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Taxonomy in a Changing World: Seeking Solutions for a Science in Crisis

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One of the fundamental quests of biology is learning what organisms inhabit the earth. To date approximately 2 million species have been described, with realistic estimates of actual diversity ranging from 4 to 12 million (Stork, 1997; Reaka-Kudla et al., 1997). But while species are disappearing at an ever increasing rate (Pimm and Raven, 2000; Thomas et al., 2004), species discovery and description—taxonomy—is facing a crisis (Wilson, 2004; Wheeler, 2004). Overcoming this "taxonomic impediment" (Rodman and Cody, 2003) is the primary goal of the ambitious and ongoing NSF PEET (Partnerships for Enhancing Expertise in Taxonomy) initiative (NSF, 1994), which has enjoyed much success in training a new generation of taxonomists (Rodman and Cody, 2003). To help estimate the impact of the NSF-PEET initiative and the status of taxonomy, we surveyed the trainees from the 1995 and 1997 NSF-PEET cohorts. PEET meetings have optimistically labeled the program as the *renaissance* of taxonomy (see also Wheeler, 2004). But as many PEET alumni (peetsters) are experiencing, taxonomic expertise is rarely required, or even relevant, when it comes to securing a job, especially in academia. Furthermore, most top-ranking evolutionary journals do not consider taxonomic revisions, and only allow species descriptions in exceptional cases of certain high-profile fossils and mammals (e.g., Jones et al., 2005; Gess et al., 2006). Further, some lower ranking journals reject taxonomic descriptions unless in a paper on a broader subject (e.g., the *Journal of Zoological Systematics and Evolutionary Research*; see author guidelines at http://www.blackwellpublishing.com/journals/jzs). Journals focusing on taxonomy typically have low measured impact, even the new and vibrant, rapid and interactive *Zootaxa*, which is enjoying an extraordinary and unprecedented growth among scientific journals and can be characterized as a "mega-journal" (Zhang, 2006; unofficial IF 2005 = 0.45). Taxonomic descriptions are—not necessarily by fact (see below), but by convention—low-impact scientific publications, barring those of newly discovered bird species, large mammals, or certain fossils.

Here we argue that an easily corrected mismeasure of the scientific impact of taxonomy—a convention not to cite taxonomic hypotheses—seriously impedes its rise as a discipline (see also Werner, 2006). We discuss other problems facing taxonomy and taxonomists and the changes and developments occurring in this field and how they can help revive the discipline. Based on our survey (see below), we also discuss job opportunities and funding priorities in taxonomy, offer comments on the NSF-PEET agenda, and provide career oriented recommendations to the new generation of taxonomists.

Taxonomy as a Fundamental Science in Crisis

Taxonomy is often considered to have little intellectual content and is seen as a descriptive science whose primary function is identification. Such a discipline could readily be replaced, e.g., by DNA barcodes. This view is mistaken (e.g., Ebach and Holdrege, 2005). Taxonomic circumscriptions are scientific hypotheses, ideally drawing from evidence from multiple sources (Dayrat, 2005; Will et al., 2005), that not only provide the most basic currency for our communications and a base for comparison across species but also make far-reaching testable predictions (Lipscomb et al., 2003; Wheeler, 2004; Will and Rubinoff, 2004). Whether populations A and B are *hypothesized* (via taxonomic descriptions) to be conspecific or heterospecific makes entirely different predictions about the properties and cohesion of A and B. If conspecific, some level of gene flow is expected, breeding between individual of A and B is unproblematic, display behaviors exhibited by male A will be understood by female B, etc. If heterospecific, gene flow is predicted to be near or at zero, and breeding barriers are predicted. For sexual organisms, any deviation of that prediction—breeding between individuals of A and B—becomes hybridization with complex and curious consequences, the subject of much study. A biologist studying A and B would ask different questions depending on the taxonomic hypothesis. Most of biology relies on taxonomic hypotheses, yet we treat taxonomy as a B discipline, publishable only in a handful of mostly low-impact journals. We treat taxonomic names (hypotheses) as given in the design and execution of scientific endeavors, and in failing to cite their authors we disregard their scientific content and impact on our own studies.

