On the quest for novelty in ecology

Gianluigi Ottaviani[1,2,3,4#], Alejandro Martínez[5], Matteo Petit Bon[1,6], Stefano Mammola[4,5,7]

[1]Institute of Botany, The Czech Academy of Sciences, Třeboň, Czech Republic

[2]Department of Botany and Zoology, Faculty of Science, Masaryk University, Brno, Czech Republic

[3]Research Institute on Terrestrial Ecosystems (IRET), National Research Council (CNR), Porano, Italy

[4]National Biodiversity Future Center (NBFC), Palermo, Italy

[5]Molecular Ecology Group (MEG), Water Research Institute (IRSA), National Research Council (CNR), Verbania Pallanza, Italy

[6]Department of Wildland Resources, Quinney College of Natural Resources and Ecology Center, Utah State University, Logan, USA

[7]Finnish Museum of Natural History, University of Helsinki, Helsinki, Finland

[#]corresponding author: gianluigi.ottaviani@gmail.com; gianluigi.ottaviani@cnr.it

Author ORCID:

GO: https://orcid.org/0000-0003-3027-4638

AM: https://orcid.org/0000-0003-0073-3688

MPB: https://orcid.org/0000-0001-9829-8324

SM: https://orcid.org/0000-0002-4471-9055

Abstract

The volume of scientific publications continues to grow, making it increasingly challenging for scholars to publish papers that capture readers' attention. While making a truly significant discovery is one way to attract readership, another approach may involve tweaking the language to overemphasize the novelty of results. Using a dataset of 52,236 paper abstracts published between 1997 and 2017 in 17 ecological journals, we found that the relative frequency of novelty terms (e.g. *groundbreaking*, *innovative*) nearly doubled over time. All journals but one exhibited a positive trend in the use of novelty terms during the studied period. Conversely, we found no such trend for confirmatory terms (e.g. *confirm*, *replicated*). Importantly, only papers using novelty terms were associated with significantly higher citation counts and were more often published in journals with a higher impact factor. While increasing research opportunities are surely driving advances in ecology, the writing style of authors and the publishing habits of journals may better reflect the inherently confirmatory nature of ecological research. We call for an open discussion among researchers about the potential reasons and implications of this language-use and scientometrics issue.

Keywords Journal Impact Factor, language use, number of citations, scientific discovery, scientific writing, scientometrics, sensationalism

The recent rise in scientific production

"*Eureka!*"– yelled Archimedes when he solved a scientific problem that, among other things, would have cost him his life. This is only one of many tales of serendipitous discoveries that populate the history of science. A common thread in these narratives is the presence of a lonely genius who, perhaps in a stroke of luck or inspiration, succeeded in shedding light on the unknown (Connor, 2005). However, the reality behind these tales can be quite different (Foucault, 1969). Modern science is a systematized body of positive knowledge (Hoyningen-Huene, 2013), primarily built through a lengthy and steady accumulation of confirmatory work, only occasionally disrupted by game-changing discoveries that typically arise from anomalous results or observations (Darwin, 1859; Kuhn, 1962). Even after such discoveries, paradigms rarely shift abruptly, and many pioneering ideas remain dormant until later researchers recognize their value (Van Raan, 2004).

In the digital era, scientific results are published at an astonishing rate (Landhuis, 2016), with the number of scientific articles published annually more than tripling over the past two decades, surpassing six million papers in 2023 (www.dimensions.ai). The field of ecology is no exception to this trend (Pautasso, 2012), as researchers struggle to keep up with the ever-growing influx of new literature (Courchamp & Bradshaw, 2018). As a result, readers must be more selective in what they consume (Mabe & Amin, 2002), while writers may adapt their language to capture attention (Weinberger et al., 2015; França & Monserrat, 2019; Mammola, 2020). Further, journals may reinforce this trend by requiring authors to emphasize the novelty of their publications. As readers striving to keep up with the relentless production of ecological literature, we sensed that

an increasing number of papers are filled with terms that, in various ways, highlight the novelty of the research. Here, we explore the question: Is this trend real or merely perceived?

We analyzed the relative use (i.e. frequency) of novelty and confirmatory terms in ecological publications over a twenty-year period. We developed a dual-hypothesis testing framework (Fig. 1). If ecological research is primarily confirmatory, we would expect a consistently higher relative use of confirmatory terms than novelty terms (H1; Fig. 1A,C). Conversely, if the pressure to stand out in the “research crowd” influences authors’ writing and journal publishing practices, we should observe a significant increase in the relative use of novelty terms over time (H2; Fig. 1B,C).

