Data- and code-archiving in the British Ecological Society journals: present status and recommendations for future improvements.

N. Cooper[1]; B.J. Allen[2]; N. Almaani[3]; R. Altwegg[4],[5]; J. Balogh[6]; H. Balti[7]; R.A. Barber[8]; M.E. Barbosa de Sousa[9]; J.G.N. Barreat[10]; C.F. Barrett[11]; R. Bates[12]; A.M.J.M. Beale[13]; L. Bliard[14]; N. Blömer[15]; D. Borovyk[16],[17]; C. Bunnenberg[18]; E.A. Bygate[19]; L. Cash[20]; N. Chatterjee[21]; T.-W. Chen[22],[23]; A. Chiti[24]; S.S.-W. Chung[25]; H. Chuquillanqui[26]; A. Ciezarek[27]; A. Clarkson[28],[29]; E. Codling[30]; A. Corradini[31]; A. Cowans[32]; S. Dartnell[33]; A.J.S. Davis[34]; L.L.M. De Benedictis[35]; G.G. Deme[36],[37],[38]; C. Devenish[39]; S. Dimri[40]; C. Dittrich[41]; K.R. Dorheim[42]; H.B. Drage[43]; M.-A. Dueñas[44]; A. Efstathiou; L.C. Evans[45],[46]; M.E. Ferreira Santos[47]; A.J. Foxx[48],[49]; R.J. Gardiner[50]; J. Gaudard[51]; W. Gearty[52]; L. Graham[53]; V.M. Graves[54]; H.M. Green[55]; R.V. Greensmith[56]; S. Gérard[57]; A.H. Halbritter[58]; T.R. Hartke[59]; R.M. Hechler[60]; B.J. Hindle[61]; P.-Y. Hsing[62]; S. Illanas[63]; G. Iossa[64]; E.E. Jackson[65]; L.A. Jones[66]; F.A.M. Jones[67]; J.A. Jones[65]; J.F. Jupke[68]; N.N. Kaunain[69]; R. Kennedy[70]; M.R. Kerr[71]; N.J. Kester[72]; M. Klaassen[73]; O. Konecka[74]; R. Krasnow[75]; R. Kukowski[76]; A. Kumar[77],[78]; R. Kuminski[79]; K.S. Kuzey[80]; L. Laccetti[81]; M. Lagisz[82]; H. Latifi[83]; N. Lecomte[84]; K.D. Luchmun; A. Lévêque[85]; A. Markitantova; B.M. Marshall[86]; E. Menares-Barraza[87]; D. Mertens[88],[89]; G. Mesbahi[90]; J. Meyer[91]; J. Millard[92]; L.M. Montilla; B. Moreira[93]; A. Morera[94]; G. Murali[95]; M.P. Murray; F. Märker[96]; K. Nagahawatte[76]; C.L. Narraway[97]; H.I. Niven[98]; A.G. Nytko[99]; B. Ohse[100]; S. Patterson[101]; H.R.P. Phillips[102]; R. Pienaar[103]; P. Pollo[104]; A. Ponce[105],[106]; L.M.V. Porto[107],[108]; E.F.R. Preston[101]; C.S. Prieul[109]; A. Prylutska[110],[111]; O. Prylutskyi[112],[113]; K. Radman-Daw[114]; A.M. Raharison[115]; R. Rao[116]; F.R. Read[117]; S. Record[118]; W. Rees[119]; R. Reeve[120]; H. Rhodes[91]; C. Rocabado[121]; A. Rouviere[65]; A. Rönnfeldt[122]; A. Sagouis[123],[124]; S.P. Sakhalkar[125]; G.S. Santos[126]; M.A. Shakur[127]; R. Shaw[128]; D. Siegieda[129]; L. Šmídova[130]; B.I. Simmons[119]; H.G. Sisley[131]; A. Sánchez-Tójar[132],[133]; F.G. Taboada[134]; N.G. Taylor[135]; H. Teague[136]; K. Thrikkadeeri[137],[138]; V. Thuroczy; A. Varah[136]; K.L. Vinay[137],[138]; C.M. Watrobska; Z.B. Williams[109]; S.M. Windecker[139],[140]

All authors except the leading and corresponding author, Natalie Cooper (natalie.cooper@nhm.ac.uk), are listed alphabetically by family name. Authors' affiliations are listed after the Reference section.

Abstract

1. Data- and code-archiving are important components of open science, as both make research more transparent, reproducible, accountable, and credible, allowing future researchers to identify errors and build on previous work. Despite progress in implementing data- and code-archiving policies in journals publishing ecology and evolution research, issues remain. To be more useful to future researchers, archived data and code must not only be archived, but also meet good practice standards.

2. We collected data from 1,861 papers published between 2017 and 2024 in the seven British Ecological Society (BES) journals, during a hackathon event. We systematically checked associated data and/or code, metadata, help files and annotations to assess archiving practices. We determined if and where data and code files were archived, whether they could be located, downloaded, and opened, and whether they had associated READMEs, digital

object identifiers (DOI) and licenses. We also recorded the file extensions used to save data/code files, and which programming languages code was written in.

3. 93% of the 1,861 papers we examined used data and ~90% used code. While 97% of the 1,735 papers that used data also archived it, only 35% of the 1,670 papers that used code also archived code. Over 85% of archived data and code could be located, downloaded, and opened. Reusability, however, was more limited; around a third of papers did not have a README or similar to explain their data/code files, and the quality of READMEs varied substantially.

4. We recommend that researchers archive their code, and that archived code be explicitly mentioned in the Data (or Code) Availability statement. We also encourage researchers to provide more accessible and informative READMEs for data and code. To help achieve these recommendations, we advocate that journals employ Data/Code editors to review data and code quality, research institutions deliver more training in open science practices, and funding bodies set clear expectations on open data and code practices.

Keywords: data-sharing, code-sharing, open code, open data, open science, repository, research integrity, responsible research.

Introduction

Open science is a set of inclusive principles and practices that ensures scientific research and its outputs can be found, accessed, reused, and built upon by everyone without restrictions (UNESCO, 2021). Archiving the data and code underlying published results is key to open science (Goldacre et al., 2019; O'Dea et al., 2021; Poisot et al., 2019; Whitlock, 2011). This allows others to reproduce analyses, identify errors and build on previous work, enhancing the quality, credibility, and reach of research (Fernández-Juricic, 2021; Fidler et al., 2017; Powers & Hampton, 2019). Furthermore, data- and code-archiving offer several benefits for authors, especially for early career researchers and researchers in the Global South (Noble et al., 2025), including higher impact, more collaborations, increased citations, and enhanced employability (Allen & Mehler, 2019; Colavizza et al., 2024; Maitner et al., 2024; McKiernan et al., 2016; Piwowar et al., 2007; Poisot et al., 2013; Vandewalle, 2012). However, some authors remain reluctant to share their data and/or code due to perceived issues such as fear of "scooping", lack of time and incentives, and insecurities about the quality of their data or code (Allen & Mehler, 2019; Evans, 2016; Gomes et al., 2022; Soeharjono & Roche, 2021).

Meta-research has shown that journals have a key role to play in encouraging data- and code-archiving (Ivimey-Cook, Sánchez-Tójar, et al., 2025; Powers & Hampton, 2019; Roche et al., 2022; Sholler et al., 2019). Over the last few decades, the scientific community has embraced data-archiving, and many funders, journals, and some preprint servers (e.g. EcoEvoRxiv) now require

data to be archived (Noble et al., 2025; Sholler et al., 2019). Most ecology and evolution journals have data-archiving policies (Berberi & Roche, 2023; Ivimey-Cook, Sánchez-Tójar, et al., 2025; Roche et al., 2022), and surveys show large improvements in compliance where archiving is mandatory (78% versus 7% sharing where data sharing was mandatory versus optional; Vines et al., 2013) or where journals strongly encourage archiving (Maitner et al., 2024; Sánchez-Tójar et al., 2025). Code-archiving is equally important but less widely mandated (Maitner et al., 2024; Sánchez-Tójar et al., 2025), though an increasing number of ecology journals now have code-archiving policies (from 15% in 2015 to 88% in 2024; Culina et al., 2020; Ivimey-Cook, Sánchez-Tójar, et al., 2025; Mislan et al., 2016).

Despite the increase in data- and code-archiving policies and mandates across the publishing ecosystem, several issues remain. These include broken or outdated links to archived data/code, data or code that are incorrect or incomplete, file types that are proprietary or outdated and can no longer be opened, and absent or limited metadata and/or documentation making data or code impossible to interpret (Ivimey-Cook et al., 2023; Roche et al., 2022). This highlights that for data- and code-archiving to be effective, merely archiving data and code is insufficient; research outputs must also be FAIR, i.e. Findable, Accessible, Interoperable and Reusable (Wilkinson et al., 2016). An analysis of 100 ecology and evolution journal articles in 2022 found that only 46% of datasets met some reusability criteria of FAIR (Roche et al., 2022); though this is an improvement compared to 27% in 2015 (Roche et al., 2015). While data-archiving is now expected, code-archiving is still limited in ecology journals. Only 27% of 346 articles from 14 ecological journals with code-archiving policies archived their code (Culina et al., 2020), despite increased concerns about reproducibility in ecology (Kambouris et al., 2024; Kimmel et al., 2023). There is also a great deal of variety in data- and code-archiving policies across journals (Ivimey-Cook, Sánchez-Tójar, et al., 2025; Sánchez-Tójar et al., 2025), which may obscure patterns in broad cross-journal studies.

Here we focus on one group of journals with common editorial policies, the British Ecological Society (BES) journals. The BES publishes seven journals: *Ecological Solutions and Evidence (ESE), Functional Ecology, Journal of Animal Ecology, Journal of Applied Ecology, Journal of Ecology, Methods in Ecology and Evolution (MEE)*, and *People and Nature (PAN)*. Data archiving has been mandatory, barring exceptional circumstances (e.g. indigenous data sovereignty; Carroll et al., 2020), at all seven journals since January 2014, and code archiving has been required for papers presenting simulations, new applications and non-standard analyses since 2017 (2015 for *MEE*). Although journal staff check each accepted paper to ensure authors have archived data and code according to BES editorial policies (https://besjournals.onlinelibrary.wiley.com/hub/editorial-policies), they do not have the skills or capacity to guarantee all requirements for data- and code-archiving, for example completeness and reusability, have been met. Editors and reviewers with subject-specific expertise can check data and code during review, but this is uncommon (XXX *pers.*

comm.). Thus, the system assumes that authors have acted appropriately. We also do not know whether the data and/or code remain accessible long-term. Here we investigate data- and code-archiving in 1,861 papers published in the BES journals between 2017 and 2024 (~20% of all papers published in the BES journals over this time period). BES journals have been among those leading the way in data- and code-archiving policies, thus these journals represent an ideal benchmark for best practice. We expected high data-archiving rates but potentially lower compliance for code. Our results provide a current snapshot of data- and code-archiving in papers published across the BES journals, allowing us to provide recommendations for future improvements that will benefit authors and readers alike.

Materials and methods

DATA COLLECTION

Assembling the list of papers

We collected data from papers published in the seven BES journals between 2017 and the end of 2024. *PAN* and *ESE* only began publishing papers in 2019 and 2020, respectively. We excluded reviews, perspectives, forum articles, commentaries and opinion pieces that rarely have data or code to archive, leaving 8,112 eligible papers (Table S1).

Collection of data by hackathon participants

Data were collected as part of a hackathon event (29-30th September 2025), where 145 (in-person and online) participants randomly selected papers from the 8,112 eligible papers, and then followed a bespoke protocol (see below) to collect the required data. Participants systematically checked associated data and/or code, and examined available metadata, help files and annotations. To minimize input errors, participants submitted data for each paper according to the protocol via a form, using dropdown or multiple choice menus whenever possible. Participants could share any queries through a dedicated online chat community (https://discord.com) to enhance a homogeneous assessment and data collection. In addition, all participants collected data for one common paper (paper number 2272) to explore data recorder variability.

Data collection protocol

The full data collection protocol is in the Supporting Information. For each paper, participants first collected data on several general variables as follows. 1) paper number (these were randomly assigned to papers before data collection); 2) DOI; 3) publication year (dropdown); 4) journal (dropdown); 5) article type (dropdown); 6) country of first author (dropdown, derived from the UN M49 standard georegions: https://unstats.un.org/unsd/methodology/m49/#geo-regions); and 7) identity of the data recorder(s). Data recorders were anonymised post-data collection and each unique data recorder, or group of data recorders, were given a recorder ID number.

Next, we extracted details about data- and code-archiving for each paper. Rather than list each question in our protocol (see Supporting Information), we have grouped questions thematically and described how we collected data for each. Information about data and code were collected separately, but they are described together below. We used existing guidelines, e.g. FAIR, FAIR4RS, TADA!, European Open Science Cloud Research Software MetaData (RSMD), to develop our protocol; though note that our protocol does not cover every aspect of these (Barker et al., 2022; Gruenpeter et al., 2024; Ivimey-Cook, Culina, et al., 2025; Wilkinson et al., 2016).

1. Does the paper use data/code? If so, are they archived?

We used the Data Availability statement to determine whether data were used and archived. A paper used data if it generated or collated a dataset essential for reproducing the main results of the study. Note that some papers analysed only pre-existing datasets (this was most common in *MEE* papers), so did not generate data but often did use code. Pilot data collection indicated that code was rarely mentioned in the Data Availability statement, so to determine whether a paper used code we read the Methods section of the paper and identified statements that made it clear that code was used, even if it was not archived (e.g. "analyses were conducted in R"). Data related to other questions listed below were only collected for papers that used data/code as appropriate.

2. Where were the data/code archived?

Not all archiving options are equally appropriate or accessible long-term (Jones et al., 2025). Therefore, we recorded where the data/code were archived. Institutional or governmental repositories, or specific projects (e.g. MoveBank), were simplified as "Other repo/database".

3. Can the archived data/code be located, downloaded, and opened?

We recorded whether the data/code were mentioned in the Data Availability statement, and whether we could find the data using the link or instructions provided. We also recorded whether the data/code files could be downloaded at the time of investigation and, if so, whether they could be opened using standard software.

4. What file extensions do the archived data/code files use?

Data/code are not accessible if proprietary software (i.e. paid for use) is required to open them. To investigate this issue, we recorded the file extensions of archived data/code files. Each paper could contain multiple data/code files and thus multiple file extensions. We recorded all unique data/code file extensions for each paper. For archived code, we also recorded the programming language the code was written in.

5. Do the archived data/code have a README (or equivalent)? If so, how useful is it?

We recorded whether the data/code had a README and how useful this README was on a scale of 1–10. For data READMEs **1** = *very brief and incomplete*, and **10** = *you can understand the dataset in just a few minutes. Contains all column headers, abbreviations, units, data sources, data dictionary, license info, paper info etc.* For code READMEs **1** = *very brief and incomplete*, and **10** = *all information about script functionality, outputs, software, packages, workflows comprehensively documented.* A detailed description of a good data/code README was provided in the protocol (Supporting Information; Box 1).

6. How complete is the archived data?

Archived data should contain all the data and metadata necessary to reproduce all the analyses and results. Issues could include providing only summary data, not providing raw data, only providing a subsample of the data, and providing insufficient data to repeat the analyses. To assess this, we recorded the completeness of the data based on a comparison of the analyses featured in the manuscript and the archived data. Completeness is difficult to assess thoroughly without reproducing the analyses in the paper, but this requires time and advanced computational skills. As a compromise, we recorded completeness on a four point scale as follows. **low** = *the main analyses of the paper cannot be repeated with the data that has been archived*; **fair** = *some analyses can be repeated but not all (~50% of analyses can be repeated)*; **high** = *most data are provided with only small omissions, for example exploratory analyses (~75% of analyses can be repeated)*; **complete** = *all the data necessary to reproduce all analyses and results are archived.*

7. How good is the code annotation?

For code to be useful, it needs to be adequately annotated. We therefore recorded how good the code annotation was on a scale of 1–10, where **1** = *not annotated at all* and **10** = *thorough annotation throughout*. A detailed description of a good code annotation was provided in the protocol (Supporting Information).

8. Are the data/code citable and reusable?

Citation is another aspect of reusability, as the lack of a globally unique persistent identifier (e.g. a DOI) and/or license can make data/code impossible to reuse for some users, for example, US government employees. We recorded whether data/code had a DOI, and/or a license and if so, what type of license.

DATA ANALYSIS

The data were cleaned, summarised, and plotted in R version 4.5.2 (R Core Team, 2025) using the following R packages: janitor v. 2.2.1 (Firke, 2016), naniar v. 1.1.0 (Tierney & Cook, 2023), patchwork v. 1.3.2 (Pedersen, 2025) and tidyverse v. 2.0.0 (Wickham et al., 2019). We cleaned all data to

ensure consistency in how free text answers were categorised. We removed 23 records with data quality issues (papers 42, 1015, 1343, 1523, 1707, 1802, 1914, 3390, 3414, 3430, 3433, 3436, 3440, 5636, 6589, 6654, 6656, 6979, 7422 and 7453, plus two records where the paper number was not recorded, and a duplicate of paper 190). All data and code required to reproduce the analyses is available on Zenodo [removed to anonymise] and on GitHub under the open source MIT license at [removed to anonymise].

To summarise and visualise the data we removed missing values, and re-coded several options as follows. Data that were only available on request or were embargoed were coded as "No" for data availability and data archiving questions. Data or code that required specific software or were too large to be downloaded/opened were coded as "Maybe" for questions about whether data/code could be downloaded/opened. Where participants specified that some, but not all, data or code files could be downloaded or opened, we re-coded this as "Yes" on the principle that something is better than nothing.

