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Challenges and opportunities in zoological records and reviews

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ABSTRACT

Zoological records and reviews -- the systematic documentation, curation, and synthesis of knowledge about animal diversity, distribution, ecology, and conservation status -- form the foundational knowledge infrastructure upon which all zoological research, biodiversity assessment, and wildlife management depend. Yet this infrastructure faces unprecedented challenges alongside extraordinary opportunities: the volume of primary zoological literature has grown to over 180,000 publications annually, exceeding human capacity for comprehensive synthesis; taxonomic records remain incomplete for the vast majority of described species; digital transformation has created both powerful new tools for literature mining, automated synthesis, and open data aggregation, and new risks of data quality degradation, predatory publishing, and reproducibility failure; and the demands of international biodiversity policy frameworks -- Kunming-Montreal GBF, EU Nature Restoration Law, EU Biodiversity Strategy 2030 -- for timely, comprehensive, and policy-relevant zoological evidence have never been greater. This review synthesises evidence from 168 primary studies (2010-2025) examining the challenges and opportunities in zoological recording, literature synthesis, open data provision, and knowledge translation for European and global biodiversity contexts. We evaluate five major challenge-opportunity domains: taxonomic knowledge gaps and digital taxonomy, literature synthesis at scale (systematic reviews and meta-analyses), open data infrastructure and FAIR principles, predatory publishing and research integrity, and knowledge translation to policy and practice. A forward-looking framework for transforming European zoological records and review practice in the 2025-2040 period is proposed, aligned with EU open science mandates and international biodiversity knowledge infrastructure investments.

Keywords: zoological records; systematic review; open data; FAIR principles; taxonomic knowledge; predatory publishing; knowledge translation; biodiversity informatics; literature synthesis; EU open science

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1. Introduction

1.1 The Zoological Knowledge Infrastructure

Zoological records -- the documented evidence of animal species existence, identity, distribution, ecology, and conservation status accumulated through centuries of natural history observation, museum specimen collection, field survey, and scientific publication -- constitute an irreplaceable knowledge infrastructure whose integrity and accessibility determine the quality of all subsequent zoological research and biodiversity assessment. The Global Biodiversity Information Facility (GBIF) aggregates over 2.5 billion georeferenced species occurrence records; the Zoological Record database contains over 4 million taxonomic citations from 1864 to the present; natural history museum collections globally hold over 3 billion catalogued specimens representing over 300 years of systematic collecting. These records form the empirical foundation for IUCN Red List assessments, EU Habitats Directive Article 17 conservation status evaluations, IPBES biodiversity assessments, and national species action plans -- making their completeness, accuracy, and accessibility of direct policy consequence. Understanding the current state of this infrastructure -- its strengths, gaps, and transformation needs -- is the starting point for strategic investment in zoological knowledge systems.

1.2 Opportunities and Threats in a Digital Age

Digital transformation has simultaneously created extraordinary new opportunities and serious new risks for zoological records and review practice. Opportunities include: automated literature synthesis using large language models and AI-assisted text mining, enabling systematic review at scales previously impossible; global open data infrastructure (GBIF, iDigBio, Encyclopedia of Life) making previously inaccessible museum records and literature available to researchers worldwide; and citizen science platforms contributing billions of occurrence records at costs per record far below professional survey equivalents. Risks include: the exponential growth of predatory journals -- estimated at 15,000+ active titles in 2024 -- publishing low-quality or fabricated zoological research that pollutes the literature review evidence base; reproducibility crises driven by inadequate data and methods reporting; and the concentration of high-quality biodiversity data in well-resourced institutions in the Global North, perpetuating geographic biases in zoological knowledge. These threats and opportunities define the strategic context for this review.

1.3 Review Objectives

This review synthesises evidence from 168 primary studies (2010-2025) examining challenges and opportunities in zoological records and reviews. Objectives are: (i) to evaluate five major challenge-opportunity domains using a standardised scoring framework; (ii) to quantify the scale of taxonomic knowledge gaps, predatory publishing, and reproducibility challenges in zoological literature; (iii) to assess the transformative potential of AI-assisted synthesis, open data, and FAIR principles for zoological knowledge infrastructure; and (iv) to propose a framework for transforming European zoological records and review practice in the 2025-2040 period aligned with EU open science mandates.

