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Trends in archaeological network research: a bibliometric analysis

Keywords

Abstract

This paper presents an overview of major trends in archaeological network research through a bibliometric analysis of a large corpus of publications on the topic between 1965 and 2016. This review is an effort to begin identifying the outlines of a burgeoning sub-discipline with its distinct traditions, including the diversity of research approaches and preferred publication venues. Network research in archaeology is at a similar stage of development to historical network research. We argue that archaeologists and historians alike interested in establishing network research as a key tool for exploring social change will have a greater chance for success to the extent that we actively collaborate, pool resources, engage in common community activities and publications, and learn from each other's successes and mistakes.

1   Introduction∗

The communities of archaeological and historical network research have much in common. They are both relatively young sub-disciplines that aim to critically explore the use of network methods and models to both address disciplinary challenges and to contribute to broader interdisciplinary debates. Moreover, both fields are faced with similar methodological challenges and opportunities: How can network research enable a better understanding of change in social systems at different temporal scales? How can complex patterns of interaction be revealed through indirect and fragmented sources? We believe that these two communities have much to gain from closer collaboration in their pursuit of addressing such questions.

This paper aims to provide an introduction to archaeological network research for the community of historical network practitioners in this inaugural issue of the Journal of Historical Network Research. We do this by outlining a number of general trends in the publication behavior of archaeological network researchers. This is achieved through a bibliometric analysis of a large and comprehensive corpus of 222 archaeological network research publications spanning the period from 1965 through 2016. This corpus was compiled using Boolean keyword searches in online research databases for journals indexed in the Web of Science as well as additional journals and books indexed on Google Scholar. Additional publications were subsequently added based on the citations within the initial sample. These publications were then manually assessed to determine whether or not they met our selection criteria. Specifically, the corpus used here includes only those publications that apply, develop, or explicitly addresses formal network methods and models in an archaeological research context. We exclude many examples where networks are used as metaphorical (as opposed to formal) descriptions of interaction processes though we note that these two different areas of research have been mutually influential in archaeology and closely allied fields.[1] The corpus is openly accessible as a Zotero library and integrated within the Historical Network Research website.[2] We explore chronological trends in the number of

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1   Hannah Knox, Mike Savage, and Penny Harvey, "Social Networks and the Study of Relations: Networks as Method, Metaphor and Form," Economy and Society 35, no. 1 (February 1, 2006): 113–40, doi:10.1080/03085140500465899.

2   Tom Brughmans and Matthew A. Peeples, "Archaeological Networks Zotero Bibliography," accessed February 15, 2017, https://www.zotero.org/groups/archaeologicalnetworks/; Historical

publications per year, research agendas and influences across different regions, co-authorship between archaeological network researchers, trends in the gender of these authors, and the publication venues for archaeological network research.

Of course, all of the patterns we document below are limited to the 222 publications compiled here. We have almost certainly missed other archaeological applications of network methods, perhaps more so in regions of the world where neither of us works. It is also important to note that this is a bibliometric analysis focused on a single area of research so it is more difficult to draw firm conclusions about how the trends we see here reflect broader disciplinary trends. We suggest that this is an area ripe for future research.

This paper is not designed to be a complete qualified literature review but rather aims to offer a quantified glimpse into a sub-discipline related to historical network research that shares some of its goals and is confronted with similar challenges. More in-depth reviews of archaeological network research are available that will provide further contextual and substantive information about the quantitative trends discussed in this paper.[3]

2   Chronological trends

Formal network science approaches have been applied in archaeological research since the late 1960s but have only recently become common. This trend is illustrated in figure 1, showing the counts of archaeological network research publications per year.

The early application of network methods was largely relegated to textbooks and methodological overviews focused on the use of mathematical techniques in archaeology.[4] In such early publications, graph theoretical methods and visualization tools were suggested as a potentially useful method for representing and analyzing archaeological data. Perhaps the earliest

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Network Research, "Historical Network Research Bibliography," accessed February 15, 2017, http://historicalnetworkresearch.org/resources/bibliography/.

3   Tom Brughmans, "Thinking Through Networks: A Review of Formal Network Methods in Archaeology," Journal of Archaeological Method and Theory 20 (April 2013): 623–62, doi:10.1007/s10816-012-9133-8; Anna Collar et al., "Networks in Archaeology: Phenomena, Abstraction, Representation," Journal of Archaeological Method and Theory 22, no. 1 (March 1, 2015): 1–32, doi:10.1007/s10816-014-9235-6.

4   E.g. D. L. Clarke, Analytical Archaeology (London: Methuen, 1968); J. E. Doran and F. R. Hodson, Mathematics and Computers in Archaeology (Edinburgh: Edinburgh University Press, 1975).

example of an application of network science techniques toward addressing a substantive archaeological question came in 1977 with John Terrell's use of Proximal Point Analysis, to model geographic networks and the most likely directions of inter-island movement in the Solomon Islands.[5] This research was influential within Pacific archaeology early on and more recently similar methods have been applied in different regional contexts. For example, Cyprian Broodbank used a related approach to model interaction networks of Early Bronze Age Aegean island communities.[6] Interestingly, Terrell and many other early archaeological adopters of network science were primarily influenced by geography and applications of graph theory and not by sociometry or the then emerging discipline of social network analysis.[7] This reflects broader trends in archaeology in the 1960s and 70s, where a large number of formal methods found their way into the so-called 'new archaeology' by way of the 'new geography'.

Until the early 2000s, archaeological network research consisted almost exclusively of isolated applications. Very few authors published more than one paper using formal network methods and there certainly was no community of archaeological practitioners of network science. This can in part be explained by the limited availability of computing power and user-friendly network software, but this is not the sole explanation. Indeed, archaeologists were early adopters of Geographical Information Systems (GIS) which suffered from the same technical limitations in the early years. It is striking that the boom of GIS applications in archaeology in the early 1990s did not go hand-in-hand with a boom in network science applications. We believe the main reason for this sporadic application is the limited cross-fertilization between quantitative sociology (and in particular social network analysis) and archaeologists, and the latter's focus on quantitative work in geography which was less concerned with networks at the time of the initial GIS boom. There are isolated examples of anthropologists/archaeologists who were more integrated in the social network analysis community, especially Per Hage who wrote a number of books applying network methods to address Pacific archaeology research topics with the prominent graph theorist Frank Harary.[8] However, the methodological

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5   John E. Terrell, "Human Biogeography in the Solomon Islands," Fieldiana Anthropology 68, no. 1 (1977): 1–47.

6   C Broodbank, An Island Archaeology of the Early Cyclades (Cambridge: Cambridge University Press, 2000).

7   Terrell pers. comm.

8   Per Hage and Frank Harary, Structural Models in Anthropology (Cambridge: Cambridge University Press, 1983); P Hage and F Harary, Exchange in Oceania: A Graph Theoretic Analysis (Oxford: Clarendon Press, 1991); P Hage and F Harary, Island Networks: Communication,

aspects of Hage and Harary's work had limited influence on archaeological method and theory outside of that region.

