Quantifying shifts in topic popularity over 44 years of *Austral Ecology*

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Abstract

The Ecological Society of Australia was founded in 1959, and the Society's journal was first published in 1976. To examine how research published in the society's journal has changed over this time, we used text mining to quantify themes and trends in the body of work published by the *Australian Journal of Ecology* and *Austral Ecology* from 1976-2019. We used topic models to identify 30 'topics' within 2,778 full-text articles in 246 issues of the journal, followed by mixed modelling to identify topics with above-average or below-average popularity in terms of the number of publications or citations that they contain. We found high interdecadal turnover in research topics, with an early emphasis on highly specific ecosystems or processes giving way to a modern emphasis on community, spatial and fire ecology, invasive species, and statistical modelling. Despite an early focus on Australian research, papers discussing South American ecosystems are now among the fastest-growing and most frequently-cited topics in the journal. Topics that were growing fastest in publication rates were not always the same as those with high citation rates. Our results provide a systematic breakdown of the topics that *Austral Ecology* authors and editors have chosen to research, publish and cite through time, providing a valuable window into the historical and emerging foci of the journal.

Introduction

One of the primary goals of the Ecological Society of Australia at its' inception in 1959 was the creation of a journal that focussed on publishing high-quality, regionally-specific ecological research (Slatyer and Saunders 1999). In 1976, this vision was realised with the publication of the first issue of *Australian Journal of Ecology.* The subsequent 44 years of publication of the *Australian Journal of Ecology/ Austral Ecology* (the name change occurring in the year 2000, and hereafter referred to as *Austral Ecology*) is a major success of which the society members can be proud. More importantly, the resulting corpus of ecological research stands as a record of the knowledge produced by students, researchers, reviewers and editors from 1976 to today. In reflecting on this achievement, therefore, it is natural to consider what themes define the corpus of research published in *Austral Ecology*: which themes are emerging or declining, what impact those themes are having via citation rates, and how the journal can continue to represent southern hemisphere ecology into the future.

In this paper, we present an evaluation of the content of the *Australian Journal of Ecology* and *Austral Ecology* between 1976 and 2019 (Volume 1 → 44) derived from topic modelling. Topic models – more technically known as Latent Dirichlet Allocation (LDA; Blei *et al.* 2003) – are a form of text mining that look for frequently occurring combinations of words to identify a user-specified number of word groupings, known as 'topics'. We then investigate trends in the popularity of topics over time. Specifically, we asked three questions:

1. What are the core topics of articles published in *Austral Ecology*?
2. How have these topics changed in prevalence over time?
3. Do topics with higher-than-average publication rates receive higher numbers of citations?

Although topic models have been widely used to investigate scientific corpora (including within ecology; Westgate et al. 2015), here we draw on several new developments to increase the detail of the insights provided by the model. First, we investigate topics within article full texts rather than abstracts only (Hintzen *et al.* 2020), as full texts are more information-rich and provide better topic coherence (Syed and Spruit 2017). Second, we use an expanded form of LDA called Structural Topic Modelling (STM; Roberts *et al.* 2019), which provides a better assessment of model convergence than historical applications. Finally, we expand on earlier statistical methods (i.e. Westgate *et al.* 2015) by calculating topic popularity both in terms of the number of articles published, and the extent to which those articles are cited, to give a more comprehensive insight into the impact of research published in this journal. In combination, these methods provide detailed insights into the content of *Austral Ecology* papers that would be difficult to achieve by manual investigation. We reflect on our findings and the changing research 'landscape' of ecology in the southern hemisphere.

Methods

Data collection and processing

We began by downloading full-text articles from Volume 1 (1976) to Volume 44 (2019), which we retrieved from the Wiley AEC website (https://onlinelibrary.wiley.com/loi/14429993). We restricted our analysis to the peer-reviewed research manuscripts (n = 2,779), excluding editorials, book reviews and hot topics. For recent articles, we downloaded the page source in HTML format, then imported the full text to R (R Core Team 2020) using custom code based on 'xml2' (Wickham *et al.* 2020). Where HTML was unavailable (mainly for older articles), we downloaded them as PDFs and used 'pdftools' (Ooms 2020) to extract full texts. Full-text data from PDFs often included multiple columns listed in the same text string, and so we wrote new custom scripts to split strings into their correct columns, and join words that had split across lines.