Results

We collected data on 1,861 papers (~20% of all papers published in BES journals from 2017–2024). The papers were fairly evenly spread across the seven journals and years, and roughly reflected the percentages of papers published in each journal and/or year (Figure 1; Table S1). Results below focus on all journals combined, but journal-specific results are shown in Figures S1-S14. Recorder variability was low (mean % agreement ± SE = 91.7 ± 3.67), except for README quality and code annotation quality variables (data README quality: median = 8, range 3-8; code README quality: median = 4, range = 1–10; code annotation quality: median = 7, range = 2–10), so care should be taken in their interpretation (Figure S15).
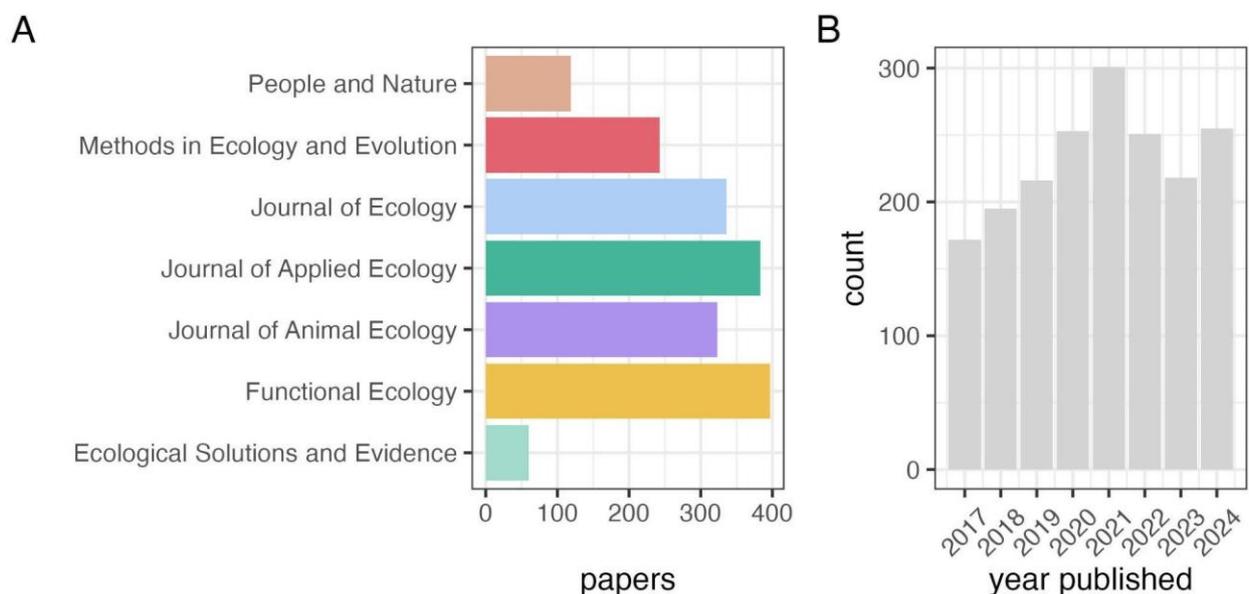
Figure 1: Number of papers in our dataset across (A) the seven BES journals and (B) years published (2017-2024). Colours in panel (A) are the official BES journal colours (https://besjournals.onlinelibrary.wiley.com/).

Does the paper use data/code? If so, are they archived?

Of the 1,861 papers in our dataset, 93% (n = 1,735) used data and 90% (n = 1,670) used code. Of these papers, 97% (n = 1,690) archived their data, but only 35% (n = 577) archived their code (Table S2, Figure 2). These numbers differed significantly across BES journals (Tables S3-S5). Almost all papers (>90%) in all journals used data, the lowest percentage was for *MEE* (75%) where papers often present software tools without using newly generated data (range excluding MEE = 92–98%). The percentage of papers using code was similarly high across all journals, except in the interdisciplinary journal *PAN* where only 62% used code (range excluding PAN = 88–94%). Rates of code archiving were low (overall 35%; range excluding MEE = 19–34%) in all journals except *MEE,* for which 89% of papers had archived at least some code (Tables S3-S4).
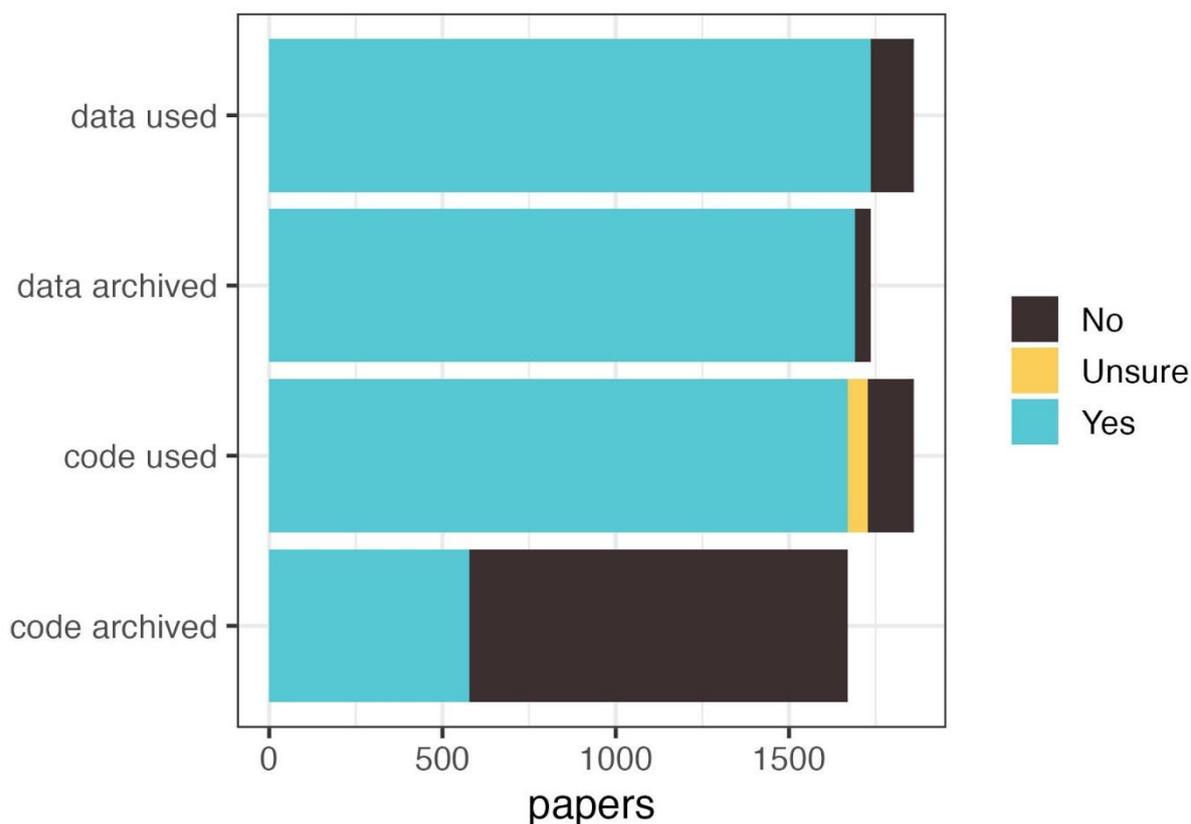

Figure 2: Number of papers in our dataset that use data or code, and whether these were formally archived. Data and code archived bars contain information only on papers that used data (n = 1,735) or code (n = 1,670) as appropriate.

1. *Where were the data/code archived?*

Overall, 57% of data files were archived in Dryad (n = 1,022), with smaller but substantial numbers archived in other repositories like Figshare (9%), Zenodo (12%) and various institutional and government repositories (17%; Figure 3A). The biggest repository for code was Zenodo (39%; n = 284), followed by GitHub, GitLab, Codeberg or similar platforms (24%; n = 177; Figure 3B). Note that 60% of code files that are hosted on GitHub or similar are also archived on Zenodo, which provides a permanent DOI. The BES archiving policy does not allow archiving at GitHub (or similar) alone (see Discussion).
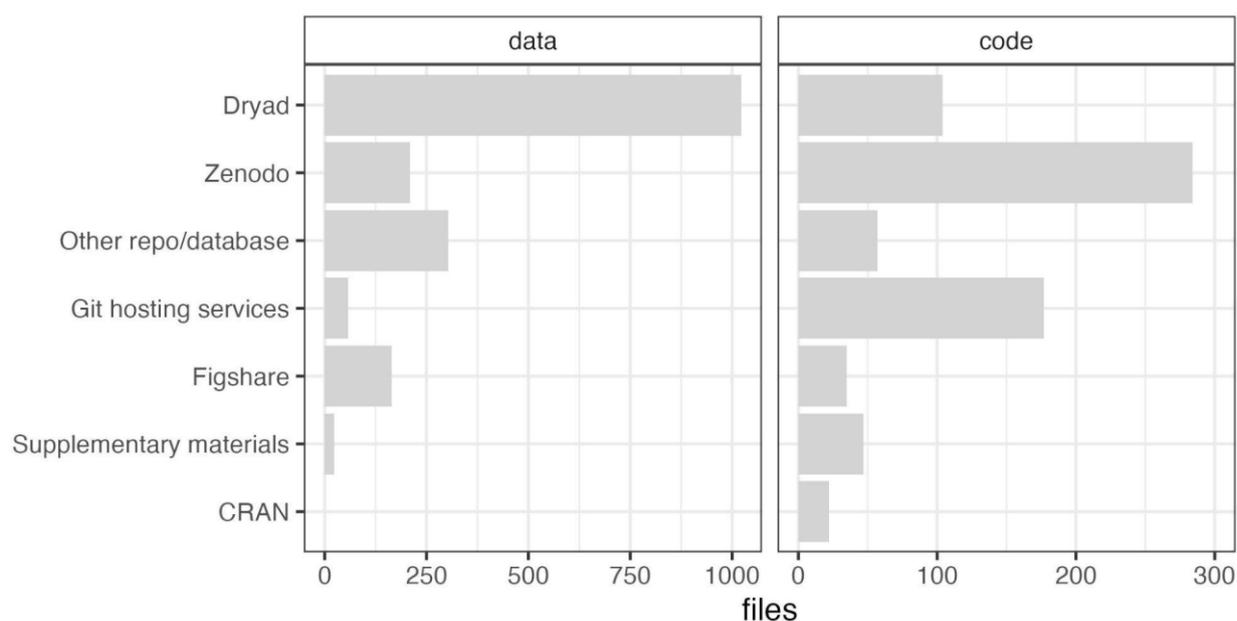

Figure 3: Archiving locations for archived data and code files from the papers in our dataset. Note the different x-axis scales for data and code. Two data files were archived on a personal website and have been omitted here to improve the clarity of the figure. Git hosting services represents an aggregate of GitHub, GitLab, Codeberg or similar platforms.

2. *Can the archived data/code be located, downloaded and opened?*

Of the 1,735 papers in our dataset that used data, 98% (n = 1,700) mentioned the data in the Data Availability statement and 97% archived data (n = 1,690; Table S2). For the 45 papers (<3%) where data were not archived, the data were either embargoed, available on request, or were not archived for privacy or security reasons. Of the 1,690 archived datasets, 97% could be accessed via the links provided in the Data Availability statement, 95% could be downloaded, and 91% could be opened (Table S2). These numbers differed slightly across BES journals (range = 91–99%; Table S3). A small number of datasets could not be downloaded or opened because they were too large or needed specific software to access (n = 41; Figure 4).

Of the 1,670 papers in our dataset that used code, only 35% (n = 577) archived it, and only 27% (n = 453, Table S2) mentioned code availability in the Data Availability statement. Of the 577 papers with archived code, 94% could be located, 93% could be downloaded, and 86% could be opened. These numbers differed slightly across BES journals; over 92% of files could be downloaded in all journals, whereas between 74% and 100% could be opened (Table S4). A small number of code files could not be downloaded or opened because they were too large or needed specific software to access (n = 34; Figure 4).
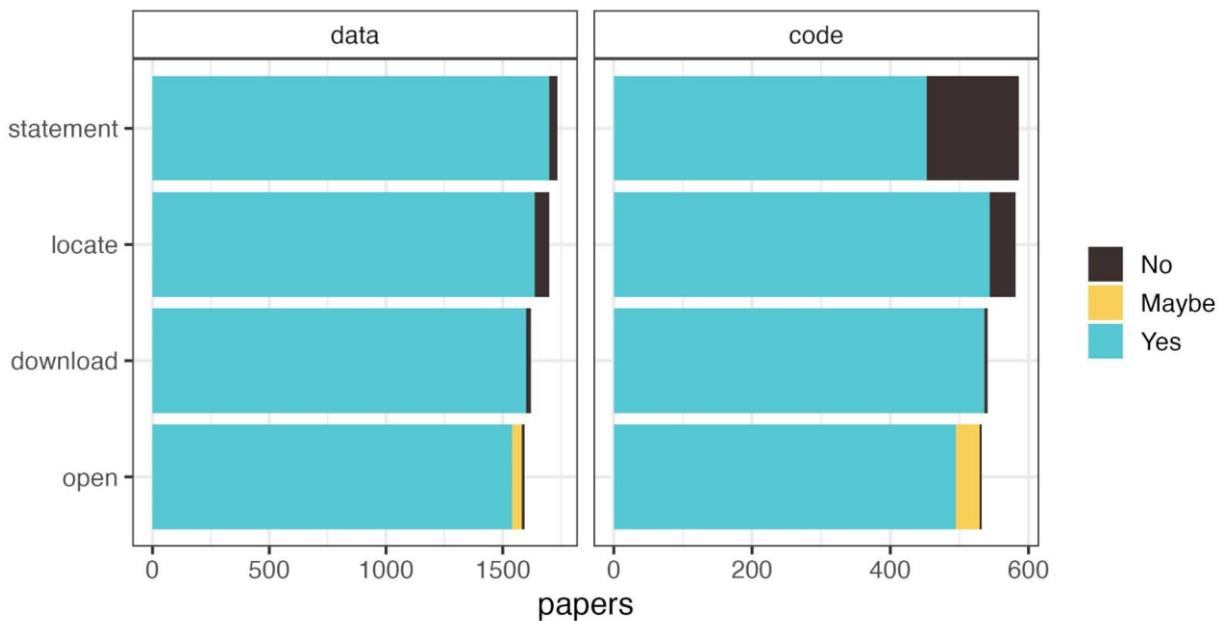

Figure 4: Number of papers where data or code were mentioned in the Data Availability statement, could be located via the link provided, could be downloaded, and could be opened. These plots only contain papers where data (n = 1,690) or code (n = 577) were archived. "Maybe" refers to files that were either too large or required specialist software to download/open. Note the different x-axis scales for data and code.

3. What file extensions do the archived data/code files use?

Data were saved with 96 different file extensions, and many papers archived multiple files with different file extensions. Of the 2,100 unique data file extensions recorded, 88% (n = 1,857) were saved with the following ten file extensions: .csv/.tsv, .doc(x), .fasta, .pdf, .rda /.rdata/.rds, .shp, .tif, .xls(x), .xml (Figure 5A). Code was primarily saved with seven different file extensions: .csv/.tsv, .doc(x), .html, .pdf, .txt, native source code (e.g. .R, .py, .jl), or notebook files (e.g. .qmd, .Rmd). Of the 645 unique code file extensions recorded, 73% (n = 473) were saved as native source code, e.g. R (.R), Python (.py) or Julia (.jl), and a further 16% (n = 101) were saved as notebook files containing native source code, e.g. Quarto, RMarkdown, or Jupyter notebooks (Figure 5B). Most code (77%, n = 497) was written in R (Figure S16).
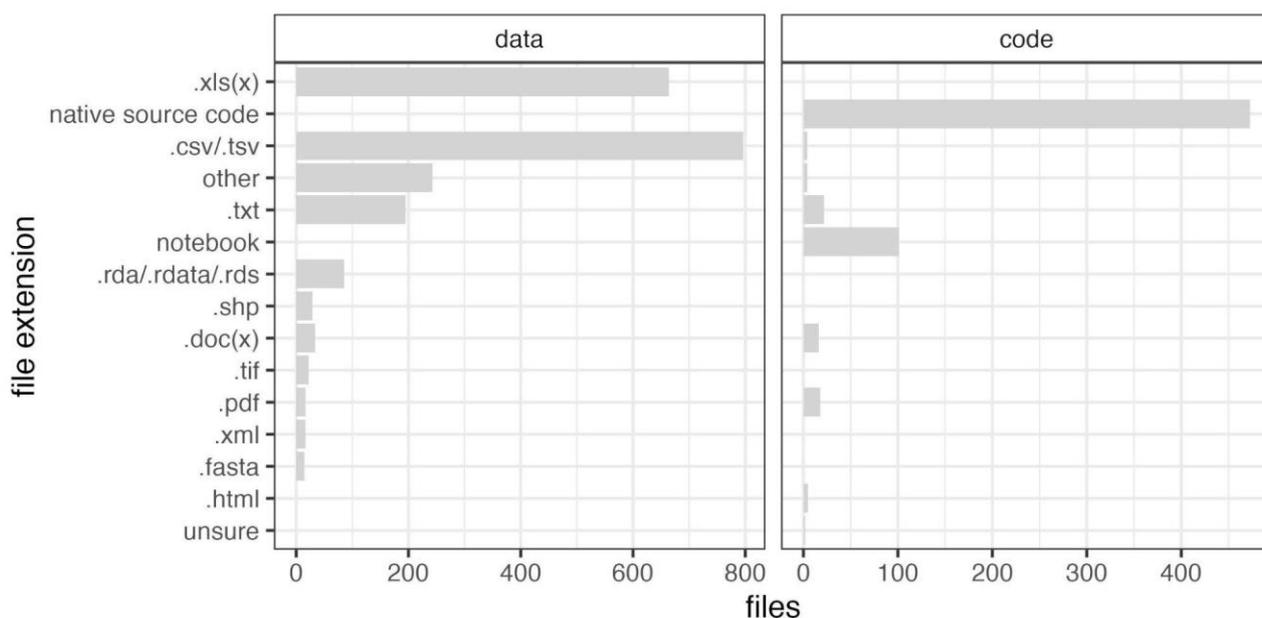
Figure 5: Number of files with unique file extensions recorded for archived data/code files. Only the top ten most recorded data file extensions are displayed, other formats are grouped together as "other". Native source code is code saved with R (.R), Python (.py), or Julia (.jl), etc. file extensions. Notebooks are either Quarto, RMarkdown, or Jupyter notebooks. Note the different x-axis scales for data and code.

