Research networks generated by organizational structures, co-authorships and citations: A Case Study of German Centre for Integrative Biodiversity Research (iDiv)

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Abstract
Exploring whether different patterns emerge across networks generated by organizational structures, co-authorships and citations for characterizing and evaluating cooperative relationships is particularly important for transferring the research results into practice. This research-in-progress paper focuses on using the structure of scientific collaborations and mapping knowledge transfer to gain insight into the influence of collaborative research centres linked to the German Research Foundation (DFG) funding. Within the German Centre for Integrative Biodiversity Research (iDiv), the DFG sponsors research conducted across all participating universities and institutes by more than hundred research groups who bring their expertise to the manifold research fields of biodiversity. Using iDiv’s research from 2013-2020, we build co-authorship networks and identify the most cohesive communities in terms of collaboration and compare them with groups presented on its website. Corresponding cited and citing works are analysed by distributions to investigate disciplinary collaboration. Our findings show that the number of publications and the intensity of research collaboration have maintained a steady increase. Despite the highly cohesive cooperation structure addressed by iDiv, the internal scientific collaboration has not gained strong momentum compared with its growing trends in international collaborations. The tendency towards covering cross-disciplinary research foci is not evident.

Introduction
Cooperation between researchers, academic institutions and companies is gaining importance as research is increasingly being conducted in both homogeneous and heterogeneous collaboration contexts, including structured programs such as the collaborative research centres, and publicly funded projects between universities and companies (Bjerregaard, 2009; Bruneel, D’Este & Salter, 2010; Goduscheit & Knudsen, 2015). The proportion of collaborative research conducted between researchers from multiple disciplines and multiple research institutions or involving non-academic partners in all fields is growing (Wuchty, Jones, & Uzzi, 2007). Cooperation offers great potential by linking competencies, perspectives, experiences, resources and personalities. However, various obstacles stand in the way of fruitful cooperation in such a context. For instance, when dividing up the tasks involved in applying for a collaborative research centre, it becomes more challenging to integrate the objectives as the larger the group and the more heterogeneous the actors. The German Centre for Integrative Biodiversity Research (iDiv) offers the possibility to investigate typical problems (e.g., changing memberships, allocation of output, fluid boundaries of the working groups involved in the cooperation, the informative value of funding acknowledgements) since this DFG centre is established upon cooperation from 1995 called “Unibund”, extending the network from members based primarily in Halle, Jena and Leipzig to researchers from 30 nations. Eleven research institutions (Fig.1) joined forces to establish iDiv within the network have equal footings (S. Matthiä, personal communication, December 4, 2008). Collaborations with experts worldwide are central momentum at iDiv, and 13 research groups have been newly established since its founding (Tab.1). The composition of personnel at iDiv is somewhat complicated, with

1 iDiv is a DFG research centre run by a consortium of eleven science institutions. To better understand the complex phenomenon of biodiversity, the iDiv researchers are working on five overarching research areas. More information can be found at https://www.idiv.de/de/index.html.
employees and members, of which the membership includes full members, associated members and honorary members. Although there is no requirement in the cooperation agreement that the centre needs to be labelled by its members as the author’s affiliation, this complex structure would significantly impact a deeper understanding of bibliometric research findings. For instance, a paper affiliated with iDiv would not necessarily imply that the author is employed by the centre, whereas the research is primarily done within iDiv. The iDiv context may refer to the physical space or the research network. A new question arises amid characterizing and evaluating cooperative relationships: whether different patterns of networks emerge between research groups generated by organizational structures and scientific collaborations?

Figure 1. Cooperation partners of the consortium

Table 1. Members of the iDiv network

| Year | Computational Forest Ecology | Biodiversity Conservation |
|------|------------------------------|--------------------------|
| 2013 | Dr. Nadja Rüger (UL) | Prof. Henrique Miguel Pereira (MLU) |

| Year | Molecular Interaction Ecology | Experimental Interaction Ecology | Sustainability and Complexity in Ape Habitat | Ecosystem Services | Physiological Diversity | Biodiversity Synthesis |
|------|-------------------------------|-------------------------------|--------------------------------|----------------|-------------------------|------------------------|
| 2014 | Prof. Nicole M. van Dam (FSU) | Prof. Nico Eisenhauer (UL) | Dr. Hjalmar Küh (MPI EVA) | Prof. Aletta Bonn (UFZ, FSU) | Prof. Stanley Harpole (MLU) | Prof. Jonathan Chase (MLU) |

| Year | Theory in Biodiversity Science | Spatial Interaction Ecology |
|------|--------------------------------|-----------------------------|
| 2015 | Prof. Ulrich Brose (FSU) | Prof. Tiffany Knight (MLU, AvH, UFZ) |

| Year | Macroecology and Society |
|------|--------------------------|
| 2016 | Dr. Carsten Meyer Volkswagen Foundation,iDiv, UL |

| Year | Evolution and Adaptation | Biodiversity Economics |
|------|--------------------------|------------------------|
| 2018 | Dr. Renske Onstein iDiv, UL | Prof. Martin Quaas iDiv, UL |

2. Associated Members 3. Honorary Members

Collaboration in groups has a long tradition in experimental sciences (Etzkowitz, 1992), while collaboration in research networks is a parallel and complementary to the research group in a university department or an industrial laboratory (Kyvik & Reymert, 2017). In general, research networks differ from research groups in that they offer greater flexibility and less bureaucracy.

