Environmental sciences research in northern Australia, 2000-2011: A bibliometric analysis within the context of a national research assessment exercise

Authors: Jayshree Mamtora*, Jacqueline K. Wolstenholme, Gaby Haddow

* Corresponding author: Jayshree Mamtora, Office of Library Services, Charles Darwin University, PO Box 41246, Casuarina, NT 0812, Australia. Email: jayshree.mamtora@cdu.edu.au; telephone: +61 8 8946 6541; fax: +61 8 8946 7022

Jacqueline K. Wolstenholme, Library and Information Services, James Cook University, Townsville, QLD 4811, Australia. Email: jackie.wolstenholme@jcu.edu.au; telephone: +61 7 4781 4215; fax: +61 7 4781 6099

Gaby Haddow, Dept. of Information Studies, Curtin University, GPO Box U1987, Perth, WA 6845, Australia. Email: g.haddow@curtin.edu.au; telephone: +61 8 9266 2707; fax: +61 8 9266 3152

Abstract

This paper reports on a bibliometric analysis of environmental sciences research in northern Australia between 2000 and 2011. It draws on publications data for Charles Darwin University (CDU) and James Cook University (JCU) researchers to present a bibliometric profile of the journals in which they publish, the citations to their research outputs, and the key research topics discussed in the publications. Framing this analysis, the study explored the relationship between the two universities' publications and their 'fit' with the environmental sciences field as defined by the Australian research assessment model, Excellence in Research for Australia (ERA). The Scopus database retrieved more records than Web of Science, although only minor differences were seen in the journals in which researchers published most frequently and the most highly cited articles. Strong growth in publications is evident in the twelve year period, but the journals in which the researchers publish most frequently differ from the journals in which the most highly cited articles are published. Many of the articles by CDU and JCU affiliated researchers are published in journals outside of the environmental sciences category as defined by Scopus and Web of Science categories and the ERA, however, the research conducted at each university aligns closely with that institution's research priorities.

Keywords: environmental sciences; northern Australia; Excellence in Research for Australia; Charles Darwin University; James Cook University; Fields of Research codes

MSC2000: 92 Biology and other natural sciences

MSC2010 62P12 Applications to environmental and related topics;

JEL: Q Agriculture

Introduction

Environmental Sciences is one of 22 overarching research disciplines assessed in the Australian Research Council's assessment exercise, Excellence in Research for Australia (ERA). It is a discipline that is difficult to define, encompassing a diverse array of topics ranging from the physical to the social sciences. In the ERA, journal publications aligned with environmental sciences are assessed using citation analysis and very little is known about how this assessment relates to the final ratings of

an institution's research in the discipline. Framed by the assessment mechanisms of the ERA and definitional challenges of the discipline, the study reported here aimed to create a bibliometric profile of environmental sciences research at two highly rated universities in northern Australia, Charles Darwin University (CDU) and James Cook University (JCU), over a 12-year period, 2000-2011.

The study is the first to examine Australian environmental sciences research with a focus on how the discipline is represented by its publications and citations. Data drawn from the Scopus and Web of Science (WoS) databases were analysed to illustrate the nature of publishing and citations in environmental sciences research by authors affiliated with the universities. Publications data were also mapped to the classification scheme used by the ERA to define discipline areas.

Environmental Sciences Research at Charles Darwin University and James Cook University

CDU and JCU have a strong record in environmental sciences research at national and international levels. In the *Times Higher Education* (2011) list of top institutions in environmental sciences and ecology in Australia and New Zealand for the period January 2000 to December 2010, which draws on citation data from the Essential Science Indicators (ESI) database, CDU was ranked 4th in Australia and 123rd world-wide. JCU was ranked 2nd in Australia and 42nd world-wide. Environmental sciences research at the universities was also rated highly in the Australian research assessment model, the ERA. At the broad discipline level, research at CDU was assessed as 'at world standard' in 2010, advancing to 'above world standard' in 2012. JCU was assessed as 'well above world standard' in both ERA rounds. The universities were also assessed in the environmental sciences sub-fields 'Environmental Science and Management' and 'Ecological Applications', for which CDU received an 'above world standard' assessment and JCU a 'well above world standard' assessment in each sub-field.

Located in northern Australia, both universities are multi-campus institutions. CDU has a primary campus in Darwin, Northern Territory, and JCU's main campus is in Townsville, Queensland. CDU is a small and relatively young regional university with five priority environmental sciences themes: coastal and marine ecology and management, freshwater ecology and management, natural resources-based livelihoods, savanna management and wildlife conservation and tropical resource futures (Charles Darwin University, 2011a). JCU's strategy aligns research with four themes, each focused on the tropics. The theme of greatest relevance to environmental sciences is tropical ecosystems, conservation and climate change (James Cook University, 2012a), with key research areas in ecology and environment, plant and animal science, geosciences, and coral reef science.

Bibliometric approaches to environmental science research

There are relatively few bibliometric studies that focus solely on environmental sciences research; it is more often the case that environmental sciences feature in studies of related areas or subfields. In part, this can be explained by the nature of the field, described by Khan and Ho (2012, p. 122) as "multidisciplinary". These authors analysed papers in the WoS category Environmental Sciences. Their results for the top cited papers in the field were dominated by articles from the United States, but one Australian paper was amongst the top 10 most cited papers. Defying the generally accepted notion that science papers are cited soon after publication, Khan and Ho (2012) found the time lag between publication and attracting 20 or more citations varied greatly, ranging from one to ten years. The authors also noted the difficulty of identifying environmental sciences publications in WoS, despite the availability of the Environmental Sciences category with which to search (p. 126). Other bibliometric studies of environmental sciences are less relevant to this paper and include Lopresti's

(2010) examination of citation accuracy and Leblond's (2012) investigation of self-citations in the field of ecology.

Bibliometric analysis of fields related to environmental sciences frequently note the important role played by the WoS Environment Sciences category. Studies on algae and bio-energy (Konur, 2011), climate change (Li, Wang & Ho, 2011), biodiversity (Lui, Zhang & Hong, 2011), and coastal eutrophication research (Sun, Ni & Ho, 2011), all note a high proportion of papers listed under Environmental Sciences. Belter (2012) also found the category featured strongly when identifying WoS papers that had cited research funded by the Office of Ocean Exploration and Research.

