Meta-analysts must lead by example and embrace all FAIR principles

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Abstract

Meta-analyses rely on comprehensive reporting of results and data in primary studies. They should therefore also strive for exemplary reporting and follow FAIR principles (Findable, Accessible, Interoperable, Reusable) for data sharing. Yet, despite growing calls for open, reliable, and transparent science, the quality, reporting and FAIRness of meta-analyses in ecology, evolution, and environmental sciences remain poorly characterised. Here, we evaluate features of methodological quality, reporting and data and code sharing practices of

81 meta-analyses published between 2016 and 2020 in ecology, evolution, and environmental sciences. Whilst we found data sharing was relatively common (68%), code sharing was rare (15%). We found low uptake of reporting guidelines (22%), a small proportion of unweighted approaches (17%) and no risk of bias assessments (0%). The FAIRness of data requires urgent attention. Most openly available meta-analytic datasets were Findable and Accessible, but less often Interoperable or Reusable. Low Interoperability and Reusability prevent verification and may explain why data reuse remains uncommon, and ultimately contributes to research waste. We found no evidence of higher FAIRness scores when studies reported having used guidelines, nor that FAIRness associated with citation rates, suggesting a lack of incentives for adopting FAIR principles. Lastly, we provide recommendations for readily implementable methodological improvements applicable to meta-analyses in any field.

Keywords: Reproducibility, Open science, Evidence synthesis, Systematic review, Meta-research, Research integrity, Data stewardship, Research standards, Scientific rigour

Introduction

Evidence synthesis is an increasingly popular research approach. It encompasses a suite of methods, such as systematic review and meta-analysis, designed to provide reliable qualitative and quantitative summaries of research on a given topic while minimising subjectivity and bias (Higgins & Green, 2015; Haddaway et al., 2015a). Systematic reviews use rigorous, ideally predefined methods to identify, critically appraise and synthesise relevant studies on a specific topic. When included studies report comparable quantitative outcomes, meta-analyses can statistically combine their results to estimate an overall effect size (usually weighted by study precision) and understand their generality and sources of variation. By distilling evidence from multiple studies quantitatively, meta-analysis carries considerable authority (Murad et al., 2016; Ioannidis, 2016; Pollo et al., 2025). They are frequently used to help synthesize conflicting results across primary studies, guide research priorities, and, importantly, inform policy and management decisions (Haddaway & Pullin, 2014). In ecology, evolution, and environmental sciences, meta-analyses are routinely used to test fundamental hypotheses (e.g., Kim et al., 2021; Dimri et al., 2026), evaluate conservation interventions (e.g., Vasconcelos et al. 2022; Gan et al. 2025; Moran et al. 2025), quantify human impacts on the environment (e.g., Capilla-Lasheras et al. 2022; Juan-Ovejero et al. 2025), and inform conservation strategies (e.g., Häkkilä et al., 2021). Meta-analysis can also contribute to reducing research waste by identifying gaps in accumulated knowledge and helping determine where additional research is needed (Grainger et al., 2020).

At their best, meta-analyses are powerful statistical tools that can provide reliable syntheses of existing evidence – often preceded by a systematic review – and shape research priorities and policy. At their worst, they risk becoming misleading analyses that mask low quality and subjective bias behind an unwarranted sense of definitive authority (Ioannidis, 2016). The conclusions of a meta-analysis depend both on the quality of the underlying studies and on the methodological decisions made throughout the synthesis process. When these decisions are inappropriate, poorly justified or insufficiently reported, meta-analyses can produce unreliable inference. Rigorous synthesising evidence remains slow and resource-intensive (Haddaway & Westgate, 2019) and is often poorly coordinated (Siontis et al., 2013). The concept of an 'open synthesis community', where data, methods, and outputs are shared transparently, has been proposed to address these challenges (Haddaway, 2018; Nakagawa et al., 2020), although such practices are still not consistently implemented.

The overall methodological and reporting quality of meta-analyses in ecology, evolution, and environmental sciences has considerable room for improvement. A survey of 102 ecological and evolutionary systematic review and meta-analyses found an average reporting score of approximately 55% across the 27-item PRISMA-EcoEvo framework, which aims to promote transparent and comprehensive reporting of systematic reviews and meta-analyses (O'Dea et al., 2021). Incomplete reporting does not necessarily imply poor quality, however, it makes it difficult to assess the quality of the meta-analysis and reduce confidence in the resulting synthesis. Lack of computational reproducibility is similarly concerning. Previous meta-research indicates that only 27–73% of some meta-analytic results can be computationally reproduced (Kambouris et al., 2024), and just 55% of individual effect-size calculations could be successfully verified (Maassen et al., 2020; see also Pollo et al., 2025; Sánchez-Tójar & D'Amelio, 2026). Perhaps most troubling, a recent study of meta-analyses of organochlorine pesticides found no difference in methodological quality between those meta-analyses cited in policy documents and those that were not (Morrison et al., 2025), suggesting that rigour does not necessarily determine influence.

Transparent methodological reporting, however, is insufficient to assess reliability and allow independent result reproduction, when the data and analytical materials underlying a meta-analysis are unavailable or poorly documented. Previous meta-research on archived data from primary empirical studies in ecology and evolution suggests that more than half of openly available datasets are neither complete nor reusable (Roche et al., 2015), a figure that has barely improved over the past decade (Roche et al., 2022). The FAIR principles provide a framework for assessing whether research data and their associated metadata are Findable, Accessible, Interoperable and Reusable by humans and machines, that is, it should be discoverable and retrievable through persistent and clearly defined access, provided in formats that facilitate computational use and sufficiently documented and licensed to support reuse (Wilkinson et al., 2016). Poor data FAIRness limits researchers' ability to verify results, reuse data for new questions, and build cumulatively on previous work (Chalmers & Glasziou, 2009; Purgar et al., 2022). Reusable data for a meta-analysis is valuable for updating existing syntheses as new evidence accumulates. Access to previously synthesised data can allow new studies to be incorporated into a meta-analysis without reconstructing the synthesis. Poor data FAIRness may partly explain why meta-analysis updating remains rare despite repeated calls for it (e.g., Nakagawa et al., 2017). Such updating is important given the abundant evidence showing that effect sizes can change in both magnitude and direction as evidence accumulates over time (Jennions & Møller, 2002; Koricheva & Kulinskaya, 2019; Brisco et al., 2024). If meta-analyses are to serve as reliable, up-to-date syntheses of evidence, the FAIRness of their underlying data requires urgent attention.

Despite the importance of reusable meta-analytical data, their FAIRness remains poorly characterised in ecology, evolution and environmental sciences. Here, we present a comprehensive and systematic assessment of methodological and reporting quality, transparency, data and code sharing, and data FAIRness in meta-analyses across ecology, evolution, and environmental sciences. Leveraging a community effort, we comprehensively evaluated 81 meta-analyses published between 2016 and 2020 by developing a protocol to efficiently and robustly assess data FAIRness. We also explored whether data FAIRness predicted citation count and compared overall scores between studies that reported following reporting or conduct guidelines (such as PRISMA, CEE etc.) and those that did not. Based on our findings, we offer practical recommendations for addressing what has been a persistent weakness of meta-analytic practice in our field.

Methods

Selection of studies

To identify published meta-analyses in ecology, evolution, and environmental sciences, we searched the Web of Science Core Collection using the terms ("*meta-analy**" OR "*metaanaly**" OR "*meta-regression*" OR "*metaregression*") in article titles, abstracts, and author keywords. The search was restricted using journal identifiers to the same predefined list of relevant journals in the field used by O'Dea et al. (2021). The complete search string and journal identifiers are in Supplement S1. The initial search returned 1,131 records, of which 29 were excluded for having a final publication date equal to 2021, leaving 1,102 eligible records published between 2016 – the year when the FAIR principles were published – and 2020. We focused on this five-year duration to include a recent sample of meta-analyses while also allowing a comparable citation window for all the included articles – by the end of 2025, all included articles had accumulated at least six years over which citation counts could be accessed (see more details below). From the 1,102 records, we selected 96 articles at random using the base R 'sample' function (R Core Team, 2024) and screened for eligibility. We excluded 15 articles that were not quantitative meta-analyses (e.g., primary studies, opinion pieces, methodological papers), so our final dataset consisted of 81 articles. Overall, our sample aimed to represent the broader pool of meta-analyses in ecology, evolution, and environmental sciences, rather than to explore differences across journals.

Assessment of methodological and reporting practices

After finalising the list of 81 eligible articles and an initial assessment performed by two student assistants (MP, VRD), we organised two collaborative hackathons with researchers experienced in evidence synthesis. The first was held as part of ESMARConf2025 on 13th June 2025, and the second follow-up hackathon was held on 20th August 2025. In total, 19 assessors contributed to the assessments: the two organisers (SD, AST), two student assistants (MP, VRD), and 15 hackathon participants (two of whom opted out of co-authorship). Of the 81 articles assessed, 73 were independently assessed by two to four assessors, whereas the remaining 8 were assessed by only the senior author (AST). All entries of each assessment were verified by either the first or last author (SD, AST).

We used a Google Form to assess methodology and transparency characteristics of the article, its supplementary material, and linked repositories. These included whether (i) inferential statistics were used to calculate effect sizes, (ii) comparability in the direction of the effect sizes was ensured, and (iii) authors reported performing a Risk of Bias assessment (RoB) of included primary studies or any other study-level bias appraisal (full list in Supplement S2). The assessment form was slightly modified between the two hackathons to improve clarity to data coders (e.g., wording of items was clarified).

To assess whether effect size direction was taken into account, we coded this item as applicable only when extracted effect sizes could plausibly take opposite signs across studies. This could occur because studies defined the contrast in opposite ways, such as treatment minus control versus control minus treatment. It could also occur when different outcomes represented the same underlying biological process in opposite ways. For example, when a meta-analysis synthesises fitness effects but some studies measure survival, whereas others measure mortality, the direction of those effect sizes have to be made comparable to avoid these effects cancelling each other (see Supplement S2 for more details). Meta-analyses were coded as “not applicable” when directional harmonisation was not necessary because the effect-size was inherently consistent (e.g., variance, heritability), or all effect sizes already had a consistent directional interpretation. For meta-analyses coded as “applicable”, we then recorded whether authors explicitly reported having considered effect-size directions to ensure all effects carried a consistent interpretation (i.e., to ensure comparability).

Three assessment items proved particularly challenging to code: whether a RoB assessment or an alternative had been performed, whether inferential statistics had been converted into effect sizes, and whether the comparability in the direction of the effect sizes had been ensured. For example, publication bias tests or methodological subgroup analyses were not always straightforward to distinguish from RoB assessment, and effect size direction was only relevant for some outcome types. Therefore, to ensure consistency across assessments, the last author (AST) independently reviewed and verified all 81 entries for these items using the text extracted by the hackathon participants and, where necessary, revised the original assessments.

We also identified whether authors reported registering a protocol/pre-registering or followed a reporting or conduct guideline, and where applicable, the name of the guideline. Additionally, we extracted general methodological descriptors including the type of effect-size measure used, whether statistical software was reported and which software was used, type of meta-analytical model used, and whether effect sizes were weighted by their sampling variances. These data were independently extracted by SD and one of two student assistants (MP, VRD), and all entries were checked by the last author (AST).

Data and code sharing, and FAIR assessments

For all 81 meta-analyses, we recorded whether authors shared processed data, raw data, and analytical code in the article, supplementary materials, or a linked repository. Processed data included the calculated effect sizes together with their associated sampling variances and any accompanying study-level information, and raw data included the summary or inferential statistics required to calculate those effect sizes (e.g., group means, standard deviations, sample sizes or correlations).

For the 55 meta-analyses that shared data, the FAIRness of the shared data (see Results below) was assessed using a protocol developed for this study and shared with the participants as a Google Form (see Supplement S3). FAIRness assessment included eight items: (i) data sharing location (e.g., Zenodo, Dryad, GitHub, Supplementary Material) [F]; (ii) whether the article provided a direct mention of the available data, link, globally unique persistent identifier (PID) or accession number for the underlying data [F]; (iii) presence of metadata other than a data dictionary [F]; (iv) whether the data could be downloaded [A]; (v) presence of a globally unique persistent identifier (PID), such as a Digital Object Identifier (DOI), which ensures long-term access [A]; (vi) data file format (e.g., .csv/tsv, .txt, .pdf, .docx) [I]; (vii) presence and type of data licence (e.g., CC BY, CC BY-NC, CC0) [R]; and, (viii) presence of data dictionary or codebook (i.e. a documentation explaining the detailed meaning of individual variables, units etc.) [R]. Note that the number of items per FAIR component was unequal (F = 3, A = 2, I = 1, and R = 2 items). Eleven assessors contributed to the FAIR assessment, with 11 (20%) studies being assessed twice independently, and all records verified by the last author (AST). Any disagreements between assessors were resolved by the first and last authors (SD, AST).

Exploratory factors associated with data sharing and FAIRness

To understand whether data FAIRness was associated with citation counts, the last author (AST) manually extracted the citation counts for each of the 81 articles from Google Scholar on 12th January, 2026. Google Scholar was used instead of other citation databases to include any citations from grey literature such as policy documents and reports, which can represent an important source of impact, particularly for applied meta-analyses (Haddaway et al., 2015b; Martín-Martín et al., 2018). Citations were recorded annually for each article from 2016 to 2025. The publication year for each meta-analysis refers to the year the article was included in a journal issue. Citations from the preceding year before publication, which were rare, were excluded from our analyses so that the citation count was calculated over the same six-year window for all articles, beginning with the publication year.

Data processing and analysis

Before the data could be analysed, we performed data cleaning and recategorisation. Data shared within an article or its supplementary materials, rather than through a repository, were classified as not having a PID (i.e., not findable). Data file formats were classified based on their alignment with the FAIR principles, with particular emphasis on interoperability and reusability. Thus, non-proprietary, machine-readable formats (.csv/tsv), structured text files (.txt), and domain-standard phylogenetic formats (.tre) were classified as FAIR-aligned (‘Yes’). Spreadsheet formats were classified as partially FAIR (‘Partial’) because, although .xlsx is based on an open specification and is machine-readable in principle, spreadsheet files may use features such as multiple worksheets, merged cells, formatting, or embedded formulas that hinder consistent automated interpretation and reuse (Broman & Woo, 2018). Document formats for sharing data (.pdf, .doc/docx) were classified as non-FAIR-aligned (‘No’), as they primarily support human readability rather than machine interoperability. For articles sharing multiple data file formats, the classification reflected the least FAIR data format present, for example, if an article provided some data files as .xlsx and some as .csv, it was classified as “Partial”. Data shared only within an article or its supplementary materials were classified as not having a data licence unless a separate data licence was explicitly provided. Before analysis, FAIR assessments were converted to numeric scores: “Yes” = 1, “Partial” = 0.5, and “No” = 0. The overall FAIRness score of each article was calculated as the mean of the eight indicators and expressed as a percentage.