Additionally, we conducted a scientometrics analysis to examine whether relationships exist between the use of novelty or confirmatory terms and (i) the Impact Factor (Journal Impact Factor) of the journal in which a paper was published or (ii) the number of citations a paper received. A relationship with Journal Impact Factor would suggest a journal’s tendency to either favor (positive relationship) or discourage (negative relationship) papers using these terms. A relationship with citation count would indicate whether readers are more (positive relationship) or less (negative relationship) likely to cite papers containing either type of term.

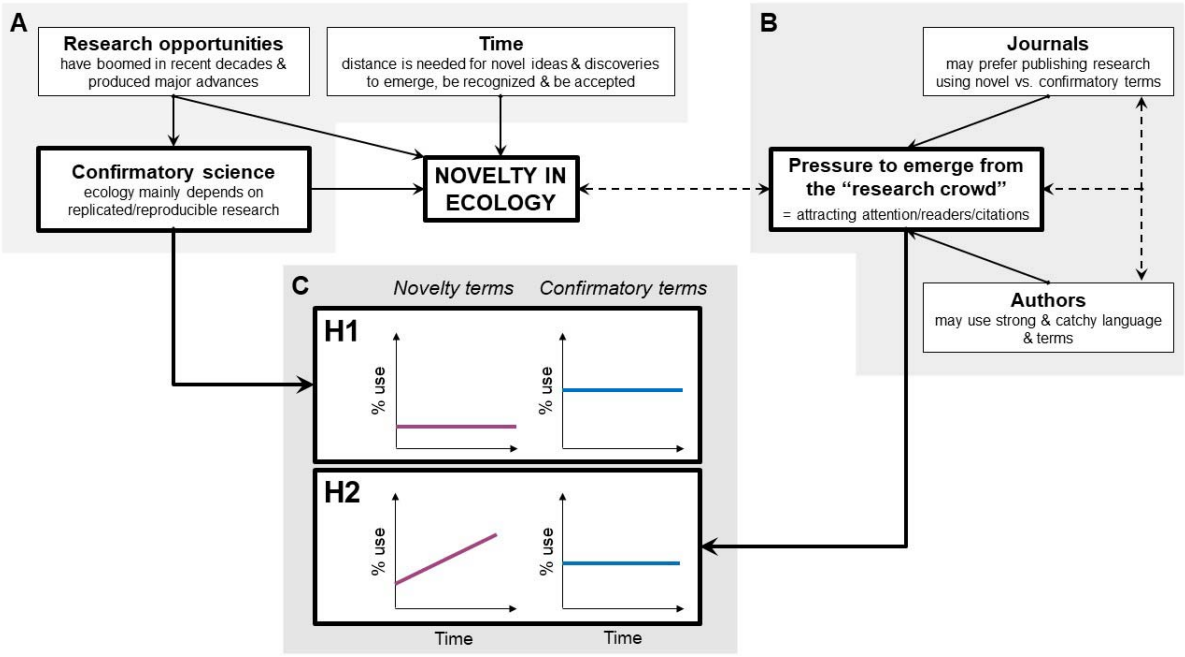

Figure 1. Schematic of the dual-hypothesis framework. The confirmatory nature of ecological research (A) contrasts with the pressure on authors and journals to stand out in an increasingly crowded research landscape (B), leading to two distinct scenarios (C). Solid arrows indicate putative direct relationships between components, while dashed arrows represent plausible interactions or synergies that, in turn, shape the hypothesized temporal patterns in the use of novelty and confirmatory terms.

Dataset and statistical analyses

We used a dataset of 52,236 papers published between 1997 (year in which Journal Impact Factor was introduced) and 2017 in 17 representative ecological journals (Mammola et al., 2021) (Table S1) – these constituting ~20% of all ecological journals listed in the Web of Science in 1997, and ~11% of those listed in 2017, and covering most of the Journal Impact Factor range in ecology (e.g. 1.3-10.8 for the year 2023). We examined the frequency of appearance (presence/absence) of a set of selected novelty

terms (“breakthrough", "groundbreaking", "innovated", "innovation", "innovative", "new", "newly", "novel", "novelty") and confirmatory terms ("confirm", "confirmatory", "replicability", “replicate", "replicated", "replication", "reproducibility") over time in paper abstracts. We focused on abstracts because they reflect the overall writing style of articles (Plavén-Sigray et al., 2017), while representing the lark mirror to capture the attention of readers (Martínez & Mammola, 2021).

