



The Growth and Disciplinary Convergence of Environmental Communication: A Bibliometric Analysis of the Field (1970–2019)

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Specialty section:

This article was submitted to
Science and Environmental
Communication,
a section of the journal
Frontiers in Environmental Science

Received: 13 November 2021

Accepted: 23 December 2021

Published: 25 January 2022

Citation:

Akerlof KL, Timm KMF, Rowan KE, Olds JL and Hathaway J (2022) The Growth and Disciplinary Convergence of Environmental Communication: A Bibliometric Analysis of the Field (1970–2019). *Front. Environ. Sci.* 9:814599. doi: 10.3389/fenvs.2021.814599

Recent reviews describe academic scholarship on environmental communication as a subdiscipline of communication studies focused on mass media. However, these reviews may not provide a full picture of the field. We searched one of the most comprehensive citation databases (Scopus) for articles published from 1970 to 2019 containing the root terms environment* communicat*. The dataset ($n = 474$) revealed an increase over time in the number of journals that publish environmental communication studies and the breadth of their National Science Foundation disciplinary categorizations. Climate communication, corporate social responsibility, and public engagement and participation represent the most frequent abstract topics. Through co-citation analysis of journals cited in references, we found that the foundational literatures informing the field have grown into dense, interconnected networks across disparate areas of scholarship that span the social sciences, natural sciences, engineering, and business. This disciplinary convergence is a positive sign for the field's potential to address problems of societal importance.

Keywords: environmental communication, bibliometric analysis, network analysis, interdisciplinarity, convergence

INTRODUCTION

The provost at a large university once commented that communication and statistics have something in common. They are both such important and useful subjects, he said, that every department wants to research and teach them. The provost's observation might similarly apply to environmental communication. Cox and Pezzullo (2015, p. 16) define this subject expansively as “the pragmatic and constitutive vehicle for our understanding of the environment as well as our relationships to the natural world.” If, as this definition states, environmental communication provides human beings with a way to make sense of the physical and natural world, academic interest in this topic might easily span myriad disciplines. Cox and Depoe (2015) say as much, noting environmental communication gives rise to not just many audiences and potential communication goals, but also to associated academic areas of study.

The field of communication itself has interdisciplinary origins and boundaries that often overlap with other fields (Leydesdorff and Probst, 2009; Waisbord, 2019; Zhu and Fu, 2019). Its scholars take varying research approaches—rhetorical, critical, cultural, and (post-) positivistic—and focus on

differing domains and forms of communication (Walter et al., 2018; Song et al., 2020). Yet, hypothesis-testing using quantitative methods has served as the predominant type of research (Walter et al., 2018) with substantial links between sub-disciplines (Song et al., 2020). Environmental communication initially emerged as an interdisciplinary effort galvanized by a variety of scholarly interests (Cox and Depoe, 2015). In the primary textbook on the topic, *Environmental Communication and the Public Sphere*, Pezzullo and Cox (2021) describe rhetorical perspectives as an early emphasis that has since widened to include other research paradigms in studying public participation, conflict management, journalism, social media, advocacy campaigns, social justice, and corporate social responsibility. By 2007, the inaugural issue of *Environmental Communication: A Journal of Nature and Culture* explored the ways in which the study of the environment and human communication might constitute its own academic field (Cox and Depoe, 2015).

However, recent studies portray environmental communication—and related fields, like science and climate communication—as narrowly focused on traditional communication disciplinary topics, especially mass media and journalism (Pleasant et al., 2002; Comfort and Park, 2018; Rauchfleisch and Schäfer, 2018; Agin and Karlsson, 2021). Due to their design, these studies may not provide a full picture of the field and its evolution. The “environmental decade” was ushered in with the signing of the National Environmental Policy Act (NEPA) and founding of the U.S. Environmental Protection Agency in 1970 (Sweet, 1979). The purpose of this study is to map the academic field of environmental communication from 1970–2019 to assess how it may have changed over the intervening decades through a bibliometric analysis of its citations. The degree to which the field is—or is not—siloed within narrow literatures and fragmented across disciplines speaks to its ability to aggregate and disseminate scientific knowledge. The circumstances in which growth of scientific knowledge is most likely to occur are when fields collaborate across their boundaries, sharing information in ways that generate synergy between them (Leydesdorff and Ivanova, 2021).

Disciplinary Specialization Versus Integration

One of the central tensions within academia is over disciplinary specialization versus integration. As Brewer trenchantly stated: “The world has problems, but universities have departments” (Brewer, 1999, p. 328). Academics wrestle with whether narrow disciplinary expertise is more likely to answer questions that have been identified as of interest—and solvable—within an epistemic community (Kuhn, 1970) or whether emphasis should be placed on application of many broad areas of scientific knowledge to solve highly intractable problems of great societal interest (Gibbons et al., 1994). The social sciences, too, have struggled over whether to focus their scholarship on fundamental or “pure” science problems or take more applied interdisciplinary approaches (Miller, 1982).

According to Kuhn (1970), academic communities provide “paradigms”—associated sets of rules, practices, and knowledge—that allow researchers to efficiently frame and

answer scientific questions. Referred to as Mode one science, this research is guided solely by disciplinary norms (Gibbons et al., 1994). Alternately, Mode two science is inspired by societal problems, unmoored from any one discipline and its associated theories and methods. While this type of research potentially allows for rapid innovation as researchers benefit from new ideas emerging across fields, it can also make knowledge aggregation more difficult due to its very diversity and lack of consistent frameworks and established communities (Salter and Hearn, 1996). Among the foremost of these challenges is the problem of communication between disciplines, ranging from where researchers publish (p. 99) to the terms they use (p. 144). Whereas a given term may have a strict operational definition in one field, in another, the same term may be understood as conventional language or alternatively, may have an entirely different meaning, making it difficult to achieve synergistic knowledge development across disciplines.

Environmental research is often conducted to address complex problems of societal importance (Lubchenco, 1998) that are aptly described as wicked (Roberts, 2000), e.g. where the solution space has many dimensions and is characterized by uncertainty (Alford and Head, 2017). Climate change is the hallmark case: a complex interaction of biogeochemical reactions at planetary scale and human behavior at societal scale. Increasingly, it has been recognized that these types of scientific challenges require a convergence approach, defined as the bringing together of subject matter experts/scientists from many disciplines to work together on solving a challenging problem that crosses disciplinary specialties (Fazey et al., 2020). In 2016, the National Science Foundation (NSF) recognized the importance of convergence by making it one of the Agency’s 10 Big Ideas (Gropp, 2016). This emphasis by NSF has impacts not only on research priorities but on graduate education. The NSF Research Traineeship (NRT) program supports graduate student training in interdisciplinary or convergent research (NSF, n.d.). Communication has been identified as a core skill to be taught in these types of environmental programs (Clark et al., 2011). For example, at the University of Maine (n.d.), its conservation-focused NRT program includes communication training. Due to the widely dispersed nature of these areas of research and graduate training, tracking the development of these fields is difficult, however.

Previous Bibliometric Studies

Only two previous studies have sought to define the boundaries of environmental communication (Pleasant et al., 2002; Comfort and Park, 2018), but systemic reviews of related fields, such as of risk, science, and climate communication, also may provide a useful lens. Both of the studies that reviewed the environmental communication literature focused on databases that primarily, or solely, consist of social science journals, and used media and/or journalistic search terms in collecting the citations. These parameters shaped their databases in ways that likely biased against the inclusion of wider disciplines and over-represented the role of media and journalism in the literature. Further, these studies do not analyze references within citations to investigate the foundational literatures that informed the research corpus.

In 2002, Pleasant et al. reviewed 963 articles published between 1945–2001, which they identified within social science, arts, and humanities databases using combinations of search terms like environment, communication, media, risk, science, nature, ecology, and rhetoric. They found that journals with the highest numbers of citations in the dataset included *Risk Analysis*, *International Journal of Mass Emergencies and Disasters*, *Journal of Communication*, *Science Communication*, and *Australian Journal of Communication*. The diversity of the literature led the authors to suggest founding a journal titled “Environmental Communication” to connect the field.

