Systematic Entomology

*Systematic Entomology* (2016), DOI: 10.1111/syen.12180

OPINION

# On typeless species and the perils of fast taxonomy

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## Introduction

In taxonomy, a passion for precision and detail is worthwhile. The plethora of available technological tools should not prevent taxonomists from adhering to the very purpose of the activity: to produce an unequivocal reference system of names, which can be achieved only with proper procedures. Depositing type specimens and reference material in museums and public collections and producing complete detailed descriptions after analysing the greatest possible number of specimens available are healthy practices that enable taxonomy to fulfill its role in science (Costello *et al.*, 2013). The urge to achieve such goals, however, may destroy this very system if the applied methods reduce the overall quality.

Recently, Marshall & Evenhuis (2015) described a new dipteran species of the family Bombyliidae based exclusively on a photograph taken during a field trip to the Republic of South Africa. Specimens of *Marleyimyia xylocopae* Marshall & Evenhuis were not collected or dissected, and reference material has not been deposited in any public institution or museum. According to the authors, the published photographic image serves as the representation of the holotype. Indeed, the photograph is the only material carrying the name of the new species. Despite their initial defence of traditional taxonomic practices, they conclude that 'collecting specimens is highly desirable, but is indeed no longer required' (Marshall & Evenhuis, 2015, p. 118). We strongly disagree.

The aim of the present paper is to advocate that certain taxonomic practices must be maintained to ensure the role of taxonomy among the biological sciences. These practices include intense fieldwork, laboratory preparation of specimens, adequate comparison of the specimens with previously described specimens, careful description of new species (with illustrations and digital photographs), proper funding for taxonomic research and, importantly, curating and maintaining biological collections.

## Old-but-not-outdated school of taxonomy

Taxonomy is the scientific activity of recognizing and describing the basic unit of biological diversity – the species – based on observable attributes in preserved, dead specimens (Schuh & Brower, 2009). The main task of taxonomy is to generate an unequivocal, stable and reliable system of names capable of depicting biological diversity. The products of taxonomic studies (species descriptions, classifications and identification keys) are scientific hypotheses that derive evidence from multiple sources (Agnarsson & Kuntner, 2007) and are open to falsification (Carvalho *et al.*, 2005, 2008). Hence, taxa are hypotheses: a system that gradually changes as it is tested against new evidence, even at the species level.

The current taxonomic practice is well known. After fieldwork and sorting, specimens that are not associated with the known diversity according to the rules of the International Code of

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Competing interests: We have no competing interests.

Zoological Nomenclature (ICZN) may represent new species. One specimen will be chosen as the holotype. As indicated by Schuchert (1897, p. 636, his emphasis), '*all* naturalists concede that type specimens constitute the most important material in a museum of natural history ( … ) it is upon the type material that the entities of natural history and its taxonomy rest.' The ICZN rules related to the eligible examples for name-bearing types (Article 72.5) are explicit: an animal or part of the animal, the fossilized remains of an animal, a colony of animals or part of a colony, microscope slides containing one or more individual organisms, and illustrations of an animal (ICZN, 1999). The proper use of species names depends entirely on the process of verifying whether additional specimens are conspecific with the specimen with which the species name is associated.

Because falsifiability is a key feature of scientific hypotheses (Popper, 1959), biological material must be available to verify the taxonomic hypotheses. Other researchers should be free to reanalyse the material used in the species description and identify new interpretations, and possibly unrecognized details that may be consistent (or inconsistent) with the original description. Names (and species descriptions) based uniquely on a photograph or photographs do not permit subsequent alternative analyses, which is one of the main concerns regarding the new bombyliid species described by Marshall & Evenhuis (2015).

## Species descriptions based on poor primary evidence

Marshall & Evenhuis's (2015) general argument for accepting their new species *Marleyimyia xylocopae* without the benefit of dead and well-preserved type specimens is debatable. If we follow Dubois & Nemésio (2007), *Marleyimyia xylocopae* would only be a valid species in a loose interpretation of Article 16.4.2 of the ICZN (1999). The holotype of the extant species has been photographed alive and described only from indirect evidence (through a single photograph); however, it was neither collected nor deposited in a collection. Even considering the 'rapidly increasing numbers of skilled "digital collectors" who are building collections of images instead of specimens' (Marshall & Evenhuis, 2015, p. 118), there is no need to abandon commendable taxonomic practices.