We used a modified version of the 'revtools' base code (Westgate 2019) to build a 'document term matrix', which lists the words present in each document and is the primary input to topic models. Modifications were required because the current version of 'revtools' (0.4.1) was built to investigate article abstracts and was too inefficient for use on article full texts. We solved this by using the 'ngram' (Schmidt and Heckendorf 2017) and 'parallel' packages to develop a more efficient method of counting terms within documents. Data showing the number of citations that each article had received in each year from 2007-2019 were provided by Wiley publishers for all articles since 2005.

Topic models

We used structural topic models, as implemented in the STM R package (Roberts *et al.* 2019), to identify 30 topics within the *Austral Ecology* corpus. While methods exist to help determine an 'optimal' number of topics for a given dataset, none of those methods is unambiguous, and we did not use them in choosing how many topics to include in our model. Instead, we arrived at 30 topics as an arbitrary number that balanced our need to summarise the large amount of information provided by article full–texts (suggesting a need for many topics), and our desire to provide a general overview of journal content rather than a description of every possible research topic.

To assess change in the prevalence of different topics over time, we first extracted a matrix of topic weights for each article. These weights give the estimated proportion of each article that consists of a given topic. We then calculated the sum of all weights for each topic and decade, then displayed these topics in rank order using a 'bump' plot (Sjoberg 2020). We used the top seven keywords from four distinct keyword identification algorithms (or 28 terms in total; see Table S1) to identify the dominant themes represented by each topic, numbering them in order of their rank in the first decade of our corpus (i.e. the 1970s).

Popularity analysis

Our final goal was to compare and contrast the results of two different methods for assessing topic popularity: one based on the number of articles published on that topic; and the second on the citation rates of those articles. We achieved this by building two statistical models of topic popularity for all articles published from 2005 onwards (i.e. the period for which annual citation data were available) and comparing their results.

We investigated growth in publication rates on a given topic following the method implemented by Westgate et al. (2015). Specifically, we began by assuming that each article could be allocated to the topic with the highest weight, and then used crosstabulation to calculate the number of articles per topic per year. We then used the 'lme4' package (Bates *et al.* 2014) to calculate a Poisson mixed model with article count as the response (n = 2,778), publication year as the predictor (1976-2019), and random intercepts and slopes for each topic. This method allowed us to discriminate between topics that were consistently highly-published (i.e. high intercepts) and those that were increasing in publication rate over time (i.e. high slopes, sometimes known as 'hot topics'). Our model of citation rates had the same predictor variable and random effect structure, but analysed the number of citations each topic had received each year between 2007 and 2019 as the response variable, for all articles published since 2005 that contained citation data (n = 1400, slightly less than the 1460 articles from this time period in our full dataset). We removed two topics (on woodlands and microhabitats) from our analysis because they were too rare to draw meaningful conclusions from, having been published on only twice since 2005. We then extracted the random intercepts and slopes from the mixed models to draw inference about growth in publication versus citation of each topic.

Results

Q1: What are the core topics of articles published in Austral Ecology?

We identified 11,555 unique terms within 2,778 documents, after removal of duplicated, rare, or uninformative terms (i.e. stop words), and used the resulting document-term matrix to build a topic model containing 30 topics (described in Table S1). Topics identified by our model related to individual study methods (genetics, statistics, monitoring), ecosystems (such as reefs, mangroves, alpine areas, deserts), taxa (herpetofauna, mammals, ants) or processes (climate change, urbanisation, cyclones, fire).

We found a small number of topics that incorporated themes that were conceptually distinct, but tended to be studied in parallel. For example, the highest weighted terms in the community ecological research topic clearly relate to the study of multi-species assemblages (i.e. commun[ity], rich[ness], function, pattern); but also included terms specific to South American research (e.g. Universidad, nacional, Argentina, cerrado, Brazil; Table S1). This implies that a high proportion of research from South America that has been published in *Austral Ecology* focusses on community ecological themes, and contains words that are rare elsewhere in the corpus (due to both linguistic and ecological differences). Similarly, several topics confounded a scientific theme with the taxa used to study them, such as pollination (which included 'bee'), grasslands ('*Themeda*'), and microhabitat studies ('*lutreolus*', apparently a reference to the swamp rat *Rattus lutreolus*), the last of which was our rarest topic consisting of 12 articles produced mainly by Barry Fox and colleages (e.g. highest weighted article: Haering and Fox 1997). A related pattern was the confounding of fields of research with their subthemes, such as landscape ecology containing terms like ‘fragmentation’ or ‘urban’, while forest ecology included the disturbance-related ‘cyclone’ and ‘hurricane’.