For all other assessment items coded as binary outcomes, we calculated the percentage of articles for which each outcome was present/true, and the 95% confidence intervals (95% CI) were calculated using the Wilson score interval using the function ‘binom.confint’ from the ‘binom’ v1.1-2 package (Dorai-Raj & Cascone, 2026), which can handle extreme proportions

(0% or 100%). The association between reporting or conduct guideline use (such as PRISMA, CEE) and FAIRness scores was assessed using Wilcoxon rank-sum tests. Associations between FAIRness scores and citation counts accumulated during the first six years after publication were assessed using Kendall rank correlations. We used the citation counts from the first six years after publication to ensure comparability across articles. Because these comparisons correspond to observational data and involve relatively small sample sizes, they should be interpreted with caution. All data processing and analyses were conducted in R v.4.4.2 (R Core Team, 2024).

Results

We assessed 81 articles categorised as meta-analyses published between 2016 and 2020 across 35 journals in ecology, evolution, and environmental sciences. The number of articles ranged from 14 to 20 per year (median = 16). Since articles were randomly selected rather than stratified by journal, the number of articles per journal ranged from 1 to 18 (median = 1). The three most represented journals were *Global Change Biology* (18), *Agriculture, Ecosystems & Environment* (6), and *Ecology Letters* (6).

Methodological and reporting assessments

Of the 81 meta-analyses, only one reported having registered a protocol (1.2%, 95% CI = 0.2–6.7%). Eighteen meta-analyses cited having followed a reporting or conduct guideline for evidence synthesis (22.2%, 95% CI = 14.5–32.4%), such as PRISMA (n = 11), CEE (n = 1) or others (n = 6). Most meta-analyses reported the statistical software used (95.1%; 95% CI, 88.0–98.1%), with R being the most commonly used (n = 57).

The type of effect size used differed across meta-analyses. Mean comparisons were the most common outcome, followed by correlations (lnRR = 31, SMD = 17, correlations = 8, odds ratios = 2), while 23 meta-analyses used other, less common effect sizes (e.g., standardised biodiversity indices, element concentrations, etc.). Our methodological assessment suggested that 18 meta-analyses (22.2%, 95% CI = 14.5–32.4%) presumably should have addressed comparability in the direction of the effect sizes, yet only 12 of these (66.7%, 95% CI = 43.7–83.7%) reported having done so. Most meta-analyses, though not all, used weighted approaches (82.7%; 95% CI, 73.1–89.4%). Zero meta-analyses reported having performed a RoB assessment; however, 12 meta-analyses (14.8%, 95% CI = 8.7–24.1%) examined methodological differences among primary studies as a potential source of heterogeneity, suggesting their authors considered whether variation in study methods might explain variation in effect sizes.

Data and code sharing

Most meta-analyses shared data (67.9%, 95% CI = 57.1–77.1%), either raw alone or together with processed data (54.3%, 95% CI = 43.5–64.7%), or processed data alone (43.2%, 95% CI = 33.0–54.1%; Figure 1). However, code sharing was substantially lower, with only 14.8% (95% CI = 8.7–24.1%) of meta-analyses sharing code. All meta-analyses that shared code, also shared data. The reproducibility potential, defined as providing both data and code, of the assessed meta-analyses was limited entirely by code availability to 14.8% (95% CI = 8.7–24.1%; Figure 1).

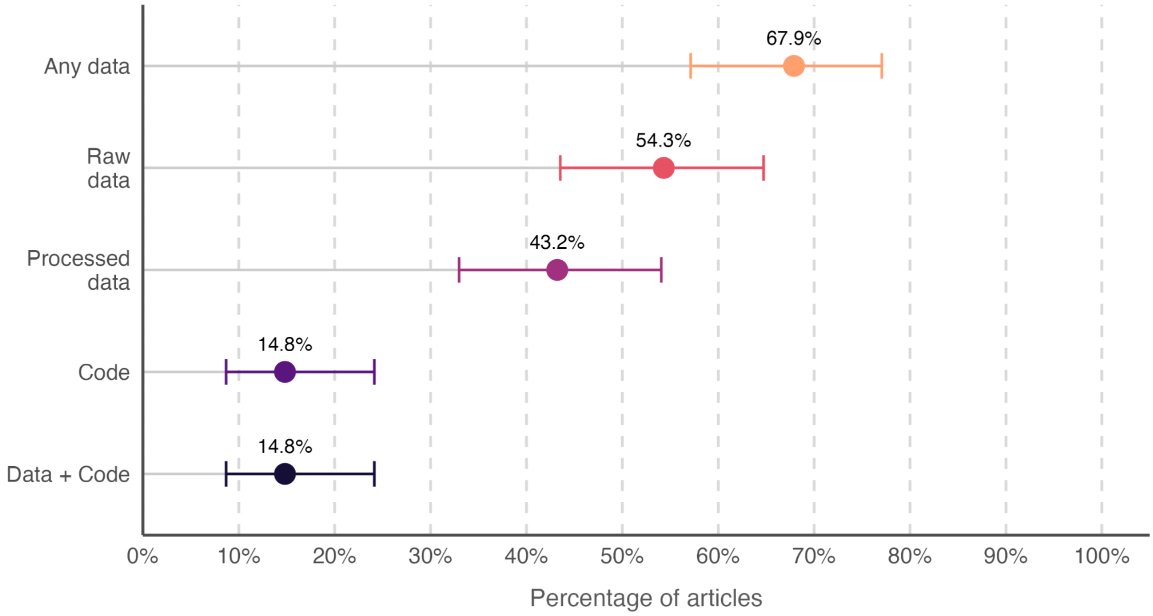

Figure 1. **Data and code sharing across 81 meta-analyses in ecology, evolution, and environmental sciences.** “Any data” includes the raw data, processed data, or both. Points represent the percentage of articles coded as sharing type of data and code, and horizontal error bars represent 95% Wilson score confidence intervals.

FAIR assessments

Among the 55 meta-analyses that shared data, Findability and Accessibility indicators were the most commonly met across the 55 meta-analyses that shared data, whereas Interoperability and Reusability indicators showed frequent gaps (Figure 2). The overall FAIR score ranged from 2 to 8 fulfilled items (range = 25 to 100%), with the median being 6.5 (81%; mean = 5.6, 70%).

Findability and Accessibility indicators were generally more frequently met than Interoperability and Reusability indicators (Figure 2). Our FAIR assessment of the data showed that: (i) 63.6% (95% CI = 50.4–75.1%) deposited data in an external repository, with Dryad being the most common (n = 22); (ii) 98.2% (95% CI = 90.4–99.7%) mentioned having shared data; (iii) 69.1% (95% CI = 56.0–79.7%) provided metadata associated with the data; (iv) 100.0% (95% CI = 93.5–100.0%) could be downloaded; (v) 61.8% (95% CI = 48.6–73.5%) of the data were assigned a globally unique persistent identifier (DOI = 33, Handle = 1) to ensure long-term access; (vi) 38.2% (95% CI = 26.5–51.4%) used only fully interoperable data formats such as .csv/tsv, whereas 43.6% (95% CI = 31.4–56.7%) used data formats with lower interoperability such as .xls/xlsx, and 18.2% (95% CI = 10.2–30.3%) shared data exclusively in non-interoperable document formats (.pdf, .doc/.docx); (vii) 63.6% (95% CI = 50.4–75.1%) provided a licence permitting data reuse, with CC0 licence being the most popular (n = 26); and (viii) 45.5% (95% CI = 33.0–58.5%) provided a data dictionary to facilitate data reuse.

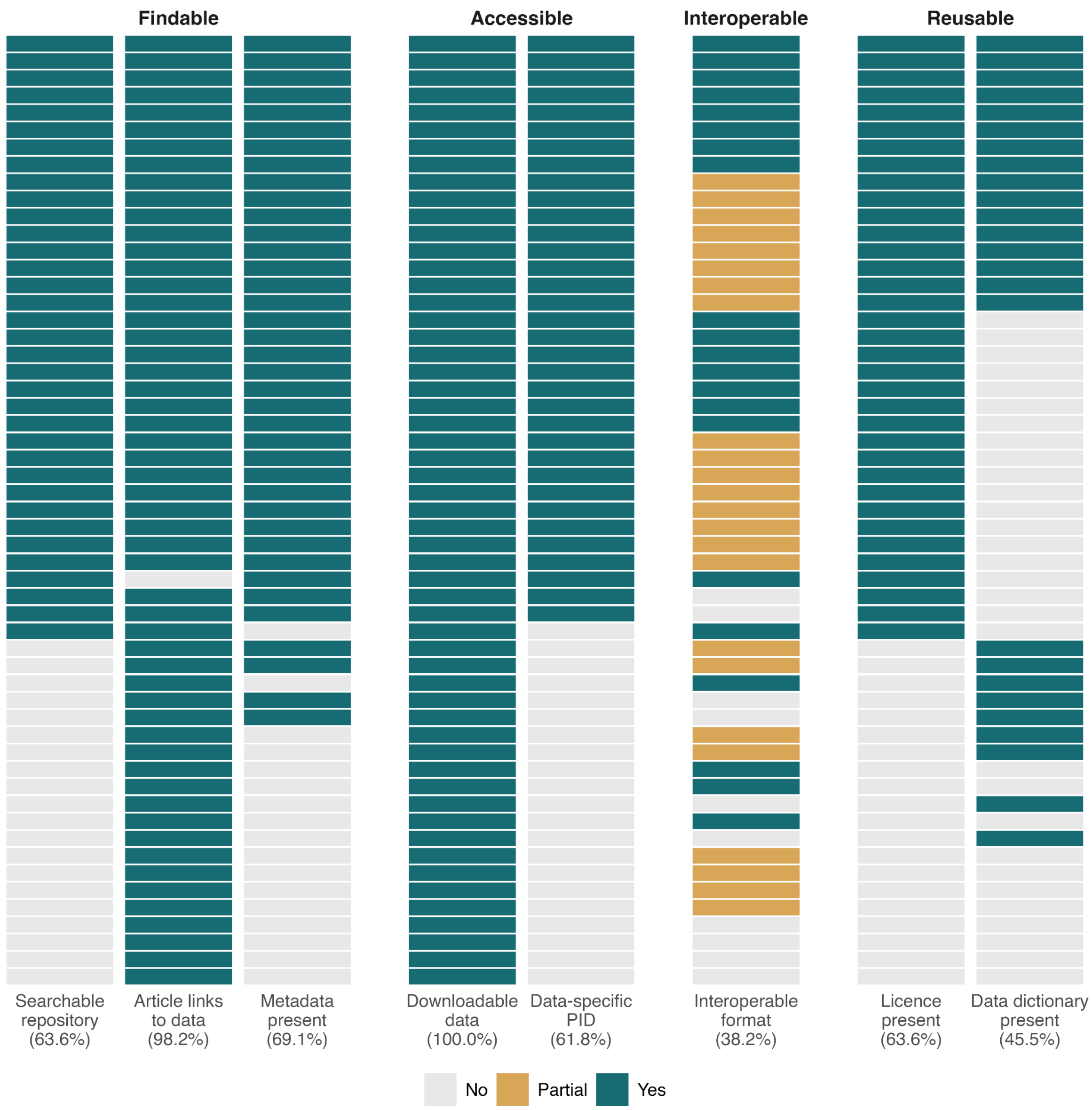

Figure 2. **FAIRness of shared data across 55 meta-analyses.** Each row represents one meta-analysis that shared data, and each column represents one FAIR indicator assessed in this study. The percentage shown indicates the proportion of the 55 meta-analyses that met that indicator.

Are guidelines associated with a higher FAIR score?

For the 55 meta-analyses that shared data, those that reported following a reporting or conduct guideline (mean = 70.5%, range = 25 to 100%, n = 14) had a similar data FAIR score than those that did not (mean = 70.1%, range = 25 to 100%, n = 41; Wilcoxon rank sum test: W = 268.5, p = 0.73; Figure 3A). We found no clear evidence of a difference in their score distribution, and the results were robust to a different statistical approach (Chi-square test: $\chi 2$ = 9.44, p = 0.58).

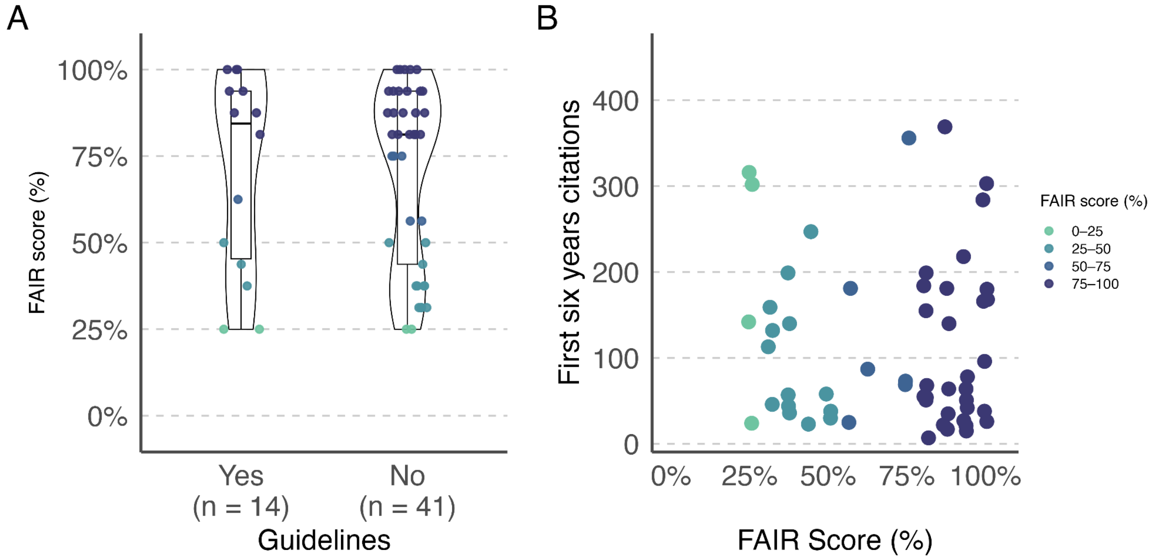

Figure 3. **Associations between data FAIRness, methodological or reporting guidance, and citation count.** (A) Reporting or conduct guidelines are not clearly associated with data FAIRness. Violin plots show the score distributions, and boxplots show the median and interquartile range. (B) Data FAIRness was not associated with the number of citations accumulated during the first six years after publication. In both panels, points represent individual meta-analyses and point colours indicate four FAIRness score categories (0–25%, 25–50%, 50–75%, and 75–100%).

