MYCOLOGICAL NOTES 15: THE SPECIES NUMBERS GAME.

Jerry Cooper, August 2012

This one is about the number of species both globally and nationally. It won't make much sense unless you know a bit about names and their application to taxa, i.e. the relationship between our labels and the real species out there in the world. I won't go back to fundamentals but I will provide a basic refresher based on an example statement of synonymy.

SYNONYMY – WHAT DO WE MEAN?

Table 1 – a synonymy

Current Name:
***Fuscoporia wahlbergii* (Fr.) T. Wagner & M. Fisch.**, (2001)

Synonyms:
Trametes wahlbergii Fr. (1849) [1848]
Polyporus wahlbergii (Fr.) Lloyd, (1917)
Phellinus wahlbergii (Fr.) D.A. Reid, (1975)
Mucronoporus wahlbergii (Fr.) Zmitr., Malysheva & Spirin, (2006)

Polyporus zealandicus Cooke, (1879)

Polyporus victoriae Berk. ex Cooke (1882)
Poria victoriae (Berk. ex Cooke) Cooke, (1886)

Xanthochrous princeps Pat., (1898)
Fomes princeps (Pat.) Sacc., (1902)

Pyropolyporus robinsoniae Murrill, (1908)
Fomes robinsoniae (Murrill) Sacc. & Trotter, (1912)

Pyropolyporus subextensus Murrill, (1908)
Fomes subextensus (Murrill) Sacc. & Trotter, (1912)

Fomes senex var. hamatus Corner, (1932)
Fomes hamatus (Corner) Imazeki, (1940)
Phellinus hamatus (Corner) Imazeki, (1943)

Fomes uncatus G. Cunn., (1948)

To see this synonymy, badly written see …
http://www.speciesfungorum.org/Names/SynSpecies.asp?RecordID=474672

The synonymy says that we have one fungal species for which the current name is *Fuscoporia wahlbergii*. That name has the basionym *Trametes wahlbergii* described by Fries in 1849 based on a single 'Type' collection. Over the years Fries species has been shifted into *Polyporus*, *Phellinus* and *Mucronoporus* by various authors who disagreed with the original classification in *Trametes*. These are homotypic synonyms, all names based on the same type.

In the opinion of the Kew checklist of British Basidiomycetes (another one of my database designs) the same fungus has been named independently based on 7 other named types, *Polyporus zealandicus* by Cooke in 1879, *Polyporus victoriae* also by Cooke in 1882, *Xanthocrous princeps* by Patouillard in 1989, *Pyropolyporus* *robinsoniae* by Murrill in 1908, *Polyporus subextensus* by Corner in 1932, and finally *Fomes uncatus* by Cunningham in 1948. Each of these original names is based on a different type. They are heterotypic synonyms of *Fuscoporia wahlbergii*. But note that some of these heterotypic original names also have later homotypic synonyms of each original name. Thus we get considerable synonym inflation.

If we decide that a bunch of type specimens all refer to the same species then how do we determine the correct name amongst the alternatives? In other words why has *Fuscoporia wahlbergii* gone to the top of the pile? The reason is the principle of priority dictated by the code of nomenclature. The epithet of earliest named type wins (sometimes it can't win because it is pre-occupied in the correct genus – but let's not go there). The earliest type in this bunch is Fries' *Trametes wahlbergii* in 1849. And, if we accept the species as a *Fuscoporia*, then the correct name is *Fuscoporia wahlbergii*. For argument let's say that we believe *Pyropolyporus* is the correct genus and not *Fuscoporia*. We cannot adopt Murrill's existing combination (*Pyropolyporus robinsoniae*) because the basionym does not have priority, it is pre-dated by (*Trametes*) *wahlbergii*. We would need to create yet another new combination *Pryopolyporus wahlbergii*, based on Fries type, with the basionym *Trametes wahlbergii*, to accommodate our circumscription of the taxon. It is through applying such rules that we end up with synonyms.

Names and homotypic synonyms

One of the databases I've been involved with for many years, and originally placed on the web when I worked at the International Mycological Institute, is IndexFungorum. IF is a fungal nomenclator, by which we mean its focus is the nomenclatural status of fungal names, i.e. where and when they were published and their status under the Code of Nomenclature as valid and legitimate. A nomenclator does not store taxonomic opinion, in other words a nomenclator says nothing about the correct name for a fungus and its synonyms. Whilst nomenclature is largely objective fact (based on the rules of nomenclature), taxonomic opinion on the correct name for an organism is subjective opinion (based on scientific evidence). So IF tells us the number of names, but not the number of taxa. The Dictionary of Fungi, on the other hand, does allow us to estimate rough figures for a consensus on the number of described species by adding up the values supplied by experts in each of the taxonomic groups contributing to its content.

The last copy of IF that I have contains 329,527 names at the rank of species (ignoring issues of validity/legitimacy). Of these 222,931 are original names (basionyms). 158,039 of those have never been re-combined, they remain assigned to their original genus, that's 71% of the total. The remaining 29% have been re-combined at least once. The 158,039 that remain unscathed hide very many old names that have no current interpretation, so these uncombined names do not all represent 'good' species. The table below show the details. 41,945 names have been recombined once (one name plus one synonym), 13,617 twice etc., up to two names which have been recombined 18 times (*Gyalecta ulmi* and *Caloplaca ferruginea*). So these are fungi that we know quite well, it's just we haven't been very good at deciding where they fit in the scheme of things. This uncertainty seems to afflict lichenologists more than most.

Table 2 – Homotypic recombinations

Names/Synonyms	Number	Percent
1	158039	70.8914%
2	41945	18.8152%
3	13617	6.1082%
4	5229	2.3456%
5	2166	0.9716%
6	946	0.4243%
7	488	0.2189%
8	228	0.1023%
9	123	0.0552%

10	77	0.0345%
11	32	0.0144%
12	22	0.0099%
13	9	0.0040%
14	3	0.0013%
15	2	0.0009%
16	1	0.0004%
17	2	0.0009%
18	2	0.0009%