It is hard to disagree with Wilson (2004) that "taxonomy can justly be called the pioneering exploration of life on a little known planet" and with Wheeler et al. (2004): "The goal of discovering, describing, and classifying the species of our planet assuredly qualifies as big science." Without taxonomy, phylogeny is impoverished (Wheeler, 2004; Korf, 2005), ecology is deprived of one its fundamental units of currency (Gotelli, 2004), and conservation biology loses focus and aim (Godfray and Knapp, 2004; Mace, 2004). Taxonomy can have a profound and instant impact on conservation planning and decisions (see, e.g., Donegan and Huertas, 2006, and associated media coverage) and may even be so potent to force some taxonomists to consider concealing locality data to prevent the exploitation of newly described, commercially marketable species (Stuart et al., 2006). Why then are journals reluctant to consider publishing taxonomic descriptions? Why the scarcity of taxonomic jobs despite the realization of its value by major funding agencies and an emerging new generation of highly trained taxonomists? In sum, why does taxonomy seem to be a poor man's science?

Major Problems and Solutions

Obviously there are many issues at stake; however, one major hurdle for taxonomy is a result of a peculiar convention: it is considered unnecessary to cite original taxonomic descriptions or subsequent taxonomic revisions—the hypotheses behind species names—even when those hypotheses crucially impact a given study and its design. When discussing a species, biological journals may (or may not) require listing in text its Latin name followed by its author, but this author's work is not referenced in cited literature (see also Werner, 2006). At the same time, it is standard to cite authors of other types of hypotheses and of other taxonomic identifiers (e.g., GenBank sequences) and tools like computer programs.

As an example, the Web of Science finds over 35,000 papers (and Google Scholar over 60,000) discussing the common fruit fly, *Drosophila melanogaster*, described by Meigen in 1830, yet Meigen (1830) has been cited less than 60 times. Clearly the hypothesis *Drosophila melanogaster* has had a major impact in science, but one that, by convention, goes unremarked. We see this as the major reason why journals avoid taxonomic publications: they are unlikely to be cited, thus lowering the journal's overall impact factor. The specifics of the above example are unimportant, the phenomenon is universal. This practice needs to change. To overcome the taxonomic impediment one important step is to start treating taxonomic hypotheses with the respect they deserve and realize their true scientific impact.

Note that we are not, of course, claiming that all 35,000 to 60,000 studies should have cited Meigen (1830)—not all papers discussing evolution need cite Darwin. Werner (2006) suggested that any mention of a full taxon name (including author and date) in a paper justified that the taxonomic paper describing that taxon be cited. We disagree with this view. Enforcing involuntary citations to taxonomic literature would be setting the discipline aside other sciences and recognizing it as "un-citable" by conventional means; a bit like a government subsidizing a produce whose production is no longer self-sustainable. Taxonomy may be old, but it doesn't need crutches. At the same time, many papers referencing taxon names, even when the journal forbids use of the full name (see Werner, 2006), should cite the taxonomic authorities. We should not bind the citation of taxonomy to some discipline-specific arbitrary conventions; the same guidelines for citation should apply to all scientific publications. For example, an ecological study comparing species composition of two habitats might cite literature used to help species identification but may not need to cite the original descriptions (or later revisions) of all the species encountered because the taxonomic hypotheses play only a relatively minor role in its finding. In contrast, a study of a hybrid zone between two closely related species should cite the underlying taxonomic work as the study crucially relies upon the taxonomic hypotheses.

It might be argued that improving citation of taxonomic hypotheses would mostly benefit those who originally described the handful of the most intensely studied taxa (most of which were described long ago and whose authors were 18th- to early 20th-century biologists) and would minimally impact modern taxonomists. We do not think this is the case because taxonomy is a vibrant discipline and its hypotheses are continuously tested, updated, and changed. It is important to note here that citing the original description of taxa in many cases may not be the most appropriate, at least not citing it exclusively. One of the reasons NSF-PEET focuses on taxonomic revisions is that such work brings together all available evidence on an entire clade and hence tests multiple species-hypotheses simultaneously. A recent, thorough, taxonomic revision arguably provides much more robust and critically tested hypotheses of the species limits of its contained taxa than did the original (not the least if they were 18th to 19th century) descriptions. Furthermore, early original descriptions are often hard to obtain and often play a small role in most recent studies of these taxa; instead these studies mostly rely on more up-to-date taxonomic revisions.

