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Commentary

Fungal under-representation is (indeed) diminishing in the life sciences

SUMMARY

A commentary in *Fungal Ecology* (Pautasso 2013) reported a significant (although shallow) increase through time in the proportion of papers mentioning fungi for 25 out of 30 keywords (ranging, e.g., from ecology to mountain, from agriculture to disease). Dam (2013) complains in his commentary about the rounding-off of the parameter estimates in the scatterplots of Pautasso (2013) and suggests the use of relative years. When repeating the analyses starting to count years from 1990, the regression lines have exactly the same *p* values, *r* squares and slopes. Dam (2013) also offers an alternative explanation for the decrease in fungal under-representation in terms of increased use of diverse keywords by researchers, potentially due to the increased importance of the h-index in evaluating scientists. One problem with this explanation is that the h-index was invented in 2005, whereas the observed decrease in fungal under-representation has occurred gradually over the period 1991–2010. Additional evidence provided here confirms the decrease in the under-representation of fungi, because 'fungal' papers have increased in proportion over the last years for the literature mentioning antibiotics, endophytes, pharmacology, patents, old-growth, humans, taxonomy, phylogeny, evolution, biochemistry, chemistry, nanotechnology, cells, microbes, meta-analysis, bioinformatics, biomaterials, biotechnology, long-term, boreal, tropical, Mediterranean and gardens.

A commentary in *Fungal Ecology* reported that fungal under-representation is diminishing, albeit slowly, in the life sciences (Pautasso 2013). That study investigated whether there is a temporal trend over the period 1991–2010 in the proportion of papers mentioning fungi out of papers retrieved from Web of Science using various keywords. A significant (although shallow) increase through time in the proportion of 'fungal' papers was found for 25 out of 30 keywords (ranging, e.g., from biodiversity to climate change, from urban to network and health).

Dam (2013) complains in his commentary about the rounding-off of the parameter estimates in the scatterplots of Pautasso (2013) and suggests the use of relative years. When repeating the analyses replacing 1991 with 1, 1992 with 2, etc., the regression lines have exactly the same *p* values, *r* squares and slopes (Table 1). This is because subtracting 1990 from the values on the *x*-axis corresponds to moving the *y*-axis to the right by 1990 in the Cartesian space, without distorting it. In other words, if the rate of increase for, e.g., the proportion of 'fungal' papers on grasslands is 1.5% per decade (0.15% per year), this is the case both if we start counting years from 1990 or from year 0. Providing additional precision to such an estimate may not help our understanding much: if the rate is 0.153% per year, at the end of the decade the proportion will still only have increased by roughly 1.5%.

What differs when using absolute versus relative years is the intercept, which in Pautasso (2013) corresponded to the proportion of 'fungal' papers published back in Ancient Roman Times (can we really be precise in such estimates?), whereas the intercept in Table 1 is the estimated proportion of 'fungal' papers published in 1990, which could be easily gauged from the scatterplots in Pautasso (2013). May I add that the intercept of regression lines is immaterial when trying to assess whether their slope is significantly different from zero.

Table 1 also provides standard errors for intercepts and slopes, as requested by Dam (2013). Significant trends as assessed from the *p* values in Pautasso (2013) are still significant when assessing them using the standard errors. For the epidemi* scatterplot, Pautasso (2013) used a quadratic function because it explains 76% of the variance, whereas a linear regression only explains 58%. It would also have been possible to fit a linear increase for the first decade and no (or a constant?) relationship for the second one. In all cases, it is clear from a visual inspection of the scatterplot that, unlike for the other topics, there has been a change in the trend towards the middle of the studied period.

Dam (2013) also criticizes the lack of information about how many papers in total were retrieved for each keyword. This information is now provided in Table 1, for each keyword on its own and when combined with 'fung*' and 'insect*'. There is no significant association of such numbers with neither r2 nor slopes of the regressions (unpubl. observations). I agree with Dam (2013) that, given the quantities of papers on each studied topic, it was "effectively impossible to judge how many papers really dealt in depth with fungi and the chosen keywords". However, this was acknowledged by Pautasso (2013): "Whilst for example not all ecological papers will be

Table 1 — Parameter estimates of the regressions in Pautasso (2013) when using 1991 = 1