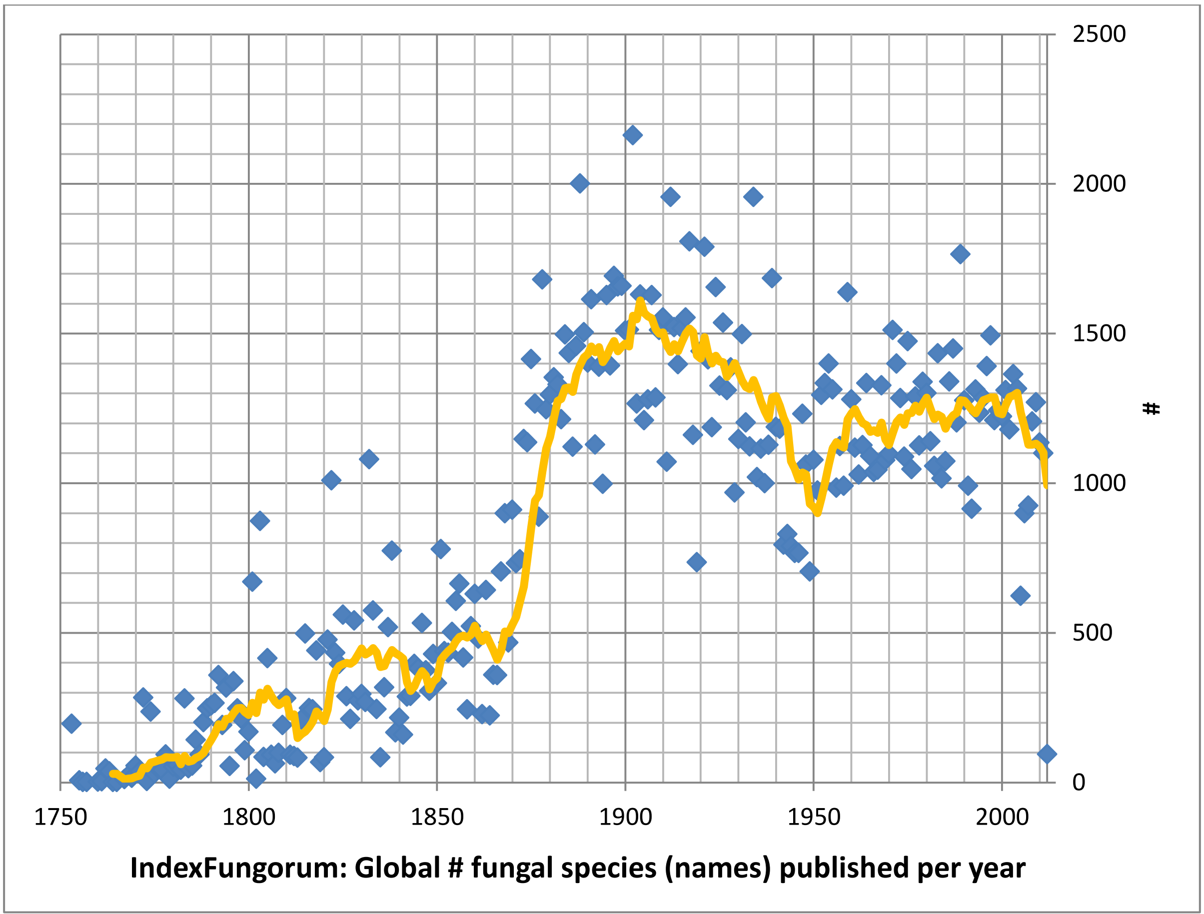
Just to emphasize, these figures for recombination are successive shifts of a species epithet to different genera and reflect differences in opinion (improved knowledge) on the appropriate position in a classification, not any uncertainty about the species itself. They are homotypic (or objective) synonyms.

Often a taxonomist will decide that two fungi named separately (and thus based on different types) represent the same taxon. We'll come back to that later. First let's examine in more detail the creation of the new names (not recombinations).

SPECIES DESCRIPTION RATES – ASSOCIATED WITH NEW FUNGAL NAMES

We can examine the rate at which taxonomists have been naming new species because IF contains the year of publication of those names.

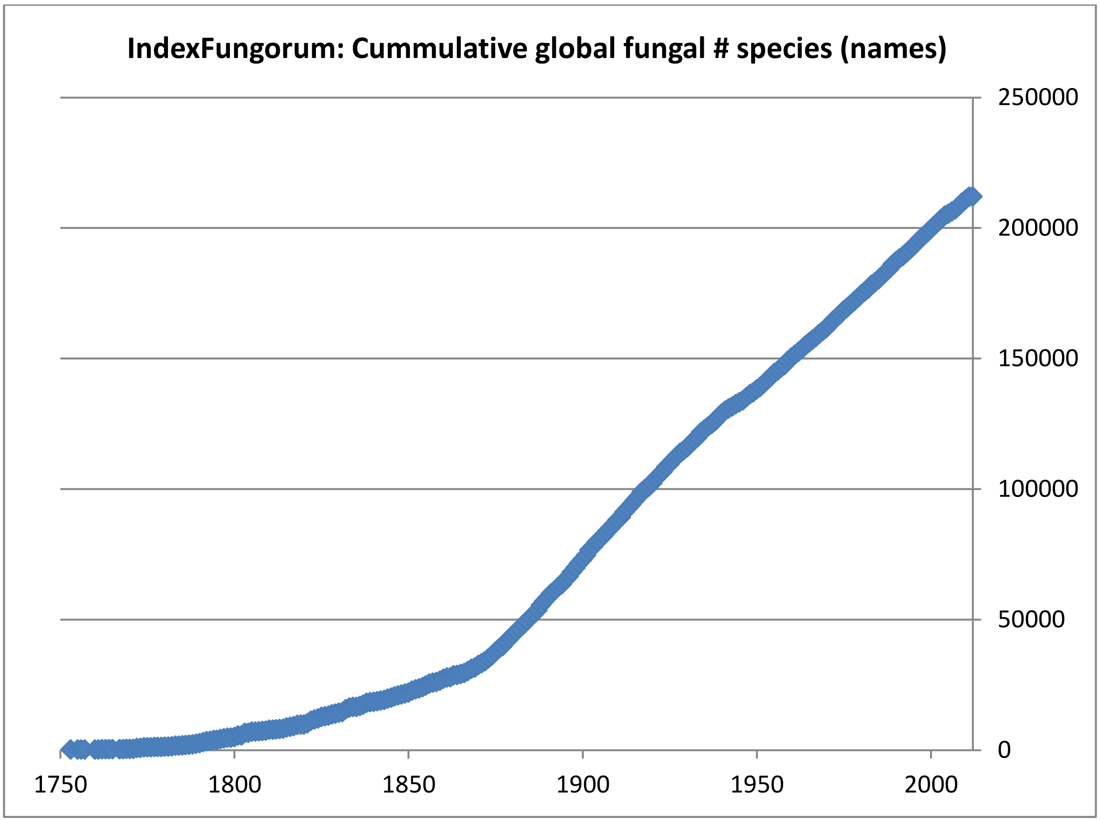
Chart 1 – IF: number of fungal species names established per year



Note this is the number of species described, which is not necessarily the actual number of species because we have a tendency to name the same species multiple times (see below).

It is interesting to speculate on the origin of the sharp increase in the 1870s. Public and economic interests in plants, insects and fungi were obviously on the increase at that time. Darwin's Origin of Species was published in 1859. Richard Owen's transformation of Natural History Museum was completed in 1880. The Smithsonian became a centre for Natural History around 1857. The Palm House completed the familiar and popular look of Kew in 1848. Economic interests across the British Empire peaked and US agriculture took off. There followed the depression and a continued post-WW2 dip. Since then we have had a steady publication rate of 1,300 new fungal names per year. There may indeed be fewer mycologists than there were historically, and maybe the geographic origin of recently named species is different to a hundred years ago, but the rate of description of new species has been fairly constant for a long time. The shape of this trend line agrees with the analysis by Costello et al (2012) for marine organisms from WORMS, and their analysis of organisms included in the Catalogue of Life. The mycological maximum pre-dates the overall trend and then both curves settle down. Plants have likewise been described at a stable rate of 2,000 per year (Knapp et al, 2005)

