



Framing the future for taxonomic monography: Improving recognition, support, and access

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1 INTRODUCTION

Taxonomic monographs synthesize biodiversity knowledge and document biodiversity change through recent and geological time for a particular organismal group, sometimes also incorporating cultural and place-based knowledge. They are a vehicle through which broader questions about ecological and evolutionary patterns and processes can be generated and answered (e.g., Muñoz-Rodríguez et al., 2019). Chiefly, monography represents the foundational research upon which all biological work is based (Hamilton et al., 2021). Moreover, monography can be a pathway to developing inclusive scientific practices, engaging diverse audiences in expanding and disseminating



indigenous and local knowledge and significance of place.

Apart from the scientific importance of monography, these comprehensive biodiversity treatments are also crucial for policy, conservation, human wellbeing, and the sustainable use of natural resources. Taxonomic, cultural and biodiversity data within monographs aid in the implementation of law and policy, such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Nagoya Protocol of the Convention on Biological Diversity (Buck & Hamilton, 2011), and the International Union for Conservation of Nature (IUCN) Red List (e.g., Neo et al., 2017).

While vital as a knowledge resource and tool for conservation and research, monographs are not available for many groups of organisms. This is of particular concern for organisms that are threatened with extinction, of medical or economic importance, and those organisms that have the potential to provide insight into biodiversity change over time because they are most susceptible to global change. In discussing the future of collections-based systematics, researchers have highlighted the importance of updated monographic workflows, collaborative teams, and effective ways to educate and disseminate the results of monographs to the public and scientific community (e.g., Wen et al., 2015; Grace et al., 2021). Here, we discuss how improving recognition, support, and access can lead to greater inclusivity while promoting a more active, sustainable, and collaborative outlook for monographic research.

2 RECOGNITION: APPROPRIATE VALUATION AND RESOURCING OF MONOGRAPHIC WORK

As an enterprise underpinning all biological and even some cultural research, monography offers uniquely transformative opportunities for the global collaboration of individuals from different fields and cultures (Tachibana, 2019; Lagomarsino & Frost, 2020). Nonetheless, we must acknowledge how the historic and ongoing role of colonialism and racism within our own institutions exerts significant influence on the practice of monographic work, limiting this practice to those with access to global resources, and to the detriment of the field. While most resources, including comprehensive scientific collections and historical literature, are located in the global north, the most critical need for monographs is in the global south, where species diversity is the most rich yet remains relatively underdocumented in the scientific literature when compared to the global north (Grace et al., 2021). Threats to biodiversity are higher in the global south as well, making the case for monography in these areas even more salient (Tilman et al., 2017).

Monographic research itself is not immune to the colonial, extractionist framework historically embedded in science (Haraway, 1984; Sheets-Pyenson, 1987; Fagan, 2007; Madsen-Brooks, 2009; Roy, 2018). Despite growing efforts to decolonize the natural sciences broadly (Baker et al., 2019; Eichhorn et al., 2020), this historical trend persists in specimen-based research (Das & Lowe, 2018). A majority of taxonomic studies are led by, and often only include, scientists from the global north, thus perpetuating the 'parachute science' phenomenon (Tancoigne & Ollivier, 2017; Asase et al., 2021). For example, about 40% of coral reef biodiversity publications involving fieldwork in Indonesia or the Philippines have no author from the country where the research was conducted (Stefanoudis et al., 2021). Colonial extractive

practices are enabled and upheld through the exclusion of knowledge-holders from local communities, even within nation states. These knowledge holders include, among others, “parataxonomists” (Janzen, 2004; Abadie et al., 2008) and indigenous peoples who are omitted from scientific work (either in practice or in credit) through historic exclusions from their lands or from academic workplaces. Furthermore, field-based research is fraught with challenges to diversity and inclusion, from the exclusionary impact of the cost of travel and field equipment, to the limited accessibility of field sites, to concerns about harassment and safety of at-risk marginalized or minoritized researchers in the field (e.g., Clancy et al., 2014; John & Khan, 2018; Demery & Pipkin, 2020; Giles et al., 2020; Morales et al., 2020).

