data call requirements, were chlorophyll *a* (309/311 waterbodies), total phosphorus (306/311), water temperature (286/311), nitrate + nitrite (281/311), pH (243/311), and Secchi disk depth (206/311).

The "zooplankton_abundance.csv" data include sampling event information along with sampler type, mesh size, depths sampled, volume collected, and which taxonomic sampling processing methods were used. Zooplankton community composition data by density were the minimum requirement for submitting data to ZIG (i.e., 311/311), and 146 of the

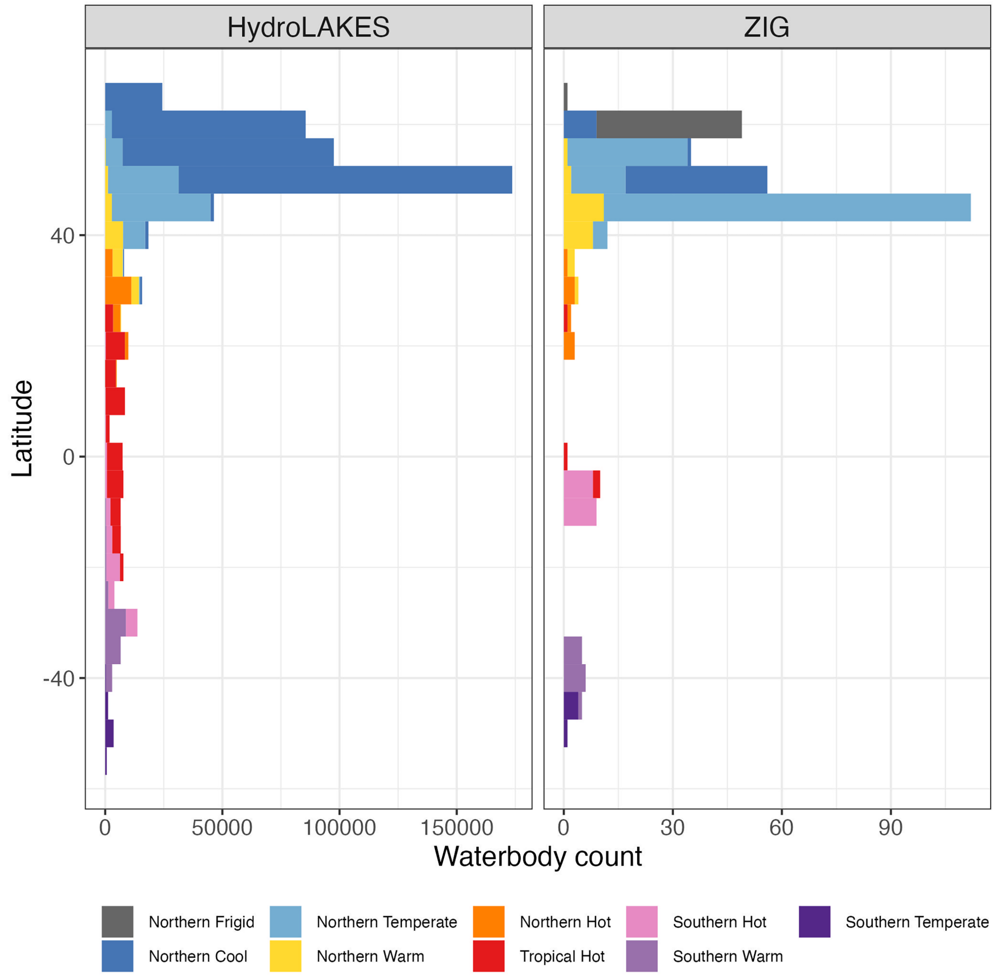

Fig. 3. Spatial distribution of waterbodies across latitude and thermal regions for the HydroLAKES (Messager et al. 2016) and ZIG datasets (Figary et al. 2026). Due to the high proportion (52%) of Northern Frigid lakes in HydroLAKES, these lakes are not displayed.