In 2018, Comfort and Park drew on the methodology of Pleasant et al. and conducted a search of the Web of Science (WoS) database using the terms environment, media, journalism, communication, television, news, press, radio, internet, and social media. To reduce the number of articles, they narrowed the list to only those citations that fell within communication subject areas within WoS. Between 1973–2017, they identified 529 articles. They found that most of the studies were from the United States, United Kingdom, and China, and that climate change had become the top keyword—a new development since the Pleasant et al. study in which environmental was the most frequent term and climate change didn’t even make the list. The authors conclude: “The analysis showed that since the 1970s, environmental communication scholars have examined journalism as a primary point of interest, with a particular emphasis on print-based news” (p. 873).

Agin and Karlsson (2021) mapped the emergence of the related field of climate change communication due to increased attention to this area. They employed the WoS, using the search terms climate change/global warming and communication/media to locate articles between 1950–2018, adding manual searches of other relevant journals. Their final sample included 407 articles from 1993–2018. The authors hand-coded data collection methodology, research focus, and the type of media studied. They found that top area of research was “media and communication” and the most common journals were *Environmental Communication*, *Public Understanding of Science*, and *Applied Environmental Communication and Education*.

Using a similar methodology as the current study, Rauchfleisch and Schäfer (2018) conducted a co-citation analysis of the science communication literature from 1996–2016 using the Scopus database, which has been cited as one of the most comprehensive, second only to Google Scholar (Martín-Martín et al., 2018) (The latter, however, delivers inconsistent search results (Gusenbauer and Haddaway, 2020), and suffers from poor quality control (Delgado López-Cózar et al., 2019) and meta-data (Jacsó, 2010)).

Using the keywords science or scientific communication, the authors located 328 articles. When their academic references were included, 2,395 academic works were identified. They then conducted co-citation and automated content analysis with Latent Dirichlet Allocation. The authors found that mass media and journalism have increasingly become the principal areas of interest: the largest sub-community, as measured by citations, was “dissemination of science via media” (247 citations).

Risk communication represents another related field with its own evolution (Fischhoff, 1995) that has critical lessons for environmental communication (Rickard, 2021). Rickard writes that in the case of risk communication, understanding what makes it “effective” requires an appreciation of what Cox and Pezzullo (2015, p. 16) have termed its “pragmatic” and “constitutive” dimensions. For these authors and Rickard, viewing communication solely as pragmatic fails to consider the ways in which communicating risk transforms societal meanings, relationships, and power dynamics.

In 2004, Gurabardhi, Gutteling, and Kuttschreuter used variations on search terms such as risk, communication, hazard, warn, environment, industry, technology, participation and public involvement to map the field of risk communication. They, too, searched WoS, finding that journals publishing work in risk communication between 1988 and 2000 included *Risk Analysis*, *American Journal of Industrial Medicine*, *Journal of Hazardous Materials*, *Radiation Protection Dosimetry*, *Health Physics*, *Journal of Occupational and Environmental Medicine*, *Environmental Health Perspectives*, *Human and Ecological Risk Assessment*, *Environmental Science and Technology*. As these titles indicate, the research examined contexts such as worker or occupational safety, and communicating risk assessments, human health, and environmental health. Media was not found to be one of the primary research areas of risk communication.

Co-Citation Analysis

Based on the limitations of previous research that attempted to define the scope of academic literature on environmental communication, we employed a more extensive bibliometric study of the field using descriptive statistics and co-citation network analyses. We conducted network analyses on reference co-citation patterns between journals to characterize relationships between disciplinary communities. Co-citation of two journals occurs when the two journals are cited together by an article in a third journal. Hence, the technique reveals which literatures are foundational to academic research areas, identifying the intellectual base of a discipline (Jarneving, 2005). Co-citation analysis has been cited as a technique that facilitates “building consilience across disciplines” by locating literature that may be dispersed across scientific communities but contains a corpus of key ideas or information relevant to the topic (Trujillo and Long, 2018, p. 1).

Structural Topic Modeling

Like Rauchfleisch and Schäfer (2018), we also use unsupervised machine learning to analyze text and identify topics and themes characteristic of articles included in this analysis. Topic modeling is a form of unsupervised machine learning that finds broad themes based on words, also known as “topics,” in a collection of documents (Maier et al., 2018; Blei et al., 2003). Topics are comprised of words commonly collocated with each other. Topic modeling is an effective exploratory and descriptive method for analyzing texts, offering a “quick read” of large collections of documents to easily evaluate themes and their

change over time or across other meaningful categories (Hase et al., 2020). Topic modeling has previously been used to find sub-disciplines or topical trends in bodies of academic literature across disciplines, such as communication (Günther and Domahidi, 2017), sociology (Lindstedt, 2019; Bohr and Dunlap, 2017), and engineering (Jiang et al., 2016). This study encompasses the first 5 decades of the environmental communication field's development to explore the journals and disciplines in which this research has been published and how the literature has changed over time.

Research Questions

RQ1: 1) From 1970–2019, in which disciplines—and their related journals—does the academic literature on environmental communication appear? 2) What are the most frequently cited articles on environmental communication? Which disciplines are they from?

RQ2: 1) In which journals are the foundational literatures for environmental communication located as measured by journal co-citation frequencies? 2) How does the nature of these co-citation networks change over time?

RQ3: 1) From 1970–2019, which topics appear in the academic literature on environmental communication? 2) How do the topics change over time?

METHODS

We conducted a search of the Scopus database for articles published from Jan. 1970 to Dec. 2019 that corresponded to the following parameters: title, abstract, or keywords containing the root *environment* communicat**. This search configuration required the two terms to occur together in the text, in essence necessitating that the article include a variation of “environmental communication.” Next, we assigned journals disciplinary categories based on National Science Foundation codes. Finally, we conducted descriptive statistics on the data set and social network analyses on the references cited by each article for the periods 1970–1989, 1990–1999, 2000–2009, and 2010–2019. (The first 2 decades were combined for the purposes of the analysis as they contain very few articles.) We also ran co-citation data by year in conjunction with each journal's NSF disciplinary categorization.

We initially recovered a set of 690 environmental communication articles from the Scopus database that included the root terms *environment* communicat** (Figure 1). In a secondary process, two coders then vetted these articles for duplication and the meaning of “environmental communication” in the text, reducing the initial set to 474 articles. In order to make this assessment, two coders reviewed the title, journal, abstract, and keywords to determine if the article is about “environmental communication.” In determining what qualifies as “environmental communication” for this study's purposes, and what does not, we adopted the following rules:

- Environment may refer to the built or natural environment.

Scopus search, 1970-2019: title, abstract, keywords (<i>environment* communicat*</i>)	
Original dataset of articles	690
Duplicate articles removed	474
Journals cited by articles	2710
Journals cited five times or more	440

FIGURE 1 | The search process generated both an original set of 474 environmental communication articles and a set of 440 journals cited by those articles 5 times or more within the years 1970–2019.

- Communication must refer to some form of human communication, whether by an individual, group, or organization.
- The communication must be about the environment or related issues, such as sustainability or pro-environmental behavior.
- The article qualifies if there is any valid reference to “environmental communication”; no estimation is made of the extent to which an article refers to environmental communication (e.g., study design vs conclusions).
- If the article is in the journal *Environmental Communication* it automatically qualifies.

Examples of communication that did not qualify included cellular or chemical communication, network systems communication, robot/computerized communication, and communication in hospitals and other work environments.