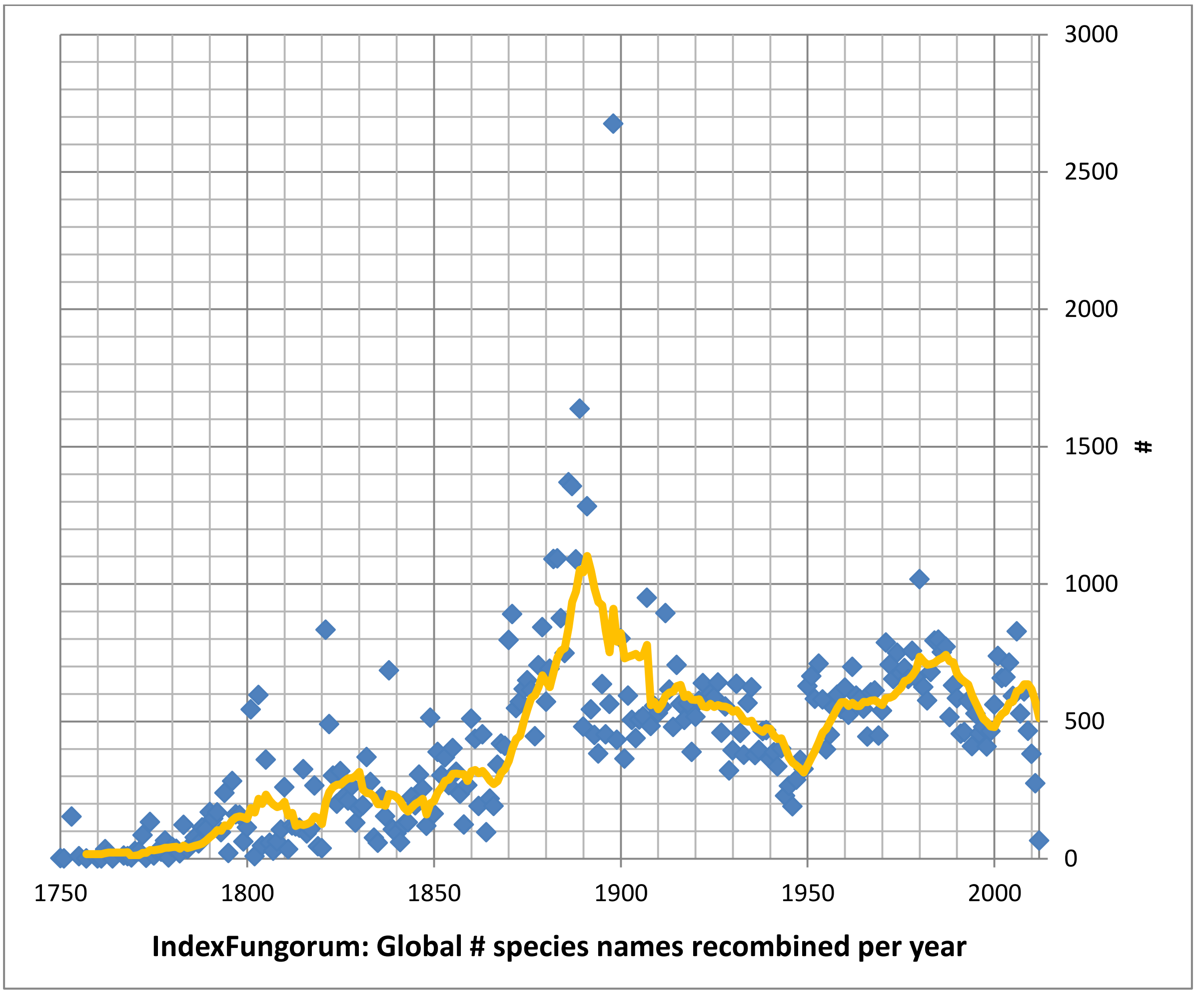
Chart 2 – Global cumulative fungal species names per year



This is the same data as Chart 1 for fungi plotted as a species name accumulation curve (names, not actual species). If we were approaching the point where all fungal species had been described then the curve would be turning over. It isn't. We are a long way from having described all fungal species. It would be interesting to see the same data for plants.

Here is the rate at which we have been recombining those fungal names associated with new species.

Chart 3 – Global fungal name recombination rate per year



So whilst we describe new species at the rate of 1,300 a year, we later change our mind about classification 500 times a year. This agrees with the estimates by Hawksworth (1991).

Unfortunately we don't yet have a long enough time series to say what has been happening since the molecular revolution. I suspect we won't see any significant change. On the one hand molecular techniques give us a more objective tool for evaluating correct classification and so recombination rates for recently described taxa should fall in the long run. On the other hand the recombination of older names will increase as they become subject to molecular scrutiny, sometimes shifting the type species of genera, with resulting wholesale recombinations of species remaining in each disestablished genus.

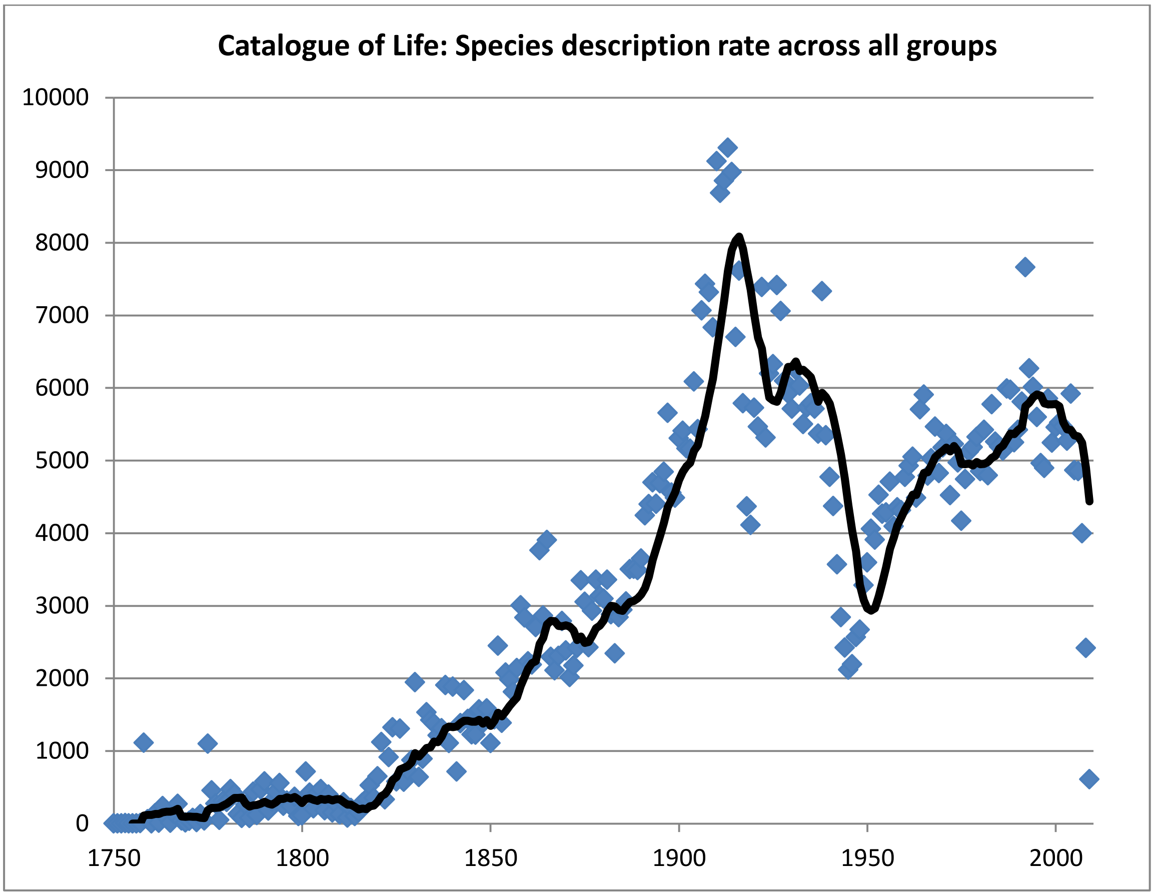
SPECIES DESCRIPTION RATES ACROSS ALL GROUPS IN THE CATALOGUE OF LIFE

The post-WW2 average across organisms represented in the CoL, as reported by Costello et al, is around 2,200 new species described per year. They excluded marine groups from their analysis. Even so, the figure is low considering we have reported values of fungi at 1,300 per year, and plants at 2,000 per year. That is already a combined total of 3,300 new species names per year, excluding the most speciose group – terrestrial insects.

I repeated Costello et al's analysis on the Catalogue of Life 2010 edition across the organism groups. CoL (2010 edition) contains 1,008,669 species names which are uncombined ('basionyms' in botanical-speak). Of those names 178,690 have no associated year of publication. A number of records have poorly formed author/year strings, constructed in non-standard ways. The data still contains homonyms which aren't nomenclaturally tagged correctly. All these were conservatively excluded from analysis leaving 811,705 names we can trust.

This just emphasizes that Global Species Databases are not always good nomenclators, and can miss/confuse data on year, place of publication and nomenclatural status etc.

