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Does counting species count as taxonomy? On misrepresenting systematics, yet again

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Abstract

Recent commentary by Costello and collaborators on the current state of the global taxonomic enterprise attempts to demonstrate that taxonomy is not in decline as feared by taxonomists, but rather is increasing by virtue of the rate at which new species are formally named. Having supported their views with data that clearly indicate as much, Costello et al. make recommendations to increase the rate of new species descriptions even more. However, their views appear to rely on the perception of species as static and numerically if not historically equivalent entities whose value lie in their roles as "metrics". As such, their one-dimensional portrayal of the discipline, as concerned solely with the creation of new species names, fails to take into account both the conceptual and epistemological foundations of systematics. We refute the end-user view that taxonomy is on the rise simply because more new species are being described compared with earlier decades, and that, by implication, taxonomic practice is a formality whose pace can be streamlined without considerable resources, intellectual or otherwise. Rather, we defend the opposite viewpoint that *professional* taxonomy is in decline relative to the immediacy of the extinction crisis, and that this decline threatens not just the empirical science of phylogenetic systematics, but also the foundations of comparative biology on which other fields rely. The allocation of space in top-ranked journals to propagate views such as those of Costello et al. lends superficial credence to the unsupportive mindset of many of those in charge of the institutional fate of taxonomy. We emphasize that taxonomy and the description of new species are dependent upon, and only make sense in light of, empirically based *classifications* that reflect evolutionary history; homology assessments are at the centre of these endeavours, such that the biological sciences cannot afford to have professional taxonomists sacrifice the comparative and historical depth of their hypotheses in order to accelerate new species descriptions.

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It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't so. (Mark Twain)

...our task is not to name species but to know them ... (Ball, 1980, p. 235)

Introduction

In a series of recent papers, the latest of which just published in *Science*, Costello et al. (2013) address aspects of the current state of global taxonomy, painting a more positive picture than previous estimates concerning rates of species extinction versus discovery (cf. Hoffmann et al., 2010; Mora et al., 2011). Costello et al. also provide guidelines to expedite the discovery process, some quite reasonable, but many of which have been proposed in more detail or advocated in a more relevant context elsewhere (e.g. Agnarsson and Kuntner, 2007; Wheeler et al., 2012). At the core of their argument is the notion that species names are at once the primary end-products of the taxonomic endeavour and the all-important commodity for conservation, placing the pace of taxonomic progress at the centre of the biodiversity crisis. Their main concern is whether we can name Earth's species before they go extinct, to which they respond in the affirmative. Reinforcing their view, Costello et al. (2013) present a series of graphs indicating that the number of new species descriptions, perhaps contrary to common perception, is on the rise. Their bottom line is that this statistic is in itself evidence that taxonomy is somehow on the right path; that it is, in short, a healthy enterprise, albeit one that needs reorganization and increased or redirected effort—bold conclusions given that none of the contributing authors is a taxonomist by trade.

Consider, for example, *why* they think species are even worth describing at all:

> Species provide the most practical metric for distinguishing habitats and tracking progress in exploring Earth's biodiversity [...] Once species are described, more detailed studies can look at populations and genetic and biochemical diversity. Species inventories draw attention to where taxonomic effort will discover most new species, including resources and ecosystems. Having a standard list of species names is essential for quality assurance in biological and ecosystem sciences and natural resource management. Another reason to discover species is to improve understanding of which and how many species will become extinct. (p. 413)

Valiant reasons no doubt, but nowhere are evolution, phylogeny, biogeography, or comparative biology mentioned. It is as if the naming and description of new species are important inasmuch as they support more general applications in other areas of biological science—a viewpoint typical of end-users of taxonomy, but far less common among practising systematists and evolutionary biologists.

While we do not dispute Costello et al.'s fundamental conclusion concerning the greater pace of new species descriptions, a trend expounded by other authors (Joppa et al., 2011) including professional taxonomists (Tancoigne and Dubois, 2013), we do take issue with two tenets central to their argument: (i) that the increasing rate of new species descriptions is at least partly indicative of a healthy global taxonomic enterprise; and (ii) that taxonomy is primarily concerned with describing new species.

Who speaks for taxonomists?

