Taxonomic uncertainty: causes, consequences, and metrics

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Abstract

Taxonomic uncertainty is prevalent across many biological groups. Yet it remains overlooked in ecology, evolution, and conservation research, leading to potential misinterpretations of biodiversity patterns. Here, we synthesize the recent literature to define taxonomic uncertainty, examine its root causes and consequences, and present key metrics for its quantification. We argue that species should not be assumed to be equivalent units in biodiversity research. To address this challenge, researchers must (i) identify taxa with uncertain boundaries, (ii) track changes in species taxonomy, and (iii) incorporate taxonomic uncertainty into macroecological studies and conservation assessments. These tasks open new research opportunities involving close collaboration among ecologists, evolutionary biologists, taxonomists, and systematists. Integrating taxonomic uncertainty into biodiversity research will improve the robustness of ecological models and conservation strategies, ultimately leading to a more accurate understanding of biodiversity.

Keywords: *Species delimitation, uncertainty, taxonomy, macroecology, taxonomic stability*

Taxonomic uncertainty in biodiversity research

Species are the fundamental unit for studying biodiversity. Yet, accurately describing and cataloguing species is an ongoing challenge. Many species – both extant and extinct – remain unknown to science [1,2]. Those formally described have been delimited using a variety of species concepts, criteria, and diverse taxonomic methods [3,4]. Additionally, only a small fraction of described species have been re-evaluated through multiple lines of evidence [5]. As a result, even the best-known groups, such as birds and mammals, are subject to frequent taxonomic changes, which can profoundly impact downstream biodiversity research and conservation [6,7].

Rapid taxonomic changes are driven by technical and epistemological progress in taxonomy, which has recently reinvigorated this discipline [5,8]. However, taxonomic research remains heavily biased, with a few taxonomic groups and regions receiving disproportional attention and several being understudied [9,10]. This disparity contributes to widespread uncertainty regarding the number and identity of species across taxa and regions [11–13]. Moreover, biases in taxonomic research result in varying degrees of uncertainty in species' boundaries. Despite this shortcoming, biodiversity research treats species as equivalent units, representing unique biological entities.

Previous studies exploring the impact of taxonomic change on biodiversity research and conservation primarily focus on how redefining species boundaries influences species counts, population sizes, and distribution ranges [13–15]. The broad interest in this topic [16, and many others] is justified because among the five tasks of taxonomy – taxon discovery, delimitation, diagnosis, description, and specimen determination [17] – species delimitation is perhaps the most challenging one. Several factors contribute to this complexity. For instance, defining species boundaries is inherently difficult, particularly for populations and species in processes of divergence and/or hybridization. Moreover, most groups lack comprehensive data on genetics, morphology, ecology, and behaviour, hindering the accumulation of the robust evidence needed to establish new species limits. Consequently, some degree of uncertainty is often associated with the delimitation of species boundaries. Although this uncertainty is increasingly acknowledged [5,12,18], we still miss clear guidelines on how to manage and incorporate such taxonomic uncertainty into biodiversity studies.

In this context, we offer a concise definition of taxonomic uncertainty, examine its root causes (both cultural and biological), and discuss its consequences. In addition, we present key metrics and methodologies for quantifying taxonomic uncertainty, and provide recommendations for scientists to address this prevalent bias in their research.

Definition of taxonomic uncertainty

Taxonomic uncertainty has been widely discussed among taxonomists, (macro)ecologists, and conservationists and the term has been used in different contexts (Table S1). Among taxonomists, it generally refers to the challenge of defining clear and unambiguous species boundaries [19,20]. For ecologists and conservationists, the term has a broader scope, encompassing uncertainty in species boundaries [e.g., 21], discrepancies in species lists [e.g., 22,23], and the proportion of unidentified or misidentified specimens in biological inventories, museum collections, and databases [e.g., 24–26]. Overall, many studies evaluate how these various sources of uncertainty affect biodiversity patterns and conservation assessments [27,28].