We used regression-like analyses (Zuur & Ieno, 2016) to examine whether the use of novelty or confirmatory terms has increased over the studied period across all papers and journals (N = 52,236). Specifically, we ran two generalized linear mixed models to test the relationship between the use of confirmatory and novelty terms and publication year, with ‘journal’ included as a random-intercept factor, assuming that abstracts from the same journal share more similar writing features than those from different journals. Given the binary nature of the dependent variable (0 = non-use of the term; 1 = use of the term in each paper), we specified a Bernoulli-family data distribution and a complementary log-log link function to account for the unbalanced distribution of zeros and ones. To provide a visual summary of the temporal trend, we plotted the frequency of term usage as the percentage of papers using novelty or confirmatory terms per year—both in aggregate (Fig. 2) and for individual journals (Fig. 3).

Next, we used a generalized linear mixed model to test whether the number of citations (response variable) is related to the relative use of novelty and confirmatory terms (fixed effects). We also included abstract length (word count) and publication year as covariates to control their potential influence on citations, and we treated ‘journal’ as a random-intercept factor. Since citations are count data, we initially specified a

Poisson-family distribution. However, the Poisson model was highly over-dispersed (dispersion ratio = 96.5, Pearson's χ^2 = 5040868.5, $p < 0.001$), so we switched to a negative binomial distribution. To examine whether the use of novelty and confirmatory terms is related to Journal Impact Factor, we ran a linear model with the same fixed effects as in the citation model. Here, we did not include 'journal' as a random effect, as it is inherently tied to Journal Impact Factor.

We ran all the analyses in R version 4.3.0 (R Core Team, 2023), using the package glmmTMB version1.1.7 for regression analyses (Brooks et al., 2017), performance version 0.9–7 for model validation (Lüdecke et al., 2021), and ggplot2 version 3.5.1 for plotting (Wickham et al., 2016).

The growing use of novelty terms in ecology

Across all journals, the relative use of novelty terms in paper abstracts doubled over the study period, increasing from ~10% in 1997 to ~20% in 2017 (Fig. 2). Regression analyses confirmed that the likelihood of an article using novelty terms was higher in recent years (*Log-Risk* ± SE: 0.16 ± 0.01, $z = 14.03$, $p < 0.001$; Conditional $R^2 = 0.05$, Marginal $R^2 = 0.02$). In contrast, we found no clear trend for confirmatory terms, whose relative use remained steady at around 3% (Fig. 2). The probability of an article using confirmatory terms also remained stable over the study period (*Log-Risk* ± SE: 0.04 ± 0.02, $z = 1.54$, $p = 0.125$; Conditional $R^2 = 0.03$, Marginal $R^2 = 0.01$). This overall pattern for novelty and confirmatory terms was similar across all journals, except for *Austral Ecology*, which—*nomen omen*—showed the opposite trend, with the use of novelty terms declining over time (Fig. 3).