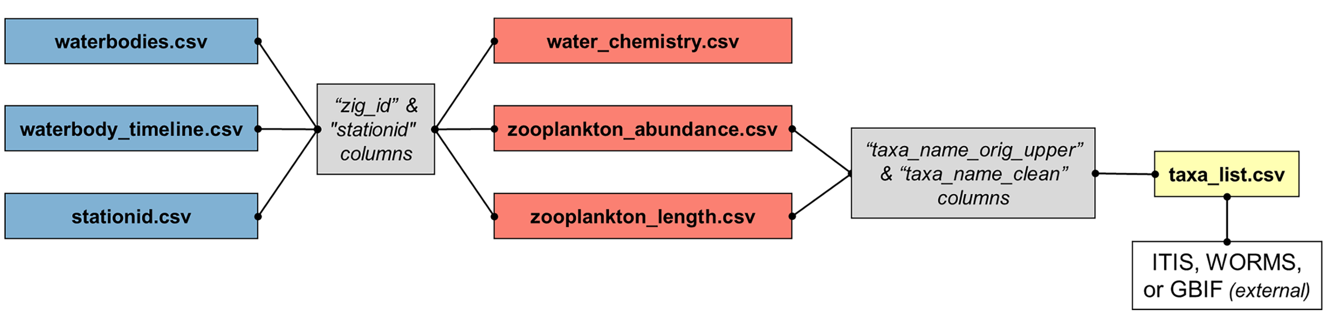

Fig. 4. Structure of the ZIG dataset. Three .csv files describe individual waterbody and sampling locations and can be linked using the "zig_id" and "stationid" columns to three .csv files containing water chemistry and zooplankton data. The taxa_list.csv provides a crosswalk between user-provided taxonomy and accepted taxonomic nomenclature using the "taxa_name_orig_upper" and "taxa_name_clean" columns, and links externally to the Integrated Taxonomic Information System (Integrated Taxonomic Information System 2024), World Register of Marine Species (WoRMS Editorial Board 2024), or Global Biodiversity Information Facility (GBIF 2024).

311 waterbodies also included biomass data (Fig. 1). The entire dataset includes information at least at the level of major zooplankton groupings (i.e., Copepoda, Cladocera, and Rotifera). Most of the dataset includes species-level information (265/311). Many datasets contain length data (80/311), with most including either individual (37/80) and/or average

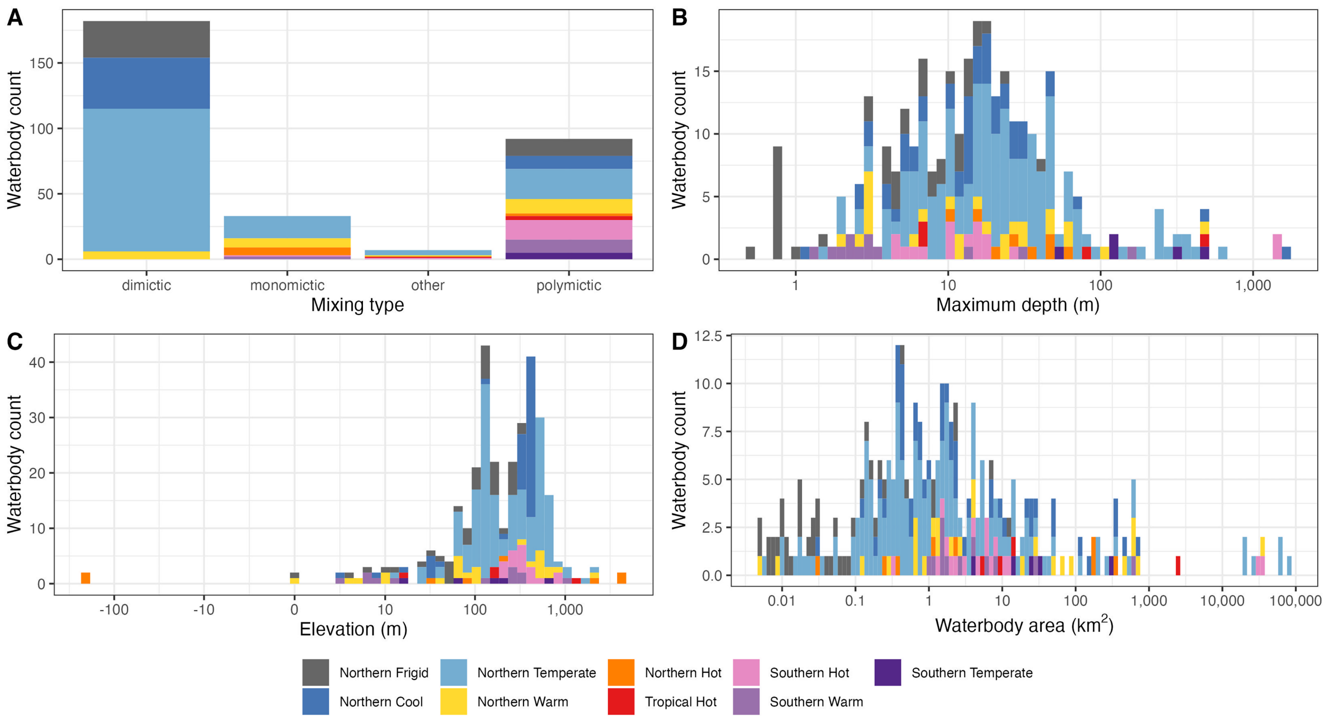

Fig. 5. Characteristics of waterbodies contained in the ZIG dataset in terms of waterbody mixing type (**A**), maximum depth (**B**), elevation (**C**), and area (**D**) across thermal regions. "Other" for mixing types includes holomictic, meromictic, and oligomictic.