Disciplinary Codes

We were unable to use Scopus codes as a classification method for the journal disciplinary specialization because they were inaccurate. For example, the journal *Environmental Communication* is coded under physical and environmental science (Elsevier, 2020). While Web of Science did classify most of the journals on the list, it categorizes more than 250 disciplines (Clarivate, 2020) and did not include all journals within our initial list of 474 Scopus references. As a result, three coders translated 76 WoS journal disciplinary categories into the National Science Foundation's codes from the Higher Education Research and Development Survey (National Center for Science and Engineering Statistics, 2021) and reconciled any differences. For 46 journals that were not coded by WoS, three of the authors coded them into a primary NSF code (See codes, Box 1, Supplementary Materials), and again reconciled any differences. If WoS categorized a journal as “communication,” the field as a

whole was assigned an NSF category of social science based on prior determinations (NSF, 2021) and previously referenced studies (Walter et al., 2018; Song et al., 2020). If WoS categorized journals with multiple codes, they also received multiple category codes within NSF. As an aside, WoS classifies *Environmental Communication* as communication and environmental studies.

Social network analyses and STM

Reference co-citation network analysis can be conducted with individual references as the units of analysis, or the journals within the references. We employ the latter method here. Many of the references cited in each of the Scopus articles were not other academic articles, but instead were newspaper citations, government reports, or even just website URLs. We cleaned the citations from each of the references before subjecting them to network analyses, reducing the set of references to solely citations from academic journals. Three coders reviewed whether each reference was from an academic journal. A final network list of the original references, their journals, and journals referenced in their citations formed the dataset for the co-citation analyses. Final cleaning to identify any variations in journal titles was conducted with OpenRefine (Verborgh and Wilde, 2013).

We conducted the journal co-citation analyses of the cleaned data using the bibliometrix package in R (Aria and Cuccurullo, 2017) for the periods 1970–1989, 1990–1999, 2000–2009, and 2010–2019, and ran co-citation frequencies by journals and their NSF disciplinary categories by year. We determined which diagnostic statistics to use in evaluating the centrality of nodes in the networks using the CINNA package in R (Ashtiani et al., 2019) (reported in **Supplementary Tables S2–5**). To understand the network structure, we utilized the Louvain method for community detection (Blondel et al., 2008). The analyses were conducted only with journals that were co-cited at least five times during 1970–2019 (**Figure 1**). For the purposes of the community analyses, only the top 50 nodes are included. Communities in network analyses represent a group of nodes (in this case, journals), densely connected to each other by a link or “edge” (such as co-citation), but not well connected to other groups of nodes (Porter et al., 2009). We relied on the Fruchterman-Reingold layout for visualizing the results.

We then conducted small world analyses of the networks based on a clustering coefficient set from a random network (Humphries and Gurney, 2008; Christensen, 2021). Values of the index greater than one indicate a small world due to high clustering and short path lengths in which “almost every element of the network is somehow ‘close’ to almost every other element, even those that are perceived as likely to be far away” (Watts, 1999, p. 495). Small-world networks are believed to be characteristic of many types of large, sparse networks. Diverse examples include connections between actors, the components of power grids, and the neurons of *C. elegans* roundworms (Watts and Strogatz, 1998). The structure of networks influences how easily information disseminates through them; small world networks are believed to be particularly effective in transmitting information (Lü et al., 2011).

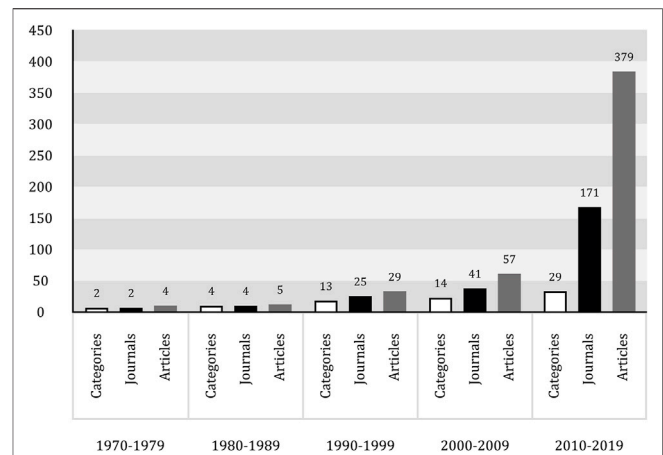


FIGURE 2 | The number of environmental communication articles has grown exponentially since the 1970s; the number of journals and disciplinary categories has also increased. The disciplinary categories represent NSF codes from the Higher Education Research and Development Survey.

We conducted topic modeling for the corpus of 447 texts consisting of article titles and abstracts using the stm package in R (Roberts et al., 2019). Following the guidance and recommendations Denny and Spirling (2018) developed for topic model pre-processing, the corpus was pre-processed by first replacing contractions with root words, making text lowercase, and removing punctuation and numbers. Common combinations of two or more words, called ngrams, were also identified and transformed into single words so they would only be counted as one word by the model (i.e., “climate change” was transformed into “climatechange”). Stopwords (i.e., “and,” “with”) within the stm dictionary were removed. Custom stopwords including the search terms, “environmental,” “communication,” “environmentalcommunication,” and “environmentalcommunications,” as well as the word “abstract” were also removed, to eliminate words that appeared in too many of the texts to have a meaningful contribution to the model.

In unsupervised methods, the number of topics must be determined by the investigators, and there is no single metric for determining the “right” number of topics (Bail, 2020). We first ran the searchK function in the stm package in R to evaluate measures of fit for a range of 10–30 topics, which is in line with recommendations for shorter documents and a focused corpus (Roberts et al., 2019). The measures of fit suggested that somewhere between 12–16 topics would be in the ideal range for the corpus. Because there is no way to automatically determine the number of topics, validation is an important part of topic modeling (Grimmer and Stewart, 2013). Models for each of the values of K were separately run and independently evaluated by four of the authors, and there was consensus that the 14-topic solution was the most coherent based on the highest probability and most unique (FREX) words.

TABLE 1 | The 10 most cited environmental communication journal articles, 1970–2019 (Citations recorded from Scopus in July 2020.)

	Journal	Scopus citations	NSF academic disciplinary codes	Full citation
1	ENVIRONMENT AND PLANNING A: ECONOMY AND SPACE	293	SOCIAL SCIENCES	Burgess, J., Harrison, C. M., and Filius, P. (1998). Environmental communication and the cultural politics of environmental citizenship. <i>Environment and Planning A: Economy and Space</i> , 30 (8), 1445–1460
2	ACCOUNTING, ORGANIZATIONS AND SOCIETY	281	BUSINESS MANAGEMENT AND BUSINESS ADMINISTRATION; SOCIAL SCIENCES	Aerts, W., and Cormier, D. (2009). Media legitimacy and corporate environmental communication. <i>Accounting, Organizations and Society</i> , 34 (1), 1–27
3	ENVIRONMENTAL DEVELOPMENT	211	OTHER SCIENCES, NOT ELSEWHERE CLASSIFIED	Leach, A. M., Galloway, J. N., Bleeker, A., Erismann, J. W., Kohn, R., and Kitzes, J. (2012). A nitrogen footprint model to help consumers understand their role in nitrogen losses to the environment. <i>Environmental Development</i> , 1 (1), 40–66
4	JOURNAL OF CLEANER PRODUCTION	162	OTHER SCIENCES, NOT ELSEWHERE CLASSIFIED; ENGINEERING	Boks, C. (2006). The soft side of ecodesign. <i>Journal of Cleaner Production</i> , 14 (15), 1346–1356
5	ENVIRONMENTAL COMMUNICATION	139	SOCIAL SCIENCES	Brulle, R. J. (2010). From environmental campaigns to advancing the public dialog: Environmental communication for civic engagement. <i>Environmental Communication</i> , 4 (1), 82–98
6	JOURNAL OF MARKETING	138	BUSINESS MANAGEMENT AND BUSINESS ADMINISTRATION	Kronrod, A., Grinstein, A., and Wathieu, L. (2012). Go green! Should environmental messages be so assertive? <i>Journal of Marketing</i> , 76 (1), 95–102
7	ORGANIZATION and ENVIRONMENT	119	BUSINESS MANAGEMENT AND BUSINESS ADMINISTRATION; SOCIAL SCIENCES	Lyon, T. P., and Montgomery, A. W. (2015). The means and end of greenwash. <i>Organization and Environment</i> , 28 (2), 223–249
8	JOURNAL OF ADVERTISING	112	BUSINESS MANAGEMENT AND BUSINESS ADMINISTRATION; SOCIAL SCIENCES	Obermiller, C. (1995). The baby is sick/the baby is well: A test of environmental communication appeals. <i>Journal of Advertising</i> , 24 (2), 55–70
9	INTERNATIONAL COMMUNICATION GAZETTE	97	SOCIAL SCIENCES	Hansen, A. (2011). Communication, media and environment: Towards reconnecting research on the production, content and social implications of environmental communication. <i>International Communication Gazette</i> , 73 (1–2), 7–25
10	PUBLIC UNDERSTANDING OF SCIENCE	87	HUMANITIES; SOCIAL SCIENCES	Jaspal, R., and Nerlich, B. (2014). Fracking in the United Kingdom press: Threat dynamics in an unfolding debate. <i>Public Understanding of Science</i> , 23 (3), 348–363