Is FAIRness associated with a higher citation count?

The number of citations accumulated during the first six publication years ranged from 1 to 435 (median = 68). The average annual citation rate during this six-year period ranged from 0.2 to 72.5 (median = 11.3), with annual citations showing a non-linear pattern that peaked, on average, between the 4th and 5th years (Figure S1 in Supplement S4). For the 55 meta-analyses that shared data, there was no statistical evidence of an association between the data FAIRness score and the number of citations accumulated during the first six years after publication of each meta-analysis (Kendall's rank: tau = -0.04, p = 0.65; Figure 3B).

Discussion

Meta-analysis has become an important tool for quantitatively synthesising evidence across multiple studies, exploring sources of heterogeneity, and addressing broader questions that cannot be answered by individual studies alone (Gurevitch et al., 2018). However, the term "meta-analysis" itself has been used inconsistently in ecology, evolution, and environmental sciences, being regularly confused with other summary analyses such as vote-counting, unweighted multiple regression methods, or other statistical analyses (Vetter et al., 2013; O'Dea et al., 2021). The misuse of the term "meta-analysis" was also apparent during our screening, which excluded articles self-identified as meta-analyses but using vote-counting, summaries of survey observations, or single dataset analyses. The statistical approaches used across the 81 meta-analyses we assessed also varied considerably. Although most meta-analyses weighted effect sizes by precision or sample size, 17% used unweighted analyses such as ANOVA, calling their validity into question. Weighting effect sizes by precision is important to account for differences in sampling uncertainty among estimates, although alternative weighting methods or unweighted analyses, in limited cases, can be justified (e.g., Morrissey, 2016; Pappalardo et al., 2023). Of the 18 meta-analyses in our sample identified as needing to address the directionality of effect sizes, only two-thirds explicitly reported doing so, calling their validity into question. Consistent direction coding is essential to make results biologically comparable without artificially cancelling one another or incorrectly combining them (Morrissey, 2016; Nakagawa & Lagisz, 2016; O'Dea et al., 2021). Recent re-analyses of published meta-analytic datasets illustrate more broadly how decisions made during effect size calculation and, specifically, inconsistent or nonexistent processes to ensure comparability in effect size direction can substantially change the evidence produced by a meta-analysis (e.g., Maassen et al., 2020; Sánchez-Tójar et al., 2020a, 2020b; Sánchez-Tójar & D'Amelio, 2026).

Formal Risk of Bias (RoB) assessments of included primary studies, which evaluate the internal validity of each primary study, is uncommon in ecology, evolution and environmental sciences (Culina et al., 2026). Since meta-analytical conclusions depend on the primary studies synthesised; RoB assessments are crucial. In our sample, although 15% of meta-analyses considered some methodological aspects of the primary studies as potential sources of variation, none conducted a formal RoB assessment, which is consistent with previous assessments (Stanhope & Weinstein, 2023; Frampton et al., 2022; Culina et al., 2026). Culina et al. (2026) recently found that only 12% of surveyed researchers with experience in evidence synthesis correctly interpreted RoB, while 40% of those who had heard the term confused it with publication bias. On the positive side, our results suggest that even though formal RoB assessments are not established practice in the field, some meta-analysts explore study-level methodological features important for the internal validity of the studies. This suggests openness to the underlying principles of RoB assessment, which together with the recently developed RoB assessment frameworks (Frampton et al., 2022; Culina et al., 2026), may help make RoB assessments routine in the field.

Data sharing is relatively common, but code sharing lags behind

Representing two-thirds of meta-analyses, data sharing was relatively common and, on average, close to five times more common than code sharing. Our findings of greater data sharing is consistent with ecology and evolution studies showing that data sharing is much more common than code sharing (e.g., Culina et al., 2020; Kambouris et al., 2024; Pollo et al., 2024; Sánchez-Tójar et al., 2025; Cooper et al., 2026). However, data availability alone is not enough to ensure reproducibility. Reproducibility assessments across disciplines consistently identify missing or inaccessible data as the major barrier to reproducing published results, followed by missing or inaccessible code (Archmiller et al., 2020; Minocher et al., 2021; Trisovic et al., 2022). When data can be accessed, code accessibility has been shown to increase reproducibility by about twofold (Miske et al., 2026). In meta-analysis, code is an essential part of the synthesis process that documents decisions about data cleaning, effect size calculation, data transformations, and model specification that may not be recoverable from the article alone (see, e.g., Maassen et al., 2020; Kambouris et al., 2024). For a form of synthesis that is not only influential but largely a computational endeavour, code availability is particularly relevant (Haddaway & Pullin, 2014; Nakagawa et al., 2017) and the code should be shared.

Shared data are Findable and Accessible, but less Interoperable and Reusable

Data and code availability, however, does not guarantee reproducibility or reusability. Even when code is shared, it is often poorly documented or fails to run (Trisovic et al., 2022; Kellner et al., 2025), while shared data require adequate documentation, structure and licensing to facilitate their interpretation and reuse. The FAIR principles provide a framework for ensuring that digital research objects are Findable, Accessible, Interoperable and Reusable by both humans and machines (Wilkinson et al., 2016). The mean FAIR score in our study was 70%, which is at the upper end of the range reported in FAIR assessments from other fields (43–71%; Poljak Bilić & Posavec, 2024; Sofi-Mahmudi et al., 2024; Hutchison et al., 2024). Findability and Accessibility were generally high, and almost all articles indicated where their data could be found, and all datasets were downloadable. However, only around two-thirds deposited data in a searchable repository, provided associated metadata, assigned a persistent identifier or included an explicit reuse licence. Fewer than half provided a data dictionary, and only 38% used exclusively non-proprietary, machine-readable formats such as .csv or .tsv. Searchable repositories and persistent identifiers support stable data discovery and citation; metadata and data dictionaries allow data to be interpreted for reusability; machine-readable formats are key for computational processing by humans and machines; and explicit licences clarify the conditions under which data may be reused. Our results indicate that the key shortcomings in shared meta-analytic datasets were Interoperability and Reusability: datasets could usually be located and opened, but were not consistently documented, structured or licensed for independent reuse. This is consistent with earlier assessments in ecology and evolution, where archived data were often incomplete (56% of archived datasets), and 56-64% of datasets lacked information that partially or entirely prevented reuse (Roche et al., 2015; Roche et al., 2022).

Meta-analysts invest considerable effort in searching for studies, extracting information, and harmonising heterogeneous data. Well-curated meta-analytic datasets could subsequently support verification, updating, and entirely new syntheses (Nakagawa et al., 2020). Merely depositing files only captures a small part of the potential value of data sharing. The observed pattern may partly reflect compliance-oriented journal and funder policies that emphasise whether data and code are made available (Sholler et al., 2019; Roche et al., 2022; Ivimey-Cook et al., 2025). Meeting such sharing requirements does not necessarily ensure that deposited files are sufficiently complete, documented or structured for reuse (Cooper et al., 2026). Applying FAIR-aligned practices would allow meta-analytic datasets to function as cumulative research objects. Ensuring the reusability of shared datasets is therefore a critical next step for improving the transparency, verification and updating of evidence syntheses (Burgard et al., 2022; Pollo et al., 2025).

Reporting and conduct guidelines, such as PRISMA, CEE guidance, and ROSES, require authors to report key features of review conduct, including search and screening decisions, synthesis methods, protocol registration, statistical software, and, increasingly, the availability of data and code (Collaboration for Environmental Evidence, 2022; Haddaway et al., 2018; Page et al., 2021). In our study, only 22% of the meta-analyses reported following a reporting guideline. Among meta-analyses sharing data, we found no evidence that studies reporting guideline use had higher FAIR scores. These tools are essential for improving the completeness of reporting in systematic reviews and meta-analyses (Pappalardo et al., 2023; Morrison et al., 2025). Nonetheless, previous assessments found that systematic reviews and meta-analyses reported, on average, only approximately 42–55% of the evaluated reporting items across fields (Polanin et al., 2020; O’Dea et al., 2021; Ivaldi et al., 2024). These guidelines, however, do not directly address how to prepare data to meet the FAIR principles (Wilkinson et al., 2016). Reporting guidance for evidence synthesis and FAIR guidance are complementary rather than interchangeable. While the former makes a synthesis more transparent and comprehensible, the latter attempts to make the underlying materials reusable for validating and updating evidence synthesis as new evidence accumulates, thereby enabling fuller use of existing research and reducing research waste (Grainger et al., 2020; Purgar et al., 2022).

Lastly, our exploratory analyses found no association between data FAIRness and citations accumulated during the first six years after publication. Some studies have reported a citation advantage when data is shared (Piwowar et al., 2007; Piwowar & Vision, 2013), including recent evidence from ecology and evolution (Maitner et al., 2024). However, those studies generally compared whether data were shared rather than investigating data FAIRness. More recently, Morrison et al. (2025) found no difference in the methodological quality of meta-analyses cited in policy documents versus those not. Citation count therefore cannot be assumed to be associated with methodological quality or data reusability, strengthening the case for journals and funders to establish these practices as expectations rather than relying primarily on researchers to adopt them for individual academic incentives such as citation benefits.

Limitations of our study

Several limitations should be considered when interpreting our findings. First, although the 81 articles were randomly selected from our eligible pool, they represent a small sample of all meta-analyses published between 2016 and 2020 in a predefined set of journals, limiting the extrapolation of our results to the wider literature or to more recent practice. Second, our FAIR assessment protocol only evaluated eight FAIR indicators, with an uneven number of items per component (F = 3, A = 2, I = 1, and R = 2 items). Different studies and different areas of research have used different criteria and scoring systems. For example, assessments based on automated tools such as F-UJI evaluated additional machine-reusability features such as standardised access protocols and controlled vocabularies (Poljak Bilić & Posavec, 2024; Sofi-Mahmudi et al., 2024). Although these criteria are valuable for assessing FAIRness across a broad range of digital research objects and for large interoperable data infrastructures, they may not always capture the features most relevant for reusability in meta-analytic datasets in ecology, evolution and environmental sciences. The FAIR principles are intentionally broad and are intended to be operationalised by research communities in ways that reflect domain-specific data types, standards and reuse needs. Our protocol therefore prioritised key practical features such as clear links to the shared data, interoperable file formats, persistent identifiers, licensing, metadata and variable-level documentation.

Study conclusions and recommendations

Our study shows that, in contrast to code sharing, data sharing is relatively common among meta-analyses in ecology, evolution and environmental sciences. Shared data were generally Findable and Accessible, whereas Interoperability and Reusability were more frequently limited. The FAIR principles provide the broad foundation for improving data stewardship, and FAIR4RS extends a similar framework to research software (Wilkinson et al., 2016; Barker et al., 2022). Additionally, the TADA and SORTEE guidelines provide field-relevant guidance to improve credibility, reproducibility, and reusability (Ivimey-Cook et al., 2025; Pick et al., 2026). The recently developed Meta-analysis Appraisal Tool for Environmental Sciences (MATES; Morrison et al., 2026) can further be used to evaluate reporting completeness in meta-analyses. Together with evidence synthesis guidelines, these frameworks can help shift practices from simply reporting what was done towards documenting and sharing the materials needed to verify and extend the synthesis for future use (Moreau et al., 2024). Since evidence syntheses increasingly inform research priorities, conservation and environmental management, their underlying data and analytical workflows must be sufficiently reusable for others to check, update, and build on as evidence accumulates (Haddaway, 2018). By distinguishing transparency from FAIRness, our study offers a more granular picture, and shows that considerable work remains before open meta-analytic datasets in ecology, evolution, and environmental sciences can be considered truly reusable.

Data and code availability statement

All materials, data and code associated with this study have been archived on Zenodo (https://doi.org/10.5281/zenodo.22706516, Dimri & Sánchez-Tójar, 2026)

AI Use Declaration:

The authors declare that AI was not used to generate the ideas or initial draft of this manuscript. GPT-5.6 Luna was used only to improve the readability of selected portions of the human-authored text. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content within this manuscript.

Authors contributions (CRediT)

SD: Data Curation (equal), Investigation (lead), Methodology (equal), Project administration (equal), Software, Validation, Visualization (equal), Writing – original draft (equal), Writing – review & editing (equal).

MP, VD, HB, AC, RF, AJF, MG, EI-C, MLJ, ML, NPM, NP-J, PP, GW, YY, CZ: Investigation (equal), Writing – review & editing (equal)

AST: Conceptualization, Data Curation (equal), Formal analysis, Funding acquisition, Investigation (lead), Methodology (equal), Project administration (equal), Software (lead), Supervision, Visualization (equal), Writing – original draft (equal), Writing – review & editing (equal).

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Conflict of interest

The authors declare having no conflict of interest.