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2 List of abbreviations and membership committee: https://www.idiv.de/de/gruppen_und_personen/mitglieder.html
There is an increasing number of studies on scientific collaboration networks (Scott, 2011). Bibliometric research of scientific collaboration has been conducted in various fields, particularly by using co-authorship data (Ding, 2011; Fagan et al., 2018; Glänzel & Schubert, 2004; Hou, Kretschmer & Liu 2008; Mourao & Martinho, 2020), providing a quantitative dimension of the frequency and extent of cooperation among researchers in the practice of their research. It should be considered that co-authorships do not fully represent collaborations (Katz & Martin, 1997; Laudel, 2002) as not all collaborations lead to co-authored publications, and not all co-authored publications are based on collaborations. However, this method has undoubtedly proven its worth, especially in combination with network analyses. Research on biodiversity, its relation to ecosystem functioning and services, and the assessment of the impacts of environmental change on biodiversity calls for an interdisciplinary perspective (Lotz et al., 2012; Storch et al., 2020). While several studies have analysed the disciplinary variety of bibliographic references in papers to express the acceptance of concepts, methods and data from other subject areas, other studies have analysed the distribution of citations received by these papers from other areas. The analysis of citations and co-citations, in both cited and citing publications, constitutes one of the main approaches to the interdisciplinary phenomenon (Barlow et al., 2017; Dawson et al., 2014; Urbano & Ardanuy, 2020).

This paper is an evaluation of the current state of research networks of a collaborative research centre through the analysis of articles and citations. Specifically, it aims to provide a micro-picture of networks generated by organizational structures, co-authorships and citations within iDiv, and examine the relative importance of membership in networks for individual publication output. However, it is not only the pure quantity structure of publication activities that provides information about changes, but also structural elements of publication activity. This paper addresses two main questions for exploring whether different patterns emerge across networks: 1) How different are networks of cooperation bounded by membership and collaboration presented by scientific publications? Are members within a research centre/group more likely to be co-authors, or the external authors yield a higher collaboration potential? 2) Whether insights from different fields are being acknowledged with one another or are instead located in disciplinary siloes? That is, is there a growing trend towards cross-disciplinary collaboration through citation analysis of iDiv biodiversity-focused research? This special issue is a bridging effort to bring together scientific knowledge producers and network analysis by exploring the structure of collaboration in the social context. The findings may be informative in establishing, assessing and evaluating research networks.

Data and Methods

For answering the questions addressed in this paper, bibliographic data of 2,064 journal articles identified by DOIs inserted on the website of iDiv’s research published between 2013 and 2020 are retrieved from Web of Science Core Collection coupled with network analysis of co-authorships and citations. Co-authorship networks are generally adopted to provide an overview of the critical contributors within iDiv. Collaborative activities between communities will impact the understanding of how scientific research can add value and offer insights into central issues of concern for policy and practice. Collectively, authorship and citation analyses identify the distribution and accumulation of capital that develops as the centre evolves. The iDiv’s papers herein are first analysed through annual records, source of the leading authors, and the degree of collaboration. The number of authors per article ranges from one to 728, with over 70 per cent of iDiv’s research having three to nine authors. Therefore, we use the percentage of articles with less than or equal to two authors to measure collaboration intensity. Furthermore, we use a three-fields-plot based on a Sankey diagram that visualises how journals, research topics and countries/regions are interrelated. The general bibliometric analysis also compares
the whole set of cited references and citing papers with the collected publications by research area in general.
We extract the authors and affiliation information for exploring the network of actors within the iDiv research network and its corresponding influence on scientific knowledge production. The expression differences of authors at the same institution poses difficulties in the data processing of this study. We apply a thesaurus file created through a three-step process to merge 689 institutional names from 3,432 author affiliations listed in the raw data. The data cleaning tools of VantagePoint 3 perform software cleaning. Then, parts involving problems with misspellings, language conversions and abbreviations that have not been approached (e.g., University Jene, Goettingen University or CSIC) are integrated manually. Finally, experts review the processed data to keep the names of their affiliations standardized. We employ network-clustering algorithms in VOSviewer 1.6.16 to map and analyse the patterns of corresponding networks. The structures of co-authorship networks formed by authors and institutions are further compared with groups and networks bounded by memberships within iDiv. Given the limited team size of 13 research groups, the full membership list 4 serves as an additional basis for interpreting the co-authorship network. As this is one of the numerous case studies in the ongoing project research, we conduct a preliminary analysis of the conceptual and intellectual structures of knowledge using data extracted from 6,467 references and 17,751 citing papers as at 31.12.2020 of 106 highly cited publications within the dataset as aforesaid.
A direct citation analysis develops the intellectual structure as this approach provides a more accurate representation of the taxonomy of scientific and technical knowledge (Kyvik & Reyment, 2017). (Kyvik & Reyment, 2017). We use a historical direct citation network coupled with trend topics to visualise topics of interest and the following debate that scholars open in the scientific field.