The current boom in archaeological network research began to gather steam beginning in the early 2000s. Alexander Bentley and Herbert Maschner published a large number of studies on the topic and edited a volume titled "Complex Systems and Archaeology" in 2003, which mainly collected papers discussing or applying complex network methods in archaeological research contexts.[9] This work by Bentley and Maschner illustrates a key explanation for the increase of archaeological network research since the early 2000s: the academic popularization of the topic by physicists. Two pairs of physicists, Watts and Strogatz, and Barabási and Albert, who published the 'small-world' and 'scale-free' network models respectively, claimed almost universal applicability of their models to real-world phenomena, which led to a surge in network science research and complexity science in general in a wide range of disciplines including archaeology.[10] The 2003 book by Bentley and Maschner discusses these two influential models in detail and much of it is concerned with how they can be applied to address archaeological research questions.

The increased influence of physicists went hand-in-hand with a more widespread availability of computing power and user-friendly network analytical software. Combined with increasingly common practice of digitizing, standardizing, and compiling large archaeological datasets, representation of archaeological data as networks for visual or statistical exploration was increasingly straightforward and accessible by the 2000s. Much archaeological network research in the early 2000s, like in many other disciplines, was concerned with identifying power-law degree distributions and small-world structures in archaeological networks or with using these concepts as explanatory models. However, there was also a continuation of the older archaeological practice of exploring spatial phenomena like road and signaling networks through spatial network methods adopted from geography. These trends are apparent in the collection of papers published in 2007 deriving from

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    Kinship and Classification Structures in Oceania (Cambridge: Cambridge University Press, 1996).

9   R. A. Bentley and H. D. G. Maschner, Complex Systems and Archaeology (Salt Lake City: University of Utah Press, 2003).

10 D Watts and S Strogatz, "Collective Dynamics of 'small-World' Networks," Nature 393 (1998): 440–42; A.-L. Barabási and R Albert, "Emergence of Scaling in Random Networks," Science 286 (1999): 509–12.

a 2006 session on the topic at the "Computer Applications and Quantitative Methods in Archaeology" conference (CAA) in Fargo (USA).[11]

In recent years we have begun to see archaeological network approaches start to go in a few distinct directions across different regional contexts. Complexity based network approaches influenced by physics and related fields have remained popular and have been particularly influential in Europe. While these methods have seen continued popularity in North America, archaeological network practitioners in this region have also increasingly begun to engage with sociology and social network analysis. This trend is perhaps driven by the formation of large research teams such as the group led by Barbara Mills centered on the University of Arizona. This interdisciplinary team includes several sociologists; among them Ronald Breiger who has been an influential practitioner of social network analyses and network theory in sociology since the early 1970s. Increasingly the North American literature involves collaborations between archaeologists and sociologists and network research directed toward sociological questions (for example, the relationship between network position and advantage for individuals and groups at various scales).[12] Based on our own positions in the burgeoning world of archaeological network research we surmise that we are likely to see the continued growth of both complex network and social network approaches in the coming years.

If we can write of the existence of a sub-discipline of 'archaeological network science', supported by an academic community of frequent practitioners with their preferred presentation and publication outlets, it is only from the 2010s onwards. Figure 1 shows a huge increase in the number of publications between 2012 and 2016. The bulk of these recent publications are symptomatic of an emerging sub-discipline: edited volumes and journal special issues dedicated to the theoretical and methodological discussion and application of network science in archaeology. These recent publications are not exclusively concerned with the discussion of network science methods for their own sake, however. Recent years have also seen a diversification in the archaeological regions, periods, and topics to which network methods have been applied. Alongside the continued interest in spatial networks and small-world/scale-free networks,

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11   Gary Lock and John Pouncett, "Network Analysis in Archaeology Session Introduction: An Introduction to Network Analysis," in Digital Discovery: Exploring New Frontiers in Human Heritage. Proceedings of the 34th CAA Conference, Fargo, 2006, ed. J. T. Clark and E. M. Hagenmeister (Budapest: Archaeolingua, 2007), 71–73.

12   Barbara J Mills et al., "Transformation of Social Networks in the Late Pre-Hispanic US Southwest.," Proceedings of the National Academy of Sciences of the United States of America, March 2013, 1–6, doi:10.1073/pnas.1219966110; Matthew A. Peeples and W. Randall Haas, "Brokerage and Social Capital in the Prehispanic U.S. Southwest," American Anthropologist 115, no. 2 (June 1, 2013): 232–47, doi:10.1111/aman.12006.

we see an increase in the exploration of large archaeological datasets represented as networks, in agent-based, equation-based, statistical network models, and applications of sociological theories and methods to archaeological data. We also see evidence of an increase in the development of original models and methods designed to address archaeological research questions. Thus, archaeologists are no longer exclusively adopting network techniques from other disciplines but are now actively contributing to network science as a whole through the development of methods and through collaborations with computer scientists, physicists, sociologists, and others. Two typical aspects of archaeological research are proving to be particularly inspirational in the development of such original network techniques: the study of spatial phenomena and methods for exploring the network drivers of long-term change in social systems.
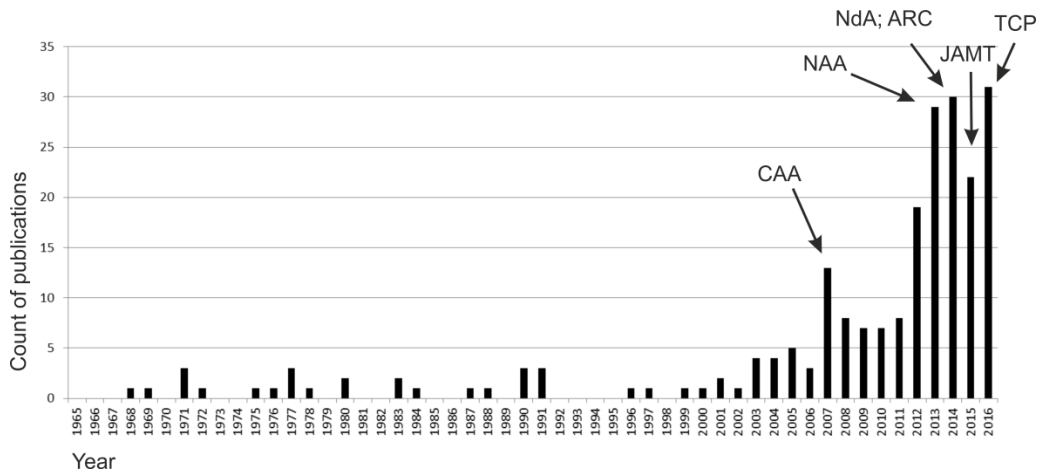

Figure 1. Frequencies of archaeological network research publications per year (n=222). Particularly high counts result from edited volumes or special issues on archaeological network research published in the proceedings of the 2007 "Computer Applications and Quantitative Methods in Archaeology" conference (CAA)[13]; a 2013 edited volume titled "Network Analysis in Archaeology" (NAA)[14];

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13   Lock and Pouncett, "Network Analysis in Archaeology Session Introduction: An Introduction to Network Analysis."
14   Carl Knappett, Network Analysis in Archaeology. New Approaches to Regional Interaction (Oxford: Oxford University Press, 2013).

a 2014 special issue in "Nouvelles de l'Archéologie" (NdA)[15]; a 2014 special issue of the "Archaeological Review from Cambridge" (ARC)[16]; a 2015 special issue of the "Journal of Archaeological Method and Theory„ (JAMT)[17]; a 2016 edited volume titled "The Connected Past" (TCP)[18].