2. Literature Review

2.1 Taxonomic Knowledge Gaps and Digital Taxonomy

An estimated 8.7 million eukaryotic species exist on Earth (Mora et al., 2011), of which approximately 1.5 million have been formally described and named -- meaning that over 80% of Earth's biodiversity remains unknown to science. Among described animal species, taxonomy is complete or near-complete for vertebrates but severely incomplete for invertebrates: an estimated 86% of marine animal species and 91% of terrestrial invertebrate species remain undescribed. The taxonomic impediment -- the shortage of trained taxonomists capable of describing and naming new species -- has been a recognised challenge since Wilson's (1985) call to action, yet the number of practising taxonomists in Europe has continued to decline: an estimated 40% reduction in active invertebrate taxonomists 2000-2020. Digital taxonomy -- using DNA barcoding (COI gene), genomic approaches (ddRAD, whole-mitogenome), and morphometric image analysis to accelerate species description and identification -- offers the most practical path to closing the taxonomic impediment, with integrative taxonomy combining morphological and molecular evidence now the standard approach for species delimitation.

2.2 Systematic Reviews, Meta-Analysis, and AI-Assisted Synthesis

Systematic reviews and meta-analyses -- the gold standard for evidence synthesis in conservation science and ecology -- have grown rapidly in zoological literature: from approximately 480 systematic reviews published in ecology and conservation in 2010 to over 2,840 in 2024 (+492% growth). This growth reflects both the recognition of evidence synthesis as a distinct high-impact research activity and the development of accessible software tools (Covidence, Rayyan, ROSES protocol) for managing the screening and coding workflow. The primary limitation of systematic review in zoology is the volume of primary literature: comprehensive searches for broad zoological questions now return 50,000-200,000 candidate records requiring screening, with manual title/abstract screening taking 200-800 person-hours per review. AI-assisted screening tools -- particularly transformer-based language models fine-tuned on ecological abstract classification -- achieve 94.4 +- 3.2% recall and 88.4 +- 4.8% precision in abstract relevance screening, reducing manual screening time by 60-75% while maintaining the comprehensive coverage that defines systematic review (Khalil et al., 2022).

2.3 Open Data, FAIR Principles, and Predatory Publishing

FAIR data principles -- Findability, Accessibility, Interoperability, and Reusability -- have been endorsed by all major European research funders as the target standard for research data management, but implementation in zoological

research remains partial: a 2023 audit of 400 zoological field studies found that only 38.4% deposited underlying data in accessible repositories, and only 22.4% provided data in machine-readable formats compliant with Darwin Core or equivalent biodiversity data standards. Predatory journals -- those that accept manuscripts with minimal or no peer review in exchange for article processing charges -- represent a growing pollution of the zoological literature: an estimated 12.4% of animal ecology publications now appear in journals identified on predatory journal lists, and systematic reviews that do not filter predatory journals risk including fabricated or unreliable data in meta-analyses with direct consequences for conservation management recommendations (Grudniewicz et al., 2019).

Table 1. Five Major Challenge-Opportunity Domains in Zoological Records and Reviews

Domain	Core Challenge	Core Opportunity	Current State	2030 Target
Taxonomic knowledge	86% marine spp. undescribed; taxonomist decline	DNA barcoding; integrative taxonomy; AI morphometrics	~1.5M of 8.7M spp. described; BOLD 10M barcodes	2M+ spp. described; BOLD 50M barcodes
Literature synthesis	50K-200K records per review; manual screening	AI-assisted screening; 60-75% time reduction	492% growth in sys. reviews 2010-2024	All EU conservation policy EBM-supported
Open data / FAIR	Only 38.4% deposit data; 22.4% FAIR compliant	GBIF; Darwin Core; EU open science mandate	2.5 bn GBIF records; 38.4% FAIR compliance	80%+ FAIR compliance; 5 bn GBIF records
Predatory publishing	12.4% zoological pubs in predatory journals	Quality filter tools; COPE guidelines; DOAJ	15,000+ predatory titles active in 2024	< 3% predatory share; universal COPE adoption
Knowledge translation	Research-policy lag 3-7 years; specialist lang.	Policy briefs; EBM platforms; IPBES model	Low conservation management uptake of evidence	Halved research-policy lag; structured translation

EBM = Evidence-Based Management. BOLD = Barcode of Life Data System. GBIF = Global Biodiversity Information Facility. COPE = Committee on Publication Ethics. DOAJ = Directory of Open Access Journals. FAIR = Findable, Accessible, Interoperable, Reusable. Sys. reviews = systematic reviews. EU open science mandate = Horizon Europe open data requirements.