4. Do the archived data/code have a README (or equivalent)? If so, how useful is it?

A README or equivalent was present for 66% (n = 1,114) and 61% (n = 351) of the papers with archived data or code respectively (Table S2). We did not record whether the same README was used for both data and code. The median README quality score was 7 for data and 6 for code (Figures 6A and 6B).

5. How complete is archived data?

Most datasets were scored as complete or as missing minor information (69% scored as complete; n = 1,087; Figure 6C). However, this should be considered an informed judgement about completeness, not verified reproducibility.

6. How good is the code annotation?

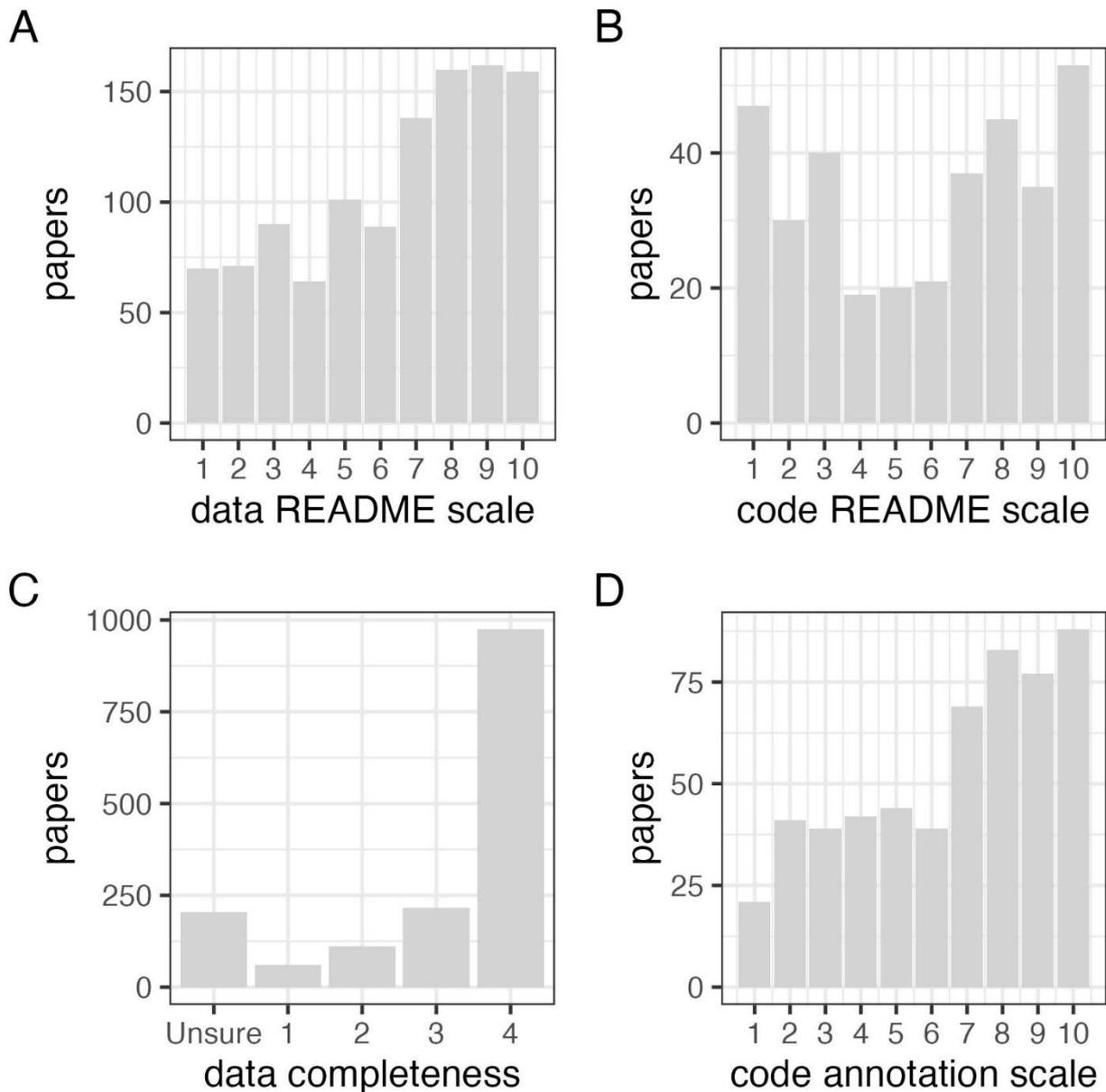The median code annotation quality score was 7 (range 1-10; Figure 6D).

Figure 6: README usefulness (A,B), data completeness (C) and code annotation score (D). For READMEs, scores range from 1 = very brief and incomplete to 10 = comprehensive (see protocol). For data completeness, 1 = low, 2 = fair, 3 = high, 4 = complete and "Unsure" means data recorders were unable to assess this. For code annotation, scores range from 1 = not annotated at all to 10 = thorough annotation throughout. Note the different y-axis scales across the four plots.

   7. Are the data/code citable?

Of the 1,690 papers with archived data, 91% (n = 1,543) had a DOI and 85% (n = 1,438) had a license (Table S2), with CC0 licenses (n = 1,076; the license used by Dryad) being most used (Figure 7A). Of the 577 papers with archived code, 79% (n = 457) had a DOI and 74% (n = 428) had a license (Table S2), with CC BY (n = 122; the license Zenodo uses by default) and CC0 licenses most used (n = 104; Figure 7B).
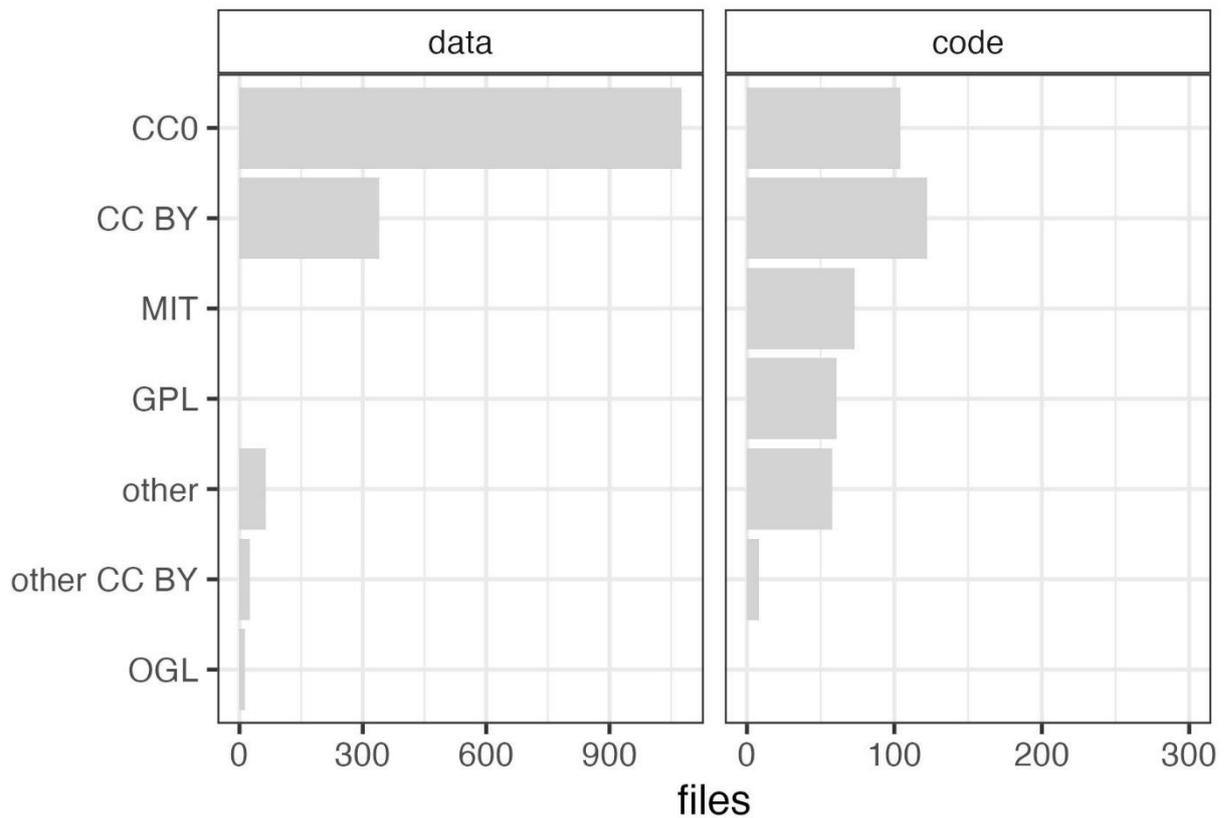
Figure 7: Number of files with unique licenses for archived data and code files. Note the different x-axis scales for data and code. Four files with "Unsure" license types have been removed from the code panel to improve readability. Other CC BY licenses include CC BY-NC, CC BY-ND, CC BY-SA and other combinations of those restrictions.

Discussion

The contrast between data- and code-archiving was a central finding of this study. Data archiving policies have achieved high compliance, and most archived datasets were accessible and citable. Code archiving, despite being required in many cases, remained uncommon; only 35% of papers using code archived it. For both data and code, however, the main limitation was not whether files could be located, downloaded or opened but whether they could be understood (and thus potentially reused) by someone outside the original research group. Documentation was frequently absent or insufficient, for example, around a third of papers lacked a README or similar to accompany their data and/or code, and many existing READMEs were not particularly useful. For code, even where code READMEs and annotation were rated highly, other factors are likely to impact the ability to reuse code, such as hard-coded paths, outdated package versions, and changes to hardware, among other flaws. Tools exist that can help with these issues (e.g. renv, docker; Merkel, 2014; Ushey & Wickham, 2026) but uptake has been slow. Overall, while the majority of data and code

archived technically met good practice criteria, many papers met only minimum requirements, meaning research integrity was low.

Our results here show higher rates of compliance than in broader studies of ecology and evolution journals (Culina et al., 2020; Roche et al., 2015, 2022). This may reflect the presence of data- and code-archiving policies at the BES journals, supporting meta-research showing that instituting such policies improves compliance rates (Ivimey-Cook, Sánchez-Tójar, et al., 2025; Sánchez-Tójar et al., 2025; Vines et al., 2013). However, good practice can plateau once policies are implemented unless further incentives are provided. The implementation and effectiveness of policies must therefore continue to be monitored and assessed. Allowing for reasonable exceptions due to privacy, security or sovereignty concerns (Carroll et al., 2020), there may be little room for improvement in the amount of data archived in papers published by the BES journals, but improvements to other aspects of data-archiving are still possible. Rates of code-archiving require extensive improvement, as does the quality of data and code documentation. Below we have identified six recommendations for future improvement.

Recommendations

1. **Authors should archive their code**. We understand there are technological, time, and expertise barriers to doing so, but there are resources that can help. The BES Guide to Reproducible Code (Cooper & Hsing, 2025) is an excellent starting point for learning more about making code more reproducible and thus easier to share. The TADA! and FAIR4RS guidelines are also excellent resources (Barker et al., 2022; Ivimey-Cook, Culina, et al., 2025). Software is an important output of many papers, thus retaining it for the future is of key importance (Di Cosmo & Zacchiroli, 2017).

2. **Journals should require a "Data and Code Availability Statement" section** rather than the commonly used "Data Availability Statement". In the papers we assessed, data and code were regularly archived together but the Data Availability statement often referred only to the data. An explicit "Data *and* Code Availability Statement" would support authors in structuring and reporting complete research archives of data and code. These statements should be presented in a structured and machine-readable format. Our study involved laborious manual parsing of Data Availability statements, which hinders continued meta-research on the topics discussed. Through coordination between journals, publishers, and funders, structured data and code availability statements could be key metadata to incorporate into publishing and funding management systems.

3. **Authors and journals should pay close attention to where data and code are being archived, using which file types**. Supplemental materials are not appropriate, as these are

not formally archived or connected to a globally unique persistent identifier like a DOI, so they can be (and have been) lost. Likewise, depositing code on GitHub, GitLab, Codeberg or similar is not sufficient (they are designed for version control, not archiving) unless the code is also deposited in a repository (e.g. Zenodo)and provided with a globally unique persistent identifier, for example a DOI. Additionally, archiving data and code with file extensions like .xls(x), .doc(x) and .pdf is not appropriate.

4. **Authors and journals should ensure minimum requirements for effective data- and code-archiving are met**. This includes providing all raw and processed data (or simulated data to run the code when the actual data cannot be shared, with any real processed/summarised data that can be shared), well-annotated code to run all analyses, a globally unique persistent identifier (e.g. a DOI), and appropriate licenses and documentation for example READMEs and worked examples or manuals. Optionally other data products such as supplemental materials from the paper could also be archived together with data and code. Note that data and code should have different licenses as standard CC licenses used for data are not intended for code (https://creativecommons.org/faq/#can-i-apply-a-creative-commons-license-to-software).

5. **Journals should provide clear and explicit guidelines for preparing data/code archives, in particular READMEs**. In the papers we assessed, READMEs were sometimes a file, sometimes a section within a data document (e.g. a tab in Excel) and varied in quality. We recommend these be separate files, and suggest some standards for what to include in Box 1. More journal or repository-specific templates and examples, along with training, would be helpful. We should aim to train everyone that the analysis is not finished until the README is completed to a high standard.

6. Finally, all of the above are easier if we **develop the habit of thinking about data- and code-archiving throughout the life cycle of a project**, not just when writing a data management plan at the start and before submitting/publishing a paper. Data management plans are excellent tools but they need to be updated/implemented regularly to be useful.

Journals have a major role to play in implementing these recommendations. We encourage journals to develop and enforce code-archiving policies (Ivimey-Cook, Sánchez-Tójar, et al., 2025), as it is difficult to make changes without incentives. Editors and reviewers should also be encouraged to pay more attention to data and code during assessment. One way to maximise the usefulness of data/code-archiving policies is to implement a mandatory checklist linked to instructions and examples during submission (or at resubmission) that ensures authors include essential features for their data and code. These should use existing guidelines, e.g. FAIR, FAIR4RS, TADA!, European

Open Science Cloud's Research Software MetaData (RSMD), STREAMS for microbiome data (Barker et al., 2022; Gruenpeter et al., 2024; Ivimey-Cook, Culina, et al., 2025; Kelliher et al., 2025; Wilkinson et al., 2016) to avoid "reinventing the wheel". *MEE*, however, (along with many other journals) already implements checklists and our results show this has not fixed all issues. We would, therefore, strongly encourage more journals to employ Data/Code Editors (Pick et al., 2025), to check data and code before publication. This would help to identify issues like incomplete data archives, poor documentation, missing metadata etc. Importantly, these editors should focus on implementing "good" rather than "perfect" practice, with respect to code-archiving in particular, following guidance in Pick *et al.* (2025). We want to encourage and empower people to share their code, not overwhelm them with overly complex technical solutions.

We also encourage learned societies and institutions to improve training for data- and code-archiving (Kohrs et al., 2023), particularly for early career researchers but also for senior researchers who struggle to keep up with current best practice in the area but are responsible for setting the standards and expectations for their research groups. Crucially, research funders should set clear expectations for data- and code-archiving practices, and explicitly encourage budgeting for data and research software engineering labour in grant applications. Good data- and code-archiving practices require dedicated, highly-skilled labour that is currently neither appropriately recognised nor systematically funded.

Conclusion

Mandatory data-archiving policies at the BES journals appear largely effective at ensuring data is archived and accessible, at least in the sample we analysed. The harder problem, which policies alone have not solved, was that while most papers met minimum data-archiving requirements, few authors engaged with practices that would make the data/code reusable. In addition, code-archiving remains uncommon even in journals with explicit requirements. Closing these gaps will require better documentation by authors, active quality checks through dedicated Data/Code Editors, institutional training, and funding structures that recognise data and code stewardship as skilled labour. The collaborative hackathon approach we used here could itself be a model other journal groups could adopt to monitor whether their policies are working as intended; and repeating such assessments at intervals would help the community track where further intervention is needed.

BOX 1: What is in a good data/code README?

