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## **RivFishTIME: A global database of fish time-series to study global change ecology in riverine systems**

Lise Comte, Juan Carvajal-Quintero, Pablo A Tedesco, Xingli Giam, Ulrich Brose, Tibor Erős, Ana F Filipe, Marie-josée Fortin, Katie Irving, Claire Jacquet, et al.

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1 **DATA PAPER**

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3 **RivFishTIME: A global database of fish time-series to study global change**  
4 **ecology in riverine systems**

5

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7 **Running title:** Time-series database of riverine fish communities

8

9 Lise Comte<sup>1,\*</sup>, Juan Carvajal-Quintero<sup>2,3</sup>, Pablo A. Tedesco<sup>2</sup>, Xingli Giam<sup>1</sup>, Ulrich Brose<sup>4,5</sup>, Tibor  
10 Erős<sup>6</sup>, Ana Filipa Filipe<sup>7,8</sup>, Marie-Josée Fortin<sup>9</sup>, Katie Irving<sup>10,11</sup>, Claire Jacquet<sup>12,13</sup>, Stefano  
11 Larsen<sup>14,15</sup>, Sapna Sharma<sup>16</sup>, Albert Ruhi<sup>17</sup>, Fernando G. Becker<sup>18</sup>, Lilian Casatti<sup>19</sup>, Giuseppe  
12 Castaldelli<sup>20</sup>, Renato B. Dala-Corte<sup>21</sup>, Stephen R. Davenport<sup>22</sup>, Nathan R. Franssen<sup>23</sup>, Emili García-  
13 Berthou<sup>24</sup>, Anna Gavioli<sup>20</sup>, Keith B. Gido<sup>25</sup>, Luz Jimenez-Segura<sup>26</sup>, Rafael P. Leitão<sup>27</sup>, Bill  
14 McLarney<sup>28</sup>, Jason Meador<sup>28</sup>, Marco Milardi<sup>29</sup>, David B. Moffatt<sup>30</sup>, Thiago V. T. Occhi<sup>31</sup>, Paulo S.  
15 Pompeu<sup>32</sup>, David L. Propst<sup>33</sup>, Mark Pyron<sup>34</sup>, Gilberto N. Salvador<sup>35</sup>, Jerome A. Stefferud<sup>36</sup>, Tapio  
16 Sutela<sup>37</sup>, Christopher Taylor<sup>38</sup>, Akira Terui<sup>39</sup>, Hirokazu Urabe<sup>40</sup>, Teppo Vehanen<sup>37</sup>, Jean R. S.  
17 Vitule<sup>41</sup>, Jaqueline O. Zeni<sup>19,42</sup>, Julian D. Olden<sup>43</sup>

18

19 <sup>1</sup>Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, Knoxville,  
20 TN 37996, USA

21 <sup>2</sup>Research Unit 5174, Laboratoire Evolution et Diversité Biologique, CNRS, Institut de Recherche  
22 pour le Développement, Université Paul Sabatier, F-31062 Toulouse, France

23 <sup>3</sup>Laboratorio de Macroecología Evolutiva, Red de Biología Evolutiva, Instituto de Ecología, A.C., El  
24 Haya, 91070 Xalapa, Veracruz, Mexico

25 <sup>4</sup>German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, 04103 Leipzig,  
26 Germany

27 <sup>5</sup>Institute of Biodiversity, Friedrich-Schiller-University Jena, 07743 Jena, Germany

28 <sup>6</sup>Centre for Ecological Research, Balaton Limnological Institute, Klebelsberg K. u. 3. 8237 Tihany,  
29 Hungary

30 <sup>7</sup>CIBIO/InBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos da Universidade do  
31 Porto, 4485-661 Vairão, Portugal

32 <sup>8</sup>Instituto Superior de Agronomia, Universidade de Lisboa, 1349-017 Lisboa, Portugal

33 <sup>9</sup>Department of Ecology and Evolutionary Biology, University of Toronto, Toronto, Ontario, M5S  
34 3B2, Canada

35 <sup>10</sup>Department of Ecosystem Research, Leibniz Institute of Freshwater Ecology and Inland Fisheries,  
36 12587 Berlin, Germany

37 <sup>11</sup>Department of Biology, Chemistry and Pharmacy, Freie Universität Berlin, 14195 Berlin, Germany

38 <sup>12</sup>Department of Aquatic Ecology, Swiss Federal Institute of Aquatic Science and Technology,  
39 Eawag, Dübendorf, Switzerland

40 <sup>13</sup>Department of Evolutionary Biology and Environmental Studies, University of Zurich, Zürich,  
41 Switzerland

42 <sup>14</sup>Department of Civil, Environmental and Mechanical Engineering, University of Trento, Trento,  
43 Italy

44 <sup>15</sup>Computational Biology Unit, Research and Innovation Centre, Fondazione Edmund Mach, San  
45 Michele all'Adige, Italy

46 <sup>16</sup>Department of Biology, York University, 4700 Keele Street, Toronto, Ontario, M3J 1P3, Canada

47 <sup>17</sup>Department of Environmental Science, Policy, and Management, University of California,  
48 Berkeley, Berkeley, CA 94720, USA

49 <sup>18</sup>Department of Ecology, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil

50 <sup>19</sup>Department of Zoology and Botany, UNESP – São Paulo State University, São José do Rio Preto,  
51 SP, Brazil

52 <sup>20</sup> Department of Life Sciences and Biotechnology, University of Ferrara, via Luigi Borsari 46,  
53 44121 Ferrara, Italy

54 <sup>21</sup>Department of Ecology, Universidade Federal de Goiás, Goiânia, GO, Brazil

55 <sup>22</sup>New Mexico Fish and Wildlife Conservation Office, 3800 Commons NE, Albuquerque, NM  
56 87109, USA