Despite some confounding of distinct themes within a single topic, we also found examples of the opposite phenomenon; that is, topics that were conceptually related but identified as distinct by our model. For example, our most common topic related to seed banks (‘germinant’, ‘seed’, ‘dormancy’; n = 167 articles) but also included ‘smoke’, despite a separate ‘fire’ topic containing a further 123 articles. Similarly, seasonal terms were distinguished from climate change, despite there being a conceptual link between seasonality and the impacts of climate on biodiversity. Finally, a theme focussed on herpetology (‘lizard’, ‘tadpole’, ‘snake’, ‘frog’, n = 150 articles) was classified as distinct from the literature on invasive species (n = 41 articles), despite Cane Toads being prominent in both topics.

Q2: How have these topics changed in prevalence over time?

We observed high inter-decadal turnover in the dominant themes within *Austral Ecology* (Figure 1). As an illustrative example, the top-ranked topic in the 1970s focussed on alpine ecology, but this topic was ranked 27th (of 30) by the 2010s. Similar declines were notable for the next three highest-ranked topics, with seasonal terms dropping from 2nd to 13th place; soil & leaf litter research from 3rd to 17th place; and plant-insect interactions from 4th to 21st place. Conversely, the bottom-two ranked topics in the 1970s – community and landscape ecology – soared to second and fourth respectively by the 2010s. A similar pattern was evident for climate change and species distribution modelling (SDM), rising from 24th to 3rd place.