3   Publication media and venues

The vast majority of archaeological network research is published in scholarly journals, but publication patterns have changed considerably through time (Table 1). Between 1965 and 2000 book sections and books were the dominant venues and only since the 2000s have journals taken the lead. This reflects publication trends in archaeology as a whole. Notable edited volumes and conference proceedings from the earlier years include pioneering publications in computational archaeology as a whole: "Mathematics in the Archaeological and Historical Sciences, Proceedings of the Anglo-Romanian conference, Mamaia 1970" and "Interpreting space: GIS and archaeology".[19]

Table 1. Count of archaeological network research publications per publication medium (n=222).

Medium	Count of publications
Book	19
Book section	46
Conference paper	16
Journal article	133
Thesis	7
Webpage	1

15   Carl Knappett, Analyse Des Réseaux Sociaux En Archéologie. Special Issue of Nouvelles de L'archéologie, 135, 2014.

16   Sarah Evans and Kathrin Felder, Social Network Perspectives in Archaeology. A Special Issue of Archaeological Review from Cambridge, 2014.

17   Anna Collar et al., The Connected Past: Critical and Innovative Approaches to Networks in Archaeology. A Special Issue of the Journal of Archaeological Method and Theory 22 (1), 2015.

18   Tom Brughmans, Anna Collar, and Fiona Coward, The Connected Past: Challenges to Network Studies in Archaeology and History (Oxford: Oxford University Press, 2016).

19   F. R. Hodson, D. G. Kendall, and P. Tăutu, Mathematics in the Archaeological and Historical Sciences, Proceedings of the Anglo-Romanian Conference, Mamaia 1970 (Edinburgh: Edinburgh University Press, 1971); Kathleen M S Allen, Stanton W Green, and Ezra B W Zubrow, Interpreting Space : GIS and Archaeology (London: Taylor & Francis, 1990).

The list of the most common publication venues shown in table 2 is heavily weighted toward recent publications and in particular the dedicated volumes and journal special issues shown in figure 1. The most common journals include five ranked in the top ten of Google Scholar's ranking of archaeology journals including broad disciplinary journals (e.g. Antiquity, Journal of Anthropological Archaeology, American Antiquity) as well as more methodologically focused venues (e.g. Journal of Archaeological Science, Journal of Archaeological Method and Theory). Perhaps not surprisingly, network science is not frequently published in journals dedicated to more specific sub-areas like cultural heritage studies, osteoarchaeology, and archaeobotany.

Table 2. Left table: Ranking of top publication venues for archaeological network research. Edited volumes and journals in which more than six archaeological network research papers are published (n=196). Right table: top ten in Google Scholar archaeology journal ranking (on 05/02/2017). Journals in bold are included in both the left and right columns.

| Book/Journal ranking	Count of publications	Journal ranking "Archaeology" Google Scholar
1: Network analysis in archaeology. New approaches to regional interaction	15	**1: Journal of Archaeological Science**
2: Journal of Archaeological Method and Theory	14	**2: Antiquity**
3: Journal of Archaeological Science	13	**3: Journal of Anthropological Archaeology**
4: The Connected Past: challenges to network studies in archaeology and history	10	4: Journal of Cultural Heritage
5: Nouvelles de l'archéologie	9	5: International Journal of Osteoarchaeology
6: Journal of Anthropological Archaeology	8	6: Vegetation History and Archaeobotany
7: Archaeological Review from Cambridge	8	**7: Journal of Archaeological Method and Theory**
8: American Antiquity	7	**8: American Antiquity**
9: Digital discovery: exploring new frontiers in human heritage. Proceedings of the 34th CAA conference, Fargo, 2006	6	9: Radiocarbon
10: Antiquity	6	10: International Journal of Heritage Studies
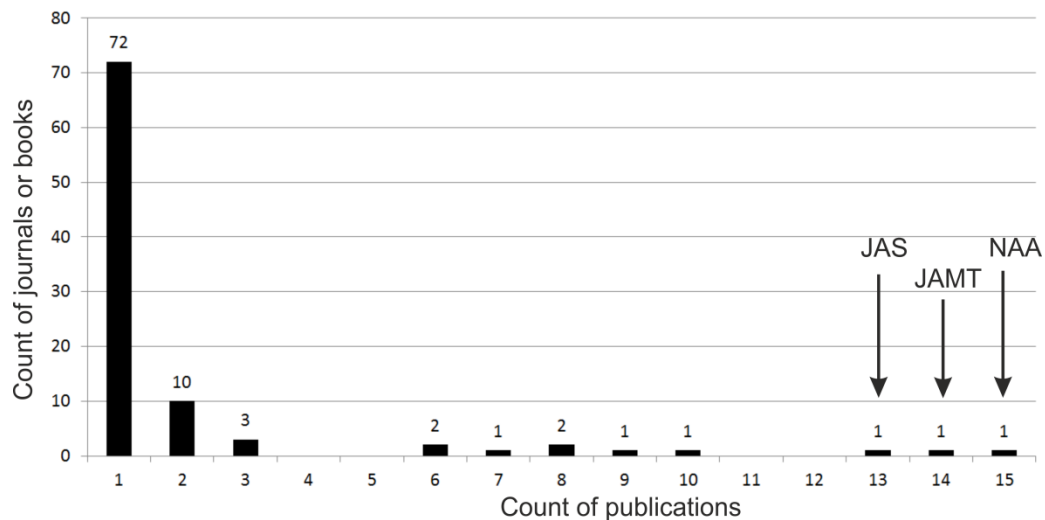
Figure 2. Frequency distribution of publication venues for archaeological network research: count of publications per journal/edited volume (n=196 publications). Top three venues: "Network Analysis in Archaeology" (NAA)[20]; "Journal of Archaeological Method and Theory" (JAMT); "Journal of Archaeological Science" (JAS).