57 <sup>23</sup>U.S. Fish and Wildlife Service, 2105 Osuna Rd NE, Albuquerque, NM 87113, USA

58 <sup>24</sup>GRECO, Institute of Aquatic Ecology, University of Girona, 17003 Girona, Catalonia, Spain

59 <sup>25</sup>Division of Biology, Kansas State University, Manhattan, KS 66506, USA

60 <sup>26</sup>Instituto de Biologia, Universidad de Antioquia, Calle 67 No.53-108 Medellin, Colombia

61 <sup>27</sup>Laboratório de Ecologia de Peixes, Department of Genetics, Ecology and Evolution, Federal  
62 University of Minas Gerais (UFMG), 31270-901, Belo Horizonte, MG, Brazil

63 <sup>28</sup>Mainspring Conservation Trust, Franklin, NC 28734, USA

64 <sup>29</sup>Fisheries New Zealand - Tini a Tangaroa, Ministry for Primary Industries - Manatū Ahu Matua, 34-  
65 38 Bowen Street, Pipitea 6011, Wellington, New Zealand

66 <sup>30</sup>Department of Environment and Science, Ecosciences Precinct, Dutton Park QLD 4102, Australia

67 <sup>31</sup>Department of Ecology and Conservation, Federal University of Paraná, Jardim das Américas,  
68 81530-900 Curitiba, Brazil

69 <sup>32</sup>Department of Ecology and Conservation, University of Lavras (UFLA), 37200-900 Lavras, MG,  
70 Brazil

71 <sup>33</sup>Department of Biology, Museum of Southwestern Biology, University of New Mexico,  
72 Albuquerque, NM 87131, USA

73 <sup>34</sup>Department of Biology, Ball State University, Muncie, IN 47306, USA

74 <sup>35</sup>Ecology and Conservation Laboratory (LABECO), Federal University of Pará (UFPA), 66075-110,  
75 Belém, PA, Brazil

76 <sup>36</sup>USDA Forest Service (Retired), Phoenix, AR 85012, USA

77 <sup>37</sup>Natural Resources Institute Finland, Latokartanonkaari 9, 00790 Helsinki, Finland

78 <sup>38</sup>Department of Biology and School of Earth, Environmental, and Marine Sciences, University of  
79 Texas Rio Grande Valley, Edinburg, TX 78539, USA

80 <sup>39</sup>Department of Biology, University of North Carolina at Greensboro, Greensboro, NC 27412, USA

81 <sup>40</sup>Salmon and Freshwater Fisheries Research Institute, Hokkaido Research Organization, Eniwa,  
82 Hokkaido, Japan

83 <sup>41</sup>Department of Environmental Engineering, Federal University of Paraná, Curitiba, Jardim das  
84 Américas, 81530-900, Brazil

85 <sup>42</sup>Department of Ecology, UNESP – São Paulo State University, Rio Claro, SP, Brazil

86 <sup>43</sup>School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA 98105, USA

87

88 \* **Corresponding author:** Lise Comte, Department of Ecology and Evolutionary Biology, The

89 University of Tennessee, Knoxville, TN, USA

90 [lgcomte@gmail.com](mailto:lgcomte@gmail.com)

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92 **Running title:** Time-series database of riverine fish communities

93

94 **ABSTRACT**

95 **Motivation:** We compiled a global database of long-term riverine fish surveys from 46 regional  
96 and national monitoring programs as well as individual academic research efforts upon which  
97 numerous basic and applied questions in ecology and global change research can be explored.  
98 Such spatially- and temporally-extensive datasets have been lacking for freshwater systems  
99 compared to terrestrial ones.

100 **Main types of variables contained:** The database includes 11,386 time-series of riverine fish  
101 community catch data, including 646,270 species-specific abundance records together with  
102 metadata related to geographic location and sampling methodology of each time-series.

103 **Spatial location and grain:** The database contains 11,072 unique sampling locations (stream  
104 reach), spanning 19 countries, 5 biogeographic realms, and 402 hydrographic basins worldwide.

105 **Time period and grain:** The database encompasses the period 1951–2019. Each time-series is  
106 composed of a minimum of two yearly surveys (mean = 8 years) and represents a minimum time  
107 span of 10 years (mean = 19 years).

108 **Major taxa and level of measurement:** The database includes 944 species of ray-finned fishes  
109 (Class Actinopterygii).

110 **Software format:** .csv

111 **Main conclusion:** Our collective effort provides the most comprehensive long-term community  
112 database of riverine fishes to date. This unique database should interest ecologists who seek to  
113 understand the impacts of human activities on riverine fish biodiversity, and model and predict



114 how fish communities will respond to future environmental change. Together, we hope it will  
115 promote advances in macroecological research in the freshwater realm.

116 **KEYWORDS:** species abundance; biodiversity; conservation; freshwater streams and rivers;  
117 Actinopterygii; temporal trends; worldwide

## 118 1| INTRODUCTION

119 Increasing awareness of the ongoing biodiversity crisis has motivated global initiatives to  
120 compile large-scale datasets of population and community abundance records that have been  
121 consistently sampled through recent times (Pereira & Cooper, 2006). Included among these are  
122 the Global Population Dynamics Database (Inchausti & Halley, 2001), the Living Planet Index  
123 database (Loh *et al.*, 2005), and more recently, the BioTIME database (Dornelas *et al.*, 2018).  
124 These databases have proven extremely useful and allowed major advancements in ecological  
125 research (e.g. Kendall *et al.*, 1998; Sibly *et al.*, 2005; Butchart *et al.*, 2010; Dornelas *et al.*,  
126 2014); however, they remain highly biased towards terrestrial and marine assemblages (e.g. only  
127 0.50% of the records concern riverine fishes in BioTIME, the most recent of these initiatives).  
128 This is unfortunate as effective strategic plans for conserving water resources that support human  
129 well-being and ecosystem integrity rely on access to comprehensive, pertinent, quantitative  
130 information regarding the status and trends of riverine biodiversity over regional to continental  
131 scales (Tickner *et al.*, 2020).