In general, Thomson Reuters data, either from WoS or ESI, has been the main citation source for environmental sciences analysis, although Gray and Hodkinson (2008) compared WoS with Scopus data in their study of environmental sciences and ecology journals. Using the different databases' citation results to rank the journals by impact factor (calculated manually for the Scopus data), the authors found "the JCR and Scopus ranks had a high degree of statistical similarity" (n.p.). Several evaluative studies have compared the main citation sources, arriving at a general consensus that WoS and Scopus complement each other, each having strengths and weaknesses in coverage (Bar-Ilan, 2008; Burnham, 2006; Meho & Yang, 2007; Salisbury, 2009).

Research assessment in Australia: Excellence in Research for Australia (ERA)

The ERA is a recent initiative in the Australian higher education sector (introduced in 2009) and very little is known about the publications profile that results in a high ERA assessment. It is a nation-wide assessment exercise which applies citation analysis as the primary quality indicator to assess science fields - using Scopus as the citation source (Australian Research Council, 2012a). Assessment of journal articles is restricted to a defined list of over 20,000 journals (Australian Research Council, 2012b). Each journal is assigned between one and three Field of Research (FoR) codes from the Australian and New Zealand Standard Research Classification Scheme (ANZSRC) (Australian Bureau of Statistics, 2008). Two-digit FoR codes are used to denote a broad disciplinary field, while four-digit codes are used for sub-fields. An article is assigned the same code(s) as those assigned to the journal in which it is published, and individual researchers have to select one to three four-digit FoR codes to represent their individual research interests. A Multidisciplinary (MD) category (assigned to 3.4% of the ERA journals) acknowledges the problems of classification for some journals. Substantial divergence between an author's view of their article's subject content and the ERA classification of the journal was found by Bennett, Genoni and Haddow (2011).

In the ERA, research is assessed in Units of Evaluation (UoE) aligned with the hierarchical system of two and four digit FoR codes. (The ANZSRC subdivides fields further with a six-digit code, but these are not used in the ERA assessment). The UoEs for the environmental sciences are: 05-Environmental Sciences, and its subfields 0501 - Ecological Applications; 0502 - Environmental Science and Management; 0503 - Soil Sciences; and 0599 - Other Environmental Sciences. The high ERA ratings for environmental sciences research at CDU and JCU suggests strong publishing activity in journals assigned the 05, 0501 and 0502 FoR codes.

This publishing activity is the focus of the study reported here. Using the ERA's FoR classification as a framework, the study aimed to establish a bibliometric profile of the:

- journals in which affiliated researchers publish most frequently;
- articles that have received the highest number of citations;
- citation database that retrieved the highest number of citations for researchers' articles; and

- key research areas discussed in the content of researchers' articles.

The bibliometric analysis tests whether environmental science publications align with the ERA classification for the field and examines the topics discussed in the publications for evidence of divergence from the classification. Furthermore, by examining the environmental sciences research publications associated with two highly ranked universities, the findings of the bibliometric analysis contributes to a deeper understanding of what constitutes 'quality' in research outputs for the field.

Methods

To undertake the bibliometric analysis, bibliographic, abstract and citation data were required for all environmental sciences articles published by researchers affiliated with CDU and JCU. A twelve year period (2000-2011) was used for the analysis. Data were drawn from both Scopus and WoS to compare the databases' results. The Science Citation Index Expanded, Social Sciences Citation Index, and Arts & Humanities Citation Index comprised the WoS search.

Articles were identified using variants of the university names as search terms and retrieved records were limited to articles and reviews, as defined by the respective databases. The searches were constructed to favour recall of records relating to environmental sciences. The WoS search included 19 Research Areas (formerly Subject Areas): agriculture; biochemistry molecular biology; biodiversity conservation; entomology; environmental sciences ecology; evolutionary biology; fisheries; forestry; genetics heredity; geography; marine freshwater biology; meteorology and atmospheric sciences; oceanography; paleontology; physical geography; plant sciences; remote sensing; water resources; and zoology. The Scopus search included five Subject Areas: agricultural and biological sciences; biochemistry, genetics and molecular biology; earth and planetary sciences; environmental science; energy. In some searches, Scopus defaults to include the multidisciplinary subject area and did so in the searches for this study. The searches and data collection was undertaken in January 2012. Journal Impact Factor (JIF) and Scimago Journal Rank (SJR) data were drawn from the 2011 editions.

To explore the alignment of articles with ERA UoEs, FoR code information was extracted from the 2012 ERA journal list (Australian Research Council, 2012b) for all journals retrieved in the searches. All journals and their associated articles were classified into one of four groups based on the FoR codes.

- 05: Environmental Sciences - journals with at least one four-digit code within 05 or the two-digit 05 code;
- MD: Multidisciplinary - journals assigned the MD code;
- Other FoR - journals in the ERA journal list with codes other than 05 and MD; and
- Not ERA - journals not listed in the 2012 ERA journal list.

In order to identify the primary research areas discussed in the content of researchers' articles, abstract and title data from the retrieved WoS records were mapped using VOSviewer (version 1.5.2; http://www.vosviewer.com/). This enabled the visualisation (Van Eck & Waltman, 2010) of environmental sciences research topics and relationships within the field at CDU and JCU. A threshold of 25 occurrences of a term was applied for JCU, while the CDU analysis used a threshold of 10 term occurrences. The different thresholds were applied to allow for the larger JCU data set, which could withstand a higher threshold of term occurrences without losing cluster definition. To simplify the JCU map only the first 200 terms, ranked as having highest relevance, were displayed. A

number of terms were excluded from the analysis, such as publisher names and headings that are commonly used in articles and do not relate to the field, such as aim(s) and conclusion(s).

Results

The Scopus and WoS database searches for environmental sciences articles produced a similar pattern of results for CDU and JCU, with Scopus returning more results for both universities.