The asymmetry of global south authorship may be greater in monographic work than in non-monographic taxonomic papers. For example, in the Flora of Ecuador series, only about 5% of the authors are Ecuadorian (A. Freire-Fierro, pers. obs. 2021), and in the Flora Iranica series only four of 97 contributors (1963–2005) are Iranian (Akhani, 2006). However, there are exceptions, such as the Flora of Southern Africa and the Flora of Pakistan series, which have an authorship majority from within the country of focus. Perhaps the best example of a national effort towards producing a comprehensive monograph of all plants, algae, and fungi of a country is the Flora of Brazil 2020 (BFG, 2018). This project included a team of 979 taxonomists, 854 of whom are from Brazil, constituting one of the most collaborative networks of taxonomists to date (BFG, 2021). While reflective of the strong and productive taxonomic communities in the global south (i.e., Latin America, southern and eastern Africa), members of these communities usually work with limited literature and

funding (for both travel to museums and field-based research), face language barriers, and encounter difficulties borrowing specimens from institutions in the global north.

The recent implementation of international protocols, while well-intentioned, further augments this inequality. For example, local policies derived from the Nagoya Protocol have aspects that increase complexity to the taxonomic workflow (Acosta & Pérez-González, 2019), the paperwork required, and the legal burden to ship specimens between countries (Fernández et al., 2021), thereby increasing the global taxonomic impediment (Prathapan et al., 2018). Additional inequalities may also arise through new technologies. For example, though DNA barcoding may accelerate revisionary systematics in hyperdiverse taxa (Meierotto et al., 2019), recent proposals to ban solely morphology-based revisions (Sharkey et al., 2021) would further disenfranchise workers without DNA expertise or access to these technologies (Zamani et al., 2021). Conversely, morphological treatments can lead to molecular work, further emphasizing the importance of morphological treatises (Grace et al., 2021). The progressing ease of long-distance communication and developments in DNA sequencing technology are allowing greater access and potential for collaboration. The onus is upon the monographic community of the global north to maximize collaboration with scientists in the global south and traditional knowledge-holders.

In addition to the historic and social factors that impact scientists engaged in monography, the metrics for scientific success in most institutions (e.g., citations, journal impact factors) do not reflect or incentivize behaviors supporting monography, and

more broadly, inclusive science (Ebach et al., 2011). This is reflected in the fact that journals focusing on taxonomic contributions often have low impact factors and citation indices or are excluded from these metrics altogether. High impact factor journals, on the other hand, often allow taxonomy to be referenced without appropriate citation of the protologue (or lack references when authorship is attributed), dampening the impact metrics for taxonomic research (Wägele et al., 2011; Steiner et al., 2015). This issue is exemplified by the initial decision by Clarivate to remove *Zootaxa*—a mega journal in zoological systematics which publishes the greatest number of new taxa and taxonomic/nomenclatural acts—from their Journal Citation Reports. Decisions like these threaten to undermine the very foundational research upon which all biological work is based (Hamilton et al., 2021). While it may be impractical or illogical for some works to formally cite the description of each species mentioned in a paper, Agnarsson and Kuntner (2007) recommend citing the protologue in instances where the hypothesis of the species is a crucial element of the research (e.g., in taxonomic, phylogenetic, hybridization, or population genetic studies). While metrics for academic success is a broadly reaching issue, the fact remains that taxonomic work faces specific and unique hurdles when it comes to recognition, and the current metric-driven system of success promotes the publication of large monographic work as a series of smaller works, each with less individual scientific impact but higher combined evaluation metrics.

The loss of expertise through attrition is particularly hard felt in countries that harbor significant species diversity yet rely strongly on bibliometric indices for evaluation of research success (e.g., Brazil, see Pinto et al., 2021). The recruitment and

retention of a scientific workforce dedicated to monography and biodiversity studies could increase to a level consistent with the real need for taxonomic expertise, if monographic work were recognized in a way consistent with its foundational impact and scientific importance (Gafney, 2005; Davies et al., 2021; Esposito et al., 2022).