In general terms, taxonomic uncertainty can arise at any of the five tasks that make up the taxonomic process, as described by Favret [17]: taxon discovery, delimitation, diagnosis, description, and specimen determination (Fig. 1). However, in the context of taxonomic uncertainty, species delimitation and specimen determination (hereafter referred to as specimen identification) are especially critical because these tasks are tackled as hypothesis testing [17,19]. Once a hypothesis is proposed, it can be refuted or supported based on new data and evidence. This implies, for instance, that different types of evidence or criteria can lead experts to produce different assessments of whether a given group of populations qualifies as a unique species or whether the correct name is assigned to a specimen. Here, we define taxonomic uncertainty as the degree of confidence in the hypothesis stating either (i) the delimitation of species boundaries, or (ii) the determination of a specimen's identity. Lower confidence in these hypotheses corresponds to greater taxonomic uncertainty. Simply put, taxonomic uncertainty refers to the extent of our confidence in species limits and accurate identification of specimens. More generally, uncertainty in any task in the taxonomic process will affect the outcome of all subsequent tasks. Additionally, the failure to identify specimens may trigger a new cycle, leading to the discovery of a new species or redefining already described species. Here, we will focus solely on the uncertainty of species delimitation and how it can introduce bias and error into our perception of biodiversity patterns across time and space.