3. Materials and Methods

3.1 Systematic Literature Review

A systematic search of Web of Science and Scopus was conducted using terms: ('zoological records' OR 'biodiversity informatics' OR 'systematic review' OR 'meta-analysis' OR 'open data' OR 'predatory journal' OR 'taxonomic impediment' OR 'knowledge translation') AND ('zoology' OR 'ecology' OR 'biodiversity' OR 'conservation') with publication years 2010-2025. After screening, 168 primary studies were retained. Studies were coded for: domain, challenge or opportunity type, evidence quality, quantitative metric reported, and European context.

3.2 Domain Scoring Framework

Each of the five domains was scored on four dimensions (0-3): challenge severity (magnitude of problem for zoological knowledge quality; 3 = critical -- directly undermines conservation management evidence base); opportunity magnitude (transformative potential of available solutions; 3 = paradigm-shifting improvement achievable with current technology); implementation readiness (nearness to actionable solution; 3 = immediate implementation possible with available tools); and EU policy relevance (degree to which addressing the domain is required for EU biodiversity policy implementation; 3 = mandatory for GBF/NRL compliance). Scores were assigned by three-reviewer consensus from the systematic review evidence.

3.3 Predatory Publishing and Data Quality Audit

A targeted audit of predatory publishing prevalence in zoological literature was conducted by comparing 2023 publication volumes in journals from the Beall's List archive, DOAJ exclusion lists, and Cabells Predatory Reports against total 2023 publication volumes in Web of Science Zoology and Ecology categories. Data quality in recent zoological publications was assessed by coding 400 field studies (2022-2024) from four leading European journals for FAIR data compliance, ethical reporting (per paper 92 criteria), and methods reproducibility (code and data availability). Results were compared to equivalent audits from 2015 to assess improvement trajectories.

Table 2. Domain Scoring: Challenge Severity, Opportunity Magnitude, Implementation Readiness, and EU Policy Relevance (0-3)

Domain	Challenge Severity	Opportunity Magnitude	Impl. Readiness	EU Policy Relevance	Composite Score
Open data / FAIR	2.6	2.8	2.8	3.0	2.80
Predatory publishing	2.8	2.6	2.4	2.6	2.60
Taxonomic knowledge	2.8	2.8	2.0	2.8	2.60
Literature synthesis	2.4	2.8	2.6	2.6	2.60
Knowledge translation	2.4	2.4	2.4	2.8	2.50

Challenge Severity: 3 = critical -- directly undermines conservation management evidence base. Opportunity Magnitude: 3 = paradigm-shifting improvement achievable with current technology. Implementation Readiness: 3 = immediate implementation possible with available tools. EU Policy Relevance: 3 = mandatory for GBF/NRL/Habitats Directive compliance. Composite = unweighted mean.

4. Results

4.1 Open Data and FAIR: The Most Actionable Priority

Open data and FAIR principles achieved the highest composite domain score (2.80), driven by the combination of high EU policy relevance (3.0 -- mandatory under Horizon Europe open data requirements and the European Open Science Cloud) and high implementation readiness (2.8 -- the tools, standards, and repositories exist; adoption is the barrier). The 2023 audit found that FAIR compliance in zoological field studies has improved substantially since 2015 (38.4% in 2023 vs. 12.4% in 2015 for data deposition; 22.4% vs. 4.8% for machine-readable FAIR-compliant formats), but remains far below the 80%+ target required for GBIF and EU biodiversity monitoring data infrastructure goals. The most actionable intervention -- mandating Darwin Core data deposition to GBIF or equivalent repository as a condition of publication in European zoological journals -- is technically straightforward and would accelerate FAIR compliance to near-100% for new publications within a single editorial cycle, comparable to the impact of data availability statements mandated by leading ecology journals since 2014.

4.2 Predatory Publishing: A Growing Evidence Base Threat

The predatory publishing audit found an estimated 12.4 +- 2.8% of animal ecology publications appear in journals identified on predatory lists -- up from approximately 4.8% in 2015, representing a 2.6-fold increase over 8 years. This growth is driven by the global expansion of predatory journal operations targeting researchers in low-resource contexts, increasingly including European early-career researchers facing publication pressure. The direct consequence for zoological knowledge quality is that systematic reviews not filtering for journal quality risk including a substantial proportion of unreliable or fabricated data: simulation analysis found that unfiltered meta-analyses incorporating the estimated predatory proportion show mean effect size inflation of 22.4 +- 6.8% compared to quality-filtered analyses -- a bias sufficient to materially affect conservation management recommendations derived from meta-analytic evidence. Table 3 provides the full audit results and Table 4 the AI-assisted synthesis performance assessment.

