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RESEARCH

Networks and themes in the publications of the New Zealand Ecological Society over the last six decades

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Abstract: The *Proceedings of the Ecological Society of New Zealand* (*PESNZ*) and its continuation, the *New Zealand Journal of Ecology* (*NZJE*), published more than 1250 articles over the 58 years from 1961–2019. Over this period, the emphasis of ecology as a science and the social context in which it is embedded have changed. Here we provide a bibliometric analysis of the history of the *PESNZ* and the *NZJE* to assess how the dominant research themes have changed through time, and the extent to which they reflect broader trends in the policy and funding landscapes. The journals' consistent focus has been on applied ecological issues, especially the effects and control of invasive mammals. However, the most discussed taxa have shifted over time (from deer to brushtail possums to rodents and mustelids). Collaboration has altered dramatically, with few author networks and single-author articles in early issues versus multi-author articles and widespread networks today. Thus, the research published by the Society reflects NZ-specific concerns and broader trends in knowledge production (e.g. the shift to team-based science). We conclude by considering the publications of the NZ Ecological Society through the lens of journals being 'clubs' for the social production of shared knowledge.

Keywords: collaboration networks, literature review, scientific publishing, text analysis, topic models

Introduction

Science is influenced by the social context in which it occurs. One way to understand how a scientific community's focus has shifted over time, and the networks that have developed within it, is to synthesise the body of research it has produced (Fire & Guestrin 2019; Nakagawa et al. 2019). For example, Réale et al. (2019) identified networks of collaboration and evaluated shifts in themes across ecology and evolution based on co-citation patterns. Heberling et al. (2019) used similar evaluations to assess the changing use of herbarium records. Alternatively, literature synthesis can evaluate changes in research focus and culture (Logan et al. 2017; Westgate et al. 2020). Three key papers in this vein have been published in the *New Zealand Journal of Ecology*. Linklater and Cameron (2001) explored differences in publication trends between New Zealand (NZ) and Australian ecologists during the period 1953–1997, and identified systemic differences in publishing between the two communities, arising, in part they argue, from different emphases in government funding. More recently, there have been assessments of leadership and diversity in the New Zealand Ecological Society (NZES) (Wehi et al. 2019a) and the use of Mātauranga Māori in the *NZJE* (Wehi et al. 2019b).

Advances in computational linguistics and text analysis provide methods that help to automate the evaluation of a body of scientific literature, although expert judgment still remains critical (Mimno 2012; Murakami et al. 2017). We use these methods to evaluate the articles published in the 58 years of the *Proceedings of the Ecological Society of New Zealand* and the *New Zealand Journal of Ecology (PESNZ* and *NZJE*, respectively). We ask if there have been thematic shifts in the publications in the Society's journals, and hence published ecological research in NZ, and the affiliations of those authoring articles in them. Thematic shifts may arise from alterations to the research environment, including institutional readjustments (e.g. formation of the Crown Research Institutes, CRIs), changes to funding bodies, evolution of the questions posed, or changes in scientific culture (e.g. the pressure to publish internationally vs locally). Here we use a comprehensive database of articles published in the *PESNZ* and the *NZJE* to ask:
(1) what is the temporal pattern in the ecosystems and taxa considered in the articles published by the NZES?
(2) have there been shifts in the institutional groups publishing?
(3) are there distinct networks of collaboration between co-authors?
(4) are there coherent clusters of reseach published and have these changed through time?

Methods

Corpus analysed

We downloaded all items tagged as having the *NZJE* as the

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publication from Scopus and the Web of Science (Common Collection) on 5 June 2019 and then Volume 43(2) on 5 December 2019. Citation counts were accurate as of 5 June 2019. The downloads included information about the articles cited in a given article and those that cite that article (via Web of Science). We merged citations from Scopus and the Web of Science and removed duplicates (using the bibliometrix R package v 2.3.2 and manual checking). Neither Scopus nor the Web of Science covered the first three (pre-1981) volumes of the *NZJE* or the 24 volumes of the *PESNZ*. These items were entered manually without citation-related information (i.e. number of citations, references cited and citing references). Over the period 1982–1995, 85 abstracts (in Scopus) were incomplete and noted as "From author(s)"; we entered these manually. Where the abstract in the journals' internet repository differed from that in the article, we used the latter. Finally, only the Web of Science contained the 1981 issues of the *NZJE,* but without abstracts, so we entered these manually.

We only considered primary research or review articles; editorial comments, book reviews, policy statements, Presidential addresses, notices, obituaries, and errata were omitted. In earlier issues of the *PESNZ* and the *NZJE* summaries of papers presented at the Society's annual meetings were published; we did not include these. Issues of the *PESNZ* published before 1960 did not contain primary research articles, so were omitted. Keywords did not appear with journal articles published before Volume 4 (1981) of the *NZJE* and were sporadic in *PESNZ*; we recorded these when present. The analysis corpus consists of 1268 items, spanning the 58 years from 1961 (*PESNZ* Vol. 8 onwards) to 2019 (*NZJE* up to Vol. 43[2]).

For each article, we recorded meta-data about:
(1) institutional affiliations of the authors: tertiary (university, polytechnic), Crown Research Institute (CRI), Government department (including predecessors of the CRIs), or other (including consultancies);
(2) focal taxa: mammal, bird, plant, invertebrate, mutualism, herpetofauna, 'soils' for invertebrates, herpetofauna and mammals we also used a second, more detailed, classification: herpetofauna: lizard, frog, tuatara; mammals: bat, seal, sea-lion, ungulate, hedgehog, rodent, mustelid, felid, macropod, multiple; invertebrates: snail, wētā, other;
(3) ecosystem: fresh-water/riparian, marine/coastal/dune, forest/shrubland, grassland/tussockland/dryland/alpine ('non-forest'), urban, wetland, agricultural (including conifer plantations and pastures);
(4) if the focus of the article was on exotic (invasive/pest) species and, if so, which species it considered;
(5) if the focus of the article was on translocation/reintroduction/restoration;
(6) if the article considered the ecosystems of an offshore island (NZ archipelago other than South Island, North Island, Rakiura-Stewart Island, Aotea-Great Barrier Island);
(7) if the focus of the article was methodological
(8) countries listed in the authors' addresses

We assessed changes in the prevalence of these categories through time. A csv file containing all items as used in the analysis is available in Perry (2021).

Bibliometric and co-occurrence analysis

We evaluated the co-occurrence of keywords (i.e. patterns in shared keywords across the corpus) and collaboration between authors (i.e. the network structure of individuals co-authoring articles). We visualised networks and identified clusters in them using the Louvain algorithm (Blondel et al. 2008) as implemented in the bibliometrix R package v 2.3.2 (Aria & Cuccurullo 2017) via ggraph v 2.0.2 (Pedersen 2020). The bibliometrix package uses the normalisation approach described by Batagelj and Cerinšek (2013), which avoids documents with many authors obscuring network structure (not a large issue for this corpus). The Louvain clustering algorithm seeks to maximise modularity in the network by building clusters with many internal but few external links. We graphed temporal patterns in the affiliation of the authors, the ecosystems and the taxa considered.

Topic models

Topic models probabilistically categorise the individual documents that form a corpus (Blei 2012). This categorisation can be supervised or unsupervised, and here we take the latter approach; the use of topic modelling in ecology is reviewed by Westgate et al. (2015). We developed topic models using Latent Dirichlet Allocation (Blei et al. 2003) based on the abstracts. Latent Dirichlet allocation (LDA) is a machine-learning method that allocates a document to a given topic (across k topics), with topics based on shared text. The approach is hierarchical with documents belonging to topics, and topics characterised by collections of words. The method estimates the probability of a document belonging to each of k topics (γ) and the probability of each word belonging to a topic (β) (Murakami et al. 2017). Developing an LDA requires selecting a value for k, the number of topics in the corpus. As Murakami et al. (2017, p. 250) comment, "… the decision on how many topics a corpus will be deemed to contain is a subjective one and the answer may be defended on the grounds of usefulness but not on the grounds of accuracy." While there are statistical approaches for optimising k they were not useful in our case (identifying 40+ topics), so after some trial and error we settled on $k = 6$.

Before building the LDA we removed stopwords (common words such as *about, above, more, high* that are unlikely to identify latent topics) from the list in the tidytext R library v 0.2.3 (Silge & Robinson 2016), and some specific to this corpus (see Supplementary Materials). We then stemmed the words using the Porter approach; stemming involves reducing words to their basic conjugates (e.g. baits, bait, baiting → bait) and facilitates identifying latent topics. We did not group inflections of the same root word (i.e. lemmatise) in the text as it contains many specialist terms not included in standard dictionaries (see Murakami et al. 2017). Our workflow is modelled on that described by Silge and Robinson (2017).

Statistical software

For the bibliometric and co-citation/keyword network analysis, we used the R package bibliometrix v 2.3.2 (Aria & Cuccurullo 2017). To manipulate the corpus we used tidytext 0.2.3 (Silge & Robinson 2016); we built the topic models (LDA) using the topicmodels R library v 0.2-9 (Grün & Hornik 2011). Data were manipulated and visualised using the tidyverse R meta-package v 1.3.0 (Wickham et al. 2019).

Results

Qualitative analysis of affiliations and themes

The NZES has published nearly 1270 research articles over 58 years (Fig. 1a). More than 1400 authors have published in

the journals, and the longest temporal range for an author is 49 years (Brian Molloy: 1970 to 2019). The average number of co-authors per article has steadily increased from around one in the mid-1970s to four in 2018–2019 (Fig. 1b). Across the biological sciences, there has been a trend for longer titles and abstracts (Fire & Guestrin 2019), which is also evident in the NZES journals (Figs 1 c, d).