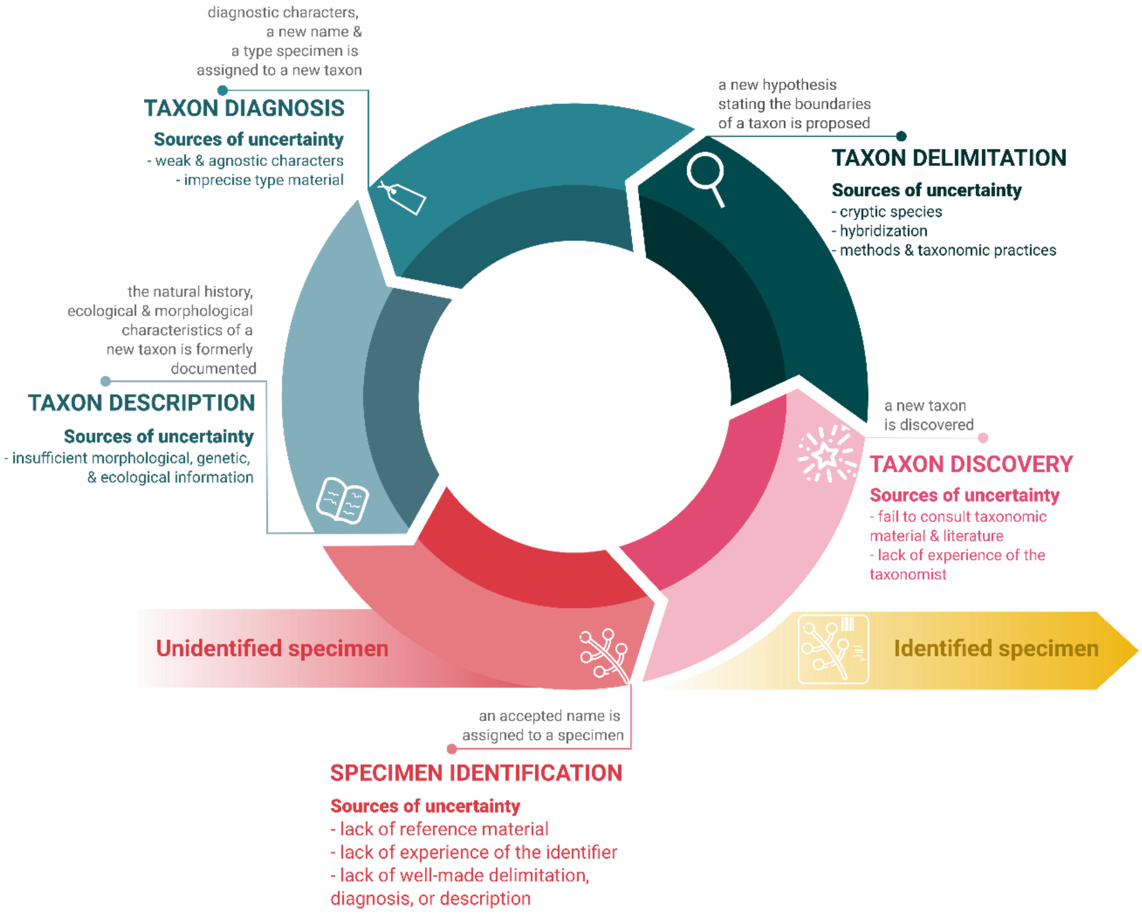


Figure 1. Taxonomic uncertainty across the five tasks of taxonomy [adapted from Favret 17]). Taxonomic practice is a recursive and iterative process, where the inability to assign a species name to a specimen may initiate a new cycle, potentially uncovering a new species or redefining the boundaries of an existing one.

Causes of taxonomic uncertainty

Delimiting a species requires hypothesizing that a taxon (which is a human construct) represents a distinct evolutionary lineage [3,19]. However, a discrete human-defined taxon often does not perfectly align with continuously evolving biological lineages [19,29]. This misalignment is the core driver of uncertainty in species limits. Thus, uncertainty in species delimitation arises from the interaction between the biological processes shaping natural lineages and the human cultural framework and perspective of those attempting to recognize them.

To determine species boundaries, taxonomists rely on species concepts, delimitation criteria, and methods. Heterogeneity in the taxonomic practice across taxa, space, and time can lead to conflicting and competing species delimitation and classification. For instance, the phylogenetic species concept tends to recognize a larger number of narrowly defined taxa compared to non-phylogenetic species concepts [30]. Applying different thresholds of a variable, such as genetic divergence, within the same group can yield different conclusions [31].

Further, experts may interpret the same data in different ways, depending on their practices and approaches [32]. For example, while “splitters” tend to recognize a greater number of species, “lumpers” are more likely to group closely related entities under fewer taxa [33].

Defining species boundaries is particularly challenging for cryptic species and shallowly diverging lineages. These lineages typically experience recent speciation, explosive radiation, genetic introgression, or frequent hybridization events [19,34,35]. Molecular techniques, including phylogenetics and population genetics, have helped define many species limits [36,37]. However, the majority of species complexes remain unresolved.

Biases in taxonomic uncertainty

The degree of taxonomic uncertainty depends on taxonomic effort and species’ biological characteristics [9]. Historically, taxonomic effort — i.e., investments in research capacity and use of integrative approaches — varies across the globe and is usually greater in temperate regions compared to the tropics [10,38]. Additionally, tropical regions harbour a larger number of species and clades, which requires significantly more research to reach the same level of taxonomic knowledge as in temperate regions. As a result, taxonomic uncertainty tends to be higher in tropical regions, a pattern known as the “latitudinal taxonomy gradient” [9].

Taxonomic effort also varies according to the characteristics of different taxa. Charismatic and conspicuous groups, such as birds, mammals, and trees, receive more attention and studies than cryptic and less appealing taxa [30,39]. Consequently, reducing uncertainty in species delimitation for several invertebrates, herbs, and fungi, for example, still requires substantial taxonomic work. Thus, historically understudied taxa are expected to undergo numerous taxonomic changes as they are revised.

Additionally, some taxa characteristics (e.g., geographic range size, phenotypic variability, evolutionary distinctiveness) can also influence the degree of taxonomic uncertainty. For instance, geographically widespread species with high phenotypic variability are more likely to have been described multiple times in the past, increasing the probability of being “lumped” during taxonomic revisions [e.g., 40]. Conversely, widespread species with low phenotypic variability have been found to harbour substantial genetic diversity, revealing cryptic biodiversity that is particularly prevalent in groups such as insects [41], fungi [42], marine invertebrates [43], and plants [37]. Such characteristics make these taxa prone to be “split” into several species after a taxonomic revision.