Despite their yearning for taxonomic results, Costello et al. (2013) fundamentally misrepresent taxonomists:

> If we narrowly define taxonomists as the *people describing species new to science*, then—contrary, for example, to statements made to a UK House of Lords committee [...] —recent decades have had two to three times as many taxonomists as before the 1960s. (p. 413; emphasis added)

This is akin to defining racing car drivers as those who own a car. Their uncritical view, also held by other end-users of taxonomy (e.g. Godfray, 2007; Miller, 2007; Joppa et al., 2011; Scheffers et al., 2012), is depreciative considering the time and resources needed to properly educate, employ, and support taxonomic specialists (de Carvalho and Ebach, 2010). Unintentionally, no doubt, Costello et al. undermine professional taxonomy in museums, institutes, and universities where serious collection-based research is undertaken. Far beyond discovering and naming new species, taxonomy is driven by evolutionary hypotheses that generate predictive classifications and improve our understanding of biotic diversity through meticulous systematic revisions and homology assessments. Conversely, non-specialists may provide species identifications and generate legitimate new species descriptions, and thereby placate growing demand, but the business of "alpha-taxonomy", while critical to capturing the magnitude of life's diversity, is by itself insufficient to build an information system from which to comprehend evolution. Surely what is sauce for the goose is sauce for the gander; would Costello et al. likewise endorse a deprofessionalizing of ecology simply because amateurs can see that cows eat grass and cats eat mice?

Although Costello et al.'s estimate of the increasing number of new species-describers is beyond dispute, it is quite irrelevant to their conclusion. Taxonomic practice was changed fundamentally with the establishment of the phylogenetic paradigm in the early 1970s as

detailed comparative analyses of relationships—the "general reference system" of Hennig (1966)—became an integral part of taxonomists' workload, adding significantly to the academic burden carried by systematic specialists. Although the number of new species-describers has increased, phylogenetic analysis, enabling the identification of monophyletic groups (those with historical reality), presented a steep empirical challenge to reveal the poorly known complexity of biological relationships, hardly a straightforward descriptive task.

Costello et al. (2013), however, still believe that the primary goal should be to fill the ranks with more new species-describers ("taxonomists"):

> The bottleneck in making progress […] is having enough people involved and their activities coordinated, and historic knowledge captured in open-access online databases. (p. 415)

So maybe not enough warm bodies are involved in taxonomy after all. But we see little value in proposing that more species descriptions be generated in the short term without simultaneously discussing the long-term nurturing of the expertise necessary to provide the intellectual context for interpreting taxonomic data.

It is widely held, including by Costello et al., that part of the problem saturating taxonomy and systematics resides in a lack of coordination and information distribution (e.g. Maddison et al., 2012). Comments and rebuttals on ostensible technological constraints have appeared elsewhere (e.g. Crisci, 2006; de Carvalho et al., 2008; Boero, 2010; Scotland and Wood, 2012; Wheeler et al., 2012; Sluys, 2013), but technical initiatives, as innovative and useful as they may be, will not change the immediate fate of systematics and collections-based research. Moreover, in a similar vein:

> These [GBIF, MorphoBank, uBio, etc.] initiatives (all of them about applying new technology to existing data rather than generating any more new data) mopped up a not inconsiderable fraction of the available money during the Biodiversity Decade [the 1990s]. Despite their promises of eventually making a taxonomist's life easier, at the moment they only represent added IT chores for the many taxonomists working on a shoestring trying to publish their research. Promoters of these initiatives regularly speak of 'getting the taxonomic community to buy into' their projects, an expression which, translated, often means that the promoters themselves have no funds to spare and the taxonomist is expected to act as an unpaid data entry secretary. (Flowers, 2007, p. 5).

These prescient words are more often repeated in the lonely corridors of collections than read in publications on the alleged shortcomings of taxonomy. There seems to have been no crippling lack of funds to undertake serious, professional taxonomy, but where that "biodiversity money" went is another matter entirely (Boero, 2010). And even when significant funds were made available in one watershed programme involving the proper training of taxonomists (the National Science Foundation's Partnership for Enhancing Expertise in Taxonomy, NSF-PEET), competitive academic jobs for the most part failed to become a reality, and long-term, continuous prospects for funding did not materialize (Agnarsson and Kuntner, 2007). Overlooking such initiatives, it seems that Costello et al. have chosen to evaluate the success of taxonomy not on the merits or the fulfilment of its mission, but on the basis of whether its most tangible and easily comprehended products have met their immediate needs.

Synonymy and the real taxonomic enterprise—classification

Costello et al.'s (2013) focus on the primacy of new species descriptions also underappreciates the extent to which deficient species descriptions hinder taxonomic progress by generating synonyms, and the long-term accrual of additional effort and resources ultimately required to remedy this. Eliminating synonyms involves considerably more scholarship and comparative research by specialists, and represents a far more formidable and laborious task. Furthermore, the proliferation of inadequate descriptions will divert the effort of systematists from innovative research, including their own descriptions of new species. One reviewer of this paper even mentioned that he refuses to review new species descriptions in groups that have not been taxonomically revised.