Keyword (tot papers)		R^2	Intercept (±s.e.)	Slope (±s.e.)	*P* value	*N* papers
ecolog*	Fungi	0.74	2.26 (±0.09)	0.055 (±0.008)	<0.001	5 722
188 985	Insects	0.19	5.33 (±0.14)	0.024 (±0.012)	0.06	9 661
biodiversity	Fungi	0.44	3.20 (±0.37)	0.117 (±0.031)	0.001	1 787
36 832	Insects				n.s.	2 170
“species richness”	Fungi	0.51	2.42 (±0.24)	0.085 (±0.020)	<0.001	780
21 391	Insects	0.31	11.7 (±0.9)	−0.201 (±0.071)	0.01	1 912
biolog*	Fungi	0.65	2.34 (±0.06)	0.039 (±0.005)	<0.001	16 472
607 668	Insects				n.s.	15 518
environment	Fungi	0.93	0.98 (±0.03)	0.033 (±0.002)	<0.001	12 663
895 856	Insects				n.s.	12 743
soil	Fungi	0.51	6.06 (±0.12)	0.042 (±0.010)	<0.001	19 237
293 287	Insects	0.20	2.32 (±0.09)	−0.015 (±0.007)	0.05	6 274
molecular	Fungi	0.97	0.77 (±0.03)	0.049 (±0.002)	<0.001	16 420
1 194 429	Insects	0.72	0.71 (±0.03)	0.020 (±0.003)	<0.001	11 326
genetic*	Fungi				n.s.	9 233
588 330	Insects	0.25	1.75 (±0.04)	−0.008 (±0.003)	0.02	9 718
landscape*	Fungi	0.69	0.30 (±0.06)	0.031 (±0.005)	<0.001	538
72 203	Insects	0.77	1.30 (±0.17)	0.111 (±0.014)	<0.001	2 065
biogeogr*	Fungi	0.22	1.32 (±0.24)	0.045 (±0.020)	0.04	357
18 366	Insects				n.s.	917
mountain*	Fungi	0.50	0.78 (±0.12)	0.016 (±0.010)	<0.001	924
68 341	Insects				n.s.	1 663
“climate change*”	Fungi	0.72	0.05 (±0.10)	0.057 (±0.008)	<0.001	455
48 880	Insects	0.47	1.02 (±0.18)	0.060 (±0.015)	<0.001	953
marine	Fungi	0.88	0.80 (±0.07)	0.069 (±0.001)	<0.001	2 389
142 416	Insects				n.s.	1 015
freshwater	Fungi				n.s.	610
37 509	Insects	0.26	2.39 (±0.12)	0.025 (±0.010)	0.02	1 023
forest*	Fungi	0.83	2.82 (±0.14)	0.110 (±0.011)	<0.001	6 782
160 617	Insects				n.s.	7 423
grassland*	Fungi	0.71	2.79 (±0.28)	0.153 (±0.023)	<0.001	1 214
25 194	Insects				n.s.	981
agric*	Fungi	0.79	2.39 (±0.12)	0.084 (±0.010)	<0.001	3 875
110 945	Insects	0.78	3.14 (±0.12)	0.084 (±0.010)	<0.001	4 697
urban*	Fungi	0.71	0.22 (±0.03)	0.014 (±0.002)	<0.001	539
133 731	Insects	0.49	0.51 (±0.08)	0.028 (±0.007)	<0.001	1 188
seed*	Fungi	0.36	5.61 (±0.12)	−0.031 (±0.010)	0.005	10 565
201 877	Insects	0.26	3.57 (±0.09)	−0.019 (±0.008)	0.02	6 734
fruit*	Fungi				n.s.	6 301
102 258	Insects	0.30	6.58 (±0.25)	−0.057 (±0.021)	0.01	5 985
food*	Fungi	0.93	0.92 (±0.04)	0.060 (±0.004)	<0.001	5 407
319 771	Insects	0.22	3.17 (±0.08)	−0.016 (±0.007)	0.04	9 471
wood	Fungi				n.s.	5 249
64 751	Insects	0.55	1.97 (±0.14)	0.056 (±0.012)	<0.001	1 724
“new species”	Fungi	0.45	3.66 (±0.35)	0.112 (±0.029)	<0.001	2 201
43 683	Insects	0.46	3.03 (±0.22)	0.073 (±0.019)	<0.001	1 752
network*	Fungi	0.43	0.21 (±0.02)	0.007 (±0.002)	<0.001	1 544
512 346	Insects	0.59	0.19 (±0.02)	0.007 (±0.001)	<0.001	1 464
epidemi*	Fungi	0.78	1.039 (±0.123)	−0.0048 (±0.0011) $[x^2]$ 0.1319 (±0.0235) $[x]$	<0.001	4 694
245 513	Insects	0.21	0.63 (±0.04)	0.007 (±0.003)	0.04	1 800
pathog*	Fungi	0.33	7.49 (±0.16)	0.040 (±0.013)	0.007	30 531
380 713	Insects	0.92	1.10 (±0.03)	0.034 (±0.002)	<0.001	5 882
disease*	Fungi	0.19	1.47 (±0.03)	0.006 (±0.003)	0.05	27 851
1 796 931	Insects	0.71	0.36 (±0.01)	0.007 (±0.001)	<0.001	7 967
health*	Fungi	0.38	0.55 (±0.23)	0.006 (±0.002)	0.003	6 492
1 027 192	Insects	0.71	0.27 (±0.01)	0.007 (±0.001)	<0.001	3 726
infect*	Fungi	0.58	4.42 (±0.08)	0.034 (±0.007)	<0.001	40 321
833 924	Insects				n.s.	11 866
immun*	Fungi	0.90	1.04 (±0.03)	0.032 (±0.002)	<0.001	16 996
1 196 557	Insects				n.s.	10 210

