

Is there a taxonomic crisis?

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Concern has been expressed around the world concerning the 'taxonomic crisis': that is, although biodiversity is being lost at an ever-increasing pace, species discovery and description (taxonomy) is facing a crisis. Recently, a number of papers have been published that suggest there is not a taxonomic crisis, based on electronic databases that contain uncritically recorded species synonyms and that do not make it clear who the taxonomist is on multi-authored papers. Claims that there have never been more taxonomists are likely to be incorrect especially if they are made by non-taxonomists not intimately familiar with the limitations of each electronic dataset and the taxonomic enterprise. In response to concerns in New Zealand about the precarious position of collections (scattered across several types of institution with separate funding sources) and associated taxonomic expertise, the Royal Society of New Zealand (RSNZ) convened a panel to look into the situation in New Zealand resulting in a report published in 2015. The panel confirmed that collections and taxonomy play an important role in a wide range of national activities (economic, biosecurity, human health, conservation, sustainable use, etc.). The RSNZ report noted the lack of strategic connection between science funders and priority setters and a lack of alignment between the funding of collections infrastructure and the delivery of services. The taxonomic workforce in New Zealand is characterised as ageing, male-dominated, and with very low numbers in the 19-30 age group. This workforce is mostly not doing taxonomic research (77% were funded to spend less than 25% on research and 59% could spend less than 10% on research) resulting in a zero to low published output for the majority. This suggests that qualified researchers are underused in New Zealand and risk not being up-to-date and in danger of eroding their capability. Compared with Canada in 2009 and Australia in 2003, New Zealand has the lowest proportion of researchers in the 20-40 age bracket. Compared with Canada, a very small proportion (4%) of researchers in museums can spend more than 50% of their time on taxonomic research in New Zealand (58% in Canada). A solution needs to be found to the problem created by diffuse responsibilities for taxonomic collections infrastructure and lack of strategic connection between science funders and priority setters. This solution should include the creation of a national co-ordination mechanism.

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Introduction

Concern has been expressed around the world concerning what has been called the 'taxonomic impediment' or 'taxonomic crisis' (e.g. Agnarsson & Kuntner 2007; Bortolus 2008). That is, although biodiversity is being lost at an ever-increasing pace, species discovery and description (taxonomy) is facing a crisis.

In the context of answering the question: 'How many species remain to be described globally?', some recent analyses (Joppa *et al.* 2011; Costello *et al.* 2012, 2013a, b) conclude that: more taxonomists are describing species than ever before, and the rate of species discovery per 'taxonomist' is falling. These authors used the decline in rate of species discovery to estimate the number of missing species. Some of their conclusions have become the subject of heated debate (Mora *et al.* 2013; de Carvalho *et al.* 2013; Bebbler *et al.* 2014; Wheeler 2014) because the results imply there is not a taxonomic crisis. Here, the controversy is further investigated and the New Zealand state of affairs analysed.

Misinterpretation of data

The reaction of some taxonomists globally has been indignant, given their individual circumstances. For example, Quentin Wheeler (2014) of Arizona State University has witnessed the steady hemorrhaging of prestige, funding, and positions from taxonomy for more than three decades. He finds that advertisements seeking to hire taxonomists to do taxonomy and grants to do taxonomy for its own sake are essentially non-existent.

Bebbler *et al.* (2014) and Mora *et al.* (2013) critiqued the analysis of Joppa *et al.* (2011) and Costello *et al.* (2013a). They question whether conclusions can be justifiably drawn from analyses of the apparent rate of new species discovery and whether conclusions can be drawn about the taxonomic workforce. They contend that answers depend on several issues. First, it is important to know where, in the discovery process, a taxon of interest is currently situated – is species discovery in its earliest stages or at a mature stage where most species have been discovered? Second, synonyms that exist unquestioned in some databases need to be acknowledged as sources of overestimation of numbers of species (Löbl & Leschen 2014). Third, it needs to be recognised that the number of full-time professional

taxonomists is not accurately represented by the total authorship of many taxonomic papers (Bebber *et al.* 2014).

Are there more taxonomists than ever before?

The contention that there are more taxonomists than there have ever been, has been analysed further. It is true that numbers of taxonomists are decreasing in some institutions of countries that formerly led in taxonomy (e.g. Anon. 2010). Nevertheless, in Asia and South America, numbers appear to be increasing (Costello *et al.* 2013a). But, the contention that taxonomists are increasing ‘exponentially’ (Joppa *et al.* 2011) is challenged by Bebber *et al.* (2014) who analyse the phenomenon of ‘author inflation’.

