PLOS | BIOLOGY

FORMAL COMMENT

# Taxonomy based on science is necessary for global conservation

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Taxonomy is a scientific discipline that has provided the universal naming and classification system of biodiversity for centuries and continues effectively to accommodate new knowledge. A recent publication by Garnett and Christidis [1] expressed concerns regarding the difficulty that taxonomic changes represent for conservation efforts and proposed the establishment of a system to govern taxonomic changes. Their proposal to "restrict the freedom of taxonomic action" through governing subcommittees that would "review taxonomic papers for compliance" and their assertion that "the scientific community's failure to govern taxonomy threatens the effectiveness of global efforts to halt biodiversity loss, damages the credibility of science, and is expensive to society" are flawed in many respects. They also assert that the lack of governance of taxonomy damages conservation efforts, harms the credibility of science, and is costly to society. Despite its fairly recent release, Garnett and Christidis' proposition has already been rejected by a number of colleagues [2,3,4,5,6,7,8]. Herein, we contribute to the conversation between taxonomists and conservation biologists aiming to clarify some misunderstandings and issues in the proposition by Garnett and Christidis.

Placing governance over the science of taxonomy blurs the distinction between taxonomy and nomenclature. Garnett and Christidis's proposal is far-reaching but represents a narrow perspective of taxonomy, as utilized by conservation, and reflects an increasingly broad misunderstanding throughout biology of the scientific basis of taxonomy, formalized nomenclature, and the relationship between them. This trend may have resulted from the attenuation of instruction in taxonomic principles and, in particular, nomenclature at many universities, in part because of a shift in research priorities away from taxonomy.

Garnett and Christidis assert that an "assumption that species are fixed entities underpins every international agreement on biodiversity conservation." This assumption demonstrates a fundamental misunderstanding of taxonomy and the evolving view of what species represent. The essential features of science include documenting natural patterns and processes, developing and testing hypotheses, and refining existing ideas and descriptions of nature based on new data and insights. Taxonomy, the science of recognizing and delimiting species, adheres to these fundamental principles. Discoveries of new organisms together with advances in methodology continue unabated, leading to a constant reevaluation of the boundaries between taxonomic entities. Species (and higher taxa) comprise related organisms that may be clustered together differently depending on which sets of criteria are emphasized. Hey et al. [9] acknowledge "the inherent ambiguity of species in nature" but point out that "species-related research and conservation efforts can proceed without suffering from, and without fear of, the ambiguity of species." Through taxonomic research, our understanding of biodiversity and classifications of living organisms will continue to progress. Any system that restricts such progress runs counter to basic scientific principles, which rely on peer review and subsequent acceptance or rejection by the community, rather than third-party regulation. Thiele and Yeates [10] cautioned that such a system "could lead to authoritarianism and a stifling of innovative taxonomic viewpoints. No other hypothesis-driven field of science would accept such a straitjacket".

Taxonomy and associated nomenclature are not without problems. Even with a common set of facts, alternative interpretations of how to classify organisms can lead to differing classifications. However, the science of taxonomy is increasingly rigorous, which can improve the foundation for targeted legislative action regarding species [11,12]. Taxonomic instability does not affect all taxonomic groups equally. Garnett and Christidis provide examples from mammals and birds, which collectively represent a small fraction (<1%) of known biodiversity [13]. These groups tend to be the subject of greater levels of taxonomic "fine-tuning"—but less so in bats and rodents, groups in which basic species discoveries frequently take place—leading to disproportionately more lumping, splitting, and nomenclatural issues. In contrast, taxonomists working on most other groups of organisms, with vastly greater diversity, are focused on the basic tasks of discovering, delimiting, and describing species, rather than rearranging classifications of taxa already described. In extreme cases, taxonomic instability results in what has become known as "taxonomic vandalism" [14,15], which usually involves self-published or non–peer-reviewed taxonomic works that unnecessarily disrupt taxonomy without a solid scientific foundation. Academic freedom, needed for scientific progress, may yield undesirable results. However, over some 250 years of taxonomy, the number of authors that would be considered taxonomic vandals is very small, and further improvements to the Codes of nomenclature may reduce the harm they do without impinging on science. Scientists have long worked to achieve a universal species concept and an accompanying set of operational criteria that could serve to define species limits across most, if not all, groups of organisms; however, this task remains incomplete for a number of legitimate reasons [16,17,18,19]. Rather than promoting the establishment of a system that would arbitrarily bias community acceptance or rejections of species-level taxonomic hypotheses, many avenues of work seem more likely to improve taxonomy and the sciences that depend on it, including the following: efforts to improve our definitions of what a species is, incorporating more taxonomists into committees of conservation organizations, and providing aid in campaigns aiming to secure funding for education and research in taxonomy, among others.

## Does taxonomy hamper conservation?

Garnett and Christidis "contend that the scientific community's failure to govern taxonomy threatens the effectiveness of global efforts to halt biodiversity loss, damages the credibility of science, and is expensive to society." We disagree.