To exemplify our point we will discuss the taxonomic work of Herbert W. Levi. Levi has produced over 100 taxonomic papers on some of the most common spider families of the Americas (Theridiidae, Tetragnathidae, Araneidae), where he revises an estimated 5000 species or more (in 10 randomly chosen revisions the average number of species revised per paper was 49, with 22 species on average described as new). Virtually any study in the Americas that involves orbicularian spiders, in one way or another, rests on the shoulders of Levi's work. Yet, according to the Web of Science, his revisions (spanning 1956 to 2006 so far, average age of revision 33 years) have been cited on average less than 10 times each. This means about 0.25 citations per year per revision and overall less than 0.2 citations per species revised.

As a point in case, *Anelosimus* Simon, 1891, is a well-known genus of spiders famous for their social behavior (Aviles, 1997; Agnarsson et al., 2006, 2007). The most studied species *A. eximius* (Keyserling, 1884) was originally described in a monumental work that includes original descriptions of numerous other well-known theridiid spiders, but that has been cited only 5 times according to the Web of Science. Original copies of this work are hard to find and its German text further limits its general usage. Thus, modern workers have relied upon Levi's (1956) more recent treatment of American *Anelosimus* (the only revision before Agnarsson, 2005, 2006). Levi's readily available revision, which provides more strongly tested taxonomic hypotheses of *A. eximius* (and several other *Anelosimus*), has been used for identification for the last half century. Levi (1956) has been cited 25 times according to the Web of Science, most studies involving *A. eximius*. Web of Science finds 78 papers (from the last 20 years) prominently discussing *A. eximius* (i.e., lists it either in the title, keywords, or abstract), whereas Google Scholar finds over 150 where the species is mentioned in text (hence including other studies where the taxonomic hypotheses may be less important). Both can be viewed as conservative estimates of the use of these hypotheses as neither tool accesses all of scientific literature. Based on these tools, the convention not to cite taxonomic literature results in the true impact of Levi's (1956) taxonomic hypothesis being underestimated by a factor of approximately 3 to 8. Similarly, his worldwide revision (Levi, 1974) of the araneid *Zygiella* F. O. P.-Cambridge, 1902, has been cited 10 times, whereas some 43 (Web of Science) to over 200 articles (Google Scholar) discuss *Zygiella* species. Levi's (1992) revision of the obscure araneids *Carepalxis* L. Koch, 1872, and *Rubrepeira* Levi, 1992, have been cited once each, whereas we found 4 papers discussing species of these genera. Hence, whether dealing with well-studied or obscure species, Levi's taxonomic revisions are under-cited. If current PEET taxonomic revisions are at a similar disadvantage, clearly their true impact is consistently being underestimated.

Of course, taxonomic revisions of high-profile taxa will tend to become more cited than revisions of groups that few people study. This problem, however, is not particular to taxonomy but applies to any field of study. Suffice to say that even though a group is relatively poorly studied, active citing of taxonomic hypotheses (when appropriate) would still, on average, increase the impact of a revision by the same factor as revisions of better studied taxa (see example above). As an additional example, the 26 *Anelosimus* species treated by Levi (1956, 1963) range from well known and intensely studied (e.g., *A. eximius*) to species that are known from a few individuals and have never been studied biologically. Yet, all these species have been discussed at least once, and 70% twice or more, in literature subsequent to Levi's revisions. It is useful to keep in mind here that the scientific impact factor is simply the number of citations in a given year of articles in the previous 2 years over the number of articles published in the previous 2 years. Hence a revision treating 50 species need only be cited twice (0.04 citations per species) in the year after publication to effectively contribute an impact factor of 2.

Underestimation of the impact of taxonomic publications necessarily means that the impact of journals publishing taxonomic papers is also underestimated. It is difficult to extrapolate these results directly to journal impact factors, but one may surmise that an increase in impact by a factor of 2 to 5 for a journal focusing on taxonomic revisions would not be far off. Such an increase in impact factor would dramatically affect taxonomy and the way taxonomic publications are evaluated. For example, one of the most prominent journals with a major taxonomic component is the *Zoological Journal of the Linnean Society*, whose 2005 impact factor was 1.98. Multiplied by a factor of 2 it would match *Evolution*; multiplied by a factor of 5, its impact would match that of *Systematic*

Biology—the second leading journal in evolutionary biology in terms of impact factor.

The senior author was recently reminded of the low prestige that taxonomic papers, and, apparently, also the journals that publish them, have. In an interview for a CNRS job in France, one of the committee's main concern was "How come you have not published in more general journals?" a question to which the honest answer "Because my thesis focused on taxonomy, which is not publishable in general journals" earned neither points nor the job.