CDU	Scopus	935 articles 322 journals	WoS	773 articles 246 journals
JCU	Scopus	4213 articles 927 journals	WoS	3229 articles 574 journals

Over the 12 year period, both universities saw substantial increases in their environmental sciences article publications. For CDU, the Scopus results show an increase of 378% over the period and WoS results indicate an increase of 280% (Figure 1a). The JCU results illustrate a threefold increase in article publications in the Scopus data, while the WoS data show a doubling of article publications over the period (Figure 1b).

FIGURE 1a ABOUT HERE

FIGURE 1b ABOUT HERE

Figure 1a: CDU Environmental Sciences Research Outputs: 2000-2011

Figure 1b: JCU Environmental Sciences Research Outputs: 2000-2011

The WoS and Scopus data were analysed to identify the journals in which the affiliated authors published their articles. The CDU search results found an overlap of 216 journals between the two databases, with 102 titles unique to Scopus and 30 journal titles unique to WoS. In the JCU results there was an overlap of 507 journals between the two databases, with 420 titles unique to Scopus and 65 titles unique to WoS.

Although Scopus produced higher overall results than WoS for both universities, the 10 most productive journals (those in which the articles are published most frequently) correspond closely. Six of the 10 most productive journals achieve the same rank in the data for each university, although the number of articles in the titles differs slightly. An exception to these findings was the JCU results for the journal *Marine and Freshwater Research*, for which there was a disparity of 17 articles, in favour of the WoS data.

In the CDU results the most productive title in both database results is an Australian journal which is at the lower end of the SJR and JIF ranges, and Australian journals feature strongly in the 10 most productive titles. Notably, only one journal in the CDU WoS results is assigned to the Environmental Sciences category by the database, whereas seven of the titles in the Scopus results are indexed with this subject area. In the JCU results, only four of the journals are classified as Environmental Science in the Scopus results. The most common category in the JCU WoS results is Marine and Freshwater Biology, with one journal assigned to the Environmental Sciences category. The most productive journals for JCU tend to have mid-range SJRs and JIFs in the respective databases. For the sake of brevity Tables 1a and 1b present the findings for only the five most productive journals for CDU and JCU researchers. (See note to access full tables of ten most productive journals).

TABLE 1a ABOUT HERE

Table 1a. CDU environmental sciences research: Five most productive journals

TABLE 1b ABOUT HERE

Table 1b. JCU environmental sciences research: Five most productive journals

Across the full results for productivity in both databases, the vast majority of journals have published less than 10 articles by CDU and JCU affiliated researchers between 2000-2011. Approximately 94% of titles in the CDU data and 87% of titles in the JCU data had published between one and nine articles.

An important consideration for researchers in the Australian higher education sector is the assignment of FoR codes to the journals in which they publish. When the 10 most productive journals for each university were analysed for their FoR code assignment, the majority fell under the 05 Environmental Sciences code while several are assigned the MD Multidisciplinary code. These results indicate that up to 75% of these articles could be attributed to environmental sciences in the ERA. A broader analysis was undertaken to identify the proportion of journal titles and articles in the full datasets that are assigned either 05 Environmental Sciences, MD Multidisciplinary, or Other FoR code. Also included in the analysis were journals and their associated papers that are not listed in the ERA 2012 journal list. Figures 2a and 2b present these findings for the full CDU and JCU datasets.

FIGURE 2a ABOUT HERE

Figure 2a. CDU publications by ERA groups (Scopus and WoS data)

FIGURE 2b ABOUT HERE

Figure 2b: JCU publications by ERA groups (Scopus and WoS data)

The findings from both databases for CDU and JCU indicate that over 50% of the journal titles are assigned an FoR code that is outside the Environmental Sciences 05 codes. At the article level for CDU, the proportions are reversed with the majority of articles published in journals with either an 05 code or MD code. A sizeable proportion of articles published by CDU researchers (over 40%) are in journals assigned codes other than those relating to environmental sciences. In the JCU results for articles by FoR category, the proportion of articles published in 05 journals is greater than for journals, but Other FoR codes remain dominant with up to 60% of articles in the Scopus set in this category. Both universities have relatively low numbers of articles that would not be eligible for assessment in the ERA.

Citation data were collected for all articles retrieved in the searches and the top 10 cited articles were analysed in more detail (Tables 2a and 2b). For the sake of brevity the Tables present the results of the top five cited articles only. (See note to access full table of results). Similar to the results for the most productive journals, the citation data retrieved from Scopus and WoS for the same articles were closely matched. However, the Scopus search function which defaulted to a multidisciplinary category affected the data retrieved for both universities, resulting in highly cited articles appearing in the Scopus set that had not been retrieved in the WoS search.

The results for CDU show that the most highly cited articles were published between 2000 and 2008, with citations per paper ranging from 106 to 823 for Scopus and 78 to 239 for WoS. Leaving aside the *Nature* and other records retrieved by the Scopus multidisciplinary default, there are four articles that overlap between the databases' results. The publishing years 2003 and 2004 were responsible for over

half of the top cited articles in Scopus and four of the highest cited articles in WoS, indicating a citation lag of between six and nine years. All highly cited articles were published in journals that are assigned 05 Environmental Sciences or MD codes. The database classification of these highly cited articles varies markedly, with Agriculture and Biological Sciences the most frequent category for the Scopus articles and the category Ecology dominating the WoS articles.

The most highly cited articles by JCU researchers in both the Scopus and WoS results have more than 1000 citations. The Scopus multidisciplinary default resulted in an overlap of only three articles between the two databases. Within the 10 most highly cited articles, the number of citations drops to 230 for Scopus and 171 for WoS. All of the highly cited articles were published between 2000 and 2007, although no association is evident between publication year and number of citations. When the full dataset from the Scopus and WoS searches are examined, 15.2% in Scopus and 14.7% in WoS have never been cited. Almost half the articles, 47.1% in Scopus and 46.6% in WoS, have been cited less than 10 times, and only 1.4% of the Scopus and 1.3% of the WoS articles have been cited more than 100 times.