Trends in authors' affiliations through time

The number of articles published per year has increased in the journals, peaking around 2010 (Fig. 1a). The increase, especially noticeable in university authorships, started shortly after the formation of the Crown Research Institutes (CRIs) in 1992; there was a second jump around 2003 when the Performance-based Research Fund (PBRF) started (Fig. 2). Over the last decade, the number of articles co-authored by individuals in the 'other' category (especially consultancies) has steadily increased.

Terrestrial ecosystems have always been the overwhelming focus of the Society's publications; New Zealand journals dedicated to freshwater and marine environments (e.g. *New Zealand Journal of Marine and Freshwater Research*) may largely account for this. Most articles concern indigenous forest ecosystems (with exotic conifer plantations included in the 'agricultural' category), presumably because most non-agricultural or urban areas are in forest. Predominately indigenous (although often grazed) non-forest ecosystems such as tussocklands have been a consistent, although varying, theme with peaks in the 1960s, late 1990s and early 2000s (Fig. 3).

The Society's journals have published more on fauna than flora (Fig. 4) despite other Royal Society journals (e.g. *New Zealand Journal of Zoology*, *New Zealand Entomologist*) providing a local outlet for such research. The ecology (including impacts) of native and exotic birds and mammals has dominated. Plant ecology has been reasonably consistently represented in absolute terms (but declining over time as a proportion of articles), while publications on invertebrates and herpetofauna have fluctuated.

Given the challenges that exotic plants and animals pose to New Zealand's ecosystems (Allen & Lee 2006), the prevalence of publications addressing their effects and control in the Society's publications is unsurprising (Fig. 5). The median prevalence of articles considering non-native species is 38%, with a strong bias towards articles consider animals over plants.

The taxonomic groups of mammalian pests addressed in the Society's publications shifts over time, potentially reflecting changes in the focus of NZ ecologists and the institutions they work for (Fig. 6). Before 2000 most papers on mammalian pests addressed ungulates, especially deer; a peak in studies on brushtail possums (*Trichosurus vulpecula*) occurred around 2000. Since then the emphasis has shifted to rodents and in the last decade studies of multiple species (especially mustelids and rodents).

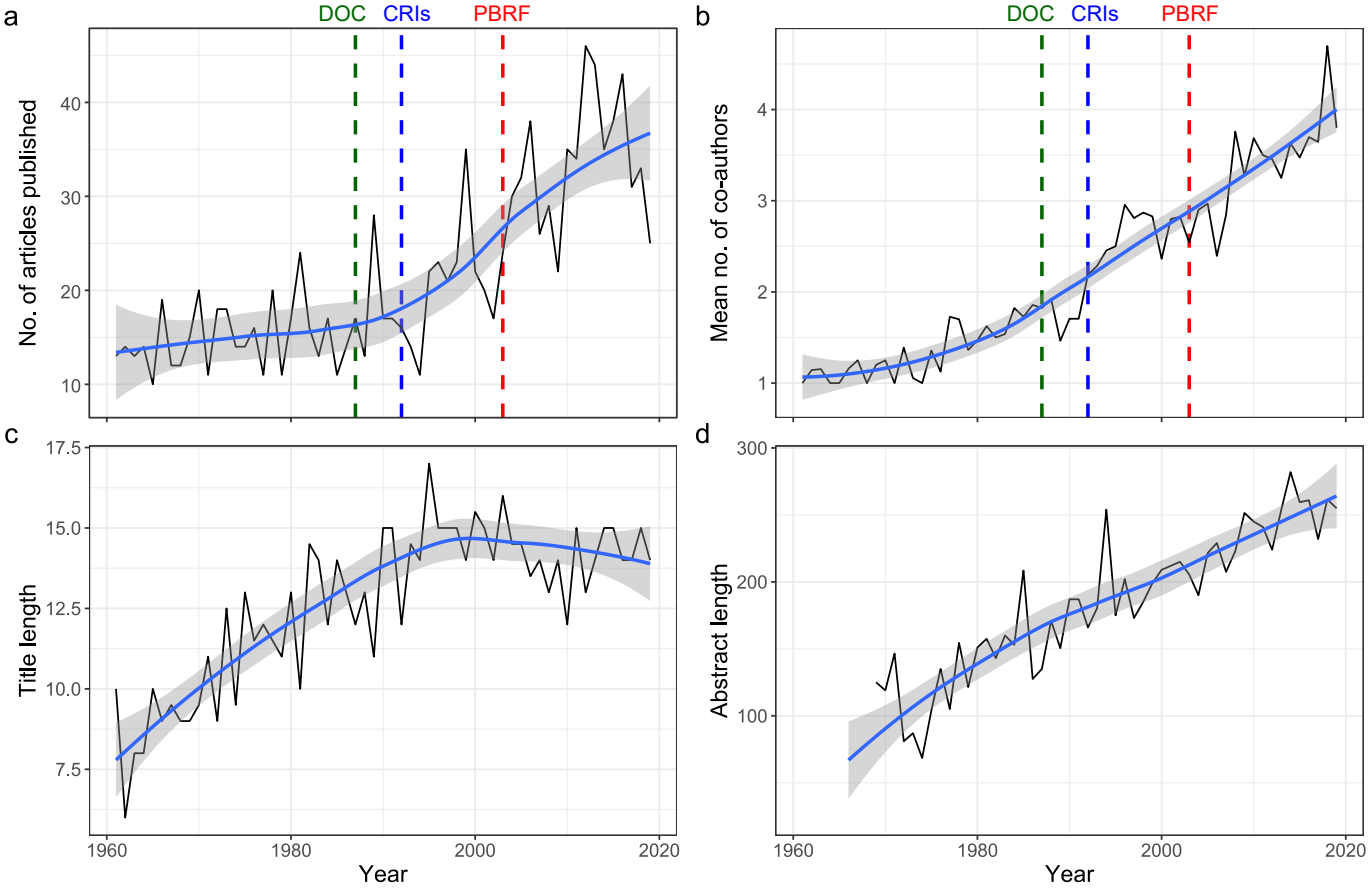

Figure 1. (a) Number of articles published per year by the *PESNZ* and then the *NZJE,* (b) the mean number of co-authors per article over time, (c) the median length of titles in published articles, and (d) the median length of abstracts in published articles. The blue vertical line is the formation of the CRIs (1992) and the red vertical line the initiation of the Performance-based Research Fund (PBRF) audit (2003). The curve fits are loess models.

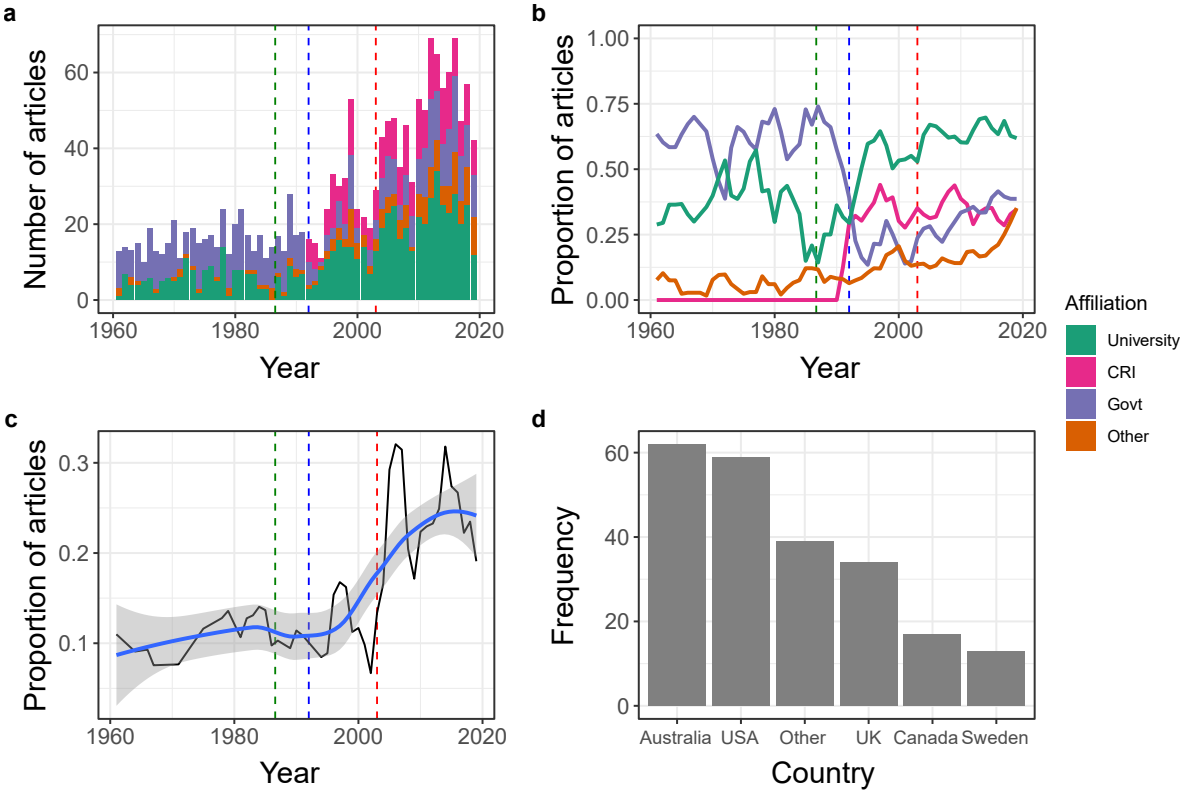

Figure 2. Changes through time in the institutional affiliation of authors in the *PESNZ* and the *NZJE* in (a) absolute and (b) proportional terms, (c) proportion of articles (three-year running mean for ease of interpretation) with an international author (based on address), and (d) counts of international addresses for countries with $n > 10$. An article may be associated with multiple institutional affiliations or countries. The blue vertical line is the formation of the CRIs (1992) and the red vertical line the initiation of the PBRF research audit (2003). Proportions in (b) and (c) show a three-year running mean for ease of interpretation.