(46/80) lengths from individual sampling events (77/80) compared to average values over multiple sampling events (3/80). Zooplankton length data are located in the file "zooplankton_length.csv."

Methods

Waterbody information, zooplankton community composition, physical and chemical water parameters, and metadata were compiled for 311 waterbodies worldwide. To identify and collate waterbody data, researchers familiar with an individual dataset aggregated and formatted data for their inclusion in the fully harmonized dataset. For each waterbody, required water physical and chemical parameters included water temperature, chlorophyll *a*, nitrogen, and phosphorus concentrations. A complete list of additional contributed variables for some, but not all, lakes can be found in the data description section above. Zooplankton abundance data were reported as density (i.e., number of individuals per unit volume), and, for a subset of waterbodies, as biomass (i.e., mass per unit volume) per taxonomic unit. The entire dataset includes information at least at the level of major zooplankton groupings (i.e., Copepoda, Cladocera, and Rotifera). However, because each lake's program may not sample all zooplankton groups, some lakes may only include information on adult crustacean zooplankton (as required for submission to ZIG), whereas others may include other taxonomic groups (e.g., rotifer species, included in 66% of lakes) or more detailed abundances of various life stages (e.g., nauplii and copepodite abundance). Zooplankton sampling methods likewise varied by sampling program (e.g., discrete or grab samples, vertical net tows). To highlight the range of ecosystems and environments contained within ZIG, we briefly summarize the available data by thermal region (Maberly et al. 2020). More detailed information for each waterbody on parameters collected and methods used can be found in Table S1 in the supplemental information. Acknowledgements for data collection; contact information and dataset descriptions of external data available in the ZIG data format; and written dataset descriptions for datasets in ZIG detailing information on waterbody characteristics, sampling approach, and years of sampling can be found as part of the ZIG dataset on EDI (Figary et al. 2026). Additional details on quality-checking procedures are provided in Technical validation section.

Northern frigid

ZIG contains data for 41 waterbodies in the Northern Frigid thermal region. All lakes are located in Canada, Alaska (USA), Finland, and Greenland, with some time series starting in 1994 and continuing through 2022. Notably, this thermal region includes single-time "snapshot" samples from 27 lakes in southern Greenland. With species-level taxonomic resolution, the samples were collected to understand the effects of fish predation on zooplankton community structure (Moosmann et al. 2024).

Northern cool

ZIG contains 49 waterbodies in the Northern Cool thermal region. All lakes are located in Canada, Finland, Sweden, Norway, Estonia, and Russia, with some time series starting in 1978 and continuing through 2020. Notably, this thermal region includes the Experimental Lakes Area ecosystems (36 lakes in Ontario, Canada), some of which are manipulated ecosystems designed to understand how ecological communities respond to various disturbances (https://www.iisd.org/ela/).

Northern temperate

ZIG contains 153 waterbodies in the Northern Temperate thermal region. All lakes are in Canada, the United States, Germany, Switzerland, France, Austria, Italy, the United Kingdom, Croatia, Czechia, Sweden, Denmark, Latvia, and Poland. Notably, this thermal region contains numerous lakes from several long-term ecological research stations designed to monitor changes in water chemistry and ecosystem function over time.

Northern warm

ZIG contains 25 waterbodies in the Northern Warm thermal region. All lakes are in Portugal, the United States, Japan, Serbia, Ireland, Croatia, Greece, Albania, and China. This thermal region includes several time series with particularly long records, including Lake Tahoe (1998–2019; USA), Lake Washington (1963–2022; USA), Biwa Lake (1990–2010; Japan), and Balaton Lake (1999–2019; Hungary).

Northern hot

ZIG contains seven waterbodies in the Northern Hot thermal region. All lakes are in Mexico, the United States, Israel, and China. Notably, the Northern Hot thermal region includes two of central Mexico's high elevation (at 4200 m a.s.l) lakes, Lago de La Luna and Lago de El Sol.