That is, they found a tendency, with time, for the number of authors on a paper to increase in several research areas, including the taxonomy of flowering plants. They point out that the authors of papers are not necessarily the authority for the species description and, over the period from 1970 to 2011, the number of authors linked with species descriptions increased three-fold. At the same time the average number of species described per author decreased. They argue that these data show that, for flowering plants, there has been a nearly constant rate of description of species over the 40-year period and that global taxonomic capacity has remained largely unchanged. But, like other branches of science, authorship has increased as students, junior staff, laboratory assistants and technical staff are included as authors, as well as, with an increase in collaborative science, colleagues who provide, for example, molecular data.

Who speaks for taxonomists?

Behind the above controversies is disquiet over the misrepresentation of taxonomists and the systematics enterprise, leading de Carvalho *et al.* (2013) to question who should speak for taxonomists. Carvalho and co-authors contend that defining taxonomists as *people describing species new to science* is akin to defining racing car drivers as those who own a car. This uncritical view belittles the effort and scholarship needed to educate and support taxonomic specialists. Unintentionally, Costello *et al.* (2013a) undermine professional taxonomy in museums, institutes and universities, where professional collection-based research is undertaken, by his acceptance of this limited definition. ‘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’ (de Carvalho *et al.* 2013).

De Carvalho *et al.* (2013) assert that taxonomists are at the mercy of bioinformaticians, phylogeographers, ecologists and those who have recruited ‘biodiversity’ to their cause. As a result, the interpretation of biodiversity is at a crossroads and is currently failing to gain institutional support and recognition. The fate of systematics and collections-based research has not been improved by the support of bioinformaticians for innovative technical initiatives. The initiatives that have applied new technology to existing data (not generating new data – e.g. GBIF, WoRMS) have mopped up a considerable fraction of the money available during the Biodiversity Decade of the 1990s (Flowers 2007). These initiatives have represented additional IT chores for taxonomists who have been expected to act as unpaid data entry technicians.

In many countries the process of *dismissing taxonomy* is still on course to destroy their expertise in taxonomy despite the fact

that taxonomy underlies the credibility of much of biological science (Flowers 2007; de Carvalho *et al.* 2013). Yet, accurate identifications supervised by an experienced systematist and scientific names linked to an appreciation of the phylogenetic position of taxa of interest are central to the longevity of conclusions from other biological sciences.

For New Zealand, many of the same trends are evident. This leads to the question of whether there are enough well-supported, practising taxonomists who are able to maintain and improve their skills and can thus provide the underpinning support for the whole biological science enterprise and society’s interests.

RSNZ Report on National Taxonomic Collections 2015

In response to concerns about the precarious position of collections and associated taxonomic expertise in New Zealand, the Royal Society of New Zealand (RSNZ) formed a panel to look into the situation in New Zealand (Anon. 2015).

The panel found that taxonomic collections (scattered across several types of institution with different sources of funding) play an important role in the accurate identification and authentication of species which underpin a wide range of economic, biosecurity, human health, conservation, sustainable use, cultural identity, scientific credibility, and quality assurance activities, to cite a few examples. The RSNZ report noted a lack of alignment between the funding of collections infrastructure and the delivery of services (Anon. 2015: 47). That is, there is weak strategic alignment between the setting of output priorities by departments and agencies that are providing services and benefits, and the input priorities of those providing the main funding to the infrastructure of collections. There is also no obvious alignment between the input science funding to research organisations and collection infrastructure, despite that fact that New Zealand depends significantly on all of these biological collections.

No solutions to this situation have been proposed in the Conservation and Environmental Science Roadmap: Discussion Paper (Ministry for the Environment and Department of Conservation 2016). In this discussion document there is no mention of the RSNZ report. On page 35 it is noted, under the Biosecurity theme, only that ‘The sustainability of taxonomy and systematics capability – and related infrastructure, such as collections – is a crucial issue that needs to be addressed’ without presenting options for solutions. This is disappointing, given that the Conservation and Environmental Science Roadmap is where we would expect to see some strategic guidance to solving the problem of weak strategic alignment. The final roadmap document is due to be released in early 2017. The RSNZ report formulated a number of recommendations (Anon. 2015: 10). Among these is a proposal for a coordination and oversight mechanism undertaken by collection holders coupled with a single point of responsibility within government for interaction and information exchange. This would allow for coherent coordination and policy development and investment in collections’ infrastructure and taxonomic capability.

The flawed characteristics of New Zealand’s national taxonomic collections’ infrastructure occur in a setting where some of the professional taxonomy workforce feels neglected and their ability to maintain their expertise is declining as are their effective numbers. Here, the real situation is evaluated based on the work of the RSNZ Panel (Anon. 2015).

