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Commentary

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

SUMMARY

Mycologists often lament a relative lack of attention to fungi, a species-rich yet under-recognized group of organisms. Is this situation getting any better? Over the last two decades, there has been a general increase in the proportion of papers mentioning fungi for studies indexed in Web of Science. Depending on the associated keyword, the percentage of 'fungal' papers varies among 0.3 % (networks) and 8 % (pathogens), and the rate of increase is between 0.06 % (disease and health) and 1.5 % (grasslands) per decade. Fungi are sometimes less often mentioned than insects (e.g. in the agriculture and climate change literature), but the representation is similar for biological, environmental, genetic, fruit, new species and network papers, and fungi are more often dealt with than insects in the soil, marine, molecular, seed, food, wood and epidemiological literature. The representation of fungi has been catching up with that of insects in papers on ecology, biodiversity, species richness, biology, biogeography, mountains, forests and grasslands, whereas insects are becoming more often mentioned than fungi in papers on landscape and freshwater systems.

Fungi are a biodiversity-rich yet relatively under-studied and under-protected kingdom (Dahlberg *et al.* 2010; Bass & Richards 2011; Minter 2011; Money 2011; Yamin-Pasternak 2011; Halme & Kotiaho 2012; Pickles *et al.* 2012). It is now well recognized that fungi play essential roles in ecosystem functioning and services, whether they act as decomposers, parasites, pathogens or symbionts (Blackwell 2011; Cantrell *et al.* 2011; Philibert *et al.* 2011; Picco *et al.* 2011; Krings *et al.* 2012; Lazniewska *et al.* 2012). A generally accepted working hypothesis is that the number of existing fungal species on Earth may be around 1.5 million (Hawksworth 2001), i.e. about six–seven times the number of known plant species (May 1992; Mora *et al.* 2011). Yet, only about 2 % of papers indexed in Web of Science using the keyword 'species richness' were about fungi over the period 1991–2004, i.e. a proportion 18 times lower than for plants (Lonsdale *et al.* 2008).

Is this fungal under-representation in the scientific literature getting any better? I carried out a search in Web of Science (WOS) (all citation databases, but excluding ISI Proceedings, which only cover the 2000s) in Apr. 2012 for the period 1991–2010 (before 1991, WOS does not search within abstracts, but only in titles; some 2011 papers may still need to be indexed). The 30 keywords used covered a range of topics in the life sciences (Fig 1). The number of retrieved papers per year was noted for each keyword (i) on its own, and (ii) together with the string 'fung*'. The percentage of 'fungal papers' (those mentioning fungi) was then calculated for each keyword. Whilst for example not all ecological papers will be retrieved using the keyword 'ecolog*' (and some retrieved papers may not be strictly ecological), the procedure allows comparability among years.

The percentage of 'fungal papers' increased significantly through time for 24 out of the 30 keywords used (80 %; Fig 1). Exceptions were papers on (i) freshwater, genetics, fruit, and wood (with no significant variation), (ii) seed (with a significant decrease), and (iii) epidemics, where a quadratic function explained 75 % of the variation in the percentage of fungal papers over time, with an increase through the 1990s but a slight decrease since 2005 (Fig 1). The rate of increase ranged from about 0.06 % per decade for papers on disease/health to about 1.5 % per decade for grassland papers. The variance in the proportion of 'fungal papers' explained by publication year ranged from 19 % for disease to 97 % for molecular papers, with an average of 63 % for the 24 keywords with a significant linear increase through time (standard deviation = 23 %).

Comparing the temporal development in fungal representation with data obtained using the same procedure for insects (keyword = 'insect*'), fungi were less represented than insects in 10 cases (ecology, species richness, landscape, biogeography, mountain, climate change, freshwater, agriculture, urban and food). There was an equivalent representation of fungi and insects for nine topics (biodiversity, biology, environment, genetic, forest, grassland, fruit, new species and networks), and a larger representation of fungi for 11 keywords (soil, molecular, marine, seed, wood, epidemics, pathogen, disease, health, infection and immunity; Fig 1). As opposed to fungi, entomological papers did not show a significant increase through time in the literature about biodiversity, biology, environment, epidemiology, biogeography, mountain, marine, forest, grassland, infection and immunity. The percentage of entomological papers declined