References:

Archmiller, A.A., Johnson, A.D., Nolan, J., Edwards, M., Elliott, L.H., Ferguson, J.M., Iannarilli, F., Vélez, J., Vitense, K., Johnson, D.H. and Fieberg, J. (2020), Computational Reproducibility in The Wildlife Society's Flagship Journals. Jour. Wild. Mgmt., 84: 1012-1017. https://doi.org/10.1002/jwmg.21855

Barker, M., Chue Hong, N.P., Katz, D.S. et al. Introducing the FAIR Principles for research software. Sci Data 9, 622 (2022). https://doi.org/10.1038/s41597-022-01710-x

Brisco, E., Kulinskaya, E., & Koricheva, J. (2024). Assessment of temporal instability in the applied ecology and conservation evidence base. *Research Synthesis Methods, 15*(3), 398–412. https://doi.org/10.1002/jrsm.1691

Broman, K. W., & Woo, K. H. (2018). Data Organization in Spreadsheets. The American Statistician, 72(1), 2–10. https://doi.org/10.1080/00031305.2017.1375989

Burgard T, Bosnjak M, Studtrucker R. PsychOpen CAMA: Publication of community-augmented meta-analyses in psychology. Res Syn Meth. 2022; 13(1): 134-143. doi:10.1002/jrsm.1536

Capilla-Lasheras, P., Thompson, M. J., Sánchez-Tójar, A., Haddou, Y., Branston, C. J., & Réale, D., et al. (2022). A global meta-analysis reveals higher variation in breeding phenology in urban birds than in their non-urban neighbours. Ecology Letters, 25, 2552–2570. https://doi.org/10.1111/ele.14099

Chalmers, I., & Glasziou, P. (2009). Avoidable waste in the production and reporting of research evidence. The Lancet, 374, 86–89. https://doi.org/10.1016/S0140-6736(09)60329-9

Collaboration for Environmental Evidence. (2022). Guidelines and standards for evidence synthesis in environmental management: Version 5.1 (A. S. Pullin, G. K. Frampton, B. Livoreil, & G. Petrokofsky, Eds.). Collaboration for Environmental Evidence.

Cooper, N., Allen, B. J., Almaani, N., Altwegg, R., Balogh, J., Balti, H., Barber, R. A., Barbosa de Sousa, M. E., Barreat, J. G. N., Barrett, C. F., Bates, R., Beale, A. M. J. M., Bliard, L., Blömer, N., Borovyk, D., Bunnenberg, C., Bygate, E. A., Cash, L., Chatterjee, N., … Windecker, S. M. (2026). Data- and code-archiving in the British Ecological Society journals: Present status and recommendations for future improvements. EcoEvoRxiv. https://doi.org/10.32942/X26W9V

Culina, A., Foster, D., Grainger, M., O'Dea, R. E., Pescott, O. L., Sánchez-Tójar, A., Boyd, R. J., Koricheva, J., Nakagawa, S., & Stewart, G. (2026). Elevating the importance of Risk of Bias assessment for ecology and evolutionary biology. Methods in Ecology and Evolution. https://doi.org/10.1111/2041-210x.70356

Culina, A., van den Berg, I., Evans, S., & Sánchez-Tójar, A. (2020). Low availability of code in ecology: A call for urgent action. PLOS Biology, 18(7), e3000763. https://doi.org/10.1371/journal.pbio.3000763

Dimri, S., Rizvi, T., Segovia, J. M. G., Ottensmann, M., & Sánchez-Tójar, A. (2026). Why do birds use green nest material? A systematic review and meta-analysis of experiments. Proceedings of the Royal Society B: Biological Sciences, 293(2075), 20260777. https://doi.org/10.1098/rspb.2026.0777

Dimri, S., & Sánchez-Tójar, A. (2026). Data and Code for "Meta-analysts must lead by example and embrace all FAIR principles". Zenodo. https://doi.org/10.5281/zenodo.22706516

Dorai-Raj, S., & Cascone, A. D. (2026). *binom: Binomial confidence intervals for several parameterizations* (R package version 1.1-2). https://doi.org/10.32614/CRAN.package.binom

Frampton, G., Whaley, P., Bennett, M. et al. Principles and framework for assessing the risk of bias for studies included in comparative quantitative environmental systematic reviews. Environ Evid 11, 12 (2022). https://doi.org/10.1186/s13750-022-00264-0

Gan, J. L., Grainger, M. J., Shirley, M. D. F., et al. (2025). Effectiveness of perches in promoting bird-mediated seed dispersal for natural forest regeneration: A systematic review. Environmental Evidence, 14, 10. https://doi.org/10.1186/s13750-025-00363-8

Grainger, M. J., Bolam, F. C., Stewart, G. B., et al. (2020). Evidence synthesis for tackling research waste. Nature Ecology & Evolution, 4, 495–497. https://doi.org/10.1038/s41559-020-1141-6

Gurevitch, J., Koricheva, J., Nakagawa, S. et al. Meta-analysis and the science of research synthesis. Nature 555, 175–182 (2018). https://doi.org/10.1038/nature25753

Haddaway, N. R. (2018). Open synthesis: On the need for evidence synthesis to embrace Open Science. Environmental Evidence, 7, 26. https://doi.org/10.1186/s13750-018-0140-4

Haddaway, N., Woodcock, P., Macura, B., & Collins, A. (2015a). Making literature reviews more reliable through application of lessons from systematic reviews. Conservation Biology, 29(6), 1596–1605. https://doi.org/10.1111/cobi.12541

Haddaway, N. R., Collins, A. M., Coughlin, D., & Kirk, S. (2015b). The role of Google Scholar in evidence reviews and its applicability to grey literature searching. PLOS ONE, 10(9), e0138237. https://doi.org/10.1371/journal.pone.0138237

Haddaway, N. R., Macura, B., Whaley, P., & Pullin, A. S. (2018). ROSES reporting standards for systematic evidence syntheses: Pro forma, flow-diagram and descriptive summary of the plan and conduct of environmental systematic reviews and systematic maps. Environmental Evidence, 7(1), 7. https://doi.org/10.1186/s13750-018-0121-7

Haddaway, N. R., & Pullin, A. S. (2014). The policy role of systematic reviews: Past, present and future. Springer Science Reviews, 2, 179–183. https://doi.org/10.1007/s40362-014-0023-1

Haddaway, N. R., & Westgate, M. J. (2019). Predicting the time needed for environmental systematic reviews and systematic maps. *Conservation Biology, 33*, 434–443. https://doi.org/10.1111/cobi.13231

Häkkilä, M., Johansson, A., Sandgren, T. *et al.* Are small protected habitat patches within boreal production forests effective in conserving species richness, abundance and community composition? A systematic review. *Environ Evid* 10, 2 (2021). https://doi.org/10.1186/s13750-020-00216-6

Higgins, J. P. T., & Green, S. (Eds.). (2015). Cochrane handbook for systematic reviews of interventions (Version 5.1.0). The Cochrane Collaboration.

Hutchison, V.B., Norkin, T., Zolly, L.S. and Hsu, L. (2024) State of the Data: Assessing the FAIRness of US Geological Survey Data, Data Science Journal, 23(1), p. 22. https://doi.org/10.5334/dsj-2024-022

Ioannidis, J. P. A. (2016). The mass production of redundant, misleading, and conflicted systematic reviews and meta-analyses. Milbank Quarterly, 94, 485–514. https://doi.org/10.1111/1468-0009.12210

Ivaldi D, Burgos M, Oltra G, Liquitay CE, Garegnani L. Adherence to PRISMA 2020 statement assessed through the expanded checklist in systematic reviews of interventions: A meta-epidemiological study. Cochrane Ev Synth. 2024; 2:e12074. https://doi.org/10.1002/cesm.12074

Ivimey-Cook, E. R., Culina, A., Dimri, S., Grainger, M., Kar, F., Lagisz, M., Moran, N. P., Nakagawa, S., Roche, D. G., Tattan, S., Sanchez-Tojar, A., Windecker, S. M., & Pick, J. L. (2025). TADA! Simple guidelines to improve analytical code sharing for transparency and reproducibility. https://doi.org/10.32942/X2D93K

Jennions, M. D., & Møller, A. P. (2002). Relationships fade with time: A meta-analysis of temporal trends in publication in ecology and evolution. Proceedings of the Royal Society B: Biological Sciences, 269(1486), 43–48. https://doi.org/10.1098/rspb.2001.1832

Juan-Ovejero, R., Bartz, M. L. C., Baretta, D., Sousa, J. P., & Ferreira, V. (2025). Effects of eucalypt monoculture plantations on soil invertebrate communities: A meta-analysis. Land Degradation & Development, 36, 1310–1325. https://doi.org/10.1002/ldr.5431

Kambouris, S., Wilkinson, D. P., Smith, E. T., & Fidler, F. (2024). Computationally reproducing results from meta-analyses in ecology and evolutionary biology using shared code and data. PLOS ONE, 19(3), e0300333. https://doi.org/10.1371/journal.pone.0300333

Kellner, Kenneth F., Jeffrey W. Doser, and Jerrold L. Belant. 2025. " Functional R Code is Rare in Species Distribution and Abundance Papers." Ecology 106(1): e4475. https://doi.org/10.1002/ecy.4475

Kim, B., Moran, N. P., Reinhold, K., & Sánchez-Tójar, A. (2021). Male size and reproductive performance in three species of livebearing fishes (Gambusia spp.): A systematic review and meta-analysis. Journal of Animal Ecology, 90, 2431–2445. https://doi.org/10.1111/1365-2656.13554

Koricheva, J., & Kulinskaya, E. (2019). Temporal instability of evidence base: A threat to policy making? *Trends in Ecology & Evolution, 34*(10), 895–902. https://doi.org/10.1016/j.tree.2019.05.006

Maassen, E., van Assen, M. A. L. M., Nuijten, M. B., Olsson-Collentine, A., & Wicherts, J. M. (2020). Reproducibility of individual effect sizes in meta-analyses in psychology. PLOS ONE, 15(5), e0233107. https://doi.org/10.1371/journal.pone.0233107

Maitner, B., Santos Andrade, P. E., Lei, L., Kass, J., Owens, H. L., Barbosa, G. C. G., Boyle, B., Castorena, M., Enquist, B. J., Feng, X., Park, D. S., Paz, A., Pinilla-Buitrago, G., Merow, C., & Wilson, A. (2024). Code sharing in ecology and evolution increases citation rates but remains uncommon. Ecology and Evolution, 14, e70030. https://doi.org/10.1002/ece3.70030

Martín-Martín, A., Orduna-Malea, E., Thelwall, M., & Delgado López-Cózar, E. (2018). Google Scholar, Web of Science, and Scopus: A systematic comparison of citations in 252 subject categories. Journal of Informetrics, 12(4), 1160–1177. https://doi.org/10.1016/j.joi.2018.09.002

Minocher, R., Atmaca, S., Bavero, C., McElreath, R., & Beheim, B. (2021). Estimating the reproducibility of social learning research published between 1955 and 2018. Royal Society Open Science, 8(9), 210450. https://doi.org/10.1098/rsos.210450

Miske, O., Abatayo, A.L., Daley, M. et al. Investigating the reproducibility of the social and behavioural sciences. Nature 652, 126–134 (2026). https://doi.org/10.1038/s41586-026-10203-5

Moran, N. P., Wang, L.-Y., Hanea, A. M., & Kompas, T. (2025). An invasive species cost review for New South Wales, Australia, highlights key drivers and limitations of economic cost estimates. NeoBiota, 104, 319–337. https://doi.org/10.3897/neobiota.104.157434

Moreau D, Wiebels K (2024) Nine quick tips for open meta-analyses. PLoS Comput Biol 20(7): e1012252. https://doi.org/10.1371/journal.pcbi.1012252

Morrison, K., Yang, Y., Williams, C., et al. (2025). Mapping meta-analyses on organochlorine pesticides reveals low methodological quality. Nature Sustainability, 8, 1270–1279. https://doi.org/10.1038/s41893-025-01634-5

Morrison, K., Pottier, P., Pollo, P., Ricolfi, L., Williams, C., Yang, Y., et al. (2026). MATES: A tool for appraising the completeness with which a meta-analysis has been reported. Environment International, 207, 109935. https://doi.org/10.1016/j.envint.2025.109935

Morrissey, M. B. (2016). Meta-analysis of magnitudes, differences and variation in evolutionary parameters. Journal of Evolutionary Biology, 29(10), 1882–1904. https://doi.org/10.1111/jeb.12950

Murad, M. H., Asi, N., Alsawas, M., & Alahdab, F. (2016). New evidence pyramid. Evidence-Based Medicine, 21(4), 125–127. https://doi.org/10.1136/ebmed-2016-110401

Nakagawa, S., & Lagisz, M. (2016). Visualizing unbiased and biased unweighted meta-analyses. Journal of Evolutionary Biology, 29(10), 1914–1916. https://doi.org/10.1111/jeb.12945

Nakagawa, S., Noble, D. W. A., Senior, A. M., et al. (2017). Meta-evaluation of meta-analysis: Ten appraisal questions for biologists. BMC Biology, 15, 18. https://doi.org/10.1186/s12915-017-0357-7

Nakagawa, S., Dunn, A. G., Lagisz, M., et al. (2020). A new ecosystem for evidence synthesis. Nature Ecology & Evolution, 4, 498–501. https://doi.org/10.1038/s41559-020-1153-2

O’Dea, R. E., et al. (2021). Preferred reporting items for systematic reviews and meta-analyses in ecology and evolutionary biology: a PRISMA extension. Biological Reviews, 96, 1695–1722. https://doi.org/10.1111/brv.12721

Page M J, McKenzie J E, Bossuyt P M, Boutron I, Hoffmann T C, Mulrow C D et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews BMJ 2021; 372 :n71 https://doi.org/10.1136/bmj.n71

Pappalardo P, Song C, Hungate BA, Osenberg CW (2023) A meta-evaluation of the quality of reporting and execution in ecological meta-analyses. PLoS ONE 18(10): e0292606. https://doi.org/10.1371/journal.pone.0292606

Pick, J. L.; Allen, B. J.; Bachelot, B.; Bairos-Novak, K. R.; Brand, J. A.; Class, B.; Dallas, T.; D'Amelio, P. B.; Fenollosa, E.; Fernández-Juricic, E.; Gomes, D. G. E.; Grainger, M. J.; Guillemaud, T.; John, C.; Krasnow, R.; Lagisz, M.; Lequime, S.; Maynard, D. S.; Nakagawa, S.; O'Dea, R. E.; Paquet, M.; Petitjean, Q.; Sánchez-Tójar, A.; van Dis, N. E.; Wilson, L. A. B.; Ivimey-Cook, E. R. The SORTEE guidelines for data and code quality control in ecology and evolutionary biology. Peer Community Journal, Volume 6 (2026), article no. e20. https://doi.org/10.24072/pcjournal.687

Piwowar, H. A., Day, R. S., & Fridsma, D. B. (2007). Sharing detailed research data is associated with increased citation rate. PLOS ONE, 2(3), e308. https://doi.org/10.1371/journal.pone.0000308

Piwowar, H. A., & Vision, T. J. (2013). Data reuse and the open data citation advantage. PeerJ, 1, e175. https://doi.org/10.7717/peerj.175

