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Forty years of coastal zone management (1975–2014): Evolving theory, policy and practice as reflected in scientific research publications

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ABSTRACT

Since its implementation as public law in the United States in 1972, the theoretical foundation of coastal management has moved forward in diverse directions. Given the time elapsed since the passage of this influential legislation and the growing number of disciplines and scientific papers published on the topic, this work employed bibliometric and social network analysis methods to quantitatively and qualitatively assess coastal management literature published during the period from 1975-2014. The results indicate that coastal management research has increased significantly over time. The emergence of the topic in scholarly work coincides with passage of the Coastal Zone Management Act of 1972 (US Public Law 92–583), and increases in productivity can often be tied to the passage of important legislation or the publication of major policy documents for action on coastal issues. Social network analyses (SNA) indicate loosely connected networks of researchers and institutions, with highly collaborative subgroups that have a significant impact on the field. SNA results also highlight the importance of federal governments and international organizations in driving research and encouraging integrated management. The results indicate that the discipline is evolving to focus more on cross-boundary management strategies, systems perspectives, and consideration of both marine and terrestrial environments.

1. Introduction

Coastal management is a dynamic process that covers the development and implementation of coordinated strategies to allocate resources and achieve conservation and sustainable multiple use of coastal areas (French, 1997). The tendency for use of the coast by many different sectors has led to a proliferation of controlling and interested coastal management stakeholders. Because of the complexity of these interactions and spatial domains, the management of coastal areas is divided into smaller units, each with its own management hierarchy, policies, and protection strategies. Consequently, theoretical and empirical studies about coastal management have flourished since the implementation of the Coastal Zone Management Act of 1972 (US Public Law 92–583). As theory has been refined, diverse drivers have taken more relevance and single-sector theories have waned in favor of more integrated approaches. For the purposes of this study, coastal management relates to the theory, policy, and decision-making processes associated with coastal resources. As such, it is our goal to identify the major trends in the evolution of the theory and practice of coastal management. Our objectives were as follows:

- To perform bibliometric (sensu Pritchard, 1969) and social network analyses of the literature published since passage of the CZMA;
- To provide an assessment of publication characteristics overall and over time to better understand the authors, institutions, journals, and interactions that have contributed to theory and practice;
- To provide an evolutionary timeline of associated management paradigms, and;
- To provide insight into past development, current trends, and future directions in the field.

The origins for theory of coastal management evolved from a collection of land use, recreation, and environmental conservation interests and practices (Godschalk, 1992; Zile, 1974). The concept, policies, and implementation mechanisms were firmly established with the creation of the Coastal Zone Management Act of 1972 (CZMA), which "established a national policy and developed a national program for the management, beneficial use, protection, and development of the land and water resources of the Nation's coastal zones, and for other purposes" (US Public Law 92–583). In 1966, the United States Congress enacted the Marine Resources and Engineering Development Act,

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focusing unprecedented attention on the nation's ocean and coastal resources (Merrell et al., 2001). The 1966 Act provided the first coordinated national program in marine science, as well as the mandate for the Commission on Marine Science, Engineering, and Resources (later known as the Stratton Commission) tasked with investigating of all aspects of coastal and marine science to recommend a national path forward for sustainable resource management (Merrell et al., 2001; Scheiber, 1998). Based in large part on the Stratton Commission's recommendations, passage of the CZMA in 1972 made the United States the first country to ratify comprehensive national coastal legislation (Godschalk, 1992). Since then, many countries have realized the problems associated with management and mismanagement of coastal resources, and have undertaken their own legislative initiatives (Conway and Lorah, 1995; Crawford, 1992; Ngoile and Horrill, 1993; Ngoile and Linden, 1997; Rosier and Hastie, 1996; Sorensen, 1993, 1997). While national legislation varies from country to country, implementation of several international conventions, treaties, and programs has increased capacity and cooperation for the protection and management of coastal and marine resources. This has raised the profile of coastal management in the international arena, resulting in an increased awareness and research activities addressing local, national, and trans-national management issues (Van Dyke, 1996).

Since its implementation as public law the theoretical foundation of coastal management has moved forward in diverse directions. From the earliest research focusing primarily on the land use and legal ramifications of the CZMA, the incorporation of a wide range of disciplines (e.g. ecology, environmental science, fisheries management, international relations, geography, disaster management; Forst, 2009) and methods have made the theory more holistic and encompassing regarding environmental and human development issues (Glaser and Glaeser, 2011; Risser, 1985). This is due, in large part, to the recognition that management of socially and ecologically complex coastal zones requires extensive scientifically-based knowledge (Nobre, 2011; Tintoré et al., 2009). Scientific publications on various aspects of coastal management have exhibited a marked increase in quantity, and the field has increasing become international in focus over the last four decades. Given the time elapsed since the passage of this influential legislation, and the growing number of disciplines and scientific papers published on the topic, several questions emerged: How have the research emphases in coastal management shifted over time? What authors, institutions, and journals have made the greatest contribution to coastal zone theory and policy development? What networks of authors and institutions are most influencing coastal management and policy? Most importantly, what are current and emerging trends, and potentials for future research? In their long-term analysis of the evolution of ecology, Neff and Corley (2009) described bibliometric analysis of publication characteristics as a powerful tool that analyzes research trends and priorities over time and across disciplines. The present study used a combination of bibliometric and social network analyses focused on the above questions.

Bibliometrics, a term and methodology introduced by Pritchard (1969: 348) as “the application of mathematics and statistical methods to books and other media of communication,” refer primarily to the research methodology employed by library and information sciences for citation and content analysis. Bibliometrics apply mathematical and statistical methods to citation and content data to assess publication characteristics (e.g. journal output, authorship, and institutional impact), and thus identify trends in published research. Conventional bibliometric methods (e.g., publication and authorship counts; means and annual trends, etc.) have been widely applied to various fields to assess research trends through an analysis of publication characteristics (Fourqurean et al., 2008; Harrison, 2006; Ratz and Conk, 2013). Network analysis has been used extensively in both the social and physical sciences (Luke, 2015) to assess the importance of context between authors and institutions (Toral et al., 2012). Social network analysis (SNA) examines the interactions and strength of connections between individual agents in relational networks. These metrics and visualization techniques create an intuitive and quantitative way to understand those interactions. SNA provides two distinct types of relational information: characteristics of networks and characteristics of the agents that form each network (Scott, 2013). Previous research using SNA in bibliographic analysis has shown how distant disciplines have contributed to interdisciplinary research and how current problems are being addressed using these multidisciplinary approaches (Chen et al., 2015), or how, through time there are increases in cooperation and interaction among individuals (Bornmann et al., 2014).

The goal of this study was to apply several bibliometric and SNA methods to quantitatively and qualitatively assess the literature published in the field of coastal management since passage of the CZMA. The analysis was conducted to identify global research trends in journal output, authorship, collaboration, and subject over time. This type of bibliometric assessment has been conducted, for example, in urban ecology (Young and Wolf, 2006), landscape ecology (Wu et al., 2012), wetland research and ecosystem restoration (Zhang et al., 2010), constructed wetlands (Zhi and Ji, 2012), fisheries management (Jaric et al., 2012), and estuarine and coastal research (Fourqurean et al., 2008). To date there has not been a similar study conducted in the field of coastal management. This information can provide valuable insight into the evolution of research tendencies and priorities that could be of interest for the academy, policy developers, and practitioners.