Tropical hot

ZIG contains four waterbodies in the Tropical Hot thermal region. The lakes are in India, Brazil, Democratic Republic of the Congo, and Rwanda and include Bakreswar reservoir in West Bengal, India, which experiences intense summer monsoons as well as two reservoirs (Carnaúba and Açude Itans) in the semiarid region of Brazil. Notably, this thermal region also includes Lake Kivu, one of Africa's Great Lakes.

Southern hot

ZIG contains 16 waterbodies in the Southern Hot thermal region. All lakes are in Brazil, Burundi, Democratic Republic of the Congo, Tanzania, and Zambia. The Southern Hot thermal region includes Lake Tanganyika, an ancient lake with samples from 1993 to 2001.

Southern warm

ZIG contains 12 waterbodies in the Southern Warm thermal region. All lakes are in Argentina and New Zealand. The Southern Warm thermal region includes Lake Taupo (or Lake Taupō), a lake originating within a volcanic caldera, where samples were collected every 3 weeks from 2000 through 2020.

Southern temperate

ZIG contains five waterbodies in the Southern Temperate thermal region. All lakes are in Chile except Lago Cochrane or Lago Pueyrredón, which spans across the Chilean and Argentine border.

Technical validation

To ensure that high data quality and integrity were maintained throughout the dataset harmonization process, we used the following validation controls within and across programs.

Validation within a program

A standardized data submission template was developed and used by all data providers. Each submitted dataset was initially checked for adherence to the submission template, ensuring consistency in column names and overall data structure. Completeness checks were conducted to identify inconsistencies in units and missing or duplicated data. Additional information was requested from data providers to validate or fill data gaps as necessary. A general data cleaning procedure was implemented using a scripted routine in the R Statistical Environment (R Core Team 2022), designed to detect and resolve duplicate entries in water chemistry and zooplankton abundance, verify data types defined in the data submission, and check waterbody geographical coordinates. Consistency checks were also performed to ensure uniform spelling and formatting of waterbody names and station IDs, and taxonomic validation was conducted to ensure that all taxa names used in the dataset were included in the taxa list. Quality control figures, including histograms, box plots, and scatter plots, were generated to visualize and evaluate data ranges, units, and potential outliers in water chemistry and zooplankton abundance data. Outliers were defined as values where the personnel conducting harmonization visually assessed parameter distributions and suspected a potential data point as spurious or outside the likely range, given the data distribution from an individual waterbody. Potential outliers and errors were sent to the original data provider for edits or confirmation and removed as needed. Consistency in sampling months and years was checked between water chemistry and zooplankton data. Finally, when potential errors were detected, personnel contacted the original data providers to ensure if modifications to the provided data were warranted.

Validation across programs

After all individual waterbodies' datasets had been harmonized and validated, data were merged into a single set of CSV files (i.e., one CSV file for each data type; Table 1). As multiple waterbodies have the same name, each waterbody was given a unique "zig_id," comprising a randomized number, beginning from one. All "zig_id"s were followed by an underscore and a number to indicate if multiple datasets for a single waterbody were included from different data providers (i.e., with different sampling methods, station locations, or temporal coverage). For example, a single waterbody with two separate datasets from different data providers was assigned the same zig_id followed by one or two (i.e., 75_1 and 75_2). Where available, we linked zig_id with the unique waterbody identifier "Hylak_id" from HydroLAKES (Messager et al. 2016) ($n = 239$) using the R package "hydrolinks" (Winslow et al. 2018). Unmatched lakes were manually confirmed. All special characters within the dataset were replaced with Latin alphanumeric characters. All character columns except waterbody and station names were returned to lowercase for consistency. All data files were quality-checked and validated, as described in more detail below. Finally, a summary file for each waterbody was sent to the corresponding data contributor to check data ranges, units, and methods; suggested changes were incorporated into the final data product.

Water physical and chemical variables

In the "water_chemistry.csv," we created a series of water quality flags to ensure proper intercomparison of samples.

Table 1. Organization of ZIG dataset with file name and content description.

File name	Description
waterbodies.csv	Waterbody information, including location, physical characteristics, contact information, sampling program descriptions, and some optional descriptions
stationid.csv	Sampling station location and additional information
waterbody_timeline.csv	Major events in the waterbodies as defined by data providers (not provided for all datasets)
water_chemistry.csv	Water physical and chemical data, including sampling methods
zooplankton_abundance.csv	Zooplankton abundance data, including sampling methods
zooplankton_length.csv	Zooplankton length data (not provided for all datasets)
taxa_list.csv	Crosswalk from the originally provided taxa_name and clean taxa information