132 Long-term studies of riverine species are limited because they require highly specialized  
133 and time-consuming sampling methods. Furthermore, rivers in remote areas are often difficult to  
134 access (Olden *et al.*, 2010; Radinger *et al.*, 2019). Nevertheless, over the past few decades, large-  
135 scale policies have been enacted in response to the rapid degradation of freshwater resources,  
136 such as the Water Framework Directive in the EU (Hering *et al.*, 2004) and the Clean Water Act  
137 in the USA (Paulsen *et al.*, 2008), which require countries to monitor and evaluate the biological  
138 integrity of surface waters through time to adopt quality standards that restore and maintain  
139 ecological integrity (Kuehne *et al.*, 2017). Beyond these official national and regional monitoring  
140 programs, the temporal dynamics of riverine systems and their fish communities have also been

141 assessed through various independent, though often local in extent, academic research programs  
142 (e.g. Gido, 2017; Matthews & Matthews, 2017). All of these institutional and academic  
143 monitoring efforts have produced considerable freshwater fish temporal data that remain largely  
144 inaccessible to the broader scientific community due to the inherent difficulty in gathering and  
145 harmonizing field data from disparate institutions and sampling protocols (Buss *et al.*, 2015).

146 To fill this important gap, we here present RivFishTIME, a compiled and curated  
147 database of long-term ( $\geq 10$  years) surveys of riverine fish communities at a fine spatial (stream  
148 reach) and taxonomic (species) resolution, using data mining approaches to harmonize existing  
149 but currently fragmented biomonitoring data sets. Riverine fish are extremely diverse in spite of  
150 the small surface they inhabit on Earth: they represent about 40% of all known fish species while  
151 occupying  $<1\%$  of available aquatic habitat (“the freshwater fish paradox” sensu Lévêque *et al.*,  
152 2008 and Tedesco *et al.*, 2017). However, they are also among the most threatened taxonomic  
153 groups on Earth because of the convergence between the high concentration of biodiversity and  
154 the many pressures resulting from human uses of freshwater resources and habitat change (Reid  
155 *et al.*, 2019; Tickner *et al.*, 2020). The RivFishTIME database provides a unique opportunity to  
156 understand the rate, magnitude, and geography of biodiversity trends, and to identify  
157 opportunities to mitigate human impacts on riverine systems (Pereira & Cooper, 2006; Anderson,  
158 2018). Due to the paucity of spatially- and temporally-extensive datasets in freshwater compared  
159 to terrestrial systems (Heino, 2011), RivFishTIME should also help ecologists close the gap  
160 between these two systems and to address a wider range of taxa in unraveling large-scale spatio-  
161 temporal biodiversity patterns.

162

## 163 **2| METHODS**

164 **2.1| Data acquisition**

165 We gathered time-series of fish community abundance data for riverine (lotic) ecosystems,  
166 broadly defined as freshwater bodies that are continually or intermittently flowing. We tried to  
167 the extent possible to exclude wetlands and brackish habitats (salinity > 0.5 ‰). Note, however,  
168 that due to the complex nature of the datasets, we do not guarantee that sites are located on free-  
169 flowing river segments (i.e. natural condition without impoundment, diversion, or other  
170 modification of the waterway). We used the following criteria for data inclusion: (1) the location  
171 of the sampling sites is known and consistent through time, (2) the sampling protocol is known  
172 and consistent through time, (3) the sampling survey sought to quantify all species in the fish  
173 community according to well-established protocols, (4) species-specific abundances are available  
174 for each survey, (5) surveys at a given site were conducted over a period of at least 10 years, and  
175 (6) at least two yearly surveys with non-null abundance are available. We considered abundance  
176 measures derived from direct fish counts, catch-effort indexes such as relative abundances (%)  
177 and catch per unit effort (CPUE), abundance classes, as well as statistically estimated  
178 abundances (e.g. Leslie method; Ricker, 1975).

179 To identify potential datasets, we used Google Search, Google Scholar and Dataset  
180 Search with different combinations of the keywords “time series”, “fish”, “abundance”,  
181 “stream”, “river”, “freshwater”, “community”, “temporal”, and “monitoring” or “monitoring  
182 program”. We screened the scientific as well as the grey literature to identify studies involving  
183 temporal datasets of fish communities and conducted similar searches in data repositories such as  
184 Dryad (<https://datadryad.org/stash>) and FigShare (<https://figshare.com/>). We also conducted  
185 targeted searches for national and regional monitoring programs by adding country names to the

186 previous keywords. For the European Union, we further used the EuMon database as a reference  
187 to identify fish monitoring databases (available at [http://eumon.ckff.si/about\\_daeumon.php](http://eumon.ckff.si/about_daeumon.php)).

188 We contacted all the authors and monitoring program coordinators to request and obtain  
189 permission to publish the data and/or ensure that the license under which the data were publicly  
190 released allowed their inclusion in our global effort (e.g. Open Government License, CC0 1.0  
191 Universal). We excluded the datasets for which we did not receive permission, unless the  
192 reusability of data was clearly stated on the online repositories where the data were released.