- Information on the manuscript it came from.
- Contact details of at least one author.
- License information. Note that this can also be provided as a separate LICENSE file.
- Recommended citation for the data/code.
- A concise description of which data/code files are needed to reproduce specific analyses/figures/tables in the paper.
- For data:
  - A brief summary of how the data were collected, from where and when (as appropriate).
  - Sources of data if it was from a literature review.
  - A list of all data files, whether they contain raw or processed/cleaned/summarised data, and briefly what they contain, e.g. life history variables.
  - Column-by-column description of the data files, along with column headers, measurement units, allowed options for categorical variables, explanations of any abbreviations, and missing-data codes.
- For code:
  - A list of all scripts and what they do, i.e. processing, analysis, plotting etc. and what they output (e.g. table 1, figure 2). Detailed descriptions may be in the script files themselves, especially for functions, but the README should list the basics of what the scripts do.
  - Details of the workflow of the code if there are multiple scripts, i.e. what order do the scripts need to be run in?
  - Which data files are needed for each script.
  - The name of the software used (e.g. R), version, and names and versions of all packages required to run the analyses, along with any particular hardware or operating system requirements.

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Author contributions

NC: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualisation, Writing — original draft. BES Data and Code Hackathon Group (all other authors): Conceptualization, Data curation, Investigation, Methodology, Writing — review and editing. All authors approved the final version for submission.

Data and code availability statement

Anonymised data are available on Zenodo (link to be added). All code to reproduce the analyses is available on Zenodo (link to be added) and on GitHub under the MIT open source license: https://github.com/nhcooper123/reproduce-reuse-recycle.

Conflict of interest statement

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Affiliations

1 Science Group, Natural History Museum London, London, UK.
2 GFZ Helmholtz Centre for Geosciences, Germany.
3 UCL, Primary Care and Population Health, UK.
4 Centre for Statistics in Ecology, Environment and Conservation, Department of Statistical Sciences, University of Cape Town, South Africa
5 DSTI-NRF Centre of Excellence in Mathematical and Statistical Sciences (CoE-MASS), South Africa.
6 Honeybee Research Center, Faculty of Biological Sciences, Goethe University Frankfurt, Germany.
7 Université Marie et Louis Pasteur, CNRS, Chrono-environnement (UMR 6249), F-25000 Besançon, France.
8 Ecosystem Stewardship, Royal Botanic Gardens, Kew, London, UK.
9 Departamento de Ciências Biológicas, Programa de Pós-Graduação em Botânica, Universidade Estadual de Feira de Santana, Feira de Santana (UEFS), Avenida Transnordestina, s/n, Novo Horizonte, CEP 44036-900, Feira de Santana, BA, Brazil.
10 Natural History Museum, London, Cromwell Road, London, SW7 5BD, UK.
11 Anglia Ruskin University, East Road, Cambridge, CB1 1PT, UK.
12 University of Nottingham, Jubilee Campus, Wollaton Road, Nottingham, NG8 1BB, UK.
13 University of Surrey, Stag Hill, Guildford, GU2 7XH, UK.
14 Aarhus University, Department of Ecoscience, Frederiksborgvej 399, 4000 Roskilde, Denmark.
15 University of Cambridge, Department of Zoology, Cambridge, UK.
16 Theoretical Ecology, Institute of Biology, Freie Universität Berlin, Berlin, Germany
17 Department of Geobotany and Ecology, M.G.Kholodny Institute of Botany, NAS of Ukraine, Kyiv, Ukraine.
18 School of Biological Sciences, University of Aberdeen, Aberdeen AB24 2TZ, UK.
19 School of Geography and Environmental Sciences, University of Ulster, Coleraine, Northern Ireland, UK.
20 University of Sheffield, Western Bank
Sheffield, S10 2TN, UK.
21 Senckenberg Biodiversity and Climate Research Institute
Frankfurt am Main, 60325, Germany.
22 J.F. Blumenbach Institute of Zoology and Anthropology, University of Göttingen, Göttingen, Germany
23 Department of Life Sciences, National Chung Hsing University, Taichung City, Taiwan.
24 Biological and Environmental Sciences, University of Stirling, FK9 4LA, Scotland UK.
25 National Marine Science Centre, Southern Cross University, 2 Bay Drive, Coffs Harbour, Australia.
26 Smithsonian National Zoo and Conservation Biology Institute, Ca. Almirante Lord Cochrane 111, Of. 110, San Isidro, 15073 Lima, Peru.
27 School of Biological Sciences, Queen's University Belfast. 19 Chlorine Gardens, Belfast, BT9 5DL, UK.
28 Natural History Museum, Cromwell Rd, South Kensington, London SW7 5BD, UK
29 University of Exeter, Stocker Rd, Exeter, EX4 4PY, UK.
30 School of Mathematics, Statistics and Actuarial Science, University of Essex, Colchester, CO4 3SQ, UK.
31 Animal Ecology Unit, Research and Innovation Centre (CRI), Fondazione Edmund Mach, San Michele all'Adige, Italy.
32 Centre of Research into Ecological and Environmental Modelling, School of Mathematics and Statistics, University of St Andrews, St Andrews, UK.
33 Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK.
34 Ecology, Department of Biology, University of Konstanz, Universitatsstrasse 10, 78457 Konstanz, Germany.
35 School of Biosciences and Veterinary Medicine, Plant Diversity and Ecosystems Management Unit, University of Camerino, Camerino, Italy.

36 Department of Biodiversity Sciences, University of Turku, Turku, Finland

37 Turku Collegium for Science, Medicine and Technology, University of Turku, Turku, Finland

38 Department of Zoology, University of Jos, Jos, Nigeria.

39 School of Life Sciences, William Smith Building, Keele University, Staffordshire, ST5 5BG, UK.

40 Department of Evolutionary Biology, University of Bielefeld, Bielefeld, Germany.

41 Institute of Hydrobiology, Faculty of Environmental Sciences, Technische Universitaet Dresden, 01062 Dresden, Germany.

42 Pacific Northwest National Laboratory's Joint Global Change Research Institute, 5825 University Research Ct, College Park, MD 20740, USA.

43 Institute of Earth Sciences, University of Lausanne, Lausanne, 1015 Switzerland.

44 UK Centre for Ecology & Hydrology, Wallingford, OX10 8BB, UK.

45 Butterfly Conservation, Manor Yard, East Lulworth, Wareham, Dorset, UK

46 UK Centre for Ecology & Hydrology, Crowmarsh Gifford, Wallingford, Oxfordshire, UK.

47 Programa de Pós Graduação em Diversidade Biológica e Conservação nos Trópicos, Instituto de Ciências Biológicas e da Saúde, Universidade Federal de Alagoas (UFAL), CEP 57072-900, Maceió, Alagoas, Brazil.

48 Chicago Botanic Garden, 1000 Lake Cook Rd., Glencoe, IL, 60022, USA

49 Northwestern University, 2145 Sheridan Rd., Evanston, IL, 60208, USA.

50 University of Exeter, Centre for Ecology and Conservation, Penryn, UK.

51 Department of Biological Sciences and Bjerknes Centre for Climate Research, University of Bergen, Norway.

52 Open Source Program Office, Syracuse University, Syracuse, NY, USA.

53 Geography, Earth and Environmental Sciences and BIFoR - Birmingham Institute of Forest Research, University of Birmingham, Birmingham, UK.

54 SRUC Aberdeen, Ferguson Building, Craibstone Estate, Bucksburn, Aberdeen, AB21 9YA, UK.

55 School of Biosciences, University of Sheffield, Sheffield, UK.

56 Independent Researcher, Newcastle-upon-Tyne, NE5 3YF, UK.

57 Organismal and Evolutionary Biology, Faculty of Biological and Environmental Sciences, University of Helsinki, P.O. Box 4 (Yliopistonkatu 3), 00014, Helsinki, Finland.

58 Department of Biological Sciences and Bjerknes Centre for Climate Research, University of Bergen, Bergen, Norway.

59 Leibniz Institute for the Analysis of Biodiversity Change, Museum Koenig, Adenauerallee 127, 53113 Bonn, Germany.

60 Department of Ecology and Evolutionary Biology, University of Toronto, Canada.

61 School of Applied Sciences, University of the West of England, Bristol, UK.

62 Faculty of Health and Life Sciences, University of Bristol, Bristol, BS8 1TU, UK.

63 Institute for Game and Wildlife Research, IREC (CSIC-UCLM-JCCM), Ciudad Real, Spain.

64 School of Natural Sciences, University of Lincoln, Brayford Pool, Lincoln LN6 7TS, UK.

65 Department of Biology, University of Oxford, Life & Mind Building, South Parks Road, Oxford, OX1 3EL, UK.

66 Department of Earth Sciences, University College London, Gower Street, London WC1E 6BT, UK.

67 Department of Wildlife, Fish and Environmental Studies, Swedish University of Agricultural Sciences, Umeå, Sweden.

68 Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland.

69 Centre for Biodiversity and Environment Research, Department of Genetics, Evolution and Environment, University College London, London, WC1E 6BT, UK.

70 Department of Biological and environmental sciences, University of Stirling, Stirling, FK9 4LA, UK.

71 Center for Ecological Dynamics in a Novel Biosphere (ECONOVO), Department of Biology, Aarhus University, Ny Munkegade 114, DK-8000 Aarhus C, Denmark.

72 Département de sciences biologiques, Université de Montréal, 1375 Avenue Thérèse-Lavoie-Roux, Montréal, Québec H2V 0B3, Canada.

73 MARE-Marine and Environmental Sciences Centre/ARNET-Aquatic Research Network, Regional Agency for the Development of Research, Technology and Innovation (ARDITI), Funchal, Portugal.

74 Royal Holloway, University of London, Egham Hill, Egham, Surrey, TW20 0EX, UK.

75 University of Maine, School of Marine Sciences, Darling Marine Center, 193 Clarks Cove Road, Walpole, ME 04573, USA.

76 Department of Organismal and Evolutionary Biology, Faculty of Biological and Environmental Sciences, University of Helsinki, P.O. Box 4 (Yliopistonkatu 3), 00014 Helsinki, Finland.

77 Department of Botany, Panjab University, Chandigarh 160014, India

78 ICAR National Bureau of Plant Genetic Resources, New Delhi 110012, India.

79 University of Aberdeen School of Biological Sciences, Zoology Building, Tillydrone Avenue, Aberdeen, AB24 2TZ, UK.

80 Ashmole Academy, Southgate, London, UK.

81 University of Naples Federico II, Complesso Universitario MSA, Via Cintia 26, 80126, Naples, Italy.

82 Department of Biological Sciences, University of Alberta, CW 405, Biological Sciences Building, Edmonton, AB T6G 2E9, Canada.

83 Dept. of Photogrammetry and Remote Sensing, Faculty of Geodesy and Geomatics Engineering, K. N. Toosi University of Technology, Tehran, Iran.

84 Departement de Biologie, Universite de Moncton, Moncton, 18, Antonine-Maillet, New Brunswick, E1A 3E9, Canada.

85 Department of Biology, University of Turku, Turku, Finland.

86 School of Biodiversity, One Health and Veterinary Medicine, University of Glasgow, UK.

87 Department of Ecology, Brandenburg University of Technology Cottbus-Senftenberg, Konrad-Wachsmann-Allee 6, 03046 Cottbus, Germany.

88 Institute for biodiversity and Ecosystem Dynamics (IBED), University of Amsterdam, Sciencepark 904,1098 XH Amsterdam, The Netherlands

89 Faculty of Agricultural Sciences, Universidad Nacional de Colombia, Sede Bogotá, Cra 30 # 45 - 03, Bogotá, Colombia.

90 Research Institute of Organic Agriculture (FiBL), Department of livestock sciences, Ackerstrasse 113, 5070 Frick, Switzerland.

91 British Ecological Society, London, UK.

92 Department of Zoology, University of Cambridge, Cambridge, UK.

93 Centro de Investigaciones sobre Desertificación (CIDE-CSIC-UV-GV), Ctra. Náquera Km. 4.5, 46113 Moncada (Valencia), Spain.

94 Sveriges lantbruksuniversitet, Uppsala, Sweden.

95 Center for Ecological Sciences, Indian Institute of Science, Bangalore, Karnataka, India.

96 School of Earth & Environmental Sciences, University of St Andrews, Bute Building, Queen's Terrace, St Andrews, KY16 9TS, UK.

97 Earthwatch Europe, 102-104 St Aldate's, Oxford OX1 1BT, UK.

98 School of Biodiversity, One Health and Veterinary Medicine, University of Glasgow, Glasgow, UK.

99 Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN, USA.

100 Ecology/Macroecology Lab, Institute for Biochemistry and Biology, University of Potsdam, Potsdam, Germany.

101 Wildlife Health, Pathobiology and Population Sciences, Royal Veterinary College, Hatfield, Hertfordshire, UK.

102 Organismal and Evolutionary Biology, Faculty of Biological and Environmental Sciences, University of Helsinki, P.O. Box 4 (Yliopistonkatu 3), 00014 Helsinki, Finland.

103 University of Wisconsin Madison, Department of Forest and Wildlife Ecology, Russell Laboratories, 1630 Linden Dr Room 240, Madison, WI 53706, UK.

104 Evolution & Ecology Research Centre, School of Biological, Earth & Environmental Sciences, University of New South Wales, Kensington, Sydney 2052 NSW, Australia.

105 Forest Science and Technology Centre of Catalonia, Ctra de Sant Llorenç de Morunys, km 2, 25280 Solsona, Lleida, Spain

106 Joint Research Unit CTFC - AGROTECNIO - CERCA, Av. Alcalde Rovira Roure 191, E-25198 Lleida, Spain.

107 Natural History Museum, Cromwell Road, London, SW7 5BD, UK

108 Universidade de São Paulo, São Paulo, Brazil.

109 Natural History Museum, Cromwell Rd, South Kensington, London, SW7 5BD, UK.

110 Falz-Fein Biosphere Reserve "Askania Nova" of the National Academy of Agrarian Sciences of Ukraine, Kyiv, Ukraine

111 Ukrainian Bat Rehabilitation Center, Kharkiv, Ukraine.

112 Falz-Fein Biosphere Reserve "Askania Nova" of the National Academy of Agrarian Sciences of Ukraine, Kyiv, Ukraine

113 V.N. Karazin Kharkiv National University, Kharkiv, Ukraine.

114 Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3AE, UK.

115 Department of Zoology and Animal Biodiversity, Animal Conservation and Biology, University of Antananarivo, Antananarivo, Madagascar.

116 Louisiana State University, Baton Rouge, LA, USA.

117 Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3AB, UK.

118 University of Maine, Maine Agricultural and Forest Experiment Station, USA.

119 Centre for Ecology and Conservation, University of Exeter, Cornwall, UK.

120 Wolfson Link Building, School of Biodiversity, One Health and Veterinary Medicine, University of Glasgow, Glasgow, G12 8QQ, UK.

121 University of Aberdeen, Tillydrone Ave, Aberdeen, AB24 2TZ, UK.

122 University of Potsdam, Inst. for Biochemistry and Biology, D-14469 Potsdam, Germany.

123 German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Leipzig, Germany

124 Department of Computer Science, Martin Luther University Halle-Wittenberg, Halle (Saale), Germany.

125 Czech Academy of Sciences, Prague, Czechia.

126 Universidade Federal do Espírito Santo, Departamento de biologia, Av. Fernando Ferrari, 550, Vitória, Espírito Santo, Brazil.

127 Centre for Ecological Sciences, Indian Institute of Science, Bengaluru, India.

128 Earlham Institute, Norwich Research Park, Colney Ln, Norwich NR4 7UZ, UK.

129 Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, 20-290 Lublin, Poland.