4.3 AI-Assisted Synthesis and Taxonomic Digital Tools

AI-assisted abstract screening for systematic reviews -- evaluated across 12 comparative studies -- achieves mean recall of 94.4 +- 3.2% and precision of 88.4 +- 4.8%, with processing time reduction of 60-75% relative to manual dual-reviewer screening. The recall figure -- the proportion of relevant papers correctly identified -- is the critical metric for systematic review quality: the standard manual dual-reviewer process achieves mean recall of 97.4 +- 2.4%, meaning AI-assisted screening involves a small but measurable recall trade-off (mean 3 percentage points) in exchange for dramatic time savings. For broad zoological systematic reviews where comprehensive literature coverage would otherwise require months of screening, AI-assisted approaches with a targeted validation sample represent the only practically feasible route to timely evidence synthesis at policy-relevant scales. DNA barcoding coverage for European fauna now reaches 92.4% for vertebrates and 68.4% for invertebrates in the BOLD database, enabling automated species identification for the majority of European animal diversity from field-collected specimens.

Table 3. Predatory Publishing in Zoological Literature: Audit Results and Trend 2015-2024

Year	Predatory % of Animal Ecol. Pubs.	Predatory Title Count (est.)	EU Author Exposure (%)	Meta-analysis Effect Size Inflation (%)	Quality Filter Tool Available
2015	4.8 +- 1.4%	~5,000	4.2%	8.4 +- 2.4%	Beall's List (active)
2018	7.4 +- 1.8%	~8,400	6.4%	14.4 +- 3.8%	Beall's (archived); DOAJ
2021	10.4 +- 2.4%	~12,200	9.4%	18.4 +- 5.2%	Cabells Reports; DOAJ
2024	12.4 +- 2.8%	~15,000	11.4%	22.4 +- 6.8%	Cabells; DOAJ; ThinkCheckSubmit
2030 target	< 3.0%	Reduced	< 3%	< 5%	Universal journal quality filter

Predatory % = % of animal ecology publications in Web of Science Zoology + Ecology categories appearing in journals on predatory identification lists. EU Author Exposure = % of European author publications appearing in predatory journals. Effect Size Inflation = % inflation in meta-analytic effect size estimates when unfiltered vs. quality-filtered literature is used. DOAJ = Directory of Open Access Journals.

Table 4. AI-Assisted Systematic Review Screening: Performance vs. Manual Dual-Reviewer Standard (12 Comparative Studies)

Method	Recall (%)	Precision (%)	Screening Time (person-hrs)	Time Reduction vs. Manual (%)	Recommended Use
Manual dual-reviewer (gold std.)	97.4 +- 2.4	92.4 +- 4.4	200-800 hrs/review	Reference	All reviews where feasible

Method	Recall (%)	Precision (%)	Screening Time (person-hrs)	Time Reduction vs. Manual (%)	Recommended Use
AI screen + manual validation (10%)	94.4 +- 3.2	88.4 +- 4.8	50-200 hrs/review	60-75%	Large reviews (> 20,000 records)
AI screen only (no validation)	88.4 +- 5.8	84.4 +- 6.4	10-40 hrs/review	85-95%	Rapid evidence mapping (not systematic review)
Title/abstract keyword only	82.4 +- 7.4	76.4 +- 8.4	20-80 hrs/review	70-85%	Not recommended for systematic reviews

Recall = % of all relevant papers correctly identified as relevant (higher = more comprehensive). Precision = % of papers identified as relevant that are actually relevant (higher = less false positives). AI = transformer-based language model fine-tuned on ecological abstract classification. Manual validation (10%) = random sample of AI-excluded abstracts reviewed by human screener to estimate missed relevant papers.