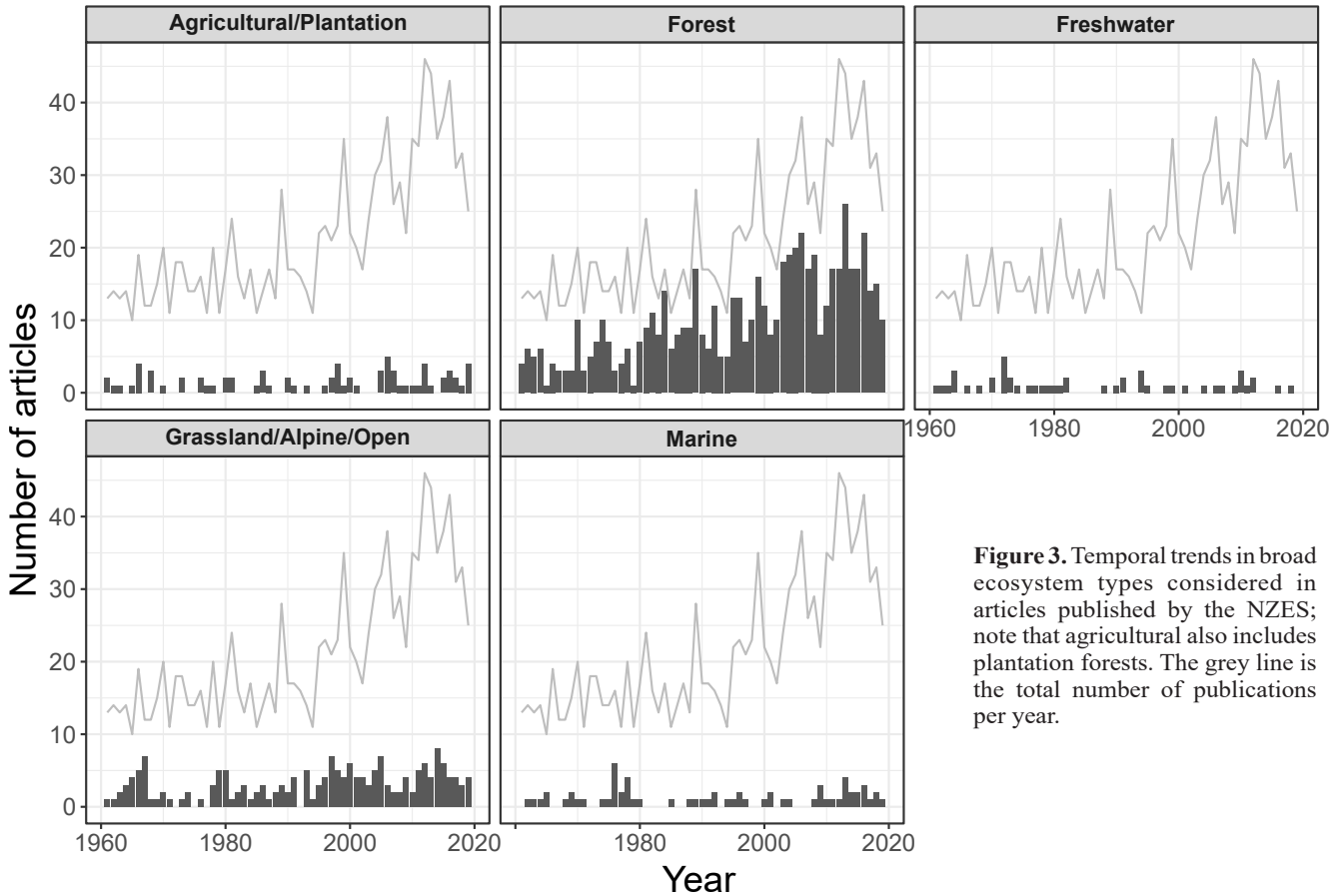

Figure 3. Temporal trends in broad ecosystem types considered in articles published by the NZES; note that agricultural also includes plantation forests. The grey line is the total number of publications per year.

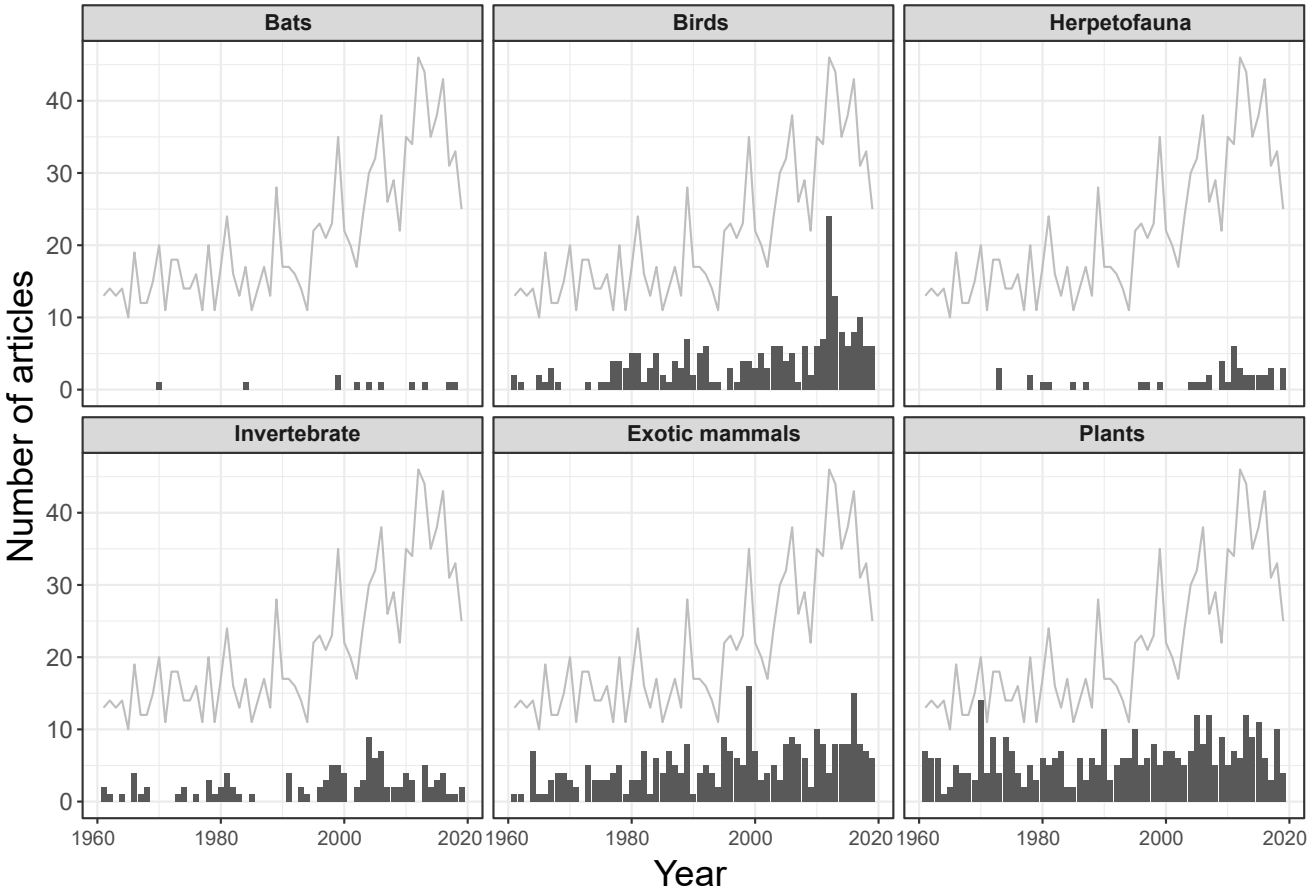

Figure 4. Trends in taxonomic groups considered in articles published by the NZES. The grey line is the total number of publications per year.