The flag column could be set as null or one of the following: "< MDL," (less than the minimum detection limit, when known) "outlier," "NO_3 only," "estimated from phytoplankton biomass," ">max depth," and "no thermocline." "< MDL" indicates that the observed value was zero, negative, or below the provided method detection limit. Method detection limits, when available, are listed in the "MDL column," with a null value meaning no value was provided. "Outlier" flags were calculated using z-scores from all data available across all waterbodies for each variable, and values outside $\pm$ 3 standard deviations were flagged. Here, the input data for standard deviation calculations were untransformed for water temperature, Secchi disk depth, thermocline depth, pH, and DO concentration. To assess measurement values across several orders of magnitude, log-transformed data were used for standard deviation calculations for all other variables. The "NO_3 only" flag is only used for "NO_2NO_3" and indicates only nitrate rather than nitrite+nitrate values. The flag "estimated from phytoplankton biomass" was only used for "chl-a" when the chlorophyll *a* concentration was estimated from the phytoplankton biovolume in an individual waterbody's dataset (Felip and Catalan 2000). The flag "> max depth" indicates that the Secchi disk was still visible while on the bottom of the waterbody. The flag "no thermocline" indicates that after measuring the temperature profile along the water column, no thermocline was detected during this sampling event (i.e., the waterbody was mixed). Consistency of measurement units for each variable was visualized across all waterbodies using histograms; values reported in inconsistent units were converted after clarification from the data provider.

Zooplankton abundance

In the "zooplankton_abundance.csv" file, null or zero values were removed from the dataset. We chose to remove both of these values because they could ultimately indicate the same information. A null value could either stem from an individual data provider not observing a given taxon or actively not searching for a given taxon when performing abundance estimates. In contrast, a zero would solely imply that a given taxon was not observed only after actively searching for that taxon. Because both of these instances qualitatively result in a taxon not being counted or observed, we removed them from the long-format of the dataset. When end users transpose the dataset into a wide format, these values can efficiently be added into the dataset post hoc.

Unit consistency for density, biomass, and, where applicable, length was visualized across all waterbodies using histograms and scatter plots; values reported in inconsistent units were converted. Exceptions include 4% of waterbodies where only relative density values were available (% composition) and one waterbody where areal density was reported (ind m^{-2}) for some years and could not be converted into volumetric density (ind L^{-1}).

Taxa list

Based on the taxa names initially provided, we created a harmonized taxa list with an accepted taxonomic name, taxonomic phylogenies, and external database information. This taxa list links to the taxa names initially provided in the zooplankton_abundance.csv and the zooplankton_length.csv through the column "taxa_name_orig_upper" (Fig. 4). The taxa_list.csv comprises multiple columns, including taxonomic classifications (phylum, class, subclass, order, suborder, infraorder, family, subfamily, genus, species, subspecies), optional information (life stage, maturity, sex), reference information for the accepted taxa name (author and year, external database, and identification number), and additional taxonomic details (additional_details, additional_ID). Further details include information such as hybrids, forms, varieties, or if multiple species or genera were included in the submitted taxa name. Not all column information was available for each taxon. All taxonomic names were first searched for in the Integrated Taxonomic Information System database (Integrated Taxonomic Information System 2024), followed by the World Register of Marine Species (WoRMS Editorial Board 2024), followed by the Global Biodiversity Information Facility (GBIF 2024). Scientific names without a match were checked for potential spelling errors and corrected as needed ("taxa_name_clean"). Due to the differences between taxonomic databases and because multiple databases were required for this global dataset, the referenced external database and identification number refer exclusively to the clean_taxa_name match and not to the other taxonomic classification columns. A total of 685 accepted zooplankton taxa names and over 154 genera are represented in the ZIG dataset.

Data use and recommendations for reuse

The ZIG dataset is well suited for spatial and temporal analysis within and across waterbodies and from regional to continental scales. Furthermore, the inclusion of unique lake identifiers from other datasets, such as HydroLAKES (Messager et al. 2016), allows for integration of ZIG with HydroLAKES-derived datasets (e.g., Lehner et al. 2022; Meyer et al. 2020; Meyer et al. 2024; Topp et al. 2021; Ehalt Macedo et al. 2022), thereby empowering an even more expansive analysis of 249 (79%) waterbodies in ZIG. These potential derived datasets could therefore be used to compare zooplankton community composition, water chemistry, thermal regimes, land use and waterbody morphometry across multiple ecosystems over large spatial scales. Beyond extant lake datasets, ZIG creates a platform for extending lake community compositional data into questions of lake community function. The harmonized taxonomies included in ZIG as well as the inclusion of unique identifiers from dynamic taxonomic databases can serve as a future opportunity to facilitate functional trait analyses at unprecedented scales. From this potential, we envision ZIG spurring numerous investigations of plankton ecology, and in turn, will facilitate future work to address critical research questions, such as:

- What are the underlying drivers of zooplankton biodiversity dynamics at regional and global scales?
- What are the major biogeographic patterns in freshwater zooplankton communities?
- What are the major biogeographic patterns in zooplankton functional traits?
- Can we infer water quality conditions using zooplankton community compositions?
- How do biodiversity trends in aquatic invertebrates compare to those for vertebrates?
- How are levels of community endemism, heterogeneity, and homogenization changing at a global scale?