Consequences of taxonomic uncertainty

The most significant consequence of taxonomic uncertainty is its potential to distort biodiversity patterns. This occurs because resolving taxonomic uncertainty often leads to taxonomic change, which can alter our understanding of the identity, number, distribution, evolution, biological interactions, and environmental requirements of species [44,45]. For instance, splitting a taxon into multiple species increases species richness [14,37], potentially rising beta diversity [13], endemism [21,46], and diversification rates [9,28,45], while reducing geographic range [13], population size [15], and niche and trait breadth [37,47] (Table 1). In contrast, lumping two or more taxa into a single species decreases richness [48,49], possibly reducing beta diversity [13], endemism [21], and diversification rates [45], but may expand geographic range [13,24], population size [15], and niche and trait breadth [37]. In turn, moving a species into another genus or family (i.e., proposing a new combination) redistributes diversity within the involved taxa [50]. In this case, the taxon that receives the species increases its richness while the other taxon experiences a decrease.

Modifications in biodiversity patterns resulting from taxonomic changes have been demonstrated in several studies. For instance, a taxonomic revision of Holarctic land snails resulted in a reduction in the number of recognized species from 124 to 105 taxa and caused major changes in assemblage patterns, including changes in species composition (in 90% of 2,528 sites in the Holarctic), a reduction in richness (in 10% of the sites), and altered species turnover rates (between 6 and 60% of the sites) [48]. In another case, revisions on mouselike birds (genus *Scytalopus*) that incorporated genetic and behavioural data led to a fourfold increase in species richness (from 11 to 49). This increase reshaped the latitudinal diversity gradient for the group, with the tropical diversity peak becoming twice as high as previously recorded, also elevating the speciation rate in tropical regions [9]. Similarly, an integrative taxonomic study of the hyperdominant Amazonian tree species *Protium heptaphyllum* (Aubl.) Marchand (Burseraceae) revealed that it comprises eight distinct evolutionary lineages [37], most being geographically restricted. These studies underscore how taxonomic uncertainty can alter our understanding of a species' ecological requirements and responses to bioclimatic gradients. Misinterpreting species boundaries can lead to incorrect assumptions about environmental drivers of species distribution, potentially causing parts of their potential range or future geographic shifts to be overlooked [47,51].

Estimates of how many species remain to be described — a concept known as the Linnean shortfall [44,52], are also affected by taxonomic uncertainty. Such estimates are typically derived from extrapolations of the cumulative the number of known species, and are obtained by projecting curves of species discoveries [53,54]. However, subsequent splitting or lumping inevitably impacts these extrapolations, leading to underestimating or overestimating the shortfall, respectively [12].

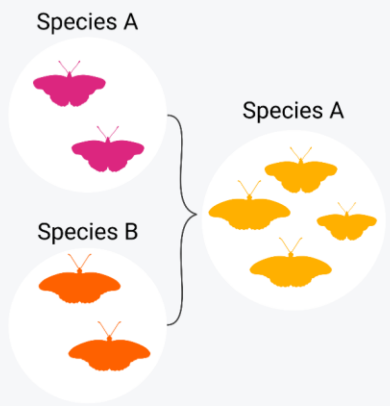
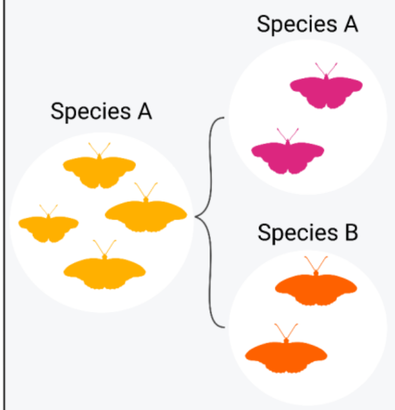
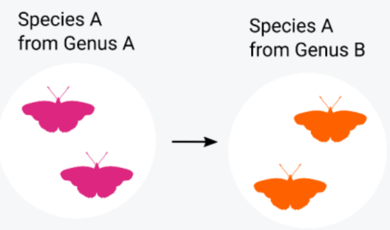
Likewise, conservation strategies may be inappropriate if species limits are uncertain, as taxa requiring protection could be mistakenly recognized as less critical or vice-versa [27,55]. Thus, species conservation status needs reassessment as taxonomic knowledge progresses. For instance, when two or more taxa are lumped, the newly defined species may no longer require the same level of protection. Conversely, when a taxon is split into two or more species, the resulting species may require further protection. This is exemplified by a taxonomic assessment of 870 species of Australian lizards and snakes revealed that 282 taxa (32%) require revision of their conservation status, and 38 taxa (4%) likely represent undescribed species that merit conservation concern [27].