4 Co-authorship

A total of 230 authors were involved in producing the 222 publications studied here. A small number of authors, like the authors of this paper, have published many archaeological network studies, however, figure 3 shows that the vast majority of authors (162) (co-)authored only one paper included in this corpus (Table 3). Figure 4 further illustrates that this pattern is not simply a product of a few publications with extremely high numbers of authors. Co-authorship is common in archaeological network research, with 99 papers having more than one author and four representing large collaborations with 10 authors or more (publications of the "Southwest Social Networks project" by Mills and colleagues and a manifesto for "Mediterranean maritime networks").[21]

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20 Knappett, Network Analysis in Archaeology. New Approaches to Regional Interaction.

21 Mills et al., "Transformation of Social Networks in the Late Pre-Hispanic US Southwest."; Barbara J. Mills et al., "The Dynamics of Social Networks in the Late Prehispanic U.S. Southwest," in Network Analysis in Archaeology. New Approaches to Regional Interaction, ed. Carl Knappett (Oxford: Oxford University Press, 2013), 181–202; Barbara J. Mills et al., Social Networks in the Distant Past, ed. Matthew A. Peeples, vol. 22, 2013; Justin Leidwanger et al., "A Manifesto for the Study of Ancient Mediterranean Maritime Networks," Antiquity+, 2014, http://journal.antiquity.ac.uk/projgall/leidwanger.

The majority of publications are still single-authored papers. These trends suggest that for most archaeologists the use of network science is infrequent, tied to a particular aspect of their research and does not dominate their research output.

Table 3. Ten authors with the highest number of archaeological network research publication counts (n=222).

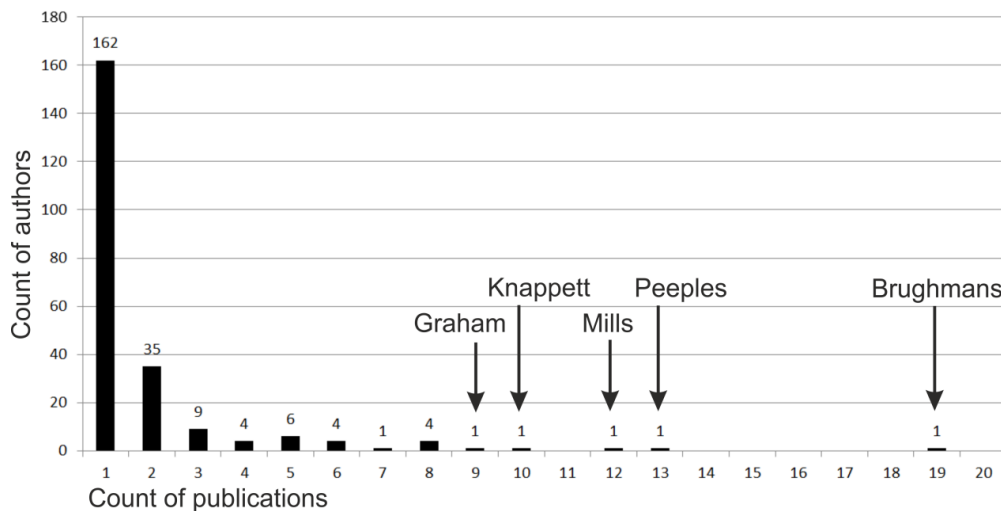| Author	Count of publications
Brughmans, Tom	19
Peeples, Matthew A.	13
Mills, Barbara J.	12
Knappett, Carl	10
Graham, Shawn	9
Collar, Anna	8
Clark, Jeffery J.	8
Evans, Tim S.	8
Rivers, Ray	8
Coward, Fiona	7

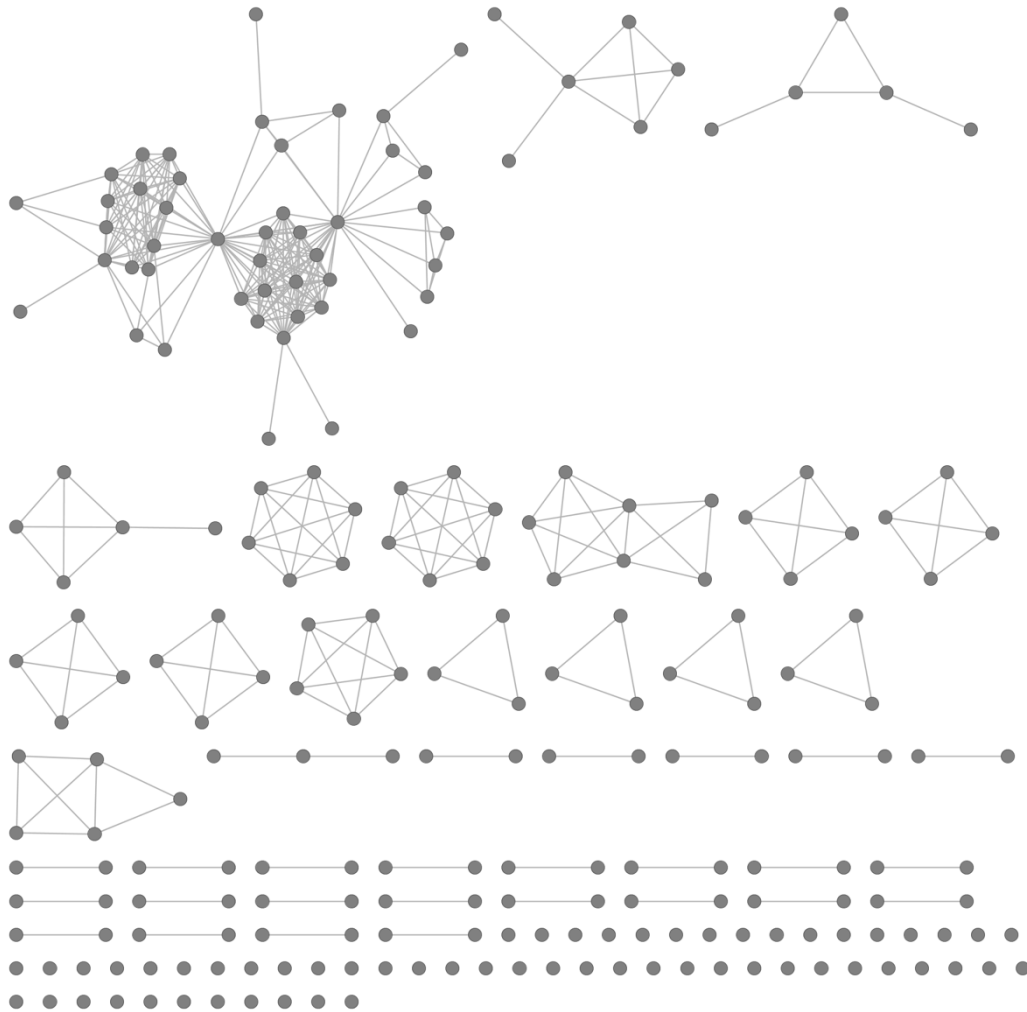**Figure 3.** Count of publications per author (n=222).

Figure 4. Co-authorship network of archaeological network research (n=222).