The journals in which the most highly cited JCU articles are published are all classified with an MD or 05 FoR code in the Scopus results, whereas three papers in the WoS data were from journals assigned 'Other FoR' codes. The two journals classified with MD in the ERA coding were also classified as Multidisciplinary in Scopus. Oddly, the only journal in the WoS list with the Environmental Sciences category was not assigned a 05 Environmental Sciences code for the ERA.

TABLE 2a ABOUT HERE

Table 2a. CDU environmental science research: Five most highly cited articles

TABLE 2b ABOUT HERE

Table 2b. JCU environmental science research: Five most highly cited articles

When the CDU and JCU lists of most productive journals (Table 1) and most highly cited articles (Table 2) are compared, it is evident that the most productive journals are not the most highly cited. For CDU, only one title from the Scopus results and two titles in the WoS results are listed in both the most productive and highly cited tables. For JCU, only one of the titles from the Scopus results and one title (with two articles) in the WoS results are listed in both tables.

The final analysis performed on the CDU and JCU publications data was to map the article titles and abstract data using VOSviewer software. Compared with database subject categories and FoR codes, mapping the terms and noun phrases used by authors in describing their articles can provide a more detailed profile of a research area. The maps display frequency of terms in the size of nodes and also relationships between terms in the creation of clusters and their relative distance from other nodes. In addition, the terms and clusters evident in the maps may indicate agreement with and divergence from the database categories and FoR codes. The WoS data was used to create the VOSviewer maps.

In the CDU map (Figure 5) the clusters in the upper left (red) and lower left (green) demonstrate a strong research focus on issues relating to the conservation and sustainable development of savanna landscapes with reference to the management of Kakadu National Park. It also highlights issues of fire and fire management of savanna and eucalyptus woodlands. A substantial body of research on the impact of climate change on these landscapes and tree species is depicted in the upper half of the map, with overlaps between management strategies on the left (red cluster) and plant physiology (yellow

cluster) on the right. The blue and purple clusters on the lower right side of the map reflect CDU researchers' focus on factors that have led to the decline of small mammals, including studies of islands. Species-specific research, ecology and evolution with respect to marine, island and mainland environmental constraints are also evident in the map. There are also links to specific climatic drivers such as the monsoonal climate of northern Australia, illustrated in some nodes in the upper and right centre of the map.

When the main terms and nodes that appear in the CDU map are considered, it is clear that areas such as ecology, zoology, forestry and other biological sciences are important fields. Some of these terms were seen in the database categories and all are associated with FoR codes outside of 05 Environmental Sciences. However, ecological impacts of climate change, ecosystem function, invasive species ecology, and landscape ecology are all key fields within the six-digit subdivision of the 05 code.

FIGURE 3 ABOUT HERE

Figure 3. CDU environmental sciences research map (WoS title and abstract data)

The VOSviewer map created for the JCU data forms six clusters. The top (yellow) cluster reflects the strong research focus in environmental sciences at JCU on corals, coral reefs and coral reef fish. Management and conservation dominate the bottom left (blue) group, with much of this work focusing on marine ecosystems and fisheries. The bottom right (red) cluster highlights genetic studies (sequence, marker) within ecological populations and evolutionary timeframes. The central right (pale blue) cluster is dominated by the terms survival, larvae, which are core to many biological studies, particularly those with a reproductive component. The bottom central (purple) cluster identifies research on disease and infection, particularly in frogs (amphibians) with the purpose of understanding and documenting the dramatic decline in populations over the last decade. The remaining cluster (green) is dispersed across the central left of the map and is dominated by the term sediment, a focus of research into the effects of terrestrial run-off to coral reefs and other marine ecosystems.

JCU's strong research in marine environments is reflected in the VOSviewer map and in the database categories assigned to the most productive journals and most highly cited articles e.g. marine and freshwater biology, ecology, conservation, genetics and molecular biology. In relation to the FoR codes assigned to these research fields, the JCU map indicates close ties with 05 Environmental Sciences e.g. Ecosystem Function, Conservation and Biodiversity, Environmental Management and Environmental Monitoring within the six-digit subdivision but also 06 Biological Sciences and 07 Agriculture and Veterinary Sciences, which includes the six-digit sub-field Fisheries Sciences.

FIGURE 4 ABOUT HERE

Figure 4. JCU environmental sciences research map (WoS title and abstract data)

Discussion

The bibliometric analyses applied in this study have established a profile of environmental sciences research, judged as high quality nationally and internationally, by two northern Australian universities, CDU and JCU.

Overall, Scopus retrieved more articles than WoS. There were minor differences between the findings for the two databases when the most productive journals and most highly cited articles were

compared, apart from those relating to the default search for the Multidisciplinary category by Scopus (discussed below). Common to each university's results is the lower SJRs and JIFs for the most productive journals compared with the most highly cited papers. While this is a logical outcome, there is an opportunity for researchers at CDU and JCU to consider their publishing practice in light of the fact that several of their most highly cited papers were published in journals with SJRs and JIFs at the mid to low end of the range. The time lag between publication and citations for both university's papers appeared to be longer than expected for a science field (Abramo, D'Angelo & Cicero, 2012), with highly cited papers being up to nine years old, which is in line with the findings of Khan and Ho (2012).

CDU researchers frequently publish in Australian journals, which may be a factor in the lower number of citations received by their most productive journals, when compared with the JCU results. However, this difference appears to hold for only a very small proportion of each university's articles, seen in the long tail of journals with fewer than 10 articles. The same profile can be seen for citations to both sets of articles, which drop away quickly from peaks of around 800 for CDU and 1400 for JCU within the 10 most highly cited articles (using Scopus data).

The results seen in Tables 1 and 2 confirm Khan and Ho's (2012) description of environmental sciences as multidisciplinary. Although the databases used an environmental sciences category for some titles listed in the most productive journals (particularly the Scopus results) and highly cited articles (for the CDU WoS results), several other subject categories were more frequently used by the databases to define these publications. In Scopus, the category Agricultural and Biological Sciences predominated. In WoS greater variation was seen, with categories such as Ecology, Biodiversity, Fisheries, and Marine and Freshwater Biology used for the journals in which CDU and JCU researchers publish.