This lack of recognition in publishing can also lead to the loss of already limited monographic expertise in academia. When taxonomists are unable to secure positions in metric-focused academic job searches, it not only impacts the current generation of taxonomists, but future generations which are neither incentivized by the status quo nor provided access to mentorship. Taxonomy may be already losing a significant degree of potential in undergraduate students who lack exposure to taxonomy during their undergraduate studies. A national survey of the publicly funded taxonomic workforce in New Zealand in 2015 found that only 16% of taxonomists are between the ages of 20–40, representing a huge risk to succession (Nelson et al., 2015). While major funding schemes (e.g., NSF PEET and PBI in the US, see de Carvalho et al., 2007; CNPq PROTAX in Brazil), have promoted greater training, it is unlikely given issues regarding the academic valuation of monographic work that trainees are later employed primarily as monographers.

We suggest two efforts that could aid in this reprioritization, aligning mentoring models with collaborative research ventures that contribute globally to a more equitable and accessible science:

(1) *Multidimensional Mentoring:*

Collaborative monographs build better opportunities for cross-generational and cross-disciplinary training. The most common model for monographic training remains an apprentice model that is not

easily scalable and does not transfer to new organisms or research programs in ways that support career mobility or flexibility. Furthermore, given the loss of taxonomic expertise in many lineages and expertise in nomenclature more broadly, the apprenticeship model is not practical (although see Partnerships for Enhancing Expertise in Taxonomy (PEET), Rodman & Cody, 2003). Rather than abandoning these practices, we must expand the goals of programs such as PEET to push for greater inclusiveness in our recruitment and retention efforts, and consider mentoring models that are highly collaborative, flexible, and more participatory, requiring a reexamination of access in the context of monography.

While broader attitudes in STEM disciplines undervalue a number of activities that do not fit within a narrow view of scientific impact, newer models for mentorship align well with monography. The concept of multidimensional mentoring stems from the recognition that a multiplicity of viewpoints and skills can be developed through a mentoring model that incorporates a diverse network of people (peers, direct supervisors, role models) and resources (books, videos, training programs) (e.g., Long et al., 2018; Davies et al., 2021), in contrast to the traditional 1:1 mentor/mentee structure. Among the many benefits of multidimensional mentoring is the potential for increased contact with mentors who share similar backgrounds or identities (Russell and Horne, 2009, Hernandez et al., 2017, O'Brien et al., 2020). This concept offers a useful model for thinking about monography, as monographic practices inherently incorporate diverse modalities and involve extended networks of users and contributors. Because monographers frequently work in institutions like science centers, natural

history museums, and botanical gardens, there are added opportunities to leverage the complexity of the network and the products involved in monography. These institutions represent the ideal venues for highlighting critical culturally-relevant issues such as the biodiversity crisis, disparities in environmental justice, and ecosystem or natural resource resilience in the face of climate change.

(2) *Contributorship and citations:*

The Contributor Roles Taxonomy (CRediT) system is a high-level contribution taxonomy, including 14 defined roles, that can be used to represent the roles typically played by contributors to scientific scholarly output, regardless of perceived size of contribution or whether the contributor plays an authorship role traditionally recognized by academic institutions (Fig. 1) (Allen et al., 2014; Brand et al., 2015). This provides a flexible system for diverse measures of impact leading to increased recognition metrics, shifting away from the conventional 'authorship' and towards the concept of 'contributorship'. The CRediT system is already being widely adopted by major publishers (e.g., eLife, Elsevier, ScholarOne, Springer), and mapping the CRediT system to monographic work would allow a pathway for our community to attribute formal academic publishing credit to a wide variety of the contributions made to monographic work (from local field guides to citizen/community scientists to collections managers), extended over the entire time frame of the research project. The roles assigned in CRediT would then be recognized through relevant literature citations for all journals containing monographic work and/or the research that depends on its conclusions. While there has been some headway by publishers to help designate this, the implementation is varied,



Figure 1. A conceptual map of various hypothetical roles in the production of a monograph. The CRediT system (Allen et al., 2014) is a framework for publications that shifts away from traditional ‘authorship’ and toward inclusive ‘contributorship’, providing a pathway for greater formal recognition of the many people involved in the production of a monograph.

and citation conventions still often only include the first author and not all co-first authors, co-corresponding authors, or co-supervisors (i.e., Teixeira da Silva, 2021).