193

## 194 2.2| Quality control

195 *Taxonomy.* We validated species scientific names using the online database Fishbase (Froese &  
196 Pauly, 2019). We used the R package *rfishbase* (as of December 2019; Boettiger *et al.*, 2012)  
197 and confirmed names with no match manually using the Catalog of Fishes (Fricke *et al.*, 2018).  
198 We then selected only records involving ray-finned fishes (Class Actinopterygii), excluding rays  
199 and lampreys, and unidentified species.

200 *Coordinates.* We harmonized the coordinate system by projecting (if necessary) the  
201 coordinates of the individual datasets using the World Geodetic System (WGS84) as reference  
202 geographic coordinate system. We visually inspected the spatial distribution of the sites with  
203 respect to their respective country, region, or state borders as given in the original data sources  
204 and discarded sites with dubious coordinates (e.g. sites located in the ocean). We also removed  
205 sites whose coordinates were located outside of any hydrographic basin using the global major  
206 river basin GIS layer in HydroSHEDS (Lehner *et al.*, 2008).

207

208 *Consistent sampling methods.* We excluded surveys lacking information on sampling  
209 methods and selected only time-series collected using a consistent sampling protocol through  
210 time. The latter evaluation was dataset-specific as dictated by the complexity of the monitoring  
211 scheme and the available metadata. For instance, surveys were deemed consistent if they did not  
212 experience any major deviation in sampling protocol, and disregarded minor variations (e.g.  
213 number of anodes or traps, area sampled) due to survey-specific constraints (e.g. water depth,  
214 habitat complexity). By contrast, several monitoring programs implemented alternate sampling  
215 protocols to compare the efficiency of different gears (e.g. seining versus electrofishing) or  
216 sampling methods (e.g. continuous versus point electrofishing); these time-series conducted at  
217 the same sites but using different sampling protocols were kept separate in the database.

218

219 *Duplicates.* We removed duplicates within individual datasets based on the coordinates of the  
220 sites, date of the survey, and species collected (e.g. due to different name attribution for the same  
221 site). We also identified potential duplicates among datasets (e.g. overlap between state-level and  
222 national databases) based on the coordinates of the sites rounded to three digits to account for  
223 different post-processing of the individual datasets.

224

### 225 **2.3| Database formatting**

226 Each entry (species abundance record) was assigned a unique (1) site, (2) survey, and (3) time-  
227 series identifier. The site ID corresponds to a given pair of coordinates, the survey ID to a  
228 sampling campaign, and the time-series ID to a combination of site  $\times$  sampling protocol. We

229 extracted the names of the sampled water bodies (e.g. creek, stream, river) from the available  
230 metadata associated with each individual dataset, that we cross-referenced against several  
231 continental and national geospatial river networks in GIS (e.g. Australian Hydrological  
232 Geospatial Fabric, Ordnance Survey Open Rivers). Additionally, each site ID was assigned to a  
233 biogeographic realm following Olson *et al.* (2001), hydrographic basin following HydroSheds  
234 (Lehner *et al.*, 2008), and administrative units (country, region and province) based on its  
235 coordinates. For each sampling ID, we aggregated abundance records if they were given  
236 separately for individuals, size classes or sub-species for each validated species name or if  
237 different sampling passes, hauls, or sub-sampling areas were considered. We also converted  
238 time-series species abundances to densities or CPUE whenever possible. The different surveys  
239 were kept independent when conducted on different occasions within the same calendar year. We  
240 provided the year together with the quarter of the survey (1: January-March; 2: April-June; 3:  
241 July-September, 4: October-December). We also provided the associated unit (abundance class,  
242 count, CPUE, individuals/100m<sup>2</sup>, Leslie index, relative abundance) for each species abundance  
243 record. Finally, we extracted basic information regarding the sampling protocol, including details  
244 on electrofishing (backpack, shore-based or boat mounted electrofishers), netting (dip nets, gill  
245 nets, beach or pelagic seines), trapping (minnow traps, fyke nets or hoop nets), and trawling  
246 techniques. Many survey protocols involve a combination of sampling approaches, rendering  
247 challenging the inclusion of detailed information about the sampling effort in a standardized  
248 way. We therefore encourage the data user to refer to each data source for more information on  
249 the sampling methods.

250           The database is organized in three tables (.csv format): the time-series table, the survey  
251 table, and the information source table. The tables can be linked using the unique dataset source

252 ID and time-series ID. The time-series table contains: (1) source ID, (2) site ID, (3) time-series  
253 ID, (4) sampling method, (5) latitude (WGS 84), (6) longitude (WGS 84), (7) biogeographic  
254 realm, (8) hydrographic basin, (9) country (ISO code), (10) region, (11) province, and (12) water  
255 body. The survey table contains: (1) time-series ID, (2) survey ID, (3) sampling year, (4)  
256 sampling quarter, (5) species scientific name, (6) abundance, and (7) abundance unit. The  
257 information source table contains the full citation(s), online link to the raw data when publicly  
258 available, as well as the name(s) and contact of the data responsible(s) for each individual  
259 dataset. Data curation was performed in the *R* (3.6.0) programming environment (R Core Team,  
260 2019).

261 A list of the data sources is found in Appendix 1; for further information consult the  
262 metadata. We provide a static version of the database with this article (1951-2019), but we aim to  
263 continue interacting with data contributors to update and add new time-series datasets to be  
264 released through the iDiv portal (<https://idata.idiv.de/idiv/Content/Databases>) and the more  
265 specialized Freshwater Biodiversity Data Portal (<https://data.freshwaterbiodiversity.eu/>).