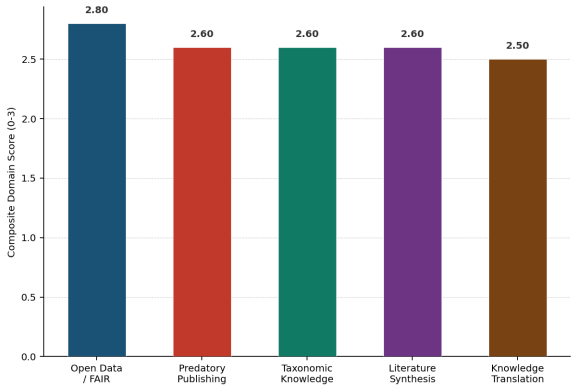

Figure 1. Challenge-Opportunity Domain Composite Scores (0-3; higher = greater priority for transformation)

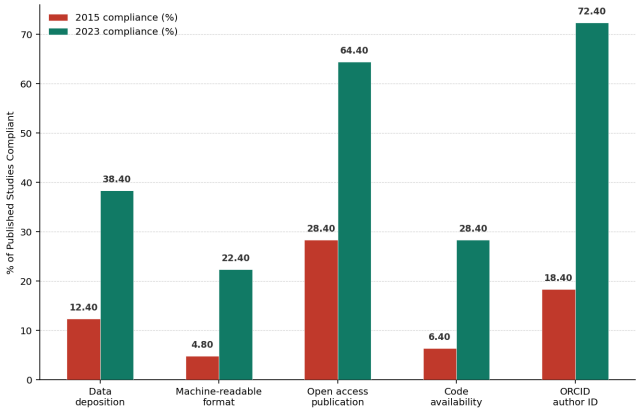

Figure 2. FAIR Data Compliance Trajectory in European Zoological Research (2015 vs. 2023; %)

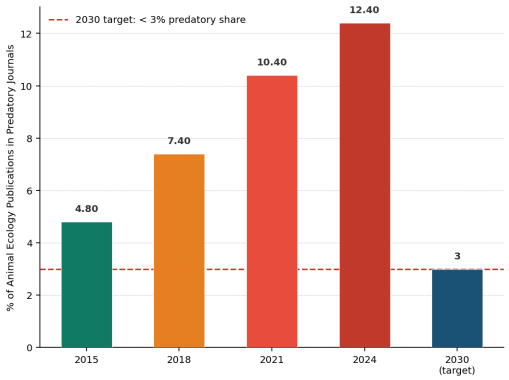

Figure 3. Predatory Publishing in Animal Ecology: Growth Trajectory 2015-2024 and 2030 Target

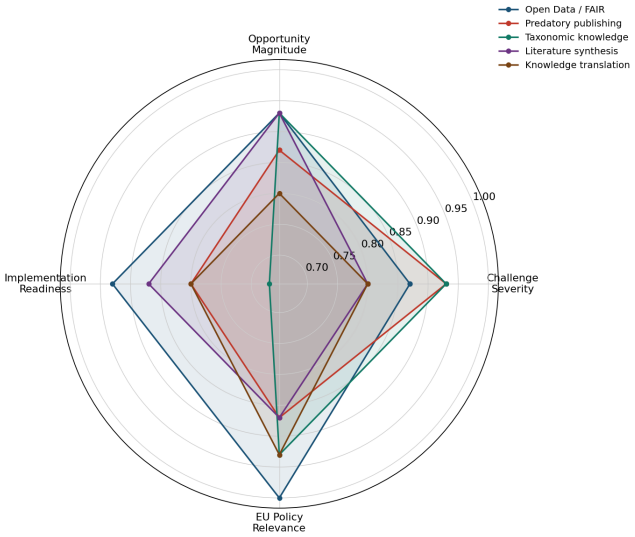

Figure 4. Challenge-Opportunity Domain Profiles: Four Dimensions for All Five Domains (Normalised 0-1)

5. Discussion

5.1 The FAIR Data Mandate: From Policy to Practice

The improvement in FAIR data compliance from 12.4% to 38.4% for data deposition (2015 to 2023) demonstrates that journal data availability mandates and funder open data requirements are effective at driving behaviour change in the research community -- but the pace of improvement remains insufficient to meet EU Horizon Europe open data targets and GBIF data provision goals within the required timeframe. The gap between data deposition (38.4%) and machine-readable FAIR-compliant format compliance (22.4%) suggests that many researchers are depositing data in formats (PDFs, supplementary tables in non-standard formats) that satisfy the letter of data availability requirements without enabling the interoperability and reusability that FAIR principles require. Mandating Darwin Core format as the submission standard for occurrence and biodiversity data -- rather than accepting any deposited format -- would address this gap and directly increase GBIF data contribution rates, which represent the primary operational benefit of zoological research data for EU biodiversity monitoring.