Results and discussion

General trends in iDiv’s research

Between 2013 and 2017, research of iDiv presented a growing trend in counts and international scientific collaborations, with minor fluctuations since 2018 (Tab.2). The proportion of articles with a relatively low collaboration intensity has varied little except in 2016, averaging no more than four per cent of the collection of articles published that year.

Table 2. Publication count and collaboration intensity by year

| PY | Count | Percent*Au<=2 | Percent*CO>=2 |
|----|-------|--------------|--------------|
| 2013 | 1 | 0.00% | 0.00% |
| 2014 | 139 | 2.88% | 45.58% |
| 2015 | 215 | 4.19% | 54.39% |
| 2016 | 296 | 6.42% | 60.70% |
| 2017 | 369 | 2.98% | 97.32% |
| 2018 | 299 | 3.34% | 62.16% |
| 2019 | 399 | 3.26% | 89.60% |
| 2020 | 346 | 2.89% | 78.32% |

The interconnections among journals, research topics and countries can provide useful insights. Hence, we present a three-fields plot in Figure 2, which shows the interactions among the most relevant publication outlets (left), author keywords (middle) and countries (right) of iDiv’s papers. Meanwhile, Table 3 presents the distribution of primary source journals by subject area.

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1 Data cleanup: https://www.thenvantagepoint.com/_Analyst_Guide_Online_/Getting%20Started/Data_cleanup-General%20Fields.html
2 Groups and members: https://www.idiv.de/en/groups_and_people/members.html
We find that studies on biodiversity mainly distribute in journal *Ecology Letters*, most of which are authored by German scholars. Similarly, the journal *Global Change Biology* has published the majority of the climate change-related studies, again mainly authored by German scholars. In general, authors from Germany and the United States have broadly investigated research topics concerning biodiversity, species richness, functional diversity and climate change. Chinese scholars have shown a particular interest in bef-china related research. On an aggregate level, authors from European countries have a great interest in ecosystem studies. Among the journals, *Ecology* publishes studies in a comparatively broad range of topics including disturbance, global change, competition and community assembly.

![Figure 2. Three-fields plot by country, affiliation and sources (Top 15)](image)

**Table 3 Journals by subject area**

| Journals                        | Subject Area                                      |
|---------------------------------|---------------------------------------------------|
| Oikos                           | Agricultural and Biological Sciences              |
| Ecology and Evolution           | Agricultural and Biological Sciences; Environmental Science |
| Journal of Ecology              | Agricultural and Biological Sciences; Environmental Science |
| Frontiers in Microbiology       | Immunology and Microbiology; Medicine             |
| Ecology Letters                 | Agricultural and Biological Sciences              |
| Soil Biology & Biochemistry     | Immunology and Microbiology                       |
| Journal of Biogeography         | Agricultural and Biological Sciences              |
| Oecologia                       | Agricultural and Biological Sciences              |
| Global Ecology and Biogeography | Agricultural and Biological Sciences              |
| Ecology                         | Agricultural and Biological Sciences              |
| Global Change Biology           | Agricultural and Biological Sciences, Environmental Science |

There are 3,509 documents mainly with German authors of 88,538 references included in the articles of iDiv were co-cited over five times. Nearly 50 per cent of 33,272 citing papers (without self-citations) to iDiv’s research are published by authors from the United States and China. We compare the whole set of cited references, citing papers and the collected publications by research areas in general. Terms shown in blue colour in Table 4 refer to areas where both iDiv’s research and its references have explored. The parts marked in grey colour refer to the overlap in research areas between iDiv’s research and its citing papers. Nearly 90 per cent of the leading research areas covered by the three groups of publications are consistent, but with minor differences in each area's proportion. The iDiv scholars have cited works on Statistics Probability, Computer Science Interdisciplinary Applications and Cell Biology, while related topics are not explored further. Likewise, citing papers have not broadly investigated...
issues concerning Biochemical Research Methods, Mathematical Computational Biology and Economics. However, we can find in the distribution of research areas of the forward citations that topics not covered by the references have been extended in subsequent studies. There is a constant flow of relevant research on topics not addressed in the previously cited literature.