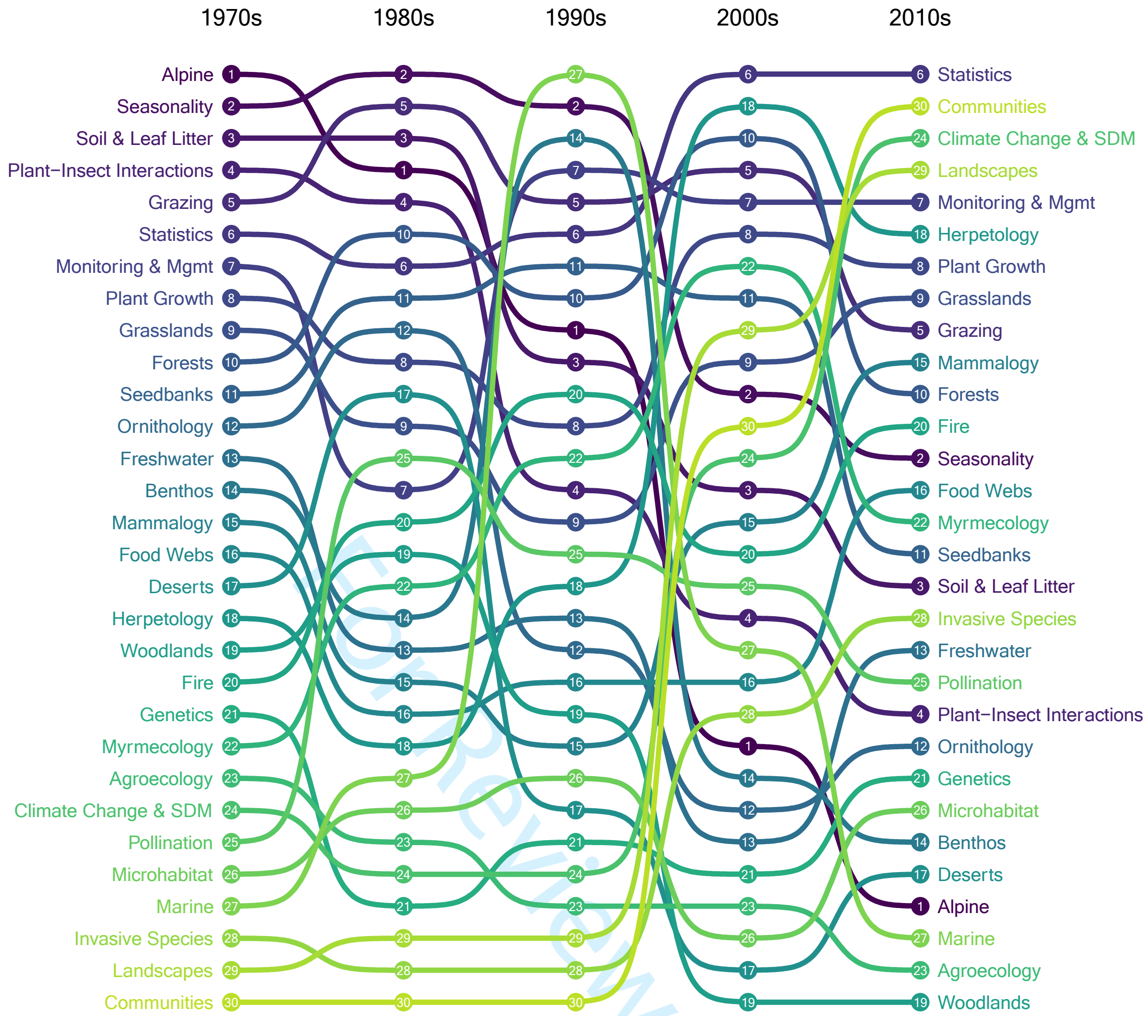

Figure 1: Bump plot showing inter-decadal change in ranked prevalence of 30 topics within the *Austral Ecology* dataset.

Not all changes were unidirectional across the 44 years of our dataset. Pollination research increased from 25th to 13th place in the 1980s, but has been in moderate decline in this corpus ever since (ending in 20th place). This trajectory is unexpected given the importance of pollination to agriculture (Klein *et al.* 2007), as well as debates over the extent of pollinator declines during this same period (Goulson *et al.* 2008). A similar (declining) trajectory was evident for research on semi-arid woodlands, moving from 19th to last place. The 1990s saw short-lived peaks in research on both benthic and marine ecology (initially ranked 14th and 27th, respectively), which may reflect the influence of Australian marine researchers at this time (e.g. Underwood 1997), or perhaps the ambassadorial role of journal editors such as

Peter Fairweather and David Ayre in promoting those fields. Research on ants (22nd) and herptiles (18th) showed peaks in the 2000s. Grasslands (9th) and forests (10th) spent the 2010s within a single rank point from their starting positions, despite following opposing trajectories in between; grasslands dropping six places by the 1990s then recovering, while forest ecology climbed as high as third place in the 2000s before dropping again.

Finally, a set of ubiquitous concepts have managed to retain a similar degree of popularity during the entire period of publication of *Austral Ecology*. Most obvious is that statistical modelling, always important in ecology, has consolidated its place to become the most frequently discussed topic in the corpus. Research on monitoring and management changed only two places (from 7th to 5th) across five decades, despite a brief dip in popularity in the 1980s. Research on plant growth (8th) and grazing (5th) were similarly unchanged in popularity over time.

Q3: Do topics with higher-than-average publication rates receive higher numbers of citations?

We found a positive relationship between the number of articles published on a topic and the number of citations that topic had received, for papers published between 2005 and 2019 (Fig. 2a). However, some topics substantially over- or under-performed in terms of total citations. Fire ecology (topic 15 in Fig. 2) was the best performer overall with 1364 citations; but research on mammalogy (topic 6, n = 1227), landscape ecology (topic 2, n = 1207) and forest ecology (topic 12, n = 1127) performed similarly well. Relative to the number of publications, research on ecological monitoring (topic 16) and invasive species (topic 4) performed similarly well. Unexpectedly, however, the two most widely published topics – community ecology (topic 1) and herpetology (topic 5) – both underperformed relative to the mean for their number of publications. In fact, community ecology received fewer total citations (n = 751) than research on invasive species (topic 4; n = 789) despite the latter having approximately a third the number of papers (n = 36 vs 103).