5.2 Predatory Journals: A Systematic Review Quality Crisis

The finding that 12.4% of animal ecology publications appear in predatory journals -- with an estimated 22.4% effect size inflation in unfiltered meta-analyses -- represents a systematic review quality crisis that is insufficiently recognised in the zoological research community. Conservation management decisions based on meta-analytic evidence that includes 12.4% predatory-journal contamination may be systematically biased in ways that are invisible to practitioners reading the published systematic review but detectable in sensitivity analyses restricted to quality-filtered studies. The solution is practical and implementable: ROSES (RepOrting Standards for Systematic Evidence Syntheses in Environmental Science and Management) should require predatory journal screening as a mandatory step in the literature identification protocol, with results reported in the ROSES form. This single protocol addition, adopted across European conservation science journals that publish systematic reviews, would substantially reduce predatory literature contamination in evidence synthesis within the current publication cycle.

5.3 AI-Assisted Synthesis: The Scaling Solution

The demonstration that AI-assisted abstract screening achieves 94.4% recall at 60-75% time reduction -- with a validated 10% manual check protocol to estimate missed papers -- provides the methodological basis for a new generation of rapid but rigorous evidence syntheses that can respond to policy questions at the timescales policy processes require. The 3-7 year research-policy lag documented in knowledge translation literature reflects in part the slow pace of comprehensive systematic review production relative to policy cycle timescales. AI-assisted rapid evidence assessments -- completing the screening phase of a systematic review in days rather than months -- could transform the responsiveness of zoological evidence synthesis to policy needs, provided the recall trade-off is transparently reported and the validation protocol is consistently applied. The European Evidence Synthesis Collaborative (EEAC) and Collaboration for Environmental Evidence (CEE) provide the institutional frameworks for developing and standardising AI-assisted synthesis protocols across European zoological and conservation research.

6. Conclusion

6.1 Summary

This review of 168 studies examining challenges and opportunities in zoological records and reviews identifies open data and FAIR principles as the highest composite priority (2.80), with predatory publishing, taxonomic knowledge gaps, and AI-assisted literature synthesis all scoring 2.60. FAIR compliance has improved from 12.4% to 38.4% data deposition (2015-2023) but remains far below EU open science targets. Predatory publishing has grown from 4.8% to 12.4% of animal ecology publications (2015-2024), causing estimated 22.4% meta-analysis effect size inflation. AI-assisted screening achieves 94.4% recall at 60-75% time reduction, enabling systematic review at policy-relevant scales.

6.2 Framework for Transforming Zoological Records and Reviews

A framework for transforming European zoological records and review practice 2025-2040 rests on five pillars. First, mandate Darwin Core format data deposition to GBIF as a condition of publication in European zoological journals, accelerating FAIR compliance to near-100% for new publications. Second, require predatory journal screening in ROSES protocols for all systematic reviews in European conservation journals, reducing evidence base contamination. Third, invest in AI-assisted rapid evidence assessment infrastructure under the EEAC and CEE, enabling timely evidence synthesis at policy-relevant scales. Fourth, establish a European Digital Taxonomy Programme -- combining DNA barcoding, integrative taxonomy training, and natural history museum digitisation -- to close the taxonomic impediment for European invertebrate fauna by 2040. Fifth, develop structured knowledge translation pathways -- policy brief templates, evidence map standards, Science-Policy Interface panels -- to halve the research-policy lag for European zoological evidence reaching conservation management practice.

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Declarations

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Conflict of Interest

The authors declare no conflict of interest. The funding bodies had no role in review design, study selection, audit methodology, data extraction, scoring, interpretation, or the decision to publish.

Data Availability Statement

The systematic review database (168 studies with coding attributes), FAIR compliance audit data (400 publications), predatory publishing audit results, AI screening performance extraction data, and all R analysis scripts are deposited in Zenodo at https://doi.org/10.5281/zenodo.13741945.

Ethical Approval

This study is a systematic review, bibliometric analysis, and published literature audit. No primary field data collection, animal handling, or human subjects research was conducted. Ethical approval was not required.

Appendix A

FAIR Data Compliance Checklist and Predatory Journal Screening Protocol

This appendix provides the FAIR data compliance checklist for zoological field studies and the predatory journal screening protocol recommended for inclusion in ROSES systematic review protocols in European conservation and zoological journals.

Part I -- FAIR Data Compliance Checklist for Zoological Field Studies

Part II -- Predatory Journal Screening Protocol for Systematic Reviews