The authors claim that species-splitting provides an incentive to trophy hunters to target small populations, affects biodiversity tallies in ways that negatively impact conservation, and results in inordinately higher funding to oversplit taxonomic groups; but they provide no evidence to support these claims. If hunters target endangered species, then such societal developments should be challenged, rather than used as justification for changing the way in which science is conducted. They cite data in Evans et al. [20] to imply that different taxonomic approaches between birds and mammals could lead to disproportionate funding relative to genetic diversity, when in fact those data (Figure 6 therein) show that the number of species in a group is not correlated with funding (e.g., fishes comprise 11% of species protected under the United States Endangered Species Act but receive 61% of government funding).

How does taxonomic instability affect conservation? Morrison et al. [21] "found that changes in taxonomy do not have consistent and predictable impacts on conservation"; they also found that "splitting taxa may tend to increase protection, and name changes may have the least effect where they concern charismatic organisms." In African ungulates, Gippoliti et al. [22] describe cases where conservation management based on the Biological Species Concept overlooks evolutionarily significant units (recognized with the Phylogenetic Species Concept), with negative consequences. The splitting of legally protected taxa may result in species not being included by name in conservation legislation or regulations, thereby losing legal protection. However, well-crafted legislation includes mechanisms to extend protection despite taxonomic changes; initiatives such as Convention on International Trade in Endangered Species (CITES) and the International Union for Conservation of Nature (IUCN) specialist groups already link taxonomy and its changes with conservation [23]. Garnett and Christidis assert that taxonomic instability negatively affects conservation. However, artificial stability arising from insufficient taxonomic work can be particularly detrimental to conservation, causing mistargeting of conservation funding by misrepresentation of population size and distribution with the flow-on effects to conservation status [11,24,25].

## More bureaucracy is not the answer

The proposal by Garnett and Christidis for the International Union of Biological Sciences (IUBS) to create a process that "restrict[s] the freedom of taxonomic action" is not only flawed in terms of scientific integrity (as outlined above) but is also untenable in practice. Nomenclature regulates how names are used to communicate taxonomic hypotheses and is governed by rules (Codes) to ensure the least possible degree of ambiguity in the application of names. The relationship between taxonomy and nomenclature is illustrated in Fig 1. These Codes have been and continue to be refined into complex and intricate legal systems (the *International Code of Zoological Nomenclature* consists of 90 articles with more than 600 subsections). A system that endeavors to impose similar controls over taxon concepts would likely be vastly more complex than, and in conflict with, the Codes. It is for good reason that the major Codes explicitly avoid interfering with taxonomic freedom.

In addition, such a system raises many questions. Would it limit the kinds of characters used to assert taxonomically important distinctions, or be biased in favor of one class of characters (e.g., molecular versus morphological), when these cannot be equated across different taxa? How would new knowledge be incorporated? Would it favor one particular species concept for all organisms (and if so, which one)? Would newly discovered species automatically

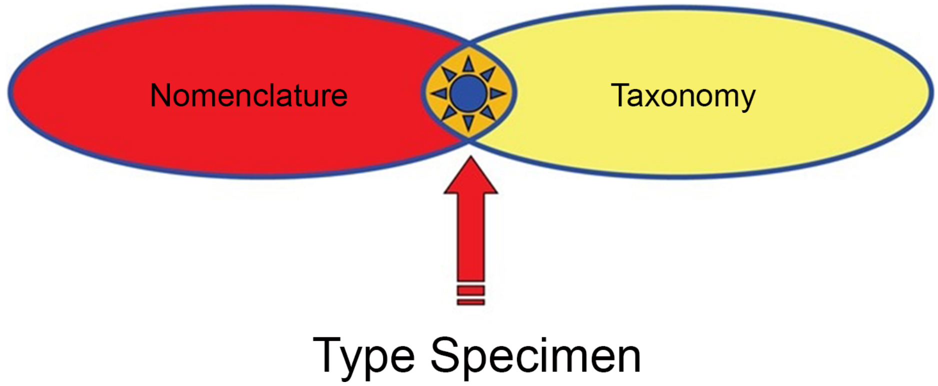


**Fig 1. Nomenclature and taxonomy intersect objectively only at the type specimen, as designated through rules established by nomenclatural codes to anchor scientific names to the biological world.**

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be acknowledged as legitimate new taxa or would they need to be approved before being considered valid? How often would the approved species lists be updated? Taking into account the vanishing taxonomic expertise, who would do this, and who would fund it? Can we afford to draw limited resources away from vital efforts to describe and catalogue biodiversity? There is already a scientific process to deal with updating taxonomy; "taxonomic revisions" carefully review all knowledge on a taxonomic group and may propose alternative classifications and relationships to accommodate new knowledge. These are peer-reviewed, published, and up to the community to accept or reject with further research. Furthermore, given that hundreds of thousands of species remain to be discovered, and that about 18,000 new species are described and named every year [26], adding layers of bureaucracy to this process would be both impractical and expensive. The governing structure proposed by Garnett and Christidis would need to include this peer review, consultation, and publication process regularly to reflect new knowledge. Therefore, it would add, and possibly duplicate, existing practice.