New Zealand taxonomic workforce

To assess the state of taxonomic expertise in New Zealand the RSNZ panel undertook a survey of individuals in taxonomy-related activities in New Zealand (Anon. 2015: 38, Appendix 5).

One hundred and seventy three individuals responded, including 10% who were retired or volunteers and 22% in the 'other' category, which included individuals working in other occupations, self-employed or unemployed. That is, the sample population contained a wide range of skills from parataxonomists up to highly experienced taxonomy practitioners, a number of whom are not working directly in taxonomy.

From this survey, it is very difficult to be certain how many professional taxonomists are employed in New Zealand because the survey questions led to ambiguity in the self-reporting of expertise and employment and the sampling regime did not allow a reliable estimation of the total population of taxonomists. Nevertheless, the impression is that New Zealand potentially has a skilled population of taxonomists that is commensurate with most developed countries, given our population size. Since we are concerned with professional taxonomy practitioners, these were separated from the basic survey population based on their answers to the survey questions. This group of 101 respondents had a number of distinct characteristics.

Fifty two respondents were affiliated with CRIs + Cawthron Institute (15% were retired); 21 respondents were affiliated with Museums (16% retired); and 28 respondents were affiliated with universities (24% retired) (Fig. 1). When those who appear not to be publicly funded are removed, the taxonomy practitioner workforce comprised 97 individuals who could be available for urgent responses, e.g. biosecurity incursions.

This group is a male-dominated, ageing workforce with peak numbers in the 51–60 age group and very low numbers in the 19–30 age group (Fig. 2). Their expertise is spread across a wide range of taxa (Fig. 3), and when aggregated according to broad organism categories, they approximated the spread across the same broad organism categories in collection holdings.

Seventy seven percent of the workforce were funded to spend less than 25% of their time on taxonomic research and 59% were funded to spend less than 10% on taxonomic research. This suggests that highly qualified researchers are underused in New Zealand. They risk not being up-to-date, in danger of eroding their capability without sufficient time allocated to support their research and associated professional development (Table 1).



Fig. 1. Proportion of retired / volunteers amongst taxonomy practitioners (from RSNZ Report Anon. 2015).

The majority (70%) of practitioners report a zero to ten publication output (Table 2) probably related to their level of expertise, low level of taxonomy funding and/or the type of position they have. Thirty nine experienced individuals reported

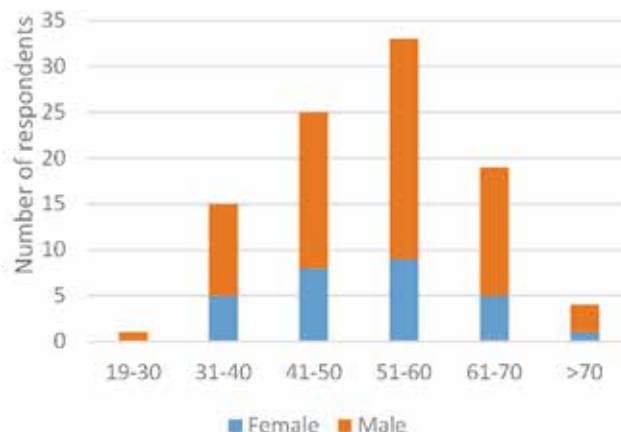


Fig. 2. Age and gender structure of employed publicly funded taxonomy practitioners (from RSNZ Report Anon. 2015).