Moreover, as taxonomy evolves, alternative classifications are proposed. Relying on different classifications to recover large-scale biodiversity patterns may lead to varying outcomes. For instance, the choice of the taxonomic database (e.g., Tropicos, GBIF) caused regional variations in bryophyte species richness, ranging from 40% to 60% across the Northern Hemisphere [56]. Typically, this problem can be addressed by comparing results using alternative classifications [7,13,48]. Additionally, inconsistencies among classifications can highlight taxa with tricky boundaries [e.g., 22], which can indicate unsolved taxonomic uncertainty.

Keeping biodiversity databases up-to-date with the most recent taxonomic classification is a demanding task that often requires re-evaluating each record. This is particularly the case when a splitting is proposed for taxa with sympatric distributions [26]. Consequently, the utility and accuracy of occurrence data for describing current species distributions depend highly on the timing of database consultations. For example, Nic Lughadha et al. [24] compared occurrence databases from 2007 and 2017 for the Neotropical plant genus *Myrcia* DC. (Myrtaceae) after a decade of intensive taxonomic work. Among 9,727 records common to both databases, they found that 27% underwent merely nomenclatural changes, whereas 4% experienced taxonomic changes, such as splitting or lumping.

The identification of specimens can also be compromised by uncertainty in species boundaries. Accurate specimen identification depends on unambiguous species delimitation and a precise diagnosis and description (Fig. 1; [17]). Thus, selecting the type specimen and the diagnostic characters used to describe a species is critical, as these will influence the future identification of specimens within that taxon. If a type specimen lacks key diagnostic characteristics or does not represent a typical individual, further identifications result in errors [57].

Table 1. Taxonomic changes (lumping, splitting, and recombination) and their impact on biodiversity patterns and species threat status.

Taxonomic change		Parameter	Effect	Reference
Lumping		**at species level**		
		endemism	= ↓	Lopes et al. 2024
		niche breadth	= ↑	Romero et al. 2014
		population size	↑	Bacon et al. 2022
		species range	= ↑	Nic Lughadha et al. 2019; Flanagan et al. 2024
		threat status	= ↓	Morrison III et al. 2009; Nic Lughadha et al. 2019
		trait breadth	= ↑	Damasco et al. 2021
		at assemblage level		
		beta diversity	↓	Nekola & Horsák 2022; Flanagan et al. 2024
		diversification rates	↓	Diniz-Filho et al. 2023
		species richness	↓	Nekola & Horsák 2022; Stropp et al. 2025
Splitting		**at species level**		
		endemism	= ↑	Dillon et al. 2005; Lopes et al. 2024
		niche breadth	↓	Romero et al. 2014; Damasco et al. 2021
		population size	↓	Bacon et al. 2022
		species range	= ↓	Damasco et al. 2021; Flanagan et al. 2024
		threat status	= ↑	Dillon et al. 2005; Morrison III et al. 2009; Simkins et al. 2019; Melville et al. 2021
		trait breadth	↓	Damasco et al. 2021
		at assemblage level		
		beta diversity	↑	Flanagan et al. 2024
		diversification rates	↑	Freeman & Pennell 2021; Diniz-Filho et al. 2023; Frateles et al. 2024
		species richness	↑	Isaac & Purvis 2004
New combination		**at species level**		
		no change	=	Flanagan et al. 2024
		at genus or higher ranks receiving the species		
		diversification rates	↑	Diniz-Filho et al. 2023
		species richness	↑	Moonlight et al. 2024

How to deal with taxonomic uncertainty

Mitigating all forms of taxonomic uncertainty requires investment in taxonomic research and training, particularly for understudied clades and areas. Such efforts are essential to ensure that the delimitation of new species and taxonomic revision are based on the most comprehensive evidence. However, even with greater resources, taxonomic uncertainty will remain prevalent. Furthermore, change is inherent to taxonomy. Consequently, scientists need tools to deal with ambiguity in species boundaries and frequent changes in species taxonomy.