130 Institute of Rock Structure and Mechanics, Czech Academy of Sciences, V Holešovičkách 41, Prague, 18200, Czechia.

131 Unaffiliated, West Sussex, UK.

132 CNC-UC, Center for Neuroscience and Cell Biology, University of Coimbra, Portugal

133 CIBB, Center for Innovative Biomedicine and Biotechnology, University of Coimbra, Portugal.

134 Centro Oceanográfico de Gijón, IEO-CSIC, 33212, Asturias, Spain.

135 Department of Zoology, University of Cambridge, Cambridge, CB2 3EJ, UK.

136 Natural History Museum, Cromwell Road, London, SW7 5BD, UK.

137 Department of Biological Sciences, Louisiana State University, Baton Rouge 70803, Louisiana, USA

138 The State of India's Birds Partnership, India.

139 Infectious Disease Ecology and Modelling Team, The Kids Research Institute Australia, Nedlands, Australia

140 School of Physics, Mathematics and Computing, University of Western Australia, Perth, Australia.

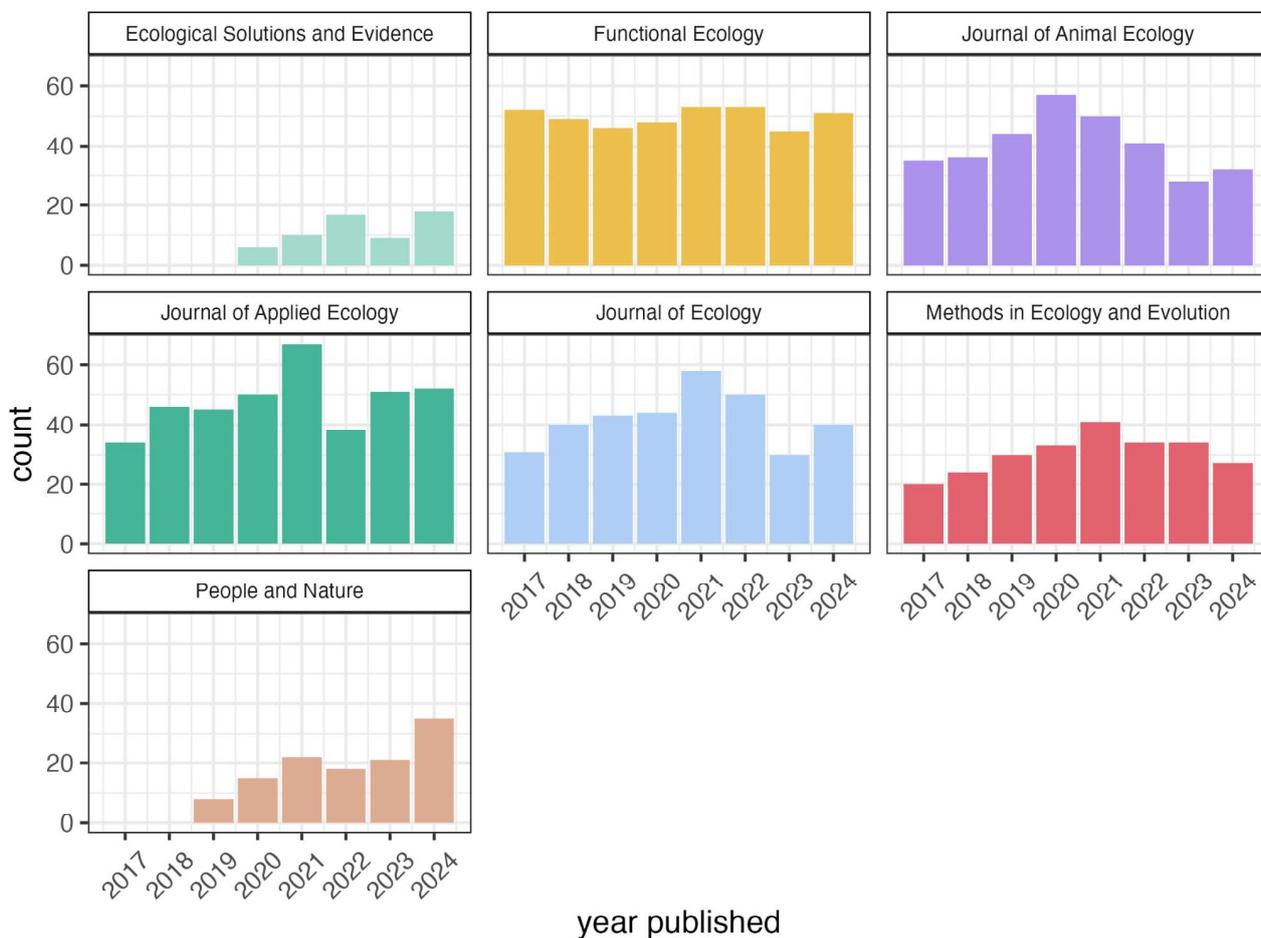<div align="center">

Supporting Information for:

Data- and code-archiving in the British Ecological Society journals: present status and recommendations for future improvements.
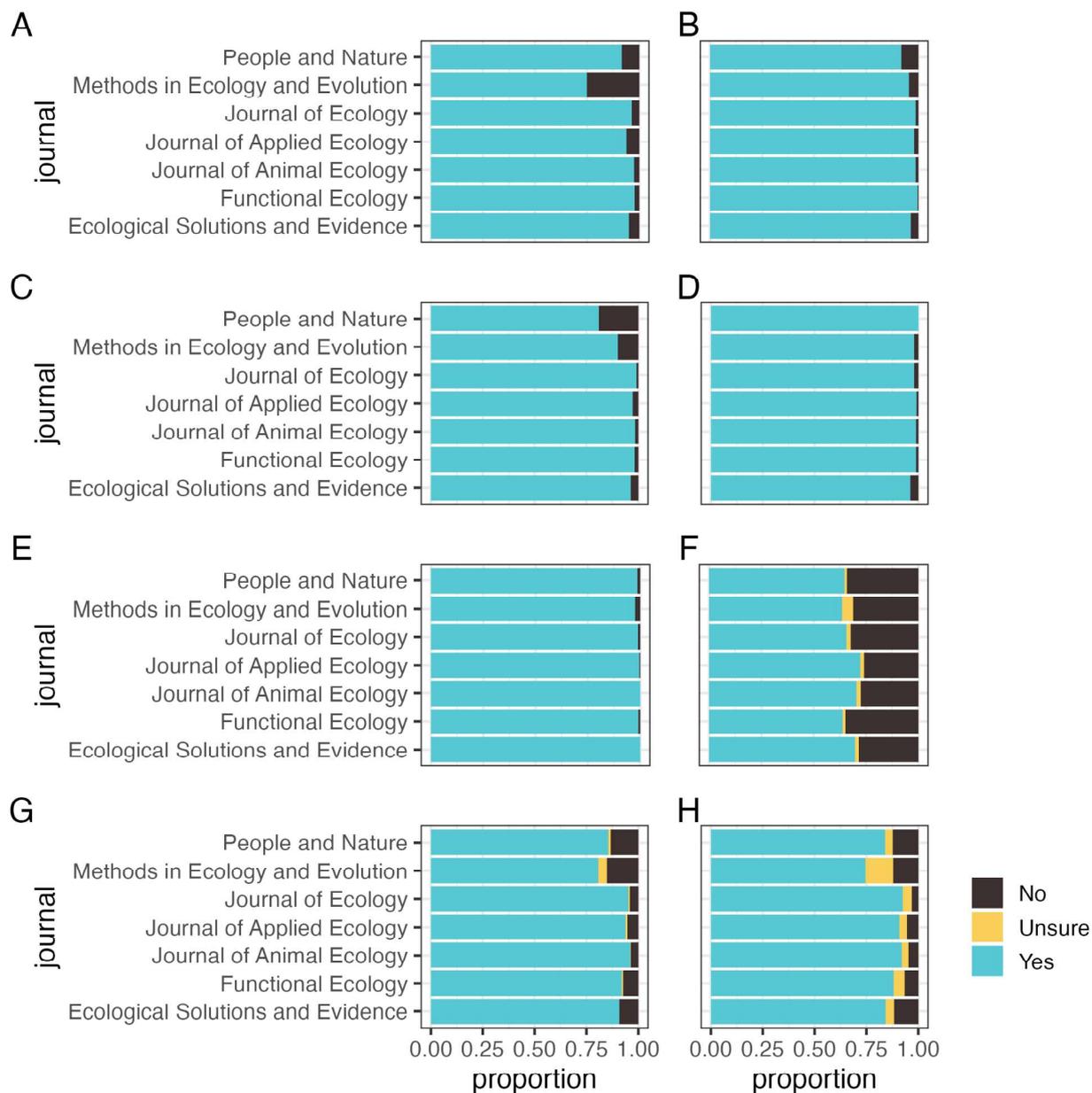
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Supplementary Figures

Results figures separated by journal

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Colours are the official BES journal colours (https://besjournals.onlinelibrary.wiley.com/).

Figure S2: Data-archiving variables across the seven BES journals.
Proportion of papers in each journal where (A) data were used in the paper; (B) data were archived; (C) there was a working link to the archived data; (D) archived data could be downloaded; (E) archived data could be opened; (F) archived data had a README or equivalent; (G) archived data had a DOI (digital object identifier); and (H) archived data had a license. Plots show the proportion of papers in each category, excluding NAs. All panels, other than the used and archived panels, contain data only for papers where data were archived.
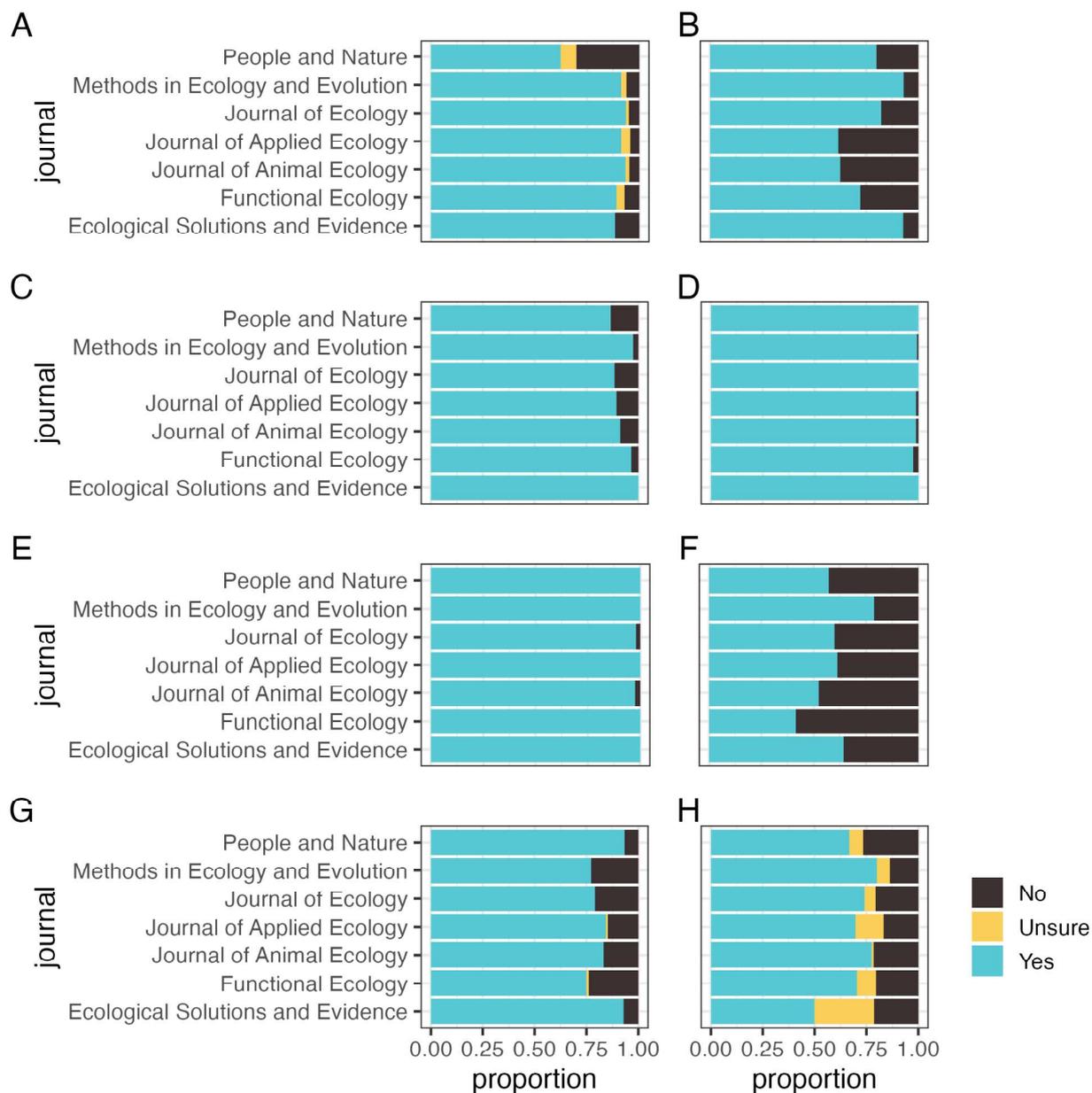
Figure S3: Code-archiving variables across the seven BES journals.

Proportion of papers in each journal where (A) code was used in the paper; (B) code was archived; (C) there was a working link to the archived code; (D) archived code could be downloaded; (E) archived code could be opened; (F) archived code had a README or equivalent; (G) archived code had a DOI (digital object identifier); and (H) archived code had a license. Plots show the proportion of papers in each category, excluding NAs. All panels, other than the used and archived panels, contain data only for papers where code was archived.
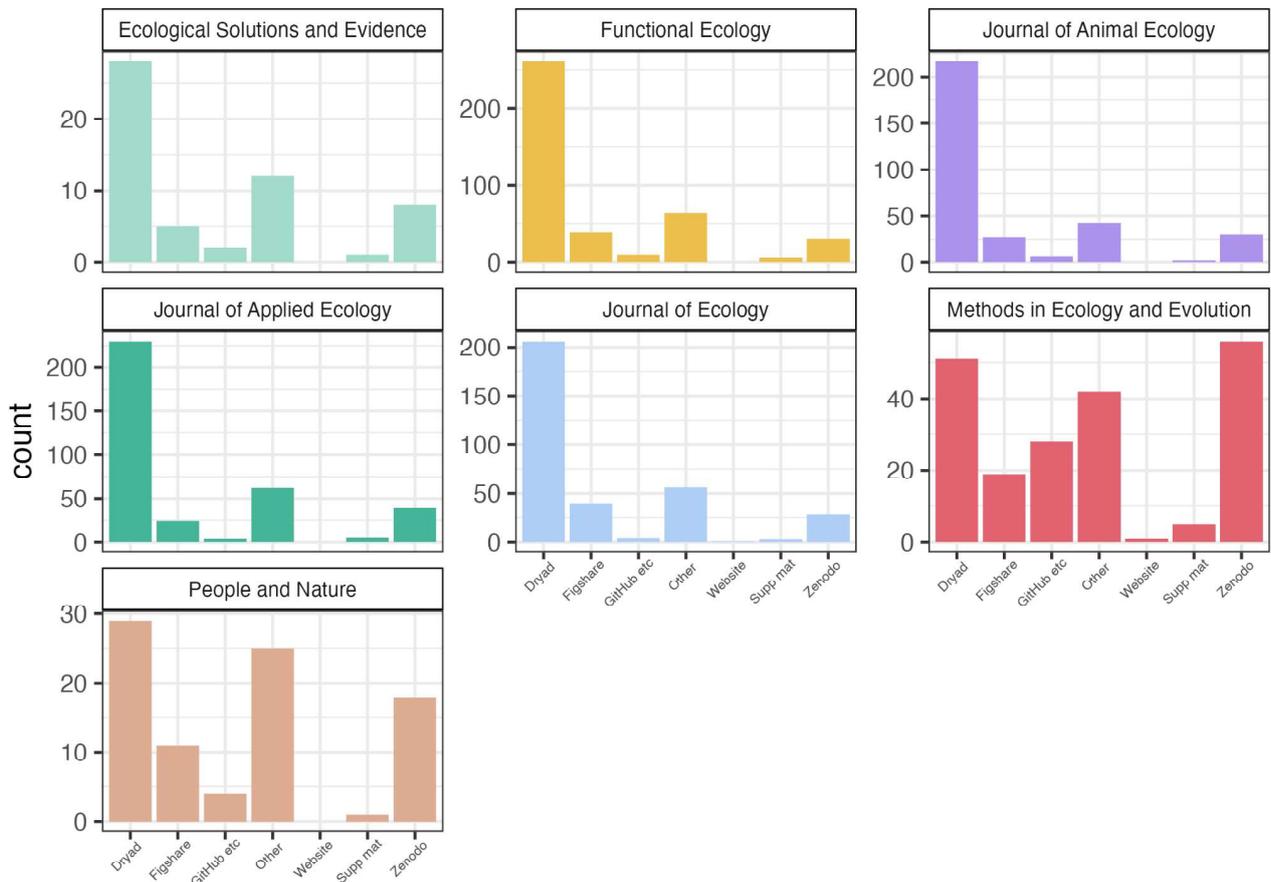
Figure S4: Archive location for archived data across the seven BES journals.

GitHub etc. represents an aggregate of Github, GitLab, Codeberg or similar platforms. Other includes institutional repositories and subject specific repositories (e.g. MoveBank). Note the different y-axis scales for each plot. Colours are the official BES journal colours (https://besjournals.onlinelibrary.wiley.com/).
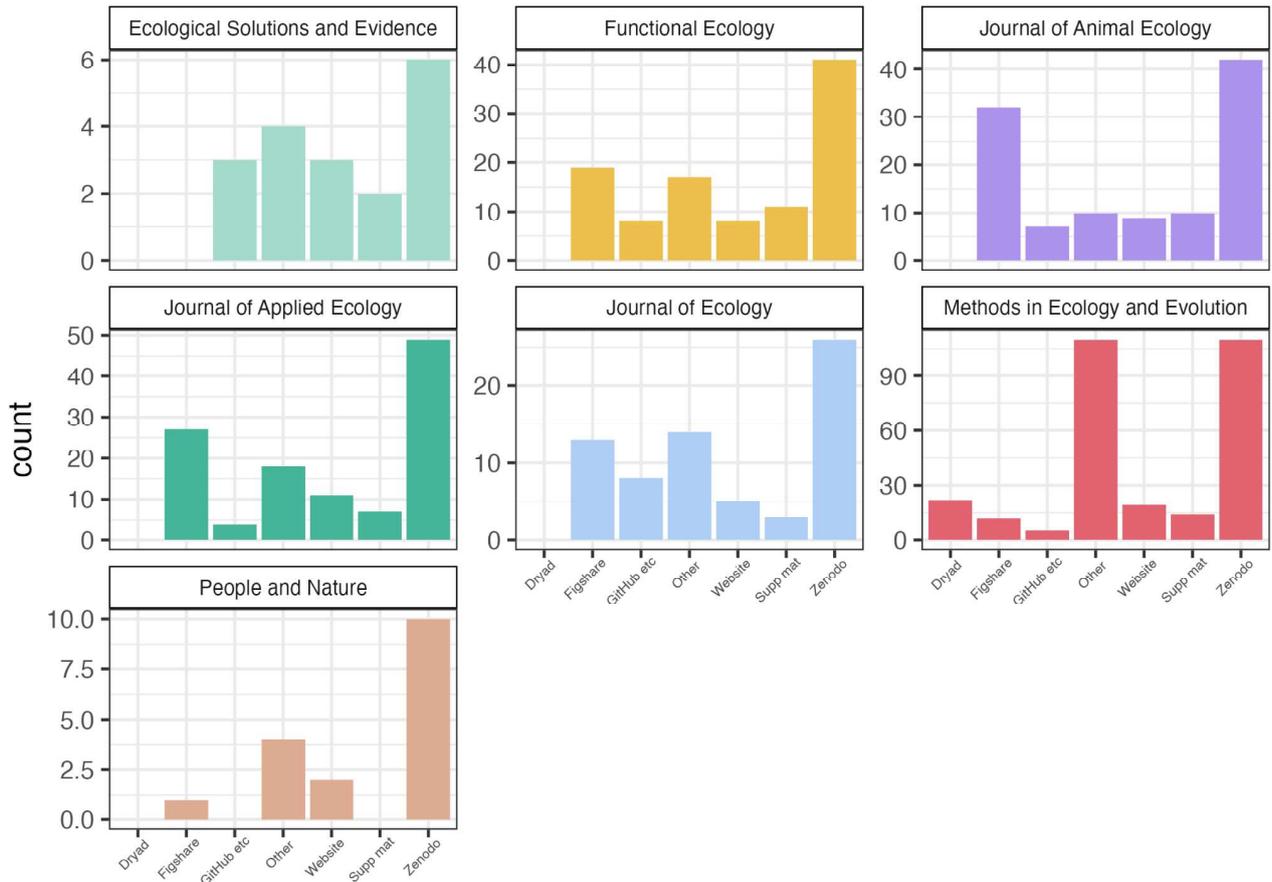
Figure S5: Archive location for archived code across the seven BES journals.