This is not an issue of using photographed specimens for the sake of understanding species distribution or population fluctuations, which are all excellent additions to taxonomy. What is under scrutiny is using photographs as the very basis of the system of names. Considering that science is based strictly on evidence (Hull, 1988), what is the evidential basis for any species description? The taxonomic community would answer 'the holotype' or specimens conspecific with the holotype. Although high-resolution camera devices are currently widespread, photographs taken in the field usually provide insufficient information for a proper species description. A picture does not allow for the identification of additional features or details that may be hidden because of a specific angle and luminosity. In this sense, solving key technical issues such as conspecificity and synonymy would be hampered. Hence, to some degree, taxonomy does require dead organisms. The use of type specimens represents 'an objective base' for the Linnaean system of biological nomenclature (Winston, 1999). For careful descriptions, high-definition photographs are obviously an excellent complement, but they do not replace dissections and laboratory work.

In dipterology, male and female terminalia are often decisive in discriminating species. However, in the case of *Marleyimyia xylocopae*, information on the terminalia cannot be retrieved. Even other conspicuous or important structures of the external morphology will never be recognized. In the unique photograph of *Marleyimyia xylocopae* presented by Marshall & Evenhuis (2015), the mouthparts (which are important for the taxonomy of bombyliids) are not evident.

The massive use of photographs for taxonomic work implies the risk of misinterpreting characters (Dubois & Nemésio, 2007). Additionally, image distortions of any size are always possible. Interesting (if bizarre) precedents are the species descriptions of Joan Fontcuberta, a Spanish visual artist. Fontcuberta's work rests on a firm zoological and botanical basis. Using photomontage and other artistic techniques, he creates profoundly credible animals and plants and derives scientific names using the Linnaean binominal nomenclature system (Fontcuberta, 1988; Fontcuberta & Formiguera, 1989). Unintentional mistakes resulting from the electronic processing of photographs would be sufficient to produce a type of 21st Century bestiary that could become a nightmare for taxonomy in the future without type specimens.

As indicated by Dubois & Nemésio (2007), the only method of ensuring that animals or plants do not exist exclusively in the mind of a person is to be able to examine a specimen on which the description was based. Where do holotypes fit in this new world of 'digital taxonomy'? How can any feature be verified in a typeless species? If improperly used, a tool that could provide excellent benefits as a source of information may result in low-quality research.

A species description grounded on deficient primary evidence is analogous to a cosmological theory based on insufficient observations and poor mathematics. In a nutshell, photographs are unsatisfactory evidence, and although they may be beautiful and useful, they are not taxonomically meaningful. A photograph should not function as a name-bearing type (Timm *et al.*, 2005). The cases of new species of large vertebrates described without collecting specimens (as Jones *et al.*, 2005; Mendes Pontes *et al.*, 2006; Li *et al.*, 2015) as cited by Marshall & Evenhuis (2015) furnish unconvincing support for this option as a general practice in biology, and this practice has been criticized elsewhere (Laundry, 2005; Timm *et al.*, 2005).

The justifications for the highly contentious *Marleyimyia xylocopae* are based on particular interpretations of Articles 73.1.4 and 16.4 of the ICZN (1999). Marshall & Evenhuis (2015) consider that Article 73.1.4 'allows' for the description of a new taxon even when it is not associated with a type specimen and suggest that Article 16.4 'allows' for the description of a nonextant species without depositing a type specimen. In their view, the description of *Marleyimyia xycolopae* would adequately follow the nomenclatural rules.