We recommend care and caution when comparing zooplankton abundance values or water chemistry data between waterbodies due to various sampling collection methods, some of which are more comparable than others. First, caution should be taken when interpreting water parameter data collected at the surface vs. samples integrated over depth. Second, caution should be used when comparing zooplankton community composition and total abundance, because different sampling collection methods were used at different stations, waterbodies, or times, including different mesh sizes, sampling devices, and sampling depths, with some sampling programs collecting zooplankton across the entire water column and others sampling the surface, epilimnion, or a specific depth range. Third, datasets in ZIG differ in terms of sample processing protocols (e.g., counting effort, number of subsamples processed), so the extent of information about rare species will differ across datasets. Fourth, care should be taken when analyzing specific taxa in the dataset, especially considering that taxonomic names and phylogenies may change over time. To mitigate spurious conclusions based on changes in taxonomies, we include unique identifiers from various taxonomic databases. Future end users are encouraged to compare static taxonomic labels within ZIG to updated taxonomic labels listed in the above-mentioned databases. Lastly, caution should be taken when interpreting and comparing zooplankton biomass values across datasets because not all datasets use the same length-weight relationships and some providers may have different methods for estimating dry- and wet-biomass. Detailed information about sample collection methods is included in the zooplankton and water parameter section of the dataset and is described in the dataset_description section of the waterbodies table. Key columns to consider for comparability in both the water chemistry and zooplankton abundance data files include "discrete_or_int," "zone," "depth_min_m," and "depth_max_m"; additional columns in the zooplankton abundance file relevant for assessing sampling comparability include "zoop_sampler_type," "zoop_mesh_um," "zoop_net_mouth_area_cm2," "zoop_liter_collected," "subsampled," "subsample_min," and "zoop_num_sample" (Table 2). Station maximum depth is included in the

Table 2. Column names and descriptions developed to harmonize many facets of water chemistry and zooplankton sampling methods across sampling programs.

Column name	Units/allowable values	Description
water_chemistry.csv		
W_discrete_or_int	Discrete or integrated	Categorical water parameter sampling method
W_zone	Surface, epilimnion, metalimnion, hypolimnion, whole water column, euphotic, epi + meta, NA	The water column zone where the sample was collected. The zone may be "NA" if W_depth_min_m and W_depth_max_m information was provided.
W_depth_min_m	Meters	Minimum water parameter sampling depth if the depth was variable over time. For discrete samples, this will be the same value as the maximum.
W_depth_max_m	Meters	Maximum water parameter sampling depth if the depth was variable over time. For discrete samples, this will be the same value as the minimum.
zooplankton_abundance.csv		
zoop_sampler_type	Tube or discrete sampler, vertical net, pump sampler, bucket, Clark-Bumpus, Schindler-Patalas trap, horizontal net	The type of zooplankton sampler that was used
zoop_mesh_um	Micrometers	The mesh size in micrometers of the zooplankton net or sieve used to concentrate the samples
zoop_net_mouth_area_cm2	Centimeters squared	The area of the zooplankton net mouth used to collect samples in centimeters squared
zoop_liter_collected	Liters	Number of liters collected if a net was not used
Subsampled	Yes, no	If subsampling was typically used during sample processing
subsample_min		If subsampling was used, the amount of the sample counted to stop subsampling as either the percent of the sample or the minimum number of organisms processed (e.g., 10%, 200 organisms)
zoop_discrete_or_int	Discrete or integrated	Categorical zooplankton sampling method
zoop_zone	Whole water column, surface, epi, meta, hypo, euphotic zone, horizontal, NA	The depth zone where the sample was collected. The zone may be "NA" if zoop_depth_min_m and zoop_depth_max_m information was provided.
zoop_num_sample		Number of samples collected during the sampling event. A value >1 indicates additional zooplankton data for this sampling event collected at a different sampling depth in this table.
zoop_depth_min_m	Meters	Minimum zooplankton sampling depth. This will be the same value as the maximum for discrete samples.
zoop_depth_max_m	Meters	Maximum zooplankton sampling depth. This will be the same value as the minimum for discrete samples.