Just as any other tool, or any other scientific hypothesis, taxonomic work should be cited when credit is due. We are convinced that once taxonomy enjoys equality in this way, there will be a positive impact on the access of taxonomists to journals and funds, increasing demand for taxonomists as employees and growing interest from students in mastering the discipline.

Responsibility, of course, also lies with taxonomists themselves. The impact of taxonomic papers, just like in any other scientific publication, depends on their content. For example, probably the majority of taxonomic papers published currently are almost purely descriptive and restricted to morphology. Although valuable, such papers (especially non-monographs) offer relatively weakly tested species-hypotheses and few tools for other researchers. Providing additional information, such as behavior, natural history, species barcodes, easy-to-use tools for identification, and phylogenetic hypotheses, will increase the impact of taxonomic papers. The discovery of new taxa also may afford opportunities to offer novel interpretations and/or hypotheses, to interpret rather than just describe.

Clearly, more journals are willing to accept, and more authors choose to cite, papers that test the validity of taxonomic hypothesis with molecular data or papers promoting or using DNA barcodes (e.g., Hebert et al., 2003a, 2003b; Tautz et al., 2003; Hebert and Barrett, 2005; Gregory, 2005; Pons et al., 2006; Robins et al., 2006; Schindel and Miller, 2006) rather than original taxonomic descriptions or revisions. This is curious, as these are merely tools in the broader toolkit of the discipline of taxonomy. However, at the same time this represents an opportunity for taxonomy and a guideline for budding taxonomists as to what skills they need in order to succeed. With the molecular revolution and the Internet, taxonomy is changing and currently even top impact journals are willing to publish cutting-edge (be it, at times, controversial) taxonomic research that combines multiple, both old and novel, tools. Taxonomists should embrace new tools that are potentially useful (such as DNA barcodes for species discovery and identification and DNA taxonomy to help test species boundaries) and catch the attention and interest of other scientists. The new generation of taxonomists should acquire the necessary skills to use such tools that, in combination with their more traditional skill set and unparalleled knowledge of their study taxa, can massively add to their marketability in the scientific job market and their scope of research.

PEET Survey

To reach the peetsters, we emailed the principal investigators (PIs) of the 1995 and 1997 grant cohorts requesting that they distribute our questionnaire to their alumni. In addition, we emailed directly every peetster for which we could obtain an email address, either provided by the PI or found by searching PEET project web pages, contact lists from PEET meetings, or running Google searches for individual names and emails. Peetsters were asked basic questions about their PEET training and given the opportunity to volunteer comments on any issue. Seventy peetsters completed the survey, or approximately 2.3 per grant (total number of grants 21 in 1995, 10 in 1997), and at least one from each of the grants. The vast majority of those who responded were graduate students who had completed their training under a PEET grant or researchers who were postdocs during their PEET funding. However, half of those who received some PEET funding as trainees in the 1995 cohort were undergraduates (GrantDoctor, 2004). Our inability to reach undergraduate trainees is difficult to explain. However, it would seem in general that our survey was most likely to reach peetsters who have continued work in taxonomy or other sciences, as universities and major companies likely to hire taxonomists tend to maintain web sites with employee listings, etc. Google searches successfully located nearly all of those who replied to our survey, while we were in this manner able to locate very few of those who did not, in particular the undergraduate trainees. Hence, it seems unlikely that many of the undergraduate trainees have established a career in taxonomy (this does not mean that the training received by undergraduates is necessarily lost, as increased awareness of systematics and taxonomy should be an asset for the future of taxonomy). Overall, we suspect that our survey disproportionally reached those who have been successful in establishing careers in taxonomy or in general secured employment in a related discipline; our results should be interpreted with this in mind, as they may give an overly optimistic view of the career successes of peetsters (see also GrantDoctor, 2004). The results of our survey (PEET alumni remarks about the program are available as Supplementary Material online at http://systematicbiology.org) can be summarized as follows: (1) The PEET initiative received near unanimous praise in terms of training and offering opportunities otherwise unavailable in taxonomy. Peetsters have conspicuously impacted taxonomy—each trainee has on average published about 3 PEET-funded monographs/papers (total 197, range 0–15, average 3 ± 3.1; many also have several additional manuscripts in preparation) and described about 9 new species (total 598, range 0–73, average 9 ± 15). (2) However, many peetsters expressed concerns (see Supplementary Material, available at http://www.systematicbiology.org/) over lack of continuity "... it's well enough that we are training taxonomists, but unless more universities are going to begin hiring traditional taxonomists, I fear that many of us will end up in other fields." Other concerns included overemphasis on molecular taxonomy: "...I also sense a widening gap between molecular systematists and traditional taxonomy that is impeding both fields." As noted by the GrantDoctor, "It seems that retiring taxonomists have been replaced, generally, not by new taxonomists but by molecular biologists and other, more fashionable specialists, who were in better positions than taxonomists to succeed in a competitive funding environment." (3) In line with these concerns, 1 to 6 years after graduation an alarming 47% of the peetsters that our survey reached no longer work on taxonomy and an additional 9% have positions where taxonomy plays only a minor role (Figure 1). About 6% are currently unemployed. Therefore, more than half of the gain in taxonomic expertise threatens to be immediately lost (or perhaps much more; see above), at least from the job market.