We can further explore the co-authorship in this corpus by representing it as a network where authors are represented as nodes with edges defined by co-authorship. The resulting co-authorship network is shown in figure 4, and it consists of a large number of components (101) because most papers have but one or two authors. This further illustrates that co-authorship is not the norm in archaeological network research. Furthermore, it adds further weight to our interpretation that the use of this particular formal method for most archaeologists is infrequent and problem-specific. Indeed, the largest connected component includes primarily those authors whose recent research output is dominated by formal network science (Table 3), as well as authors of papers with a very high number of authors (Figure 5). Figure 6 offers a closer look at this largest connected component. The use of the Louvain clustering method

enables us to identify groups of authors that have particularly dense co-authorship among themselves and less with authors in other groups. The two largest groups consist of the few papers mentioned above with a high number of co-authors, as well as papers co-authored by one of these authors. The other three groups represent a few papers that are co-authored with a bridging member of the bigger groups. These bridging members are identified by the betweenness centrality measure (represented as node size in Fig. 6). A few authors, in particular Barbara Mills and Tom Brughmans, are co-authors with members of different groups, giving them a high betweenness score. The handful of authors in this component with a higher betweenness score pursue a methodological interest in archaeological network research (alongside their other research interests), which leads them to co-author with a range of authors that share their methodological interest.
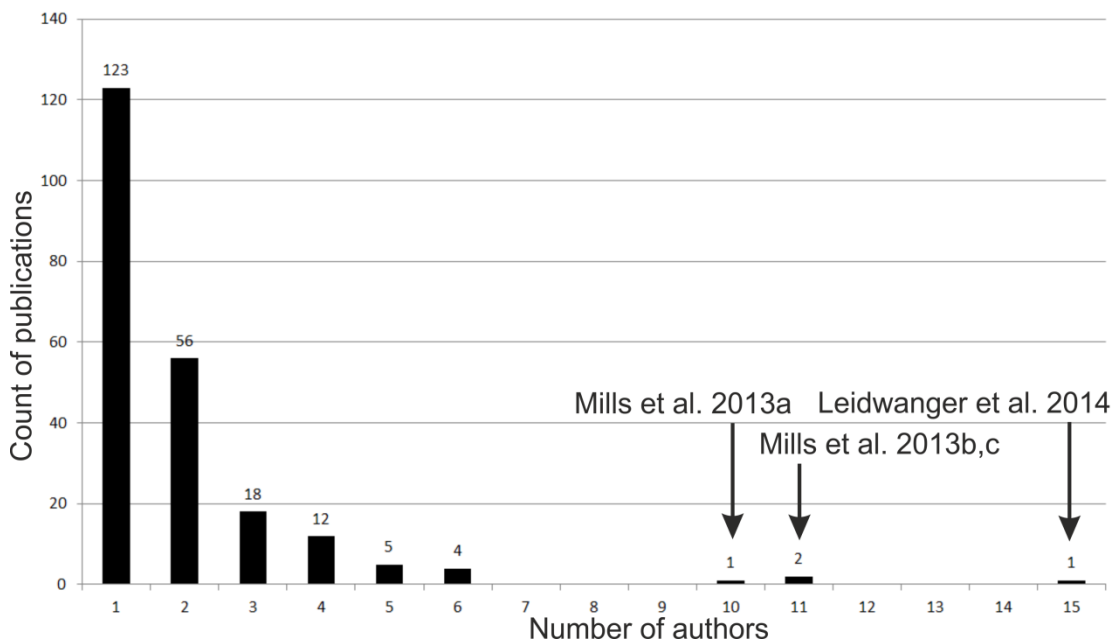

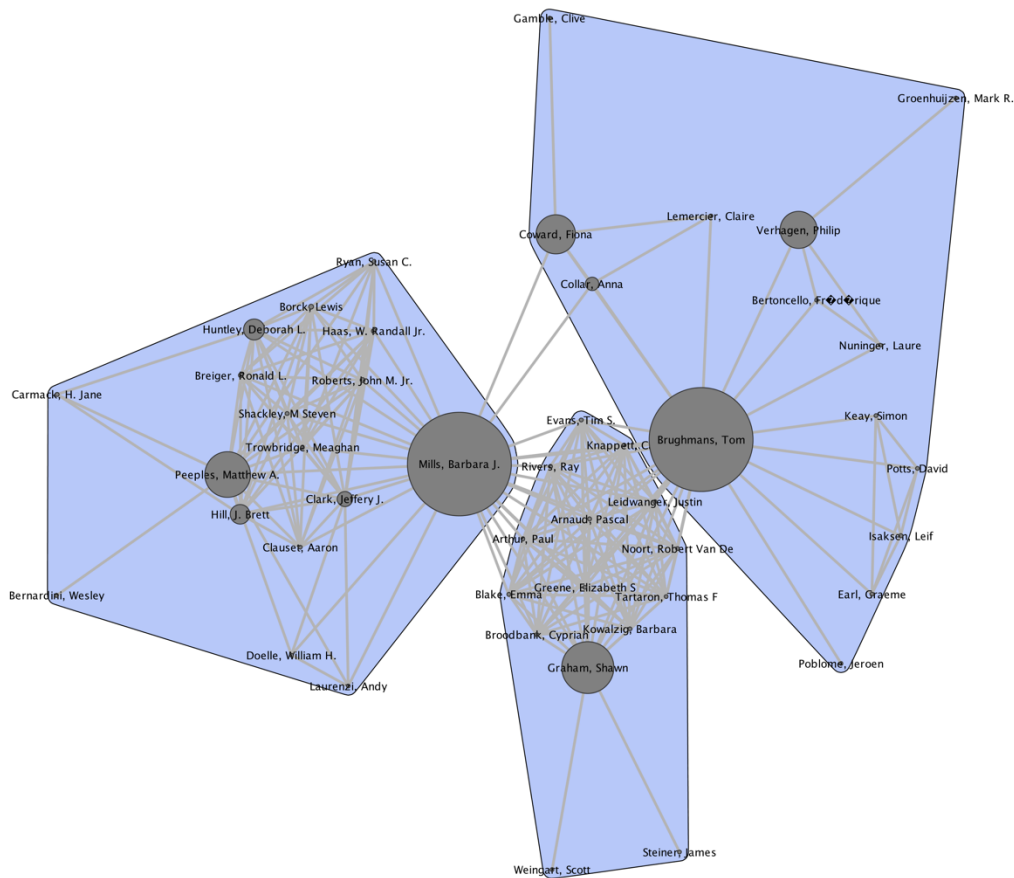**Figure 5.** Count of publications per number of authors (n=222).

Figure 4. Largest connected component of co-authorship networks shown in figure 5. Node size represents betweenness centrality; nodes grouped following Louvain clustering algorithm.