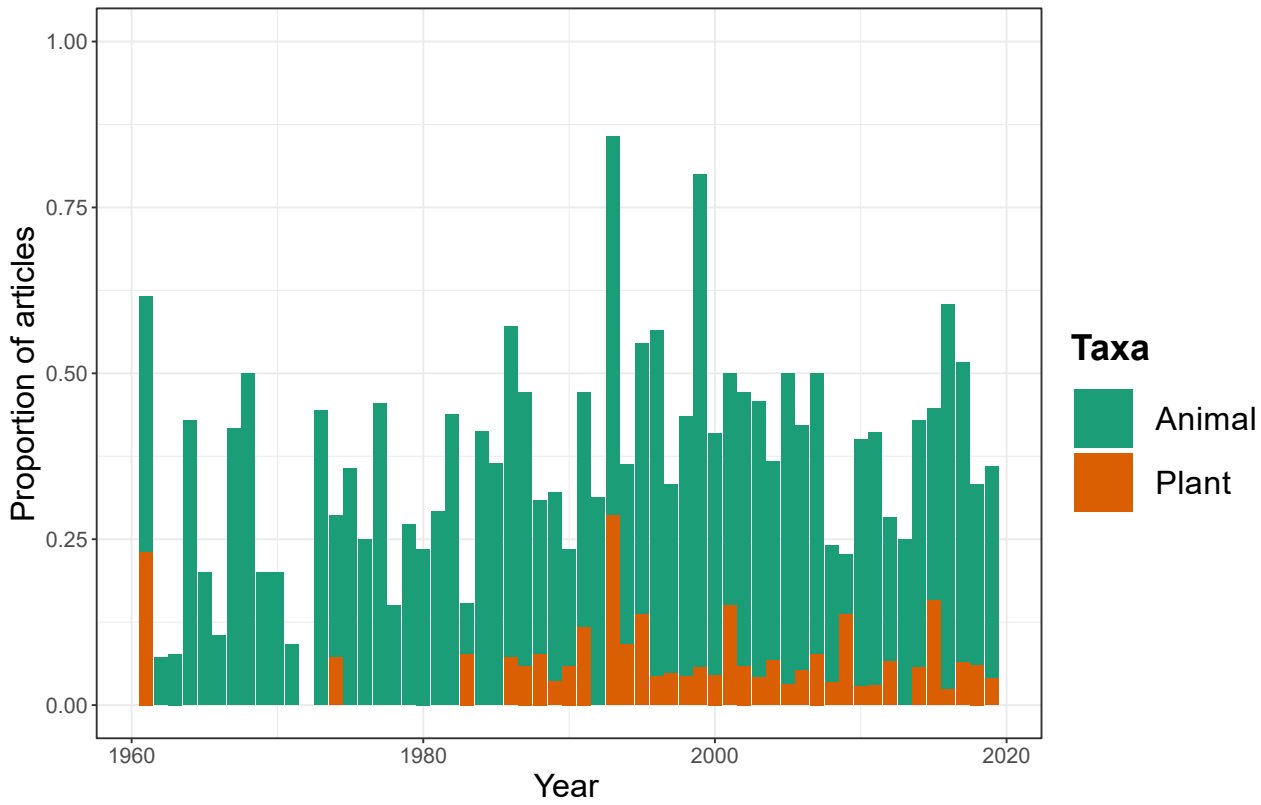

Figure 5. Trends in the proportion of all articles published each year addressing exotic species separated into articles focusing on animals vs. plants.

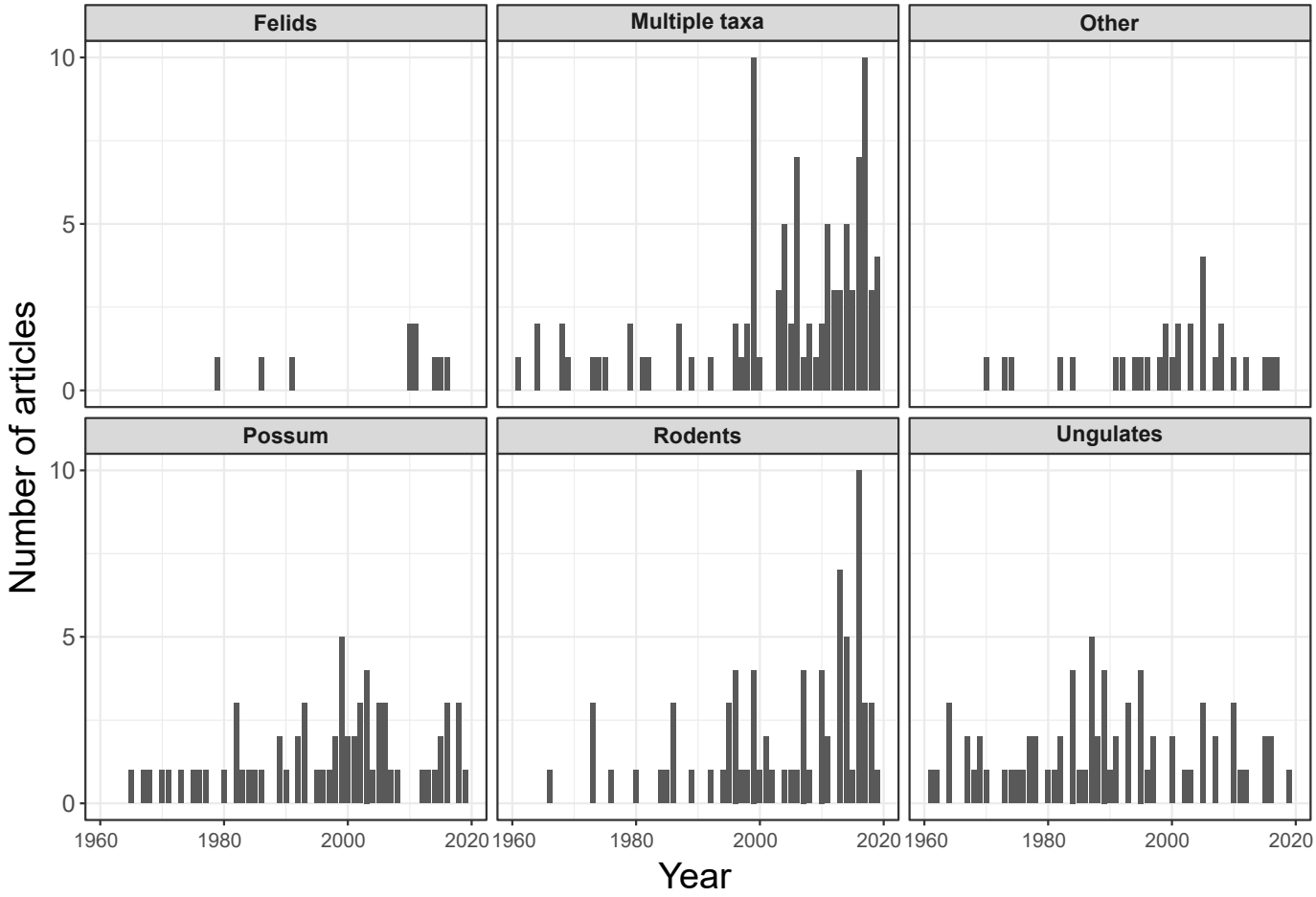

Figure 6. Trends in mammal pest species considered in articles through time.

Authorship and author networks

Groups of collaborating co-authors in the NZES journals (Fig. 7) represent a combination of institutional groups and thematic interests. The composition of these networks has changed over time: structurally, the network of co-authorship has increased from pre-1980 (a highly disconnected network); 1980–2000 to post-2000 (increasing connection); after which a much more connected collaboration network formed (Fig. 7). It is also interesting to note that the most prominent clusters appear to be based around Maanaki Whenua – Landcare Research sites (Lincoln, Dunedin, and Hamilton), with the University groups smaller and with fewer participants.

Associations and topic models

Title and keyword associations

The frequency of the appearance of single words in the titles of the articles published by the NZES reflects the prevalence of studies on mammalian pest species (see Appendix S1 in Supplementary Materials). The largest cluster concerns baiting (especially 1080) and control of possums and other mammalian pests. The other clusters are small and reflect taxonomic or geographic labels; although not informative of themselves, these clusters reflect the research themes published in the journals. There are more evident patterns of association between author keywords, reflecting the emphasis on the effects and control of mammalian pests in forest environments (Fig. 8). The Louvain clustering algorithm identifies five overlapping clusters of keywords: (1) ecology of invasive mammals (brushtail possums and rodents), (2) pest control (cats and rabbits) using toxins, (3) a broad swathe of NZ conservation ecology and biology, (4) predator control (stoats) in beech forest, and (5) a suite of topics encompassing plant-animal mutualisms and the effects of invasive vertebrate species. Although many important invasive mammal species are separate nodes (i.e. used and delineated as keyword terms by authors), invasive plants are lumped together as a single node ('weeds'). Despite the research activity focused on them, there are no separate nodes in Figure 8 for widespread plant weeds such as gorse, broom, *Hieracium*, and lodgepole pine. In short, they do not occur frequently as author keywords. Of the 5310 unique author keywords, the top two explicitly named invasive plant species are *Pinus radiata* and *Hieracium* (n = 6 and 5, respectively vs. n = 91 and 37 for brushtail possum and ship rat).

Latent Dirichlet allocation (LDA) topic models

Analysis of the abstracts of the 1268 articles identified some distinct, if overlapping themes (Fig. 9; Appendix S2). Classifying the corpus into six (k = 6) topics confirms the journals' emphases on various overlapping facets of applied ecology, especially the effects and control of exotic mammals, which to some extent all topics, other than topic 5, reflect (even if topic 5 is the most frequent).