With assessments in the ERA 2010 and 2012 exercise of 'at', 'above' and 'well above' world standard for the Environmental Sciences UoE, it would be expected that a strong publishing and citation record would be observed in this study for the relevant FoR code categories. The findings for JCU show the majority of articles had been published in journals with Other FoR codes. However, the most highly cited papers were all published in 05 Environmental Sciences or MD assigned journals and because the ERA assessments are based on citation analysis, it could be concluded that the highly cited articles have been an important influence in the ERA assessment of quality in the field. They may also partly explain the difference in the assessments between CDU and JCU. Nevertheless, the substantial proportion of papers falling outside the Environmental Sciences or MD FoR codes for both universities means that environmental sciences researchers at the universities may not be receiving full attribution for their work.

The VOSviewer maps provide a profile of environmental sciences research at each university from the perspective of the researchers and the words they use in titles and abstracts. They present an interesting tension between the stated strategic priorities of the universities and the classification of that research by databases and FoR codes. There is close alignment between the content of papers by CDU and JCU affiliated researchers and the research themes of the respective universities. CDU's research strengths have been outlined as being tropical, desert and Indigenous knowledge with a key focus on environment and livelihoods (Charles Darwin University, 2011b), which the VOS map reflects. At JCU, tropical systems, including coral reef research form major research themes of the university (James Cook University, 2012b) and these are clearly defined in JCU's map. On the other hand, many of the terms and clusters seen in the VOS maps differ from the relatively limited environmental sciences classification assigned by databases and the ANZSRC classifications.

Limitations

Recognising limitations to the study is important in terms of acknowledging that the results can be interpreted variously. They also provide a caveat for future researchers who are seeking to define environmental sciences.

The range of research fields encompassed by the term environmental sciences creates difficulties for bibliometric research. It influences the selection of search terms to retrieve relevant records from the major databases and the variation in classification policies makes it difficult to standardise the search results returned. With the aim of making the search results as consistent and also as comprehensive as possible, this study used 19 categories in Web of Science and five in Scopus. A further complication was that Scopus defaults some subject area searches to include the multidisciplinary category. This, combined with the higher number of journals indexed by Scopus, partly explain the higher retrieval of results from Scopus compared with WoS.

The default multidisciplinary search anomaly in Scopus resulted in important differences in the most highly cited articles analysis, which saw a number of highly cited journals being included in the Scopus but not the WoS results. A second search of WoS was conducted for both universities using the closest equivalent category, Science, Technology and Other Topics, to identify the extent of additional environmental sciences papers that were not found in the original WoS search. This resulted in an additional 36 records by CDU affiliated authors, half of which were related to the environmental sciences. Of these, five papers had 143 citations or more and appear in the most highly cited papers in the Scopus list. If these papers had been located in the original WoS search, the two databases would have produced almost exactly the same top 10 cited papers for CDU. Similarly, for JCU affiliated papers, an additional 184 articles were retrieved. Only three of the original most highly cited articles in the WoS results would have remained if these additional articles had been located in the first search. Two of the articles had been cited 1678 and 1439 times; a higher count than the most highly cited article in the results, as reported in Table 2b.

Conclusion

This study aimed to establish a profile of environmental sciences research in northern Australia, specifically looking at how high quality assessment, at national and international levels, is reflected in research publications. The findings indicate that researchers in the field have been publishing at increasingly higher rates over the past five years, however they are publishing most frequently in journals with lower indicators such as Impact Factors and Scimago Journal Rank. Although Scopus retrieved more articles than WoS for both the universities, there were only minor differences between the databases' results when most frequently published journals and most highly cited articles were analysed.

Environmental sciences research at CDU and JCU is recognised by the ERA and the *Times Higher Education* ranking as of high quality and yet the classification mechanism of the ERA (FoR codes) and databases in which research articles are indexed are often at odds in terms of defining the field. The VOSviewer maps demonstrate that the research being conducted at each university is closely aligned with the research themes of each university, however the way in which research assessment occurs in Australia means that a sizeable proportion of this research may not be attributed to environmental sciences researchers. This is due to the potential for a mismatch between the assignment of FoR codes to individuals and to the journals in which they publish. On the other hand, the ERA's use of citation analysis as the key indicator of quality, and the findings of this study that

show the majority of highly cited articles were assigned to the environmental sciences code, suggests these articles may play a very strong role in gaining a high quality assessment.

Note

Full tables for the 10 most productive journals and 10 most highly cited articles are available at https://research.jcu.edu.au/researchdata/default/detail/696d3c5e3ad33013fd6f3d40bae9f5dd/.