RESULTS

[RQ1] Literatures in which environmental communication appears between 1970–2019

The number of academic articles on environmental communication increased exponentially between 1970 and 2019 (Figure 2). During the 1970s, only four articles appear within the Scopus database, but by 2010–2019, 379 are published. The growth curve suggests that by 2030 more than another 800 academic journal publications will have been published on environmental communication ($y = 0.8252 \times e^{1.1536x}$; $R^2 = 0.9486$). These articles appear in an increasingly wide range of journals and disciplinary fields (Figure 2; Supplementary Table S1A, B). Only two journals, within two disciplinary categories, were represented in the 1970s, compared to 171 journals across 29 disciplinary categories in the last decade.

Between 1970–2019, the most cited environmental communication articles included those from the journals *Environment and Planning A: Economy and Space*, *Accounting, Organizations and Society*; and *Environmental Development*

(Table 1). However, the journals *Environmental Communication*, *JCOM: Journal of Science Communication*, and *Science Communication* published the largest numbers of environmental communication articles (Table 2). The top National Science Foundation disciplinary categories that correspond to the journals where the environmental communication literature predominates (Table 3) are the 1) social sciences; 2) other social sciences, not elsewhere classified; and 3) business management and business administration; social sciences. Even within just the list of the top 10 journals and disciplinary areas, there is considerable diversity, ranging from the social sciences to business, life sciences, and engineering.

Further, as the field of environmental communication grows over the decades, it becomes more multi- and inter-disciplinary. Within the first decade (Figure 2), the four environmental communication references appear in the *Journal of Environmental Education* and *Environmental Science and Technology*. In the second decade (1980s), the topic remains primarily in communication and education journals, but broadens to development and other international topics (*Journal of Environmental Education*, *Ambiente*, *Development Communication Report*, and *Environmental Communication and Information*). By the 1990s, it explodes into the life and

TABLE 2 | The top 10 journals for environmental communication from 1970–2019 include a wide range of journals. The first year of publication for each journal is listed in parentheses, obtained from UlrichsWeb Global Serials Directory.

	Journal name	# Of articles
1	ENVIRONMENTAL COMMUNICATION (2007)	68
2	JCOM: JOURNAL OF SCIENCE COMMUNICATION (2002)	26
3	SCIENCE COMMUNICATION (1979)	23
4	APPLIED ENVIRONMENTAL EDUCATION and COMMUNICATION (2002)	18
5	JOURNAL OF CLEANER PRODUCTION (1993)	10
6	PUBLIC UNDERSTANDING OF SCIENCE (1992)	10
7	JOURNAL OF ENVIRONMENTAL EDUCATION (1969)	7
8	ENVIRONMENTAL EDUCATION RESEARCH (1995)	6
9	INTERNATIONAL COMMUNICATION GAZETTE (1955)	6
10	BUSINESS STRATEGY AND THE ENVIRONMENT (1992)	5

TABLE 3 | The top NSF disciplinary journal classifications for environmental communication from 1970–2019 include the social sciences, business management, education, the life sciences, and engineering.

	NSF disciplinary category	# Articles, 1970–2019
1	SOCIAL SCIENCES	249
2	OTHER SCIENCES, NOT ELSEWHERE CLASSIFIED	35
3	BUSINESS MANAGEMENT AND BUSINESS ADMINISTRATION; SOCIAL SCIENCES	25
4	OTHER SCIENCES, NOT ELSEWHERE CLASSIFIED; ENGINEERING	21
5	OTHER SCIENCES, NOT ELSEWHERE CLASSIFIED; SOCIAL SCIENCES	18
6	EDUCATION; SOCIAL SCIENCES	18
7	LIFE SCIENCES	14
8	ENGINEERING	12
9	BUSINESS MANAGEMENT AND BUSINESS ADMINISTRATION	11
10	OTHER SCIENCES, NOT ELSEWHERE CLASSIFIED; LIFE SCIENCES	11

conservation sciences, and corporate and environmental management (examples include *Corporate Environmental Strategy*, *International Journal of Phytoremediation*, *Technical Communication Quarterly*, *Communicatio*, *Environmental and Planning A: Economy and Space*). Across the next 30 years, the number of journals publishing in this area—and their disciplinary areas—continues to increase.

[RQ2] Journal co-citation networks defining foundational environmental communication literatures