GitHub etc. represents an aggregate of Github, GitLab, Codeberg or similar platforms. Other includes institutional repositories and subject specific repositories (e.g. MoveBank). Note the different y-axis scales for each plot. Colours are the official BES journal colours (https://besjournals.onlinelibrary.wiley.com/).
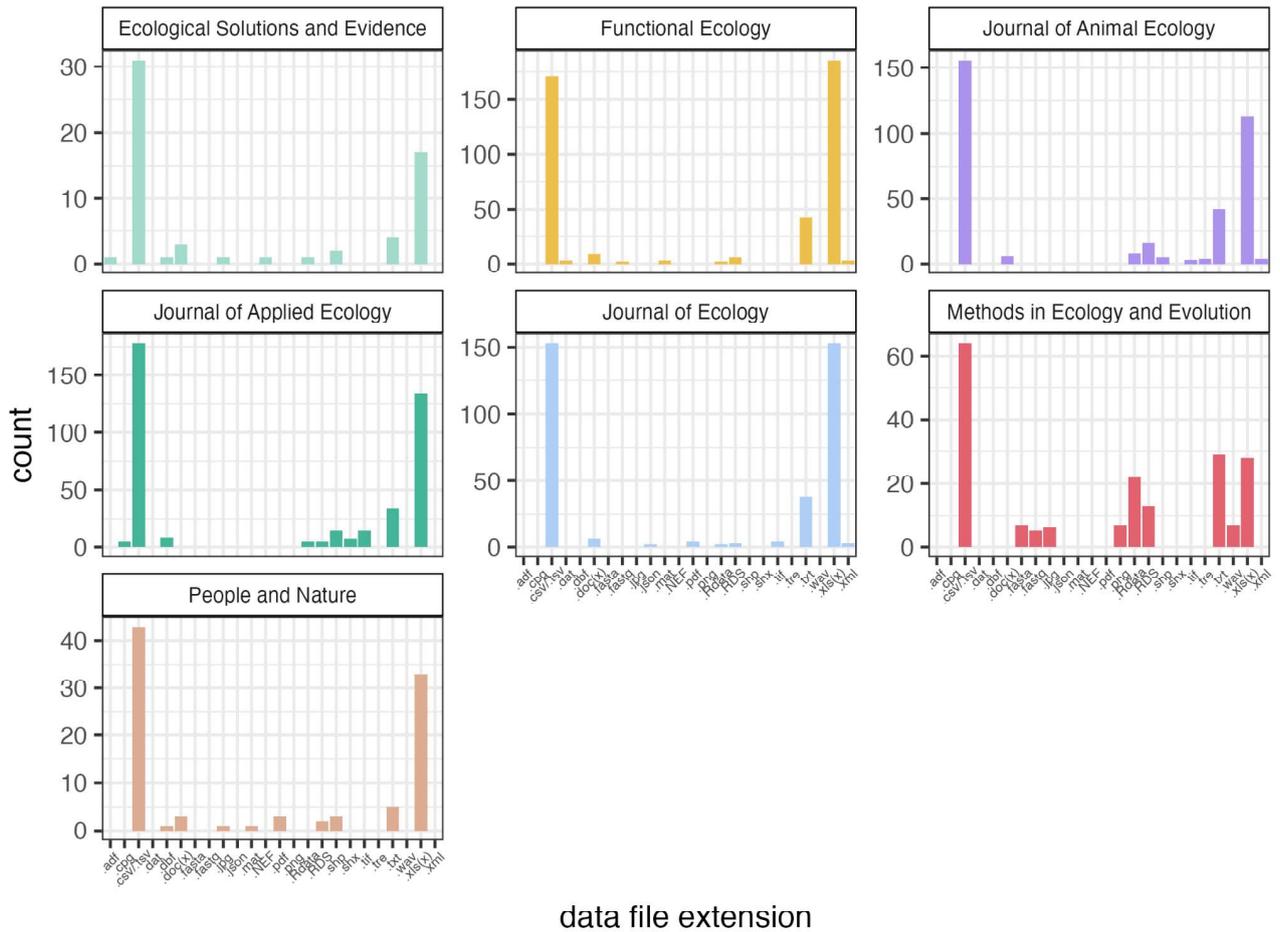
Figure S6: File extensions for archived data across the seven BES journals.

Numbers are data files with unique file extensions. Note the different y-axis scales for each plot. Colours are the official BES journal colours (https://besjournals.onlinelibrary.wiley.com/).
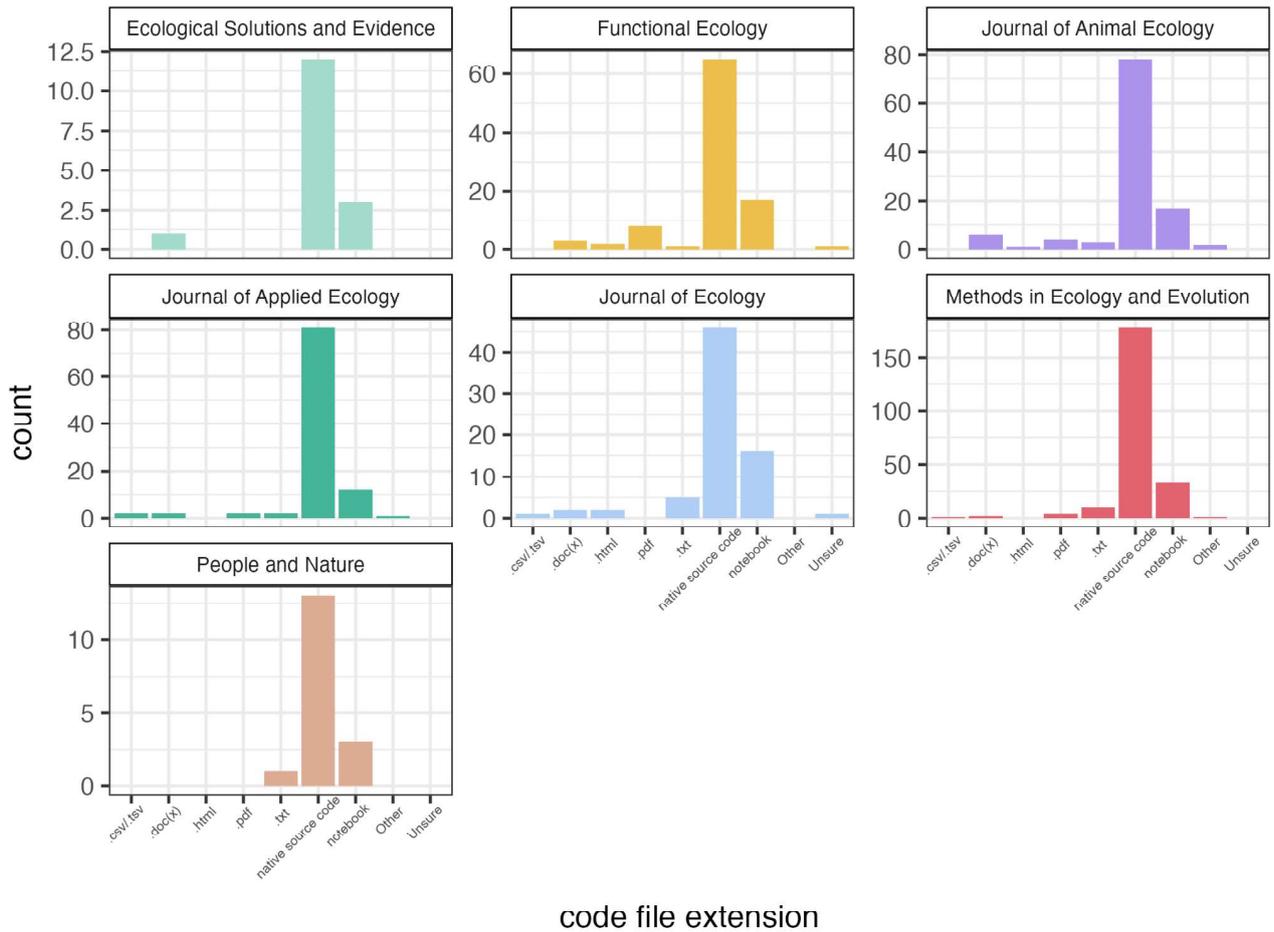
Figure S7: File extensions for archived code across the seven BES journals.

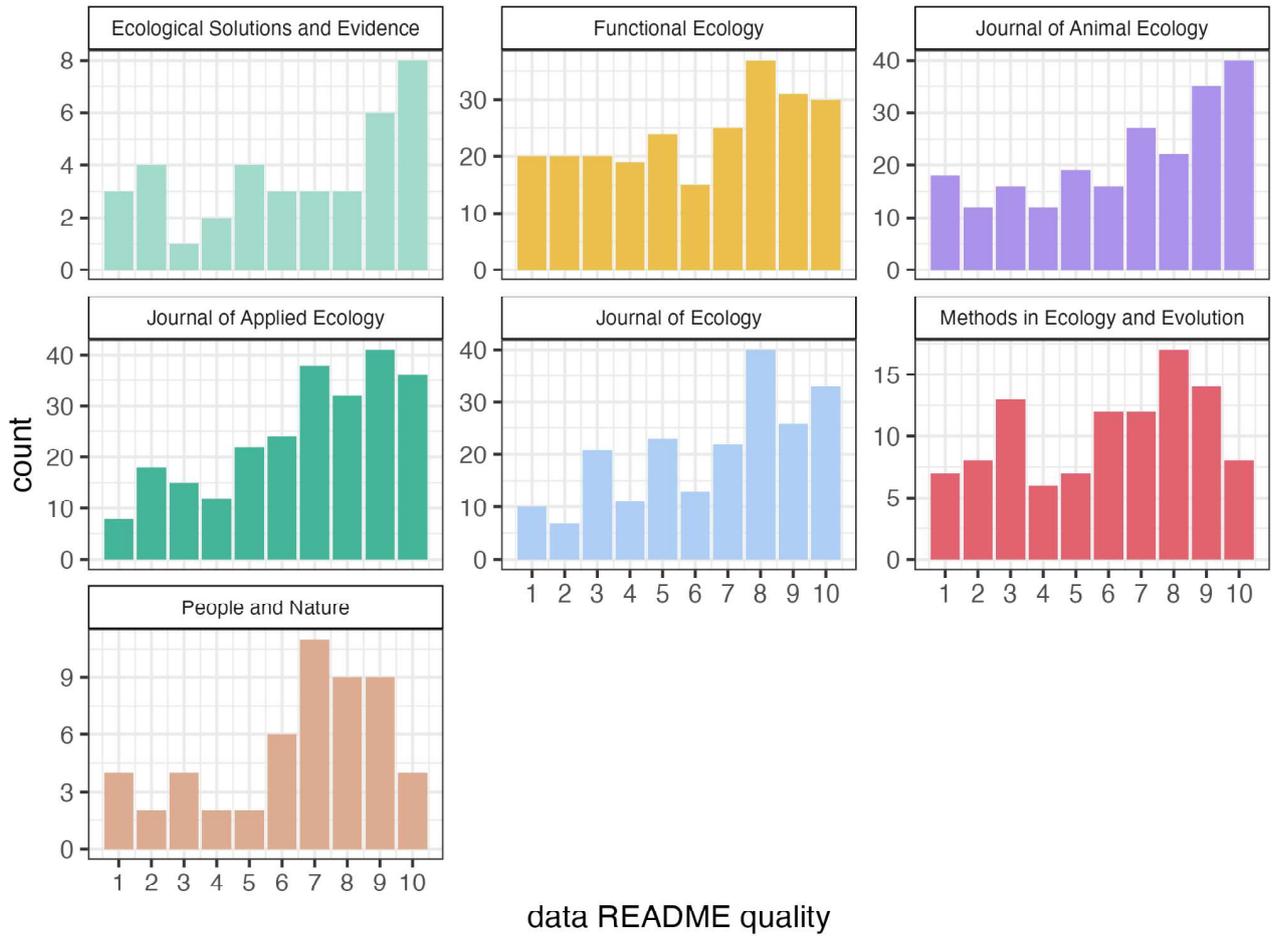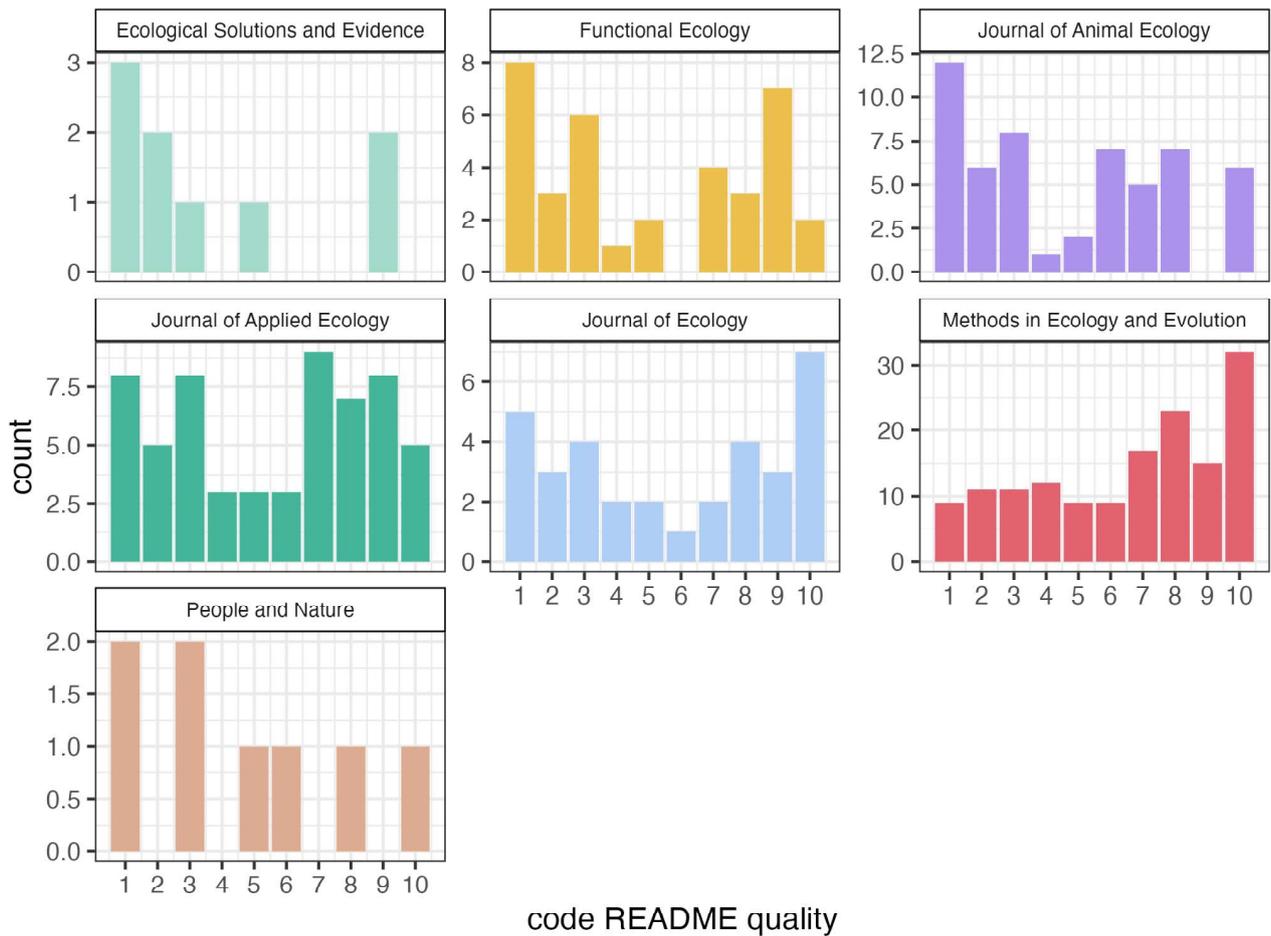Numbers are code files with unique file extensions. Note the different y-axis scales for each plot. Colours are the official BES journal colours (https://besjournals.onlinelibrary.wiley.com/).

Figure S8: README quality for archived data across the seven BES journals.