However, according to Article 16.4 of the ICZN (1999), only holotypes of extant taxa should be housed in a public scientific collection. *Marleyimyia xycolopae* is obviously an extant species. Accordingly, its type specimen should be deposited in a scientific collection. The argument used by Marshall & Evenhuis (2015) that the specimens are rare and difficult to capture should be considered with extreme caution. The difficulty of collecting a particular species may be related to inaccuracies or failures in the collection methods because numerous studies have demonstrated that different field sampling techniques present distinct levels of effectiveness (e.g. Noyes, 1989; Arthurs *et al.*, 2015). Moreover, a substantial proportion of the described biological diversity is composed of rare or difficult-to-collect species. This trend ultimately represents a rather universal justification for sloppy taxonomy. Marshall & Evenhuis (2015) use Article 73.1.4 to justify a photograph as a name-bearing type. In our view, this article applies to specific prior cases in which type specimens were lost or absent and a photo or illustration was permitted to carry the name of the species. The Linnaean species based on Marcgrave and Piso's spectacular work (Boeseman, 1994) are the most classical example, and although such work was acceptable for the early stages of taxonomy, it does not provide an example for contemporary taxonomy. Moreover, this rationale does not properly apply to *Marleyimyia xycolopae*. In short, Marshall and Evenhuis published a nomen nudum because their discovery is backed only by a photograph and not by a type specimen.

Thus, adjustments and corrections to the ICZN, especially to Article 73.1.4, are necessary and urgent (Polaszek *et al.*, 2005). Enthusiasm for the idea of associating names with beautiful species of questionable delimitation based only on photographs may be highly damaging to the practice of taxonomy. A modification to the ICZN would prevent the creation of other species names based solely on illustrations or photographs without real and proper type specimens. We agree with Dubois & Nemésio (2007), who advocate for the explicit fixation and deposition of a type specimen in a public collection following any species description. Such a simple modification of the ICZN will reduce both the ambiguity of the rules and mistaken interpretations.

## Glimpse into the future

Performing scientific activities based on inexpensive, albeit time-consuming, technology; providing morphological information for publication in low-impact-factor journals that may be entrenched in hermetic text (Dececchi *et al.*, 2015); and collecting designated holotypes, still generates a system of extraordinary efficiency. The value of the entire system does not depend on the type (or cost) of the information. In addition to optical microscopy, scanning electron microscopy, nanotomography and confocal microscopy are extremely valuable in detailing an animal's ultrastructure (e.g. Alencar *et al.*, 2003; Sukontason *et al.*, 2003; Wang *et al.*, 2014). Digital photography and computational resources are also useful tools in the search for precision and detail in species descriptions. 'Digital insect collecting', therefore, adds to taxonomy as an additional source of information but cannot replace traditional procedures. Indeed, different sources of taxonomic data should aggregate in the process of generating inferences to produce a better nomenclatural system.

There are new and old methods of capturing data; however, there is no such thing as 'old' taxonomy. Whenever vouchers are not maintained, the databases accumulate mistakes and errors. This observation leads to a discussion of the crucial role of museums and collections, even in molecular-based taxonomy. Marshall & Evenhuis's (2015) statement that 'collecting specimens is highly desirable, but is indeed no longer required' may have the equivalent effect of dropping an atomic bomb on natural history museums. In a time when traditional institutions are being closed or strongly impacted by unilateral government funding cuts, statements such as this might be (un)intentionally misinterpreted in a dangerous way by funding agencies and governmental decision makers. Over the last three decades, natural history museums all over the world have witnessed serious staff cuts, budget cuts and other financial difficulties. This development appears to be largely related to the inaccurate view by decision-makers that curatorial and careful taxonomic work is not mandatory for cataloguing biodiversity (Suarez & Tsutsui, 2003; Kemp, 2015), which is simply wrong. Natural history museums are the official storage depots for all information on biodiversity (Kemp, 2015). Biological collections represent the 'museum's "soul" and *raison d'être*' (Alberch, 1993). Such museums have begun to expand their functions to include genetic databases, other molecular and DNA-based data (Giribet, 2015), and digital image databanks (Marshall, 2008; Marshall & Evenhuis, 2015). In addition, we must consider that a significant proportion of the unknown biodiversity awaiting description is already deposited on shelves of museum collections (Fontaine *et al.*, 2012).