Given that the likely bias in our data is in the direction of overestimating the employment rate and the percentage of PEET trainees currently working on taxonomy, these numbers do not compare favorably with general science and engineering figures (data from NSF, 2001) in the United States. In those figures, unemployment rates in 1997 were only 1.3% for recent doctorate holders (compared to 6% in our survey); i.e., those having completed their degrees in the previous 6 years. In biology, a relatively narrow gap occurs (NSF, 2001) between those who most wanted academic employment (75.1%) and those who found such employment or postdoctoral positions (66.4%, or 88% success rate). Research and development was the most desired activity among recent biology doctorate holders (95%), with 85.5% actively pursuing it (NSF, 2001). Among all recent degree holders, only 6.9% reported being dissatisfied with their doctoral programs, and 12.5% of them were dissatisfied with their jobs. Overall, 39.5% of employed recent doctorate holders work in a sector different from what they most desired when they began their doctoral program (47–56% of PEET graduates surveyed, and perhaps up to 80% total if all trainees are considered [GrantDoctor, 2004] currently do not have jobs focusing on taxonomy).

One must also wonder if the first PEET alumni will not tend to saturate the tiny taxonomy job market, so that later PEET trainees are at an even larger disadvantage. It seems that keeping track of each PEET cohort and the fate of its peetsters should be a priority for NSF-PEET and would provide a tool to guide decision making and direct funding priorities.

The Job Market and Recommendations for Funding in Taxonomy

Two issues stand out from our survey (see Supplementary Material): the immense importance and influence of NSF-PEET in training taxonomists and the lack of jobs and funding for taxonomists once trained. Funding agencies should seek a balance between training and career opportunities; for example, by the establishment of research partnership institutions with NSF and other agencies, or else resources invested are being lost. As peetsters commented, "This is a wonderful program. It may prepare a student in a wide array of skills and techniques (both classical and modern). However, the jobs in which (pure or general) taxonomic expertise is needed are very scarce"; "In sum, PEET is a fine start to solving the taxonomic impediment, but it is not enough. As it is now, it trains students in skills absolutely not required by the job market"; "Some of people who came out of the same PEET pool as I have may be unemployable because their dissertations did not include a molecular component"; and "PEET offers an opportunity to work on discovering diversity, but it is not career oriented, and it is left entirely to PEET alumni to acquire some of the skills that the current job market seeks." The lack of job opportunities for taxonomists can be confirmed on a daily basis by simply seeking jobs on the NatureJobs web site (http://www.nature.com/naturejobs/index.html) using the keyword "taxonomy." Very rarely is there even

FIGURE 1. Current employment status of 70 cohort 1995 and 1997 PEET alumni (peetsters). It should be noted that "employed in taxonomy" is an optimistic estimate of the degree to which peetsters are actively working on taxonomy; this category includes jobs such as university professorship where the research agenda is largely up to the individual, and also jobs were phylogeny, rather than taxonomy (see Wheeler, 2004), is at the core.

a single ad where "taxonomy" occurs in the job advertisement text and the few that occasionally do typically have only a minor focus on taxonomy. For example, a search on October 9, 2006, found one job advertisment with the word taxonomy in the text; however, the main focus of the job was on administration and the scientific focus was on phylogeny. These concerns are particularly worrisome coming from the 1995 and 1997 cohort peetsters, as later graduates may find that their tiny job market is already oversaturated by previous peetsters. The dichotomy between somewhat lofty short-term goals and practicality is exemplified by the strong focus of NSF on "underrepresented taxa." To be sure, the goal is admirable and has transferred interest to groups that have been understudied. However, for the trainees specialized in those taxa it may have been a disservice: "... those groups of organisms... are underrepresented for a reason—few places will hire people to work on them. Consequently, it is very difficult for a student to base their career on working on a group of organisms featured in the PEET program."

