The value of herbaria to diverse collections-based research

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Herbaria should promote the broader scientific relevance of biological collections instead of focusing on collections as exclusive infrastructure for taxonomy. Globally, funding cuts to herbaria and their impact on collections management and collections-based research have been highlighted (Dalton 2003; Barker 2012). The financial problems of herbaria have largely been seen through the lens of systematics, for which under-resourced herbaria have become a widely recognised impediment (Suarez and Tsutsui 2004; Barker 2012). Plant taxonomy has suffered from the loss of taxonomic research positions in herbaria and a lack of access to adequate research grants for pure systematics (Barker et al. 2012). Herbaria are traditionally 'taxonomic institutions' sensu Barker et al. (2012), and therefore the under-funding of herbarium operations such as databasing and maintaining up to date specimen determinations has also been discussed mainly in terms of the impact on taxonomy.

From the perspective of collections management, adequate, up to date taxonomy is essential to ensuring individual specimens and their associated data can be appropriately archived, retrieved and used. The value of collections is therefore increased by taxonomic work. Taxonomy, as is often said, also fundamentally underpins biological sciences directly via species concepts (Tautz et al. 2003; Bebber et al. 2010).

Notwithstanding the important links between collections and taxonomy, collections support a wider range of biological disciplines, not only indirectly as infrastructure for nomenclature and species concepts, but directly as sources of data themselves. The critical importance of scientific collections as infrastructure for diverse fields of science led to the formation of SciColl ("Scientific Collections International"; see www.scicoll.org). Applications of data from biological collections include tracking disease and pest vectors, biological invasions and species distributions through time and space (Suarez and Tsutsui 2004; Aikio et al. 2010). Herbaria enable convenient sampling sweeps across geographically separated collections to detect species that may be useful bioindicators (e.g. species that hyperaccumulate nickel; Brooks et al. 1977), or that have antibacterial properties (Eloff 1999). A significant advantage of herbarium collections as data sources is spatial and temporal (historical) coverage that cannot be replicated by de novo field collections (Dalton 2003; Guerin et al. 2012). For this reason, they have been used to assess changes in plant size, leaf morphology and flowering phenology through time in response to global change (McGraw 2001; Gallagher et al. 2009; MacGillivray et al. 2010; Guerin et al. 2012; Leger 2013) and for continental-scale analyses of biodiversity (Crisp et al. 2001). Herbarium specimens can be used to supplement field-based studies of population genetics and to provide historical records of species occurrences prior to habitat fragmentation (Suarez and Tsutsui 2004; McCallum et al. 2013).

From a pragmatic perspective, the financial value of herbarium specimens can be seen as the cost of re-collecting them for new studies, which would undoubtedly be high. By circumventing new field costs for research, specimens serve as longterm research infrastructure, for taxonomy and therefore the nomenclatural basis of biology, but also for research on functional morphology, phenology, elemental and isotopic tissue composition, species distributions, biogeography, phylogeography, community phylogeny, phytochemistry and biogeochemistry. The real value of collections to future research is even higher as a material record of remote locations, extinct populations or past environments that cannot be replicated.

Viewing herbaria principally as collection-based research infrastructure rather than

the exclusive institutions of taxonomists immediately broadens the range of relevant scientific disciplines and can only expand the value and reach of collections. Arguing that herbaria should be funded to support taxonomy risks offsetting the cost of maintaining base operations only against the research outputs of a few taxonomists employed mainly within herbaria. Perhaps we would be better off spruiking the benefits of collections-based research infrastructure that enables diverse research outputs by internal and external researchers. Just as databasing, species concepts, nomenclature and up to date determinations enrich collections, so do genomic, chemical and phenotypic data generated from collections-based ecological research.

Herbaria and their funders should of course continue to support taxonomy and adequate funding for taxonomy is an important issue. The question is whether the core purpose of herbaria should remain to exclusively undertake taxonomic research or whether it should be to support any relevant collections-based research. Given that government support for funding in-house taxonomic research positions is low (Barker 2012), generating new interest in maintaining collections might be better achieved by highlighting their diverse benefits.

To conclude, while taxonomy is under-funded and remains critical to biology and collections-management, herbaria have more intrinsic value than as the basis for a single field. For this reason the argument for better herbarium funding should be the importance of specimen curation and diverse specimen-based research, not just the demise of support for taxonomy.

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