2. Materials and methods

A number of systematic review articles have been published since 1972 on some aspect of coastal research, including insights on human development, natural processes, and biochemical change. A number of systematic review articles have been published since 1972 on some aspect of coastal research, including insights on human development, natural processes, and biochemical change. As the field of coastal zone management has evolved, several efforts were undertaken to synthesize current knowledge. For example, Cicin-Sain and Belfiore (2005) reviewed the challenges to incorporate marine protected areas under an integrated marine management approach. Similarly, Kroon and Brodie (2009) discussed adaptive approaches to watershed management in connection with coastal water quality. Curtin and Prellezo (2010) also provided an in-depth literature review as a means to understand marine ecosystem-based management. Finally, Liquete et al. (2013) examined the effects of incorporating ecosystem services (as opposed to just extractive activities) into new approaches for management and conservation of coastal and marine ecosystems. However, there has not been a historical perspective analysis on the field of coastal zone management.

To address this deficiency, we initiated an unsupervised search of two of the most comprehensive reference databases (Scopus and Web of Science) for articles that included the words ‘coastal management’ in the keywords and/or title to compile a bibliography of all papers related to some aspect of coastal management between since 1972. Scopus is a multidisciplinary database of Elsevier that indexes 20,800 peer-reviewed journals (including 2600 open access journals) from more than 5000 publishers (Elsevier B.V., 2014). This includes citation references across the disciplines of science, technology, medicine and social science. Web of Science is the multidisciplinary database of Thomson Reuters. According to Journal Citation Reports (JCR), it indexes over 12,000 scientific and scholarly journals with seven citation indexes focusing on the applied sciences, but also including the social sciences and art and humanities. We drew citation reference counts from Google Scholar, a reference database that indexes across an array of scholarly databases and thus provides the most accurate count of total article citations. These databases were chosen to complement each other, as none of the resources are all-inclusive, but together they establish a relatively comprehensive look at social and applied coastal science research (Adriaanse and Rensleigh, 2011).

Document information gathered included author(s), year of publication, title, source (journal title), document type, author keywords, author addresses, cited reference count, publisher information, page count, ISSN, subject category, among other source data. Full records were downloaded to a reference manager (EndNote Thomson Reuters software), and exported to a spreadsheet (Microsoft Excel 2011) for further analysis. The journal impact factor was obtained from the JCR in 2015. Country and institutional contributions were estimated by affiliation location of the authors of the papers (when available). Articles originating from England, Scotland, Northern Ireland, and Wales were classified under a United Kingdom heading. Articles from Hong Kong and Taiwan were included in a China heading. Articles from French Guiana, French Polynesia, and Reunion were incorporated into a France heading. Articles from Tasmania were incorporated into an Australia heading.

The unsupervised search of titles and keywords, resulted in over 22,000 references self-identified as coastal management related. At the time of collection, the earliest article available through Web of Science or Scopus was published in 1975, thus determining the start date for our analyses. Duplicates and articles unrelated to the theory and practice of coastal management were eliminated. This targeted classification resulted in 5461 references processed for authors, title, year, institution, and assigned an individual record number. Co-authored references were replicated (including record number) and then separated by author to allow for the analysis of clusters and networks. All articles referring to coastal management between 1975 and 2014 were assessed on the following attributes: overall publication and distribution characteristics; journal publication characteristics; publication characteristics of country, institution, and author; social networks of country, institution, and author; and title words and phrases.

SNA was done using the statistical package R (R version 3.3.1, 2016; along with the packages ergm, statnet and network). The metrics used are broadly categorized as agent metrics and network metrics. The agent metrics include indegree centrality (agents within the network with the most influence based on the number of direct links; Freeman, 1979), and betweenness centrality (the number of times an individual is the relay point or connector between other network agents). When applied to all agents, these parameters can indicate the spread of information and knowledge between agents that drive research paradigms (Luke, 2015; Toral et al., 2012). Network metrics include size (number of agents), number of links, density (the number of links that exist in a network divided by the maximum possible number of links that could exist); diameter (longest of the shortest paths across all pairs of nodes which represents the linear size of the network); isolates (agents not connected); components (the maximally connected subgroup within a network in which there is at least a path between all pairs of agents); and cliques (groups of agents who have all possible connections to each of the others, this a category within components). Combined, these parameters provide help to visualize the entire network and means of displaying influential structures within (Luke, 2015; Van Eck and Waltman, 2014).

3. Results

The collected references were categorized into different groups to collate information, analyze trends and extract information about collaborative networks.

3.1. Articles

Fig. 1 displays the total number of articles included in the targeted classification. The earliest publications in the search meeting our selection criteria appeared in 1975, three years after the enactment of CZMA legislation. From 1975 to 2013 (2014 only included articles published through September), the number of articles increased from 3 in 1975 to 548 in 2013; and the difference in cumulative trends during each decade was evident. As a result, power and exponential models were established to describe the relationships between the annual cumulative number of articles, and the ten-year periods between 1975 and 2014. A quantitative analysis of the overall increase in publications resulted in a quadratic fit (r2 = 9449; RMSE 33.25; N = 40) confirming that publication growth has been substantial over time. Fig. 1 also shows that research in the field grew slowly but steadily up to 1991, at which point the total number of articles published markedly increase. This sharp increase may be a result of the call for integrated coastal management set forth in Agenda 21 of the United Nations Conference of Environment and Development and the Framework Convention on Climate Change, which encouraged exchange among scientists internationally to support research and dissemination of its results to improve and sustain coastal resources (Smith, 1999; UNEP, 1992).

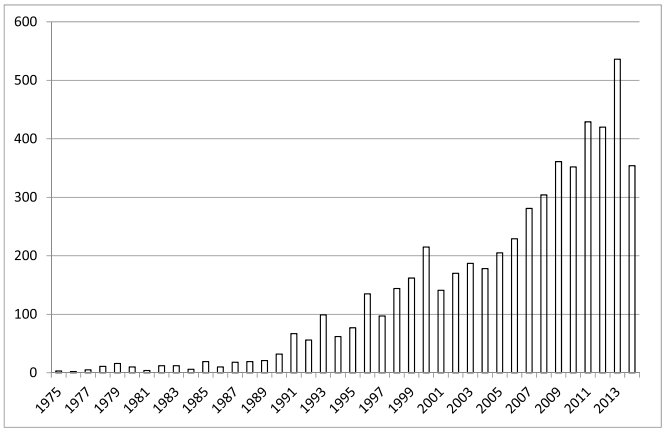

Fig. 1. Number of articles published annually.

While there have been many influential articles on the topic, there are certainly some that have been more influential than others based on the number of citations they have received (Table 1). The most highly cited paper appeared in the journal *Science* and was written by Professor Benjamin S. Halpern from the University of California Santa Barbara and a host of co-authors. This paper, cited more than 2000 times by a wide range of disciplines, synthesizes spatial data on coastal activities to provide flexible tools for ecosystem-based management and marine spatial planning Also of note, Professor W. Neil Adger of the University of Exeter was first or second author on 4 of the top 10 most cited papers, for a total of 4221 citations. Dr. Adger's work focuses on global environmental change, ecological economics, and sustainability of linked human-natural systems, and has been highly influential across disciplines.