On what taxonomic groups should funding then be focused? If the goal is to maximize the discovery and description of species before they disappear from the planet, it might make sense that new taxonomic training is distributed among major groups in relation to their diversity. Figure 2 shows the distribution of PEET expertise in relation to known diversity of organisms. The two show some correspondence, but one may ask if this match should be closer. Alternatively, diversity might be maximized by focusing on clades with vastly different biologies, irrespective of their species richness. For example, the surveyed peetsters studying insects focused exclusively on the four major groups (Diptera, Coleoptera, Hymenoptera, and Lepidoptera), whereas perhaps the greater functional, morphological, chemical, and physiological diversity might be discovered by sampling less densely but from more of the "minor" insect orders. We feel these considerations are certainly relevant, but the bottom line is that to be effective, funding decisions must reflect both priorities in taxon discovery/description and—for lack of a better term—*demand* for taxonomic knowledge in the job market. If the latter is ignored, only employed grant recipients, and not graduate students, can afford to devote their research to the discovery and description of underrepresented taxa.

Another problem facing peetsters relates to the core of the PEET program: monographic revisions. Taxonomic monographs are wonderful tools and, in terms of knowledge of the taxon, perhaps the ideal way of publishing taxonomy (Rodman and Cody, 2003). However, in the era of impact factors, a biologist who publishes few, very large papers (inevitably in rather small journals) is at a disadvantage to one who publishes smaller articles more frequently. This is even more so when considering how very few journals accept large (especially