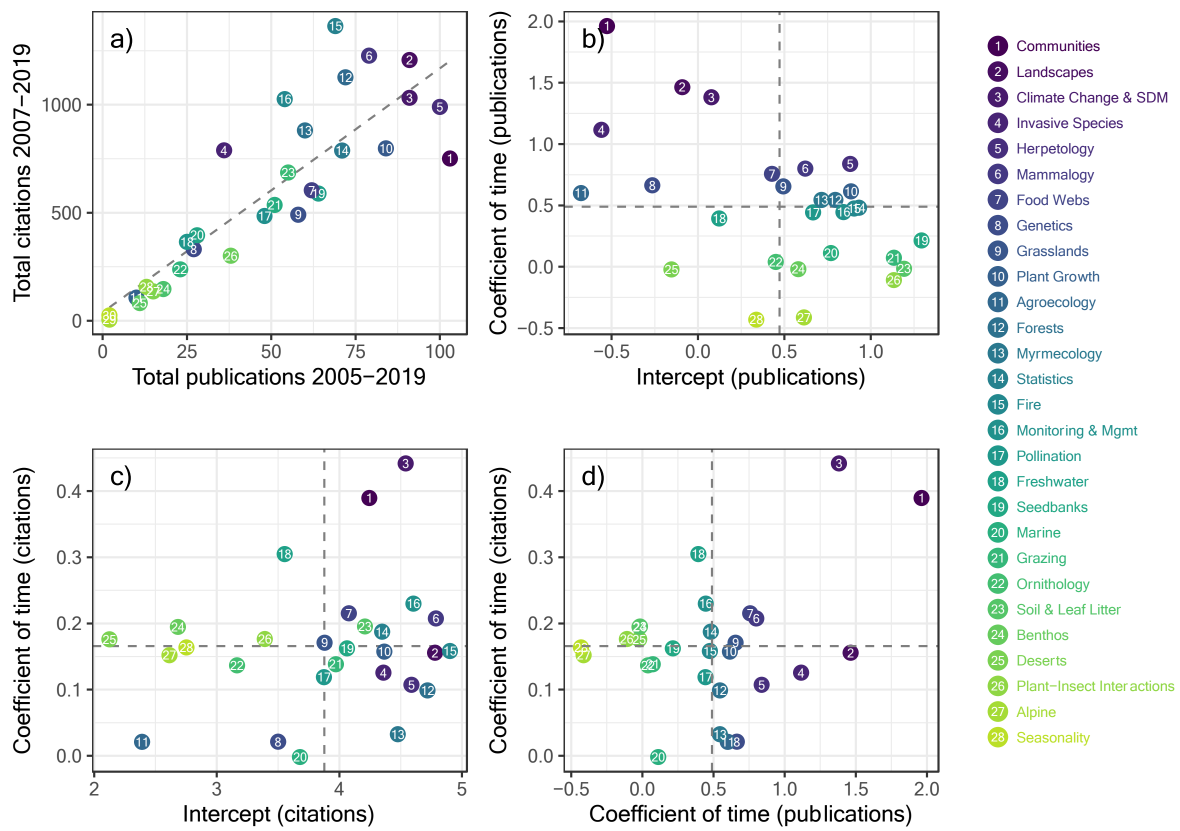

Figure 2: Comparison of topic popularity as assessed by publication and citation rates for 28 topics in the Austral Ecology corpus. a) Counts of total citations and total publications by topic for all articles published since 2005 (and citations summed from 2007 onwards). b) Topic-level random intercepts (x) and slopes (y) from a model of publication rates over time, 1976-2019. c) Topic-level random intercepts (x) and slopes (y) from a model of citation rates over time, 2010-2019. d) Comparison of topic-level slopes from the publication (x) and citation (y) models. In all panels, topics are coloured in order of their change in publication rate over time (y axis in panel b), which is different from their order in Figure 1. The dashed line in panel (a) is a linear regression line, while in panels (b) through (d) dashed lines show the value of the fixed effect for each term.

Mixed modelling of publication rates from 1976-2019 showed a set of topics that had been frequently published but are now in decline (i.e. those on seedbanks, leaf litter, grazing experiments and plant-insect interactions; bottom-right quadrant of Fig. 2b), as well as a set of ‘hot topics’ that were historically rare but have experienced high growth rates in recent years (including community ecology, landscape ecology, and climate change; top-right quadrant of Fig. 2b). These findings were broadly consistent with those presented in Figure 1; but our analysis of citation results showed a different pattern entirely. In particular, two topics with low numbers of total citations relative to publication rates (Fig. 2a) are actually growing in citations at extremely high rates (Fig. 2c); these were research on community ecology (topic 1) and climate change and SDM (topic 3). The ecology of freshwater systems (topic 18) is also growing in citations at a high rate, moving from 11 citations in 2010 to over 60 in both 2018 and 2019. Conversely, research on benthic communities (topic 20), agroecology (topic 11), genetics (topic 8) and myrmecology (topic 13) have experienced relative declines in citations over time.

Comparison of growth rates in citations versus publications (Fig. 2d) showed that among the set of topics that have grown rapidly in publication rate (i.e. topics 1-5), there was a clear separation between those that were growing quickly in citations and those with relatively little growth. Specifically, community ecology (topic 1) and climate change (topic 3) research have increased rapidly in both publications and citations; but landscape ecology, herpetological and invasive species research (i.e. topics 2, 4 & 5) have received average or below-average growth in citations since 2007. In contrast, topics that had lower-than-average growth in publications between 2007 and 2019 showed low variability about the average in terms of their increase in citations over time. The exception to this pattern was marine research (topic 20) which experienced almost no growth in either publications or citations over this time period, suggesting that research on this topic has simply moved to other journals in recent years.