Chart 4 – Global species description rates in the Catalogue of Life



This does show the same trend as fungi with a more pronounced dip during WW2 and then a description rate of around 5,500 species per year since 1970. The figure will still be an under-estimate because of the number of poorly formed names I removed. In addition CoL claims to be 70% complete (1.3million of an estimated 1.9 million), so, by extrapolation, we would expect the real global species description rate to be around 8,000-9,000 species per year across all organism groups. On the other hand the State of Observed Species Report (SOS 2011) indicates 19,000 species described in 2011, of which 10,000 were insects, and Chapman (2009) quotes similar historic figures. So where are the missing 10,000 named species per year? They would appear to be accummulating much faster than CoL is adding them. Incidentally SOS estimates global totals by accummulating previous yearly totals. Unfortunately this approach is accummulating the number of names, not the number of species, and is not taking into acount subsequent synonimisation – today's species is tomorrow's synonym (30% of the time for fungi).

THE REAL NUMBER OF FUNGAL SPECIES, AND THE NUMBER OF SYNONYMS

Now let's turn our attention to analysing fungal species numbers rather than names. The Dictionary of Fungi (2008 edition) estimates there are 97,330 described fungal species. So we have 329,527 names for 97,330 species. On the face of it the implication is 3.4 names per species (3.4 current name + synonyms). In fact the average synonymy should be lower because of the number of old forgotten names that aren't considered amongst the 97,330 species. But we can do better than this estimate for synonymy.

IndexFungorum has a partner database called SpeciesFungorum. This database tracks taxonomic opinion. It is a simple database because it effectively consists of one table with one column which points a subset of IF records to a 'preferred' name. The sources of preferred names in SF are numerous, including the lists used at CABI, at CBS, Landcare and elsewhere. It isn't always clear where the taxonomy originates. That contrasts with the way we handle taxonomic opinion with the Landcare databases. In those databases we track as much as possible the literature sources of the taxonomic opinion we are following, and to a certain extent we also capture alternative opinions which exist in the literature and we promote one of those as the 'preferred view' from Landcare.

SF currently contains opinion on 48,227 species or 52% of the estimated known number (the DOF figure). Let's examine those numbers in a bit more detail. The 48,227 species are represented by 129,126 names. In other words the average combined synonymy rate (heterotypic and homotypic) is 2.7, i.e. on average there are 2.7 names for every species. This synonymy includes both heterotypic names, and the homotypic synonyms of each of the heterotypic names. If your brain hurts at that statement then look back at the synonymy statement at the beginning of the article. To make it simpler to understand forget about names for a minute. Ultimately every name can be traced back to a 'type', i.e. a single physical specimen (or surrogate for a specimen where it does not exist). So, on average, how many types correspond to a single species? The 48,227 species correspond to 66,368 types (basionyms). In other words there are on average 1.4 types per name, but there are more homotypic names associated with each of those types. The 1.4 names per type is reflecting the inability of taxonomists to determine that something has been described before; perhaps they didn't have access to the literature or comparative material, or the organism is cryptic, not easy to describe and not easy to trace. They end up naming something again. Then to compound the problem with describing the same species multiple times, they also can't decide where to classify it and so shift things again. It is this combinatorial multiplication that leads to the 2.7 names per species problem.

The situation is enumerated in more detail in the table below. 85% of species are represented by 1 type, 9.7% are represented by 2 types and so on, down to one species that is represented by 80 types, i.e. the same species was named independently 80 times (according to somebody's taxonomic opinion).

Table 3 – Global fungal synonymy rates

Number of types	Number of species	Percent
1	54211	85.2093%
2	6183	9.7185%
3	1540	2.4206%
4	679	1.0673%
5	347	0.5454%
6	199	0.3128%
7	115	0.1808%
8	94	0.1477%
9	61	0.0959%
10	43	0.0676%
11	30	0.0472%
12	22	0.0346%
13	14	0.0220%
15	12	0.0189%
14	11	0.0173%
16	9	0.0141%
17	9	0.0141%
20	5	0.0079%
22	5	0.0079%
21	4	0.0063%
18	4	0.0063%

32	3	0.0047%
25	3	0.0047%
19	3	0.0047%
26	2	0.0031%
27	2	0.0031%
49	1	0.0016%
45	1	0.0016%
44	1	0.0016%
38	1	0.0016%
30	1	0.0016%
28	1	0.0016%
24	1	0.0016%
37	1	0.0016%
50	1	0.0016%
70	1	0.0016%
86	1	0.0016%

Table 4 – Globally the ten most synonymised fungal names

Current name	# types	# names	What is it?
Candida albicans	86	192	pathogen of humans
Saccharomyces cerevisiae	70	113	baker's yeast
Glomerella cingulata	50	72	plant pathogen
Phellinus gilvus	49	128	bracket fungus
Rhizopus arrhizus	45	61	pin mould
Colletotrichum coccodes	44	49	plant pathogen
Daedalea flavida	38	75	bracket fungus
Favolus tenuiculus	37	56	bracket fungus
Diaporthe eres	32	54	ascomycete
Peronospora farinosa	32	43	plant pathogen

Candida albicans has been described independently 86 times and is known by a whopping 206 different names! Imagine you were trying to search the literature for all relevant articles on this species. You would need to systematically search under each of the 206 alternative names.

Also notice how many of the top offenders are pathogens. It's natural that organisms receiving the greatest attention also end up with the most alternative names.

The New Zealand species addition rate

So having looked at the addition rates on a global scale let's focus our attention on New Zealand.

Chart 5a – Number of NZ fungal, plant & terrestrial invertebrate species by description dates