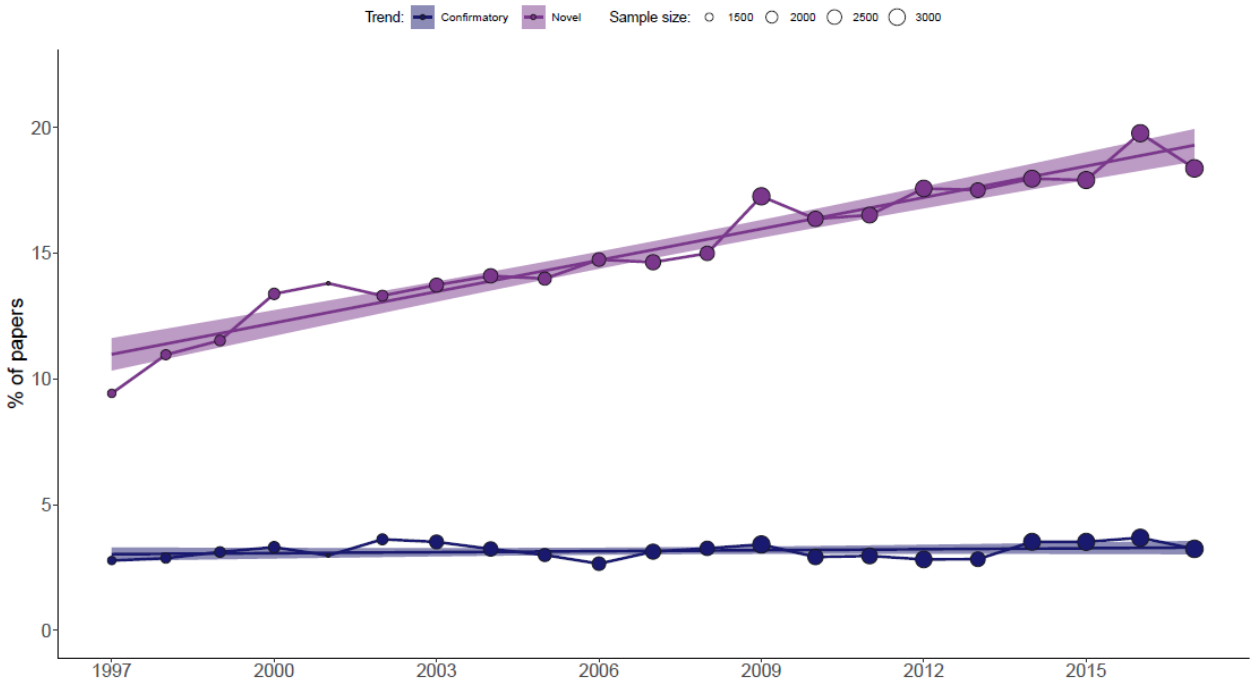

Figure 2. Increasing use of novelty terms in ecological abstracts. Temporal trends in the relative use (i.e. annual frequency [%]) of novelty and confirmatory terms across 17 selected ecological journals (Table S1). Dot size represents the number of articles published each year. Regression lines and confidence intervals are included for visual clarity.