Discussion

We used topic modelling to investigate themes in the articles published by the *Australian Journal of Ecology* and *Austral Ecology* over the last 44 years. While no single analysis can provide a complete summary of such a large and detailed corpus, our analysis revealed notable themes of research published in this journal, and how those themes have changed in popularity over time. We hope that these insights both support a deeper reflection on the past, present and future strengths of *Austral Ecology* as a forum for ecological research, and for reflection on southern-hemisphere ecological research in general. Below we expand and reflect on some noteworthy findings from our analysis.

One clear pattern from our analysis was that the fastest-growing themes in *Austral Ecology* reflect bodies of research that are prevalent in the broader ecological literature (Milner-Gulland *et al.* 2013; Kim *et al.* 2018). By far the largest change in prevalence over time in our corpus was the explosion of community ecology research, which has expanded from a single article in 2001 (Soares *et al.* 2001) to 24 articles in 2019, making it the second-ranked theme across all articles published 2010 to 2019 (Fig. 1). Several of the highly-weighted concepts in this topic – including research on biotic assemblages and functional ecology – have grown substantially since the early 2000s, and so it is unsurprising that they have an influence here. Indeed, the shift in emphasis from single-species to multi-species research was noted at the time as a growing trend in the ecological literature (Lindenmayer *et al.* 2007). Further, early work by Anderson (2001) on multivariate analysis published in *Austral Ecology* may have helped drive submissions on that topic to this journal. Behind community ecology, the fastest-growing topics were invasive species research and two subthemes of spatial ecology: one focussing on landscape-scale processes such as fragmentation and urbanisation; and the other biogeographic scales incorporating climate change and species distribution modelling (SDM; Fig. 2b), which reflect a similar shift towards spatial tools for understanding the threats to biodiversity from biotic invasion, habitat loss and climate change (e.g. Hansen *et al.* 2020; Hoffmann *et al.* 2019; Kearney 2019; Lima *et al.* 2020).

In contrast, topics relating to specific locations or study systems have been in decline. For example, the reduction in marine research, ornithology, leaf litter dynamics, plant-insect interactions and alpine botany (topics 20, 22, 23, 24, 26 and 27 in Fig. 2) may reflect a loss of submissions to multidisciplinary journals, more targeted journals, or may result from the increased number of journal options that ecologists have to publish in. In 2000 there were 100 journals identified by Thomson Web of Science in the Ecology discipline; in 2019, this expanded to 168 journals. This increase in journal submission options within disciplines is consistent across Zoology (2000: 112 journals compared to and 2019: 168 journals), Plant Sciences (2000: 137 and 2019: 234), Environmental Sciences (2000: 127 and 2019: 265), Entomology (2000: 68 and 2019: 101), Marine and Freshwater Sciences (2000: 71 and 2019: 106) and Multidisciplinary Sciences (2000: 49 and 2019: 71). Therefore, we find it unlikely that topics in decline within the *Austral Ecology* corpus have declined in absolute terms; rather that they are simply being published in a wider range of sources than were available when the journal was founded.

While patterns of publication growth in *Austral Ecology* reflected wider trends in the global ecological literature (Borrett *et al.* 2014; Carmel *et al.* 2013), topics with high mean numbers of publications (i.e. the intercept in Fig. 2b) were more indicative of the specific research foci of southern-hemisphere ecologists in general, and Australian ecologists in particular. The preponderance of research on fire was perhaps the most obvious example of regional bias, having been recognised as a major driver of biotic change for decades (e.g. see Gill *et al.* 1981), and remaining a key focus of research in many countries including Argentina, Australia, Brazil and South Africa (e.g. Blanckenberg *et al.* 2019; Hoffmann *et al.* 2019; Santacruz-García *et al.* 2019; Geary *et al.* 2020). Two topics relating to mammalian food webs – one focussing on the species involved (i.e. dingos, cats) and the other on diet analysis – were also highly prevalent, reflecting the disproportionate impact that introduced predators have had on Australian ecosystems relative to other locations around the world (Woinarski *et al.* 2015). Less expected was the presence of two taxonomic specialties in this group; one on myrmecology reflecting a long tradition of research on this group within Australia and South Africa (e.g. Andersen and Muller 2000), and the second on herpetology reflecting the high richness and endemism of the Australian frog and reptile fauna (Slatyer *et al.* 2007; Roll *et al.* 2017), potentially in combination with a dedication to that fauna expressed in the work of long-term Managing Editor Mike Bull (see Gardner *et al.* 2020). Finally, topics with global application but specific relevance to an Australian context were also evident, such as ecological monitoring (highest weighted article: Lindenmayer *et al.* 2012) and forest ecology (Metcalfe *et al.* 2008).