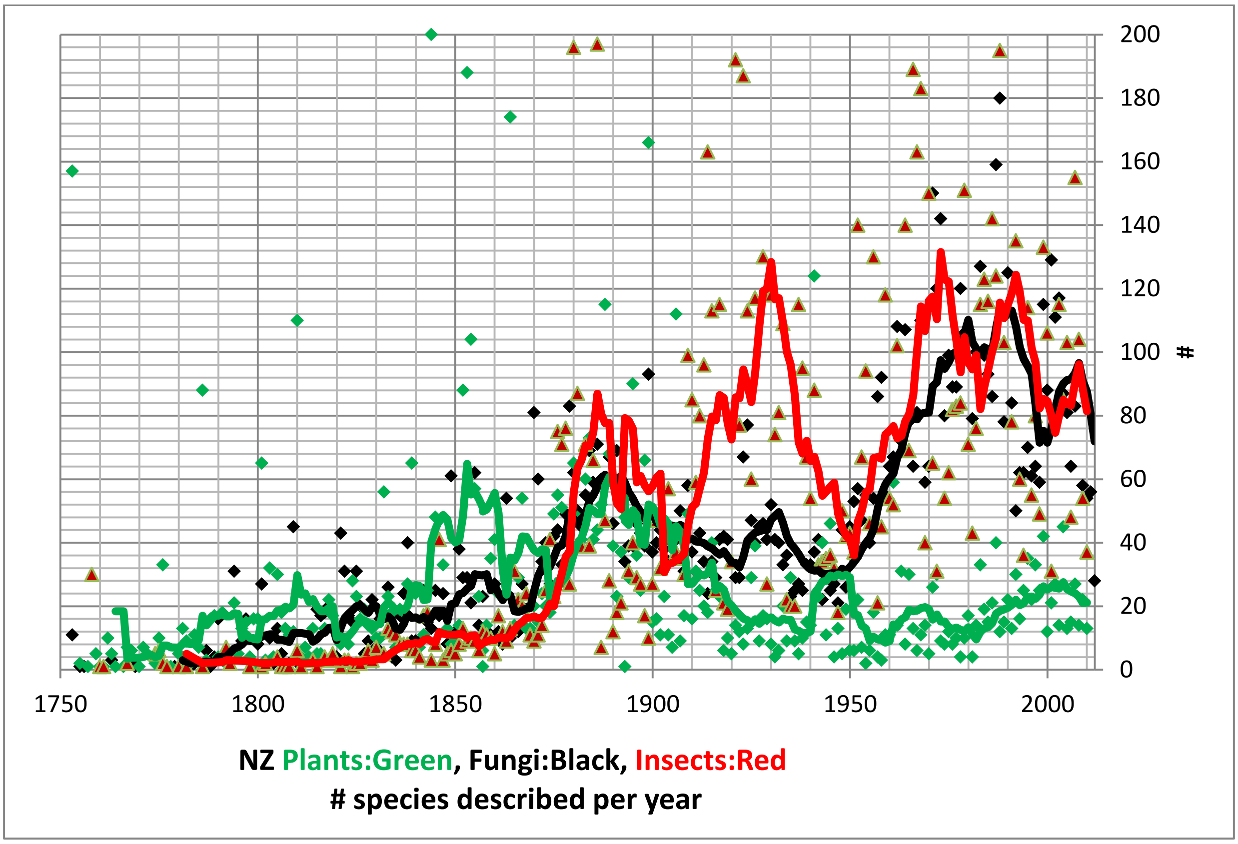
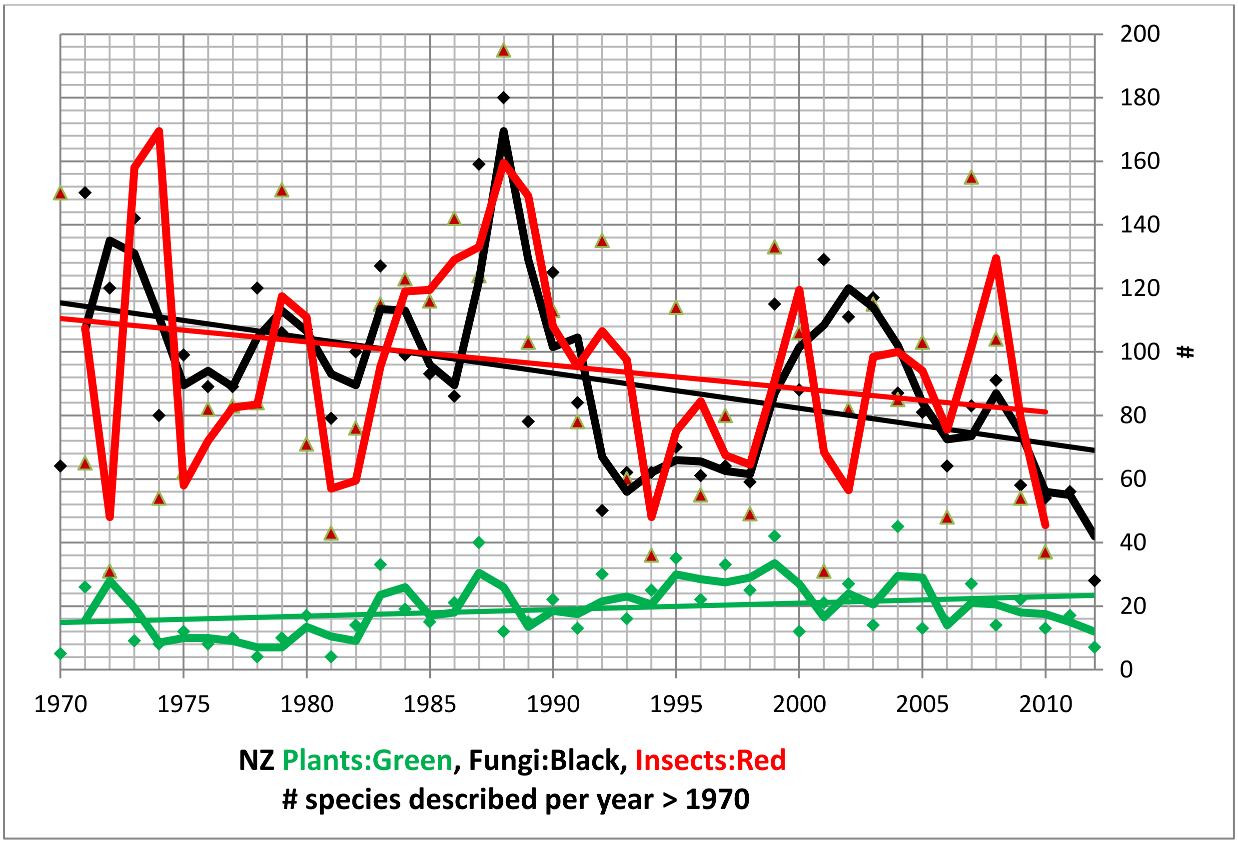


Chart 5b – Number of NZ fungal, plant & terrestrial invertebrate species by description dates (> 1970)