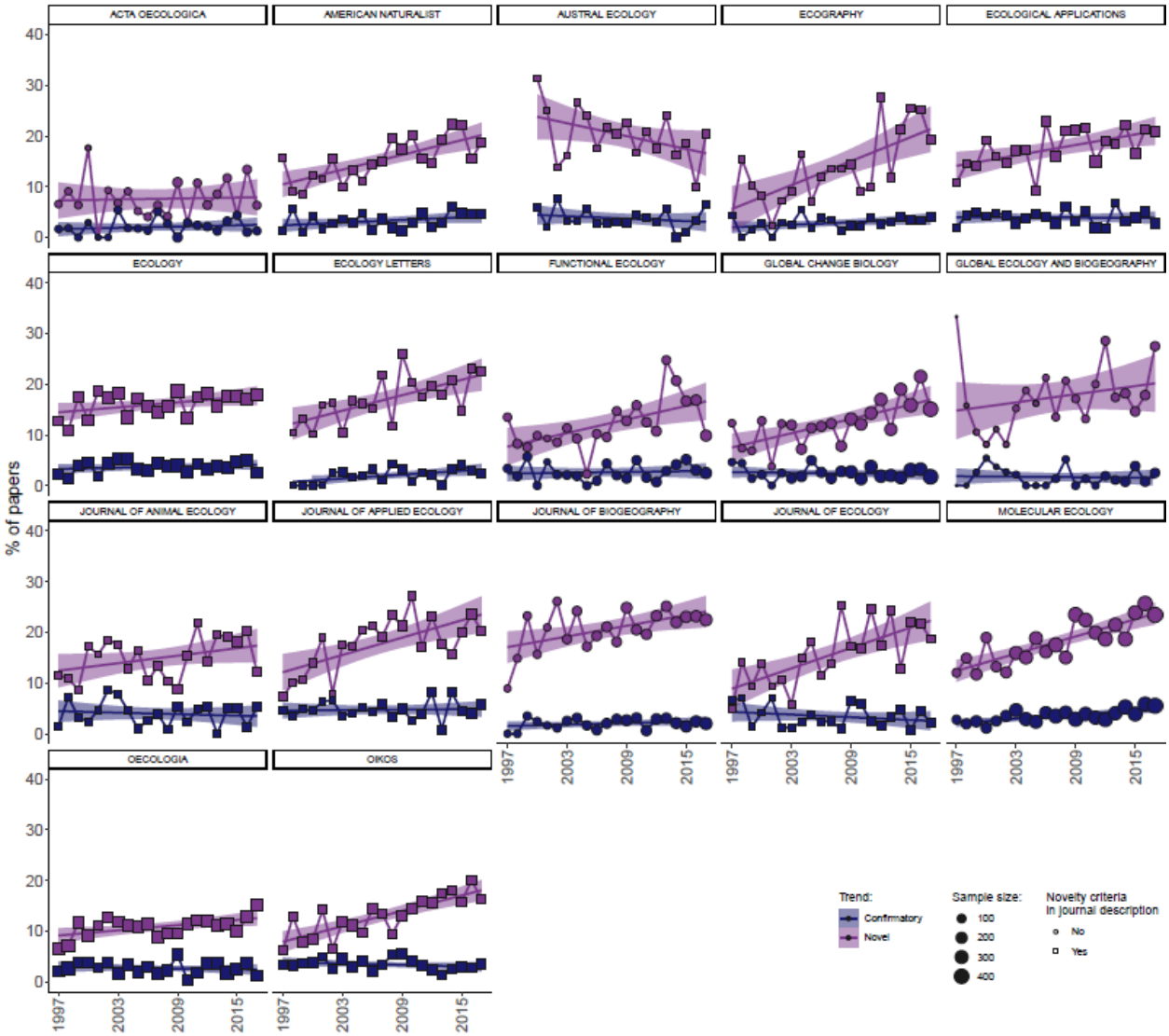

Figure 3. The trend of increasing use of novelty terms in ecological abstracts is consistent across all but one journal. Temporal trends in the relative use (i.e. annual frequency [%]) of novelty and confirmatory terms for each of the 17 selected ecological journals. Symbols indicate whether novelty is a criterion mentioned in the journal description (Table S1), and their size corresponds to the number of articles published each year. Regression lines and confidence intervals are included for visual clarity.

The use of novelty terms was positively associated with both the number of citations and Journal Impact Factor, whereas no such relationships were found for confirmatory terms (Fig. 4). Abstract length (number of words) was positively associated with the number of citations and negatively with Journal Impact Factor, while publication year was negatively related to the number of citations (i.e. more recent papers receive fewer citations than older ones) and positively with Journal Impact Factor. The unexplained variance suggests that several other factors, not accounted for in this analysis, are likely influencing article impact—something that is well-documented in the "science of science" literature (e.g., Tahamtan et al., 2016, 2019; Mammola et al., 2022).

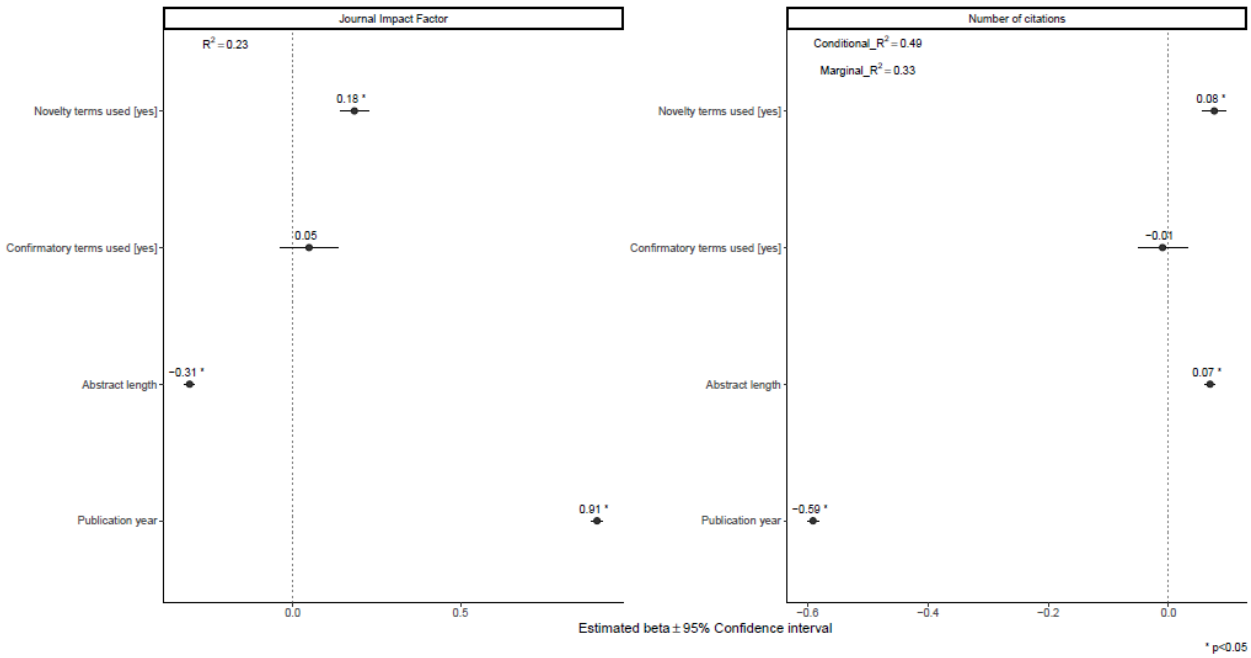

Figure 4. Publication impact is tightly associated with the use of novelty terms. Forest plots summarize the estimated parameters of regression models testing the relationship between novelty and confirmatory terms, abstract length (number of words),

and publication year on the Journal Impact Factor (left panel; based on a linear model) and the number of citations (right panel; based on a generalized linear mixed model). Bars represent 95% confidence intervals. Variance explained is reported as both conditional R^2 (random + fixed effects) and marginal R^2 (explained by fixed factors alone). Asterisks (*) indicate significant effects ($\alpha = 0.05$).