One shortcoming of our analysis was that the high concordance between community ecological studies and research from South America meant that our topic model confounded them, making it difficult to distinguish between geographic and thematic drivers of publication rates. For example, the three highest-weighted articles in this topic all investigated multiple species in South American ecosystems; these were the works of Pinhero et al. (2002; 94% weight), Canavero et al. (2019; 74%) & Francisco et al. (2018; 64%). Further, it is clear that both themes have increased in prevalence over the same time period; community ecology has grown in importance across the ecological literature (as discussed above), and South American research has benefitted from concerted efforts to make the journal more inclusive of southern hemisphere research and increase its exposure in a wider range of countries. Indeed, wider circulation outside of Australia was a key motivation for changing the journal name from *Australian Journal of Ecology* to *Austral Ecology* in 2000. While beyond the scope of this study, avoiding issues of this kind could be achieved via a more nuanced approach involving the extraction of methodological, taxonomic or geographic information, and running topic models on the remaining text. This approach would allow a detailed investigation of ecological themes, but also an assessment of how those themes vary among research clusters, taxa or regions (Millard *et al.* 2020). From an editorial perspective, the positive outcome of increases in South American research highlights a relative paucity of research from the South Pacific Islands, South-East Asia, and a larger number of southern African countries. Further work to increase participation from those regions could benefit the diversity and richness of the work published in *Austral Ecology*.

Finally, it is interesting to note that we found no correlation between the topic-level publication and citation rates (Fig. 2d). For example, several topics which are growing in popularity among authors are suffering below-average citations rate increases, including genetics, herpetology and invasive species research (topics 8, 5 & 4 in Fig. 2d). Similarly, among aquatic topics, freshwater research (topic 18) is increasing rapidly in citations despite being rarely published, while citations of marine research (topics 20 & 24) are in relative decline. The lack of correlation between these parameters is unexpected, but one potential explanation is statistical: these analyses are likely to be sensitive to the time window under investigation, as well as to the likely presence of time lags between popularity in publication versus citation, meaning that a more detailed investigation may reveal subtleties not evident in our analysis. Certainly, it would be unwise for authors to make decisions about what types of articles to write – or editors which articles to publish – based on these observations. What is clear, however, is that any analysis of popular topics based solely on publication rates (e.g. see Westgate *et al.* 2015) risks missing important information on the uptake of those findings by other researchers (as identified via citation rates). Therefore, we suggest future authors consider these issues in more detail, potentially by drawing on analysis of co-citation networks in combination with themes identified via text mining (an approach known as 'research weaving'; Nakagawa *et al.* 2018).

Conclusions

Austral Ecology has published on a large variety of topics in its 44 years of existence, and while some themes are now rarely seen, others have emerged and come to define a relatively large proportion of the content of the journal. Indeed, each decade has seen a change in emphasis reflecting the scope of the journal and the interests and learnings of southern-hemisphere ecologists at that time: alpine and plant-invertebrate interactions peaking in the 1970s; pollination, ornithology & grassland research in the 1980s; marine research in the 1990s; myrmecology and herpetology in the 2000s; and spatial ecology, invasion biology and research from South America in the 2010s. This flexibility is a strength of the journal that will allow *Austral Ecology* to continue to support emerging themes, and underrepresented regions, into the future.