Note the different y-axis scales for each plot. The median score for all journals is 7, except for *Methods in Ecology and Evolution* where the median is 6. Colours are the official BES journal colours (https://besjournals.onlinelibrary.wiley.com/).
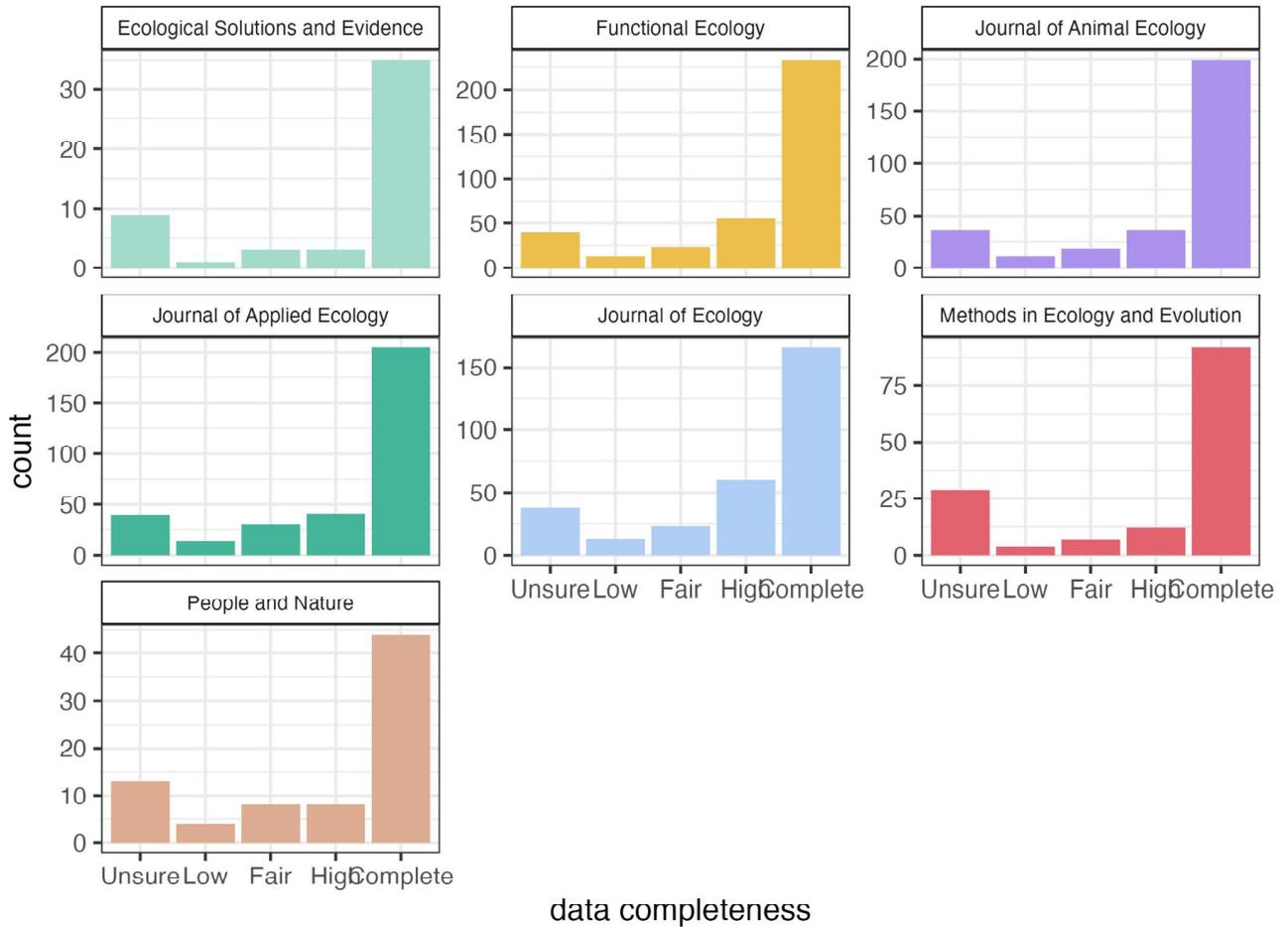
Figure S9: README quality for archived code across the seven BES journals.

Note the different y-axis scales for each plot. The median score for each journal was as follows. *Methods in Ecology and Evolution* = 7, *Journal of Applied Ecology* and *Journal of Ecology* = 6, *Functional Ecology* and *Journal of Animal Ecology* = 4.5, *People and Nature* = 4, *Ecological Solutions and Evidence* = 2. Colours are the official BES journal colours (https://besjournals.onlinelibrary.wiley.com/).

Figure S10: Data completeness for archived data across the seven BES journals.

Note the different y-axis scales for each plot. Colours are the official BES journal colours (https://besjournals.onlinelibrary.wiley.com/).
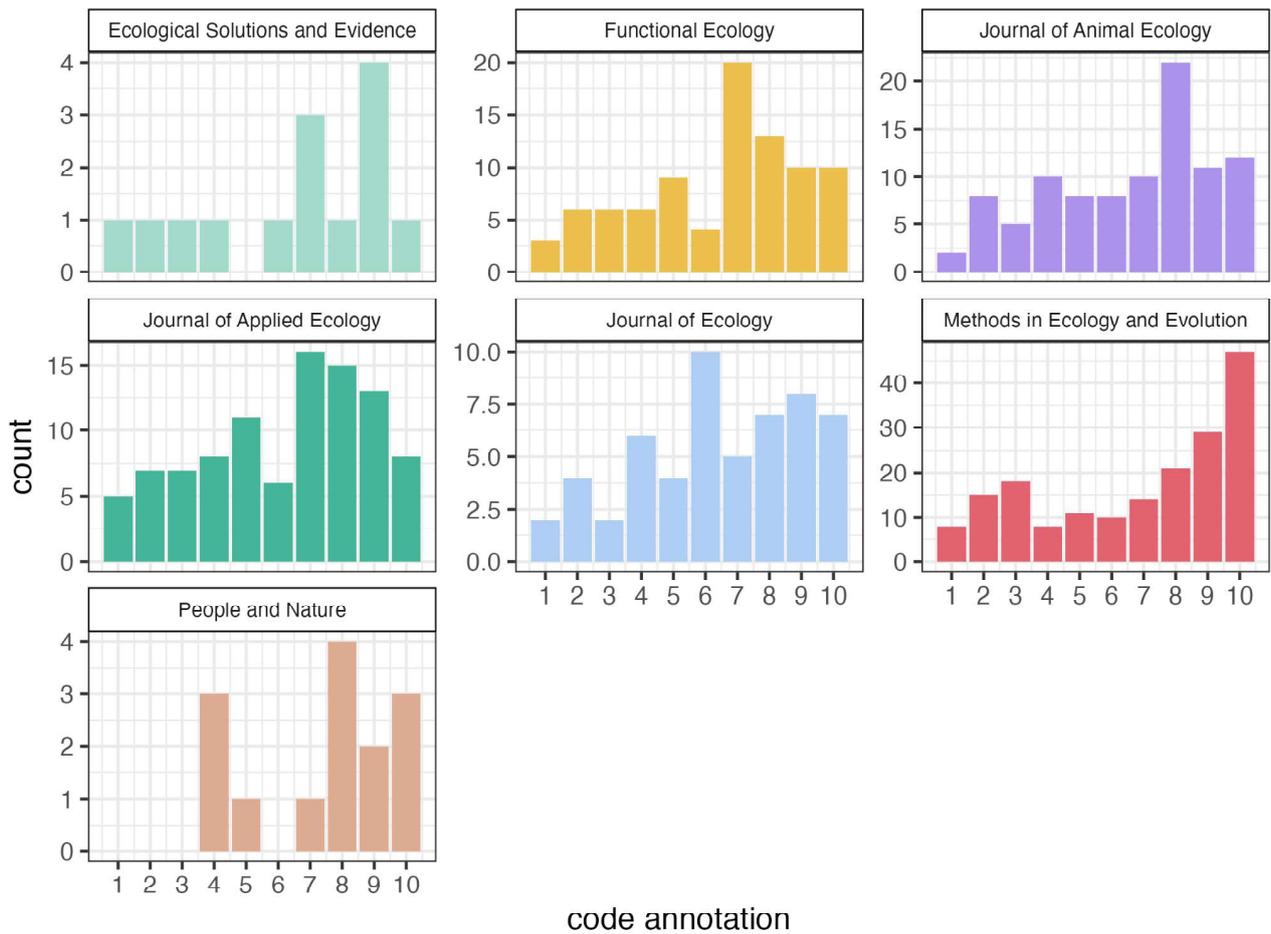
Figure S11: Code annotation quality for archived code across the seven BES journals.

Note the different y-axis scales for each plot. Median annotation quality for each journal was as follows. *Methods in Ecology and Evolution* and *People and Nature* = 8, *Ecological Solutions and Evidence*, *Functional Ecology*, *Journal of Animal Ecology* and *Journal of Applied Ecology* = 7, and *Journal of Ecology* = 6. Colours are the official BES journal colours (https://besjournals.onlinelibrary.wiley.com/).
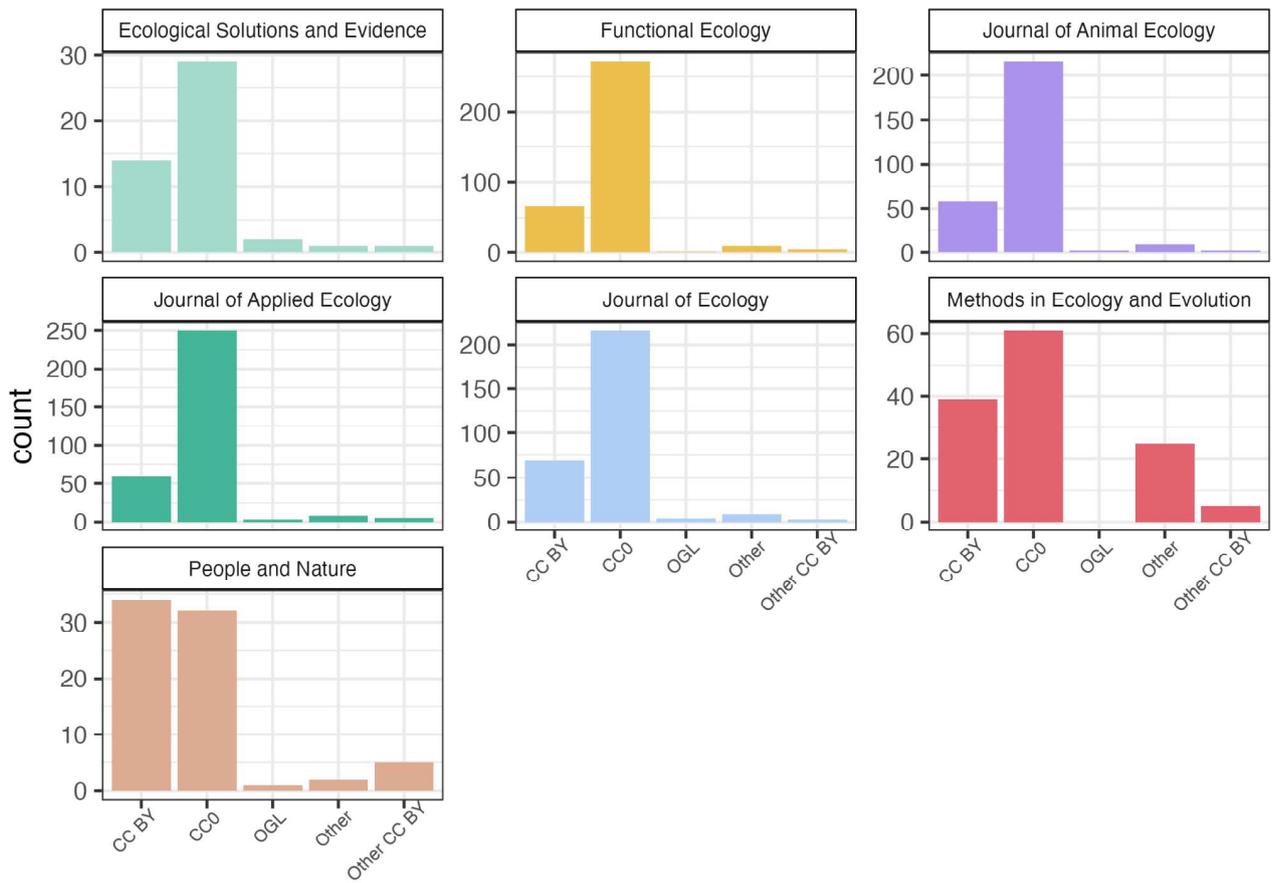
Figure S12: Licenses for archived data across the seven BES journals.

Note the different y-axis scales for each plot. Colours are the official BES journal colours (https://besjournals.onlinelibrary.wiley.com/).
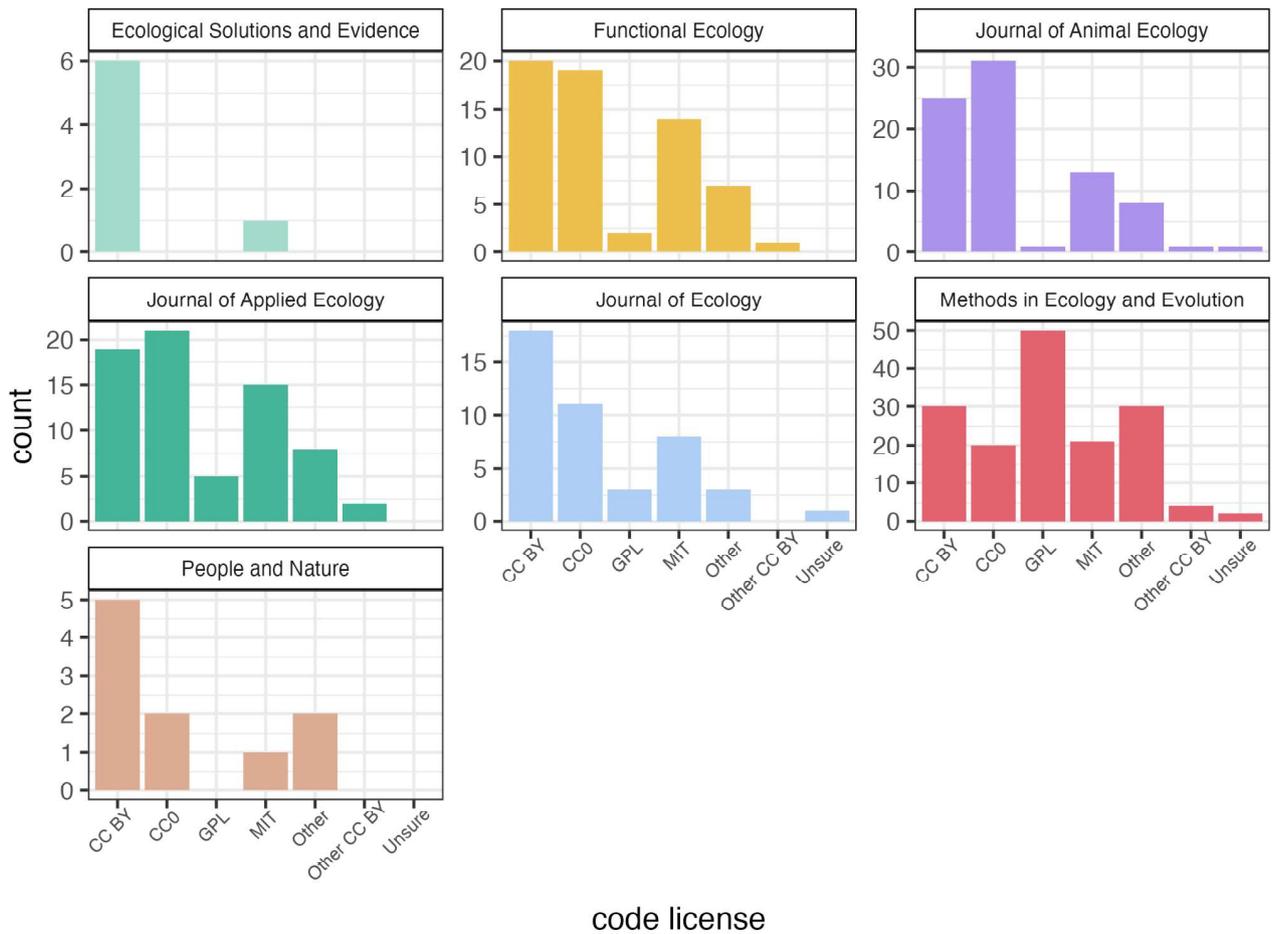
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Note the different y-axis scales for each plot. Other CC BY includes CC BY-SA, CC BY-NC etc. Colours are the official BES journal colours (https://besjournals.onlinelibrary.wiley.com/).
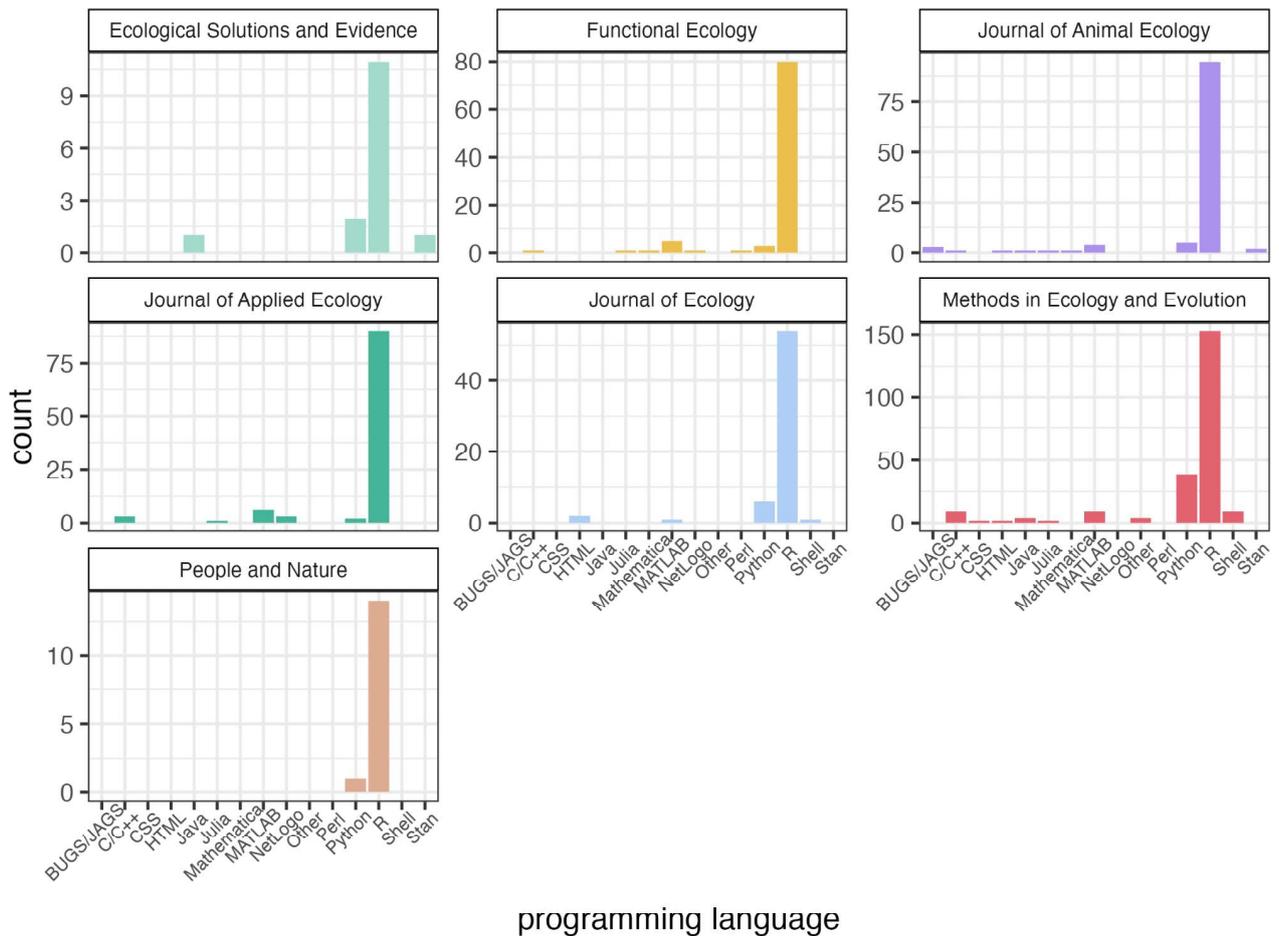
Figure S14: Programming languages of code across the seven BES journals.