5   Gender

There are more than three times as many male authors than there are female authors in this corpus of published archaeological network research (Fig. 7a). This is largely a product of the high number of single authored papers by male authors (Fig. 7b). Overall, there are almost five times as many papers that are authored by exclusively male authors than papers with only female authors, and the number of both male and female authored papers is equally low (Fig. 7b, grey bars). This pattern of limited co-authorship between male and female authors as compared to exclusively male authored papers is still very much present when we exclude all single authored papers (Fig. 7b, black bars): co-authored papers are still almost twice as often exclusively male authored whilst exclusively female co-authored papers are extremely rare. Figure 8 breaks this pattern down as a chronological trend. Between 1965 and 2005, published archaeological network research was almost exclusively male-authored. From

2005 onwards the number of papers (co-)authored by female researchers increased slowly in both absolute numbers and as a proportion of all papers per year. In 2015 and 2016 the number of papers with at least one female author outnumber papers with exclusively male authors, although the latter still account for almost 50%. These trends generally reflect broader trends in archaeology in that the increasing gender parity among archaeological professionals is not yet mirrored by parity in publication patterns.
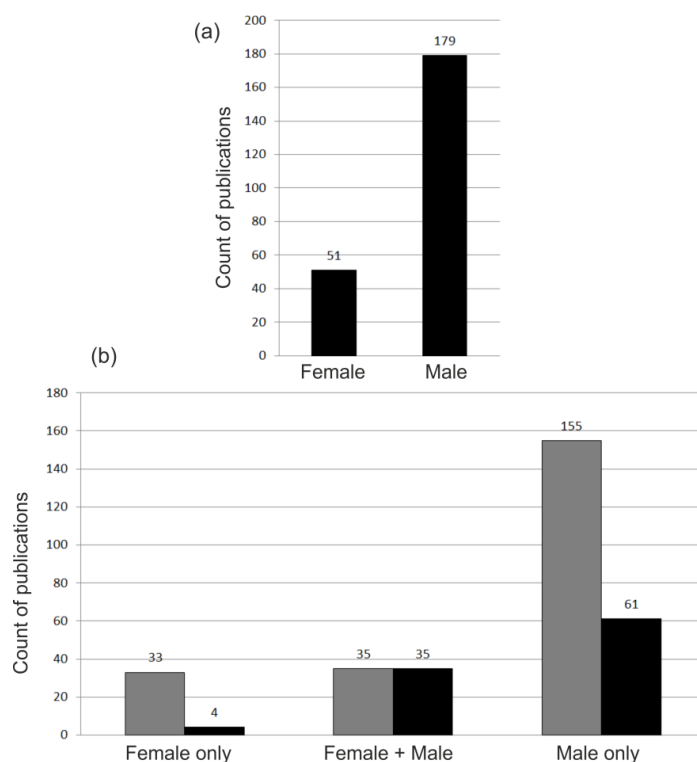

Figure 5. (a) Number of female and male authors in the corpus. (b) number of female only authored, mixed authored and male only authored papers in all papers (grey) and in multi-author papers only (black).

For example, in a recent critical assessment of gendered publication patterns in American archaeology, Bardolph compiled information from over 4,500 articles in 11 journals spanning the period from 1990 to 2013 and found that women accounted for 29% of published work in her sample.[22] In our corpus, women account for 22% of archaeological network publications in the complete sample going back to 1964 and 28% of publications since 1990 suggesting that

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22   Dana Bardolph, "A Critical Evaluation of Recent Gendered Publishing Trends in American Ar-chaeology," *American Antiquity* 79, no. 3 (2014): 522–40.

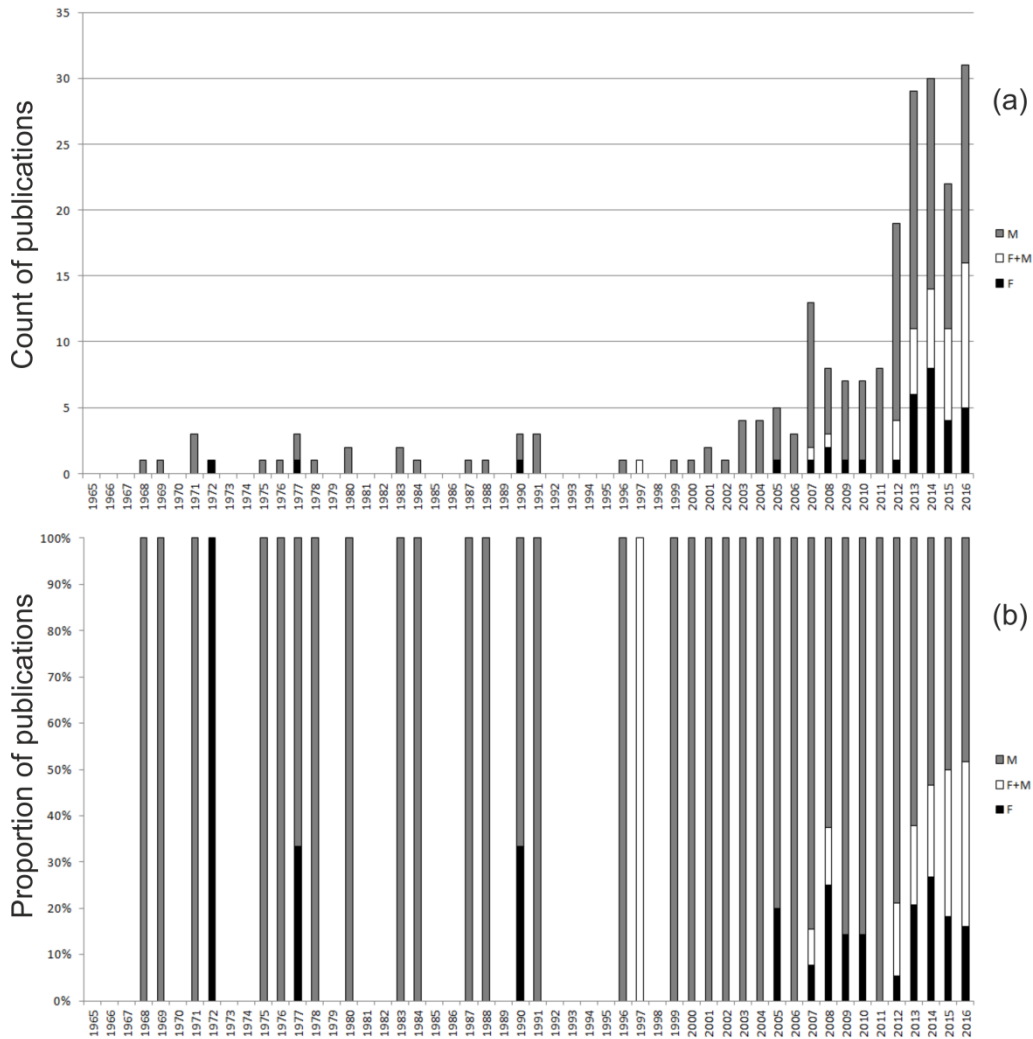gendered publication trends in archaeological networks closely mirror trends in at least American archaeology.