3 SUPPORT: BUILDING INTERDISCIPLINARY RELATIONSHIPS AND SUCCESSION

Although monography is often still primarily a solo art (Bebber et al., 2013), modern monographs can involve multicultural and multi-disciplinary collaborations. Indeed, monographic work is quite amenable to the collaborative nature of modern scientific endeavors (e.g., Fišer et al., 2009; Grace et al., 2021). A stronger impetus for networking across biological research communities would enhance funding potential for monographic work, while grounding other biological research (and increasing the potential for reproducibility). Although there are many potential ways for allied fields and monographic research to be mutually supportive (e.g., Gotelli, 2004; Halme et al., 2015; Murray et al., 2017), sample collection and documentation by ecologists, field biologists or molecular biologists may not align with the needs/standards for monography (Funk et al., 2018), and integrating taxonomists into allied research can be viewed as complicating workflows (Granjou et al., 2014). To aid in aligning disparate goals, funding agencies and publishers could, for example, require that all sample collection meet international standards as part of data management and reproducibility criteria. This would increase the inclusion of taxonomic researchers as an integral part of research teams to support appropriate biodiversity documentation and ensure that any specimens were adequately deposited into publicly accessible collections. For example, Sheldon (2016) describes the

mutual benefits afforded by both taxonomists and ecologists when they “carpool” their efforts. While the goals and methods behind both disciplines are considerably different, Sheldon (2016) provides a good case study for how ecology can reciprocally benefit taxonomy and can even sometimes lead to ecologists contributing to the field of taxonomy directly.

The publication of monographs, especially those involving large numbers of taxa with global distributions, can be increased by expanding the breadth of those who collaborate with monographic work. Many allied fields (i.e., phylogenetics, anatomy and physiology, ecology, toxinology, computational biology, population genetics, comparative genetics and genomics) are not well-integrated with monographic work, with researchers in well-aligned fields often unaware of existing monographs or not fully aware of their relevance or scientific value. This lack of integration may complicate the interpretation of ecological, physiological, or biological data (Bortolus, 2008; Vink et al., 2012; Prié et al., 2012; Daglio and Dawson, 2019; Lagomarsino and Frost 2020), but also means that there are many unrealized opportunities for comparative studies. Collaborative monographs are clearly in the realm of hypothesis-testing research, as they include species delimitations (Valdecasas et al., 2014), comparative analyses, and phylogenetic inferences (e.g., Magalhães et al., 2017; Cui et al., 2019; Mandiwana-Neudani et al., 2019). Monography therefore holds the potential to create opportunities for internationally collaborative, cross-generational, and cross-disciplinary training, building international capacity fielded by a more inclusive and well-trained set of scientists addressing the biodiversity crisis. Similarly, it is crucial that administrators of institutions where taxonomic work is

conducted (i.e., universities, museums) are educated about the importance of monographs and the skills, knowledge, and time commitment needed to complete them, something that could be strengthened through advocacy by colleagues from allied fields.

Along these lines, the future of monography may necessitate a shift from the long, rigid format of monographs to a series of smaller standalone monographic papers or living monographs, sometimes referred to as e-monographs. Removing the strict requirements of what is considered a monographic work immediately makes these efforts more accessible to produce and consume. An e-monograph of the papaya family (Caricaceae) by Carvalho et al. (2015) demonstrates how this can look in practice. Works such as the World Spider Catalog (2021), AntCat (Bolton 2021), and Brazilian Flora 2020 (BFG, 2021) are also representative of how information that traditionally would be represented in taxonomic monographs can be represented in an accessible, online format that can be readily updated.