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FIGURES

Figure 1a. CDU Environmental Sciences Research Outputs: 2000-2011

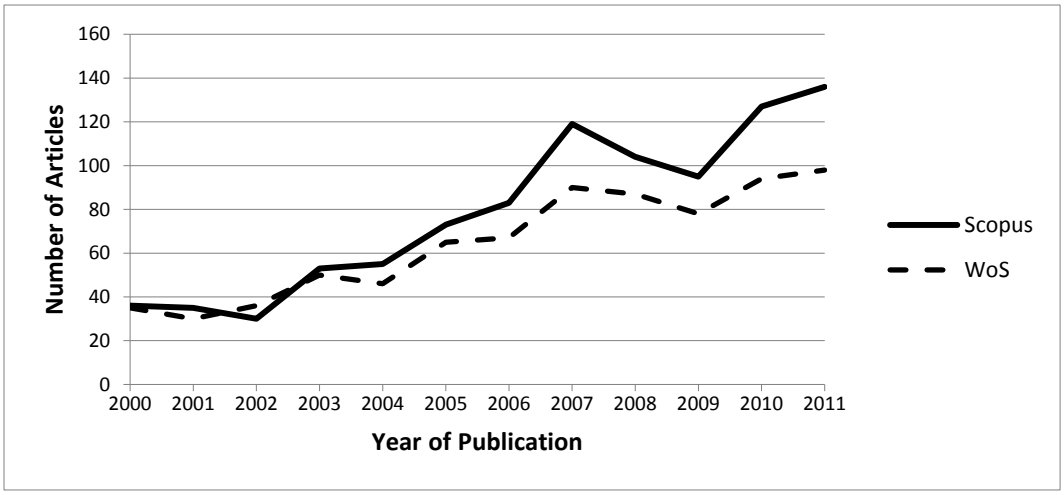


Figure 1b. JCU Environmental Sciences Research Outputs: 2000-2011

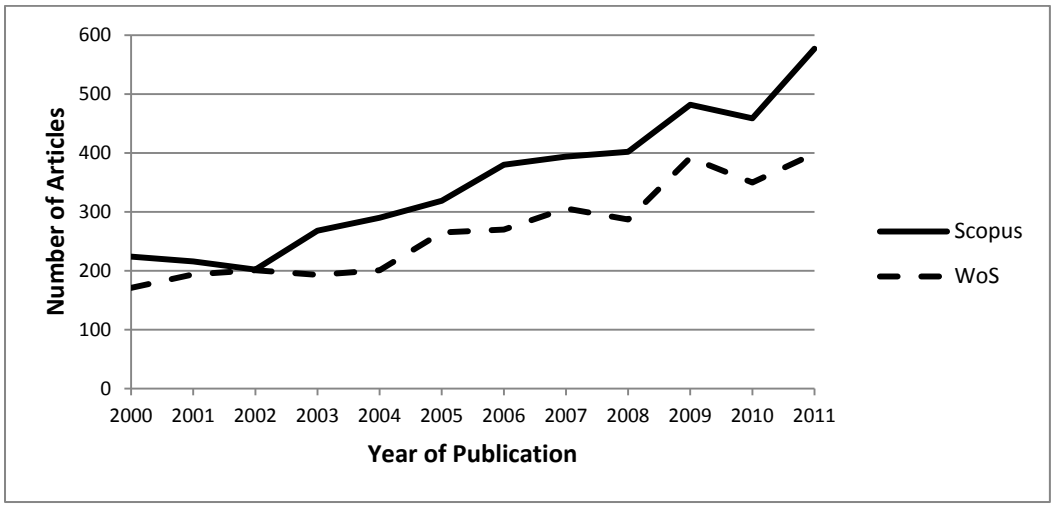


Figure 2a. CDU publications by ERA groups (Scopus and WoS data)

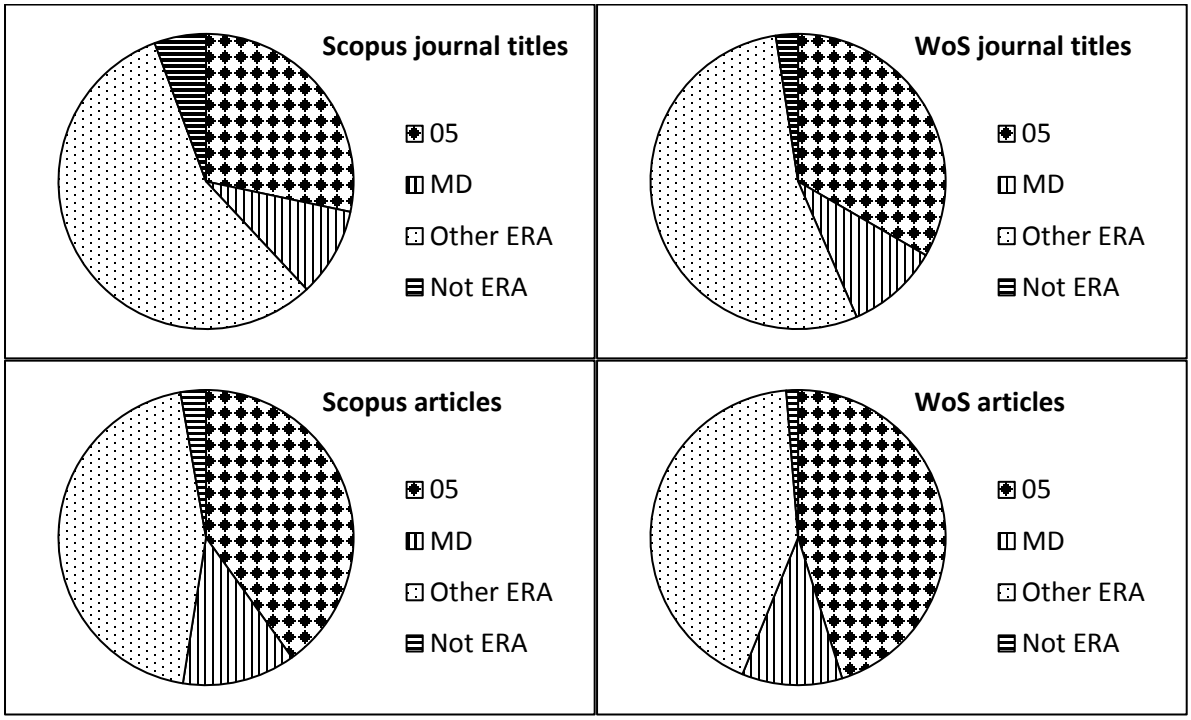


Figure 2b: JCU publications by ERA groups (Scopus and WoS data)