Figure 6. Count of male only, mixed and female only publications per year (a) and as a proportion of all publications each year (b).

6 Author-venue network

Finally, we explore the information discussed in the previous sections as a multi-modal network (Fig. 9). In this network, nodes represent both authors and publication venues and are color-coded by gender. Edges represent co-authorship for a pair of authors and publication by an author in a publication venue. This network allows us to expand our previous study of co-authorship

by highlighting further similarities between groups of authors in publication venues and gender.

This network is far less fragmented than the co-authorship network, consisting of 45 components as opposed to 101. This approach thus highlights similarities in the publication behavior of the authors in this corpus: very few researchers co-author their archaeological network work, but many publish in similar venues. Indeed, the largest connected component of the co-authorship network consisted of only 49 authors (Fig. 6), a mere 21% of all authors in the corpus. When we account for similarity based on publication venue the largest connected component shown in figure 10 includes 159 authors, or 69% of all authors in the corpus. This pattern can only in part be explained by the special issues and edited volumes dedicated to archaeological network research: the "Journal of Archaeological Science" and the "Journal of Anthropological Archaeology" are popular publication venues despite not having special issues on the topic. This result suggests that archaeological network practitioners might be a more tight-knit community than suggested by the co-authorship network and that publication in specific journals is a key feature of this community.

It is also interesting to note the relative prominence of female scholars in the largest connected component despite their numerical minority. The largest connected component includes 118 male and 41 female authors (Fig. 10). But the betweenness centrality ranking of this component reveals a particularly high score for a number of female authors (Table 4). We already discussed the prominence of Barbara Mills in the co-authorship network, which is reflected again in the current network. However, Jessica Munson has a particularly high betweenness score in this network because her work ties the papers and authors published in the "Journal of Anthropological Archaeology" and "PLOS ONE" into this largest connected component. A further difference between the author-journal network and the co-authorship network is the high betweenness score of Søren Sindbæk, who connects papers and authors published in the "European Journal of Archaeology". These betweenness scores of the latter two authors in particular reveal how their work crosses different academic communities: they contribute to the methodological debates on archaeological network research as revealed through their publications in an edited volume on the topic, but co-author their other archaeological network research with scholars and publish it in venues that are most relevant for the substantive archaeological side of their research. Whereas the betweenness scores of some authors like Barbara Mills and Tom Brughmans are driven largely by their active involvement in methodological discussions on archaeological network research, the score of other authors like Jessica Munson and Søren Sindbæk reflect their roles in widening and diversifying archaeological network research.
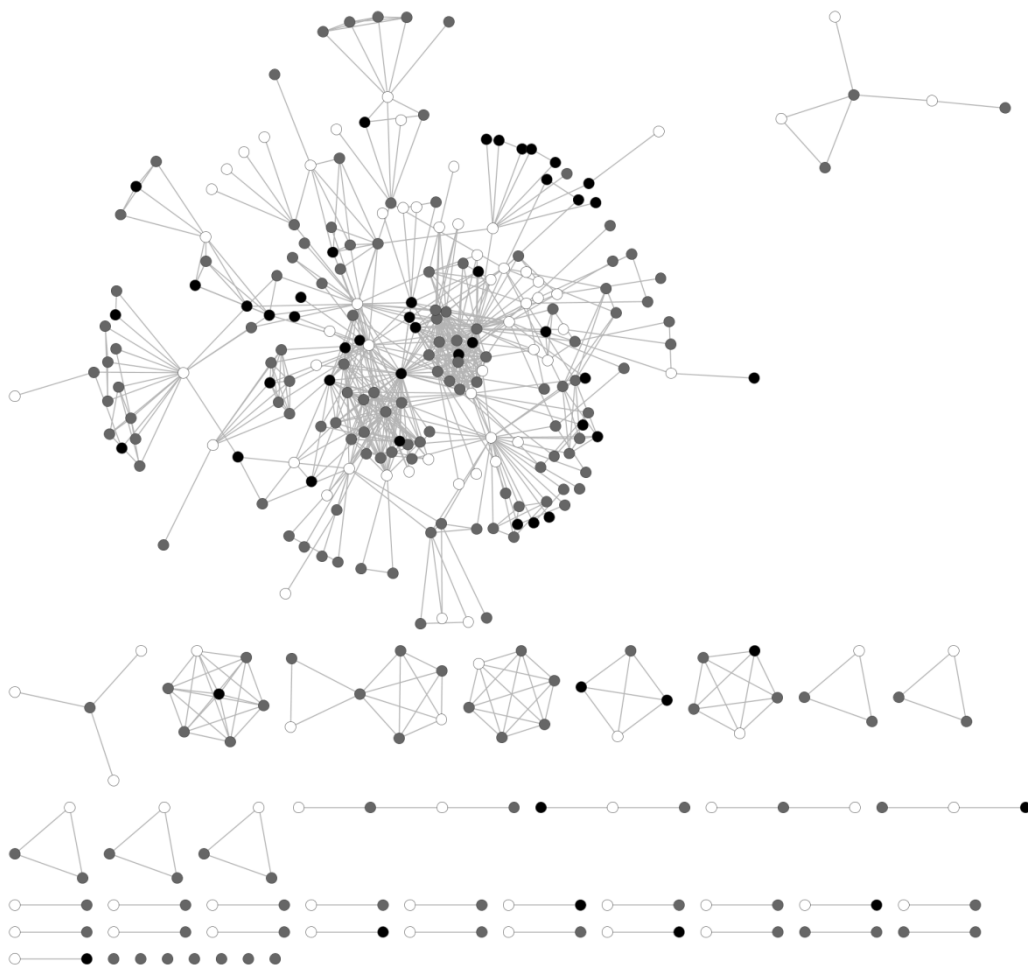
Figure 7. Author-venue network: nodes represent both authors (female = black; male = grey) and publication venues (white), edges represent both co-authorship of a pair of authors and publication by an author in a publication venue.
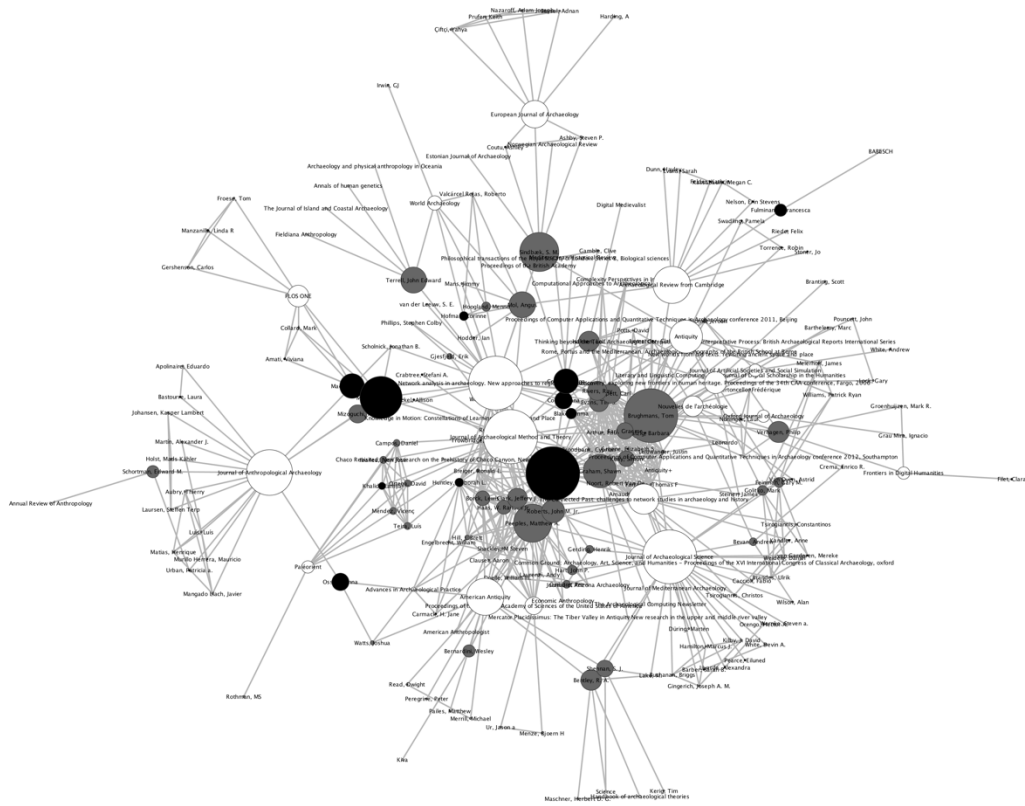
Figure 8. Largest connected component of the author-venue-gender network presented in figure 9. Node size represents betweenness centrality.