Although digitalization and web-based technology present steps towards the modernization of taxonomy (Godfray, 2002), such 'digital' taxonomy should not herald an abandonment of physical collections. Hence, fieldwork remains extremely important. As Marshall & Evenhuis (2015) correctly state, collecting potential type specimens has been increasingly challenged because of national and regional laws and restrictions, and complications in the transportation of specimens. This reality should be considered an opportunity for international cooperation. The community of dipterists throughout the world (employed, retired and independent systematists) provides a clear example of the intense collaboration and networking that occurs in pursuit of species-level taxonomy (e.g. Brown *et al.*, 2009, 2010; Borkent & Brown, 2015; Lamas *et al.*, 2015).

## Final remarks

A substantial amount of work lies ahead for present and future generations of taxonomists. In the case of Diptera, Evenhuis *et al.* (2008) indicate that there are approximately 153 000 described species. Scheffers *et al.* (2012) estimate a total of 240 000 species of flies in the world (which means that there are 90 000 species yet to be discovered and described), whereas

 

Brown (2005) predicts that there may be ten undescribed species for each known species. The average lag time between discovering/collecting a new species and its description for certain groups is estimated to be 21 years (Fontaine *et al.*, 2012; Kemp, 2015). This information is shocking based on our expectations of identifying the actual diversity of life on Earth, particularly when considering that the process of describing insect species is relatively more rapid. Thus, methods must be developed to accelerate the identification of new species; however, the intention of taxonomists should be to advance our knowledge of biodiversity while retaining the prerequisites for proper species description and identification. Eliminating regular taxonomic procedures, including collecting, publishing in peer-reviewed journals and depositing types in museums, may result in bad taxonomy. Neither academic researchers nor nonspecialists would benefit from a profusion of manuscripts presenting poor species descriptions.

The effect of a more rapid taxonomy produced by excellent specialists on a single dipteran genus may not be so severe. Stephen A. Marshall and Neal L. Evenhuis are taxonomists who have provided pivotal contributions to dipterology. The problem is broader in scope. As a regular process, error cascades have the potential to destroy the accuracy and reliability of taxonomy. Contributions to a better taxonomy are welcome, and there is a need to increase the quality and accessibility of information to a broader public (Godfray, 2002). Typeless species and fast taxonomy are dispensable. Every scientific challenge related to biodiversity – from conservation issues to the comprehension of evolutionary history – demands a more precise taxonomy and not more species names (Bortolus, 2008). Hence, this appears to be an appropriate moment to reflect on the purposes of taxonomy and reaffirm its values (Wharton, 1959; Wheeler *et al.*, 2012, 2014; Giribet, 2015; Kemp, 2015; Lee & Palci, 2015; Wanninger, 2015).

Wheeler (2014) wisely noted that identifying species, conducting cladistic analyses and retrieving information are important components of taxonomy because the final aim of taxonomy is to provide a comprehensive overview of the origins and diversification of life using a phylogenetic scheme based on species descriptions. Such an understanding requires the training of people who can properly interpret characters and modernize data collections to improve storage and public access. This issue is related to the importance of maintaining programs of taxonomic research (Lamas *et al.*, 2015). The notion that taxonomy will be strengthened through faster description methods, simplification or eliminating steps (collecting and dissection) is highly mistaken. Technology should add to the process of constructing taxonomic inferences, and it should complement and not replace successful procedures that are outdated only in a narrow view.

## Acknowledgements

The authors would like to thank Marcelo R. Carvalho (USP) for providing comments and Patricia Kiss (UNICAMP) for furnishing references on Joan Fontcuberta. We also thank CAPES for providing a fellowship (B.K.), CNPq for providing grants (#455858/2014-4, C.M.D.S.; # 563256/2010-9, C.J.E.L.) and fellowships (#309240/2013-1, D.S.A.; #304713/2011-2, C.J.B.C.; #304935/2013-1, C.J.E.L.; #302584/2012-9, C.A.M.P.; #300382/2010-3, M.S.C.) and FAPESP for providing grants (#2014/05793-1, D.A.F.; #2010/52314-0, C.J.E.L.; #2013/16524-9, R.L.F.).

C.M.D.S, C.J.E.L. and D.S.A. took the lead in coordinating, discussing, synthesizing, and writing the manuscript. All of the authors provided expertise to the project and contributed significantly to the ideas presented here, as well as to the drafting and revision of the paper.

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Accepted 3 March 2016

 