According to Costello et al., a significant portion of available species names in some taxonomic groups (perhaps exceeding 90%) may represent junior synonyms, which they believe strengthens their argument that the number of existing species may be grossly overestimated. While we agree that there are many invalid names out there (although how they obtained their estimate is unclear), there was no attempt to calibrate the rate of description or synonymy, or to reconcile these rates with biological reality. There are, on the other hand, a great number of available names that need to be *resurrected*, especially within unrevised groups. For example, the popular South American pirarucu, one of the largest known freshwater fishes, which has been considered monospecific (*Arapaima gigas*) since the revision of Günther (1868), was recently verified as being composed of at least four species, all with names available in the literature (Stewart, 2013). The South American catfish *Rhamdia quelen* was considered the senior synonym of nearly 50 available names (Silfvergrip, 1996), but more detailed taxonomic investigations are reversing this situation by recognizing several geographically restricted species to which many available names in the literature will need

to be applied (Anza, 2006). This undoubtedly demonstrates that understanding the total number of valid species requires a much more complex formulation than Costello et al. suggest (not to mention other variables that require consideration); their compilation is tentative at best.

Costello et al. (2013) acknowledge the potential setback of synonymy, but make no concession for the fact that non-specialists usually lack the training necessary to formulate and test scientifically meaningful classifications. Describing species at an increased pace will not, alone, ameliorate the biodiversity crisis nor alleviate the taxonomic impediment; but understanding *taxa* and their historical relationships—through *classification*—might achieve both. Professional taxonomists provide the empirical basis not only for biodiversity inventories, but also for understanding biological evolution and historical geographical relationships; the theory of plate tectonics, for example, established its early momentum based to a large extent on data addressing the evolutionary relationships of species. Costello et al., however, view species as simplistic, quantifiable entities whose histories are irrelevant, thus failing to comprehend that species are neither static nor somehow equivalent in a historical or numerical sense.

The decline of professional expertise in taxonomy, especially in more developed nations (Gropp, 2004; Wheeler, 2004; Schmidly, 2005; Agnarsson and Kuntner, 2007; Frost, 2013), where hiring at major universities is to a large extent determined by overhead allowances from big grants, is an inescapable reality. If taxonomists were more in demand, and could procure necessary overhead, they would be kept on staff. Hence the frequent reinventing of institutional missions and cutbacks in scientific staff, especially collection-oriented specialists, in natural history museums (for a recent and alarming example see Morell, 2012).

Costello et al. (2013) demonstrate that more authors are involved in naming species. This is easy to comprehend with present-day trends for increasing multiauthorship and collaborative work, but the fact that this is happening while professional positions are in decline only makes the erosion of taxonomy more evident; positions for full-time, professional taxonomists are diminishing in the UK, USA, Australia, and elsewhere (e.g. Hopkins and Freckleton, 2002; Drew, 2011; Sluys, 2013). The number of active taxonomists is not equivalent to simply counting those who have described a new species; it is important to discriminate supported, full-time taxonomists from "surviving taxonomists". The former are becoming rarer, whereas the latter include a substantial part of the taxonomy workforce. These taxonomists more or less regularly publish taxonomic papers (species discovery and revisions), but divert part of their professional time to research programmes that are not truly taxonomic (in ecology, genetics, etc.). Even though this pluralistic trend represents a natural and desirable progression for some taxonomists, others publish in these fields and collaborate on diversified research projects as a defence against unfavourable administrative evaluations.

When non-specialists name a species, it is unlikely that the quality of their work will match a revision published by a taxon specialist, even though the quality of their taxonomic hypotheses may fluctuate significantly depending on the group under study (a disconcerting example is provided by Kaiser et al., 2013). Costello et al., however, have a different perspective:

> Already, half of all new species of European animals, including the less charismatic species, are being described by amateurs […] The increasing accessibility of information through the Internet and mobile telephones is already providing new opportunities to aid species identification. (p. 415)

Involving the public at large in the taxonomic enterprise may indeed be productive (see also Fontaine et al., 2012a; Wheeler et al., 2012), but contributes no more to taxonomic progress in the broad sense than identifying trees or butterflies through a mobile phone app. Although we fully realize that there are competent self-taught taxonomists who make genuine contributions, quality and progress in taxonomy will continue to depend on long-term education enriched with a rigorous theoretical, philosophical and epistemological underpinning. Moreover, non-professionals, by definition, are not "professionally" obligated to train students, and therefore are exempt from the much needed role of educating new generations of taxonomists. Costello et al.'s solution to the biodiversity crisis, much like early suggestions to enlist parataxonomists to identify morphospecies without incentivized training (e.g. Oliver and Beattie, 1996; see Goldstein, 1997), hinges on the goodwill and self-sacrifice of these (generally) well intentioned but uninvested folks. Just as Golding and Timberlake (2003) urged taxonomists to "bridge the gap" between taxonomists and ecologists by focusing their efforts on groups of organisms more immediately relevant (to ecologists), Costello et al. utterly fail to grasp the relevance of taxonomy in terms of its higher purpose for comparative biology.