Table 4. The twenty highest ranked authors and publication venues according to betweenness centrality in the author-venue network shown in figure 10.

Ranking betweenness centrality author-venue network	
Ranking	Author or venue
1	Brughmans, Tom
2	Network analysis in archaeology. New approaches to regional interaction
3	Journal of Archaeological Method and Theory
4	Journal of Archaeological Science
5	Mills, Barbara J.
6	Journal of Anthropological Archaeology
7	Munson, Jessica L.
8	Sindbæk, S. M.
9	Peeples, Matthew A.
10	American Antiquity
11	Archaeological Review from Cambridge
12	Graham, Shawn
13	Antiquity
14	The Connected Past: challenges to network studies in archaeology and history
15	European Journal of Archaeology
16	Mol, Angus
17	Terrell, John Edward
18	Coward, Fiona
19	Macri, Martha J.
20	Roberts, John M. Jr.

7   Conclusion

Although network approaches in one form or another have a long history in archaeology, it is only recently that we can start to map the edges of this emerging sub-discipline. Archaeologists have long been ravenous consumers of methodological advances from other fields. Indeed, early applications of network and graph methods in archaeology largely came out of geography and mathematics, both fields that were influential in many areas of archaeological research in the mid-twentieth century. Since the early 2000s, the increasing prevalence of the interdisciplinary field of complexity science and work in physics and computer science has spurred on a new surge in archaeological network research. Advances in software and the increasing availability of large databases have certainly played a role in the current boom in archaeological

network research (and these explanations have often been invoked) but this review suggests that these were not the only factors.

Perhaps a sign of a maturing sub-discipline, we are also starting to see distinct traditions of network research emerge within archaeology. While research in the vein of complexity science remains popular, many researchers and teams are increasingly relying on models and methods from sociology and social network analyses to address both disciplinary questions but also to engage in broader debates in the social sciences using archaeological data. Although this direction is perhaps currently more common among North American network practitioners, we see some indications that such approaches are spreading throughout the field. In a young sub-discipline like this, we see such divergent approaches in a positive light as potential sources of innovation. Combining the efforts of archaeologists and historians will no doubt lead to further diversification and innovation.

The bibliometric study presented here paints a picture of a field driven forward by several different complementary processes. Indeed, much of the recent surge in archaeological network publications can be attributed to journal special issues and edited volumes, many of which have been published in widely read and highly cited venues. This suggests that archaeological network practitioners have captured the attention of the broader field. The co-authorship analysis further demonstrates that a small number of researchers and teams have dedicated substantial effort toward developing and applying network scientific approaches to archaeology, but there are also many researchers whose work involves only a minor network component. This brings to mind similar trends in applications of GIS in archaeology in the 1990s and early 2000s, we expect that increasingly network methods will become another "tool in the toolbox" for all archaeologists even as specialists continue to further develop the sub-discipline. Further, our exploration of gendered publication patterns reflects broader trends in archaeology: that is to say, despite increasing gender parity among archaeologists, gender parity in archaeological network publication practices has lagged. We argue that it is important to document such trends as the field moves forward and suggest that historical network practitioners might benefit from a similar study.

As we stated in our introduction archaeological and historical network applications have much in common and there is certainly much to be gained by connecting the trajectories of both fields. On the methodological side, archaeologists and historians are grappling with many of the same challenges in using fragmentary and partial textual and material data to reveal complex and nuanced patterns of interaction in the past. There has been considerable effort and numerous publications focused on the development of new methods and alteration of existing methods for different kinds of data in both fields. Beyond this, while in both archaeology and history, network methods and

models have primarily been applied to address important ongoing disciplinary debates, both fields also have the potential to provide new insights for network science in general. In particular the historical perspective provided by both fields could contribute to current areas of growth in network science including the exploration of dynamic networks, network evolution, and long-term drivers of social change.

As two practitioners of archaeological network science who have spent much of our recent research efforts on network topics, we argue that archaeologists and historians are natural partners and should work to coordinate in our efforts to expand into new areas of research. One major way to facilitate such coordination is the production of resources that will help us all stay abreast of developments in such a diverse field. A major step in this direction is the publication of the Historical Network Research bibliography.[23] The archaeological section was compiled by the authors for the bibliometric analyses presented above but this bibliography also contains references compiled by others for many areas of historical network research. Importantly, this resource has been placed online in an open source format as a Zotero group so that the entire community of archaeological and historical network practitioners can contribute to it. We invite you to explore the bibliography and join the collaborative groups. This bibliography will no doubt become an essential resources for the archaeological and historical network communities and further has the potential to expand the audience and reach for such research.

Archaeological and historical network approaches are at a similar stage of development. Both are young fields facing similar challenges for methodological advancement, disciplinary acceptance, and both are poised to make contributions to the broader realm of network research in general. We argue that archaeologists and historians alike interested in establishing network research as a key tool for exploring social change will have a greater chance for success to the extent that we actively collaborate, pool resources (like the HNR bibliography), engage in common community activities and publications (conferences, journal special issues, books), and learn from each other's mistakes. We hope this new journal spurs some of that conversation.

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