Polanin, J. R., Hennessy, E. A., & Tsuji, S. (2020). Transparency and reproducibility of meta-analyses in psychology: A meta-review. Perspectives on Psychological Science, 15(4), 1026–1041. https://doi.org/10.1177/1745691620906416

Poljak Bilić, L., & Posavec, K. (2024). FAIRness of research data in the European humanities landscape. Publications, 12(1), 6. https://doi.org/10.3390/publications12010006

Pollo, P., Lagisz, M., Macedo-Rego, R. C., Mizuno, A., Yang, Y., & Nakagawa, S. (2025). Reliability of meta-analyses in ecology and evolution: (mostly) good news from a case study on sexual signals. Proceedings of the Royal Society B: Biological Sciences, 292(2047), 20242782. https://doi.org/10.1098/rspb.2024.2782

Pollo, P., Lagisz, M., Yang, Y., Culina, A. and Nakagawa, S. (2024), Synthesis of sexual selection: a systematic map of meta-analyses with bibliometric analysis. Biol Rev, 99: 2134-2175. https://doi.org/10.1111/brv.13117

Purgar, M., Klanjšček, T., & Culina, A. (2022). Quantifying research waste in ecology. Nature Ecology & Evolution, 6, 1390–1397. https://doi.org/10.1038/s41559-022-01820-0

R Core Team. (2024). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Roche, D. G., Kruuk, L. E. B., Lanfear, R., & Binning, S. A. (2015). Public data archiving in ecology and evolution: How well are we doing? PLOS Biology, 13(11), e1002295. https://doi.org/10.1371/journal.pbio.1002295

Roche, D. G., Berberi, I., Dhane, F., Lauzon, F., Soeharjono, S., Dakin, R., & Binning, S. A. (2022). Slow improvement to the archiving quality of open datasets shared by researchers in ecology and evolution. Proceedings of the Royal Society B: Biological Sciences, 289(1975), 20212780. https://doi.org/10.1098/rspb.2021.2780

Sánchez-Tójar, A., & D'Amelio, P.B. (2026). Fifty years later, and we still don't know about badges of status. Ecology & Evolution. http://doi.org/10.1002/ece3.73578

Sánchez-Tójar, A., Bezine, A., Purgar, M., & Culina, A. (2025). Code-sharing policies are associated with increased reproducibility potential of ecological findings. Peer Community Journal, 5, e37. doi: 10.24072/pcjournal.541

Sánchez-Tójar, A., Lagisz, M., Moran, N. P., Nakagawa, S., Noble, D. W. A., & Reinhold, K. (2020a). The jury is still out regarding the generality of adaptive "transgenerational" effects. Ecology Letters, 23(11), 1715–1718. https://doi.org/10.1111/ele.13479

Sánchez-Tójar, A., Moran, N. P., O'Dea, R. E., Reinhold, K., & Nakagawa, S. (2020b). Illustrating the importance of meta-analysing variances alongside means in ecology and evolution. Journal of Evolutionary Biology, 33(9), 1216–1223. https://doi.org/10.1111/jeb.13661

Sholler, D., Ram, K., Boettiger, C., & Katz, D. S. (2019). Enforcing public data archiving policies in academic publishing: A study of ecology journals. Big Data & Society, 6(1). https://doi.org/10.1177/2053951719836258

Siontis, K. C., Hernandez-Boussard, T., & Ioannidis, J. P. A. (2013). Overlapping meta-analyses on the same topic: Survey of published studies. *BMJ, 347*, f4501. https://doi.org/10.1136/bmj.f4501

Sofi-Mahmudi, A., Raittio, E., Khazaei, Y., Ashraf, J., Schwendicke, F., Uribe, S. E., & Moher, D. (2024). COVID-19-related research data availability and quality according to the FAIR principles: A meta-research study. PLOS ONE, 19(11), e0313991. https://doi.org/10.1371/journal.pone.0313991

Stanhope J, Weinstein P. Critical appraisal in ecology: What tools are available, and what is being used in systematic reviews? Res Syn Meth. 2023; 14(3): 342-356. https://doi.org/10.1002/jrsm.1609

Trisovic, A., Lau, M.K., Pasquier, T. et al. A large-scale study on research code quality and execution. Sci Data 9, 60 (2022). https://doi.org/10.1038/s41597-022-01143-6

Vasconcelos, S., Jonsson, M., Heleno, R., Moreira, F., & Beja, P. (2022). A meta-analysis of biocontrol potential and herbivore pressure in olive crops: Does integrated pest management make a difference? Basic and Applied Ecology, 63, 115–124. https://doi.org/10.1016/j.baae.2022.06.002

Vetter, D., G. Rücker, and I. Storch. 2013. Meta-analysis: A need for well-defined usage in ecology and conservation biology. Ecosphere 4(6):74. http://dx.doi.org/10.1890/ES13-00062.1

Wilkinson, M. D., Dumontier, M., Aalbersberg, I. J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J.-W., Bonino da Silva Santos, L., Bourne, P. E., Bouwman, J., Brookes, A. J., Clark, T., Crosas, M., Dillo, I., Dumon, O., Edmunds, S., Evelo, C. T., Finkers, R., Gonzalez-Beltran, A., Gray, A. J. G., Groth, P., Goble, C., Grethe, J. S., … Mons, B. (2016). The FAIR guiding principles for scientific data management and stewardship. Scientific Data, 3, 160018. https://doi.org/10.1038/sdata.2016.18

Supplement S1: Complete Search String

We searched the same set of ecology and evolutionary biology journals used in O'Dea et al. (2021). Those journals were derived from a list of journals classified under the "Ecology" and "Evolutionary Biology" categories in the 2017 ISI InCites Journal Citation Reports. Duplicate journals were removed, and both print and electronic ISSNs were included where available. We used the following string in our Web of Science search:

(TI = ("meta-analy*" OR "metaanaly*" OR "meta-regression" OR "metaregression") OR AB = ("meta-analy*" OR "metaanaly*" OR "meta-regression" OR "metaregression") OR AK = ("meta-analy *" OR "metaanaly*" OR "meta-regression" OR "metaregression")) AND IS= ("13652486" OR "14610248 "OR "01678809" OR "16000706"OR"14668238" OR "00063207" OR "14321939" OR "14712954" OR "15231739" OR "20457758" OR "13652664" OR "09218009" OR "13652745" OR "16161599" OR "1365294X" OR "14209101" OR "19395582" OR "13652435" OR "17264189" OR "2041210X" OR "15585646" OR "13652656" OR "21508925" OR "15375323" OR "17517370" OR " 16000587" OR "13652699" OR "1744957X" OR "14657279" OR "15731464" OR "15577015" OR "22120416" OR "14350629" OR "15738477" OR "13652427" OR " 14712148" OR "15729710" OR "09258574" OR "03043800" OR "14724642" OR "17524571" OR "16541103" OR "1526100X" OR "10958312" OR "15749541" OR "23519894 "OR "15735052" OR "01695347" OR "14391791" OR "14320762" OR "21619549" OR "16171381" OR "0022541X" OR "15729761" OR "14338319" OR "14429993" OR "09123814" OR "17083087" OR "17545048" OR "01401963" OR "01692046" OR "15371719" OR "2397334X" OR "14726785" OR "15733017" OR "15409309" OR "1432184X" OR "10968644" OR "1654109X" OR "16161564" OR " 19360592" OR "13652540" OR "17550998" OR "00314056" OR "1438390X" OR " 15507424" OR "00652504" OR "17596653" OR "10959513" OR "14691795" OR " 15891623" OR "20511434" OR "11769343" OR "19342845" OR "22132244" OR " 22244662" OR "00220981" OR "14657333" OR "19413300" OR "14697831" OR " 01106465" OR "13653008" OR "24501395" OR "15731642" OR "10353712" OR " 0003455X" OR "15452069" OR "17447429" OR "11645563" OR "03672530" OR " 00472484" OR "17529921" OR "08000395" OR "16083334" OR "1076836X" OR " 19385455" OR "13652028" OR "17279380" OR "20412851" OR "10301887" OR " 02757540" OR "14230445" OR "10960031" OR "15882756" OR "22145753" OR " 15735133" OR "14390574" OR "15220613" OR "19339747" OR "13504509" OR " 15731561" OR "14321432" OR "08858608" OR "21996881" OR "14753057" OR " 10369872" OR "23524855" OR "02497395" OR "15482324" OR "19968175" OR " 18741746" OR "10960325" OR "13991183" OR "19436246" OR "18094392" OR " 1146609X" OR "24108200" OR "00030031" OR "13488570" OR "15735125" OR " 18185487" OR "03051978" OR "00030090" OR "0079032X" OR "1065657X" OR " 19954263" OR "1432041X" OR "2073106X" OR "16423593" OR "1476945X" OR " 14427001" OR "19399170" OR "11956860" OR "20419139" OR "1525142X" OR " 21553874" OR "1876312X" OR "03781844" OR "14455226" OR "17513758" OR " 00220930" OR "15525015" OR "1944687X" OR "02705060" OR "14645262" OR " 14772019" OR "14390469" OR "1860188X" OR "17451019" OR "20513933" OR " 00280712" OR "19385307" OR "0029344X" OR "16181077" OR "19385331" OR " 0340269X" OR

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List of Journals with the iSSN:

ISSN as in the search string	Formatted ISSN	Journal Name
13652486	1365-2486	Global Change Biology
14610248	1461-0248	Ecology Letters
01678809	0167-8809	Agriculture, Ecosystems and Environment
16000706	1600-0706	Oikos
14668238	1466-8238	Global Ecology and Biogeography

00063207	0006-3207	Biological Conservation
14321939	1432-1939	Oecologia
14712954	1471-2954	Proceedings of the Royal Society B: Biological Sciences
15231739	1523-1739	Conservation Biology
20457758	2045-7758	Ecology and Evolution
13652664	1365-2664	Journal of Applied Ecology
09218009	0921-8009	Ecological Economics
13652745	1365-2745	Journal of Ecology
16161599	1616-1599	Marine Ecology Progress Series
1365294X	1365-294X	Molecular Ecology
14209101	1420-9101	Journal of Evolutionary Biology
19395582	1939-5582	Ecological Applications
13652435	1365-2435	Functional Ecology
17264189	1726-4189	Biogeosciences
2041210X	2041-210X	Methods in Ecology and Evolution
15585646	1558-5646	Evolution
13652656	1365-2656	Journal of Animal Ecology
21508925	2150-8925	Ecosphere
15375323	1537-5323	American Naturalist

17517370	1751-7370	ISME Journal
16000587	1600-0587	Ecography
13652699	1365-2699	Journal of Biogeography
1744957X	1744-957X	Biology Letters
14657279	1465-7279	Behavioral Ecology
15731464	1573-1464	Biological Invasions
15577015	1557-7015	Ecological Monographs
22120416	2212-0416	Ecosystem Services
14350629	1435-0629	Ecosystems
15738477	1573-8477	Evolutionary Ecology
13652427	1365-2427	Freshwater Biology
14712148	1471-2148	BMC Evolutionary Biology
15729710	1572-9710	Biodiversity and Conservation
09258574	0925-8574	Ecological Engineering
03043800	0304-3800	Ecological Modelling
14724642	1472-4642	Diversity and Distributions
17524571	1752-4571	Evolutionary Applications
16541103	1654-1103	Journal of Vegetation Science
1526100X	1526-100X	Restoration Ecology

10958312	1095-8312	Biological Journal of the Linnean Society
15749541	1574-9541	Ecological Informatics
23519894	2351-9894	Global Ecology and Conservation
15735052	1573-5052	Plant Ecology
01695347	0169-5347	Trends in Ecology and Evolution
14391791	1439-1791	Basic and Applied Ecology
14320762	1432-0762	Behavioral Ecology and Sociobiology
21619549	2161-9549	Freshwater Science
16171381	1617-1381	Journal for Nature Conservation
0022541X	0022-541X	The Journal of wildlife management
15729761	1572-9761	Landscape Ecology
14338319	1433-8319	Perspectives in Plant Ecology, Evolution and Systematics
14429993	1442-9993	Austral Ecology
09123814	0912-3814	Ecological Research
17083087	1708-3087	Ecology and Society
17545048	1754-5048	Fungal Ecology
1401963	0140-1963	Journal of Arid Environments
1692046	0169-2046	Landscape and Urban Planning
15371719	1537-1719	Molecular Biology and Evolution

2397334X	2397-334X	Nature Ecology & Evolution
14726785	1472-6785	BMC Ecology
15733017	1573-3017	Ecotoxicology
15409309	1540-9309	Frontiers in Ecology and the Environment
1432184X	1432-184X	Microbial Ecology
10968644	1096-8644	American Journal of Physical Anthropology
1654109X	1654-109X	Applied Vegetation Science
16161564	1616-1564	Aquatic Microbial Ecologyn
19360592	1936-0592	Ecohydrology
13652540	1365-2540	Heredity
17550998	1755-0998	Molecular Ecology Resources
00314056	0031-4056	Pedobiologia
1438390X	1438-390X	Population Ecology
15507424	1550-7424	Rangeland Ecology & Management
00652504	0065-2504	Advances in Ecological Research
17596653	1759-6653	Genome Biology and Evolution
10959513	1095-9513	Molecular Phylogenetics and Evolution
14691795	1469-1795	Animal Conservation
15891623	1589-1623	Applied Ecology and Environmental Research

20511434	2051-1434	Conservation Physiology
11769343	1176-9343	Evolutionary Bioinformatics
19342845	1934-2845	Evolutionary Biology
22132244	2213-2244	International Journal for Parasitology: Parasites and Wildlife
22244662	2224-4662	Israel Journal of Ecology & Evolution
00220981	0022-0981	Journal of Experimental Marine Biology and Ecology
14657333	1465-7333	Journal of Heredity
19413300	1941-3300	Journal of Soil and Water Conservation
14697831	1469-7831	Journal of Tropical Ecology
01106465	0110-6465	New Zealand Journal of Ecology
13653008	1365-3008	Oryx
24501395	2450-1395	Polish Journal of Ecology
15731642	1573-1642	Urban Ecosystems
10353712	1035-3712	Wildlife Research
0003455X	0003-455X	Annales Zoologici Fennici
15452069	1545-2069	Annual Review of Ecology, Evolution, and Systematics
17447429	1744-7429	Biotropica
11645563	1164-5563	European Journal of Soil Biology
03672530	0367-2530	Flora