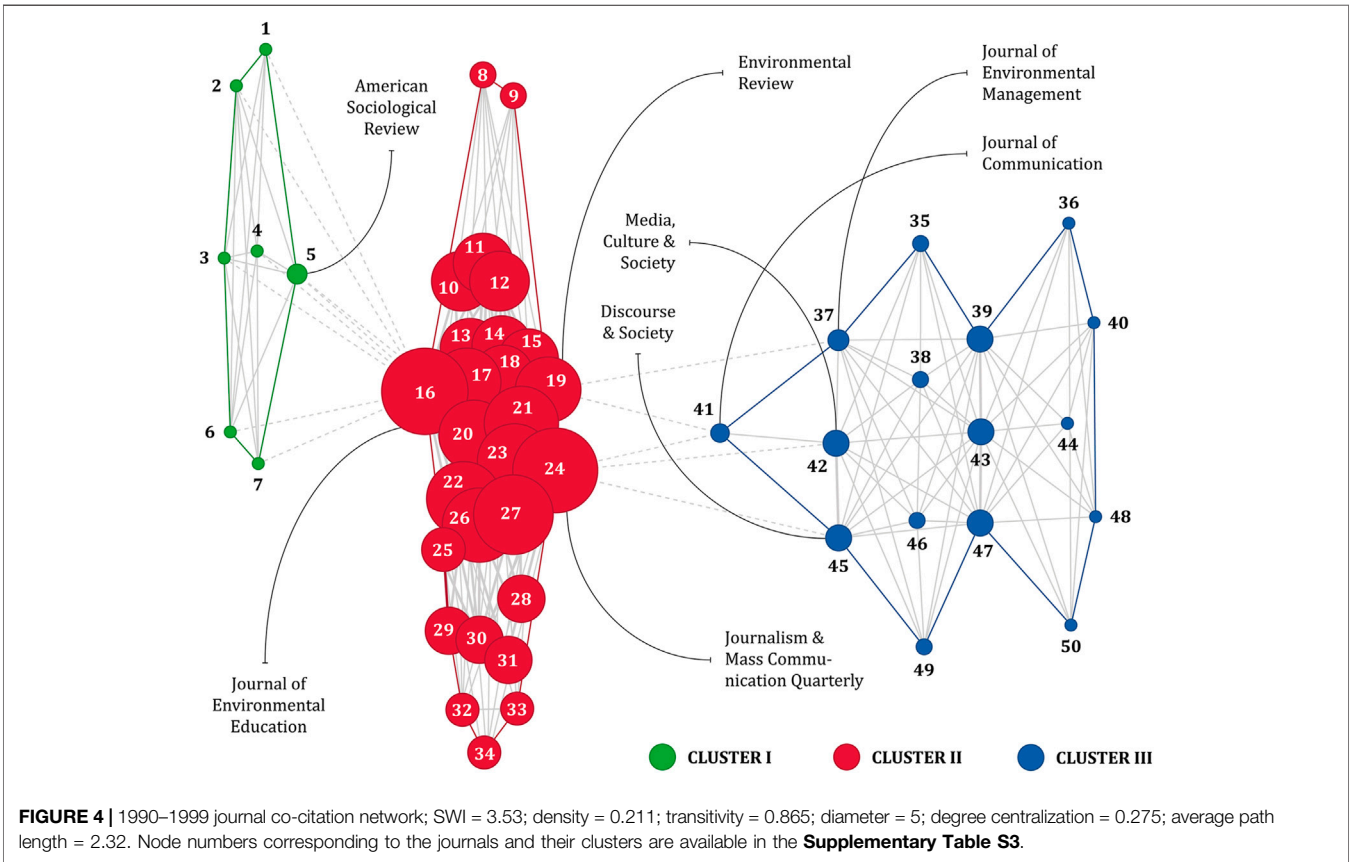
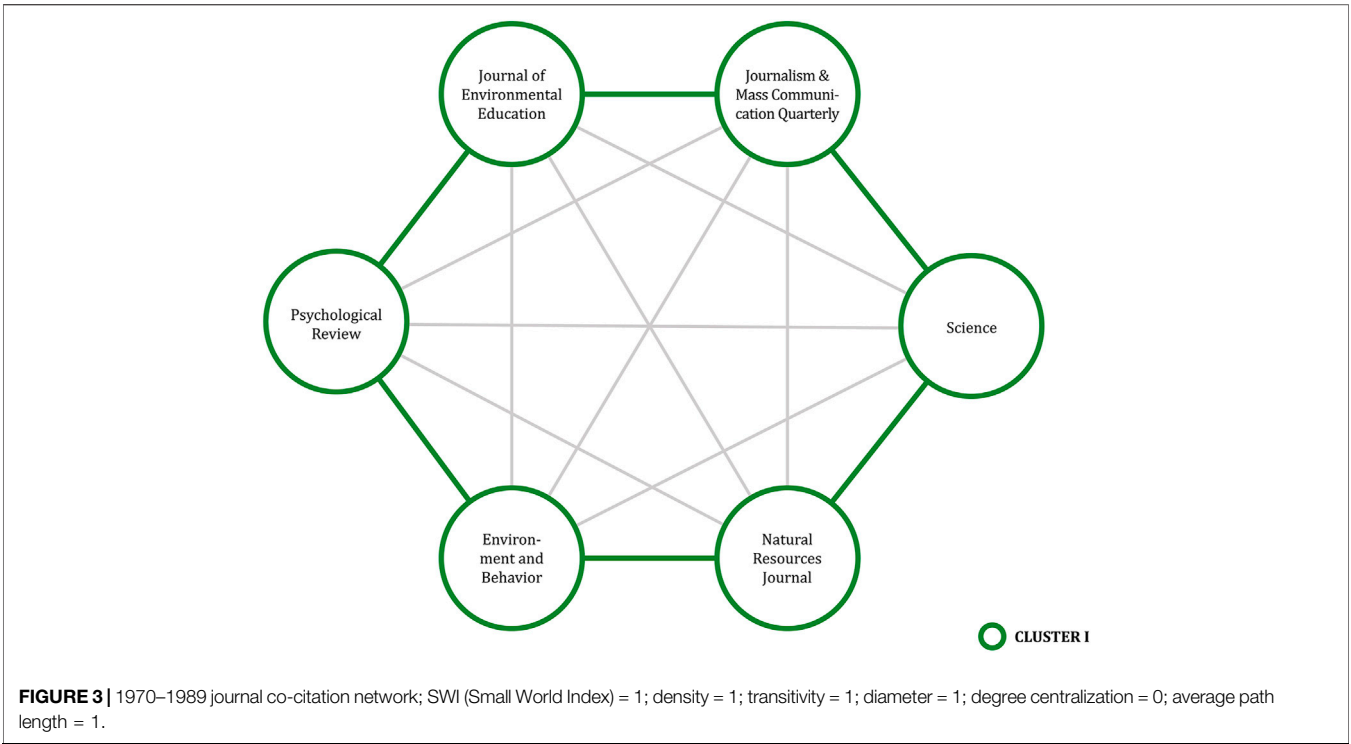
Whereas the 474 original articles from the Scopus database were from 186 unique journals, they cited 2,710 journals and 12,235 article references. In conducting the journal co-citation network analysis, we only included those journals that appear within the reference lists of the original Scopus environmental communication articles five or more times, thereby dropping the total number of unique cited journals from 2,710 to 440. As is apparent from an animated gif of journal co-citations year by year in which each journal is a colored dot within the NSF disciplinary categorizations, 1992–2019 co-citations are increasingly cross-disciplinary: <https://bit.ly/36BkN5G>. (Yearly journal co-citations are sparse in prior years.)