4 ACCESS: EXPANDING WHO PARTICIPATES IN AND BENEFITS FROM MONOGRAPHY

We cannot succeed at documenting Earth's biodiversity at the rate that is necessary without becoming more collaborative and inclusive in our scientific practice (Costello et al., 2013). Therefore, we must establish efficient and inclusive monographic research communities that broaden the idea of partners in monography beyond the traditional academic community, extending to the expertise of non-academic scientists (i.e., "parataxonomists" as in Janzen, 2004), community-based volunteers (e.g., Foster-Smith & Evans, 2003; MacFadden et al., 2016;

but see Abadie et al., 2008; MacKenzie et al., 2017), and traditional knowledge-holders (Huntington, 2000; Mekbib, 2007; Cheng et al., 2020).

In building monography working groups, we must integrate plans to center inclusive practices, incentivize participation, and deal with inevitable difficulties arising from disagreements, competitiveness, prejudice, or distrust. In building this guiding structure, therefore, it is critical to work with experts in collaboration, such as organizational psychologists, to ensure that practices are inclusive of all voices and partners. Early work phases should include an initial assessment and a listening phase with the communities identified as partners, so that appropriate incentives can be identified (for a non-monographic example of contact with communities from project inception, see Athayde et al., 2016). Logistically, the approach will likely vary from group to group, with some groups having more robust existing communities or resources than others. Variation will also exist on multiple biological axes such as habitat type, age of taxon (i.e., extinct or extant), conservation status, and size of organism. Socioculturally, this approach will vary by region, country, or cultural group for both the monographers, as well as all the communities involved. We have identified two existing models that align well with monographic work: the Communities of Practice (CoP) model and the Collective model (Fig. 2).

The Communities of Practice (CoP) model, influential in management and promoted in academia by the Association of Science and Technology Centers (ASTC), is an organizing structure for knowledge transfer and creation (Lave and Wenger, 1991; Wenger et al., 2002). This model supports individuals collaboratively engaged in overlapping work, providing a foundation for monographic

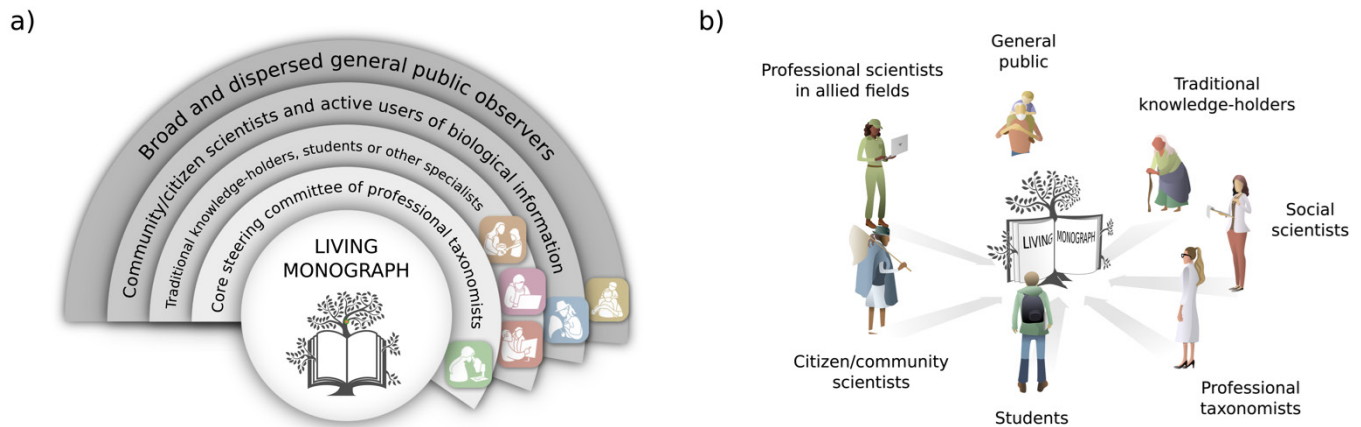


Figure 2. Models for monography working groups. a) The Communities of Practice model (Lave and Wenger, 1991; Wenger et al., 2002) supports individuals collaboratively engaged in overlapping work. Individuals with more intense direct involvement in the work of the monograph would be placed at the center, however this is fluid with individuals increasing their involvement moving toward the center and individuals disengaging with the collaborative project moving to the periphery. b) The Collective model (Lindkvist, 2005) focuses on mutual engagement, centralized decision making, and shared methodologies, and emphasizes local knowledge, free agency, and mutual recognition of differing ways of knowing. Though each individual sees the organism of focus from a different angle, they are all looking at the same biological entity, and have the opportunity to expand their perception and viewpoint as they interact with one another.