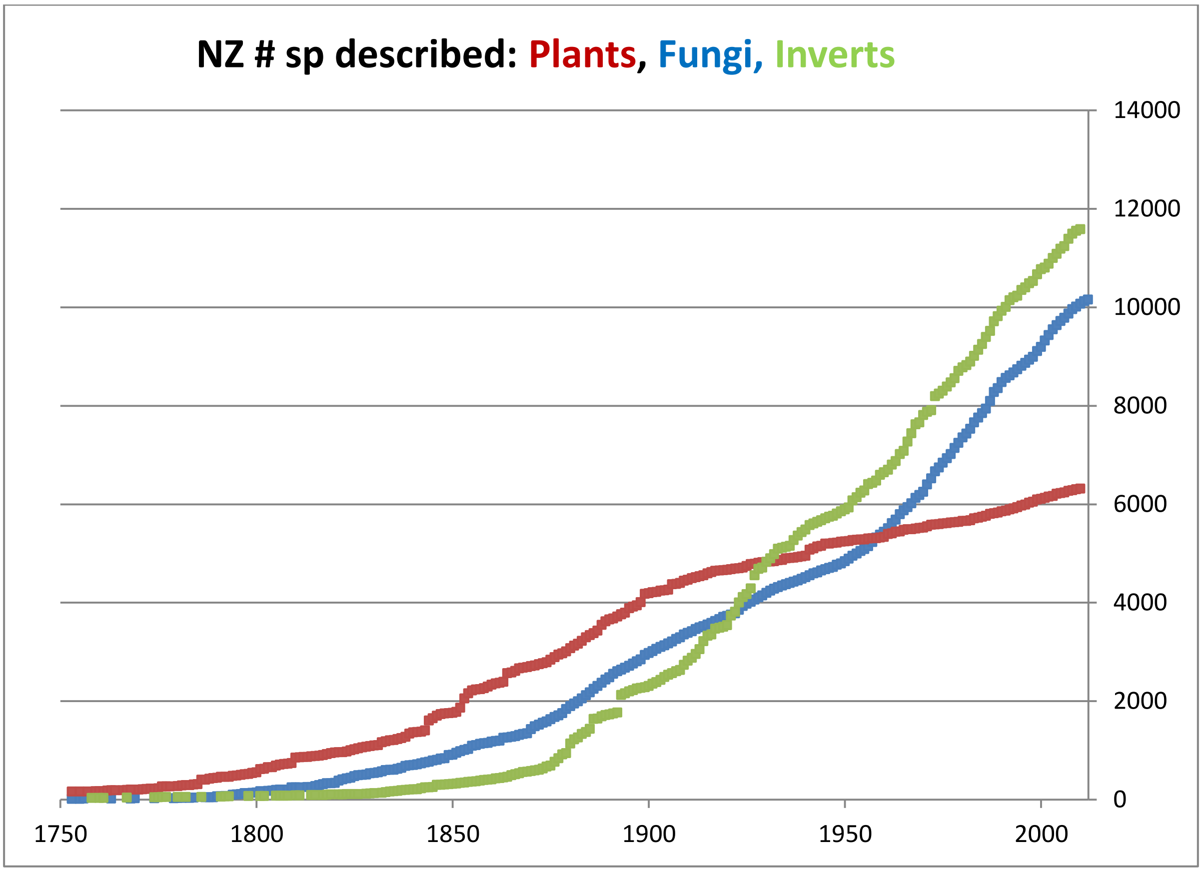


These charts show the number of species recorded from New Zealand each year by the date of description. For fungi it excludes lichens (included in the plant figures). It is not the year of first introduction, but rather the year the species was described. Newly described NZ indigenous species may be known for a long time before they get formally described. Likewise, introduced and some indigenous species may have been named many years before they get recorded in New Zealand. The chart is therefore an imperfect representation of the effort we have been putting into finding and naming species. The charts show some similar trends and differences to the trends at the global level for fungi specifically (Chart 1) and all groups in the catalogue of Life (Chart 4). New Zealand fungi got attention in the 1880s, about a decade before the rest of the world. We then had the same post WW2 dip as the rest of the world but then we took off in the 50s, as a consequence of Cunningham & Dingley and the glory days of DSIR. The sharp decline around 1990 is suspiciously close to the disestablishment of DSIR and the creation of the Crown Research Institutes in 1992. Also, notice the difference in the trend line for plants, fungi and terrestrial invertebrates. The fungal and invert rate in New Zealand overtook the plant rate around 1910 and stayed that way. The magnitudes of the trend lines for fungi and insects are remarkably similar, and plants lower, which is interesting considering the national resource available to study plants relative to fungi and insects. The post DSIR crash did not affect the rate of plant description in the same way it affected fungi and invertebrates. The rate of plant discovery has remained stable and is increasing slightly, whilst the rates for fungi and terrestrial invertebrates crashed around 1990 and despite some recovery around 2000 they remain on a significant downward trajectory. That is a concern considering the most significant economic impacts to our primary industries come from insect pests and fungal/bacterial/viral pathogens. Our ability to find and label what we have must surely bear some relationship to biosecurity incursion risk? These figures suggest the risk of pests/pathogens going unnoticed early, when we can do something about them, is increasing.

Whether the decline 1990-1995 and the disestablishment of DSIR in 1992 is a coincidence or not requires further analysis. The following is my opinion on what has happened, based on these data and personal observation, and I may be wrong. It was probably seen as a good idea to bring all DSIR systematics research together into a single CRI, which became Landcare Research. I imagine the thinking was that such a move would provide critical mass, and would be better able to service the systematics requirements of areas of research in ecology, agriculture, forestry and so on, as well as supporting 'alpha taxonomy' – discovering and describing our biodiversity. As a consequence, what used to be the DSIR 'Plant Disease Division' got split from the areas it served, which ended up in different CRIs Ag Research, Crop & Food, Hort Research, Forest Research (some entities pre-dated CRIs). That logical approach to rationalisation rapidly became undermined by the competitive funding model. CRIs had to compete with each other for the limited funding from central government, and so the reality of research in one CRI supporting work in other CRIs rarely happened and inter-CRI/agency communicating channels declined. Research in economic mycology continued within Landcare Research with reduced capacity but it was also stimulated to some extent within other CRIs to service internal requirements. Also as a consequence of the poor collaboration/communication that original capability in DSIR was re-invented within MAF (now the Ministry of Primary Industries – this year at least). The result is a clear overall decline in taxonomic research effort in groups of critical economic importance. In the last two years CRIs have a new Core Funding model and inter-CRI competition is reduced. That's a situation we are still getting used to, but initial signs of renewed collaboration are good. But the Core Funding model, where each CRI decides on, and funds, its own research priorities, may not solve a fundamental problem. The new model simply internalises competition within each CRI and the consequent prioritisation may have negative national consequences. Research having cross-CRI/agency research/operational benefit is at risk of being perceived as lower priority within the context of a single CRI. Thus critical areas of cross-outcome/cross-agency national public-good research may be at serious risk of being squeezed further, to the point of failure. Checks and balances need to be effective to stop that natural tendency. This kind of national public good research needs a national coordination framework to evaluate, prioritise and protect against erosion. Surely the scenario I outline here is rather obvious? What am I missing? The data demonstrate we have made things worse by isolating mycological research, not better, and it has become less efficient and less cost-effective at the national level. The existing research funding/coordination environment will not improve the situation without intervention.

But back to systematics rather than politics. Are we reaching the point where we have described all New Zealand species?

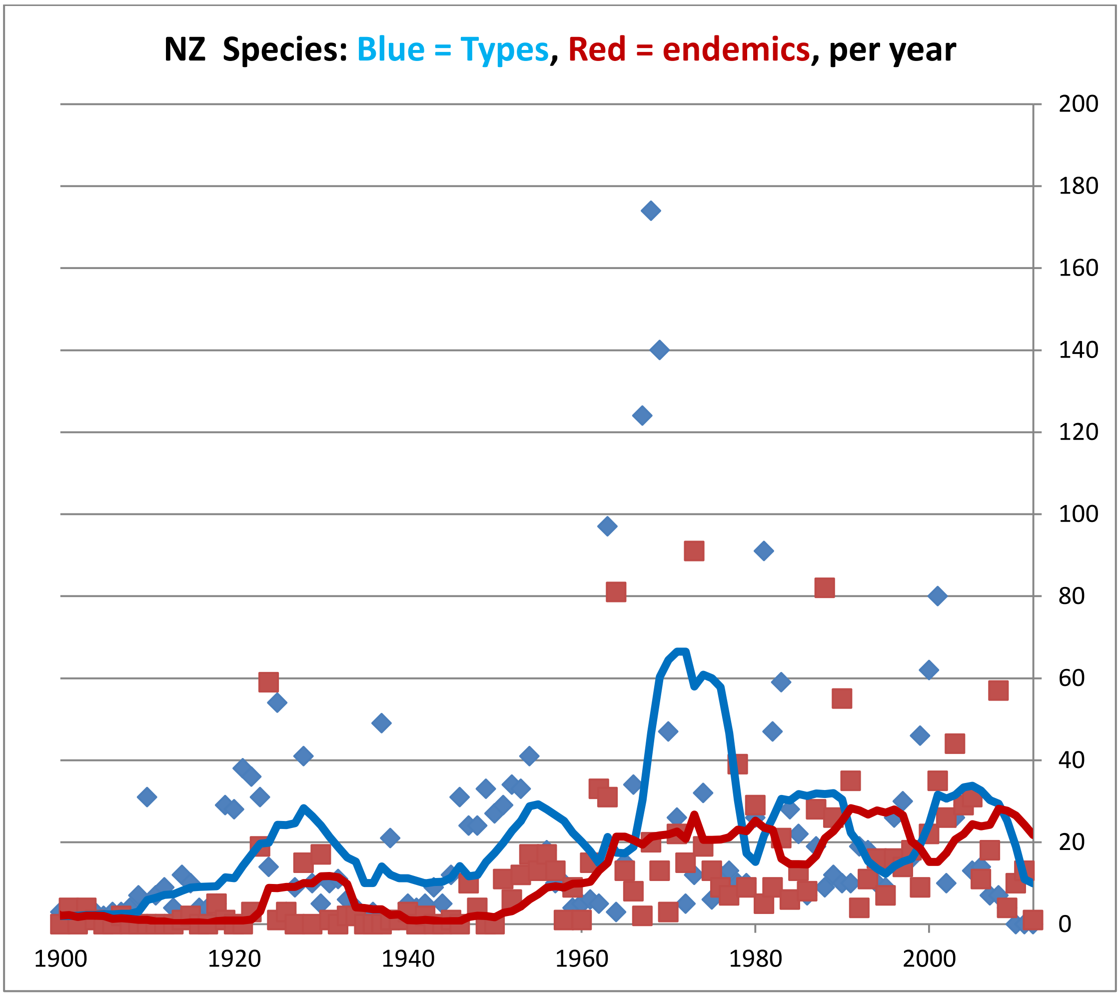
Chart 6 – NZ cumulative species curves



The answer is clearly no. There is no sign of the fungi and terrestrial invertebrate trajectories levelling off, whilst plant description is flattening.