Next, we describe seven metrics to quantify taxonomic uncertainty. Broadly, these metrics can be grouped into those that (i) quantify the degree of confidence in species boundaries and (ii) assess the history of taxonomic changes, shedding light on taxonomic stability and the likelihood of future changes. Multiple metrics can be combined to address specific research questions.

Confidence in species boundaries

<u>Taxonomists' assessment:</u> The degree of confidence in species boundaries can be directly evaluated by consulting taxonomists of a given biological group. These consultations can be performed through structured questionnaires directed at specialists in a group to evaluate whether a taxon requires taxonomic revision and to anticipate the potential outcomes of such revisions. This approach has been applied to assess taxonomic uncertainty in extinct vascular flora in Northern America [58], Australian squamates [27], and New World coral snakes [28]. Besides structured questionnaires, the Delphi method can also be employed to gather taxonomists' assessments. This method uses a structured communication technique to collect expert assessments and achieve consensus through a series of questionnaires interspersed with feedback [59]. Participants provide their responses anonymously and refine them through multiple iterative rounds.

However, these consultations present challenges when they focus on groups with a large number of species or a shortage of taxonomists. Another significant hurdle is reconciling divergent taxonomists' perspectives from different research groups and taxonomic schools. Despite these challenges, the assessment captures the experiences and perceptions of taxonomists, as well as specific characteristics of taxa (e.g., species complexes) that are often unavailable in the literature or difficult to quantify using other metrics.

<u>Effort in taxonomic revisions:</u> Confidence in species' boundaries can also be assessed by quantifying effort in revisionary work (e.g., synopses, revisions, monographs). The rationale is that a taxon that has been repeatedly revised without any resulting taxonomic changes likely

holds a widely accepted and well-established delimitation [60]. This effort can be quantified by assessing the frequency and timing of revisions for each taxon. Ideally, for taxa that have undergone taxonomic changes, the effort should be measured from the most recent taxonomic change onward. Nonetheless, acquiring temporal information on taxonomic change across a large number of taxa is still challenging.

<u>Thoroughness of species description:</u> The reliability of species limits can be evaluated by considering the scope of information used to delimit a taxon. The rationale is that taxa delimited using a comprehensive set of information are more robust and less likely to undergo future taxonomic changes [61–63]. The scope of information justifying species boundaries can be assessed using variables such as the number of morphological characters measured, the lines of evidence integrated to delimit the taxon, and the number and geographical coverage of examined specimens. These variables can be obtained by consulting published taxonomic works, including protologues, taxonomic revisions, and monographs. However, a major challenge of this approach is the time required to compile data and access the literature, as each species description must be individually examined. This bottleneck can be overcome by applying AI-assisted text-mining techniques. Currently, a few studies have assessed the thoroughness of species description — e.g., for birds [61], helminth parasites [62], and squamate reptiles [64]. These studies indicate that species descriptions have become increasingly detailed over time.

<u>Biological characteristics of the taxon:</u> Certain biological characteristics make some taxa more prone to have uncertain boundaries. Closely related taxa with overlapping geographical distribution and similar ecological or morphological traits pose significant challenges for delimitation [9,36]. Identifying where such taxa occur and to which clade they belong can highlight biological groups and regions where taxonomic uncertainty is most pronounced. For instance, a study using machine learning models to predict the presence of undescribed mammal species among described ones from a range of biotic and abiotic variables identified small-bodied taxa with large geographical ranges and high variability in temperature and precipitation as prime candidates for harboring hidden diversity [65]. Similarly, a study on New World coral snakes combined macroecological variables (e.g., body size, geographic range size) with taxonomists' assessment of species-splitting likelihood to quantify uncertainty in species delimitation [28]. These studies underscore the value of integrating species characteristics with advanced modelling techniques to identify and address taxonomic uncertainty.