00472484	0047-2484	Journal of Human Evolution
17529921	1752-9921	Journal of Plant Ecology
08000395	0800-0395	Polar Research
16083334	1608-3334	Russian Journal of Ecology
1076836X	1076-836X	Systematic Biology
19385455	1938-5455	Wildlife Monographs
13652028	1365-2028	African Journal of Ecology
17279380	1727-9380	African Journal of Range & Forage Science
20412851	2041-2851	AoB PLANTS
10301887	1030-1887	Australian Systematic Botany
02757540	0275-7540	Chemistry and Ecology
14230445	1423-0445	Chemoecology
10960031	1096-0031	Cladistics
15882756	1588-2756	Community Ecology
22145753	2214-5753	Current Opinion in Insect Science
15735133	1573-5133	Environmental Biology of Fishes
14390574	1439-0574	European Journal of Wildlife Research
15220613	1522-0613	Evolutionary Ecology Research
19339747	1933-9747	Fire Ecology

13504509	1350-4509	International Journal of Sustainable Development & World Ecology
15731561	1573-1561	Journal of Chemical Ecology
14321432	1432-1432	Journal of Molecular Evolution
08858608	0885-8608	Natural Areas Journal
21996881	2199-6881	Österreichische Botanische Zeitschrift
14753057	1475-3057	Polar Record
10369872	1036-9872	The Rangeland Journal
23524855	2352-4855	Regional Studies in Marine Science
02497395	0249-7395	Revue d'Écologie
15482324	1548-2324	Systematic Botany
19968175	1996-8175	Taxon
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1146609X	1146-609X	Acta Oecologica
24108200	2410-8200	African Journal of Wildlife Research
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13488570	1348-8570	Anthropological Science
15735125	1573-5125	Aquatic Ecology
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19954263	1995-4263	Contemporary Problems of Ecology
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14427001	1442-7001	Ecological Management & Restoration
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1876312X	1876-312X	Insect Systematics & Evolution

03781844	0378-1844	Interciencia
14455226	1445-5226	Invertebrate Systematics
17513758	1751-3758	Journal of Biological Dynamics
00220930	0022-0930	Journal of Evolutionary Biochemistry and Physiology
15525015	1552-5015	Journal of Experimental Zoology Part B: Molecular and Developmental Evolution
1944687X	1944-687X	Journal of Fish and Wildlife Management
02705060	0270-5060	Journal of Freshwater Ecology
14645262	1464-5262	Journal of Natural History
14772019	1477-2019	Journal of Systematic Palaeontology
14390469	1439-0469	Journal of Zoological Systematics and Evolutionary Research
1860188X	1860-188X	Landscape and Ecological Engineering
17451019	1745-1019	Marine Biology Research
20513933	2051-3933	Movement Ecology
00280712	0028-0712	Natural History
19385307	1938-5307	Northeastern Naturalist
0029344X	0029-344X	Northwest Science
16181077	1618-1077	Organisms Diversity & Evolution
19385331	1938-5331	Paleobiology
0340269X	0340-269X	Phytocoenologia

14421984	1442-1984	Plant Species Biology
14322056	1432-2056	Polar Biology
18739652	1873-9652	Polar Science
01380338	0138-0338	Polish Polar Research
19385293	1938-5293	Proceedings of the Academy of Natural Sciences of Philadelphia
18397263	1839-7263	Proceedings of the Linnean Society of New South Wales
07176317	0717-6317	Revista Chilena de Historia Natural
19385412	1938-5412	Southeastern Naturalist
00384909	0038-4909	The Southwestern Naturalist
13653113	1365-3113	Systematic Entomology
05643295	0564-3295	Tropical Ecology
02408759	0240-8759	Vie et Milieu
15270904	1527-0904	Western North American Naturalist
09096396	0909-6396	Wildlife Biology
14636409	1463-6409	Zoologica Scripta
13541013	1354-1013	Global Change Biology
1461023X	1461-023X	Ecology Letters
00301299	0030-1299	Oikos
1466822X	1466-822X	Global Ecology and Biogeography

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00218901	0021-8901	Journal of Applied Ecology
00220477	0022-0477	Journal of Ecology
01718630	0171-8630	Marine Ecology Progress Series
09621083	0962-1083	Molecular Ecology
1010061X	1010-061X	Journal of Evolutionary Biology
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02698463	0269-8463	Functional Ecology
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13669516	1366-9516	Diversity and Distributions
11009233	1100-9233	Journal of Vegetation Science
10612971	1061-2971	Restoration Ecology
00244066	0024-4066	Biological Journal of the Linnean Society
13850237	1385-0237	Plant Ecology
03405443	0340-5443	Behavioral Ecology and Sociobiology
09212973	0921-2973	Landscape Ecology
14429985	1442-9985	Austral Ecology
07374038	0737-4038	Molecular Biology and Evolution
09639292	0963-9292	Animal Welfare
15409295	1540-9295	Frontiers in Ecology and the Environment
00953628	0095-3628	Microbial Ecology

2769667		Unknown
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09483055	0948-3055	Aquatic Microbial Ecology
19360584	1936-0584	Ecohydrology
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10557903	1055-7903	Molecular Phylogenetics and Evolution
13679430	1367-9430	Animal Conservation
00713260	0071-3260	Evolutionary Biology
15659801	1565-9801	Israel Journal of Ecology & Evolution
00221503	0022-1503	Journal of Heredity
00224561	0022-4561	Journal of Soil and Water Conservation
02664674	0266-4674	Journal of Tropical Ecology
00306053	0030-6053	Oryx
15052249	1505-2249	Polish Journal of Ecology
10838155	1083-8155	Urban Ecosystems
1543592X	1543-592X	Annual Review of Ecology, Evolution, and Systematics
623257		Unknown

10674136	1067-4136	Russian Journal of Ecology
10635157	1063-5157	Systematic Biology
00840173	0084-0173	Wildlife Monographs
01416707	0141-6707	African Journal of Ecology
10220119	1022-0119	African Journal of Range & Forage Science
09377409	0937-7409	Chemoecology
07483007	0748-3007	Cladistics
15858553	1585-8553	Community Ecology
22145745	2214-5745	Current Opinion in Insect Science
03781909	0378-1909	Environmental Biology of Fishes
16124642	1612-4642	European Journal of Wildlife Research
00980331	0098-0331	Environmental Conservation
00222844	0022-2844	Journal of Molecular Evolution
03782697	0378-2697	Plant Systematics and Evolution
00322474	0032-2474	Polar Record
03636445	0363-6445	Systematic Botany
00400262	0040-0262	Taxon
18741738	1874-1738	Theoretical Ecology
00405809	0040-5809	Theoretical Population Biology

21933081	2193-3081	Web Ecology
02775212	0277-5212	Wetlands
00445967	0044-5967	Acta Amazonica
24107220	2410-7220	African Journal of Wildlife Research
09187960	0918-7960	Anthropological Science
13862588	1386-2588	Aquatic Ecology
17986540	1798-6540	Aquatic Invasions
19954255	1995-4255	Contemporary Problems of Ecology
0949944X	0949-944X	Development, Genes and Evolution
2833888		Unknown
1520541X	1520-541X	Evolution & Development
19344392	1934-4392	Human-Wildlife Conflicts
1399560X	1399-560X	Insect Systematics & Evolution
15525007	1552-5007	Journal of Experimental Zoology Part A
00222933	0022-2933	Journal of Natural History
09475745	0947-5745	Journal of Zoological Systematics and Evolutionary Research
18601871	1860-1871	Landscape and Ecological Engineering
17451000	1745-1000	Marine Biology Research
10926194	1092-6194	Northeastern Naturalist

14396092	1439-6092	Organisms Diversity & Evolution
00948373	0094-8373	Paleobiology
0913557X	0913-557X	Plant Species Biology
07224060	0722-4060	Polar Biology
00973157	0097-3157	Proceedings of the Academy of Natural Sciences of Philadelphia
0370047X	0370-047X	Proceedings of the Linnean Society of New South Wales
0716078X	0716-078X	Revista Chilena de Historia Natural
15287092	1528-7092	Southeastern Naturalist
03076970	0307-6970	Systematic Entomology
03003256	0300-3256	Zoologica Scripta

Supplement S2: Hackathon Google Form

Participants will receive by email a set of **5 meta-analyses** to extract data from after contacting Shreya Dimri at shreyadimriofficial@gmail.com. Please submit **one form entry per meta-analysis**.

If you finish your assigned set and are willing to contribute further, feel free to request an additional set by emailing Shreya.

This form is designed to guide data extraction during the hackathon, where participants will contribute to a meta-research project investigating potential issues in published meta-analyses in ecology and evolution.

These include several transparency indicators such as data- and code-sharing, and quality indicators such us the failure to properly adjust effect size directions across studies, as well as undisclosed inferential statistics conversions into effect sizes. Importantly, what we are trying to do here is to categorise meta-analyses that may have incurred in certain quality issues that we will further explore after the hackathon (e.g., using their data and code, if any provided). For example, meta-analyses that do not mention any sign adjustments will be further explore to understand if they actually forgot to or simply did not have to adjust effect sizes direction. Last, we also want to investigate the prevalence of Risk of Bias assessment in the field. We have provided more information, along with some examples, in this Google Docs.

We do not send the **supplementary material associated with each published article but remember to check it out yourselves (by going to the DOI of the article)**. For example, information about the methods used (e.g., details of the effect size calculation and other conversions) could be provided in the Supplementary Material/Appendix.

All questions are mandatory, so if you comes across a situation where the **section to describe does not apply to you, please type 'NA' (Not applicable).** This is to ensure that every question is seen, assessed and thoughtfully answered by all participants.

Section 1: Participant Information :
This information will be used to reach out to you for follow-up if needed and to generate an extractor ID for the analysis later.

i. Your name (e.g., Shreya Dimri). Please make sure to use the exact same name (copy-paste recommended) for each form submission.

ii. Email (e.g., may be used for follow-up, if needed). Please make sure to use the exact same email (copy-paste recommended) for each form submission.

iii. Would you like to be invited as co-author and further contribution should these data be used in an eventual manuscript?: Yes/No

iv. Meta-analysis ID, which you can find in the list of meta-analyses you will receive by email.

v. Meta-analysis Title (please copy and paste the title exactly as it appears in the published article)

Section 2: Effect Size Direction and Handling

In meta-analyses, effect sizes from different studies must have **consistent directions (i.e. signs) to be meaningfully combined**. That is, the signs associated with each effect size (positive or negative) must reflect the real underlying relationship between the two variables being synthesized to avoid effect sizes cancelling each other out. When necessary, this often involves flipping effect size signs (e.g., multiplying by –1), standardizing reference groups, or re-coding variables. Proper handling ensures that a “positive” or “negative” effect carries the same meaning across all studies. **We are interested in whether and how authors reported addressing this issue**—did they mention aligning directions, adjusting signs, or re-coding treatment and control groups or variables?

(For more information, including several examples from published meta-analyses, please see this Google Docs.)

Please remember, the aim of this data extraction is to assess whether authors explicitly report how they dealt with the effect size direction. We do not imply that if they did not report the effect size direction handling they did not deal with it. We will further explore the data if they have provided it to make such an assessment.

There will be cases where the direction is not applicable to the effect size in consideration. For such a case please use **NA (Not applicable)** and describe your assessment of why it is not applicable.

1. Did the authors explicitly address whether effect size directions were adjusted to ensure consistency across the entire meta-analytic dataset?
    - Yes
    - No
    - I do not know
    - Not applicable/ NA (remember to describe the reasoning behind your choice)
    - Other (please describe this below)

2. If you chose Other as the option above, please describe it here; otherwise type NA.

3. Comments

Section 3: Handling inferential statistics

In many meta-analyses, effect sizes (e.g., correlations) or summary statistics (means and variances) are not directly reported in the original studies. Instead, authors often extract inferential statistics—such as p-values, t-values, F-values, or χ^2-values—and convert them into standardised effect sizes (e.g., Cohen's d, Hedges' g). We're interested in whether the meta-analysis you're reviewing used such conversions and, if so, whether the methods for doing so were clearly described.

(For more information, please see example in Google Docs.)

1. Did the authors report extracting inferential statistics (e.g., p-values, t-values, F-values, or χ^2-values) from primary studies to calculate effect sizes?
    - Yes
    - No
    - I do not know
    - Not applicable/ NA (this could apply for cases where effect size is an absolute value or an effect size such as correlation coefficient)
2. If yes, what types of inferential statistics were used to calculate effect sizes?
    - P-values
    - T-values
    - F-values
    - X^2-values
    - R^2
    - U
    - Wald
    - Not applicable/ NA (if you did not choose Yes above, please use this option)
    - Others
3. If you chose Others above, please specify the inferential statistics used by the authors; otherwise type 'NA'.

4. Were the statistical transformations or formulas used to convert inferential statistics into effect sizes clearly reported in the main text or supplementary materials?
    - Yes, all formulas were provided
    - Yes, but only some formulas were provided
    - No, formulas were not provided, but the authors referenced the sources they used
    - No, formulas were not provided and the authors did not reference any sources
    - Not applicable/ NA (Use this for cases when you chose NA for inferential statistics type)
5. Please copy-paste the text from the article that you used to make the decision above; otherwise type 'NA'.

6. Comments

Section 4: Data and code sharing

We are interested in whether the authors publicly shared the meta-analytic dataset (either processed or raw) and the analysis code—via a repository (e.g., Dryad, Zenodo, Figshare, GitHub), a website (e.g., personal or institutional), or the article's supplementary materials.

Processed data refers to the calculated effect sizes and their associated sampling variances. These are often labeled as *yi* and *vi*, respectively, or may appear as more specific terms such as *lnRR* and *VlnRR*, *Zr* and *VZr*, or *d* and *Vd*, among others. Processed data would include **mainly the effect sizes, sampling variance associated with the effect size** and some other details.

Raw data refers to the summary or inferential statistics used to compute the effect sizes. For example:

- In a meta-analysis of Fisher's Z-transformed correlations, the authors should report the original correlations (e.g., Pearson, Spearman). If they also converted inferential statistics into correlations before applying the Fisher's Z transformation, those inferential statistics should also be reported.
- For a meta-analysis using standardized mean differences (e.g., Cohen's *d* or Hedges' *g*), the underlying group means, standard deviations, and sample sizes for each group (e.g., treatment vs. control) should be reported.