3.2. Journals

The 5461 articles in the sample were published in 891 journals. From these 891 journals, the top 21 journals (by number of articles published) represent a wide range of disciplines, from law and engineering to more specialized coastal management field publications. Table 2 presents these journals with the following data subdivisions: total number and percentage of articles, impact factor (IF), and ISI subject category as reported in Journal Citation Reports (JCR; jcr.incites.thomsonreuters.com). These core journals produced more than half (51.62%) of the coastal management-related research from 1975-2014. *Ocean and Coastal Management* (formerly known as *Ocean and Shoreline Management* from 1988-1991 and *Ocean Management* from 1973-1986), a monthly journal, ranked first with 818 (15.0%) published articles; the quarterly journal *Coastal Management* (formerly known as *Coastal Zone Management Journal* from 1973-1986), ranked second with 475 (8.7%) articles; *Marine Policy, Journal of Coastal Research,* and *Journal of Coastal Conservation* ranked 3rd, 4th, and 5th respectively. While the top 21 journals accounted for most of the 5461

Table 1
The twenty most-cited papers between 1975 and 2014.

Number of Citations	Paper
2139	Halpern, B. S. et al. 2008. A global map of human impact on marine ecosystems. *Science* 319 (5865): 948–952.
1268	Adger, W. N. 2003. Social capital, collective action, and adaptation to climate change. *Economic Geography* 79 (4): 387-404
1260	Lotze, H. K. et al. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science* 312 (5781): 1806–1809
1220	Adger, W. N. et al. 2005. Social-ecological resilience to coastal disasters. *Science* 309 (5737): 1036-1039
1054	Kelly, PM and Adger, WN. 2000. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Climatic Change* 47 (4): 325-352
918	Palmer, M. A. et al. 2005. Standards for ecologically successful river restoration. *Journal of Applied Ecology* 42 (2): 208-217
679	Tompkins, E. L. and Adger, W. N. 2004. Does adaptive management of natural resources enhance resilience to climate change? *Ecology and Society* 9 (2): 14 pgs.
558	Pomeroy, R. S. and Berkes, F. 1997. Two to tango: The role of government in fisheries co-management. *Marine Policy* 21 (5): 465-480
446	Agardy, T. et al. 2003. Dangerous targets? Unresolved issues and ideological clashes around marine protected areas. *Aquatic Conservation-Marine and Freshwater Ecosystems* 13 (4): 353-367
435	Barbier, E. B. et al. 2008. Coastal ecosystem-based management with nonlinear ecological functions and values. *Science* 319 (5861): 321–323.
412	Roy, P. S. et al. 2001. Structure and function of south-east Australian estuaries. *Estuarine, Coastal and Shelf Science* 53 (3): 351–384.
400	McClanahan, T. R. and Mangi, S. 2000. Spillover of exploitable fishes from a marine park and its effect on the adjacent fishery. *Ecological Applications* 10 (6): 1792-1805
401	Patz, J. A. et al. 2004. Unhealthy landscapes: Policy recommendations on land use change and infectious disease emergence. *Environmental Health Perspectives* 112 (10): 1092–1098.
399	Dugan, J. E. and Davis, G. E. 1993. Applications of marine refugia to coastal fisheries management. *Canadian Journal of Fisheries and Aquatic Sciences* 50 (9): 2029–2042.
363	Botsford, L. W. et al. 2001. Dependence of sustainability on the configuration of marine reserves and larval dispersal distance. *Ecology Letters* 4 (2): 144-150
361	Costanza, R. and Ruth. M. 1998. Using dynamic modeling to scope environmental problems and build consensus. *Environmental Management* 22 (2): 183–195.
317	Naiman, R. J. et al. 2000. Riparian ecology and management in the Pacific Coastal Rain Forest. *Bioscience* 50 (11): 996–1011.
306	Borja, A. 2005. The European water frameworks directive: A challenge for nearshore, coastal and continental research. *Continental Shelf Research* 25 (14): 1768–1783.
295	Micheli, F. et al. 2004. Trajectories and correlates of community change in no-take marine reserves. *Ecological Applications* 14 (6): 1709–1723.
289	Pollnac, R. B. et al. 2001. Discovering factors that influence the success of community-based marine protected areas in the Vasayas, Philippines. *Ocean and Coastal Management* 44 (11–12): 683–710.

Citation data collected from Google Scholar in 2015.

articles, journals with only one paper accounted for 8.42%, and journals with less than 3 articles accounted for another 17.82%. Unsurprisingly, as the emphasis in research on the topic has changed, so too has the lead journal in the field (Fig. 2). For example, from 1975 to 1980 the journal with the highest number of articles was *Natural Resource Lawyer,* a publication that ran from 1968 to 1985 and published by the American Bar Association. This is logical, as the legality and implementation implications were still being determined immediately after enacting legislation in the United States. For most of the 1980's the professional journal of The Coastal Society, *Coastal Zone Management Journal* (currently known as *Coastal Management*) dominated the field. The Coastal Society is a U.S.-based 501c3 nonprofit organization that brings together private sector, academic, and government professionals to address primarily US coastal issues. Since the mid-1990s, *Ocean and Coastal Management* has become the preferred publication, followed by the *Journal of Coastal Research.* In both cases, these journals have a

Table 2
Top 21 most active journals between 1975 and 2014 with number of articles, impact factor, and ISI subject category of journals (2015).

Rank	Journal Title	TP (%)[a]	IF[b]	ISI Subject Category
1	Ocean and Coastal Management	818 (15.0)	1.748	Oceanography, Water Resources
2	Coastal Management[c]	475 (8.7)	0.877	Environmental Sciences
3	Marine Policy	343 (6.3)	2.610	Environmental Studies, International Relations
4	Journal of Coastal Research	281 (5.1)	0.980	Environmental Sciences, Physical Geography, Multidisciplinary Geosciences
5	Journal of Coastal Conservation	114 (2.1)	0.898	Environmental Sciences, Marine and Freshwater Biology
6	Marine Pollution Bulletin	103 (1.9)	2.991	Environmental Sciences, Marine and Freshwater Biology
7	Environmental Management	90 (1.6)	1.724	Environmental Sciences
8	Journal of Environmental Management	67 (1.2)	2.723	Environmental Sciences
9	Ambio	64 (1.2)	2.641	Environmental Engineering, Environmental Sciences
10	Estuarine, Coastal and Shelf Science	55 (1.0)	2.057	Marine and Freshwater Biology, Oceanography
11	Ecology and Society	53 (1.0)	2.774	Ecology
12	Biological Conservation	50 (0.92)	3.762	Biodiversity Conservation, Ecology, Environmental Sciences
13	Fisheries Research	42 (0.77)	1.903	Fisheries
t-14	Aquatic Conservation: Marine and Freshwater Ecosystems	39 (0.71)	2.136	Environmental Sciences, Marine and Freshwater Biology, Water Resources
t-14	Water Science and Technology	39 (0.71)	1.106	Environmental Engineering, Environmental Sciences, Water Resources
16	Sea Technology	33 (0.60)	0.101	Ocean Engineering
t-17	Ecological Applications	32 (0.59)	4.093	Ecology, Environmental Sciences
t-17	Ecological Indicators	32 (0.59)	3.444	Environmental Sciences
19	Land Use Policy	31 (0.57)	2.631	Environmental Studies
t-20	Environmental Science and Policy	29 (0.53)	3.018	Environmental Sciences
t-20	PLoS One	29 (0.53)	3.234	Multidisciplinary Sciences

Data gathered from Journal Citation Reports (jcr.incites.thomsonreuters.com).
[a] TP, total publications.
[b] IF, impact factor.
[c] Formerly known as Coastal Zone Management Journal (1973–1986).