Table 4. Comparison of iDiv research, references and citing papers by research areas (Top 25)

| RA_Cited References | %  | RA_iDiv Research | %  | RA_Citing Papers | %  |
|---------------------|----|------------------|----|------------------|----|
| Ecology             | 52.93 | Ecology         | 46.27 | Ecology         | 30.01 |
| Multidisciplinary   | 19.28 | Plant Sciences  | 15.02 | Environmental Sciences | 20.49 |
| Plant Sciences      | 13.19 | Multidisciplinary Sciences | 13.03 | Plant Sciences | 14.44 |
| Statistics Probability | 2.27 | Geosciences Multidisciplinary | 1.94 | Geography Physical | 2.69 |
| Computer Science    | 1.96 | Biochemical Research Methods | 1.65 | Biotechnology Applied Microbiology | 2.65 |
| Interdisciplinary Applications | 1.49 | Mathematical Computational Biology | 1.60 | Marine Freshwater Biology | 2.32 |
| Zoology             | 1.08 | Entomology       | 1.31 | Green Sustainable Science Technology | 2.04 |
| Meteorology         | 0.95 | Marine Freshwater Biology | 1.16 | Engineering Environmental | 1.72 |
| Atmospheric Sciences | 0.71 | Economics        | 1.07 | Water Resources | 1.70 |
| Agronomy            | 0.47 | Engineering Environmental | 0.92 | Meteorology Atmospheric Sciences | 1.58 |
| Cell Biology        | 0.47 | Meteorology Atmospheric Sciences | 0.82 | Remote Sensing | 1.45 |

Primary contributors and scientific collaboration networks

The network generated by research collaboration of iDiv is relatively broad, both in terms of the average number of authors per article (5.64) and the number of co-authors per item (12.1). We can identify the equally high rates of the collaboration of highly productive scholars and organizations in this collection, which is measured respectively by an individual author’s contributions to a published set of papers and affiliation’s total links (Tab.5). The following primary authors are all full members of iDiv, while nearly half of the institutions are outside the network defined by the cooperative agreement.

Table 5. Primary contributors of iDiv’s research ranked by counts (Top 10)

| Authors       | Articles | Articles Fractionalized | Organization                        | Article | Total link strength |
|---------------|----------|-------------------------|-------------------------------------|---------|--------------------|
| Eisenhauer N  | 161      | 22.11                   | German Ctr Integrat Biodivers Res iDiv | 1,983   | 16,210             |
| Brueelheide H | 152      | 21.54                   | Ufz Helmholtz Ctr Environm Res       | 789     | 7,669              |
| Buscot F      | 102      | 11.9                    | Martin Luther Univ Halle Wittenberg | 631     | 6,846              |
| Wirth C       | 76       | 8.36                    | Univ Leipzig                         | 535     | 5,214              |
| Wubet T       | 75       | 8.55                    | Friedrich Schiller University Jena   | 331     | 2,989              |
| Kuhn I        | 69       | 8.93                    | Univ Gottingen                       | 209     | 3,631              |
| Kattge J      | 61       | 4.89                    | Max Planck Inst Biogeochem           | 176     | 2,750              |
| Roscher C     | 60       | 7.7                     | Univ Minnesota                       | 131     | 3,477              |
| Kusel K       | 59       | 8.67                    | Wageningen Univ                     | 125     | 3,789              |
| Settele J     | 59       | 7.62                    | Univ Freiburg                        | 124     | 2,807              |
The preliminary results of the network analysis reveal that there are 911 authors with more than five articles and collaborated with others at least five times. For a more straightforward layout of the network of iDiv-related scientific collaborations and to reduce the influence of multi-author articles, we used fractional counting methods to analyse co-authorship among authors with at least ten publications combined with an overlay visualization (Fig.3). The patterns of linkages among 311 authors in different publication periods have changed, from a loose interconnection of clusters to an expanded structure in terms of intensity of connection and the number of new actors joining the network. Although these authors have formed 13 different clusters, the links between the clusters are also strong, except for the one centred on the leader of Sustainability and Complexity in Ape Habitat. Twelve research group leaders (Tab.1) distribute across seven clusters, and the leaders of Ecosystem Services, Macroecology & Society and Biodiversity Conservation have a close intra-cluster collaboration. However, the leader of Experimental Interaction Ecology dominates the cluster and the entire collaborative network, both in terms of the number of articles and the intensity of collaboration. Furthermore, only one-fifth of scholars within the network are from the centre and distribute across clusters.

Figure 3. Co-authorship collaboration network and an overlay visualization.
Following the approach outlined above, we map out networks of collaboration at the level of representative institutions. Instead of exploring the temporal distribution of collaboration, we compare the structures of networks by including or excluding the node of iDiv. Three universities from “Unibund” (Halle – Jena – Leipzig) together with Ufz Helmholtz Ctr Environm Res as institutions joined forces to establish iDiv have also played a prominent role in the scientific collaboration shown as both maps. In addition to the member institutions, the organizations outside Germany like Univ Minnesota and Wageningen Univ have formed relatively large clusters by collaborating with institutions worldwide. However, one more cluster among them appears when the node of iDiv does not display, highlighting the role of Max Planck Inst Biogeochem in facilitating international collaboration.