Remember, we do not require you to go through the entire shared dataset but if you find some essential information missing please respond **No** to the questions below (e.g. if authors did not share the sampling variance but only the effect size answer No for processed data, if authors did not share the sample size or variance answer No for raw data)

1. Did the authors share the **processed data** used in the meta-analysis (e.g., effect sizes and their associated sampling variances, if applicable)? Note that often times but not always these may correspond to columns *yi* and *vi*. -
    - Yes
    - No

2. If you answered "Yes," where can the **processed data** be accessed? Please provide the link(s). If the data is available in the article's supplementary materials, include the article's link. If there is more than one link (e.g., GitHub and Dryad), please list all links separated by a semicolon ";" (e.g., *https://github.com/ASanchez-Tojar/meta-analysis_egg_hormones_and_fitness; http://doi.org/10.5281/zenodo.14930059*); otherwise type NA.

3. Did the authors share the **raw data** extracted from the primary studies (e.g., means, variances, sample sizes, inferential statistics values, etc.)?
    - Yes
    - No

4. If you answered "Yes," where can the **raw data** be accessed? Please provide the link(s). If the data is available in the article's supplementary materials, include the article's link. If there is more than one link (e.g., GitHub and Dryad), please list all links separated by a semicolon ";" (e.g., *https://github.com/ASanchez-Tojar/meta-*

analysis_egg_hormones_and_fitness; http://doi.org/10.5281/zenodo.14930059*); otherwise type NA.

5. Did the authors share any **programming code** (e.g., R scripts)? You don't need to confirm if all code was provided—just whether at least some code was made available. If the authors used a click-based program and did not report a clear step-by-step guide on how to generate the estimates, you should answer "No".
   - Yes
   - No

6. If you answered "Yes," where can the **programming code** be accessed? Please provide the link(s). If the data is available in the article's supplementary materials, include the article's link. If there is more than one link (e.g., GitHub and Dryad), please list all links separated by a semicolon ";" (e.g., *https://github.com/ASanchez-Tojar/meta-analysis_egg_hormones_and_fitness; http://doi.org/10.5281/zenodo.14930059*); otherwise type 'NA'.

7. Comments

Section 5: Risk of Bias Assessment

Risk of Bias (RoB) assessment (sometimes called Critical Appraisal, though the two are not identical) in systematic reviews and meta-analyses involves evaluating potential methodological biases (systematic errors) within individual studies—that is, their internal validity. This process helps us interpret research findings in the context of these biases. We are interested in how frequently meta-analysts in the field conduct Risk of Bias assessments and, if so, which specific tools or methods they use.

Please note that Risk of Bias refers to assessments made at the individual study level within a meta-analysis. **Publication bias, which concerns the entire set of studies, is not included here**, as our focus is on biases affecting individual studies.

1. Did the authors explicitly report performing a Risk of Bias (RoB) assessment on the individual primary studies included in the meta-analysis?

   - Yes
   - No
   - I do not know

2. If yes, which Risk of Bias (RoB) tool(s) did they use? You'll find a list of common options below, along with a link to a more comprehensive list here. (Please note that PRISMA and other reporting guidelines are not Risk of Bias tools.)

   - CEESAT (Collaboration for Environmental Evidence Synthesis Assessment Tool)
   - COSMIN ROB

- COSMIN ROB for PROMS
- PROBAST
- QUADAS-2
- QUADAS-C
- QUAPAS
- RoB 2
- ROBINS-E
- ROBINS-I
- ROBIS
- ROBVALU
- Not applicable/ NA
- Others

3. If you selected Others above, please specify the tool here; otherwise type 'NA'.

4. Beyond using explicit Risk of Bias tools, did the meta-analysis **address/assess potential biases at the individual study level through other methods**?

   For example, by categorizing effect sizes/studies and comparing them based on whether the original studies used or were affected by.

   Please keep in mind publication bias tests are not RoB assessment.

   Some examples of what **would not be included here** are..
   - Authors imputed SD, SE
   - Authors excluded studies that did not provide data
   - Authors plotted a funnel plot to understand sampling bias

   - Blinding Vs. Non-Blinding in data collection
   - Selective Reporting Vs. Non-selective Reporting
   - Missing Data Vs. Complete Data
   - Other
   - None

5. If you selected other, please provide information on the potential bias that the authors accounted for; otherwise type 'NA'.
   Please note examples such as comparisons of effect sizes between studies with different data-collection protocols, selective reporting checks (but not publication bias test), or any analytical adjustment aimed at study-level bias.

6. Comments

Google Document describing Effect Size Handling

Effect Size Direction and Handling:

In meta-analyses, effect sizes from different studies must have consistent directions to be meaningfully combined. For example, if one study reports a treatment increases a trait (positive effect) while another reports it decreases the same trait (negative effect), these effects need to be made directionally comparable to avoid cancelling each other out. When necessary, this often involves flipping effect size signs (e.g., multiplying by –1), standardizing reference groups, or re-coding variables. Proper handling ensures that a "positive" or "negative" effect carries the same meaning across all studies. We are interested in whether and how authors addressed this issue—did they mention aligning directions, adjusting signs, or re-coding treatment and control groups or variables? (For more information, please see the Hackathon Protocol.)

Did the authors explicitly state or address whether effect size directions were adjusted to ensure consistency across the entire meta-analytic dataset?: Yes/No/I do not know/ Other(please describe)

……

Hackathon Google Form Updated:

ESMARConf2025 Hackathon:

Extent of Incomparable Effect Size Transformations and Directions in Ecology and Evolution

We insist you begin data extraction by reading through this document to familiarise yourself with some of the concepts that will be required to answer the question. You can always come back to this document when you get stuck at a particular question that you wish to assess and see if the confusing scenarios you are facing are already described in the examples here.

Effect Size Direction and Handling

Here is an excerpt from Cooper et al. 2019: The Handbook of Research Synthesis and Meta-analysis, that should help better understand the importance of considering the direction of the effect sizes.

11.2.3 Direction of the Effect

The discussion that follows applies to all the effect-size indices in this section—that is, D, d, and g. The direction of the effect (for example, group 1 versus group 2 or group 2 versus group 1) is arbitrary, except that it must be consistent from one study to the next. That is, if a mean difference above 0 in study A indicates that group 1 did better, *then a mean difference above 0 in studies B, C,* [. . .] *must also indicate that group 1 did better. Although the direction is arbitrary, several useful conventions make it easier to interpret the results. When we are comparing treated versus control, it is conventional to compute the difference as treatment minus control. For a pre- or post-design this would be post minus pre. When we follow this convention, the direction of the effect will be as follows: if the treatment increases the mean score, the mean difference will be positive; if the treatment decreases the mean score, the mean difference will be negative. As a general rule, it is a good idea to follow this convention because the results will follow the usual pattern. For example, if the treatment is intended to boost scores, we expect to see the mean difference to right of zero. Similarly, if the treatment is intended to lower scores, we expect to see the mean difference to the left of zero. Although the convention is therefore useful, it is arbitrary. If we chose to reverse the position of the two groups, the effect-size format would change but the substantive meaning would remain the same. Concretely, the three effects sizes would be modified as follows. If we switched the position of the two groups, the new raw mean difference would be DNew = −DOld , (11.32) the standardized mean difference would be dNew = −dOld , (11.33) and Hedges' g would be gNew = −gOld . (11.34) That the decision to put one group or the other first is arbitrary, is especially important when we are comparing two active treatments, rather than a treatment and a control. If some studies compute A minus B and others compute B minus A, we need to ensure that all the results are in the same direction before we enter them into the meta-analysis. We could apply formulas (11.32) to (11.34) to the effect size and confidence interval as needed, to reverse the direction of the effect for any given study.*

Example of effect size calculation reporting

Example 1

Original article: https://doi.org/10.1111/ele.70100

Based on what is reported in that article, here are the answers to the following questions:

- Did the authors explicitly address whether effect size directions were adjusted to ensure consistency across the entire meta-analytic dataset?
    - **Yes**
- Did the authors report extracting inferential statistics (e.g., p-values, t-values, F-values, or χ^2-values) from primary studies to calculate effect sizes?
    - **Yes**
- Were the statistical transformations or formulas used to convert inferential statistics into effect sizes clearly reported in the main text or supplementary materials?
    - **Yes, all formulas were provided**
- Did the authors explicitly report performing a Risk of Bias (RoB) assessment on the individual primary studies included in the meta-analysis?
    - **No**
- Beyond using explicit Risk of Bias tools, did the meta-analysis address/assess potential biases at the individual study level through other methods?
    - **Other: e.g., comparing experimental vs observational studies, selective vs nonselective reporting, complete vs incomplete reporting**

2.6 Effect Size Calculation

To quantify the relationship between egg hormones and fitness, we combined both Pearson's correlation coefficients r and biserial correlations rbis—throughout we refer to simply r for simplicity. First, for correlation coefficients other than Pearson's r (e.g., Spearman's rho correlation coefficient), percentages, absolute values or inferential statistics (e.g., F-value, t-value, Chi-square value), we calculated Pearson's r using the equations from Nakagawa and Cuthill (2007) and Lajeunesse (2013; Supporting Information S7). For tests that lacked information on directionality, we determined it from the text, figures, or by directly asking the authors via email. We then calculated the variance in Pearson's r (Vr) as Vr = (1—r2)2 ÷ (N—1) (Borenstein et al. 2009). Second, for experimental studies in which two groups were compared (control vs treatment), we transformed the means, SDs and sample sizes of the fitness proxies of interest of each group into biserial correlations coefficients and calculated their sampling variance following Jacobs and Viechtbauer (2017) with the function 'escalc' from the R package 'metafor' v.2.4–0 (Viechtbauer 2010).

[...]

In all cases, effect sizes were coded so that fitness proxies were positively correlated with overall fitness. Specifically, for 'egg mortality,' 'hatching failure,' and 'offspring *mortality,' the sign of the effect sizes (k = 5 effect sizes, N = 3 studies) was inverted to ensure comparability across all fitness proxies.*

[...]

We performed three phylogenetic multilevel meta-regressions to investigate the impact of methodological differences on the relationship between maternal egg hormones and both maternal and offspring fitness proxies. In the first model (MP.1), we included 'hormone type' (levels: androgens, glucocorticoids and thyroids), 'study type' (levels: correlational and experimental) and their interaction as moderators (k = 397, N = 53).

[...]

In addition, to test whether effect sizes are larger in studies that selectively or incompletely report statistically significant results, we conducted two meta-regression models. To test the effect of partial or selective reporting, we included 'partial or selective reporting' (levels: yes and no), 'hormone type,' and their interaction as moderators. To examine the effect of data reporting completeness, we initially planned to include 'data reporting completeness' (levels: complete and incomplete), 'hormone type,' and their interaction as moderators. However, due to insufficient data for glucocorticoids and thyroids, we could only test this for androgens (k = 333, N = 46), so our final model included 'data reporting completeness' as the only moderator. We also had pre-registered a meta-regression to test if blind data collection leads to smaller effect sizes as shown in previous studies (Freeberg et al. 2024; Holman et al. 2015; Keaney et al. 2024), but we could not perform this test because only 3 studies reported to have used a blind data collection protocol.

Example 2

Original article: https://doi.org/10.1093/evlett/qrae051

Based on what is reported in that article, here are the answers to the following questions:

- Did the authors explicitly address whether effect size directions were adjusted to ensure consistency across the entire meta-analytic dataset?
  - **Not applicable/ NA**
- Did the authors report extracting inferential statistics (e.g., p-values, t-values, F-values, or χ^2-values) from primary studies to calculate effect sizes?
  - **Not applicable/ NA**

- Were the statistical transformations or formulas used to convert inferential statistics into effect sizes clearly reported in the main text or supplementary materials?
    - **Not applicable/ NA**
- Did the authors explicitly report performing a Risk of Bias (RoB) assessment on the individual primary studies included in the meta-analysis?
    - **No**
- Beyond using explicit Risk of Bias tools, did the meta-analysis address/assess potential biases at the individual study level through other methods?
    - **None**

Effect Size Calculation

*Our effect sizes of interest were: (i) the relative magnitude of DGEs (narrow-sense heritability or h2) and IGEs (social h2; aims 1, 3, and 4), (ii) unstandardized variances associated with DGEs (VA) and IGEs (VIGE), which we log-transformed prior to the analyses to better match model assumptions (aim 3), (iii) DGE and IGE evolvability (IDGE and IIGE; aim 3), (iv) DGE-IGE correlation (rDGE-IGE; aim 4), which when not reported, was calculated as COVA-IGE divided by the square root of the product of VA and VIGE, and (v) total heritable variance, τ2 (i.e., the ratio of total heritable variation and phenotypic variance, aim 4), which was calculated as [VA + CovA-IGE*2*(n − 1) + VIGE*(n − 1)2]/VP, where n is group size (Bijma, 2010; Bijma et al., 2007b). As in previous meta-analyses (e.g., Dochtermann et al., 2019; Holtmann et al., 2017), for most of our analyses, we treated intra-class correlations as equivalent to Pearson's correlation coefficients (r) and applied Fisher's Z transformation to obtain our main effect size of interest (i.e., Zr and its associated sampling variance, VZr).*

Example 3

Original article: https://doi.org/10.7554/eLife.37385

Based on what is reported in that article, here are the answers to the following questions:

- Did the authors explicitly address whether effect size directions were adjusted to ensure consistency across the entire meta-analytic dataset?
    - **No**
- Did the authors report extracting inferential statistics (e.g., p-values, t-values, F-values, or χ^2-values) from primary studies to calculate effect sizes?
    - **Yes**
- Were the statistical transformations or formulas used to convert inferential statistics into effect sizes clearly reported in the main text or supplementary materials?
    - **No, formulas were not provided, but the authors referenced the sources they used**
- Did the authors explicitly report performing a Risk of Bias (RoB) assessment on the individual primary studies included in the meta-analysis?
    - **No**
- Beyond using explicit Risk of Bias tools, did the meta-analysis address/assess potential biases at the individual study level through other methods?
    - **Other: e.g., testing the effect of sampling effort**

Summary data extraction

Some studies had more than one effect size estimate per group of birds studied. When the presence of multiple estimates was due to the use of different statistical analyses on the same data, we chose a single estimate based on the following order of preference: (1) direct reports of effect size per group of birds studied (e.g., correlation coefficient), (2) inferential statistics (e.g., t, F and χ2 statistics) from analyses where group ID was accounted for and no other fixed effects were included, (3) direct reports of effect size where individuals from different groups where pooled together, (4) inferential statistics from models including other fixed effects.