Mastering the minutiae of morphological and taxonomic description, elucidating historical relationships (phylogenetic, biogeographic), and producing predictive classifications are tasks that require time, specific training, and institutional commitment, but that ultimately will contribute much more to our understanding of the biota (Grimaldi and Engel, 2007; Ebach et al., 2011; Sluys, 2013). Alas, Costello et al. (2013) fail to realize this:

> If each species is considered a book of knowledge for which we lack a title page, then we need to catalog 0.5 to 6.5 million more books. Ten times more books are already in the U.S. Library of Congress, and each book may have taken as much or more effort to produce as one species description. But many people write books, not just those who are employed to do so. (p. 415)

In other words, describing all species may be within reach if we simply apply ourselves enough and recruit multitudes of eager non-professionals. But the comparison between "cataloguing" (classifying) species with cataloguing books in a library lays bare Costello et al.'s lack of appreciation for systematic classification—the position of a species or other taxon in a biological hierarchy reflects its relationships, that is, it represents a scientific hypothesis; homology assessment and predictive classifications are therefore *necessary correlates* to the description of species. Whereas the goal of such a classification is to present an arrangement that reflects history accurately and efficiently, the arrangement of books in a library, on the other hand, reflects an artificial system devised by librarians to streamline the storage and retrieval of books. Hence Costello et al.'s priorities end with getting all of those books written, all of those species described, sidestepping their historical biology and capacity to illuminate history. Fair enough for end-users of taxonomic data, keen to re-engineer these data without full regard for their reliability or longevity (Prendini, 2005; Wheeler, 2009), but less so for systematists and the science of comparative biology.

More end-user misconceptions

Costello et al. reinforce why taxonomic specialists see repeated references to the "taxonomic impediment"—the purported inadequacy of the present taxonomic enterprise to deal with the biodiversity crisis—as a spectre, an academic bully perennially employed to belittle the professional taxonomic/systematic venture. Their views are symptomatic of non-taxonomists who create impressive but oversimplified graphs to assess the "health" of taxonomy while simultaneously misinterpreting its complexity and purpose (e.g. Joppa et al., 2011). Rather than worry whether we "can name Earth's species before they go extinct", we should be more concerned with our ability to do scholarly comparative research into their history before professional taxonomists go extinct. In contrast, though, we are told:

> Taxonomists are not in danger of extinction. They are increasing in numbers […] We believe that with modestly increased effort in taxonomy and conservation, most species could be discovered and protected from extinction. (Costello et al., 2013, p. 416)

But the "modestly increased effort" amounts to no trivial task:

> A full-time taxonomist might examine a few thousand specimens, and describe a hundred species, a year. Thus, the equivalent of 500 taxonomists over 10 years is needed to describe this backlog of undescribed species in collections, and this effort needs to be complemented by new field expeditions. (p. 416)

Collecting specimens in the field, identifying material (both newly and previously collected; see Fontaine et al., 2012b), curating material in collections, conducting collections-based research at institutions worldwide, performing comparative analyses, sorting out synonymies, etc., are endeavors far more complicated and time-consuming than the above nonchalant passage suggests. Costello et al., however, seem remotely aware of this, as elsewhere:

> [taxonomists] will become more in demand as more species mean more diagnostic challenges to discriminate species (p. 416).

Indeed! More specimens collected, and more groups examined and curated, add to the growing workload already facing systematists, especially given the diversity of modern tools available to gather relevant data (Padial et al., 2010; Goldstein and DeSalle, 2011). Consider, for example, the case of herpetological specialists working in Madagascar (Glaw et al., 2012). The discovery through modern molecular techniques of cryptic diversity underlying morphologically variable chameleon species served only to amplify a systematic revision already under way. Such discoveries, while welcome, add significantly to the workload, as a greater effort is required to reconcile morphological variation, diagnoses, new descriptions, and identification keys with molecular data (if so desired). Moreover, the task of actually naming the newly discovered species is often delayed, or even becomes a secondary priority, once molecular analyses are finalized and evolutionary implications published (for further herpetological examples see Fouquet et al., 2007; Vieites et al., 2009). In other words, the more we probe the more we find, and the more complex the job becomes (astoundingly, the opposite conclusion was reached by Joppa et al., 2011). This more conceptually significant challenge renders the "quick" description of untold new species impractical and illusory, and therefore excluded from contributing substantially to a systematic paradigm that aims to discover historically meaningful patterns.