work as carried out by a community, rather than a single monographer. The monographic CoP model is imagined as a series of fluid concentric circles (Fig. 2a). Education or more intense involvement, such as a graduate degree or intensive taxonomic study outside of academia, could lead an individual from the periphery to the center, or disengagement with the collaborative project could move a central actor to the periphery. The core is a steering group of individuals continually committed to the monographic project, which is continuously being redefined and improved. By encouraging broader involvement into the monographic project, such as through a dedicated community of iNaturalist users, the CoP model provides a useful framework for funneling participation into a central information source: the living monograph. The FOSSIL project is an example of the CoP model being implemented in systematic

work, with collaborative work between paleontological amateurs, professionals, and their societies alike (MacFadden et al., 2016).

An expanded CoP model proposed by Lindkvist (2005), the Collective, may provide further support in overcoming the historical inertia of racism and settler colonialism, as the CoP model can perpetuate inherent power dynamics based on access to institutional support and privileged knowledge (a Western scientific background, Roberts, 2006). Whereas the CoP model depends on mutual engagement, centralized decision making, and shared methodologies, the Collective model emphasizes local knowledge, free agency, and mutual recognition of differing ways of knowing. Depicted visually, the Collective model is like a group of individuals gathered around a campfire, representing the organismal group/taxon itself (Fig. 2b). Each element of the collective acts independently to contribute knowledge

to the monograph; i.e., iNaturalist users sitting at one end of the campfire may contribute to distributional understanding, molecular phylogeneticists at another may contribute understanding of evolutionary relationships, and traditional knowledge-holders sitting at the circle in equal standing contribute place-based, linguistic, or ethno-biological insights. Though each actor may see the organism in the center of the circle from a different angle, they are all looking at the same biological entity, and have the opportunity to expand their perception and viewpoint as they interact with one another. With collaboration based on trust rather than control, collaborative communities are more likely to flourish in the long term than communities based on control (for a non-monographic example, see Athayde et al., 2016). An example of collaboration between scientists and the Ngāti Kuri in New Zealand can be found in Nelson et al. (2019). As a product of this collaboration, the iwi provided the specific epithet and received species authority recognition. A review by Veale et al. (2019) includes case studies in which taxonomists worked with indigenous leaders to provide meaningful names for newly described species in New Zealand. Furthermore, individuals can contribute their expertise to more than one Collective, depending on their knowledge base and how it scales to different “campfires” (i.e., organismal lineages). The main obstacle to full implementation of the Collective model in science is the fact that authorship structures are still inherently hierarchical, but the CRediT taxonomy can help identify specific contributions, and represents a feasible touchstone toward the changes proposed by Teixeira da Silva (2021). This interconnectedness of Collectives will promote greater trust and leverage relationships to provide sharing of best

practices, tools, and technologies that can enhance the rate at which monographs are produced and create a sustainable ecosystem for multidimensional mentoring across the tree of life.

5 FINAL REMARKS

Implementing steps addressing these three barriers of recognition, support and access will make monographic research more effective and inclusive. However, we recognize there are many additional facets to consider, and these vary according to the organism, taxonomic unit, and geographical focus of the monograph. By expanding our work to include communities of practice, redefining how monographic work is formally credited, and enhancing our mentorship practices and collaborations to provide greater support and access, monography will begin to be modernized. Collaborations between the global north and south may also mitigate barriers to certain resources such as molecular work, equipment, collections, and literature. Our direct scientific impacts will be further improved by incorporating place-based contexts for biodiversity awareness and knowledge, engaging stakeholders that are integral to conservation and mitigation of biodiversity loss and improving capacity to accelerate the documentation and conservation of biodiversity under extinction threat.

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