"stationid.csv," which will help users interpret the sampling location and how it relates to water column sampling depths. Future users should also note that "waterbodies.csv" includes other important information to consider before using the data, such as dataset and waterbody descriptions (e.g., if the waterbody has multiple basins).

ZIG may also be used for temporal analysis of waterbodies with adequate time series data. However, for this type of analysis, we recommend caution when selecting and using a subset of the data. First, for some waterbodies, there may be changes in sampling methods over time within a sampling program, including changes in sampling locations, zooplankton collection equipment and methods, or the reported water physical and chemical characteristics. These can include changes in the sampling station location or multiple sampling stations within a single waterbody and different stations sampled for water chemistry vs. zooplankton communities. Second, water physical, chemical, and zooplankton community data were not always sampled on the same date within a waterbody (i.e., water chemistry sampled one to several days before/after zooplankton sampling was done in some instances) or at the same station_id. However, information regarding sampling station(s), sampling dates, sampling methods, and sampled depths for water chemistry and zooplankton are documented in the corresponding water physical, chemical, and zooplankton abundance files. Despite this limitation, future users are encouraged to report exactly how they matched zooplankton community data with physical and chemical data to ensure reproducibility across studies. Finally, future users of the ZIG dataset should be aware of the variability in the level of taxonomic detail during zooplankton sample processing (e.g., some have identification to group or species level, some to species level for only cladocerans). The level of taxonomic detail may also change across time within a single waterbody along with changes in personnel, as documented in the "zooplankton_abundance.csv" file of the dataset.

ZIG is not intended or designed to be a dynamic dataset with continuous, automated updates. However, end users can use the ZIG data and metadata structures to easily integrate additional data into ZIG for further analyses. We also encourage publishing additional data to EDI, or another open data repository, in the ZIG format to further expand the usability of the dataset into the future. This will empower inclusion of updated time series as well as new sampling locations for future users.

Comparison with existing datasets

To our knowledge, the ZIG dataset is the most comprehensive, globally expansive dataset of inland zooplankton communities to date. The data included in ZIG have been aggregated and quality-controlled to ensure internal consistency and comprehensive metadata and to allow for future integration of new zooplankton data. In addition, the spatial and temporal coverage of the ZIG dataset, as well as the inclusion of co-located and contemporaneous limnological measurements, set it apart from existing published lake zooplankton datasets that are often snapshot samples spanning local to national scales (e.g., US EPA NLA—Pollard et al. 2018; Canada Lake Pulse—Huot et al. 2019; and Lakes380—lakes380.com). For comparison, the Coastal and Oceanic Plankton Ecology, Production and Observation Database (COPEPOD—O'Brien 2010) is a harmonized compendium of marine zooplankton community composition intended to assess zooplankton community change over space and time (https://www.st.nmfs.noaa.gov/copepod/). Like ZIG, COPEPOD includes extensive metadata validation to ensure that data presented to end users are of the highest quality, especially considering that COPEPOD likewise relies on expansive, crowdsourced data sharing contributions. Even within lake zooplankton community time series, ZIG's data content and taxonomic details are notable, as many of the included time series extend beyond crustacean abundance and include rotifers (66% of waterbodies), thereby enabling investigation of non-crustacean zooplankton responses to limnological variation as well.