History of taxonomic change

Congruence of species lists: Updates in species lists are inevitable and necessary. Comparing alternative species lists can highlight hotspots of taxonomic disagreement, indicating species for which boundaries remain uncertain [22,32]. For example, a study comparing 665 raptor birds across four species lists found that 212 (32%) were not consistently recorded in all lists [22], and may merit further taxonomic studies.

Digital name salience: When alternative classifications are proposed, multiple names may be simultaneously applied for the same taxon. Additionally, a time lag exists between a new taxonomic proposal and its widespread acceptance and adoption. This delay occurs because taxonomic databases are updated at varying intervals. The latest generation of digital tools provides a range of options to assess the prominence of taxonomic names [66]. These tools, such as Ngram Viewer [67], allow scientists to evaluate the current level of consensus and temporal trends in the usage of competing taxonomic hypotheses, especially for taxa that have been extensively studied.

Taxonomic changes (splitting and lumping): Temporal trends in splitting and lumping offer insights into the taxonomic history of a group, revealing how frequently species boundaries have been adjusted. Such trends are typically expressed through curves of annual rates of splitting or lumping events, as well as synonym rates [33,49,64,68,69]. The shape of these curves, when interpreted in light of the group's taxonomic history, provides means to evaluate taxonomic stability and gain insights into future changes. For instance, ascending or asymptotic curves — indicating accelerated or stable rates of splitting or lumping in recent years — may indicate taxonomic instability and potential for further changes. Conversely, descending curves could suggest that the group is approaching stability or is in a period of reduced taxonomic activity [68][69]. Finally, low or near-zero rates of taxonomic change may reflect insufficient taxonomic effort, signalling potential future changes.

Temporal trends of taxonomic changes are commonly based on the rates or accumulation of synonyms relative to all described species [e.g., 68]. Establishing such curves is relatively straightforward, as the necessary data, i.e., a list of accepted species and their associated synonyms, are available on online platforms (e.g., GBIF, World Flora Online, or World Register of Marine Species). However, these platforms lack critical temporal metadata on synonyms, specifically the year and publication in which accepted species names were synonymized. Consequently, recovering historical splitting or lumping trends requires consulting primary taxonomic literature. While this work is time-consuming, novel text-mining techniques may help to unlock textual information. So far, studies reporting historical rates of splitting and lumping are scarce and restricted to very few groups [e.g., 33,49,69].

Incorporating metrics of taxonomic uncertainty into (macro)ecological models and conservation assessments

Next, we suggest four possible ways that metrics of taxonomic uncertainty can be explicitly incorporated into biodiversity research.

(i) Bayesian and regression models: Metrics of uncertainty in species boundaries can be incorporated as priors into Bayesian statistical algorithms or generally as weight parameters in regression and classification models to describe macroecological patterns and inform conservation decisions.

(ii) Sensitivity analysis: Metrics of uncertainty in species boundaries and rates of taxonomic change can be integrated into sensitivity analyses to assess the impact of taxonomic uncertainty on biodiversity patterns and species conservation status.

(iii) Maps of biogeographical ignorance: Metrics of uncertainty in species boundaries can serve as an additional layer for constructing maps of biogeographical ignorance [70].

(iv) Time series analysis: Temporal trends in splitting and lumping can be used to identify periods of taxonomic instability, which can be accounted for in time-series analyses.

Concluding remarks

Centuries of taxonomic research, along with recent advances in analytical tools, have been pivotal in reducing taxonomic uncertainty. However, taxonomic efforts remain unevenly distributed across taxa and regions, and species boundaries in many clades are inherently ambiguous. Consequently, species should not be treated necessarily as equivalent units in biodiversity research. To address this challenge, it is essential to (i) identify taxa with uncertain limits, (ii) keep track of taxonomic changes, and (iii) explicitly incorporate metrics of taxonomic uncertainty in (macro)ecological studies and conservation assessments (see Outstanding questions). A comprehensive account of taxonomic uncertainty will not only enhance the robustness of macroecological models and conservation assessments but also provide a more accurate representation of biodiversity's complexities. This task strongly depends upon a close collaboration among ecologists, evolutionary biologists, taxonomists, and systematists.