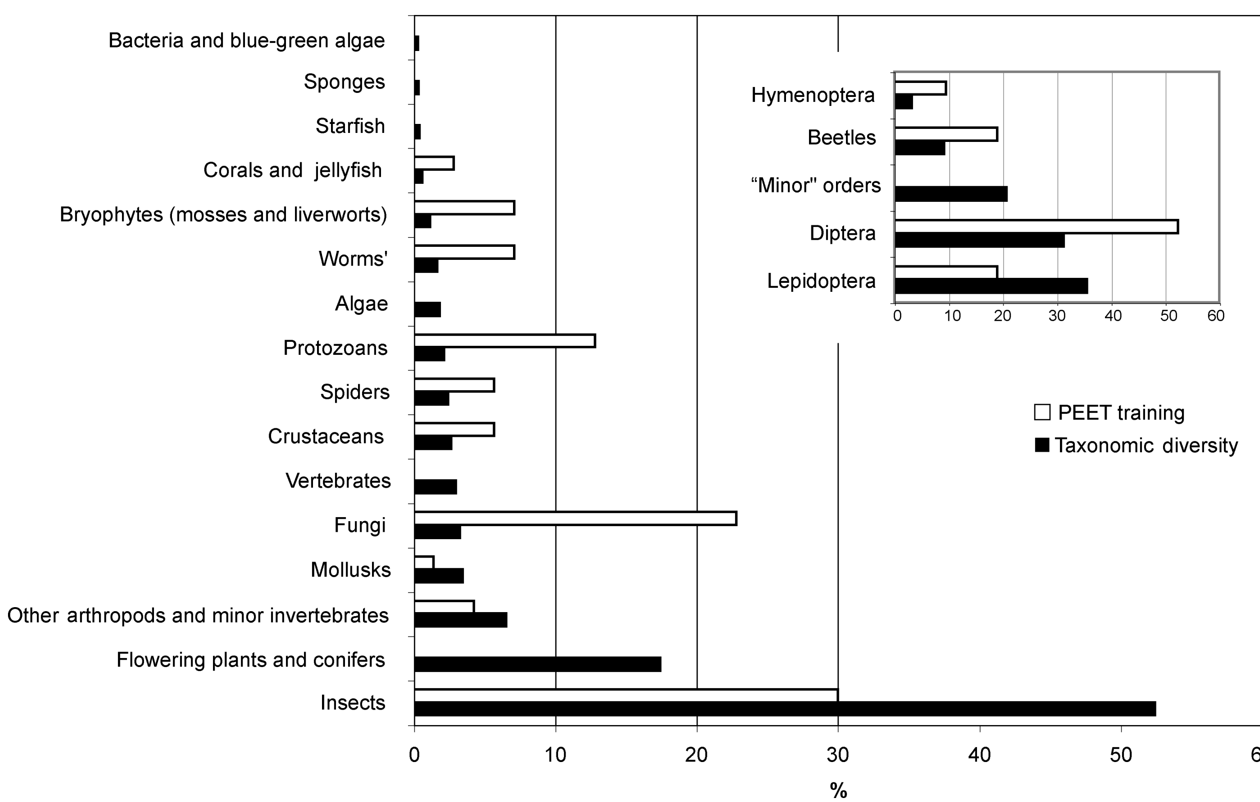

FIGURE 2. The distribution of known species diversity across major groups (source: McNeely et al., 1990), and the taxonomic expertise of the 1995 and 1997 cohort NSF-PEET trainees according to our survey. Smaller bar chart shows finer taxonomic division within insects.

taxonomic) papers and how long it takes to publish them: "The only regret I have is the length of time that it has taken me to publish my thesis. I would be a strong advocate of publishing smaller articles as you go for the experience and to get the information out there ASAP." In line with this, a great number of the 1995 and 1997 peetsters have not yet published their theses (or only in parts). Competing for jobs with few publications, in low-impact journals, is difficult but something taxonomists focusing on monographs are particularly likely to find themselves doing. Finally, unpublished theses in general can be cited and can directly impact science; taxonomic work that ultimately remains in an unpublished thesis, however, is valueless, for it is not acknowledged, e.g., in case of zoology, by the International Code of Zoological Nomenclature (ICZN, 1999). We fully endorse the vision of NSF-PEET to advance monographic research in taxonomy, but to focus exclusively on monographs may be poor advice to students of taxonomy soon to enter the job market.

We illustrate this problem with a hypothetical PEET thesis on spiders. In it the trainee has revised a clade containing four readily diagnosed subclades (e.g., genera). The approach advocated by the PEET initiative (monographic research) and in our experience by at least some PEET advisers would be to publish the monograph as a whole. If the work is scientifically sound and of some general interest, it might be accepted for publication in a journal such as the *Zoological Journal of the Linnean Society* (work representing purely taxonomy of an obscure group few people are aware of might not be accepted in such a journal, a problem faced by some peetsters). After years of work, the alumnus has one (hefty) publication in a good impact journal (impact factor = 1.98). A sensible alternative would be to divide the work into four logical units (four clades are revised) and send each to different, more or less specialized journals, say one paper to *Zoologica Scripta*, one to *Invertebrate Systematics*, and two to the *Journal of Arachnology* (all have published papers on spider taxonomy recently). In this case, the alumnus would have four papers, most, if not all, would be published faster, and the impact factor in total would be $1.906 + 1.217 + 2 \times 0.557 = 4.237$. If these are all the papers on the alumnus's curriculum vitae, hardly anyone can argue against the latter approach.

Right or wrong, the scientific funding agencies today tend to discriminate against researchers with few monographic/low-impact papers, which is especially problematic for taxonomists. An example we know well, and appears rather typical of European Union nations, is the Slovenian Research Agency (ARRS). ARRS has implemented a national database of all registered researchers (http://sicris.izum.si/) that uses a formula to calculate bibliographic points of researchers based on the number of publications in the past 5 years, the journal impact factors, the number of authors, etc. (from http://www.arrs.gov.si/sl/akti/prav-znan-strok-uspesn-06.asp). Thus, a publication counts 80 to 100 points if published in the top quartile within a field, 60 to 80 points in the second, 40 to 60 in the third, and 20 to 40 in the fourth quartile of journal impact factors. The lower bound points are augmented by the formula:

$$20 \times (\text{IF} - \text{IFmin})/(\text{IFmax} - \text{IFmin})$$

where IF = impact factor; IFmin and IFmax = lowest and highest journal IF values within the quartile, respectively. The total score is divided by the number of authors, and short papers (less than four pages) receive 80% score. For example, a single author of a paper longer than four pages published in the *Zoological Journal of the Linnean Society* would receive, for this publication, a score of $80 + [20 \times (1.98 - 1.407)/(5.286 - 1.407)] = 82.95$. The journal's IF is 1.98, and it falls into the top quartile of the journals within the field Zoology (it ranks 12 out of 114); the highest ranking zoological journal IF is 5.286, and the lowest journal in the upper quartile IF is 1.407.