Table 2 – As in Table 1, for an additional set of 30 keywords

Keyword (Tot papers)		R^2	Intercept (±s.e.)	Slope (±s.e.)	P value	N papers
fossil*	Fungi	0.18	0.92 (±0.09)	0.015 (±0.008)	0.06	448
40 327	Insects	0.74	2.33 (±0.15)	0.088 (±0.012)	<0.001	1 391
antibiot*	Fungi	0.32	3.42 (±0.15)	0.037 (±0.013)	0.009	5 472
141 127	Insects				n.s.	949
herbari*	Fungi				n.s.	319
2 575	Insects				n.s.	42
endophyt*	Fungi	0.55	63.69 (±3.06)	0.0960 (±0.0283) [x^2] −1.5240 (±0.5822) [x]	0.004, 0.02, resp.	3 450
5 644	Insects	0.35	9.85 (±0.95)	−0.247 (±0.080)	0.006	372
pharmac*	Fungi	0.81	0.42 (±0.04)	0.026 (±0.003)	<0.001	2 792
372 511	Insects				n.s.	1 773
patent*	Fungi	0.40	0.21 (±0.01)	0.019 (±0.005)	0.003	151
34 732	Insects	0.52	0.45 (±0.04)	−0.165 (±0.004)	<0.001	89
old-growth	Fungi	0.47	3.80 (±0.74)	0.245 (±0.062)	<0.001	295
4 211	Insects				n.s.	186
sustainab*	Fungi				n.s.	815
64 103	Insects				n.s.	920
human*	Fungi	0.96	0.37 (±0.02)	0.029 (±0.001)	<0.001	12 502
1 743 485	Insects	0.66	0.49 (±0.02)	0.009 (±0.001)	<0.001	10 556
taxonom*	Fungi	0.21	5.34 (±0.25)	0.046 (±0.021)	0.04	4 256
71 672	Insects	0.59	2.95 (±0.19)	0.082 (±0.016)	<0.001	2 876
systematics	Fungi				n.s.	1 055
24 689	Insects	0.56	1.86 (±0.22)	0.089 (±0.018)	<0.001	725
phylogen*	Fungi	0.82	2.81 (±0.21)	0.163 (±0.018)	<0.001	5 756
114 072	Insects	0.64	3.84 (±0.16)	0.077 (±0.014)	<0.001	5 576
evolution*	Fungi	0.82	0.67 (±0.04)	0.028 (±0.003)	<0.001	6 281
610 867	Insects	0.79	1.60 (±0.05)	0.036 (±0.004)	<0.001	12 558
biochem*	Fungi	0.82	1.10 (±0.06)	0.048 (±0.005)	<0.001	3 852
229 486	Insects				n.s.	3 671
chem*	Fungi	0.80	0.90 (±0.03)	0.020 (±0.002)	<0.001	16 689
1 451 717	Insects				n.s.	12 976
botan*	Fungi				n.s.	437
12 684	Insects	0.59	2.31 (±0.56)	0.239 (±0.047)	<0.001	677
nano*	Fungi	0.60	0.451 (±0.056)	0.0023 (±0.0005) [x^2] −0.0517 (±0.011) [x]	<0.001	888
485 370	Insects	0.25	0.19 (±0.02)	−0.005 (±0.002)	0.02	588
cellular	Fungi	0.76	0.73 (±0.04)	0.023 (±0.003)	<0.001	3 832
377 909	Insects				n.s.	2 689
neuro*	Fungi	0.20	0.53 (±0.01)	−0.0024 (±0.0011)	0.05	4 795
963 768	Insects	0.87	1.13 (±0.02)	−0.019 (±0.002)	<0.001	8 706
microb *	Fungi	0.84	6.49 (±0.15)	0.121 (±0.012)	<0.001	16 145
199 877	Insects				n.s.	2 720
meta-analysis	Fungi	0.58	−0.35 (±0.08)	0.033 (±0.007)	<0.001	174
39 258	Insects	0.58	0.03 (±0.06)	0.024 (±0.005)	<0.001	142
bioinformatic*	Fungi	0.66	−0.19 (±0.21)	0.104 (±0.018)	<0.001	257
17 423	Insects	0.85	−0.27 (±0.09)	0.079 (±0.008)	<0.001	179
biomaterial*	Fungi	0.63	−0.02 (±0.01)	0.032 (±0.006)	<0.001	99
22 078	Insects	0.61	−0.09 (±0.05)	0.023 (±0.004)	<0.001	55
biophysic*	Fungi				n.s.	143
22 233	Insects	0.48	2.26 (±0.23)	−0.076 (±0.019)	<0.001	268
biotechnol*	Fungi	0.35	3.11 (±0.37)	0.010 (±0.031)	0.006	1 254
28 310	Insects				n.s.	529
long-term	Fungi	0.24	0.53 (±0.03)	0.006 (±0.002)	0.03	2 917
481 868	Insects	0.22	0.49 (±0.03)	0.005 (±0.002)	0.04	2 669
boreal	Fungi	0.88	1.30 (±0.27)	0.257 (±0.022)	<0.001	730
15 123	Insects				n.s.	562
tropical	Fungi	0.52	2.17 (±0.16)	0.060 (±0.014)	<0.001	2 450
83 959	Insects				n.s.	2 926
Mediterranean	Fungi	0.34	0.92 (±0.14)	0.037 (±0.012)	0.007	744
52 734	Insects				n.s.	1 390
garden*	Fungi	0.73	1.34 (±0.27)	0.160 (±0.023)	<0.001	595
18 104	Insects	0.42	1.99 (±0.32)	0.097 (±0.027)	0.002	572