Outstanding questions

(i) How to achieve robust estimates of taxonomic uncertainty for all groups of organisms?

(ii) How can databases such as GBIF and The Catalogue of Life provide integrated data on historical records on taxonomic change?

(iii) How to establish a communication channel between ecologists and taxonomists working across various groups and geographical regions? - This would not only improve ecological models but also give better visibility (and citation) for taxonomic works.

Acknowledgments

This manuscript is partially derived from a working group on "Biodiversity Shortfalls" held in January 2024 and sponsored by the National Institutes for Science and Technology (INCT) in Ecology, Evolution, and Biodiversity Conservation (CNPq proc. 465610/2014-5 and FAPEG proc. 201810267000023).

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LM, JS, and RJL led the writing; LF and TL searched for papers to compile Table S1; all authors contributed to the writing.

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Taxonomic Uncertainty: Causes, Consequences, and Metrics

Supplementary Material

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Table S1. Contextual usage of taxonomic uncertainty in the ecological, evolutionary, conservation, and taxonomic literature.

Contextual usage of taxonomic uncertainty	Conceptual studies	Empirical studies
Species delimitation	Hey (2001) [1]; Hey et al. (2003) [2]; Isaac et al. (2004) [3]; Balakrishnan (2005) [4]; Garnett & Christidis (2017) [5]; Freeman & Pennell (2021) [6]; Thiele et al. (2021) [7]; Stropp et al. (2022) [8]; Diniz-Filho et al. (2023) [9]; Braby et al. (2024) [10]	Isaac & Purvis (2004) [11]; Dillon et al. (2005) [12]; Morrison III et al. (2009) [13]; Jones et al. (2012) [14]; Elith et al (2013) [15]; Romero et al. (2014) [16]; Vinarski & Kramarenko (2015) [17]; Simkins et al. (2020) [18]; Knapp et a. (2021) [19]; Melville et al. (2021) [20]; Kitchener et al. (2022) [21]; Nekola & Horsák (2022) [22]; Conix et al. (2023) [23]; Flanagan et al. (2024) [24]; Frateles et al. (2024) [25]; Lopes et al. (2024) [26];
Specimen identification	Balakrishnan (2005) [4]	Cayuela et al. (2011) [27]; Molinari-Jobin et al. (2011) [28]; Ensing et al. (2012) [29], Goodwin et al. (2015) [30], Vogel Ely et al. (2017) [31]; Micael et al. (2017) [32]; Potter et al. (2018) [33]; Nekola et al. (2019) [34]; Nic Lughadha et al. (2019) [35]; Fernández-López et al. (2021) [36]; Rodrigues et al. (2022) [37]; Coca-de-la-Iglesia et al. (2024) [38];
Incongruence in species-list	Thomson et al. (2021)	Duarte et al. (2014) [39]; McClure et al. (2020) [40]; Conix et al. (2024) [23]

Data compilation for Table S1:

We searched the scientific literature for articles on taxonomic uncertainty indexed in the Web of Science (WoS). We used the keyword "taxonomic uncertainty" and refined the search in "Topic" including titles, abstracts, and keywords. We limited the search to articles published between 2000 and 2024, including WoS categories of Conservation, Ecology, Evolution, Plant Science, and Zoology. This search was conducted on November 4, 2024, returning 178 articles. We then excluded articles that focused solely on the taxonomic delimitation of a given biological group, e.g., species description or taxonomic revisions (N = 65). As the number of articles that discussed taxonomic uncertainty more broadly was rather small (N = 13), we gathered 27 more scientific articles that we had prior knowledge of and were relevant to the topic. Then, for each article (N = 40), we extracted the contextual usage of taxonomic uncertainty (species delimitation, specimen identification) and assessed the type of research (conceptual or empirical) (Table S1).

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