266

### 267 **3| RESULTS**

268 Our database includes 11,386 time-series of riverine fish compiled from 46 individual source  
269 datasets, representing a total of 106,785 surveys and 646,270 individual species abundance  
270 records at 11,072 unique sites. Survey-specific species richness across all time-series ranges  
271 from 1 to 50 species, and covers 944 ray-finned fish species. The surveyed sites display a wide  
272 distribution along longitudinal and latitudinal gradients, spanning 19 countries, 402 hydrographic  
273 basins, and 5 biogeographic realms (Fig. 1a). Despite broad geographical coverage, we note a



274 clear spatial bias towards the Palearctic (European Union) and, to a lesser extent, Nearctic (North  
275 America) and Australasia realms. The abundance time-series are largely represented by  
276 individual counts, followed by densities (individuals/100m<sup>2</sup>) and CPUE (Fig. 1b). Abundance  
277 classes, Leslie index and relative abundance represent < 1% of the time-series. Electrofishing is  
278 by far the main sampling technique used to record the time-series, although variations are  
279 noticeable among biogeographic realms (Fig. 1c). For instance, dipnetting sampling techniques  
280 are only represented in the Neotropics, whereas gillnetting is the most common gear in the  
281 Afrotropics.

282         The time-series cover a time period from 1951 to 2019 and are mainly concentrated over  
283 the last two decades (average first year = 1996; Fig. 2a). Surveys have been conducted primarily  
284 in the 3rd (July-September) and 4th (October-December) quarters of the year, especially in the  
285 Palearctic and Nearctic realms (corresponding to periods of low flows), but all quarters are  
286 represented in the different biogeographic realms (Fig. 2b). The mean time span of the time-  
287 series is of 19 years and ranges from 10 to 68 years, with the longest time-series located in the  
288 Palearctic (Fig. 2c). The sites were sampled from (non-necessarily consecutive) 2 to 52 years,  
289 with an average number of yearly surveys of 8 years (Fig 2d). Again, the highest number of  
290 yearly surveys was found in the Palearctic. The completeness of the time-series (i.e. ratio of  
291 number of yearly surveys to the overall time span) ranges from 4 to 100%, with a mean value of  
292 45% (Figure 2e). Importantly, the degree of completeness is largely uncorrelated to the time span  
293 of the time-series ( $r = 0.05$ ).

294

## 295 4| CONCLUSIONS

296 Our collective effort provides the most comprehensive long-term community database of riverine  
297 fishes to date, spanning large biogeographic, climatic and hydrographic gradients. Almost all  
298 biogeographic realms are represented but it is important to note that our database is not exempt  
299 from spatial bias. For instance, less than 1% of the time-series belong to the Afrotropic or  
300 Neotropic realms, whereas 84% belong to the Palearctic realm. These spatial gaps often present  
301 in biodiversity-rich regions (tropical areas, southeast Asia) are likely to mirror the current  
302 networks of freshwater monitoring programs (Buss *et al.*, 2015; Radinger *et al.*, 2019) as well as  
303 biodiversity research efforts (Martin *et al.*, 2012), and hence will be prioritized in future updates  
304 of RivFishTIME. We also warn data users that species abundance may not be directly  
305 comparable across sites without a full understanding of the specifics of sampling approach and  
306 effort, with respect to their selectivity and efficiency (Goffaux *et al.*, 2005; Portt *et al.*, 2006;  
307 Oliveira *et al.*, 2014; Benejam *et al.*, 2012), and refer to the original data sources for more  
308 information about the sampling protocols.

309         Despite these unavoidable limitations associated with secondary datasets collected for  
310 multiple purposes, we are confident that RivFishTIME will stimulate new research in the fields  
311 of global change ecology and macroecology. First and foremost, it will provide the needed  
312 baseline information for conservation and restoration efforts to bend the curve of freshwater  
313 biodiversity loss (Tickner *et al.*, 2020). For instance, the fish abundance time-series could be  
314 used to assess population or community trends in different rivers of the world, broadening the  
315 taxonomic and spatial representation of existing indicators of the status of global biodiversity  
316 (e.g. Living Planet Index). Coupled with high-resolution environmental time-series, this unique  
317 database could also help to decipher the underlying drivers of biodiversity changes in riverine  
318 systems, including (but not limited to) habitat fragmentation and destruction, invasive species,

319 pollution, hydrologic alteration and climate change (e.g. Chen & Olden, 2020, Erős *et al.*, 2020).  
320 In turn, this knowledge could be integrated into ecological models used to forecast how fish  
321 communities will respond to future environmental change, paving the way to mitigate those  
322 impacts. RivFishTIME could also offer new macroecological insights into the implications of  
323 river network complexity on community structure and assembly processes across extensive  
324 environmental gradients (e.g. community composition, population persistence, spatial synchrony  
325 in community dynamics) – questions that have long fascinated ecologists but have been so far  
326 primarily explored through theoretical approaches.

327

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427

## 428 **Data Storage and Documentation**

429 We provide a temporary link to the database at <https://figshare.com/s/97c447c4f16d92baf254>

430 (confidential; for review purposes only). The database and associated DOI will be made publicly  
431 available through the iDiv portal (<https://idata.idiv.de/idiv/Content/Databases>) upon publication.

432

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486

#### 487 **DATA AVAILABILITY**

488 RivFishTIME is publicly available through the iDiv Biodiversity Portal:

489 <https://doi.org/10.25829/ividiv.1873-10-4000>. We kindly ask the users to cite this paper as well as

490 the source of each primary dataset in any published material produced using these data. We

491 encourage any potential data contributor to contact LC with possible datasets to expand the

492 database. Updates of RivFishTIME will be curated through the iDiv Biodiversity Portal and also

493 released through the more specialized Freshwater Biodiversity Data Portal

494 (<https://data.freshwaterbiodiversity.eu/>).