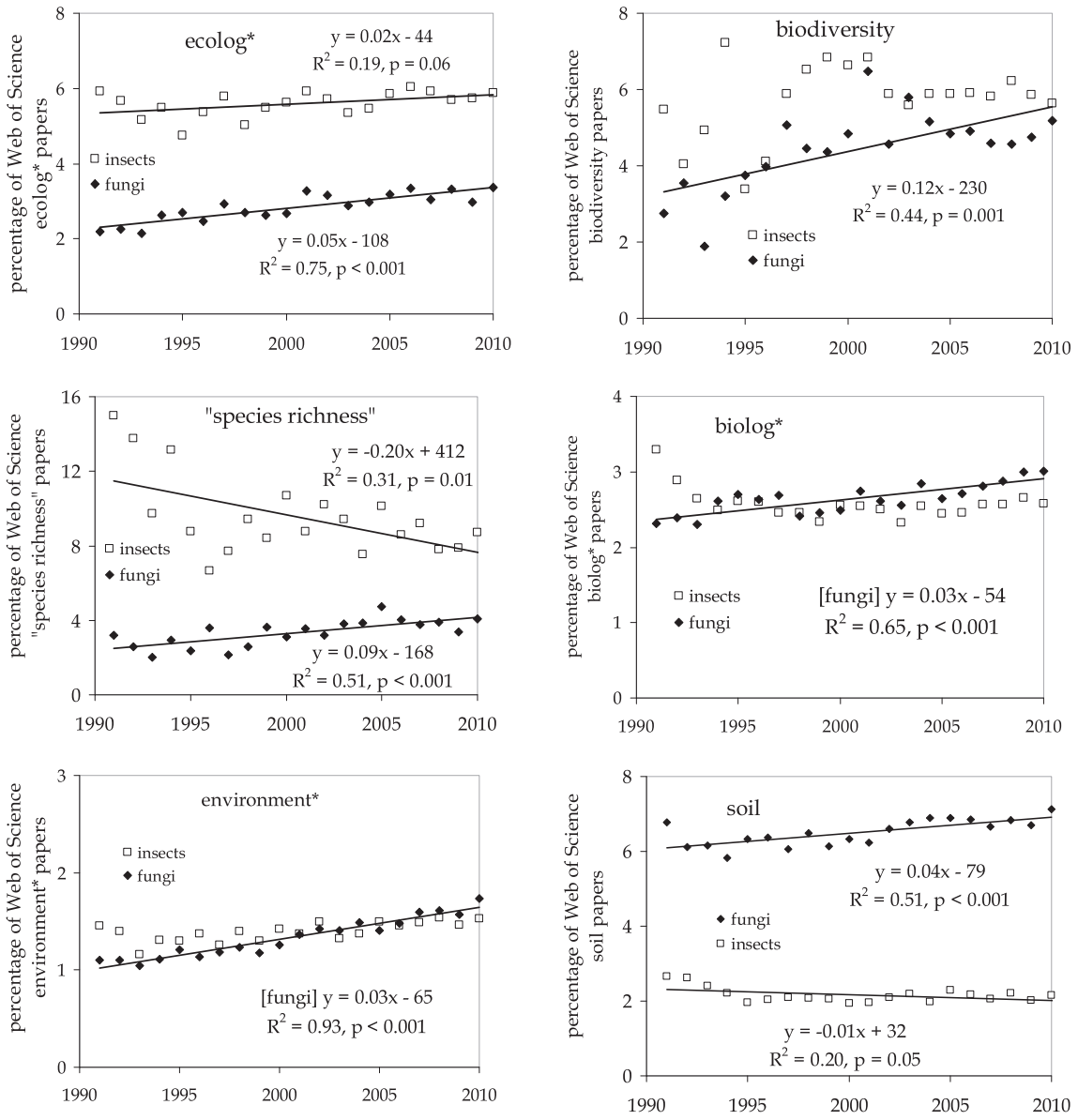

Fig 1 – Variation in the proportion of papers mentioning fungi (filled diamonds) and insects (empty squares) in the publications indexed in Web of Science (1991–2010, all citation databases with exclusion of the conference proceedings) in Apr. 2012 retrieved using as keyword (in the search field 'topic') 'ecolog*', 'biodiversity', "species richness", 'biolog*', 'environment*', 'soil', 'molecular', 'genetic*', 'landscape*', 'biogeog*', 'mountain*', "climate change*", 'marine', 'freshwater', 'forest*', 'grassland*', 'agric*', 'urban*', 'seed*', 'fruit*', 'food*', 'wood', "new species", 'network*', 'epidemi*', 'pathog*', 'disease*', 'health*', 'infect*' and 'immun*'.

through time for papers on species richness, soil, genetics, seed, fruit and food. This may suggest that, unlike mycologists, entomologists are struggling to keep up with the rapid increase in publications on, e.g., species richness and biodiversity (~12 and 75 times more papers were indexed in WOS in 2010 compared to 1991 for these two keywords).

On the whole, there is scientometric evidence that fungi are getting more attention in the biological, ecological and environmental literature. This implies that mycologists are (slowly) managing to get their message (that fungi are of key importance in ecosystems) across the life sciences. Particularly noteworthy are the increases in the proportion of fungal papers in the molecular, climate change, marine and food literature. It should be mentioned that a constant proportion would already be a good result, given the strong increase through time in the number of life science publications indexed in WOS over the last two decades (Pautasso 2010). The recent negative temporal trend in the proportion of 'fungal papers' on epidemics is of concern, given the rising importance of some fungal pathogens of humans (Casadevall *et al.* 2002) and the continued risk posed to crops and ecosystems worldwide by fungal pathogens of plants – which is likely to grow due to global change (MacLeod *et al.* 2010; Moslonka-Lefebvre *et al.* 2011; Gurr *et al.* 2012; Fisher *et al.* 2012; Pautasso *et al.* 2012). However, no such recent