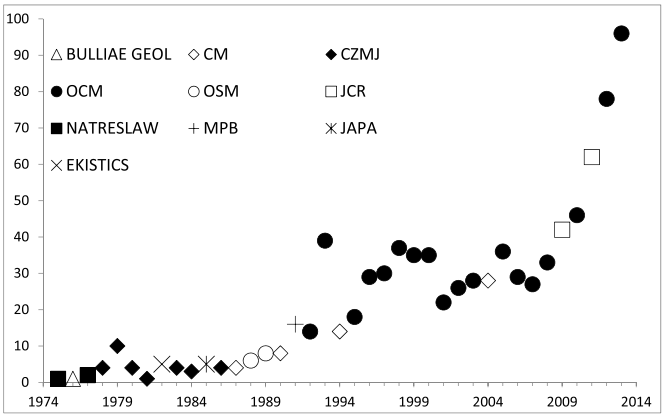

Fig. 2. Journals with most articles published annually. Code: BULLIAE GEOL-Bulletin of the International Association of Engineering Geology; CM-Coastal Management (1987–2014); CZMJ-Coastal Zone Management Journal (1973–1986); EKISTICS-Ekistics-the Problems and Science of Human Settlements; JAPA-Journal of the American Planning Association; JCR-Journal of Coastal Research; MPB-Marine Pollution Bulletin; NATRESLAW-Natural Resources Lawyer (1968–1985); OCM-Ocean and Coastal Management; OSM-Ocean and Shoreline Management.

particular international focus, which reflects a trend toward a more globalized research environment (Toral et al., 2012).

Impact factor is the measure of frequency with which the 'average article' in a journal is cited in a particular year, and is calculated by dividing the number of current citations by the total number of articles published during the same period of time. The impact factor is useful for standardizing the relative influence of journals with widely varying numbers of research articles (Rohli and Liu, 2008). Oftentimes, impact factor is also used as a de facto measure of research quality. However, Gisvold (1999) argues that impact factor is not an appropriate indicator of research quality, as it generally upgrades articles of poor quality, downgrades high quality, and inaccurately represents individual citation rates. Further, higher journal impact factor may not accurately decide the power of a journal on certain issues. For example, the journal with the highest impact factor (4.093) in this study is the scientific journal of the Ecological Society of America, known as *Ecological Applications.* This indicates that on average, articles from this journal are cited four or more times per year. However, given the specialized scope of this publication to study the application of ecological science to environmental problems, we were unable to determine if articles related specifically to coastal management are cited as frequently. Further, *Coastal Management's* impact factor of 0.877 is relatively low in value compared to other journals in the field. However, the regularity with which influential scholars publish in the journal (e.g. Dr. Alan T. White of the Nature Conservancy and Dr. Porfirio M. Aliño of the Marine Science Institute University of the Philippines Diliman), as well as the sheer volume of articles published, likely influence coastal zone research.

3.3. Authors

We examined individual authors, author-institution connections, and authorship patterns over time to understand the demographics of the scientific community driving coastal management research. From the 5461 published articles, there were 11,973 corresponding authors hailing from 147 countries and 3620 identified institutions. Table 3 presents the top 20 most prolific authors of research pertaining to coastal management between 1975 and 2014 published a total of 420 papers (7.7%). The most prolific author over the study time span is Dr. Alan T. White of the Nature Conservancy, whose work focuses on fisheries, marine protected areas, and food security. Dr. White published 33 papers on the topic, with 8 first authorships. Dr. Steve Fletcher of Plymouth University (UK) follows closely behind with 31 papers published, and ranks at the top with 20 first authorships. Dr. Fletcher's work focuses on marine and coastal policy, with emphases on marine governance and integrated coastal management.

Table 3
Top 20 most prolific authors between 1975 and 2014.

Rank	Author	Publication Period	Number of Papers	First Author Pubs.	First Author Rank
1	White, A. T.	1993–2014	33	8	t-10
2	Fletcher, S.	2000–2014	31	21	1
3	Christie, P.	1997–2014	28	10	t-5
4	Pomeroy, R. S.	1995–2014	27	10	t-5
5	Cinner, J. E.	2004–2014	26	11	4
6	Nicholls, R. J.	1996–2014	25	6	t-14
7	Jimenez, J. A.	1997–2014	21	2	19
t-8	Turner, R. K.	1995–2014	21	10	t-5
t-8	Pollnac, R. B.	1997–2014	20	3	18
10	Cooper, J. A. G.	2000–2014	19	9	t-8
t-11	Alino, P. M.	2000–2014	18	0	20
t-11	Halpern, B. S.	2004–2014	18	7	13
t-11	Olsen, S. B.	1997–2014	18	12	3
t-11	Vallega, A.	1993–2007	18	16	2
t-11	Williams, A. T.	1995–2014	18	4	17
t-16	Harvey, N.	1988–2014	17	8	t-10
t-16	Micheli, F.	2003–2014	17	6	t-14
t-18	Ferreira, J. G.	2003–2014	15	6	t-14
t-18	McClanahan, T. R.	1997–2014	15	9	t-8
t-18	McGlashan, D. J.	2000–2012	15	8	t-10

Overall, mean authorship was 3.07 with a median of two authors per article. The maximum number of authors on one article was 61 (see Patz et al., 2004), three articles had more than 30 authors, and 14 had more than 20 authors. Co-authorship varied from 893 articles (7.45%) with a single author, 3403 (62.31%) with two authors, 676 (12.38%) with three authors, and 634 (11.70%) with four or more. Subsequently, we examined shifts in authorship over time. There has been a steady increase in the number of authors per scientific paper. Similar patterns have been noted across a range of scientific fields (e.g. fisheries science see Jaric et al., 2012; biomedical research, chemistry, mathematics; see Glanzel, 2002). Between 1975 and 1984, the mean authorship of articles published on the topic was 1.35, with most of the papers being single-authored work. Between 1985 and 1994, mean authorship increased to 1.67 – and again to 2.42 between 1995 and 2004. The most recent decade examined (2005–2014), mean authorship increased to 3.66 with a median of two. A range of factors likely fuels this marked increase. As noted by Fourqurean et al. (2008), the trend toward more specialized and interdisciplinary research means that larger teams are working together to address complex coastal issues. Further, the increasingly globalized research environment has encouraged authors and institutions to increase collaborative efforts (Toral et al., 2012). Finally, there is increased acknowledgement of scholarly contribution, particularly for junior scientists who substantially participate but who may previously have gone uncredited. (Bozeman and Youtie, 2016).

We examined the interconnections among authors using social network analysis (SNA) to better understand collaborative efforts and the potential for hubs of influence or "schools of thought". An assessment of research productivity literature indicates various studies linking scientific productivity, as measured in terms of publications, to collaboration between individual researchers and institutions. Lee and Bozeman (2005) sampled university researchers, and found that collaboration was the strongest predictor of publication productivity. Similarly, Adams et al. (2005) studied the effects of research team size and internal and external collaborations, which showed that scientific productivity increases with larger research groups. Author SNA metrics for this study (shown in Table 4) indicate the total number of authors included in the analysis (11,973), the number of authors with collaborators (11,080), the total number of collaborations (11,530), diameter, and cliques. SNA diameter indicates the shortest path between

Table 4
Network analysis results for author and institutions network parameters.