There have been shifts in the prevalence of the topics identified by the LDA model (Fig. 10a). Topic 5 (various topics about plant ecology and vegetation dynamics) dominated early issues of the journal (around 40% of documents through the

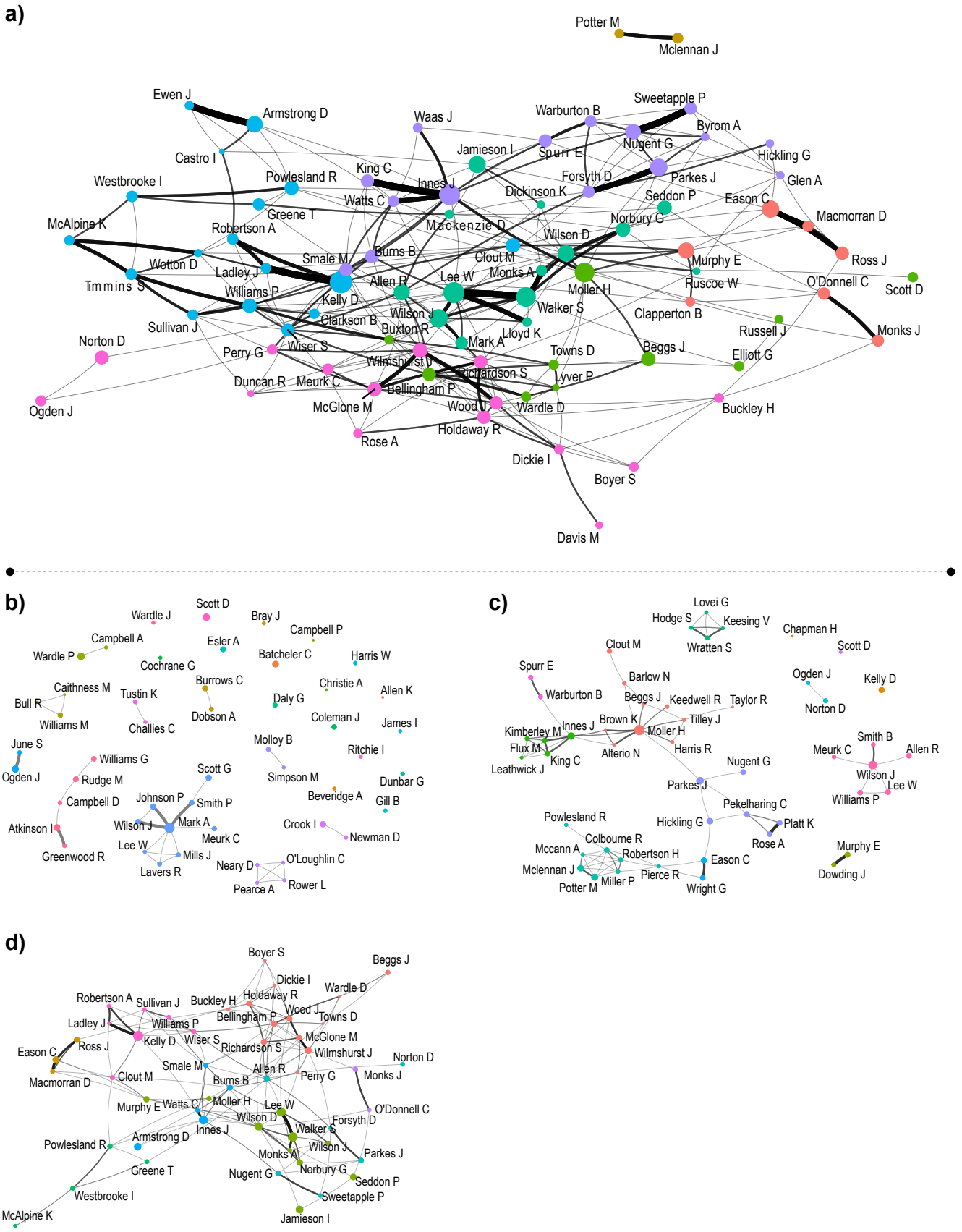

Figure 7. Collaborative networks of NZ ecologists as represented by co-authorship in the *PESNZ* and the *NZJE*. Colours represent statistical clusters identified by the Louvain algorithm, line widths the number of links between authors and point (node) sizes the number of links (degree) for a given author. (a) all years, (b) prior to 1980, (c) 1980-2000, and (d) since 2000. For (a) the top 80 most connected authors (degree) are included, and for (b–d) the top 50. Isolates (unconnected authors) do not necessarily imply lack of linkages with other authors, just few linkages with prolific NZJE authors. Note that we have not synonymised names where the same author may have used different surnames during their career.

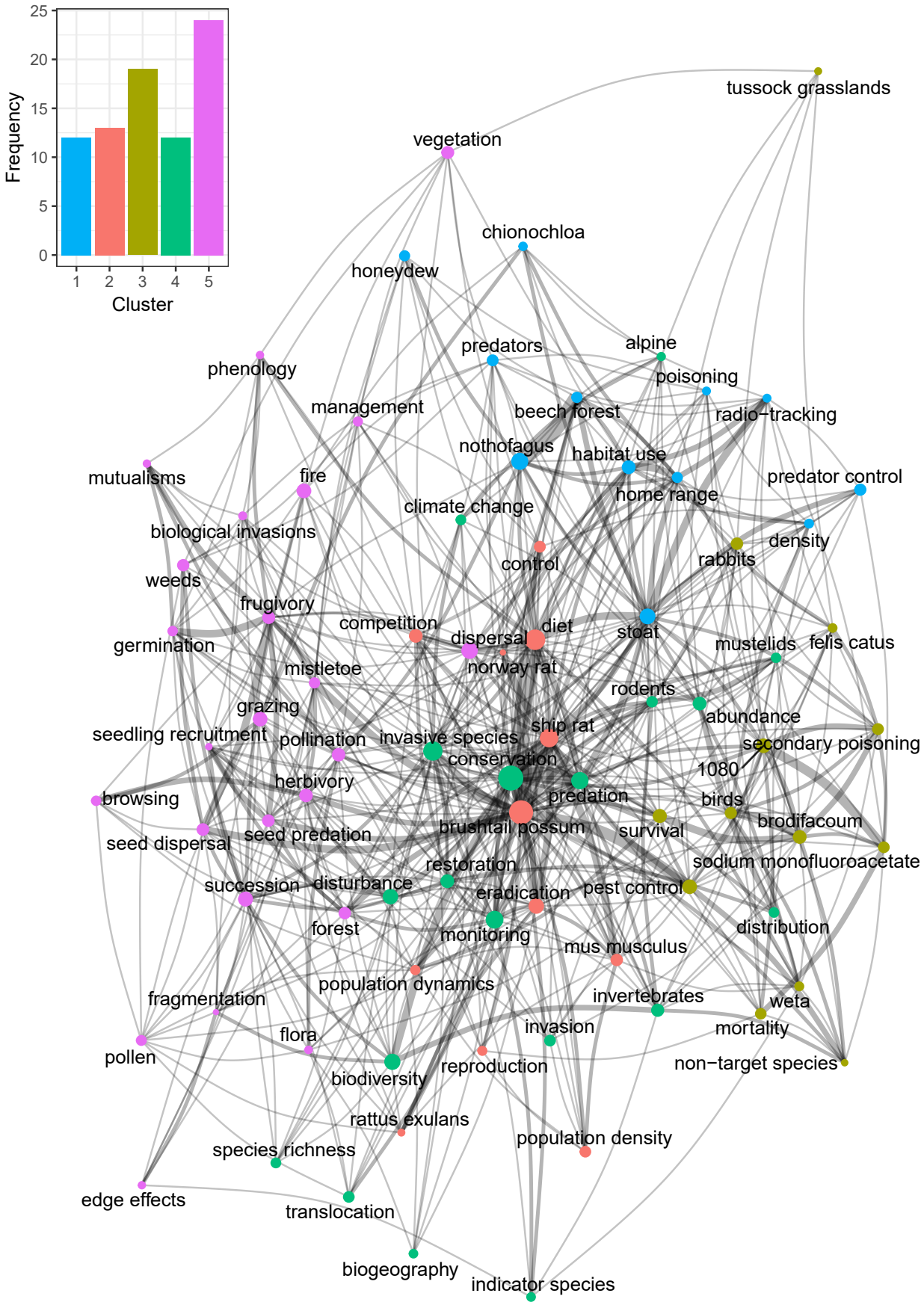

Figure 8. Network of co-occurrence of author keywords in the *PESNZ* and *NZJE*, 1966–2019, with colours representing clusters identified by the Louvain algorithm. The inset bar graph shows the frequency of each cluster. Top 80 keywords shown. The size of the nodes represents the frequency of each keyword and the link thickness the number of links between pairs of keywords. Some keywords