So what is the rate at which we are naming New Zealand fungal species? We can get a handle on that by looking at the number of indigenous/endemic species described per year, and the number of New Zealand types housed in the PDD national 'fungarium'.

Chart 7 – Number of endemic species described, and number of types added to PDD per year

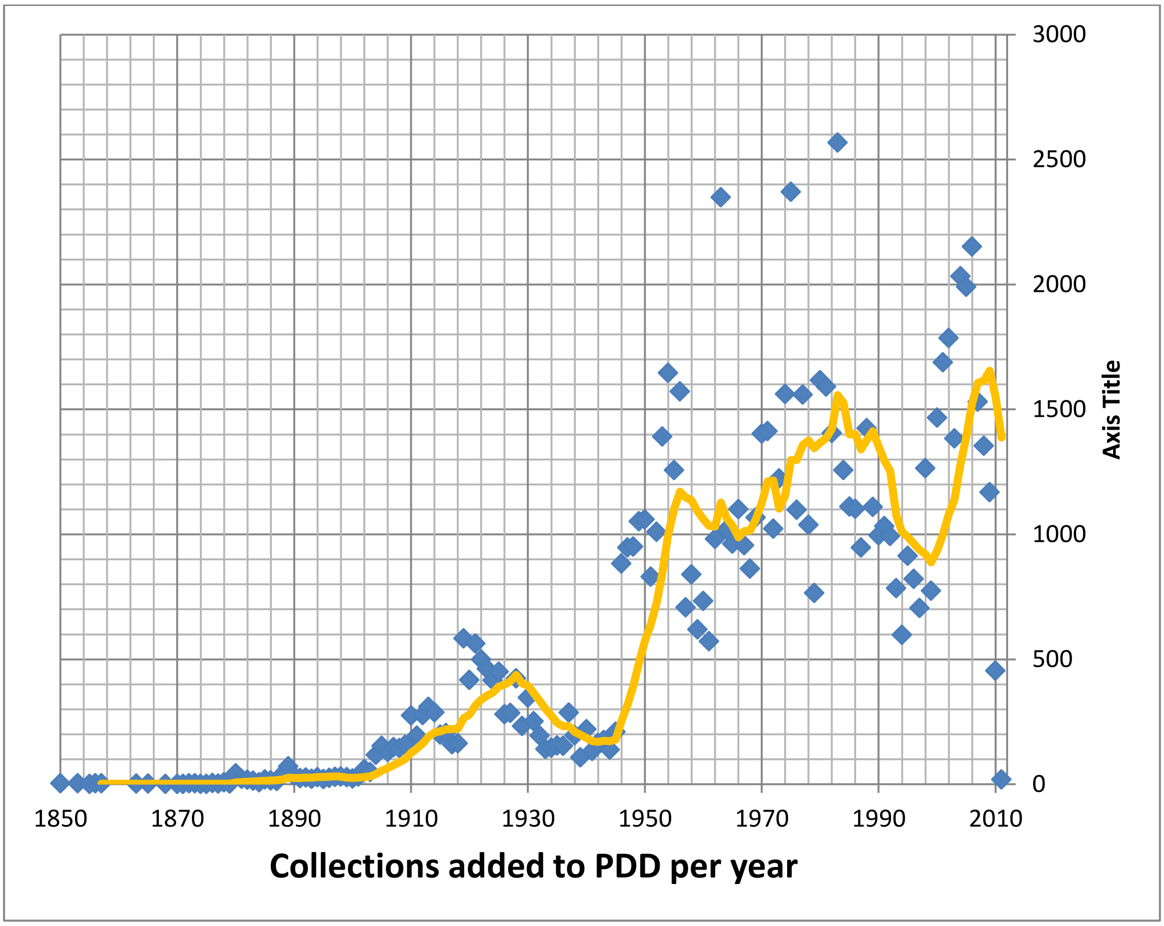


The blue Type data are numbers for those New Zealand types housed within PDD, whereas the figure for NZ named endemic species should be more inclusive of data held globally about New Zealand species. The data are noisy and of low amplitude but on average we name about 20 new fungal species per year (and about 25 new plants per year). Consider that against the global figure of 1,300 per year. I.e. in one of the world's developed counties, a member of the OECD and an acknowledged biodiversity hot-spot we describe just 1.5% of the global total. To see how much we differ, say to Europe or the US would require more data than I have available. Evidence for plants (Joppa et al, 2012) for American biodiversity hot-spots support the rather obvious conclusion that they contain most undescribed plant species. Moreover the rate of description of plant species in those hot-spots is increasing exponentially. By extrapolation, hotspots, including New Zealand, also contain the most undescribed fungi (6 times as many), but it's for sure there isn't an exponential increase in their description, and certainly not in New Zealand. We haven't been able to mobilise the same level of resources for our fungi that Mexico, Equador and Peru have mobilised for studying their plants. I guess that's not surprising – just a little depressing.

New Zealand Fungarium addition rates

If we turn our attention not to species and names but to collections housed in the PDD national 'fungarium'.

Chart 8 – number of collections added to PDD per year

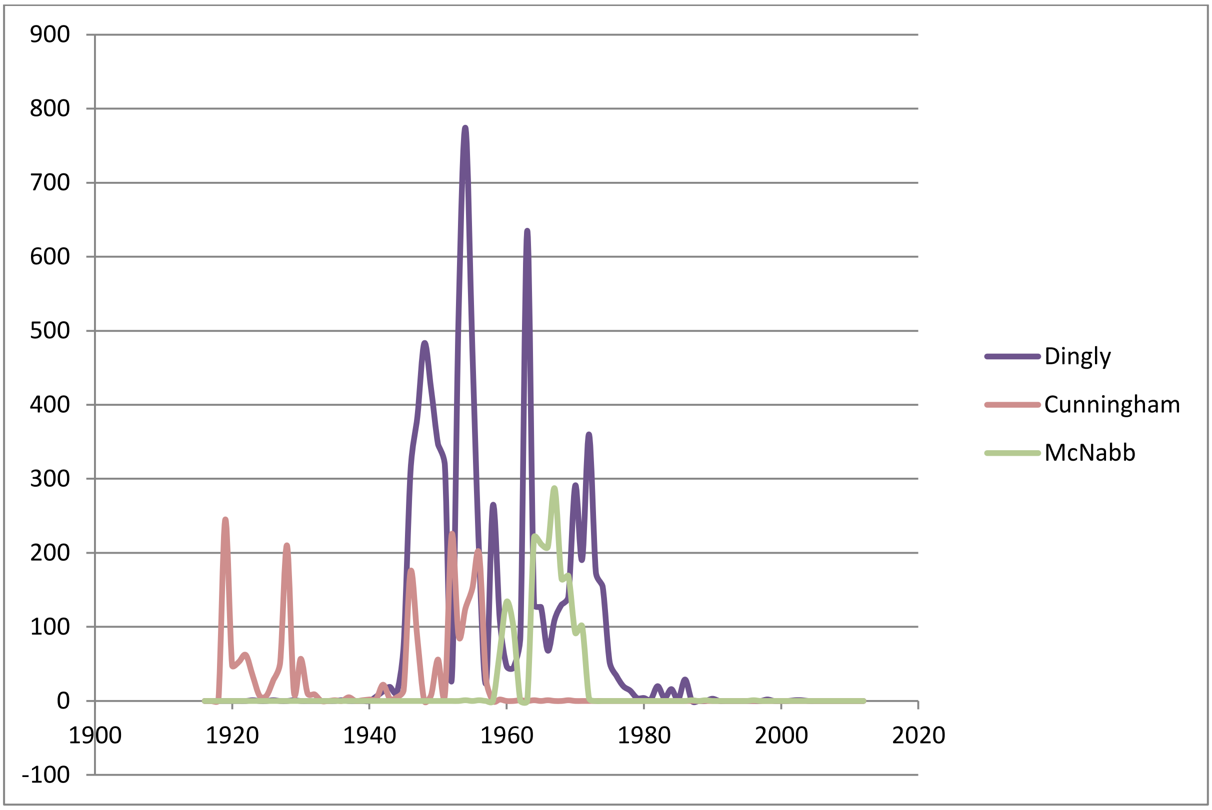


It shows the same basic curve as the number of new NZ species. Let's look a bit more closely: who provided collections, and when.