retrieved using the keyword ‘ecolog*’ (and some retrieved papers may not be strictly ecological), the procedure allows comparability among years.”

Dam (2013) also offers an alternative explanation for the decrease in fungal under-representation in terms of increased use of diverse keywords by researchers, potentially due to the increased importance of the h-index in evaluating scientists. One problem with this explanation is that the h-index was invented in 2005, whereas the observed decrease in fungal under-representation has occurred gradually over the period 1991–2010. Moreover, not all countries may be evaluating researchers using the h-index or similar indicators. For example, in the country where I work now there are many researchers on fixed-term jobs with higher h-index than many researchers with permanent positions. As for an increased use of keywords, this is difficult to test because Web of Science does not seem to allow a search restricted to the keywords used by the authors. Moreover, this explanation overlooks the absence of an increasing trend in the proportion of papers mentioning insects in the literature on various topics for which papers mentioning fungi are proportionately increasing.

A similar difference between fungi and insects is found when repeating the analysis of Pautasso (2013) for another set of 30 keywords (Table 2): ‘fungal’ papers have increased in proportion over recent years for the literature mentioning antibiotics, endophytes, pharmacology, patents, old-growth, humans, taxonomy, phylogeny, evolution, biochemistry, chemistry, nanotechnology, cells, microbes, meta-analysis, bioinformatics, biomaterials, biotechnology, long-term, boreal, tropical, Mediterranean and gardens, whereas the proportion of papers mentioning insects has significantly increased for about 50% of these topics only (Table 2). Incidentally, for endophytes and nanotechnology, a quadratic function explained more variation in the proportion of ‘fungal’ papers than a linear regression, with an initial decrease and a recent increase.

These additional data are consistent with the (slow) decrease in fungal under-representation in the life sciences reported in Pautasso (2013). Anybody trying to keep up with the mycological literature (including literature reviews relevant to fungi) is likely to agree that papers relevant to mycologists are increasing in numbers. Nonetheless, to redress the traditional lack of attention to fungi compared to less diverse but more studied groups, papers on fungi have to increase in numbers proportionately more than the rest of the literature (which is also rapidly expanding). This is the pattern that appears to be present in many (not all) cases in the life science literature, whether we use years relative to 1990 or to 2013 yr ago.

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