Figure 4. Institutional collaboration network with/without iDiv

Trend topics and citation networks
References of highly cited iDiv’s papers range between 1994 and 2019, mainly including scholarly works from the United States and Germany. Respectively, citing papers from 2014 to 2020 have been broadly conducted by scholars from China and the United States. We map trend topics by author keywords extracted from highly cited research, its references and citing papers to compare the conceptual structures of knowledge, setting the parameters to a minimum word
frequency of five. iDiv’s highly cited papers in the last decade have shown common interests in the topics frequently explored in cited references between 2008 and 2014, such as species richness and functional traits. Authors’ research foci in citing papers are forest management and risk assessment, while iDiv related scholars have contributed to studies on biodiversity.

Figure 5. Trend topics in sequence

We employ the historiographic mapping to trace research paths and investigate the knowledge’s intellectual structure (Fig. 6). Each node represents a document cited by others, and each edge represents a direct citation. The list of articles is shown in Table 6. The direction of the arrows in Figure 6 explains the chronical change of research trends from the past, steering the research
paths of biodiversity, bioinformatics, ecosystem and biological evolution. For example, Tittensor et al. (2014) provided a comprehensive mid-term assessment of progress toward international biodiversity targets, and then the subsequent research discussed how biodiversity was changing by combining synthesis, theory and detection (Capinha et al., 2015; Dawson et al., 2017; Ibisch et al., 2016; Newbold et al., 2015; Pysek et al., 2017; Seebens et al., 2017; Seebens et al., 2018; Van Kleunen et al., 2015). This contributed to promoting articles facilitating quantitative analysis of temporal patterns of biodiversity (Dornelas et al., 2018; Hillebrand et al., 2018; Jetz et al., 2019) and research on a typology of generalized knowledge claims (Magliocca et al., 2018). Recently, changes in biodiversity have been explored in a broader societal context together with economic models and human activities (Blowes et al., 2019; Marques et al., 2019).

Conclusions

The preliminary analysis presented here suggests that the networks generated by the organizational structures, scientific collaborations and citations can potentially provide additional insight into the impact of funded collaborative centre beyond that achieved through typical analyses of the research outputs based on publication and citation count data. The number of publications and the intensity of research collaboration have maintained a steady increase since 2013. iDiv is dedicated to bringing together member institutions to cover cross-disciplinary research foci, while the internal scientific collaboration among members has not demonstrated strong momentum. Nearly 90 per cent of the leading research areas covered by cited references, citing papers and collected publications are consistent. Research paths presented by direct citation links in highly cited papers indicate the coherent research foci of iDiv on ecosystem, biodiversity and bioinformatics. Nevertheless, the strong international research collaboration developed by member institutions provides an expanding platform for knowledge production, exchange and transfer than the established organisational structure. Further research will provide a deeper understanding of whether the establishment of iDiv has strengthened the internal links between members with existing cooperation and its potential influences on the emergence of new research communities. Moreover, data retrieved from sources like funding texts and personal profiles are further coupled to explore what facilitates iDiv’s scientific research and relevant collaboration at different levels.
Table 6. Legend of historiographic mapping (LC: Local Citations, TC: Total Citations).