495

#### 496 **BIOSKETCH**

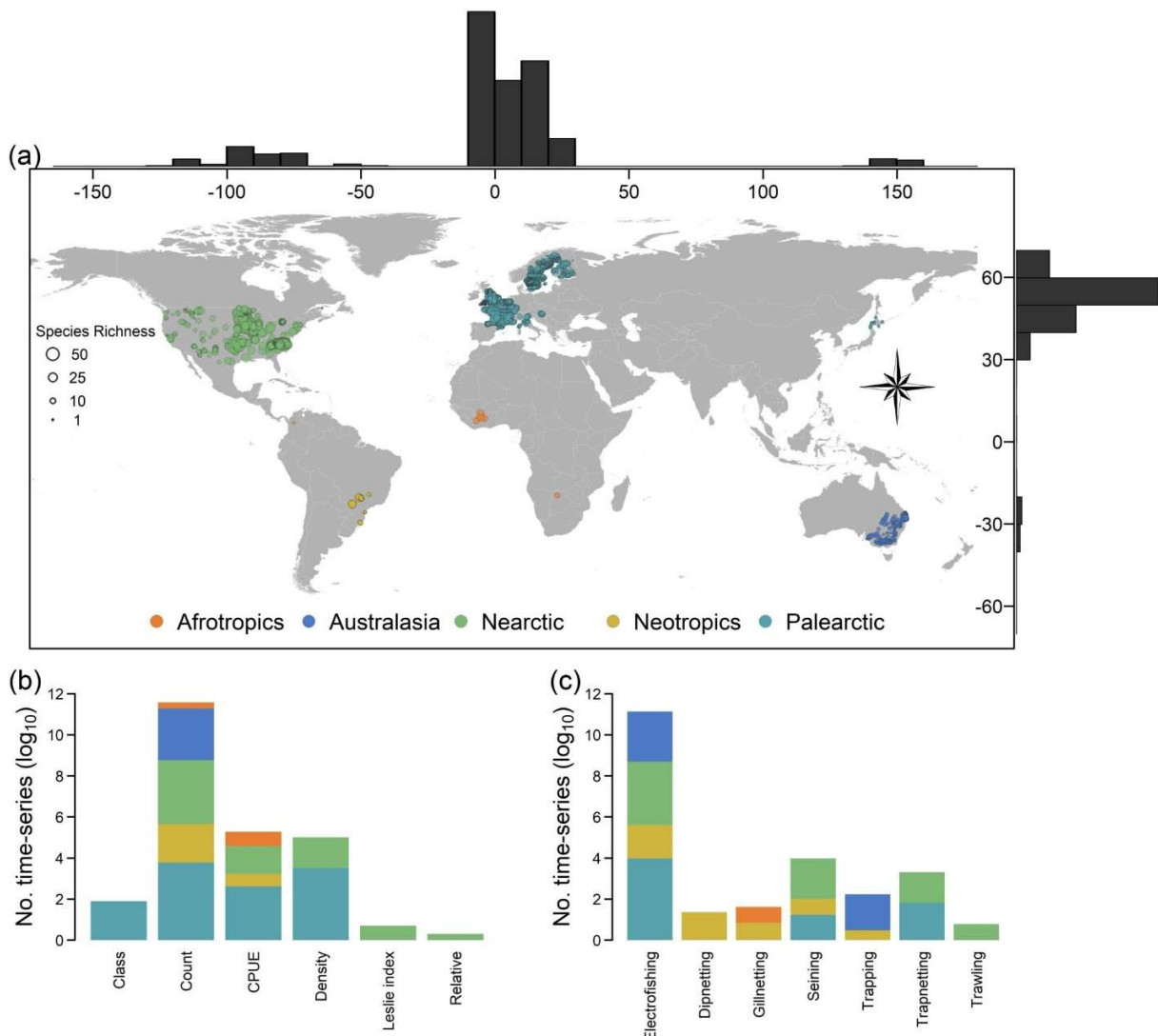
497 Lise Comte is a global change ecologist who is interested in the mechanisms shaping the

498 (re)distribution of biodiversity in an era of global environmental change, with a special emphasis