Author Contributions

Stephanie E. Figary, Michael F. Meyer, Rachel M. Pilla, Warren J. S. Currie led the project. Stephanie E. Figary, Michael F. Meyer, Rachel M. Pilla, Rosalie Bruel, Alicia Cortés, Zeynep Ersoy, Shuqi Lin, Shin-ichiro S. Matsuzaki, Maria Cintia Piccolo, Silva M. Sundberg, Celia C. Symons attended in person conceptualization meetings. Stephanie E. Figary, Warren J. S. Currie, Javier Alcocer, María Belén Alfonso, Caitlin M. Andrews, Orlane Anneville, Ana M. Antão-Geraldes, Shelley E. Arnott, Syuhei Ban, Arnab Banerjee, Gábor Bernát, Jessica E. Beyer, Kätlin Blank, Kelly L. Bowen, Christer Brönmark, Sarah H. Burnet, Cayelan C. Carey, Rossana Caroni, Moitreyee Chakrabarty, Sudeep Chandra, Kirsten S. Christoffersen, Alicia Cortés, Maria Cristina Crispim, Elvira de Eyto, Luciana De Souza Cardoso, Bridget R. Deemer, Curtis L. DeGasperi, Jianming Deng, Jean-Pierre Descy, Inta Dimante-Deimantovica, Nadia Diovisalvi, Renata Dondajewska-Pielka, Jonathan P. Doubek, Tvrtko Dražina, Hilary A. Dugan, Zorka Dulić, Ashley A. Dunker, Gaël Dur, Brie A. Edwards, Jolanta E. Ejsmont-Karabin, Rocio Fernandez, Heidrun Feuchtmayr, Maria Soledad Fontanarrosa, Elena Forasacco, László G.-Tóth, Evelyn E. Gaiser, Gideon Gal, Anita Galir, Javier R. Garcia de Souza, Scott F. Girdner, Ryszard Goldyn, K. David Hambright, David P. Hamilton, Lars-Anders Hansson, Susan P. Hendricks, Huihuang Chen, Pascal M. Isumbisho, Stéphan Jacquet, Jun Yang, Martin J. Kainz, Maciej Karpowicz, Samiullah Khan, Katarzyna Kowalczewska-Madura, Natalia Kuczyńska-Kippen, Silke Langenheder, Barbara Leoni, Fabio Lepori, Arni H. Litt, Eleanor B. Mackay, Marina M. Manca, Blake Matthews, Linda May, Yvonne R. McElarney, Rosemberg F. Menezes, Ewa Merz, Evangelia Michaloudi, S. Jannicke Moe, Dörthe C Müller-Navarra, Veronica Nava, Jens C. Nejstgaard, Ulrike Obertegger, Luis A. Oseguera, Michael J. Paterson, Maria Cintia Piccolo, Roberta Piscia, Francesco Pomati, Serena Rasconi, Brian L. Reid, Leonardo L. Ribeiro, Florencia M. Rojas Molina, Joanna Rosińska, Lars G Rudstam, James A. Rusak, Olga O. Rusanovskaya, Nico Salmaso, Jouko Sarvala, S. Geoffrey Schladow, Anne E. Scofield, Facundo Scordo, Jaromír Sed'a, Katie J. Senft, Svetlana V. Shimaraeva, Eugene A. Silow, Maria Špoljar, Dietmar Straile, Jon N. Sweetman, Celia C. Symons, Andrew J. Tanentzap, Barbara Tartarotti, Stephen J. Thackeray, Jan-Erik Thrane, Maxim A. Timofeyev, Jörg Tittel, Pablo Urrutia-Cordero, Piet Verburg, Danielle Machado Vieira, Heather L. Wander, Shohei Watanabe, James M. Watkins, David S. White, Sabine Wollrab, Horacio E. Zagarese, Matiss Zagars, Petr Znachor contributed data. Stephanie E. Figary, Michael F. Meyer, Rachel M. Pilla, Javier Alcocer, Ana M. Antão-Geraldes, Jessica E. Beyer, Rosalie Bruel, Tyler J. Butts, Braden C. DeMattei, Mariam Elmarsafy, Sarah D. Lawhun, Christopher J. McLimans, Evangelia Michaloudi, Manuel E. Muñoz-Colmenares, Kayden C. Nasworthy, Ulrike Obertegger, David A. Ortiz, Lorena Pinheiro-Silva, Anna G. Schmidt, Anne E. Scofield, Kirill Shchapov, Silva M. Sundberg, Celia C. Symons, Andrew J. Tanentzap, Vivian Yorojo Moreno harmonized datasets for compiling into ZIG. Stephanie E. Figary, Michael F. Meyer, Rachel M. Pilla, Ana M. Antão-Geraldes, Rosalie Bruel, Inta Dimante-Deimantovica, Zorka Dulić, Brie A. Edwards, Heidrun Feuchtmayr, Fabio Lepori, Lorena Pinheiro-Silva, Facundo Scordo, Dietmar Straile, Silva M. Sundberg, Barbara Tartarotti compiled data into the ZIG dataset. Stephanie E. Figary, Michael F. Meyer, Rachel M. Pilla, Warren J. S. Currie, Javier Alcocer, Braden C. DeMattei, Shuqi Lin, Rosemberg F. Menezes, Dörthe C Müller-Navarra, Lorena Pinheiro-Silva, James A. Rusak, Olga O. Rusanovskaya, Anna G. Schmidt, Svetlana V. Shimaraeva, Eugene A. Silow, Maxim A. Timofeyev, David S. White, Sabine Wollrab contributed to writing the original manuscript. All authors provided edits and approved of the final manuscript.

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Conflicts of Interest

None declared.

Data Availability Statement

Data are publicly available in the Environmental Data Initiative repository at https://doi.org/10.6073/pasta/a3b54599e2066b04819df04a24dc9e34.

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Supporting Information

Additional Supporting Information may be found in the online version of this article.

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