The products of taxonomic research underpin all biological research, but the proposal by Garnett and Christidis would regulate taxonomy primarily in the context of conservation. This has important potential ramifications because any supervisory body would implicitly have the power to direct, through its actions and judgments, the lumping or splitting of taxa according to conservation, economic significance, or political agendas to affect resource streams directed to those taxa. The process would also be vulnerable to conflicting pressures from advocacy groups in many areas, including conservation, trade, bioprospecting, and particularly politics. Even within birds, one of the groups that exemplify the problem that the proposal seeks to solve, taxonomic committees for managing taxa have had a mixed track record [27].

Certainly, there are many ways taxonomists can improve the value and impact of their research to conservation biology and other biological disciplines, such as explicitly citing the species concept employed in new taxonomic descriptions and including information on distributions, ecology, conservation status, and potential threats. Better and more modern approaches to organizing scientific names of organisms could also be expanded. In addition to overseeing the Codes of nomenclature, IUBS supports the International Committee on Bionomenclature (ICB) to promote harmony among the different Codes as nomenclature becomes increasingly digital. The development of online nomenclatural registration and indexing systems (e.g., the International Plant Names Index, ZooBank, various mycological registries, List of Prokaryotic Names with Standing in Nomenclature) offer improved access to nomenclatural information. These help avoid perpetuation of errors in the literature and thus increase stability and decrease ambiguity of taxon names.

Improvements are not limited to the Codes. Efforts such as the Catalogue of Life, with its numerous contributors and broad spectrum of users, already provide a valuable service for many taxonomic groups in asserting a reference classification and set of species concepts covering all life. This illustrates the potential for building a robust framework for a stable taxonomy to serve those initiatives that benefit from such stability, including conservation. These efforts can be improved by filling the existing gaps in taxa, training new taxonomists, improving the quality of information included for certain groups (e.g., distribution, conservation status), and by incorporating systems that track changes in both taxon names and circumscriptions through mapping of taxonomic concepts [28].

Dynamic taxonomy reflects the scientific nature and progress of the discipline. Artificially and arbitrarily constraining taxonomy through the system proposed by Garnett and Christidis would damage scientific credibility far more severely than misperceptions about the taxonomic process. “Absolute stability of taxonomic concepts—and nomenclature—would hinder scientific progress rather than promote it” [29].

## Conservation is crucial

The dynamic nature of taxonomic progress may be at odds with some aspects of conservation legislation, resulting, in part, from a mutual misunderstanding of the fundamental processes involved with both taxonomy and conservation. We advocate a solution that allows input, collaboration, and cooperation, from both conservation biologists and taxonomists, with a multidisciplinary approach towards a new framework for legislation that does not rely on the false premise that species are “fixed entities”. The development of “best practices” by both conservation biologists and taxonomists working together could avoid many unnecessary problems when using taxon names to represent vulnerable biological units in nature, thereby improving the effectiveness of their protection without impeding scientific progress.

Rather than redefine how one of the core disciplines of biological sciences is conducted, a more effective approach is to redefine how conservation legislation is enacted and implemented. The process of changing legislation requires acts of governments, which can take years to accomplish. However, fundamentally altering a system of classifying nature that has successfully endured more than two and a half centuries would have many detrimental consequences. Most of the problems for conservation resulting from the dynamic taxonomic process could be avoided entirely if future conservation legislation followed the lead of existing international conventions by explicitly referencing the specific taxon concept implied by a name, that is, by citing the original species description or a recent scholarly taxonomic treatment. Taxonomists and conservation biologists should join forces to promote effective legislative mechanisms to deal with a changing taxonomy rather than engage in infighting about the proper way to do taxonomy. This is exemplified by CITES, which adopts standard nomenclatural references [23] to define species or taxonomic groups and which periodically revises the adopted standards in response to evolving taxonomic consensus.

Many have argued that conservation legislation should focus on protecting entire ecosystems rather than rely on enumerated lists of species (e.g., [30]). While this approach requires a solid taxonomic foundation to characterize the ecosystems in question, the legislation itself would be insulated from specific changes to taxon names and concepts. In cases in which legislation includes specific taxa by name, such as harvesting or endangered species regulations, it should make the intended taxonomic concepts clear with reference to published treatments. That will allow unambiguous understanding even if the nomenclature and classification change because of taxonomic advances.

The critical importance of taxonomy and the taxonomic process in the global quest to mitigate biodiversity loss cannot be overemphasized. Without a robust taxonomic paradigm that is based on science and unconstrained by unnecessary and counterproductive bureaucracy, conservation efforts will ultimately suffer, potentially leading to devastating and irreversible impacts on global biodiversity.

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