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Appendices

Table S1: Keywords by topic, according to four different term selection metrics

Topic	Label	Highest Probability	Frequency & Exclusivity	'Lift' Metric	'Score' Metric
1	Genetics	populous host genet infect parasite sample isolate	infect genet allele haplotype gene disease loci	qiagen amova agarose genbank polymerase virulent nucleotide	infect host genet haplotype parasite populous allele
2	Agroecology	plant weed pasture zealand control manage moth	weed broom buffel zealand pasture moth browse	cryptostegia buffel melicytus tawa ramiflorus weed monilifera	weed pasture moth possum pest zealand buffel
3	Herpetology	female male lizard frog body size adult	lizard tadpole snake frog python shine male	anstis hemipenes hoplocephalus langkilde lesueurii liasis mahony	female male frog tadpole snake lizard python
4	Forests	tree forest canopy rainforest site stand height	cyclone tree crown trunk canopy rainforest hurricane	dbhob brokaw dendrocnide pohlman treefall castanospermum alstonia	tree forest rainforest canopy cyclone hurricane liana
5	Statistics	model variable estimate sample value spatial predict	model predictor parameter regressed linear best predict	tibshirani correlogram weibull aicc ndvi moloney colinear	model akaike variable spatial ndvi aicc predictor
6	Seedbanks	seed germinant seedling soil disperse remove bank	germinant seed smoke dormancy seedling heat diaspore	elaiosome ungerminated myrmecochory scarification imbibition scarified germinant	seed germinant seedling smoke dormancy soil diaspore
7	Deserts	arid rainfall dune sand desert grass acacia	mulga triodia spinifex swale elephant vesicaria chenopod	andado impala mulga piosphere triodia aepyceros basedowii	triodia mulga spinifex dune swale elephant vesicaria
8	Landscapes	habitat patch landscape site edge fragment remnant	remnant urban edge fragment landscape patch road	mcgarigal chalinolobus mormopterus clutter debinski murcia nyctophilus	urban landscape remnant patch fragment habitat reptile
9	Benthos	site sample disturb mine abund sediment estuary	estuary mangrove saltmarsh crab sediment estuarine tidal	avicennia macrobenthos ceriops macrobenthic	estuary sediment benthic saltmarsh meiofauna estuarine tidal

				nemertean saltmarsh macrofaunal	
10	Soil & Leaf Litter	soil litter nutrient concentric site sample nitrogen	decomposition litter phosphorus litterfall potassium nutrient microbial	throughfall litterbag menage nitrification denitrification mesofauna litterfall	soil litter litterfall decomposition nitrogen phosphorus nutrient
11	Communities	commune rich function pattern forest variable environmental	universidad nacional argentina nestedness cerrado brazil bromeliad	estadual akodon chusquea oligoryzomys pesquisa programa universidad	cerrado brazil argentina universidad nacional chaco bromeliad
12	Ornithology	bird nest honeyeater forage colony abund observe	honeyeater noisy hummingbird magpie passerine bird ford	blakers chrysoptera cuckoo cyanoleuca fantail hainsworth lalage	honeyeater bird nectar hummingbird noisy nest wattlebird
13	Woodlands	australia western banksia termite table cone woodland	jarrah dryandra cone wandoo fynbos termite ericifolia	fraseriana jarrahdale drepanotermes bettenay kwongan eneabba dryandra	jarrah banksia dryandra wandoo termite fynbos serotinous
14	Food Webs	food prey diet feed forage predate consume	item diet prey stomach isotope intake trophic	penguin gizzard stomach item hobson millet intestine	prey diet isotope food stomach chick spider
15	Monitoring & Mgmt	ecolog manage will ecosystem monitor system research	programme monitor ecologist decision issue principle scientist	societal rigour intellectual discipline scientist politicians lesson	biodiverse ecosystem monitor manage policy scientist environmental
16	Pollination	flower fruit plant pollinate pollen visit inflorescence	pollinate bees inflorescence flower mistletoe floral visitor	colletidae halictidae ollerton stamens stigma stigmatic apis	flower nectar pollen pollinate inflorescence fruit mistletoe
17	Grasslands	treatment plant plot biomass experi grass control	treatment biomass pots themeda experimental experi sward	lauenroth vulpia lolium tiller austrodanthonia osmocote sward	treatment biomass grass plot plant graze grassland
18	Marine	fish density abund alga reef recruit habitat	reef alga kelp shore algal snail coral	macroalgal cellana coralline cystophora jernakoff labridae larkum	fish alga kelp reef seagrass limpet coralline
19	Alpine	site vegetal altitude zone occur alpine slope	lichen peat alpine cushion bryophyte snow sporocarp	lanigerum richea atherosperma bogong aspleniifolius athrotaxis phlogopappa	pollen cushion alpine snow lichen sporocarp nothofagus
20	Mammalogy	trap mammal predate populous island anim small	dingo mice cats scat rats wallaby foxs	dingo canid coman lagotis lupus macrourus mustela	dingo rodent trap mice cats mammal rattus