[...]

Effect size coding

Regardless of their source (primary or summary data), we transformed all estimates (e.g., ρ, F statistics, etc) into Pearson's correlation coefficients (r), and then into standardized effect sizes using Fisher's transformation (Zr) for among-study comparison. We used the equations from Nakagawa et al., 2007 and Lajeunesse, 2013.

[...]

For the subset of studies for which the primary data of the agonistic dyadic interactions were available (12 out of 19 studies; Table 1), we ran a multilevel meta-regression including sampling effort and its squared term as z-transformed moderators (Schielzeth, 2010). The squared term was included because of the observed *logarithmic relationship between sampling effort and the method's performance (Sánchez-Tójar et al., 2018b). This meta-regression tested whether sampling effort had an effect on the meta-analytic mean: (i) a positive estimate would indicate that the meta-analytic mean may have been affected by the inclusion of studies with unreliable estimates of dominance rank. In contrast, (ii) a negative estimate would indicate that effect sizes were larger when based on unreliable estimates of dominance rank and hence provide evidence for the existence of publication bias.*

Supplement S3: FAIR Checklist

The purpose of FAIR principles is to make data not just reusable for human scientists but also machine findable and usable. Please see Wilkinson et. al 2016 (and/or https://www.go-fair.org/fair-principles/) for more information about the FAIR principles.

In this assessment, **we will not evaluate all the FAIR principles** because we will focus on “simply” assessing **the quality of the datasets that were already shared** - the FAIR principles generally apply more broadly. That is, here we want to assess how well the data and their accompanying information support understanding and reuse, and we want to do that by using some of the FAIR principles.

Glossary Terms

We would like to clarify what we imply by each term to allow for more objective evaluations of the criteria.

1. **Data**: To evaluate these criteria, we will consider both raw (i.e., values extracted from individual articles for calculating the effect size(s) of interest, or in some cases, used directly as effect sizes in the meta-analytic models) and processed data (i.e., already-calculated effect sizes and associated sampling variances) as data.

2. **Metadata**: For our purposes, metadata refers to information for a user to understand the content of the repository (or folder/zip) where the data (and other materials) were shared, specifically:
    - Title of the dataset(s)
    - Authors/creators
    - Contact information
    - Abstract or description
    - Keywords,
    - Date of creation/publication
    - Language
    - Licensing
    - Funding sources
    - Access restrictions, etc.

3. **Data Dictionary/Code Book**: A data dictionary or code book explains what each variable means in more or less detail, including a clear description of

variables, units, and coding (e.g., sex: male, female). Strictly speaking, a data dictionary is a type of metadata, because it provides “data about the data.” However, for the purpose of our assessment, it is useful to consider it as a **separate, more detailed layer of documentation**. We will evaluate metadata and data dictionaries separately in two different questions.

Box 2 | The FAIR Guiding Principles

To be Findable:
F1. (meta)data are assigned a globally unique and persistent identifier
F2. data are described with rich metadata (defined by R1 below)
F3. metadata clearly and explicitly include the identifier of the data it describes
F4. (meta)data are registered or indexed in a searchable resource

To be Accessible:
A1. (meta)data are retrievable by their identifier using a standardized communications protocol
A1.1 the protocol is open, free, and universally implementable
A1.2 the protocol allows for an authentication and authorization procedure, where necessary
A2. metadata are accessible, even when the data are no longer available

To be Interoperable:
I1. (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.
I2. (meta)data use vocabularies that follow FAIR principles
I3. (meta)data include qualified references to other (meta)data

To be Reusable:
R1. meta(data) are richly described with a plurality of accurate and relevant attributes
R1.1. (meta)data are released with a clear and accessible data usage license
R1.2. (meta)data are associated with detailed provenance
R1.3. (meta)data meet domain-relevant community standards

Our adjusted FAIR principle checklist

Once the list is finalised, we will create a corresponding Google Form that all participants will use to assess the FAIRness of the shared datasets (one entry per study).

1. Findable

“To be **Findable,** any Data Object should be uniquely and persistently identifiable”

- Dataset (s) has a **globally unique and persistent identifier** (e.g., DOI, Handle, ARK, Accession Number [e.g., *omics* data], etc) that is separate from the persistent identifier (DOI) of the published article.

  What is a persistent identifier? A ***persistent identifier*** *is a* ***permanent, globally unique, and stable digital label*** *that always points to the same data object — even if its location changes.*

  Usually, in our field, DOI is the most common persistent identifier. Remember, GitHub repository links are not persistent identifiers, and, although OSF projects provide a DOI, the DOI refers to the live, editable project rather than a fixed, time-stamped version, so it is not ideal for formally sharing or citing *data, and thus, we will treat OSF sharing as NOT complying with having a persistent identifier.*

- Rich metadata accompanies the dataset(s), usually added to a recognised repository along with the data (e.g., Zenodo, Dryad, Figshare, institutional repository).

  *What constitutes rich metadata? **Rich metadata** provides clear, detailed information about a dataset's content, context, and structure.*

  Assessing the completeness of the metadata is beyond our purposes, and thus, here, we only want to know if some metadata is available and clearly identifiable (i.e., if the data is not in a repository that requires metadata by default (see examples below), is there a "README", "metadata", etc. file providing some of the fields outlined above?).

  In repositories like Dryad and Zenodo, basic metadata is required upon submission (usually including title, abstract, and authors' name, how and when the data was collected and a brief description of the dataset); thus, metadata would be required by default. Sometimes, metadata may appear (as a standalone or in addition to the repository's required metadata) as a README file within the shared folder.

- Data is registered/indexed/shared in a **searchable resource**.

  What is a searchable resource? Repositories like Dryad, Zenodo, Figshare, OSF, etc. can be searched using the repositories' search engine/search query. However, Supplementary Materials of an article, Private Links (e.g., personal websites), etc. are not searchable or permanent resources.

  Where is the data shared:
  - DataVerse
  - Dryad
  - Figshare
  - GBIF
  - NCBI GenBank
  - Zenodo
  - PANGEA
  - OSF
  - Institutional repository
  - GitHub or GitLab
  - Personal website
  - Supplementary materials
  - Other (please specify)

2. Accessible

"Data is **Accessible** in that it can always be obtained by machines and humans"

- The dataset(s) can be **downloaded**.

  For example, if a DOI is provided (e.g., 10.5281/zenodo.14930059), you should be able to access and download the data by visiting the corresponding link (https://doi.org/10.5281/zenodo.14930059).

3. Interoperable

For data to be considered interoperable:

- Data should be provided in standard, **non-proprietary formats** (e.g., .csv, .tsv, .txt, .json, .jsonld, .parquet, .arrow, .xml; **NOT**: .xls, .xlsx, .numbers, .sps, .pdf, .doc, .docx, .RData).

  PDF, screenshots, etc. are not machine-readable formats, and .xlsx, .xls, .numbers etc. are not non-proprietary formats. Although .RData can be used with open source software (i.e., R), this data format restricts its use, as it requires knowledge of R to extract the data, and may be dependent on the version of R that was used to save it.

  Please choose the data format used:

  - .csv/tsv
  - .doc(x)
  - .txt
  - .xls(x)
  - .numbers
  - .RData
  - .Rds
  - .pdf
  - .sql(ite)
  - .sps
  - .nex
  - .odt
  - .ods
  - Other (please specify)

4. Reusable

- Dataset includes a clear and accessible **license** (e.g., CC-BY, CC0).

  Absence of a license does not allow users to legally use the data. "Available upon request", "Contact the authors" or "Rights reserved by publishers" would also imply that the data is not accessible and lacks an open use license.

  Please choose which license was used:

  - CC0 (Public Domain Dedication)
  - CC BY (Attribution)
  - CC BY-SA (Attribution, ShareAlike)
  - Open Data Commons PDDL
  - Open Data Commons ODC-BY (Attribution)
  - Open Government License (OGL)
  - CC BY-NC (Attribution, NonCommercial)
  - CC BY-NC-SA (Attribution, NonCommercial, ShareAlike)
  - CC BY-ND (Attribution, NoDerivatives)
  - CC BY-NC-ND (Attribution, NonCommercial, NoDerivatives)
  - GNU GPL/MIT/Apache 2.0 *(ideally used for code rather than data)*
  - Publisher copyright/Rights reserved
  - Available upon request/Contact the authors
  - No license present
  - Other *(please specify)*

- A **data dictionary or code book** is provided to explain what each variable means in more or less detail, including a clear description of variables, units, and coding (e.g., sex: male, female).

  Note that here we are not referring to metadata (see above), even though sometimes variable descriptions are provided as part of the README.

Supplement S4: Additional citation and journal-policy information

Citation Information

The 2018 five-year impact factor, which we extracted from Web of Science for these 35 journals, ranged from 0.7 to 14.8 (median = 4.3). The total citation counts across all years (i.e., from 2016 to 2025) ranged from 1 to 793 (median = 96), whereas those for the first six years after publication of each meta-analysis ranged from 1 to 435 (median = 68).

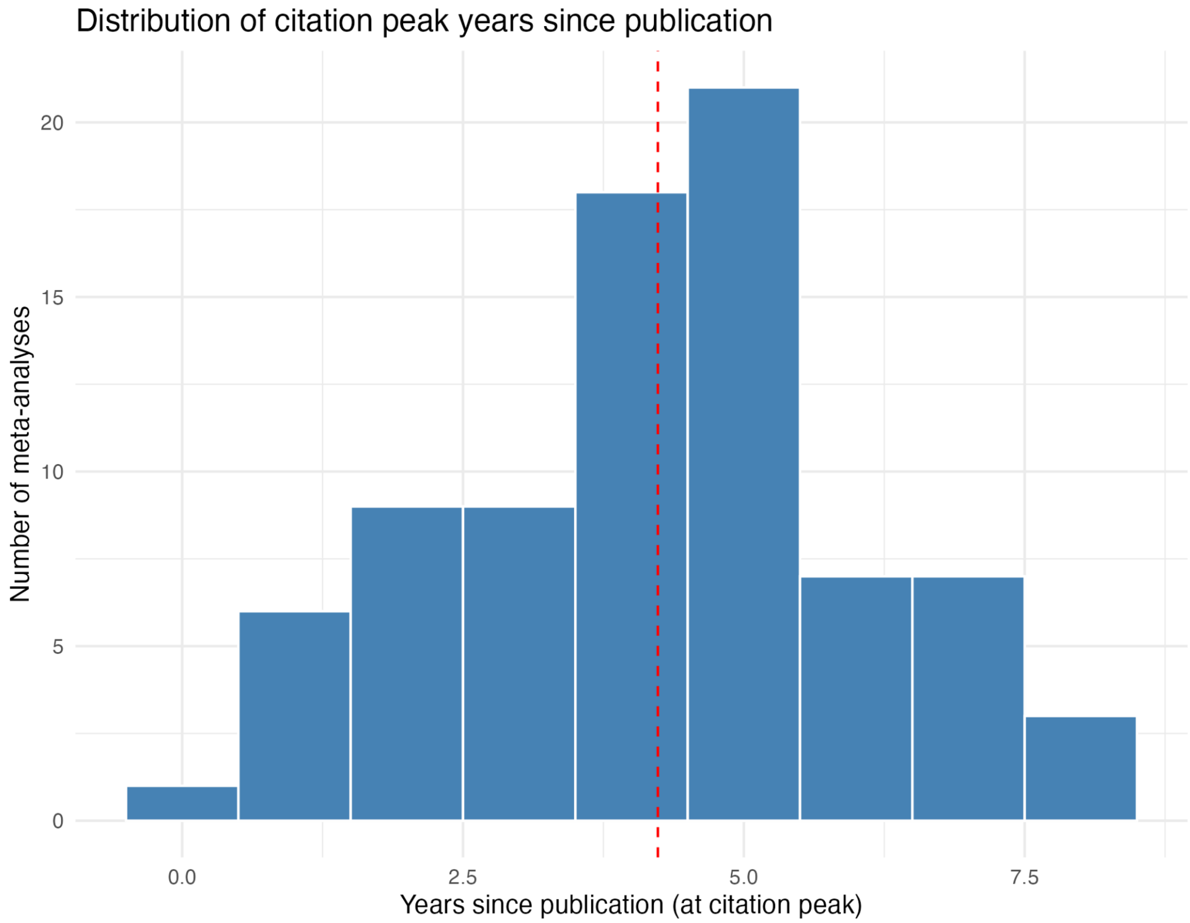

Figure S1. Distribution of the observed annual citation peak year among 81 meta-analyses. For each meta-analysis, annual Google Scholar citation counts were relative to the formal year of publication. Bars show the number of meta-analyses with an observed maximum in each year since publication, and the dashed vertical line indicates the mean observed peak year. Because articles published later in the 2016–2020 sampling period had shorter citation follow-up through 2025, the distribution may be affected by right truncation and does not reflect the distribution of lifetime citation peaks.

Journal Policy Information

To explore whether journal requirements were associated with data-sharing, we determined the data-sharing policy in place at each journal when each article was published. We used the classification developed by Berberi and Roche (2022), which categorised journal policies as "none," "weak," or "strong." We accessed their dataset on 3 October 2025. For 9 of the 35 journals in our sample, no policy implementation date was recorded in the dataset. We contacted these journals using a standardised email template (see below), sent up to 3 reminders when necessary, and obtained implementation dates for 6 of the 9 journals that were missing this information. For the remaining three journals, the implementation year was coded as "NA," and articles from these journals were excluded from the analyses.

Is data sharing associated with journal policy requirements?

Most meta-analyses (61.3%, 95% CI = 50.0–71.5%) were published in journals with a data-sharing policy in place at the time of publication (strong = 39, weak = 7, none = 29, NA = 6).

Email template for contacting the journals:

Dear Editorial Office and Production Team of XXX,

I hope this message finds you well.

I am writing on behalf of our research team conducting a study on data-sharing practices across ecology and evolution journals. Your journal has been identified as having an excellent record in terms of promoting data-sharing, and we sincerely appreciate the efforts you have made to support open research.

As part of our analysis, we are interested in understanding when your journal implemented its data-sharing policy. Could you kindly let us know the year in which the policy came into effect? This information is crucial for accurately interpreting trends in data-sharing behavior over time in our study.

We greatly appreciate your time and assistance and would be happy to acknowledge your journal in our study if appropriate.

Thank you very much for your help.

Warm regards,
Dr. Alfredo Sánchez-Tójar