Table 5 - The top ten New Zealand collectors

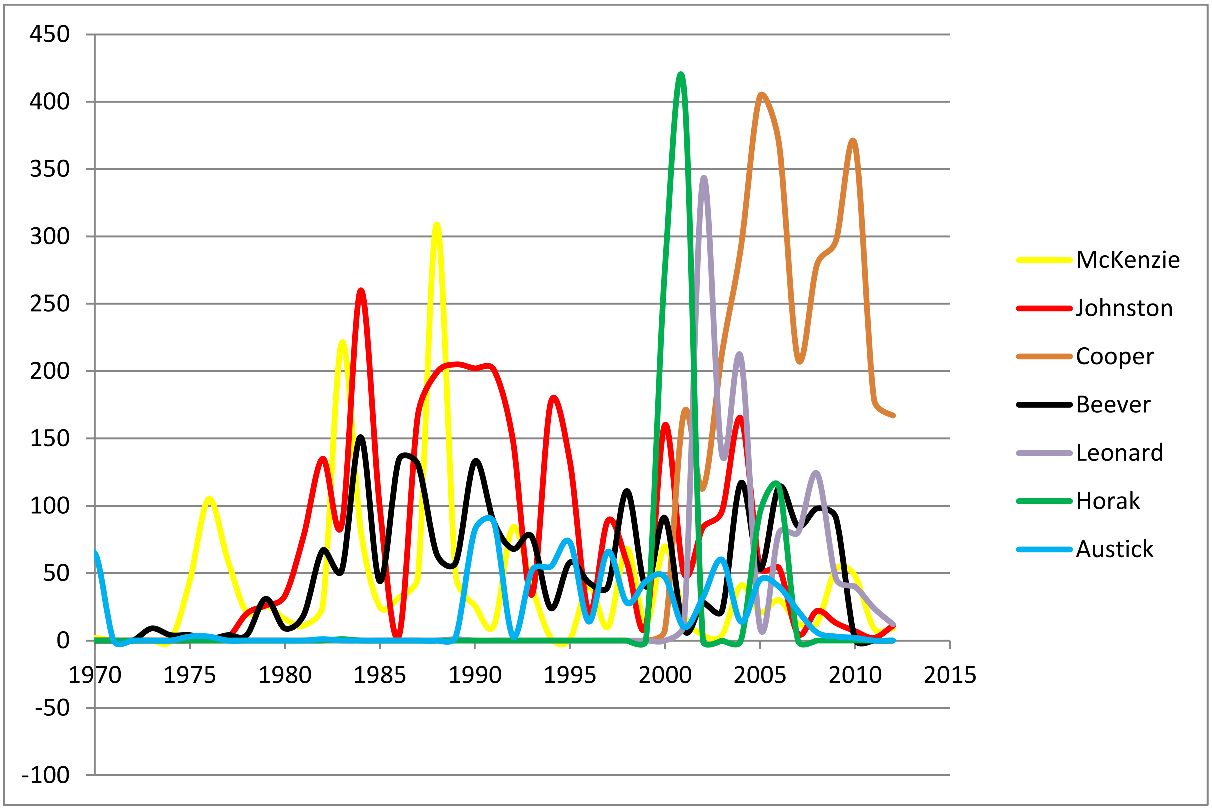
Collector	#
J.M. Dingley	7714
P.R. Johnston	3147
J.A. Cooper	3072
R.E. Beever	2191
G.H. Cunningham	2055
R.F.R. McNabb	1769
E.H.C. McKenzie	1712
P. Leonard	1121
E. Horak, A. Horak	896
P.K.C. Austwick	894

Chart 9 - Collections per collector over time – the DSIR years



Joan Dingly was a prodigious collector over 30 years. Nobody has come close to the same effort.

Chart 10 - Collections per collector over time – the CRI years



Overall we see the same critical decline on the disestablishment of DSIR in 1992, but since 2000 there has been a sign of recovery, largely a result of Egon Horak, Pat Leonard and myself. Whilst the former two collectors focus on agarics, my collection is crosses several fungal groups. Egon's agaric collections may dominate figures in the years he has collected in New Zealand. He has yet to deposit much material he is still researching. So at least maybe we have the material to name new species in the future on the basis of recent collections for some groups, even if we don't currently have the taxonomists or economic climate to actually do the work. And PDD isn't the only fungal collection in New Zealand accummulating such material.

Estimates of total described and undescribed fungal species

The generally accepted prediction for the total number of fungal species is 1.5 million (Hawksworth, 1991). Hawksworth based his analysis on ratios of fungi/plants in areas where both groups are well studied and the data indicated a consistent 6:1 ratio of fungi to plants. He then used the global estimate of plant species at that time of 270,000 to arrive at his figure of 1.5 million. The current estimate of plant species is 300,000 (The global working plant checklist) and so perhaps the 1.5 million should be revised up slightly. Schmit & Mueller (2007) estimate a lower bound of 750,000 fungi. On the other hand Blackwell (2011) estimates 5.1 million fungi. This estimate is however based on the results of high throughput sequencing of environmental samples, and the evidence currently suggests the technique coupled with current analysis pipelines can grossly overestimate 'operational taxonomic units', so personally I view this estimate with suspicion. Mora et al, 2011, estimated 611,000 fungi. They quote 43,271 'catalogued fungi' which is incorrect. Their approach is based on statistics of higher taxa, which for fungi at least, remain fluid entities, currently under molecular re-construction. So for fungi at least, their analysis is suspect.

In New Zealand we have the NZFUNGI & CHR (lichens) databases, which are reasonably up to date and complete. The combined fungal and plant data are brought together through the New Zealand Organisms Register (NZOR). This tells us we have 7,558 fungi with only 1,958 of those considered to be indigenous and the rest introduced. For plants we have more certainty on their indigenous/introduced status and we have 5,895 indigenous plants. Let's ignore fungi associated with naturalised introduced or cultivated plants for the moment, and also assume that most of the indigenous plants have already been described. Hawksworth's 6:1 ratio then tells us we can expect 35,000 fungi. So even if we consider the inclusive figure of 7,558 fungal species then we have described just 22% of our indigenous fungi. This figure is almost certainly an underestimate when we consider the impact of both introduced/cultivated plants and their associated introduced fungi.

So, at the global level, we have a lot of work to do in bridging the gap between the 97,000 we know about and the estimated 1.5 million total. With new fungi being described at the rate of 1,300 per year it will take 1,403 years to complete the task. In New Zealand it will take us at least 1,372 years to describe or missing 27,000 species at the rate of 20 per year.

Of course we don't actually need to describe all fungi. That is stamp-collecting mentality. I would contend that we need both the broad overview of all fungal species which can be provided by recent molecular techniques, coupled with detailed traditional systematic knowledge of a representative subset of taxa, focussed on those which are commonly encountered, or of conservation or economic importance. Whilst it is certainly possible to name and describe all plants (just because we can), it is not possible or sensible to do the same for fungi using traditional methods. We need to get the balance right, but even that balance still needs much more resource than we currently have. We should also perhaps carry out a re-evaluation of what went wrong after the disestablishment of DSIR for mycological research in New Zealand, and put it right.

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