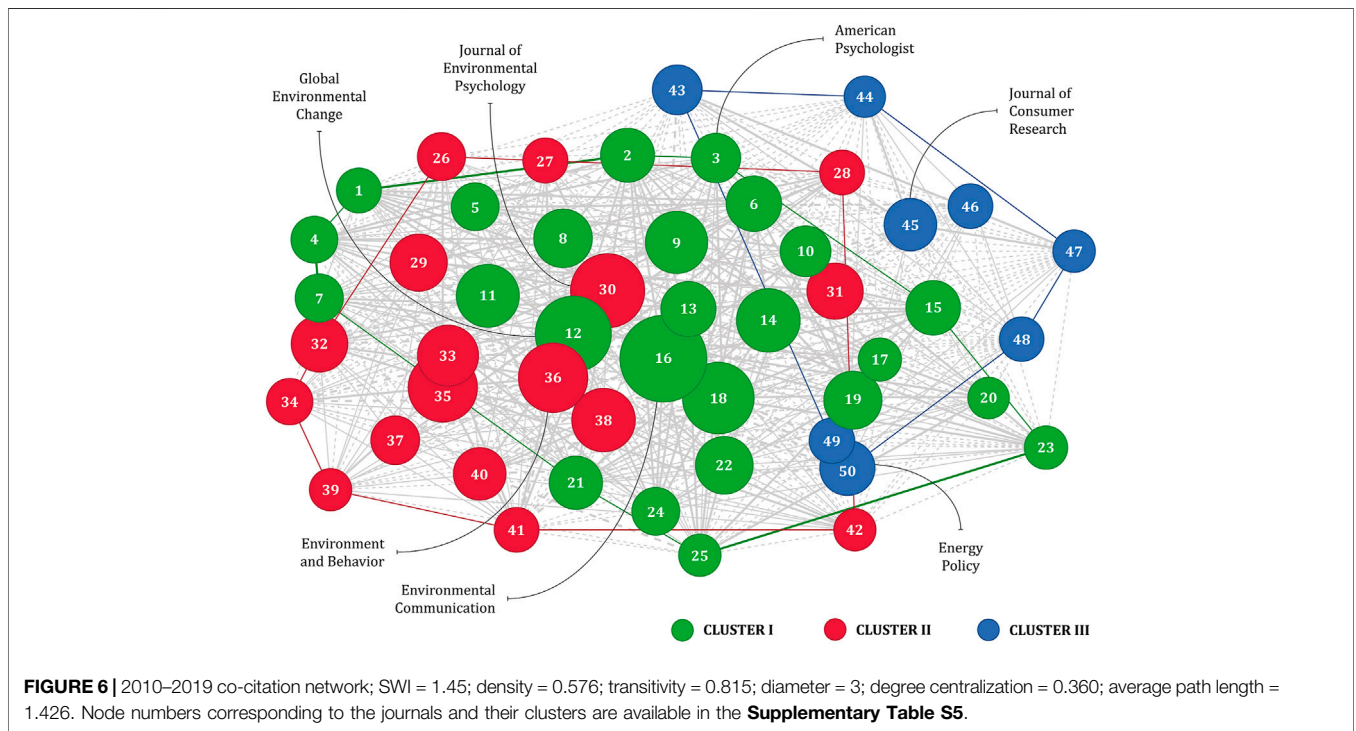
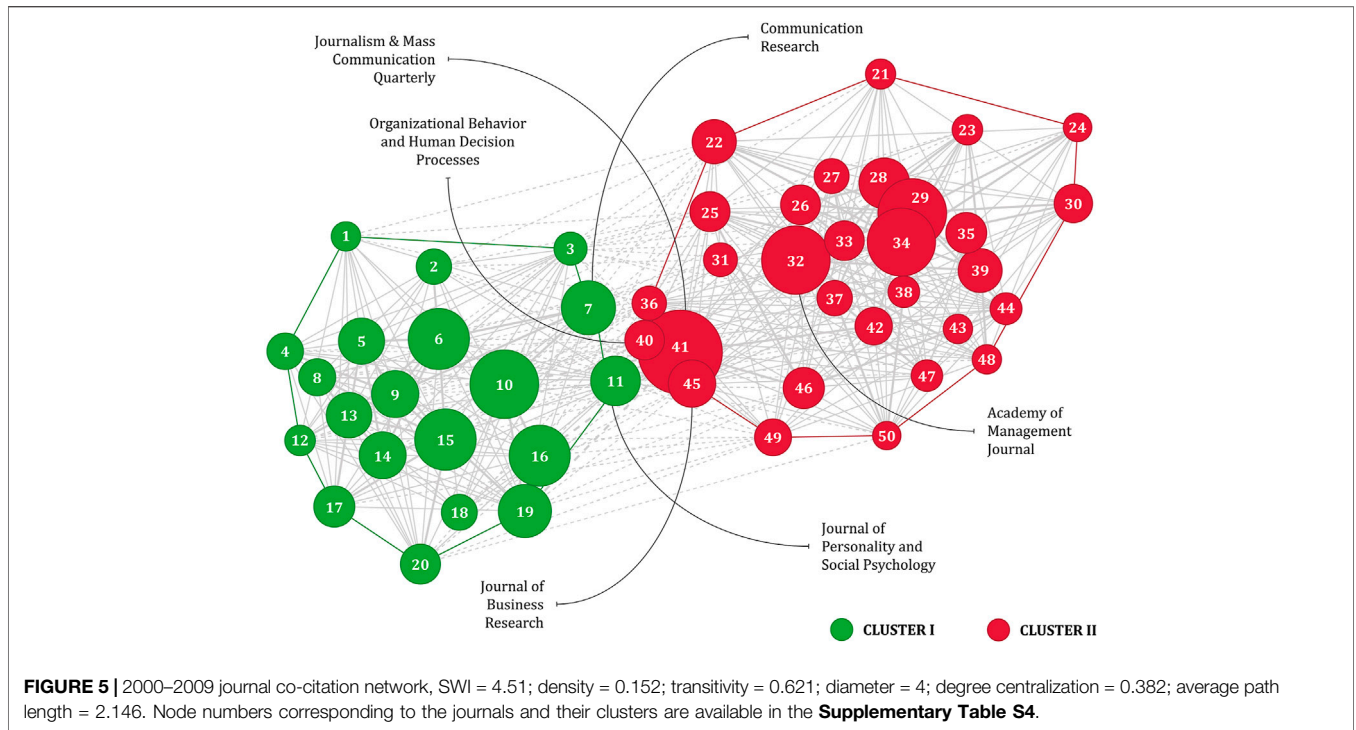
All of the networks from 1990–2019 demonstrate “small world” characteristics with a Small World Index (SWI) of >1 (Figures 3–6). The nodes in each of the network visualizations represent cited journals; a full list of all journal names by node

number is available in **Supplementary Tables S3–5**. Edges represent co-citation of the journals in which the frequency of co-citation equals the edge weight. The most central journals in each of the clusters (Figures 3–6) are listed. There is a wide array of centrality measures that can be used to assess the role of nodes in networks (Bloch et al., 2019). Decay centrality was selected based on indicators within the CINNA package in R (Ashtiani et al., 2019), and in evaluating the measure for its relevance to the subject matter, e.g. that the influence of disciplines depends on citation path and reach (Bloch et al., 2019). Nodes—in this case, journals—identified through decay centrality are believed to lead to maximum diffusion throughout a network (Tsakas, 2019).

1970–1989. In the first 2 decades, there are only six journals in the network (Figure 3). After dropping any journals that appear less than five or more times within the reference lists of the original Scopus environmental communication articles, the only citing journal from the original Scopus list of 474 is *Journal of Environmental Education*, which is classified with the NSF categorization as education and social sciences. References include the journals *Environment and Behavior*, *Journal of Environmental Education*, *Journalism and Mass Communication Quarterly*, *Natural Resources Journal*, *Psychological Review*, and *Science*. There is just one cluster.

1990–1999. By the 1990s, there are 69 journals in the network across three clusters of journals (Figure 4), with each cluster encompassing a mix of disciplines. While most of the journals fall within the social sciences, they also include business management and administration, education, humanities, engineering, life





sciences, geo/atmospheric/ocean sciences, and other sciences and non-science and engineering fields. The most central journals to the network are within the largest of the clusters (Cluster II, $n = 27$): *Environmental Review*, *Journal of Environmental Education*, and *Journalism and Mass Communication Quarterly*. The *Journal of Communication* connects this cluster to the next largest group

(Cluster III, $n = 16$). The most central network journals within this cluster include *Discourse and Society*, *Journal of Environmental Management*, and *Media, Culture and Society*. This group also includes journals that cross the natural and social sciences such as *Journal of Environmental Management*, *Environment and Planning A*, *Global Environmental Change*,

TABLE 4 | Themes and topics from STM, total proportion of abstracts with each primary topic, and highest probability words for each topic.

Theme/name	Primary topic		K	Highest probability words
	%	n		
Climate Change Communication	19	90	4 7	information, science, change, public, climate, health, climatechange, study, data, risk media, climate, climatechange, change, study, pro, social, influence, news, behavior
Corporate Social Responsibility	17	82	6 8 11	product, corporate, green, companies, performance, eco, products, information, strategies, practices forest, policy, scientific, consensus, claims, issues, product, certification, analysis, corporations green, companies, based, web, research, media, study, report, policy, paper
Public Engagement and Participation	11	56	13	public, science, research, social, community, knowledge, climatechange, understanding, local, change
Sustainability and Social Change	9	43	9	sustainability, development, social, field, forest, sustainable, policy, research, article, environment
Environmental Rhetoric and Discourse	8	39	10	analysis, rhetoric, discourse, ecology, essay, rhetorical, environment, can, article, study
Environmental Management	7	35	1	management, waste, information, species, study, education, research, biodiversity, food, system
Energy and Technology Communication	7	34	5	energy, nuclear, public, online, media, issues, political, education, meat, power
Environmental Health	7	31	2	risk, health, pollution, air, public, water, information, quality, research, impact
Environmental Education	6	28	3	students, environment, education, science, world, conflict, nature, public, risk, based
Visual and Narrative Communication	4	19	12	advocacy, narrative, visual, persuasion, research, issue, study, public, environment, can
Conservation and Biodiversity	4	17	14	nature, conservation, human, water, media, article, unitedstates, biodiversity, use, can

and *Journal of Environmental Planning and Management*. The smallest of the clusters (Cluster I, $n = 7$) includes a mix of social science and educational journals such as *American Sociological Review*, *Educational Gerontology*, *Environmental Education Research*, and *International Research in Geographical and Environmental Education*.