Parameter	Author Network (%)	Institution Network (%)
Agents[a]	11,973 (100.0)	3620 (100.0)
Connected Agents[b]	11,080 (92.54)	2895 (79.97)
Isolated Agents[c]	893 (7.46)	725 (20.03)
Ties	11,530	4725
Diameter/distance	27	15
Largest clique	34 (4 or more)	12 (5 or more)

[a] Agents indicates total number of participants in each network.
[b] Connected agents indicates participants with ties to other participants.
[c] Isolated agents indicate participants with no ties to other participants.

Table 5
Social network analysis centrality measures for top 20 authors.

Rank	Author	Degree	Author	Betweenness
1	Aliño PM	76	Christie P	499.3
2	Christie P	60	Cooper JAG	443.0
3	Aguirre AA	60	Cinner JE	401.4
4	Aswani S	52	Fletcher S	353.2
5	Agardy T	48	Cummins V	255.0
6	Bricker SB	48	Halpern BS	237.8
7	Abbiati M	48	Jimenez JA	181.0
8	Alves FL	47	Dodds W	179.0
9	Almany GR	39	Ferreira M	176.0
10	Fletcher S	38	Almany GR	162.3
11	Cinner JE	37	Agardy T	162.0
12	Aarnikhof SGJ	37	Fluharty DL	156.3
13	Bateman IJ	35	Bricker SB	140.8
14	Alcolado PM	33	Borja A	139.5
15	White AT	33	Jin D	137.0
16	Carpentier A	33	Garces LR	129.0
17	Allen RG	33	Beck MW	122.5
18	Jimenez JA	32	Johnson D	120.0
19	Ardron JA	30	Aswani S	112.0
20	Castilla JC	30	Benavente J	103.0

the two most distant nodes in the collaborative network, and is representative of the relative size of the network. In this case, the diameter of the network is 27, indicating a loosely connected network of researchers made up of many relatively isolated research groups. This is further supported by the presence of 34 cliques of four or more, indicating subgroups of highly collaborative researchers that are relatively isolated from other groups.

The SNA author metrics (see Table 5) show that Dr. Porfirio M. Aliño of the Marine Science Institute University of the Philippines Diliman has the highest indegree centrality value in the study with 76 network connections. The indegree centrality measures influence by indicating the number of direct links a researcher has to other researchers. Dr. Aliño's work focuses primarily on coral reef ecology, marine protected areas, and community-based approaches to sustainable fisheries management, and he has collaborated and published extensively with researchers across disciplines and internationally. Also notable are the indegree centrality values for Dr. A. Alonso Aguire and Dr. Patrick Christie, each having 60 network connections. Dr. Aguire heads a program of collaborative research at George Mason University that focuses on wildlife disease ecology and the links to human health and conservation of biodiversity. Dr. Christie is a member of the School of Marine and Environmental Affairs faculty at the University of Washington, and his work focuses on human dimensions of marine conservation employing marine protected areas, ecosystem-based management, and sustainable fisheries technologies. Dr. Christie also had the highest betweenness centrality value (499.3), indicating he frequently acts as the bridge between other clustered groups of researchers and is likely to have higher ability to control the flow of information or exchange of ideas across networks (Freeman, 1979). Of note are the betweenness centrality values for Dr. J. Andrew G. Cooper and Dr. Joshua Cinner, with 443 and 401.4 respectively. Dr. Cooper is a faculty member in the with the Environmental Sciences Research Institute in the School of Geography & Environmental Sciences at Ulster University, and his work focuses on coastal geomorphology, climatology, and implications of urbanization and development on coastal management. Dr. Cinner is a research professor and chief investigator with the ARC Centre of Excellence for Coral Reef Studies at James Cook University, and his work focuses on interdisciplinary approaches to studying how socioeconomic factors influence the ways in which people use, perceive, and govern coral reefs.

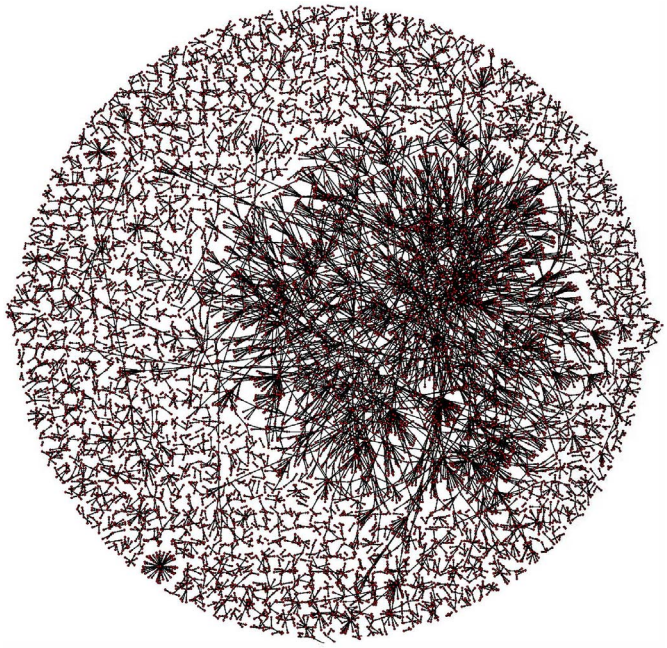

Fig. 3. Complete network of coastal zone management authors, 1975–2014.

The author network visualization (Fig. 3) shows a very diffused association among its members (SNA density of 0.00015), with striking number of isolated authors on the periphery. A closer examination of the largest groups of collaborators (4 or more cliques; Table 4) resulted in 12 groups with all possible connections and shows six cliques with more than 4 authors (Fig. 4; names not in grey). The clique visualization identifies authors who are central or work extensively with large groups. Fig. 4 indicates that of the top authors (Table 3), Dr. White (The Nature Conservancy) and Dr. Christie (University of Washington) also have a highly connected group of collaborators. However, Fig. 4 uses the number of connections (degree) in this subset (cliques of 4 or more) to calculate the author's degree. This results on names in a larger font than expected from the degree analysis of the whole author network.

3.4. Countries and institutions

We examined individual institutions, institutional collaborations, and authorship patterns by country and institution over time to understand how regional organizations are driving coastal management research. The database query for number of institutions and geographic location indicates 3620 different institutions in 147 countries. Table 6 presents the top 20 most prolific countries of origin for individual authors publishing research pertaining to coastal management between 1975 and 2014, which represents 61.43% of the database. Based on country of origin, authors from the United States represent the largest bloc with 21.70% of authors, followed by the United Kingdom (9.8%), and Australia (7.19%). These three countries represent nearly forty percent of all published research during this period. The 20 top countries of origin by institution (Table 6) followed a similar pattern, with 72.90% of all coastal management research conducted by this group.

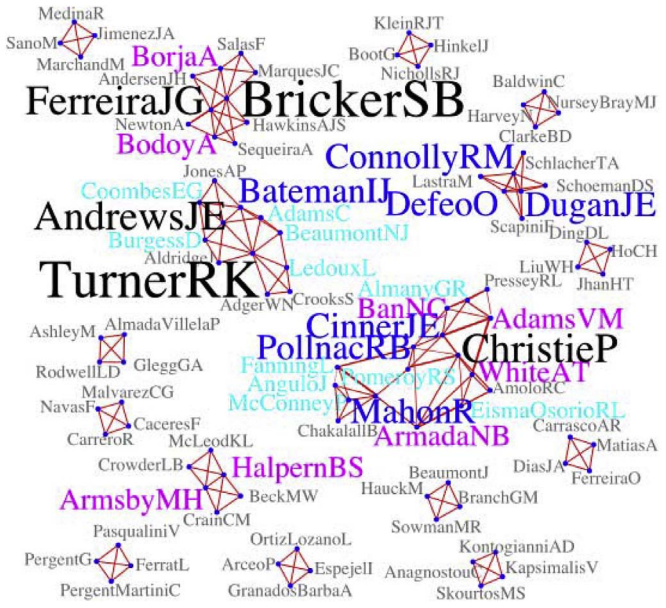

Fig. 4. Largest networks of coastal zone management collaborators, 1975–2014 (cliques of four or more).