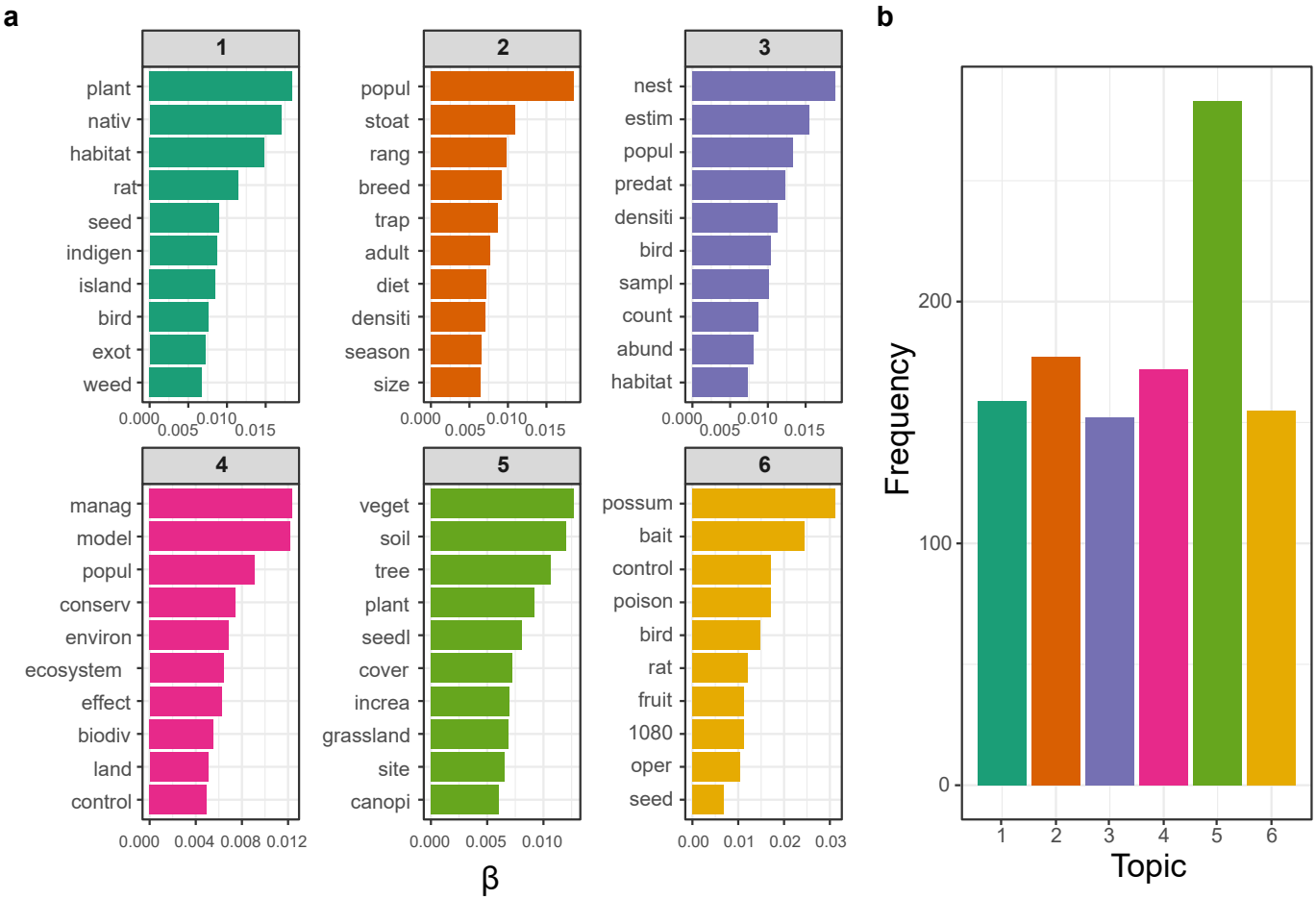

Figure 9. (a) Top terms (β) in the six topic models identified in the corpus of articles and (b) the frequency of each topic in the corpus as a whole (1970–2019). Note that we stemmed the text and so not all terms are accepted English words.

1970s and 1980s) but declined to around 15% in 2019. Topic 4 (conservation and management) shows a U-shaped frequency with a decline in the 1990s before a recent renaissance. The remaining topics all address various facets of the management and ecological effects of exotic mammalian species and have remained close to the expected null frequency under an equal topics model ($1/k = 0.167$). Pronounced single-year peaks in some topics' prevalence may reflect the special issues published by the Society (Fig. 10b); for example, the spike in topic 6 in 1999 coincided with a collection of papers considering the "Ecological Consequences of Poisons used for Mammalian Pest Control".

Discussion

Shifts in the institutional groups publishing in the NZES publications

The number of articles per year published in the *PESNZ* and then the *NJZE* has increased. So too has the number of co-authors per paper, reflecting broader trends in science publishing (including ecology, Logan et al. 2017). Over the nearly six decades that the NZES has published scientific articles, there have been significant shifts in the organisation of science in NZ in the tertiary and government sectors. In April 1987, the Department of Conservation formed from components of the disestablished Forest Service, Wildlife Service, and Department of Lands & Survey, the first two of which had very substantial science capabilities. In 1992, the Crown Research Institutes (CRIs) formed out of the Department of Scientific and Industrial Research (DSIR) and the research component of other government bodies. Of the CRIs, Manaaki Whenua - Landcare Research, in particular, has had a mission closely aligned with the applied focus of the majority of *NZJE* articles. During the 2000s research assessment exercises such as the Performance-based Research Fund (PBRF; instituted in 2003) have undoubtedly influenced publication decisions among university researchers. For example, some universities have encouraged research staff to avoid local journals in favour of international ones, but this seems not to have affected absolute number of university submissions to the *NZJE* and other local New Zealand journals (Smart 2009). However, as the publication productivity of the universities has continued to rise steeply since 2003, it is likely that the proportion of university output going to local journals has fallen. A trend to more international collaboration has probably furhter intensified this trend (Fig. 2c). The proportional representation of different components of the NZ research community has remained remarkably constant since the late 1990s. The formation of the Department of Conservation in 1987 seems not to have had an immediate effect on publication patterns. The shift to the CRI structure in 1992 resulted in a short-term decline in government scientists publishing in the journal (and anywhere due to reorganisation), but their proportion has increased and remained consistent since around 2000. Despite changes in

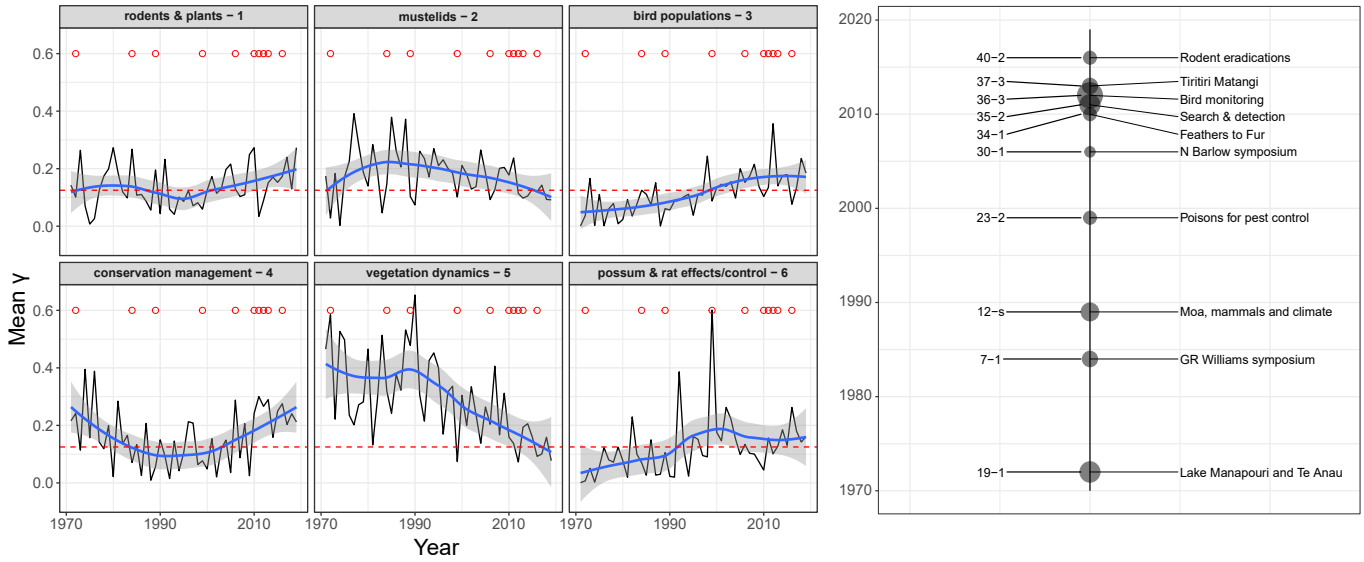

Figure 10. Changes in the prevalence of the topics identified by the LDA through time as measured by the mean gamma values over the period 1970–2019. The curve fits are loess models, the horizontal red line is at the null expectation under an equal topics (k = 6; f = 0.167) model and the red circles are the years special issues were published. The timeline shows the special issues the PESNZ and NZJE have published.

publication pressures in NZ's universities, especially with the introduction of the PBRF (Hodder & Hodder 2010), university-based scientists remain frequent co-authors in the journal and have increased in proportional representation since a nadir in the 1990s. Over the last decade, the proportion of papers with authors from beyond the CRIs, Government or University has increased.

Temporal patterns in the ecosystems and taxa in the NZES publications

The broad ecosystem types considered have been consistent through time, with an emphasis on forest ecosystems (accounting for 9.0–**46**–82.0% [min–**median**–max] over the period 1961–2019). On the other hand, the broad taxonomic groups considered in the journals' pages have shifted. The number of articles focused on birds has tracked the long-term increase in the number of articles published per year; those considering mammals have declined slightly in proportional terms (although they are difficult to disentangle from those considering birds in some cases), and those focused on plants have declined over time proportionally. The fraction of papers addressing the ecology, impacts and management of exotic species has steadily increased (medians of 20% vs. 42% during the 1960s and 2010s, respectively), while that investigating the fundamental ecology of native species has declined. These shifts in emphasis reflect the topics that applied ecology has addressed in NZ and, in particular, the recent trend to studies addressing the effects of mammalian pests on NZ's native avifauna. Westgate et al. (2020) conducted an analysis similar to ours on the 44 years of publications in *Austral Ecology*. They reported considerable turnover in topics through time, but that recent trends in topic prevalence seemed to track broader trends in ecology with a rise in statistical ecology and invasion ecology (although the latter remains much less prevalent than in the *NZJE*) during the 2010s and a decline in site- and species-specific research. Westgate et al. (2020) ascribed the decline in site- and species-specific research in *Austral Ecology* to the emergence of more specialised journals for such research to be published in rather than a decline in research in those topics. Despite this trend, there remains a bias towards some regionally significant topics in *Austral Ecology* (e.g. fire ecology) as with invasion biology in the *NZJE*.