2000–2009. During this decade, the number of journals in the network more than doubles, reaching 181 by 2009, but the network also becomes more interconnected. Compared to the previous decade, the average path length decreases from 2.32 to 2.15 and degree centralization increases from 0.28 to 0.38. The network features only two clusters (**Figure 5**). Cluster I ($n = 29$) has a business and management emphasis while Cluster II ($n = 21$) consists of a mix of primarily social science journals. A journalism publication is the most central node in the network—*Journalism and Mass Communication Quarterly* (Cluster II)—followed by *Journal of Business Research* (Cluster II), *Journal of Personality and Social Psychology* (Cluster I), *Organizational Behavior and Human Decision Processes* (Cluster II), *Academy of Management Journal* (Cluster II), and *Psychological Bulletin* (Cluster II).

2010–2019. The network more than doubles between 2010 and 2019. The 436 journals in the network fall into three clusters (**Figure 6**), but the network becomes less centralized and more interconnected than in the previous decade. The average path length drops to 1.43 and degree centralization to 0.36. The decay centrality measures are constant across this network because of its interconnectedness, so cluster rank is used instead to establish comparative centrality (Chen et al., 2013). The first and third most central journals in the network are *Environmental Communication* and *Global Environmental Change*. They fall into a cluster of publications (Cluster I, $n = 25$) in which many of the journals publish research spanning the natural and social sciences, such as *Risk Analysis*, *Climatic Change*,

and *Wiley Interdisciplinary Reviews: Climate Change*. Cluster II ($n = 17$) features *Journal of Environmental Psychology*—the second most central journal in the network. It is joined in the group by *Environment and Behavior*, *Science*, *Environmental Education Research*, and an assortment of social science journals. The least connected of the journal clusters, Cluster III ($n = 8$), features *Energy Policy* and a mix of business and social science journals (*Journal of Consumer Research*, *European Journal of Social Psychology*).

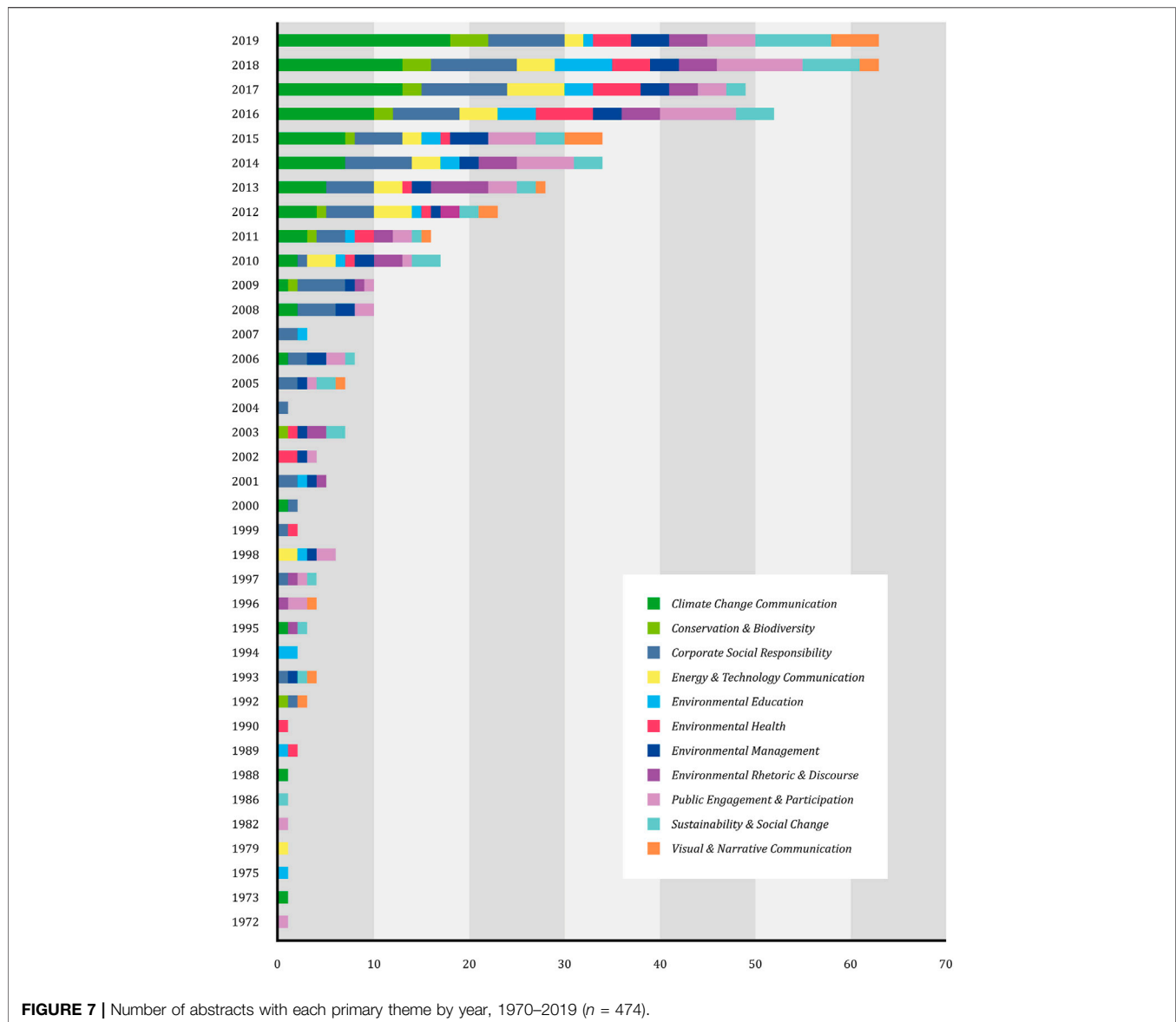
[RQ3] Topics and topic evolution in the environmental communication literature

A 14-topic model consisting of 11 themes was determined to be the best fit (**Table 4; Supplementary Tables S6–7**). The most prominent theme focused on *Climate Change Communication*—the primary topic in 19% of the abstracts. The second most common theme was *Corporate Social Responsibility*, which was a primary theme in 17% of the abstracts. The third most frequently occurring primary topic was *Public Engagement and Participation* in 11% of the corpus.

In the first few decades, the small number of abstracts makes it difficult to discern any trends, but as the literature grows, some topics take on particular importance (**Figure 7**). Namely, the climate change communication theme first appears in the mid-2000s and becomes a prominent theme in the 2010s.

DISCUSSION

This study illustrates the degree to which the environmental communication literature, while focused on environmental education initially, exponentially grows, widens, and becomes more integrated over the period of approximately 5 decades to



include broader communities across the social, life, physical, and management sciences. To demonstrate how diverse this literature is, the top 3 most cited journal articles between 1970–2019 in environmental communication are not from communication journals, but rather *Environment and Planning A: Economy and Space*, *Accounting, Organizations and Society*, and *Environmental Development*.

The top journals—those with the most published articles during the period—are communication journals, however: *Environmental Communication*, *JCOM*, and *Science Communication*. While we did not assess factors that might explain why some of the articles—and associated journals—were more cited than others, the size of author collaborations and the degree of article interdisciplinarity may contribute to some of the differences. Globally, inequality in citation rates is growing, with the top 1% of scholars cited at

increasingly high rates compared to the rest; top cited authors not only have more collaborators, but greater levels of publication productivity (Nielsen and Andersen, 2021). Another potential factor in the observed citation differentials between the journals may be interdisciplinarity. Some evidence suggests that the top 1% cited papers are more interdisciplinary, and that interdisciplinarity plays a particularly strong role for fields with lower overall citation rates, such as the humanities (S. Chen et al., 2015).

In the first 2 decades (1970s–1980s), the journals with the most co-citations demonstrate the wide range of foundational literature that underlies the development of the field: *Journal of Environmental Education*, *Science*, *Natural Resources Journal*, *Psychological Review*, *Journalism and Mass Communication Quarterly*, and *Environment and Behavior*. Environmental education, journalism and mass media, and psychological

literatures have continued to inform the field, but have been joined by increasing numbers of interdisciplinary journals like *Risk Analysis* and *Global Environmental Change* (1990s), and management literatures like *Academy of Management Journal*, *Journal of Business Research*, and *Organizational Behavior and Human Decision Processes* (2000s).