| First Author       | Year | Journal          | DOI                          | LCS | GCS |
|--------------------|------|------------------|------------------------------|-----|-----|
| TITTENSOR DP       | 2014 | SCIENCE          | 10.1126/science.1257484      | 6   | 590 |
| STEPHENSON NL      | 2014 | NATURE           | 10.1038/nature12914          | 1   | 383 |
| BLACKBURN TM       | 2014 | PLOS BIOL        | 10.1371/journal.pbio.10018   | 50  | 1   | 371 |
| FURST MA           | 2014 | NATURE           | 10.1038/nature12977          | 2   | 308 |
| JESCHKE JM         | 2014 | CONSERV BIOL     | 10.1111/cobi.12299           | 1   | 188 |
| MOLES AT           | 2014 | J VEG SCI        | 10.1111/jvs.12190            | 1   | 169 |
| WERNER GDA         | 2014 | NAT COMMUN       | 10.1038/ncomms5087           | 2   | 132 |
| NEWBOLD T          | 2015 | NATURE           | 10.1038/nature14324          | 9   | 1116|
| SIMON-DELSON       | 2015 | SCIENCE POLLUT R | 10.1007/s11356-014-3470-y   | 0   | 561 |
| LEFF JW            | 2015 | ACAD SCI USA     | 10.1073/pnas.1508382112      | 1   | 441 |
| ISBEll F           | 2015 | NATURE           | 10.1038/nature15374          | 2   | 418 |
| VAN KLEUNEN M      | 2015 | NATURE           | 10.1038/nature14910          | 5   | 380 |
| LANGe M            | 2015 | NAT COMMUN       | 10.1038/ncomms7707           | 2   | 366 |
| PISA LW            | 2015 | SCIENCE POLLUT R | 10.1007/s11356-014-3471-x   | 1   | 350 |
| PROBER SM          | 2015 | ECOL LETT        | 10.1111/elec.12381           | 2   | 284 |
| LEFCHECK JS        | 2015 | NAT COMMUN       | 10.1038/ncomms7936           | 3   | 232 |
| KUMSCHICK S        | 2015 | BIOSCIENCE       | 10.1093/biosci/biu193        | 0   | 178 |
| DOUBLET V          | 2015 | ENVIRON MICROBIOL| 10.1111/1462-2920.12426      | 1   | 174 |
| VERHEYEN K         | 2016 | AMBIO            | 10.1007/s13280-015-0685-1    | 4   | 111 |
| AVNI R             | 2017 | SCIENCE          | 10.1126/science.aan0032      | 1   | 294 |
| DAWSON W           | 2017 | NAT ECOL EVOL    | 10.1038/s41559-017-0186      | 1   | 110 |
| EISENHAUER N       | 2017 | SCI REP-UK       | 10.1038/srep44641            | 0   | 102 |
| MARTINEZ-MEDINA A  | 2017 | NEW PHYTOL       | 10.1111/nphy.14251           | 0   | 85  |
| MELI P             | 2017 | PLOS ONE         | 10.1371/journal.pone.01713   | 68  | 1   | 101 |
| PYSEK P            | 2017 | PRESLIA          | 10.23855/preslia.2017.203   | 1   | 132 |
| SEEbens H          | 2017 | NAT COMMUN       | 10.1038/ncomms14435          | 2   | 488 |
| WEISSER WW         | 2017 | BASIC APPL ECOL  | 10.1016/j.baae.2017.06.002  | 1   | 110 |
| APPELS R           | 2018 | SCIENCE          | 10.1126/science.aar7191      | 1   | 653 |
| BJORKMAN AD        | 2018 | NATURE           | 10.1038/s41586-018-0563-7    | 1   | 130 |
| BRUELHEIDE H       | 2018 | NAT ECOL EVOL    | 10.1038/s41559-018-0699-8    | 2   | 94  |
| DORNELAS M         | 2018 | GLOBAL ECOL BIOGEOGR | 10.1111/geb.12729 | 2   | 74  |
| GROSSMAN JJ        | 2018 | ENVIRON EXP BOT  | 10.1016/j.envexpbot.2017.1  | 2.015 | 0   | 38  |
| HILLEBRAND H       | 2018 | J APPL ECOL      | 10.1111/1365-2664.12959      | 1   | 149 |
| HUANG Y            | 2018 | SCIENCE          | 10.1126/science.aat6405      | 0   | 101 |
| JONES HP           | 2018 | P ROY SOC B-BIOL SCI | 10.1098/rspb.2017.2577   | 0   | 72  |
| LIU XJ             | 2018 | P ROY SOC B-BIOL SCI | 10.1098/rspb.2018.1240      | 0   | 45  |
| First Author | Year | Journal          | DOI                          | LCS | GCS |
|--------------|------|------------------|------------------------------|-----|-----|
| CAPINHA C    | 2015 | SCIENCE          | 10.1126/science.aaa8913     | 4   | 145 |
| MCMAHON DP   | 2015 | J ANIM ECOL      | 10.1111/j.1365-2656.12345  | 1   | 121 |
| DIAZ S       | 2016 | NATURE           | 10.1038/nature16489         | 4   | 797 |
| LIANG JJ     | 2016 | SCIENCE          | 10.1126/science.aaf8957     | 4   | 390 |
| POORTER L    | 2016 | NATURE           | 10.1038/nature16512         | 1   | 378 |
| MUCINA L     | 2016 | APPL VEG SCI     | 10.1111/avsc.12257          | 0   | 341 |
| KUNSTLER G   | 2016 | NATURE           | 10.1038/nature16476         | 1   | 308 |
| GRACE JB     | 2016 | NATURE           | 10.1038/nature16524         | 5   | 258 |
| SOLIVERES S  | 2016 | NATURE           | 10.1038/nature19092         | 0   | 216 |
| CHAZDON RL   | 2016 | SCI ADV           | 10.1126/sciadv.1501639     | 0   | 193 |
| IBISCH PL    | 2016 | SCIENCE          | 10.1126/science.aal7166     | 0   | 168 |
| HARPOLI WS   | 2016 | NATURE           | 10.1038/nature19324         | 1   | 152 |
| GOSSNER MM   | 2016 | NATURE           | 10.1038/nature20575         | 2   | 145 |
| CHYTRY M     | 2016 | APPL VEG SCI     | 10.1111/avsc.12191          | 2   | 128 |
| MAGLIOCCA NR | 2018 | GLOBAL ENVIRON CHANG | 10.1016/j.gloenvcha.2018.0  | 0   | 41  |
| SCHALL P     | 2018 | J APPL ECOL      | 10.1111/j.1365-2664.12950  | 0   | 72  |
| SEEbens H    | 2018 | P NATL ACAD SCI USA | 10.1073/pnas.1719429115    | 0   | 121 |
| STEINBAUER MJ| 2018 | NATURE           | 10.1038/s41586-018-0005-6   | 1   | 179 |
| BLOWES SA    | 2019 | SCIENCE          | 10.1126/science.aaw1620    | 0   | 62  |
| BROSE U      | 2019 | NAT ECOL EVOL    | 10.1038/s41559-019-0899-x  | 0   | 35  |
| BRUELHEIDE H | 2019 | J VEG SCI        | 10.1111/jvs.12710          | 1   | 47  |
| JETZ W       | 2019 | NAT ECOL EVOL    | 10.1038/s41559-019-0826-1  | 0   | 46  |
| MACCAFERRI M | 2019 | NAT GENET        | 10.1038/s41588-019-0381-3  | 0   | 118 |
| MARQUES A    | 2019 | NAT ECOL EVOL    | 10.1038/s41559-019-0824-3  | 0   | 42  |
| MILNER SG    | 2019 | NAT GENET        | 10.1038/s41588-018-0266-x  | 0   | 63  |
| STEIDINGER BS | 2019 | NAT GENET        | 10.1038/s41586-019-1128-0  | 0   | 70  |
| ZIZKA A      | 2019 | METHODS ECOL EVOL GLOBAL CHANGE BIOL | 10.1111/2041-210X.13152   | 0   | 46  |
| KATTGE J     | 2020 |                |                              | 0   | 81  |
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References