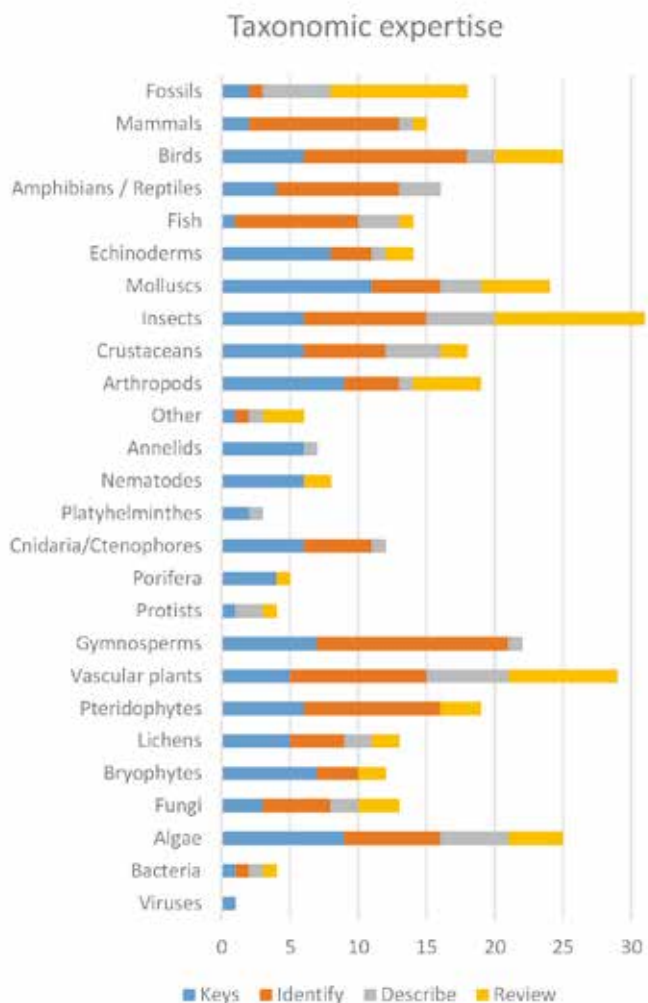


Fig. 3. Highest taxonomic level attained by 97 publicly funded practitioners report against higher level taxa / groups. Horizontal axis is number of reports. Note that some individuals have skills relating to several taxa so the numbers do not add up to total respondents. Keys = can recognise species with keys or reference materials, Identify = can identify species, Described = have written species descriptions, Revise = have written a taxonomic revision. (From RSNZ Report Anon. 2015).

Table 1. Number of publicly funded practitioners reporting being able to spend a range of their time on taxonomic research (from RSNZ Report Anon. 2015).

Time	Numbers	%
0%	7	7
<5%	25	26
10%	25	26
25%	17	18
50%	13	13
75%	10	10
100%	0	0
Total responses	97	100

a total accumulated output of more than 20 journal articles and a small number had the highest output of taxonomic revisions.

Compared with a survey in Canada in 2009 (Anon. 2010) and Australia in 2003 (Anon. 2003/2006), New Zealand has the greatest imbalance in its taxonomic workforce, with 16% in the 20–40 age bracket (Table 3) compared with 36% in Canada and 23% in Australia. Both Canada and Australia appear to have been more regularly recruiting younger taxonomists.

Patterns of time spent on taxonomic research in New Zealand and Canada, at selected types of institution, indicate that there is a vastly larger proportion of New Zealand taxonomists who are underutilised in their speciality (Table 4).

Looking forward

New Zealand's aim should be to achieve a healthy, internationally connected, professional employed workforce in New Zealand that includes a basic number of professional taxonomists who are able to contribute to accurate identification and authentication of species relevant to the national interest. These individuals should also have enough funded research time to be regular contributors to new species discovery. As well as species discovery, these individuals should be contributing to knowledge of the evolution and relationships (systematics) of the New Zealand flora and fauna in relation to the rest of the world.

Table 2. Numbers of publicly funded practitioners who have published varying quantities of papers, reviews and books/book chapters (from RSNZ Report Anon. 2015).

Output	0	1–5	6–10	11–20	>20
Journal articles	1	32	6	17	39
Reviews	21	24	10	2	4
Books/chapters	20	34	10	5	4

Table 3. Comparison of the proportional age structure of the taxonomy workforce of New Zealand, Australia (2003), and Canada (2009) (from RSNZ Report Anon. 2015).

Age range, years	New Zealand	Canada	Australia
20–30	1%	11%	10%
31–40	15%	25%	22%
41–50	26%	20%	30%
51–60	34%	26%	24%
61–70	20%	13%	15%
>70	4%	6%	-

Table 4. Proportion of employed research taxonomists who are funded to spend > 50% of their time on taxonomic research from RSNZ Report Anon. 2015).

Institution type	New Zealand	Canada
Museum	4%	58%
Universities	2%	32%
Government laboratories and CRI + Cawthron Institute	19%	49%

This will not be achieved unless misunderstandings about the role of taxonomic collections infrastructure and associated taxonomic/systematic science can be corrected. We need to better characterise the potential workforce through the promulgation of a definition of a professional taxonomist/systematist and associated professions and how they should be trained.

A further, well designed survey, that is clear about definitions, of how individuals are employed, their qualifications, characteristics, output and what is expected of them in their work should be undertaken, aimed at getting a better idea of the total taxonomy population.

The lead ministries need to acknowledge and own the problem created by diffuse responsibilities for taxonomic collections infrastructure and the lack strategic connection between science funders and priority setters.

A way forward needs to be formulated based on the recommendations in the RSNZ report (Anon. 2015) that includes an overall strategy and policy and creation of a national co-ordination mechanism (see Executive Summary reprinted in this volume, pages 80–82).

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