Table 6
Top countries of origin for authors and institutions.

Country	Number of Authors (%)	Rank	Number of Institutions (%)	Rank
United States	2599 (21.70)	1	695 (19.20)	1
United Kingdom	1173 (9.80)	2	290 (8.01)	2
Australia	861 (7.19)	3	196 (5.41)	3
Canada	405 (3.38)	t-4	105 (2.90)	8
France	405 (3.38)	t-4	162 (4.48)	4
Spain	366 (3.05)	6	116 (3.20)	7
Netherlands	313 (2.61)	7	94 (2.60)	t-10
Italy	288 (2.41)	8	119 (3.29)	6
Germany	259 (2.16)	9	143 (3.95)	5
China	229 (1.91)	10	94 (2.60)	t-10
Portugal	227 (1.90)	11	56 (1.55)	t-16
Philippines	180 (1.50)	12	65 (1.80)	14
Brazil	178 (1.49)	13	95 (2.62)	9
Sweden	157 (1.31)	14	42 (1.16)	20
South Africa	143 (1.19)	15	44 (1.22)	19
India	134 (1.12)	t-16	89 (2.46)	12
Norway	134 (1.12)	t-16	52 (1.44)	18
Mexico	131 (1.09)	18	57 (1.57)	15
Greece	124 (1.04)	19	56 (1.55)	t-16
Japan	115 (0.96)	20	69 (1.91)	13

Based on country of origin, institutions from the United States represent the largest bloc with 19.20%, followed by the United Kingdom (8.01%), and Australia (5.41%).

Table 7 highlights the 20 most productive institutions conducting research on coastal management. This includes ten institutions from the United States, three from both Australia and Great Britain, and one each from Canada, Portugal, Spain, and Sweden. The National Oceanic and Atmospheric Administration (NOAA)(156), the University of Rhode Island (113), the University of Washington (86), James Cook University (82), and the Commonwealth Scientific and Industrial Research Organisation (CSIRO)(78) were the top five research institutions during this time period. Notable is that NOAA in the United States, CSIRO in Australia, and the Consejo Superior de Investigaciones Cientificas (CSIC) in Spain are all federally-supported organizations tasked with conducting collaborative research on coastal issues in their respective countries and beyond. Further, oftentimes an institutions level of productivity directly relates to the tenure of a single highly productive

Table 7
Top 20 institutions.

Rank	Institution	Number of Articles
1	NOAA (USA)	156
2	U Rhode Island (USA)	113
3	U Washington (USA)	86
4	James Cook U (AUS)	82
5	CSIRO (AUS)	78
6	U East Anglia (GBR)	69
7	U Newcastle (GBR)	54
8	U California Santa Barbara (USA)	50
9	U Plymouth (GBR)	49
10	CSIC (ESP)	48
t-11	Oregon State U (USA)	47
t-11	Stanford U (USA)	47
t-13	Duke U (USA)	46
t-13	U Queensland (AUS)	46
15	Nature Conservancy (USA)	45
16	Louisiana State U (USA)	44
17	Stockholm U (SWE)	43
18	U British Columbia (CAN)	42
t-19	U North Carolina (USA)	41
t-19	U Algarve (POR)	41

author. For example, the University of Washington is the third most productive institution in the study, and home to Dr. Christie, whose 28 papers account for approximately a third of all the university's output on the topic. Similarly, Dr. Fletcher's tenure at the University of Plymouth (31, 62%) and Dr. Cinner's at James Cook University (28, 34%) have significant impacts on institutional productivity. The maximum number of institutions collaborating on one article was 27 (see Alcolado et al., 2001) from 12 countries, the second most collaborative article had 23 institutions also from 12 countries (Newton et al., 2014), and four had more than 15 institutions. In contrast to co-authorship, the collaborative efforts among institutions varied from 20.03% articles from a single institution, an indication of research groups within one single institution, 45.11% with two institutions; 13.29% with three and 21.57% with four or more.

Institutional SNA (shown in Table 4) indicates the total number of institutions included in the analysis (3,620), the number of institutions with collaborators (2,895), the number of collaborations (4,725), diameter, and cliques. These confirmed the expected smaller network sizes with a diameter of 15 and a more diffused network (density of 0.0011). The results also indicate 12 cliques of five or more institutions. These metrics (see Table 8) show that the National Oceanic and Atmospheric Agency (NOAA) from the United States has the highest indegree centrality value with 129 network connections. This is followed closely by the Commonwealth Scientific and Industrial Research Organization (CSIRO) from Australia with 116 connections, and James Cook University with 101 connections. The top 20° values for institutions show a mix of federal agencies and academic institutions. The betweenness parameter resulted in NOAA with a value almost twice as the next institution CSIC, followed by James Cook University in Australia with similar indices. As mentioned before the percentage of isolates (institutions without connections) was high for this network, so we removed them from the visualization analysis to clarify the representation. This resulted in graph of a loose network with several central institutions (Fig. 5), with smaller cliques aligned in the periphery and larger cliques towards the center of the diagram. Similar to the author analysis, a visualization of clusters of five or more agents (institutions) was performed (Fig. 6). In contrast to the author's clusters, the institution clusters showed a core of agents that with interactions connecting the whole subnetwork (Fig. 6).

3.5. Research emphasis: titles and title phrases

Title analysis assessed shifts in the patterns of title words, terms,

Table 8
Social network analysis centrality measures for top 20 institutions.

Rank	Institution (Country)	Degree	Institution (Country)	Betweenness
1	NOAA (USA)	129	NOAA (USA)	10361.03
2	CSIRO (AUS)	116	CSIC (ESP)	6559.83
3	James Cook U (AUS)	101	James Cook U (AUS)	6038.69
4	Duke U (USA)	88	Duke U (USA)	3918.52
5	Australian Nat U (AUS)	81	CEFAS (GBR)	2519.84
6	CSIC (ESP)	71	Oregon State U (USA)	2472.29
7	Delft U Tech (NLD)	62	CSIRO (AUS)	2303.83
8	U Washington (USA)	59	Louisiana State U (USA)	2222.26
9	U Rhode Island (USA)	56	U East Anglia (GBR)	2186.32
10	Aarhus U (DNK)	52	Griffith U (AUS)	2165.57
11	U California Santa Barbara (USA)	47	IFREMER (FRA)	2137.47
12	CEFAS (GBR)	45	Pontificia U Catolica Chile (CHL)	1993.34
13	U East Anglia (GBR)	43	U Algarve (POR)	1966.50
14	CNRS (FRA)	42	Dalhousie U (CA)	1547.25
15	Stanford U (USA)	42	Stanford U (USA)	1450.89
16	IFREMER (FRA)	41	U Rhode Island (USA)	1408.53
17	U Stockholm (SWE)	40	Delft U Tech (NLD)	1250.57
18	Nature Conservancy (USA)	40	Deltares (NLD)	1243.93
19	Oregon State U (USA)	38	U California Davis (USA)	1186.14
20	U Plymouth (GBR)	38	Nature Conservancy (USA)	1119.59
21	U Algarve (POR)	36	CNRS (FRA)	1108.01