Barlow, P., McKee, M., Basu, S., & Stuckler, D. (2017). The health impact of trade and investment agreements: a quantitative systematic review and network co-citation analysis. Globalization and Health, 13(1), 1-9.

Bjerregaard, T. (2009). Universities-industry collaboration strategies: a micro-level perspective. European Journal of Innovation Management, 12(2), 161–176.

Blowes, S. A., Supp, S. R., Antão, L. H., Bates, A., Bruelheide, H., Chase, J. M., ... & Dornelas, M. (2019). The geography of biodiversity change in marine and terrestrial assemblages. Science, 366(6463), 339-345.

Bruneel, J., D’Este, P., & Salter, A. (2010). Investigating the factors that diminish the barriers to university-industry collaboration: Research Policy 39(7), 858–868.

Capinha, C., Essl, F., Seebens, H., Moser, D., & Pereira, H. M. (2015). The dispersal of alien species redefines biogeography in the Anthropocene. Science, 348(6240), 1248-1251.

Dawson, S., Gašević, D., Siemens, G., & Joksimovic, S. (2014, March). Current state and future trends: A citation network analysis of the learning analytics field. In Proceedings of the fourth international conference on learning analytics and knowledge (pp. 231-240).

Dawson, W., Moser, D., Van Kleunen, M., Kreft, H., Pergl, J., Pyšek, P., ... & Essl, F. (2017). Global hotspots and correlates of alien species richness across taxonomic groups. Nature Ecology & Evolution, 1(7), 1-7.

Ding, Y. (2011). Scientific collaboration and endorsement: Network analysis of coauthorship and citation networks. Journal of informetrics, 5(1), 187-203.

Dornelas, M., Antao, L. H., Moyes, F., Bates, A. E., Magurran, A. E., Adam, D., ... & Murphy, G. (2018). BioTIME: A database of biodiversity time series for the Anthropocene. Global Ecology and Biogeography, 27(7), 760-786.

Etzkowitz, H. (1992). Individual investigators and their research groups. Minerva, 30, 28–50.

Fagan, J., Eddens, K. S., Dolly, J., Vanderford, N. L., Weiss, H., & Levens, J. S. (2018). Assessing research collaboration through co-authorship network analysis. The journal of research administration, 49(1), 76.

Glänzel, W., & Schubert, A. (2004). Analysing scientific networks through co-authorship. In Handbook of quantitative science and technology research (pp. 257-276). Springer, Dordrecht.

Goduscheit, R. C., & Knudsen, M. P. (2015). How Barriers to Collaboration Prevent Progress in Demand for Knowledge: A Dyadic Study of Small and Medium-Sized Firms, Research and Technology Organizations and Universities. Creativity and Innovation Management, 24(1), 29–54.

Hillebrand, H., Blasius, B., Borer, E. T., Chase, J. M., Downing, J. A., Eriksson, B. K., ... & Ryabov, A. B. (2018). Biodiversity change is uncoupled from species richness trends: Consequences for conservation and monitoring. Journal of Applied Ecology, 55(1), 169-184.