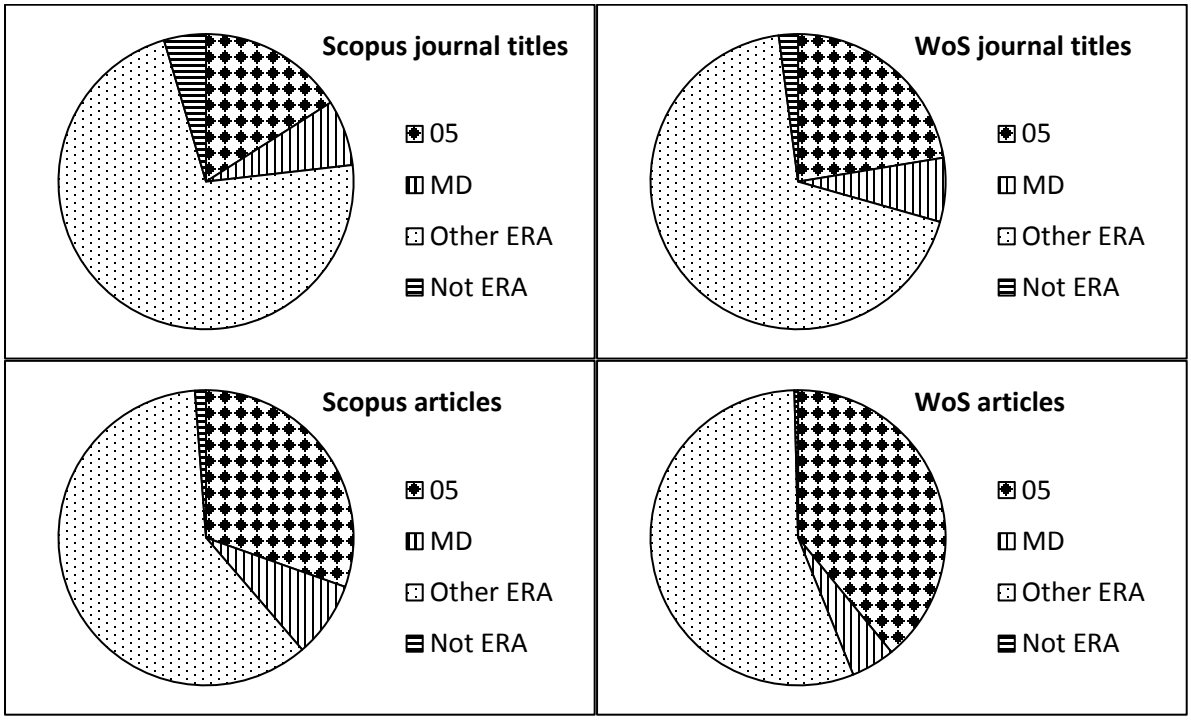


Figure 3. CDU environmental sciences research map (WoS title and abstract data)

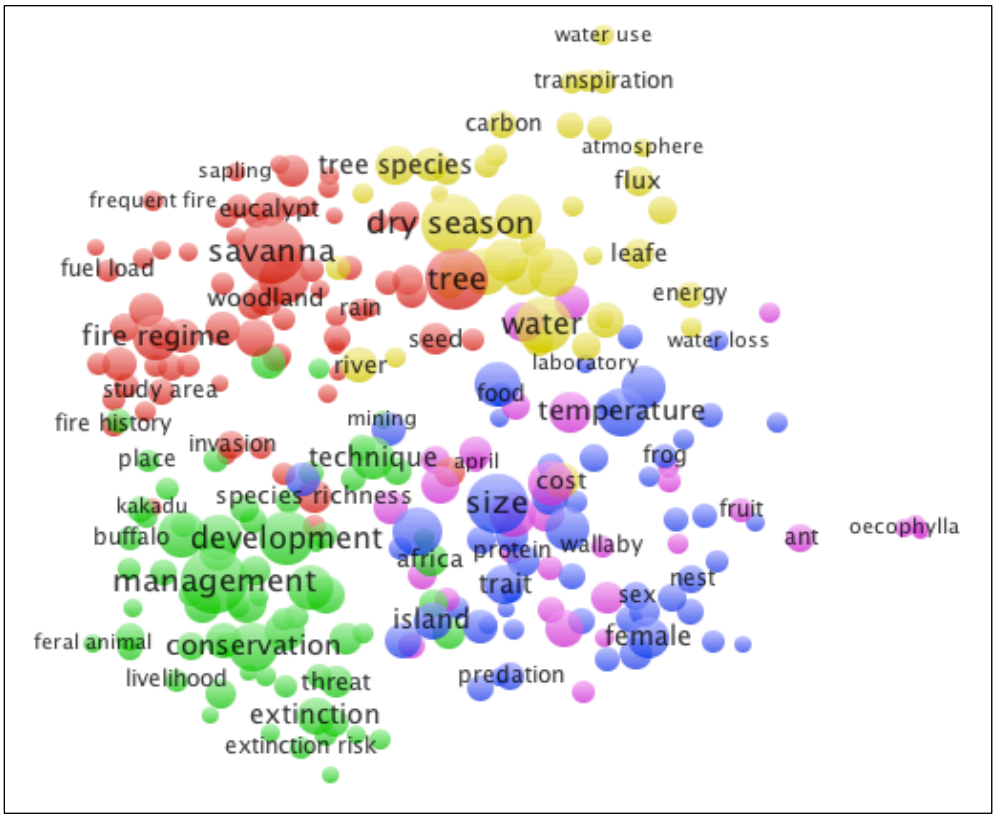
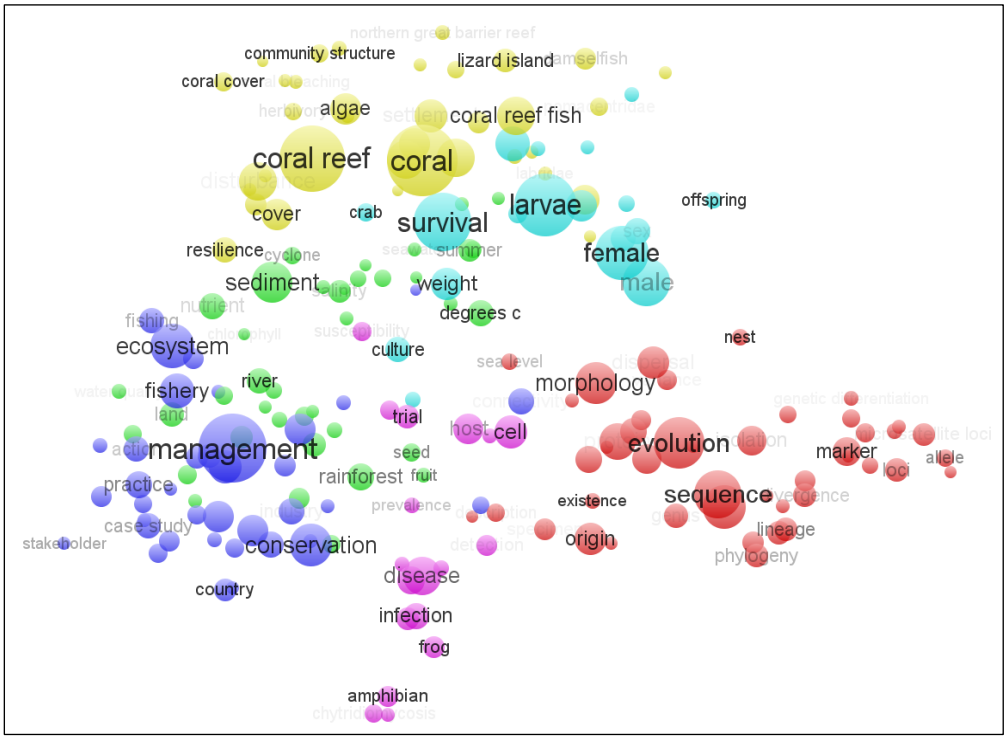