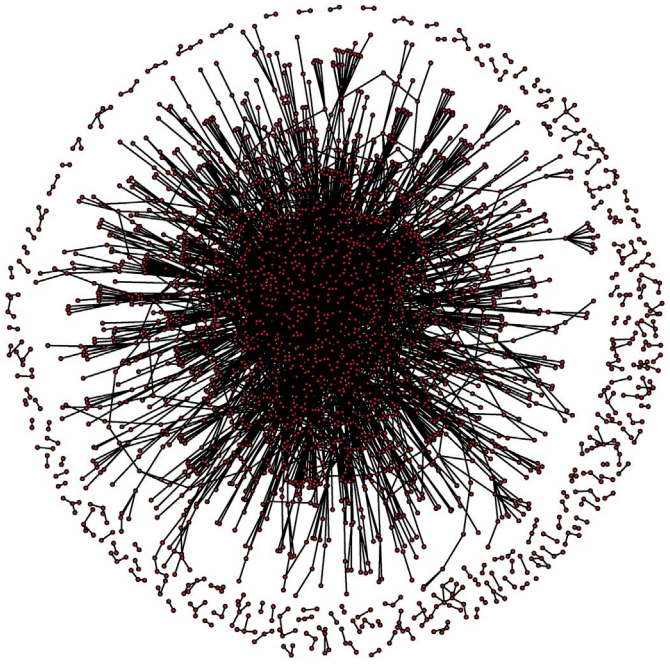

Fig. 5. Complete network of collaborating instititons, 1975–2014.

and research over time (Milojević et al., 2011; Rice and Chapin, 1996). Milojević et al. (2011), in their study of the cognitive structure of library and information science, noted that the use of title words and phrases to elucidate the foundations and trends of scientific research is relatively neglected but can provide useful information about the evolution of research. The title of an article is the first thing a reader sees, and is generally carefully crafted to provide essential information within the article. Title analysis can illustrate the time evolution and relative importance of specific research topics. In this study, analysis of individual words and phrases in article titles and author keywords followed the usual practice of excluding common functional or

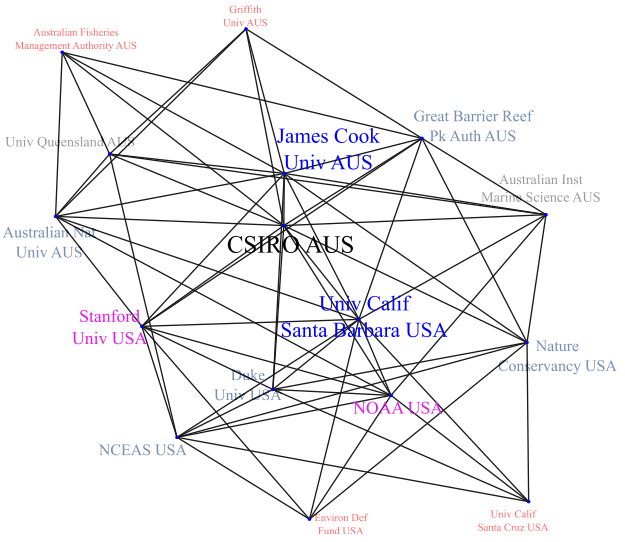

Fig. 6. Largest networks of coastal zone management collaborators, 1975–2014 (cliques of five or more).

nonspecific terms (e.g. the, is, at, which, on, etc.). Titles for all 5461 articles were processed using WordStat (Provalis Research, version 7.1, 2016) to identify the most common words and phrases over time. Author keyword analysis, which also assesses trends in research, is another commonly used bibliometric method. However, given the inconsistency of keyword availability and format over the 40-year period of this study, we conducted qualitative keyword analysis afterwards to better understand emergent research trends identified in title analysis.

Overall and decadal analyses identified the 20 most frequently used title phrases (Table 9). As expected, 'integrated coastal management' and 'coastal zone management' are the two most frequently used phrases over time. While we may have omitted these terms based on their use as initial search qualifiers, they denote temporal shifts in research focus. During the first decade of analysis, a majority of all articles published on the topic include the phrase ‘coastal zone management’ in the title (46; 63%). These works tend to focus heavily on U.S. management and legislation, with an emphasis on state-level policy development and implications for specific industries. It is not until 1992 (see Hildebrand and Norrena, 1992) that the term ‘integrated coastal management’ (ICM) emerges in the literature. During the entire study period, the ranking and percentage of ICM increased from 2nd (25; 5.5%) in the 1985–1994 period, 2nd (168; 8.6%) in the 1995–2004 period, and finally moving ahead of ‘coastal zone management’ during 2005–2014 to assume top ranking (196; 6.5%). Sorensen (1993) makes the following distinctions between ICM and other coastal zone management efforts: 1) ICM is a process that takes place over a considerable time period; 2) ICM focuses on cross-boundary relationships and management strategies; 3) there are often multiple coastal zone management strategies involved in an ICM effort; 4) ICM management strategies are based on a systems perspective, and; 5) ICM efforts have geographic boundaries that extend from ocean environments to some inland limit. The appearance of ICM in the literature may be attributed to the UN development of Agenda 21 (1992), and particularly Chapter 17 *Protection Of The Oceans, All Kinds Of Seas, Including Enclosed And Semi-Enclosed Seas, And Coastal Areas And The Protection, Rational Use And Development Of Their Living Resources*, which calls for an international integrated approach to protection and development of marine and coastal resources.

In line with the international call for integrating coastal and marine management, other concepts have emerged over time that indicate shifts in coastal management research from single issues or governance in isolation to more complex interactions within coastal systems. For

Table 9
20 Most used title phrases.

Rank	Phrase	TP[a]	1975–1984 R[b] (%)	1985–1994 R (%)	1995–2004 R (%)	2005–2014 R (%)
1	Integrated Coastal Management	389	N/A[c]	2 (5.5)	2 (8.0)	1 (6.5)
2	Coastal Zone Management	384	1 (63.0)	1 (19.1)	1 (14.4)	2 (5.3)
3	Marine Protected Area	191	N/A	*N/R*[d]	t-9 (1.7)	3 (4.6)
4	Climate Change	164	N/A	*N/R*	7 (1.8)	4 (3.7)
5	Coral Reef	126	N/A	9 (1.0)	t-9 (1.7)	5 (3.0)
6	Sea Level Rise	111	N/A	3 (3.7)	t-11 (1.5)	t-8 (2.1)
7	Ecosystem-Based Management	108	*N/R*	*N/R*	t-11 (1.5)	6 (2.5)
8	Geographic Information Systems	103	N/A	N/A	4 (2.0)	10 (2.0)
9	Fisheries Management	89	N/A	t-8 (1.7)	3 (2.2)	7 (2.3)
10	Coastal Planning	84	2 (12.3)	t-4 (3.2)	8 (1.7)	t-13 (1.3)
11	Risk Management	77	N/A	N/A	18 (0.2)	t-8 (2.1)
12	Water Quality	75	N/A	t-4 (3.2)	15 (1.1)	t-13 (1.3)
13	Sustainable Development	73	N/A	t-8 (1.7)	6 (1.9)	16 (1.2)
14	Community-Based	64	N/A	*N/R*	5 (1.9)	17 (0.9)
15	Decision Making	56	N/A	N/A	16 (0.7)	15 (1.2)
16	Ecosystem Services	53	N/A	N/A	*N/R*	11 (1.5)
17	Environmental Management	52	N/A	7 (2.0)	14 (1.2)	t-19 (0.8)
t-18	Marine Spatial Planning	49	N/A	N/A	N/A	12 (1.4)
t-18	Coastal Resource Management	49	N/A	6 (2.5)	13 (1.5)	t-19 (0.8)
20	Water Framework Directive	42	N/A	N/A	17 (0.4)	18 (1.0)