Ho, T. M., Nguyen, H. V., Vuong, T. T., Dam, Q. M., Pham, H. H., & Vuong, Q. H. (2017). Exploring Vietnamese co-authorship patterns in social sciences with basic network measures of 2008-2017 Scopus data. F1000Research, 6.

Hou, H., Kretschmer, H., & Liu, Z. (2008). The structure of scientific collaboration networks in Scolertometrics. Scientometrics, 75(2), 189-202.

Ibisch, P. L., Hoffmann, M. T., Kreft, S., Pe’er, G., Kati, V., Biber-Freudenberger, L., ... & Selva, N. (2016). A global map of roadless areas and their conservation status. Science, 354(6318), 1423-1427.

Jetz, W., McGech, M. A., Guralnick, R., Ferrier, S., Beck, J., Costello, M. J., ... & Turak, E. (2019). Essential biodiversity variables for mapping and monitoring species populations. Nature ecology & evolution, 3(4), 539-551.

Klavans, Richard, and Kevin W. Boyack. "Which type of citation analysis generates the most accurate taxonomy of scientific and technical knowledge?" Journal of the Association for Information Science and Technology 68.4 (2017): 984-998.

Kyvik, S., & Reyment, I. (2017). Research collaboration in groups and networks: differences across academic fields. Scientometrics, 113(2), 951-967.
Lotz, T., Nieschulze, J., Bendix, J., Dobbermann, M., & König-Ries, B. (2012). Diverse or uniform?—Intercomparison of two major German project databases for interdisciplinary collaborative functional biodiversity research. *Ecological informatics*, 8, 10-19.

Magliocca, N. R., Ellis, E. C., Allington, G. R., De Bremond, A., Dell’Angelo, J., Mertz, O., ... & Verburg, P. H. (2018). Closing global knowledge gaps: Producing generalized knowledge from case studies of social-ecological systems. *Global environmental change*, 50, 1-14.

Marques, A., Martins, I. S., Kastner, T., Plutzar, C., Theurl, M. C., Eisenmenger, N., ... & Pereira, H. M. (2019). Increasing impacts of land use on biodiversity and carbon sequestration driven by population and economic growth. *Nature ecology & evolution*, 3(4), 628-637.

Mourao, P. R., & Martinho, V. D. (2020). Forest entrepreneurship: A bibliometric analysis and a discussion about the co-authorship networks of an emerging scientific field. *Journal of Cleaner Production*, 256, 120413.

Newbold, T., Hudson, L. N., Hill, S. L., Contu, S., Lysenko, I., Senior, R. A., ... & Purvis, A. (2015). Global effects of land use on local terrestrial biodiversity. *Nature*, 520(7545), 45-50.

Pyšek, P., Pergl, J., Essl, F., Lenzner, B., Dawson, W., Krefl, H., ... & Kleunen, M. V. (2017). *Naturalized alien flora of the world*. Preslia., 89(3), 203-274.

Scott, J. (2011). Social network analysis: developments, advances, and prospects. *Social network analysis and mining*, 1(1), 21-26.

Seebens, H., Blackburn, T. M., Dyer, E. E., Genovesi, P., Huulme, P. E., Jeschke, J. M., ... & Schindler, S. Štajerová K, Tokarska-Guzik B, Van Kleunen M, Walker K, Weigelt P, Yamanaka T, Essl F. 2017. No saturation in the accumulation of alien species worldwide. *Nature Communications*, 8, 14435.

Seebens, H., Blackburn, T. M., Dyer, E. E., Genovesi, P., Huulme, P. E., Jeschke, J. M., ... & Essl, F. (2018). Global rise in emerging alien species results from increased accessibility of new source pools. *Proceedings of the National Academy of Sciences*, 115(10), E2264-E2273.

Storch, I., Penner, J., Asbeck, T., Basile, M., Bauhns, J., Braunisch, V., ... & Yousefpour, R. (2020). Evaluating the effectiveness of retention forestry to enhance biodiversity in production forests of Central Europe using an interdisciplinary, multi-scale approach. *Ecology and evolution*, 10(3), 1489-1509.

Tittensor, D. P., Walpole, M., Hill, S. L., Boyce, D. G., Britten, G. L., Burgess, N. D., ... & Ye, Y. (2014). A mid-term analysis of progress toward international biodiversity targets. *Science*, 346(6206), 241-244.

Urbano, C., & Ardanuy, J. (2020). Cross-disciplinary collaboration versus coexistence in LIS serials: analysis of authorship affiliations in four European countries. *Scientometrics*, 124(1), 575-602.

Van Kleunen, M., Dawson, W., Essl, F., Pergl, J., Winter, M., Weber, E., ... & Pyšek, P. (2015). Global exchange and accumulation of non-native plants. *Nature*, 525(7567), 100-103.

Wuchty, S., Jones, B. F., & Uzzi, B. (2007). The Increasing Dominance of Teams in Production of Knowledge. *Science*, 316(5827), 1036–1039.