Job candidates and employed scientists competing for national funds are compared based on their overall score. For example, the minimum threshold for a principal investigator on grant applications is a score of 100 points solely from impact factor journal articles in the past 5 years. If our hypothetical peetster is to compete in this scheme, he/she would not be eligible for funds with a score of 82.95 (the case of one large publication) but would comfortably compete with the score of 259.96 from the four smaller publications.

For efficient use of funding in taxonomy, it is essential that funding agencies recognize what is needed for newly trained taxonomists to find employment, and that they directly impact the current job market by funding jobs in traditional taxonomy. As we have argued above, the status of taxonomy can improve greatly if the scientific community agrees to start acknowledging taxonomic hypotheses as equal to any other. Combined with use of funds aimed to first advance the researcher, and second knowledge of the taxon, NSF-PEET's ambitious goal of overcoming the taxonomic impediment can indeed be accomplished.

Our essay is perhaps biased towards the state of affairs in North America, although many peetsters, like us, are not U.S. citizens and currently use their taxonomic skills elsewhere. We focus on NSF-PEET for it is, to our knowledge, the largest long-term ongoing effort to overcome the taxonomic impediment via training of taxonomists. We do not, however, want to downplay the taxonomic crisis in other parts of the world where taxonomy may be fairing worse still. But precisely because our focus is on probably the best case for taxonomy (PEET), the problem discussed is likely conservative compared to the actual global crisis in the field. There are some new taxonomic initiatives in Europe (e.g., EDIT; see Tillier and Roberts, 2006) and other parts of the world (e.g., Joly, 2006), but these aim primarily at increasing the efficacy of distribution of taxonomic information rather than training and creating jobs for taxonomists. Taxonomy is, for example, not specifically featured in the new Seventh Research Framework Program of the European Commission, the major funding organization in Europe, which sets the research standards for the immediate future (2007 to 2013). Hence, we use this opportunity to urge granting agencies outside North America, such as the European Research Council, to follow the eminent example set by NSF-PEET and devise their own taxonomic initiatives and thus improve the status of taxonomic funding, which remains crucial for discovering and documenting the World's biological heritage.

Advice for Future Taxonomists

It is important that the training of the new generation of taxonomists focuses on skills required by the job market and that young taxonomists plan their own career early on. Taxonomy, like many other fields, is increasingly multidisciplinary (see, e.g., Smith et al., 2006) and taxonomists need to keep up with the evolution of the discipline, gaining competence in molecular methods, interactive databasing and identification keys, dissemination of data over the Internet, etc. Trainees are encouraged to consider alternative strategies for publishing their work and consider broadening their research scope to improve their competitiveness. Large monographic treatments are idealistic, but for training graduate students, several smaller publications, and publications in higher ranking journals, will usually be preferable when the time comes to apply for a job. Integrating descriptive taxonomy with other biological fields, such as phylogenetics, biodiversity conservation, molecular biology, ecology, ethology, and biogeography, can only improve the taxonomy-based products, gain access to high-impact publication venues, and improve the trainees' chances of employment and scientific funding.

Concluding Remarks

Taxonomy is crucial to understanding biodiversity in a world facing its rapid loss. Training a new generation of taxonomists is an extremely important priority in the NSF-PEET agenda and one that can certainly be deemed successful (Rodman and Cody, 2003). However, unless careers in taxonomy are available, the availability of training—no matter how good—will not prevent the loss of taxonomic expertise. Taxonomy needs more jobs, and it is necessary for funding agencies to balance funding for training with funding that makes available taxonomic careers; as shown above, currently as much as half the funding for taxonomic training, or even much more, may be lost due to lack of job opportunities. However, we believe taxonomy is a strong enough discipline to survive and thrive in the changing scientific world. What is needed first is a correct measure of its scientific impact, achieved by citing taxonomic work when credit is due. Taxonomists should also do their share to keep up with the changing field by (1) synthesizing knowledge not merely describing species; (2) embracing and acquiring skills in the use of new tools and technologies to combine with traditional ones; and (3) work towards increasing recognition of taxonomy and its importance among the public and the funding agencies.

High-impact taxonomy in the near future will be interdisciplinary, interactive, and almost certainly represent "... the confluence of 'Barcode of Life' genetic taxonomy ... classical morphological taxonomy, and 'use it or lose it' concepts of conservation of biodiversity." (Herre, 2006: 3949, on Smith et al., 2006).

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