[a] TP, total publications.
[b] R, rank of the title phrase.
[c] Not available because title word did not appear in articles published.
[d] Present but not ranked.

example, during the study period, the ranking of 'marine protected area' (MPA) increased from the only two mentions before 1995 (see Fiske, 1992; Agardy, 1993) to 9th (25; 1.7%) in the 1995–2004 period and 3rd (164, 4.6%) from 2005-2014. The emergence of MPAs in relation to coastal management coincided with the publishing of the IUCN *Guidelines for Establishing Marine Protected Areas* (Kelleher and Kenchington, 1991), which outlined the first major effort to establish a global system of marine protected areas – including basic principles for identifying areas, the planning process, and governance considerations. While studies of sea level rise have been ongoing since the 1940s, "sea level rise" was noted first in this study by Titus (1986) and was ranked 3rd (15; 3.7%) in the period between 1985 and 1994; the topic ranking has fluctuated slightly over time from 11th (22; 1.5%) in the 1995–2004 period to 8th (74; 2.1%) in the 2005–2014 period. The similarly-focused phrase 'climate change' has increased in ranking, from its first mention (see Parsons, 1991 and; Paw and Thia-Eng, 1991) to 7th (28; 1.8%) in the 1995–2004 period and 4th (132; 3.7%) in the 2005–2014 period. This may be attributable to the 1990 publishing of the first assessment report of the Intergovernmental Panel on Climate Change (IPCC), which clearly links climate change to sea level rise – and thus to direct impacts to coastal ecosystems and populations. The term ecosystem-based management has increased in use over time from its first mention (see Clark, 1980), tying with 'sea level rise' for 11th place (23; 1.5%) in the 1995–2004 period and 6th (77; 2.5%) between 2005 and 2014. Conversely, the more general term 'environmental management' has decreased in percentage and ranking from 7th (2.0%) in 1985–1994 to 14th (1.2%) in 1995–2004 and 19th (0.8%) in the 2005–2014 period; as has 'coastal resource management,' decreasing from 6th (2.5%) in 1985–1994 to 13th (1.5%) in 1995–2004 and 19th (0.8%) in the 2005–2014 period. 'Ecosystem services' first appeared in the coastal management literature in 2003 (see Moberg and Ronnback, 2003) and rose to 11th (48, 1.5%) in the 2005–2014 period. While origins of ecosystem services are in the 1970s, their emergence in this literature coincides with the publishing of the Millennium Ecosystem Assessment in 2003, which provided a summary of the scientific work being done and a framework for management of ecosystems through this lens. Most recently, 'marine spatial planning' has emerged as a key research topic. It was first mentioned in 2006 (see Tyldesley, 2006) and rose to the twelfth most commonly uses phrase between 2005 and 2014 (49, 1.4%).

4. Discussion and conclusions

Based on 5461 publications obtained from Scopus and Web of Science, and supplementary information gathered from Google Scholar, we conducted a bibliometric exploration to provide an overview of coastal management literature over a 40-year time period. We used multiple source databases in recognition of the potential for bias toward particular disciplines, and in an effort to include the majority of articles published on the topic. While we feel that there is a sufficiently wide range of articles included to identify key characteristics and trends over time, we recognize that our methodology may have some limitations. First, the choice of databases and search terms means that some influential articles not represented on either platform were excluded from the study. Second, over time more and more articles from decades past are being digitized and made available, but these early articles may not have been available at the time of data collection. Third, as noted by Mongeon and Paul-Hus (2016), English-language journals are over-represented in Scopus and Web of Science, which may mean that authors who publish exclusively in other languages may be under-represented in the analyses. Finally, the focus on journal articles means seminal reports, white papers, and books are not included. That said, we used the most thorough search strategy given the realistic constraints of time and resources. We applied our inclusion and exclusions strategies as consistently as possible to identify publications that provide an adequate sample suitable for the summary analyses conducted.

Results indicate that coastal management research has increased significantly over time. The emergence of the topic in scholarly work coincides with passage of the Coastal Zone Management Act of 1972 (US Public Law 92–583), and marked increases in productivity can often be tied to the passage of important legislation or the publication of major policy documents for action on coastal issues. For example, publication productivity markedly increased after the 1992 publication of Agenda 21, which outlined strategies for sustainable coastal management globally, nationally, and locally. This is not to say that key research concepts did not appear before the publication of key legislation or policy, but that the volume of work conducted rose significantly after major policy initiatives. The relative influence of academic research on policy initiatives is an unanswered question worth pursing in the future. Scientific publications on various aspects of coastal management have increasing become international in focus over

the last four decades as well. Shifts in journal publication characteristics, and author and institution affiliations indicate a more globalized research environment. From the earliest research focusing primarily on the land use and legal ramifications of the CZMA, the incorporation of a wide range of disciplines such as ecology, fisheries management, international relations, geography, and disaster management has made the research more holistic and interdisciplinary over time. Notable is a shift from 'coastal zone management' to 'integrated coastal management' as the discipline focuses on cross-boundary relationships and management strategies, adds a systems perspective, and recognizes geographic boundaries that consider both marine and terrestrial environments. Again, the importance of major policy papers and positions to influence research and management is recognized by the emergence of particular terms. For example, concepts such as ecosystem services and marine protected areas have clear links to both international policy publications and highly productive and collaborative researchers.

Through social network analysis (SNA) of both authors and institutions, we sought to identify "scholarly hubs" and "schools of thought" that have a significant impact on coastal management research. SNA results for both authors and institutions indicated overall loosely connected networks with subgroups of highly collaborative researchers who have a significant impact on the field. While the use of SNA analysis facilitates the identification of the most influential authors, it also generated questions about what these highly productive and collaborative people mean to their institution. In particular, while many of the most connected authors come from multi-disciplinary environments, their SNA metric value oftentimes did not correspond to the SNA value of the institution. The use of these metrics made it clear how collaborative authors work can influence particular subtopics within the field such as coral reef management and marine protected areas. The SNA metrics also indicated the importance of federal governments and international organizations in driving research and encouraging integrated management. While countries with extensive shorelines and high economic coastal interests dominate the development of theory and policy development, organizations such as the United Nations have an outsized role in encouraging integrated approaches across the globe.

This bibliometric assessment of coastal management literature was designed to identify global research trends in journal output, authorship, collaboration, and subject over the forty year period from 1975-2014. From its origins as a disparate collection of land use, environmental conservation, and legal theories, interests, and practices, the research trajectory of coastal management has moved forward in diverse directions. While some veins of research become less common over time, others are always emerging and taking root. Current and emerging environmental challenges (e.g. accelerating sea-level rise, enhanced storm surges), coupled with a gradually increasing coastal populations, will result in applied science with increased relevance to not only coastal communities but to ecosystem sustainability and humankind in general.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ocecoaman.2017.12.003.

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