Networks of collaboration between co-authors in the NZES publications

Co-citation networks show distinct networks of co-authorship in the journals' publications (Fig. 7). The composition of these networks has shifted over time reflecting the natural dynamics of the contributor community. However, more importantly, there have been substantial shifts in their topology as the collaboration network (as reflected in author co-occurrence) has become much more connected. This change presumably reflects broader changes in science: team-based approaches have become the norm (Wuchty et al. 2007); criteria for authorship have widened; and digital interconnectedness has made co-authorship—and in particular extensive author lineups—very much easier. In NZ, this collaboration (also reflected in the number of co-authors on papers; Fig. 1b) has been accelerated by funding frameworks such as the National Science Challenges and before that science programs funded by the Foundation for Research, Science and Technology.

Associations and topics

Some enduring themes in NZ ecology and some prominent NZ ecologists do not appear in the pages of the Society's journals. Linklater and Cameron (2001) estimated that the *PESNZ* and the *NZJE* accounted for just 9% of all papers published by authors who published in those journals. That 9% of articles is almost certainly not a random selection of those authors' research. Nevertheless, the trends in associations and themes published in the *PESNZ* and the *NZJE* are revealing of the research foci of NZ ecologists. The first point to note is that over the 58 years they have been published there has been a consistent emphasis on applied ecology, and in particular the effects and management of exotic invasive species (e.g. topics 1, 2, 4 and 6 in the LDA model; also commented on

by Linklater & Cameron 2001). Over time, the emphasis in articles published on effects and control of exotic mammals has shifted, with an increased focus on rat and stoat predation and density/population estimation. Meanwhile, the number of articles considering vegetation dynamics (topic 5) have steadily declined. While these patterns reflect changes in the perceived challenges facing NZ's ecosystems and the associated funding landscape, they also likely reflect the interests of a small pool of authors who have published relatively frequently in the journals. For example, despite the research attention they receive in NZ (Hulme 2020), there is a paucity of articles on invasive plant species. Finally, in a qualitative sense, it is interesting to see that some very current (2020) topics have been long debated in the pages of the Society's journals, e.g. the differing views of Peters (1975) and Spurr (1979) re the use of 1080, others have faded but remain of historical curiosity (e.g. Pollock's (1970) discussion of the NZ otter or waitoreke).

Finding its niche? The place of the NZJE

One of this article's reviewers asked us: "what are the features of the *NZJE* that have enabled it to succeed when other society and local journals have struggled?" We first checked if such a claim of relative success is, indeed, justified. We compared two key bibliometric indicators—normalised number of articles published per year and impact factor—with other NZ journals that regularly publish ecological research and five international ecology journals. From 1990 to the mid-2010s, the *NZJE* steadily increased output before a drop beginning in 2015. This growth (until 2015) is similar to that in other international journals (e.g. the *Journal of Ecology*) but quite different from the other NZ-based journals we looked at, all of which have declined since 2000. The *NZJE*'s impact factor (two-yearly average of citations per paper; IF) increased from around 2005 to a plateau since 2010, but has remained consistently higher than the others since 2000. Meanwhile, the IF of the *New Zealand Journal of Botany* and the *New Zealand Journal of Zoology* has remained reasonably steady over the period assessed and the *New Zealand Journal Marine and Freshwater Research* has seen a recent increase (starting 2012–13). In short, the trend in the number of research articles published in the *NZJE* is quite different from other NZ journals publishing ecological research, but those in IF are less so. The answer, therefore, is that *NZJE* has done better than comparable local journals in output and impact. A second point to consider in the journals' success is that for as long as it has been available electronically, papers in *New Zealand Journal of Ecology* have been free to all readers (society members or not, local or international) making the journal effectively open access. There has been considerable debate about the advantages of open access (OA) publication models (Swan 2010; Mounce 2013; Wang et al. 2015; Tennant et al. 2016). However, the decision of the NZES to retain the OA status of the *NZJE* may have contributed to its success in terms of attracting authors, especially if impact is measured in ways that do not emphasise citation scores (e.g. in policy).

Before discussing this nominal success it is worth reflecting on the situation of a local journal serving a small scientific community. Local journals suffer from four disadvantages. They have low prestige; they have low submission rates; they have a small pool of potential contributors; and they have the double handicap of a restricted topic area plus a restricted location. The low volume of submissions is particularly problematic because this inevitably results in yearly fluctuations in the nature of those submissions. For example, if a local ecology journal were to have a run of articles on mycology, it would not be long before, despite its masthead, it would be seen as a mycological journal. This perception would further diminish its pool of contributors already weakened by the imperative, driven by both scientists and their institutions, to publish in international outlets (e.g. the PBRF; Rowland 2005; Hodder & Hodder 2010).

The DSIR—the original publisher of most of the local journals we have considered—attempted to grapple with these disadvantages, which it saw mainly through the lens of profitability (or rather lack thereof), by encouraging them to position themselves as extra-regional journals. This attempt failed. The Royal Society of New Zealand, the unwilling heir to the DSIR journals after the disestablishment of the DSIR, after years of neglecting them, partnered with international publisher Taylor & Francis in late 2009 (for analysis see Rowland 2003, 2004). Despite being re-labelled as 'international' journals and having access to the resources of a global publishing platform, they have mostly not recovered from the decline that set in around 2000 (Fig. 11b). In making this shift, the Royal Society was simply following an international trend of increasing dominance of academic publication by a smaller number of publishers (e.g. the Ecological Society of America journals have partnered with Wiley since 2016; Larivière et al. 2015).

Local journals do have some advantages, however, and these are likely to grow rather than diminish in the near future. Local journals are likely to be connected formally or informally with a national society such as the NZES. They benefit in several ways from this connection. Many of the society members will feel a sense of the journal being 'their' journal and support it not only through submissions but also through serving as editors or reviewers. In our experience, it has been far easier to obtain qualified reviewers for the *NZJE* than for other international ecological journals (a total of six; GLWP and MSM = 3 each) where we have served as editors. The local knowledge thus harnessed often means a more engaged and informed review. Connection to a local society also means that a journal will often be asked to publish symposia on local topics. These have been important in keeping the profile of the *NZJE* journal high. As an example, the 13 articles in the Feather to Furs symposium of 2010 have averaged 90 (median 76) citations in Google Scholar (September 2020) and the *NZJE*'s impact factor peaked in the following years. Local journals are sometimes derided as being "journals of last resort" but they perform an invaluable function in ensuring science that may not be of exceptional novelty but of local importance finds a home and an audience that it would struggle to find internationally. Finally, massive improvements in digital connectedness, availability of platforms for publishing science, effective tools for accessing publications, and the spread of open access formats have somewhat levelled the playing field for local journals.

A potentially valuable role for local journals is that they provide space for student-led publications. However, reasonable though this might seem, it is difficult to directly assess the prevalence of such publications in the *NZJE* and almost impossible to compare it to other journals. If there is a higher pool of student-led papers in the *NZJE* than in other journals, there may be a different distribution in the number of articles per author (a longer tail). Comparison of the *NZJE* with other local and international ecological journals does not suggest this (Fig. 12). The distribution of the number of authors per article is remarkably similar across journals. If we consider the ratio of the number of unique authors to the