Numbers are unique code files in different programming languages. Note the different y-axis scales for each plot. Colours are the official BES journal colours (https://besjournals.onlinelibrary.wiley.com/).
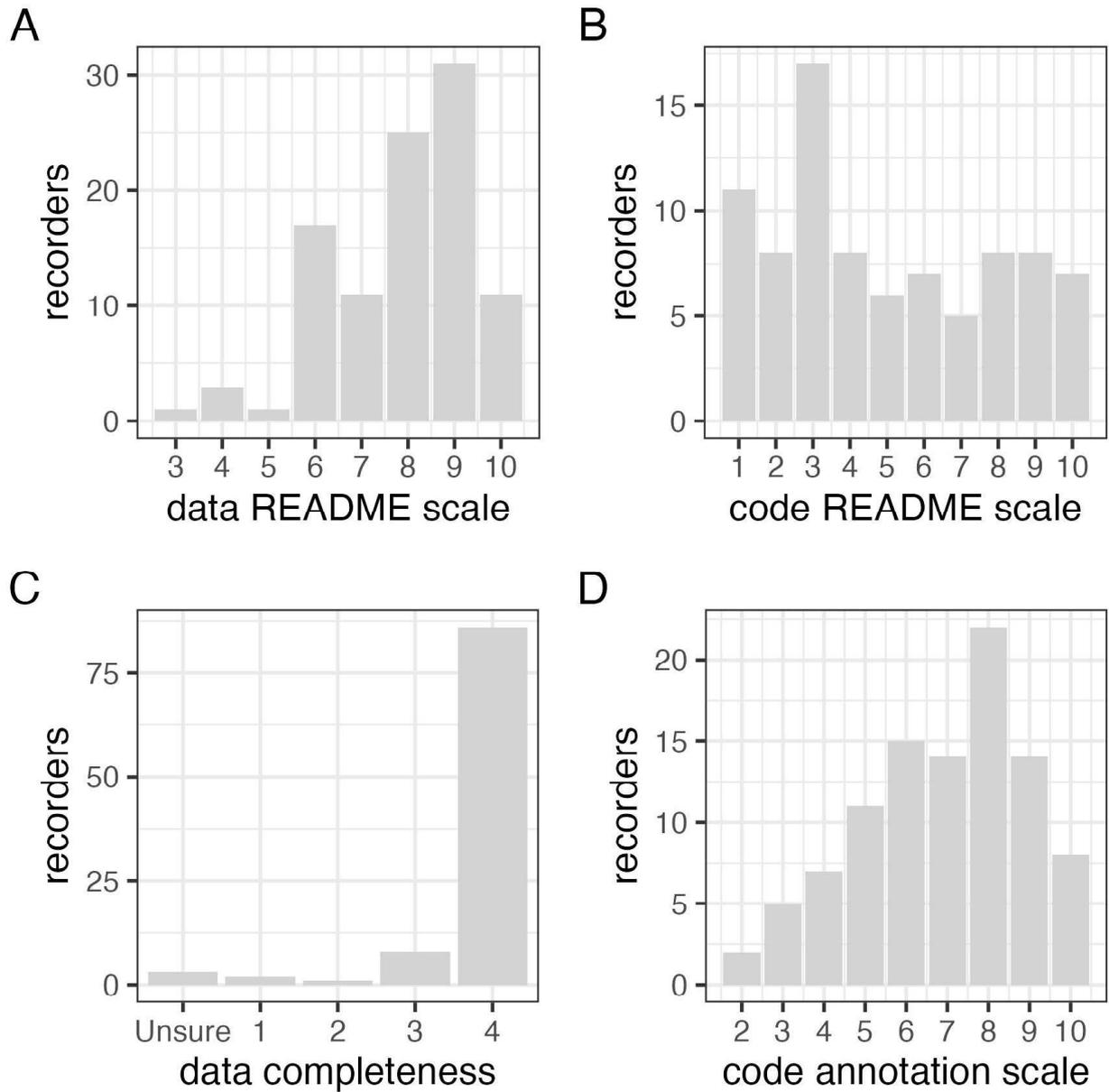
Recorder variability

100 unique data recorders collected data for paper 2272. Recall that unique data recorder IDs were given to each unique individual and group of recorders, so this is not the same number as the total number of participants.

All 100 unique data recorders extracted identical information for 24 out of the 35 variables we used in our analyses (69%). Note that one recorder was unable to open the data or code because of issues with their computing setup, so we have counted this as correct. One recorder did not think code had been archived so did not answer any code questions so we excluded their results for the code questions.

Across all variables, mean percentage agreement (± SE) was 91.7% (± 3.67). Of the variables without perfect congruence, most are minor issues: (i) four recorders stated that the data did not have a license, but accurately noted the license type so this was likely a data entry error; (ii) one recorder did not think code was in the data availability statement; (iii) 12 recorders did not identify that the code had a README; (iv) two recorders did not identify the DOI for code (likely because it was shared with the data); (v) 12 recorders did not identify that the code had a license and thus did not record a license type; and (vi) one recorder recorded the wrong license for the code.

Of the four scaled variables, data completeness was reasonably consistent across recorders. It was scored as "complete" by 86 of the 100 recorders and eight scored it as "high", one as "fair", two as "low" and three as "unsure". Variability was higher for README quality and code annotation (Figure S18). Data README quality ranged from 3 to 10 (median = 8, interquartile range = 7–9), code README quality ranged from 1 to 10 (median = 4, interquartile range = 3–8), and code annotation ranged from 2 to 10 (median = 7, interquartile range = 5.25–8). Consequently, care should be taken in interpreting results for these three variables (Figure S15).

Figure S15: Recorder variability.

Results for data collected from paper 2,272 for README usefulness (A,B), data completeness (C) and code annotation score (D). For data completeness, 1 = low, 2 = fair, 3 = high and 4 = complete. Note the different y-axis scales across the four plots.

Other results figures
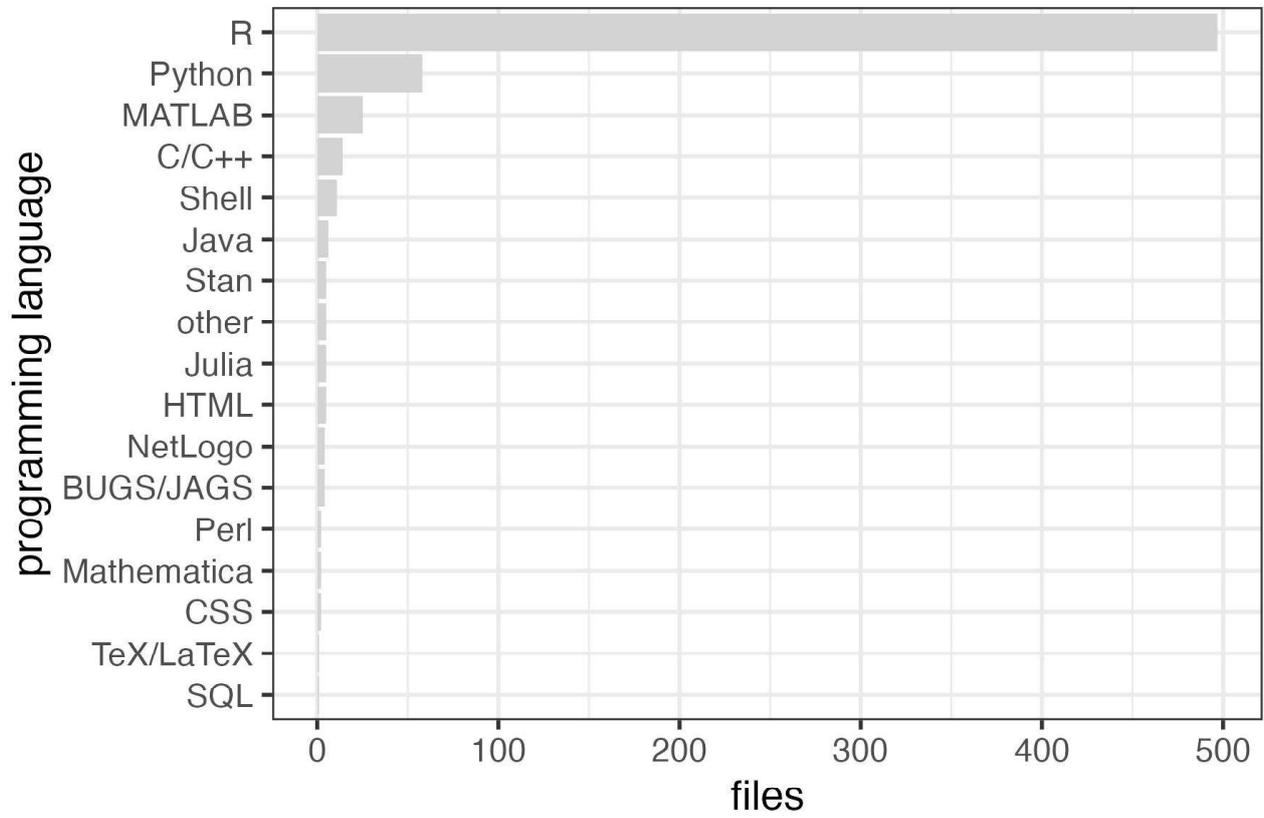
Figure S16: Numbers of unique code files written in each programming language.

Supplementary Tables

Table S1: Numbers of papers published in the seven BES journals between 2017 and 2024, and the number of these that are in our dataset.

% published = papers published in the journal/year as a percentage of the total published across all seven journals/eight years. % dataset = papers in the journal/year that are in our dataset as a percentage of the total that are in our dataset from all seven journals/eight years.

Journal	published	% published	dataset	% dataset
Ecological Solutions and Evidence	255	3.14	60	3.22
Functional Ecology	1,554	19.2	397	21.33
Journal of Animal Ecology	1,282	15.8	323	17.36
Journal of Applied Ecology	1,618	19.9	383	20.58
Journal of Ecology	1,494	18.4	336	18.05
Methods in Ecology and Evolution	1,377	17	243	13.06
People and Nature	532	6.56	119	6.39
TOTAL	**8,112**	-	**1,861**	-

Year	published	% published	dataset	% dataset
2017	730	9.00	172	9.24
2018	809	9.97	195	10.48
2019	943	11.6	216	11.61
2020	1,090	13.4	253	13.59
2021	1,228	15.1	301	16.17
2022	1,115	13.7	251	13.49
2023	1,047	12.9	218	11.71
2024	1,150	14.2	255	13.7
TOTAL	**8,112**	-	**1,861**	-

Table S2: Summary results for data and code across all seven journals combined

Numbers of papers in our dataset where data and/or code were used, archived, mentioned in the Data Availability statement, could be accessed via the link provided, could be downloaded, could be opened, had a README or similar, had a DOI (digital object identifier) and had a license. % columns represent the percentages of all papers included in this study (n = 1,861), papers that used data (n = 1,735) or code (n = 1,670) only; or papers with archived data (n = 1,690) or code (n = 577) only.

Data/ Code	Variable	n	% of total papers	% of total papers where data/code were used	% of total papers where data/code were archived
Data	Used in paper	1,735	93.23	-	-
Data	In Data Availability statement	1,700	91.35	97.98	-
Data	Archived	1,690	90.81	97.41	-
Data	Link works	1,633	87.75	94.12	96.63
Data	Can be downloaded	1,600	85.98	92.22	94.67
Data	Can be opened	1,541	82.80	88.82	91.18
Data	Has README or similar	1,114	59.86	64.21	65.92
Data	Has DOI	1,543	82.91	88.93	91.30
Data	Has license	1,438	77.27	82.88	85.09
Code	Used in paper	1,670	89.74	-	-
Code	In Data Availability statement	453	24.34	27.11	78.51
Code	Archived	577	31.00	34.55	-
Code	Link works	544	29.23	32.57	94.28
Code	Can be downloaded	536	28.80	32.10	92.89
Code	Can be opened	495	26.60	29.64	85.79
Code	Has README or similar	351	18.86	21.02	60.83
Code	Has DOI	457	24.56	27.57	79.20
Code	Has license	428	23.00	25.63	74.18

Table S3: Summary results for data divided by journal.

Numbers of papers where data were used, mentioned in the Data Availability statement, could be accessed via the link provided, could be downloaded, and could be opened. % are the percentages of all papers for the used column (corresponding to the column **% of total papers** in Table S2), and % percentages of papers that used data for the other columns (corresponding to the column **% of total papers where data/code were used** in Table S2).

Journal	total		used		archived		link		download		open	
	n	%	n	%	n	%	n	%	n	%	n	%
All	1,861	-	1,735	93.23	1,690	97.41	1,633	94.12	1,600	92.22	1,541	88.82
Ecological Solutions and Evidence	60	3.22	57	95	55	96.49	53	92.98	51	89.47	51	89.47
Functional Ecology	397	21.33	388	97.73	387	99.74	380	97.94	371	95.62	361	93.04
Journal of Animal Ecology	323	17.36	315	97.52	311	98.73	306	97.14	302	95.87	295	93.65
Journal of Applied Ecology	383	20.58	360	93.99	353	98.06	343	95.28	338	93.89	327	90.83
Journal of Ecology	336	18.05	324	96.43	320	98.77	317	97.84	310	95.68	304	93.83
Methods in Ecology and Evolution	243	13.06	182	74.9	174	95.6	157	86.26	149	81.87	126	69.23
People and Nature	119	6.39	109	91.6	100	91.74	81	74.31	79	72.48	77	70.64

Table S4: Summary results for code divided by journal.

Numbers of papers where code was used, archived, mentioned in the Data Availability statement, could be accessed via the link provided, could be downloaded, and could be opened. % are the percentages of all papers for the used column (corresponding to the column **% of total papers** in Table S2), and % percentages of papers that used code for the other columns (corresponding to the column **% of total papers where data/code were used** in Table S2).

Journal	total	used n	used %	archived n	archived %	statement n	statement %	link n	link %	download n	download %	open n	open %
All	1,861	1,670	89.74	577	34.55	544	32.57	536	32.1	495	29.64	453	27.13
Ecological Solutions and Evidence	60	53	88.33	12	22.64	13	24.53	14	26.42	14	26.42	14	26.42
Functional Ecology	397	354	89.17	88	24.86	84	23.73	82	23.16	78	22.03	65	18.36
Journal of Animal Ecology	323	302	93.5	103	34.11	94	31.13	91	30.13	84	27.81	65	21.52
Journal of Applied Ecology	383	350	91.38	102	29.14	93	26.57	92	26.29	86	24.57	64	18.29
Journal of Ecology	336	315	93.75	60	19.05	51	16.19	54	17.14	54	17.14	50	15.87
Methods in Ecology and Evolution	243	222	91.36	197	88.74	183	82.43	192	86.49	190	85.59	170	76.58
People and Nature	119	74	62.18	15	20.27	12	16.22	13	17.57	13	17.57	13	17.57