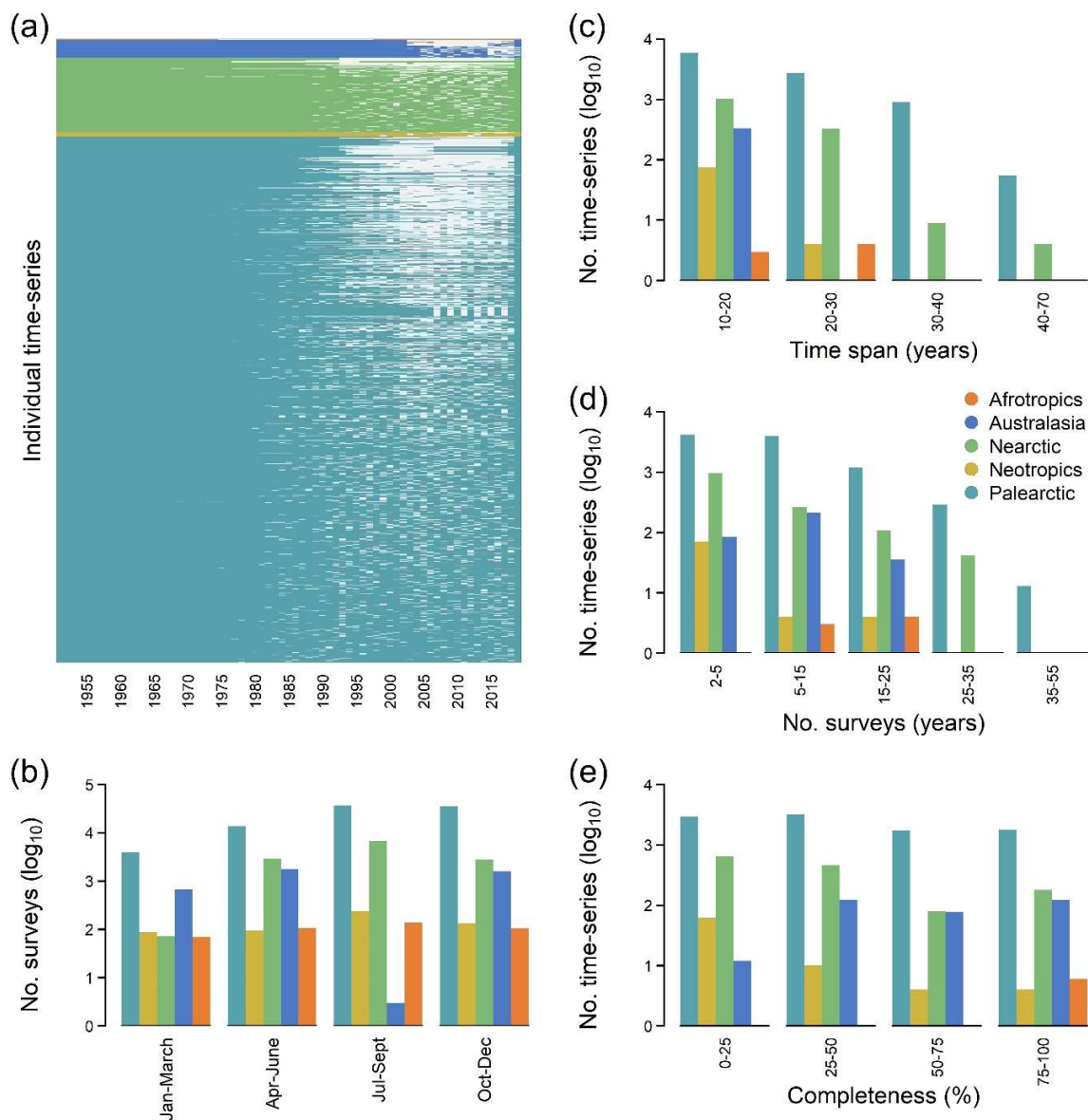
499 on freshwater fish. All co-authors share the common goal of advancing freshwater biodiversity  
500 conservation and hope that RivFishTIME will generate new knowledge to help bend the curve of  
501 global freshwater biodiversity loss.

502



504

505 **Figure 1.** (a) Map showing the distribution of the time-series where each time-series is  
 506 represented by a dot with colors indicating the biogeographic realm and size representing fish  
 507 species richness (averaged across surveys). Inset histograms display the distribution of the time-  
 508 series according to latitude and longitude. Barplots show the distribution of the time-series with  
 509 respect to the (b) type of abundance, and (c) primary sampling method. Note the log<sub>10</sub>(x+1) y-  
 510 axes in (b)-(c).



511

512 **Figure 2.** (a) Temporal distribution of the yearly surveys relative to the period covered by the  
 513 database (1951-2019). Each time-series appears in rows where the background colors correspond  
 514 to the biogeographical realms and white indicates sampled years. (b) Temporal distribution of the  
 515 surveys with respect to the quarter of the year. Temporal characteristics of the time-series with  
 516 respect to the (c) overall time span, (d) number of yearly surveys, and (e) completeness defined  
 517 as the ratio between the number of yearly surveys and the overall time span (expressed in %).  
 518 Note the  $\log_{10}(x+1)$  y-axes in (b)-(e).

## Appendix 1 - Data sources

SourceID	Citations	URLaccess
1	Agència Catalana de l'Aigua (2003); Agència Catalana de l'Aigua (2010); Agència Catalana de l'Aigua (2018)	<a href="http://aca.gencat.cat/">http://aca.gencat.cat/</a>
2	Zeni <i>et al.</i> (2017); Casatti <i>et al.</i> (2009)	–
3	Universidad de Antioquia-Empresas Publicas de Medellin (2019)	–
4	Erős <i>et al.</i> (2014)	–
5	Gammon (2013)	–
6	Ecosystem Health Monitoring Program Queensland (2019)	<a href="https://hlw.org.au/report-card/">https://hlw.org.au/report-card/</a>
7	Finnish electrofishing register Hertta (2019)	<a href="https://wwwp2.ymparisto.fi/koekalastus_sahko/yhteinen/Login.aspx?ReturnUrl=%2fkoekalastus_sahko">https://wwwp2.ymparisto.fi/koekalastus_sahko/yhteinen/Login.aspx?ReturnUrl=%2fkoekalastus_sahko</a>
8	Sigouin (2017)	<a href="https://open.canada.ca/data/en/dataset/fe2441a6-8ae4-4884-b181-cd7ec53bd842">https://open.canada.ca/data/en/dataset/fe2441a6-8ae4-4884-b181-cd7ec53bd842</a>
9	Whitney <i>et al.</i> (2016)	–
10	Gido <i>et al.</i> (2013); Gido <i>et al.</i> (2019)	–
11	Kesner and Marsh (2010)	<a href="https://www.rosemonteis.us/documents/kesner-marsh-2010">https://www.rosemonteis.us/documents/kesner-marsh-2010</a>
12	Griffith (2017); Griffith <i>et al.</i> (2018)	<a href="https://doi.org/10.23719/1376690">https://doi.org/10.23719/1376690</a>
13	Occhi, V. T. & Vitule, J. R. S. (Unpublished data)	–