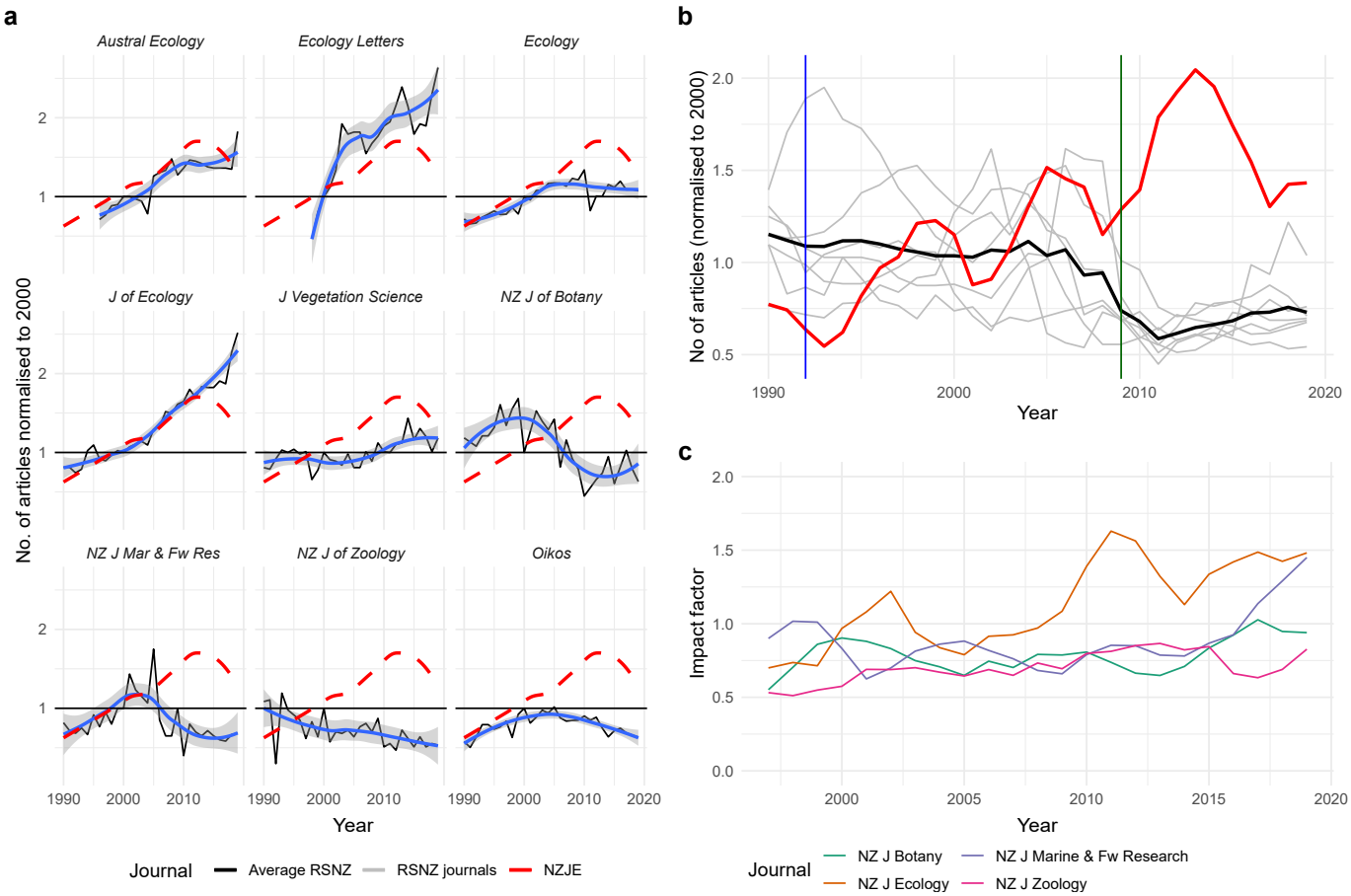

Figure 11. (a) Normalised trends (relative to 2000) in the number of articles published by three NZ and six international journals that publish ecological research; the red dashed line is the trend for the *NZJE*. (b) normalised trends (three-year running median) in number of articles in the *NZJE* and the journals published by the RSNZ (blue line is 1992 when the journals were handed over to the Royal Society and green line is 2009 when the journals co-partnered with Taylor and Francis. (c) impact factor for the four NZ ecological journals in (a) (IF from Thompson citation reports).

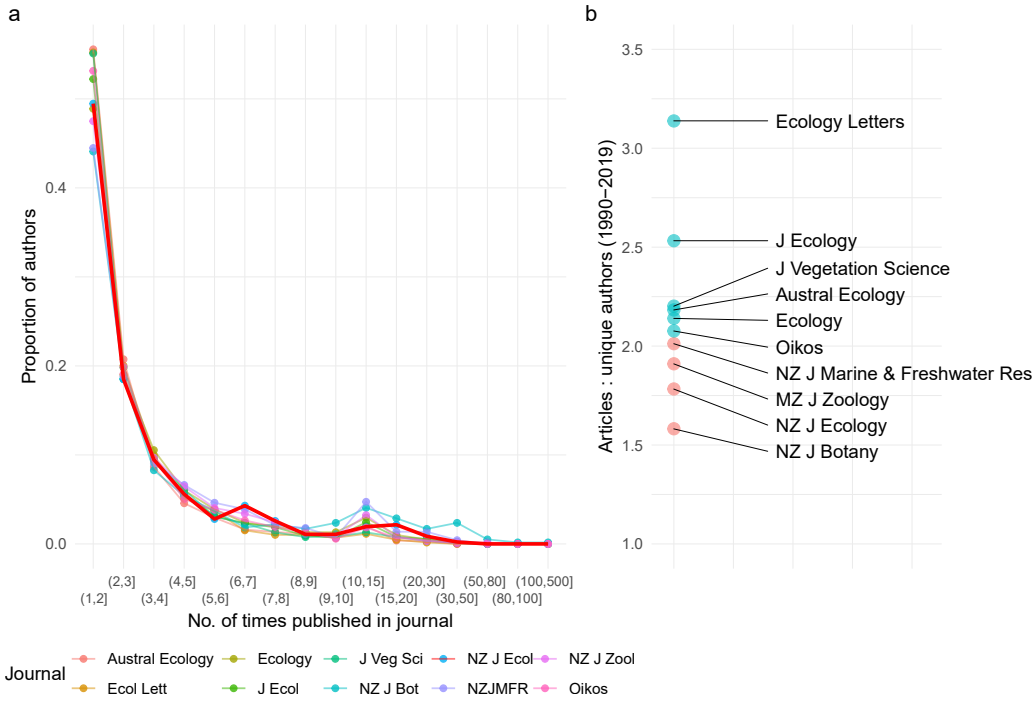

Figure 12. (a) Distribution of the number of times authors have published in a selection of NZ and international journals publishing ecological research and (b) the ratio of the number of articles published to the number of unique authors 1990–2019 (the smaller the ratio, the smaller the pool of unique authors); colours denote international vs NZ journals.

number of articles (1990–2019), then the NZ journals tend to show lower values (i.e. fewer unique authors scaled by journal output presumably reflecting smaller author pools) than some international journals but are similar to each other. In short, the *NZJE* may be an outlet for student-led research, but the author pool seems little different from comparable journals.

Austral Ecology (formerly *Australian Journal of Ecology*) provides an interesting comparison with the *NZJE*. Both are society journals and both have a history of publishing commentaries and perspectives on matters of interest to the local ecological communities they serve. However, *Austral Ecology* is an international journal, calling itself "A journal of ecology in the Southern Hemisphere", whereas the *NZJE* has remained local in focus. Westgate et al. (2020) comment that since 2010 there has been a marked increase in South American ecologists (i.e. affiliated to South American institutions) in *Austral Ecology* suggesting it does provide somewhat of a Southern Hemisphere focus. However, few New Zealand or South African ecologists have published in *Austral Ecology* over the last decade (authors on 69 and 89 of 1089 articles since 2010 respectively), and few Australians publish in the *NZJE* (Fig. 5; 33 of 398 articles since 2010). Based on analysis of *Austral Ecology* and the *NZJE* up until the late 1990s, Linklater & Cameron (2001) note differences in the ratio of fundamental ecology to applied (especially invasion) ecology in the journals, with invasion biology being more prevalent in the NZJE. The topic models presented here (Figs. 9, 10) for the *NZJE* and in Westgate et al. (2020) for *Austral Ecology* also suggest differences in the recent focus of the journals' publications (e.g. the prevalence of statistical ecology in *Austral Ecology* post-2010 vs. consistent focus on invasive mammals in *NZJE*). However, this differentiation does not seem to have attracted a flow of NZ-based authors to *Austral Ecology* or vice-versa. Perhaps so few New Zealand ecologists publish in *Austral Ecology* and vice-versa simply because of the respective groups' perspectives of the journals.

We suspect that the relative success of the *NZJE* to date in the New Zealand local journal ecosystem is owed above all to support by the NZES and thus, in a variety of ways including financial and in-kind, by the various private, government and university groups concerned with ecological science and environmental management. In essence, the *NZJE* has moved towards being a 'knowledge club' or social production technology (Potts et al. 2017) – "the most effective journals operate as clubs, providing frameworks and protocols for the production of knowledge and the creation of trust within a specialised community" (Hartley et al. 2019, p. 28). The enduring focus of the society on the conservation of New Zealand ecosystems and in particular the effects of vertebrate pests provides a stable platform for the journal. This broad theme has retained its relevance over many years, and if anything has increased with recent initiatives such as Predator-free New Zealand (Peltzer et al. 2019). How NZ ecologists have addressed this topic has changed over time reflecting shifts as to what taxon or ecosystem is regarded as of most pressing concern but the general thrust remains. For whatever reason, however, the research attention on invasive plants in NZ has not been evident in the publications of the journal.

Nevertheless, there is a problem with a journal such as the *NZJE* being primarily linked to a single theme because, in practice, it shrinks its declared scope, which, in turn, slows potential growth into promising new areas and discourages some authors. As such, the journal can become vulnerable to disruption if, for instance, interest in the theme should dwindle. It would therefore be in the long-term interest of the *NZJE* to expand the range of articles published. However, New Zealand, for its size, has a rather large suite of journals that often (or in the recent past did) publish ecological articles: *New Zealand Journal of Botany*, *New Zealand Journal of Zoology*, *New Zealand Journal of Freshwater and Marine Research*, *New Zealand Journal of Forestry*, *Journal of the Royal Society of New Zealand.* All face the issues outlined above. Moreover, all are in competition, whether they know it or not, to publish a limited supply of local articles, international outreach having been largely a failure. In our opinion, the field of local science publishing is well overdue for some rationalisation, which would provide New Zealand with fewer, but much stronger and more diverse journals.

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Author contributions

GP compiled the database and conducted the analysis. GP and MSM contributed substantially to writing the manuscript.

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Supplementary material

Additional supporting information may be found in the supplementary material file for this article:

Appendix S1. Network depiction of co-occurrence of words in titles in the *PESNZ* and *NZJE*.

Appendix S2. Distribution of γ values (probability of membership) for each topic identified via LDA.

Appendix S3. Stopwords used in the Latent Dirichlet allocation.

Appendix S4. Rationalisation of species names and removal of place names in keywords (Fig. 8).

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