What could be behind the rising trend of novelty terms?

We found strong evidence supporting our perception that more and more papers are using novelty terms, while confirmatory terms showed no obvious temporal patterns and were generally much less used by researchers over the studied 20-year timespan (Fig. 2, Fig. 3). Concurrently, the use of novelty terms tended to attract more citations and was associated with journals having higher Journal Impact Factors compared to the use of confirmatory terms (Fig. 4). As a result, we rejected H1 of our dual-hypothesis framework, while H2 received striking support (Fig. 1). The increasing use of novelty terms was confirmed across all our analyses, emerging across all journals (Fig. 2), as well as within individual journals (Fig. 3). The only exception was the Australian journal *Austral Ecology*, which exhibited a temporal decline in the relative use of novelty terms, for which we do not have a plausible explanation for this anomalous "down-under" pattern. Taken together, these findings support the idea that the pressure to stand out from the "research crowd" felt by both researchers and journals plays a key role in the current ecological writing and publishing landscape (Fig. 1).

Still, we can only speculate about the possible causes driving the upward trend in the use of novelty terms in the last two decades, as correlation does not necessarily imply causation. Perhaps, thanks to recent conceptual developments (Dubois & Peres-

Neto, 2022) and the increasing availability of data and analytical tools (e.g. Besson et al., 2022; Cardoso et al., 2020; McCallen et al., 2019; Tosa et al., 2021; Mammides & Papadopoulos 2024), ecologists are now truly able to make groundbreaking discoveries and write novel stories at an accelerating pace. However, the history of science suggests that game-changing findings are rare and take time to be recognized (Morris, 2009; Van Raan, 2004). This view is further supported by a recent overview illustrating how papers are increasingly less likely to make scientific breakthroughs (Park et al., 2023).

We must then face an uncomfortable alternative possibility: are we, as ecologists, using a more sensationalized and novelty-driven language (either consciously or unconsciously) to increase our chances of catching readers' attention amidst the incessant production of scientific literature (scenario depicted in Fig. 1B, C) (Weinberger et al., 2015; Doubleday & Connell, 2017; Mammola, 2020)? This speculation is supported by the positive significant relationship between the use of novelty terms, but not the use of confirmatory terms, and both number of citations and Journal Impact Factor (Fig. 4). These relationships also suggest that Journal Impact Factor could benefit from publishing papers that use novelty terms, as they are more likely to attract citations. Indeed, journals may be contributing to this trend. Among the 17 ecological journals included in our analysis, about 65% explicitly mention novelty as a criterion in their current author guidelines (Table S1). Similarly, novelty is a core requirement in pre-peer review editorial decisions for some journals (Arnqvist, 2013). Thus, this "quest for novelty" may partly stem from the challenges faced by journals in attracting readers and citations. At the same time, more "novel" papers may tend to be

published in journals with higher Journal Impact Factor, further shaping the observed patterns. In other words, such complex feedback loops between researchers and journals may have therefore largely contributed to generating the spike in the use of novelty terms in ecological literature.

Limitations of the study

A deeper mechanistic understanding of what drives these scientometrics patterns related to writing and publishing behaviors would require a closer examination of each manuscript included in this study. This step would imply reading each of the >50k papers, and perhaps even contacting corresponding authors asking for their feedback and reasons behind the choice of using or not novelty terms. We are also aware that the selection of terms and searched journals can affect the revealed patterns. However, thanks to the representativeness of the chosen ecological journals, Journal Impact Factor range, and set of selected terms, we are confident that what we have found offers a reliable picture of what has happened in the studied 20-year timespan.

On the importance and impacts of confirmatory science and of language use in ecology

Ecology is experiencing unprecedented research opportunities worldwide. However, like any other scientific discipline, knowledge-building progresses through a lengthy and steady cumulative process, with most basic and applied research being inherently confirmatory in nature (Hoyningen-Huene, 2013). Novel ideas and discoveries may emerge in response to idiosyncrasies arising from observational or experimental

studies, which also form the theoretical foundations upon which we built—and ultimately rejected—our H1. Nevertheless, the frequency of new discoveries in ecology typically occurs at a rate of only a few per year or decade (Morris, 2009), which contrasts with the trends we observed in our study.