Figure 4. JCU environmental sciences research map (WoS title and abstract data)



TABLES

Table 1a. CDU environmental sciences research: Five most productive journals

Scopus					Web of Science (WoS)				
FoR code	**Journal title**	**No. papers**	**SJR**	**Subject Area**	**FoR code**	**Journal title**	**No. papers**	**JIF**	**JCR Category**
06	Australian J of Botany	35	0.675	Agricultural and Biological Sciences	06	Australian J of Botany	37	1.111	Plant Sciences
05	Wildlife Research	30	0.735	Agricultural and Biological Sciences; Environmental Science	05	Wildlife Research	29	1.323	Ecology; Zoology
05	Austral Ecology	27	1.039	Agricultural and Biological Sciences; Environmental Science	05	Austral Ecology	26	1.824	Ecology
05	J of Biogeography	24	1.839	Agricultural and Biological Sciences; Environmental Science	05	J of Biogeography	18	4.544	Ecology; Geography, Physical
05	Biological Conservation	18	2.098	Agricultural and Biological Sciences; Environmental Science	05	Biological Conservation	18	4.115	Biodiversity Conservation; Ecology; Environmental Sciences

FoR (Field of Research code)
SJR (Scimago Journal Rank)
JIF (Journal Impact Factor)
JCR (Journal Citation Reports)

Table 1b. JCU environmental sciences research: Five most productive journals

Scopus					Web of Science (WoS)				
FoR Code	**Journal title**	**No. papers**	**SJR**	**Subject Area**	**FoR Code**	**Journal title**	**No. papers**	**JIF**	**JCR Category**
06	Marine Ecology: Progress Series	161	1.408	Agricultural and Biological Sciences; Environmental Science	06	Marine Ecology: Progress Series	164	2.711	Ecology; Marine & Freshwater Biology; Oceanography
05	Coral Reefs	155	1.325	Agricultural and Biological Sciences	05	Coral Reefs	154	3.878	Marine & Freshwater Biology
06, 07	Aquaculture	91	1.093	Agricultural and Biological Sciences	06, 07	Aquaculture	91	2.041	Fisheries; Marine & Freshwater Biology
MD	Marine & Freshwater Research	74	0.757	Agricultural and Biological Sciences; Earth and Planetary Sciences; Environmental Science	MD	Marine & Freshwater Research	91	1.595	Fisheries; Limnology; Marine & Freshwater Biology; Oceanography
05	Marine Biology	66	0.955	Agricultural and Biological Sciences; Environmental Science	05	Marine Biology	69	2.276	Marine & Freshwater Biology

FoR (Field of Research code)
SJR (Scimago Journal Rank)
JIF (Journal Impact Factor)
JCR (Journal Citation Reports)

Table 2a. CDU environmental science research: Five most highly cited articles

Scopus					Web of Science (WoS)				
Pub year	**Journal of cited article**	**No. cites**	**SJR**	**Subject Area**	**Pub year**	**Journal of cited article**	**No. cites**	**JIF**	**JCR Category**
2004	Nature FoR: MD	823	14.548	Multidisciplinary	2004	Trends in Ecology & Evolution FoR: 05	239	15.748	Ecology; Evolutionary Biology; Genetics & Heredity
2004	Trends in Ecology & Evolution FoR: 05	234	8.702	Agricultural and Biological Sciences	2008	Trends in Ecology & Evolution FoR: 05	119	15.748	Ecology; Evolutionary Biology; Genetics & Heredity
2004	Proc of the National Acad Sciences of the USA FoR: MD	227	5.350	Multidisciplinary	2003	Biological Conservation FoR: 05	109	4.115	Biodiversity Conservation; Ecology; Environmental Sciences
2000	Nature FoR: MD	194	14.548	Multidisciplinary	2006	Conservation Biology FoR: 05	105	4.692	Biodiversity Conservation; Ecology; Environmental Sciences
2003	Nature FoR: MD	181	14.548	Multidisciplinary	2006	Ecology & Society FoR: MD	88	2.516	Ecology

Table 2b. JCU environmental science research: Five most highly cited articles

Scopus					Web of Science (WoS)				
Pub year	**Journal of cited articles**	**No. cites**	**SJR**	**Subject Area**	**Pub year**	**Journal of cited articles**	**No. cites**	**JIF**	**JCR Category**
2004	Nature FoR: MD	1422	14.548	Multidisciplinary	2006	Ecography FoR: 05	1038	4.188	Biodiversity Conservation; Ecology
2006	Ecography FoR 05	1031	2.395	Agricultural and Biological Sciences; Biochemistry, Genetics and Molecular Biology; Earth and Planetary Sciences; Environmental Science	2000	Ecology FoR: 05	698	4.849	Ecology
2003	Science FoR: MD	843	11.187	Multidisciplinary	2005	Trends in Ecology & Evolution FoR: 05	242	15.748	Ecology; Evolutionary Biology; Genetics & Heredity
2000	Ecology FoR: 05	725	3.336	Agricultural and Biological Sciences	2001	Coral Reefs FoR: 05	203	3.878	Marine & Freshwater Biology
2004	Nature FoR: MD	604	14.548	Multidisciplinary	2000	Coral Reefs FoR: 05	200	3.878	Marine & Freshwater Biology