Notably, in the decade after its founding (2010s), *Environmental Communication* becomes a central journal in the co-citation network. While in the 1990s and 2000s various disciplinary literatures form more discrete communities, in the 2010s, the communities become denser and more interconnected, demonstrating convergence across their foundational cited works. From the 1990s onward, the networks take on small world characteristics, demonstrating that even though there are distinct communities defined by co-citation, they are connected by relatively short pathways that allow for ease of information dissemination, and likely contribute to the increased connectivity between the communities demonstrated from 2010–2019.

Mass media and journalism in environmental communication. Of note, while journalism and mass media topics continue to represent areas of interest for journals within these networks over time, they do not dominate them. *Journalism and Mass Communication Quarterly* plays a central role in the co-citation networks of the 1990s and 2000s but is less prominent by 2010–2019. Previous studies on environmental communication that focus heavily on mass media key words in conducting their database searches likely overemphasize this dimension of the field as a result (Pleasant et al., 2002; Comfort and Park, 2018). Interestingly, a study of the risk communication literature that did not employ media keywords did not find this emphasis (Gurabardhi et al., 2004), while a study of science communication did (Rauchfleisch and Schäfer, 2018), which may speak to differences in foci within related fields.

Recent dramatic changes in traditional news media may be an alternative reason for this decrease in prominence (Grieco, 2020). Social media is an increasing area of study as it has become a larger source of news for members of the public (Hansen, 2019). Technological and economic pressures have led to dramatic restructuring of news rooms and layoffs among journalists, which has disproportionately affected environmental journalists (Friedman, 2015). Aside from media, there are many other contexts in which environmental communication occurs (Akerlof et al., 2021). For example, it can play a role in social transformation, constructing or deconstructing communities through deliberation and discourse (Peterson et al., 2016). Fishkin and Luskin (2005) as well as Webler et al. (2014) provide methods for listening to communities' assessments of their environmental concerns and supporting them in analyzing and addressing these challenges.

Business management and interdisciplinary literatures

Perhaps one of the most surprising findings of this study is the degree to which business and management journals address environmental communication. To our knowledge, this has not been previously acknowledged with the potential exception

of academic research studying discourses on greenwashing (Plec and Pettenger, 2012; Cox and Pezzullo, 2015). While it is difficult to ascertain why this literature might be relatively ignored by communication scholars, traditionally corporate environmental efforts have been viewed with suspicion by some in academia (Wright and Nyberg, 2015). That being said, the business literature is less central to the networks by 2010–2019.

Further, climate change communication was a common topic in the titles and abstracts we analyzed using stm, tracking an increasing role of interdisciplinary climate/global change journals within the field of environmental communication. Indeed, the focus on climate change in recent decades may have facilitated disciplinary convergence. One of the benefits of interdisciplinary journals is their ability to facilitate communication between diverse disciplinary communities, but they also may make it more difficult to maintain the same level of rigor that epistemic communities may impose through their own journals (Salter and Hearn, 1996).

Study limitations

Admittedly, the search terms used to identify environmental communication literature were limited and likely excluded a wide array of literature that would be considered by most as falling within the field, i.e., papers in which the terms environment* communicat* did not appear in the title, abstract, or key words. For example, much climate communication research that does not use the term environment would not be included. However, we found one of the largest limitations to be quality of the data in Scopus. In cleaning the data, we discovered high rates of errors in references: inaccuracy and inconsistency in journal names, article titles, and authors. To limit this impact, we therefore chose to only conduct the co-citation analyses on journals, which could more easily be verified than article titles, authors, etc. For other authors considering these types of analyses, data quality is a significant problem, often masked by some of the programs that conduct relatively automated bibliometric analyses.

In categorizing journal disciplines, we also did not analyze journals for the frequency in which they publish articles that take different approaches to the study of communication, whether rhetorical, critical, cultural, or (post-) positivistic. Instead, we relied on WoS and NSF categories, which largely blurred those distinctions. Further, for fields that promote the publication of books instead of journal articles, such as in the humanities, this analysis of journal publications may not fully represent their productivity.

Methodological recommendations for future bibliometric studies. Based on the experiences of the authors, and the growth of this type of research in environmental communication-related fields, we make a number of recommendations others may wish to consider to reduce potential bias and other sources of error. First, any study of an interdisciplinary topic should refrain from using search filters that limit journals to within specific disciplines or areas (social sciences or humanities, for example). Second, the use of specific key words should be defended in the methodology, and may require more sophisticated data collection techniques, such as described by Shemilt et al. (2014), to accurately capture

literatures that span disciplines. Finally, any study using citation databases such as Scopus or WoS should implement—and report—a strategy for data cleaning of the initial citations and their references. While citation databases present very attractive sources of information, due to inaccuracies in publication citations or problems internal to the database, they are also often rife with errors (Franceschini et al., 2016). See, for example, Zupic and Čater (2015) for a discussion of cleaning within bibliometric analysis.

Future Research

This study assessed networks of journals that either have published environmental communication literature or were cited by articles identified in the initial search. A number of hypotheses about the characteristics of interdisciplinary research could be tested by extending this research. Subsequent research should evaluate which articles have become most central within co-citation networks and their characteristics. Specific measurements of interdisciplinarity and “synergy” between fields can be drawn from these types of analyses (Leydesdorff and Ivanova, 2021). Furthermore, network analysis paired with machine learning could be used to generally better understand the evolution of fields and the topics they study. Within the science of science, research has evaluated the degree to which interdisciplinary teams within universities contribute to greater research success (Leahey and Barringer, 2020). Environmental communication represents another field in which to test the impact of varying levels of collaboration and interdisciplinarity on citations and research impact. Lastly, any subsequent studies should include analysis of research paradigms and a broader scope of publications, such as books.

Implications for Curricula

This study also has implications for ways that lecturers design environmental communication courses, such as those that play an important role in convergence graduate education (University of Maine, nd). In creating syllabi, instructors can more accurately depict the interdisciplinarity of the topic by including reading that spans the social and natural sciences and humanities. In doing so, students will consider both the “constitutive” and “pragmatic” dimensions of language use that Rickard (2021) discussed as important for both environmental and risk communication. The diversity of disciplines that contribute to the field of “environmental communication” that we found within this bibliometric study aligns with what we have from communicators themselves. Akerlof et al. (2021) found four distinct perspectives among environmental communication professionals: capacity-builders, translators, policy and decision-supporters, and cultural changemakers. Each perspective has a somewhat different disciplinary focus with implications for the design of graduate education:

- capacity developers: multi-disciplinary literatures in natural resource management and environmental sciences;
- information translators: journalism and public relations;
- communicators for policy and decision-making: psychology, public policy, and political science;
- and cultural changemakers—social movements.

CONCLUSION

Environmental communication represents a field of exponential growth that is increasingly focused on climate communication and that is highly interdisciplinary with foundational knowledge converging across disciplines to inform its development. Instead of siloed disciplines, we found dense, interconnected networks of journals across widely disparate areas of science. This level of convergence represents an enormously positive sign for the continued health of the field and its potential to answer fundamental questions about the ways that humans choose to relate to their natural and physical environments.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://osf.io/pjxdv/?view_only=98b505129e5d47079b1e9ead783facca.

AUTHOR CONTRIBUTIONS

KA, KT, KR, and JO contributed to the conception and design of the study. KA and KT performed the analyses. KA, KR, JH and KT conducted coding. KA wrote the first draft of the manuscript. All authors wrote sections of the manuscript. All authors contributed to manuscript revision, and read and approved the submitted version.

FUNDING

This work was supported by George Mason University’s Office of the Provost and Executive Vice President under a Curriculum Improvement Grant (2019–2020).

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenvs.2021.814599/full#supplementary-material>

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