From a semantic and cognitive standpoint, words are not just tools for communicating our key findings to other scientists or the broader public (Feynman, 1969), but also serve as the building blocks of knowledge construction (Martínez & Mammola, 2021). We wonder whether the increasing use of sensationalized language (Mammola, 2020), where novelty may be exaggerated, could influence our thinking process at various levels. After all, understanding what is truly new is crucial—not only when writing and disseminating results but also when designing future projects and experiments. Without this clarity, we risk reinventing the wheel. We join the call to evaluate publications based on their quality, soundness, clarity, and replicability, giving less emphasis to their confirmatory or novelty (true or claimed) nature (Pautasso, 2013; Romero, 2017). Encouragingly, this approach seems to be increasingly adopted by ecological journals, especially (but not exclusively) open-access ones. Therefore, we emphasize the importance of starting a conversation about the potential root-causes and implications of this linguistic and scientometrics trend for the scientific community and science communication at large.

Author contributions

GO conceived the research idea, with significant inputs to further develop it provided by SM, AM, MPB. SM gathered the data and conducted the statistical analysis. GO and SM led the writing, and all coauthors contributed to revisions.

Acknowledgements

We thank François Munoz (recommender at PCI Ecology), François Massol, and an anonymous reviewer for providing very constructive feedback during the revision process.

Funding information

GO and MPB were supported by the long-term research development project of the Czech Academy of Sciences (No. RVO 67985939). GO and SM acknowledge the support of NBFC (National Biodiversity Future Center) funded by the Italian Ministry of University and Research, P.N.R.R., Missione 4 Componente 2, “Dalla ricerca all’impresa”, Investimento 1.4, Project CN00000033 (funded by the European Union – NextGenerationEU). MPB is also supported by the National Science Foundation (grant no. ANS-2113641).

Data accessibility statement

Data supporting this study is available in Figshare: https://doi.org/10.6084/m9.figshare.12941639.v1.

The analytical pipeline to reproduce the analyses is also available in GitHub: https://github.com/StefanoMammola/Ottaviani_et_al.

Artificial Intelligence (AI) declaration

No AI technologies have been used.

Conflicts of interests/Competing interests declaration

Nothing to declare.

References

Arnqvist, G. (2013). Editorial rejects? Novelty, schnovelty! *Trends in Ecology & Evoution, 28*, 448–449.

Besson, M., Alison, J., Bjerge, K., Gorochowski, T.E., Høye, T.T., Jucker, T. et al. (2022). Towards the fully automated monitoring of ecological communities. *Ecology Letters, 25*, 2753–2775.

Brooks, M.E., Kristensen, K., van Benthem, K.J., Magnusson, A., Berg, C.W., Nielsen, A., Skaug, H.J., Maechler, M., & Bolker, B.M. (2017). glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. *The R Journal*, *9*, 378-400.

Cardoso, P., Branco, V.V., Borges, P.A.V., Carvalho, J.C., Rigal, F., Gabriel, R., et al. (2020). Automated discovery of relationships, models, and principles in ecology. *Frontiers in Ecology and Evolution, 8*, 530135.

Conner, C. (2005). A people's history of science: miners, midwives, and low mechanicks. Nation books

Courchamp, F., & Bradshaw, C.J.A. (2018). 100 articles every ecologist should read. *Nature Ecology and Evolution, 2*, 395–401.

Darwin, C. (1859). *The origin of species*. John Murray.

Doubleday, Z.A., & Connell, S.D. (2017). Publishing with objective charisma: Breaking science's paradox. *Trends in Ecology & Evolution, 32*, 803–805.

Dubois, F., & Peres-Neto, P.R. (2022). Games researchers play: conceptual advancement versus validation strategies. *Trends in Ecology & Evolution, 37*, 399–401.

Feynman, R. (1969). What is science? *The Physics Teacher, 7*, 313–320.

Foucault, M. (1969). *L'archéologie du savoir*. Editions Gallimard.

França, T.F., & Monserrat, J.M. (2019). Writing papers to be memorable, even when they are not really read. *BioEssays, 41*, 1900035.

Hoyningen-Huene, P. (2013). *Systematicity: The nature of science*. Oxford, UK: Oxford University Press.

Kuhn, T.S. (1962). *Structure of the scientific revolutions*. Chicago, USA: University of Chicago Press.

Landhuis, E. (2016). Scientific literature: information overload. *Nature, 535*, 457–458.

Lüdecke, D., Ben-Shachar, M.S., Patil, I., Waggoner, P., & Makowski, D. (2021). performance: an R package for assessment, comparison and testing of statistical models. *Journal of Open Source Software*, *6*, 3139.

Mabe, M.A., & Amin, M. (2002). Dr Jekyll and Dr Hyde: author-reader asymmetries in scholarly publishing. *Aslib Proceedings, 54*, 149–157.