Taxonomy dismissal

Why concern ourselves with the misconceptions of Costello et al. (2013), or with the dissatisfaction of

end-users who may lack a deeper appreciation of the legitimate systematic endeavor? On an intellectual landscape where lack of science education has reached a near pinnacle, and where few members of the lay public distinguish different branches of biology, it is unsettling that professional biologists of any stripe view species descriptions as the final (and only) frontier of taxonomy. One would hope informed readers would simply ignore such naive commentary. Unfortunately, however, papers such as Costello et al. (2013) may contribute to the corporate, bottom-line mentality of mover-and-shaker administrators who see systematics as an outdated branch of Victorian natural history, or one that simply can't bring in the big bucks. While at the mercy of bioinformaticians, phylogeographers, ecologists, and others who have recruited "biodiversity" as their own favorite child, the field of systematics, on which the interpretation of biodiversity ultimately depends, is at a crossroads and stands a smaller chance of accruing institutional support and recognition. This novella is currently playing out in several American, European, and Australian institutions, in which collections-based research and taxonomic science were once mainstays. Even more astonishing is that editors at *Science*, a journal with strict publication criteria and extensive penetration, can find it appropriate to print a four-page paper on an important field of science written by non-practitioners without providing a forum for discussion or informed peer review.

Contrary to the thesis of Costello et al. (2013), the negative anti-intellectual trends regarding support for taxonomy that are presently sweeping developed nations may find their way into the policies of institutions in countries where this science still thrives. At present that is our perception of the current state of events in Brazil, for example, where the *h*-index and journal impact factors are being used as criteria by federal institutions to evaluate taxonomists without regard for the qualitatively unique criteria on which revisionary taxonomic work realizes its merit. Employing these criteria *per se* is not the problem, but *how* they are employed clearly is—comparisons must be done *within* an area of research, not among disciplines with completely different profiles (e.g. ecology versus taxonomy) as is currently the practice; nor can they be employed in a non-contextual, absolute manner. Not to mention that these metrics have little relevance to taxonomy anyway (e.g. Krell, 2000; Ellis, 2002; see especially Boero, 2010; Valdecasas, 2011 for illuminating comments on this topic). Impact factors are also wielded as means of devaluing traditional museum publications, monographs, and other journals that represent important outlets for publication in taxonomy—as more "applied" journals gradually increase their impact factors, less applied, taxonomy-friendly journals that increase their impact factors at a slower rate become demoted to lower echelons of ranking lists. As an example, we highlight the Brazilian federal Qualis journal-ranking system, wherein few, if any, taxonomy-friendly journals make the top 25% (the percentile given an all-important A grade) among those classified in the area "biodiversity". Taxonomy in Brazil, meanwhile, is a burgeoning field that represents a significant portion of the country's science, not to mention the region's relevance to the global taxonomic endeavor—according to the Thomson Reuters (formerly ISI) Web of Science database, plant and animal sciences in Brazil represent a significant amount of the total global productivity in these fields, and close to twice that of ecology and environmental sciences (Tabarelli and Santos, 2011, 2012). What started as a slow trickle might eventually turn into a flood if current scientometric trends imported from applied areas are not reversed or critically reconsidered:

> the process of *taxonomy dismissal* is still on course in many countries that, unfortunately, are not learning from the mistakes of the USA and are destroying their expertise in taxonomy, to follow a false modernity that is only linked to the power of some scientific lobby. The disgraces of taxonomy, however, are not limited to the abuse of the Impact Factor in ranking disciplines and scientists. (Boero, 2010, pp. 219–220, emphasis added)

As Costello et al. (2013) note in their opening paragraph, taxonomy underlies much, if not all, of biology. Why then do end-users fail to demonstrate a more significant comprehension or appraisal of this science, either conceptually or epistemologically? Without a strong institutional infrastructure, and professional, dedicated comparative systematists producing hypotheses on the identity and relationships of taxa and the areas they inhabit, "applied" biology would be as baseless as a cork floating in the ocean, and the similarity among species, as well as their uniqueness, would be uninterpretable. Perhaps it is time, after decades of repeated argument (e.g. Wilson, 1971), for end-users to come to grips with systematic science for what it is—an independent, theoretically grounded undertaking whose improvement cannot be pursued at the expense of its conceptual base, and certainly not by sacrificing the historical context of its hypotheses for the sake of expediting the description of new species.

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