14	Terui <i>et al.</i> (2018)	–
15	Iowa DNR (2013)	<a href="https://data.iowa.gov/Environment/BioNet/e7yf-f5fs">https://data.iowa.gov/Environment/BioNet/e7yf-f5fs</a>
16	Milardi <i>et al.</i> (2020)	–
17	Levêque <i>et al.</i> (2003)	–
18	Pyron <i>et al.</i> (1998)	–
19	Gido (2017)	<a href="https://doi.org/10.6073/pasta/150e218b069074a8ecede85a7406d43f">https://doi.org/10.6073/pasta/150e218b069074a8ecede85a7406d43f</a>
20	McLarney <i>et al.</i> (2013)	<a href="http://coweeta.uga.edu/dbpublic/personnel_bios.asp?id=wmclarney">http://coweeta.uga.edu/dbpublic/personnel_bios.asp?id=wmclarney</a>
21	Long Term Resource Monitoring Program (2016)	<a href="https://www.umesc.usgs.gov/data_library/fisheries/fish1_query.shtml">https://www.umesc.usgs.gov/data_library/fisheries/fish1_query.shtml</a>
22	Matthews and Marsh-Matthews (2017)	<a href="https://doi.org/10.5061/dryad.2435k">https://doi.org/10.5061/dryad.2435k</a>
23	Murray-Darling Basin Authority (2018)	<a href="https://data.gov.au/data/dataset/murray-darling-basin-fish-and-macroinvertebrate-survey">https://data.gov.au/data/dataset/murray-darling-basin-fish-and-macroinvertebrate-survey</a>
24	Minnesota Pollution Control Agency (2018)	<a href="https://cf.pca.state.mn.us/water/watershedweb/wdip/search_more.cfm?datatype=assessments">https://cf.pca.state.mn.us/water/watershedweb/wdip/search_more.cfm?datatype=assessments</a>
25	Montana, Fish, Wildlife & Parks (2019)	<a href="http://gis-mtftp.opendata.arcgis.com/items/8192e75218c6460ba97ba3dd0a2fb3a5">http://gis-mtftp.opendata.arcgis.com/items/8192e75218c6460ba97ba3dd0a2fb3a5</a>
26	U.S. Geological Survey (2019)	<a href="https://aquatic.biodata.usgs.gov/clearCriteria.action">https://aquatic.biodata.usgs.gov/clearCriteria.action</a>
27	U.K. Environmental Agency (2019)	<a href="https://data.gov.uk/dataset/d129b21c-9e59-4913-91d2-82faef1862dd/nfpd-freshwater-fish-survey-relational-datasets">https://data.gov.uk/dataset/d129b21c-9e59-4913-91d2-82faef1862dd/nfpd-freshwater-fish-survey-relational-datasets</a>

28	North Carolina Department of Environmental Quality (2018)	<a href="https://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/ecosystems-branch/fish-stream-assessment-program">https://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/ecosystems-branch/fish-stream-assessment-program</a>
29	Fagundes <i>et al.</i> (2015)	–
30	Winston <i>et al.</i> (1991); Taylor (2010)	<a href="https://onlinelibrary.wiley.com/doi/full/10.1111/fwb.13211">https://onlinelibrary.wiley.com/doi/full/10.1111/fwb.13211</a>
31	Mosie and Makati (2018)	<a href="https://www.gbif.org/dataset/77929c0a-7506-4b2d-a49d-10fc3312d50d">https://www.gbif.org/dataset/77929c0a-7506-4b2d-a49d-10fc3312d50d</a>
32	Office Francais de la Biodiversite (2019)	<a href="http://www.naiades.eaufrance.fr/acces-donnees#/hydrobiologie">http://www.naiades.eaufrance.fr/acces-donnees#/hydrobiologie</a>
33	Oklahoma Water Resources Board (2019)	<a href="http://home-owrb.opendata.arcgis.com/search?tags=fish">http://home-owrb.opendata.arcgis.com/search?tags=fish</a>
34	Agencia Vasca del Agua (2019)	<a href="http://www.uragentzia.euskadi.eus/informazioa/ubegi/u81-0003341/eu/">http://www.uragentzia.euskadi.eus/informazioa/ubegi/u81-0003341/eu/</a>
35	Ortega <i>et al.</i> (2015)	–
36	Davenport, S.R. (Unpublished data)	–
37	Dala-Corte <i>et al.</i> (2017)	–
38	Bêche <i>et al.</i> (2009); The Resh Lab (2019)	<a href="https://nature.berkeley.edu/reshlab/">https://nature.berkeley.edu/reshlab/</a>
39	Toronto and Region Conservation Authority (2018)	<a href="https://data.trca.ca/dataset/2018-watershed-fish-community">https://data.trca.ca/dataset/2018-watershed-fish-community</a>
40	U.S. Fish and Wildlife Service (2017)	–
41	Steffèrud, J. A. (Unpublished data)	–

42	Sers (2013)	<a href="https://www.slu.se/en/departments/aquatic-resources1/databases1/database-for-testfishing-in-streams/">https://www.slu.se/en/departments/aquatic-resources1/databases1/database-for-testfishing-in-streams/</a>
43	Benejam <i>et al.</i> (2010); Merciai <i>et al.</i> (2017)	–
44	Miyazono and Taylor (2015)	<a href="https://bioone.org/journals/The-Southwestern-Naturalist/volume-60/issue-1/MP-02.1/Long-term-changes-in-seasonal-fish-assembly-dynamics-in-an/10.1894/MP-02.1.short">https://bioone.org/journals/The-Southwestern-Naturalist/volume-60/issue-1/MP-02.1/Long-term-changes-in-seasonal-fish-assembly-dynamics-in-an/10.1894/MP-02.1.short</a>
45	Rinne & Miller (2006)	–
46	Van Thuyne <i>et al.</i> (2013); Brosens <i>et al.</i> (2015)	<a href="https://ipt.inbo.be/resource?r=vis-inland-occurrences">https://ipt.inbo.be/resource?r=vis-inland-occurrences</a>

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