Mammides, C., & Papadopoulos, H. (2024). The role of large language models in interdisciplinary research: Opportunities, challenges and ways forward. *Methods in Ecology and Evolution*, *15*, 177–1776.

Mammola, S., Piano, E., Doretto, A., Caprio, E., & Chamberlain, D. (2022). Measuring the influence of non-scientific features on citations. *Scientometrics*, *127*, 4123–4137.

Mammola, S., Fontaneto, D., Martínez, A., & Chichorro, F. (2021). Impact of the reference list features on the number of citations. *Scientometrics. 126*, 785–799.

Mammola, S. (2020). On deepest caves, extreme habitats, and ecological superlatives. *Trends in Ecology & Evolution, 35*, 469–472.

Martínez, A., & Mammola, S. (2021). Specialized terminology reduces the number of citations to scientific papers. *Proceedings of the Royal Society B, 288*, 20202581.

McCallen, E., Knott, J., Nunez-Mir, G., Taylor, B., Jo, I., & Fei, S. (2019). Trends in ecology: shifts in ecological research themes over the past four decades. *Frontiers in Ecology and the Environment, 17*, 109–116.

Morris, C. (2009). *Milestones in ecology*. Princeton, USA: Princeton Press.

Park, M., Leahey, E., & Funk, R.J. (2023). Papers and patents are becoming less disruptive over time. *Nature, 613*, 138–144.

Pautasso, M. (2012). Publication growth in biological sub-fields: Patterns, predictability and sustainability. *Sustainability, 4*, 3234–3247.

Pautasso, M. (2013). Focusing on publication quality would benefit all researchers. *Trends in Ecology & Evolution, 28*, 318–320.

Plavén-Sigray, P., Matheson, G.J., Schiffler, B.C., & Thompson, W.H. (2017). The readability of scientific texts is decreasing over time. *eLife, 6*, e27725.

R Core Team (2023). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.

Romero, F. (2017). Novelty versus replicability: virtues and vices in the reward system of science. *Philosophy of Science, 84*, 1031–1043.

Tahamtan, I., & Bornmann, L. (2019). What do citation counts measure? An updated review of studies on citations in scientific documents published between 2006 and 2018. *Scientometrics*, *121*, 1635–1684.

Tahamtan, I., Safipour Afshar, A., & Ahamdzadeh, K. (2016). Factors affecting number of citations: A comprehensive review of the literature. *Scientometrics*, *107*, 1195–1225.

Tosa, M.I., Dziedzic, E.H., Appel, C.L., Urbina, J., Massey, A., Ruprecht, J., et al. (2021). The rapid rise of next-generation natural history. *Frontiers in Ecology and Evolution, 9*, 480.

Van Raan, A.F. (2004). Sleeping beauties in science. *Scientometrics, 59*, 467–472.

Weinberger, C.J., Evans, J.A., & Allesina, S. (2015). Ten simple (empirical) rules for writing science. *PloS Computational Biology*, *11*, e1004205.

Wickham, H. (2016). *ggplot2: elegant graphics for data analysis*. New York, USA: Springer-Verlag New York.

Zuur, A.F., & Ieno, E. N. (2016). A protocol for conducting and presenting results of regression-type analyses. *Methods in Ecology and Evolution*, *7*, 636–645.

Table S1. The 17 journals selected for the analysis and sample size (readapted from Mammola et al., 2021).

Journal name	Initial year	Timespan selected	N of primary research articles used	Use and requirement of novelty terms in journal description*
Acta Oecologica	1983	1997–2017	1,408	No
American Naturalist	1867	1997–2017	2,852	Yes
Austral Ecology	2000	2000–2017	1,434	Yes
Ecography	1978	1997–2017	1,743	Yes
Ecological Applications	1991	1997–2017	3,051	Yes
Ecology	1920	1997–2017	5,505	Yes
Ecology Letters	1998	1998–2017	2,098	Yes
Functional Ecology	1987	1997–2017	2,326	No
Global Change Biology	1995	1997–2017	3,937	No
Global Ecology and Biogeography	1993	1997–2017	1,377	No
Journal of Animal Ecology	1932	1997–2017	2,250	Yes
Journal of Applied Ecology	1964	1997–2017	2,407	Yes
Journal of Biogeography	1974	1997–2017	2,852	No
Journal of Ecology	1913	1997–2017	2,170	Yes
Molecular Ecology	1992	1997–2017	6,209	No
Oecologia	1968	1997–2017	5,446	Yes
Oikos	1949	1997–2017	3,812	Yes

* Novelty terms considered in the journal description (i.e. scope and authors' guidelines; search conducted in 2021) are the same as of the paper abstract search.