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*Research*

# Fisheries co-management in a digital age? An investigation of social media communications on the development of electronic monitoring for the Northeast U.S. groundfish fishery

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ABSTRACT. Fisheries regulators have increasingly incorporated video monitoring systems, also known as electronic monitoring, into programs for fisheries data collection and documentation of bycatch. Electronic monitoring has recently emerged as one potential solution for fisheries monitoring and catch accounting in the Northeast United States, where fisheries regulators will soon require all commercial groundfish trips to be monitored either by electronic monitoring or human observers. Fisheries managers, scientists, and industry stakeholders have cooperated to some extent to solve some of the logistical and technical hurdles of electronic monitoring through recent pilot projects and coordination meetings. Whereas prior research has assessed the outcomes of stakeholder interactions in traditional venues (e.g., fisheries council meetings, workshops), we interrogated the dynamic connections between stakeholders in discussions about electronic monitoring policies and initiatives in the social media environment. Using social network and content analysis, we examined electronic monitoring-related discourse among Northeast U.S. fisheries stakeholders on Twitter over a period of 2 years. This research represents the initial phase of a multi-year study on co-management aspects of decision-making in Northeast U.S. federally managed fisheries. Our initial findings revealed that environmental NGOs and federal science agency organizations drive the discourse on electronic monitoring, but information-sharing between environmental NGOs, government, and industry as a form of cooperation appears to take shape with some fishing industry and community organizations joining the conversation. These preliminary results suggest that cross-stakeholder communications are prevalent, but expanding discursive networks will be necessary in realizing diverse participation in cooperative fisheries projects, particularly those aimed at implementing new approaches to fisheries science and management, as in the case of electronic monitoring for the Northeast groundfish fishery.

Key Words: *co-management; electronic monitoring; fisheries; social media; social network analysis*

## INTRODUCTION

Many different stakeholder organizations across institutional domains are active in the pursuit of promoting sustainable and healthy fisheries and fishing communities. These stakeholders, representing views from academia, government, community non-profits, and industry, sometimes work collaboratively across institutional boundaries. For example, the National Marine Fisheries Service of the National Oceanic and Atmospheric Administration (NOAA) has entire divisions dedicated to facilitating cooperative research between commercial fishing businesses and government researchers to better assess fisheries resources and improve harvesting technologies. Some boundary-spanning organizations serve to broker relationships between other traditionally adversarial organizations. One research organization, the Gulf of Maine Research Institute, for instance, has convened government and industry organizations for multi-day workshops to reduce collaboration barriers (GMRI 2020). Although exemplary collaborations across institutional boundaries do occur, many stakeholder organizations do not work with one another and often are in opposition, promoting conflicting ideas and practices related to sustainable fisheries. Industry organizations may advocate for flexibility in restrictions in order to increase local seafood production as a goal to promote sustainability, whereas environmental non-profit organizations may be more concerned with regulatory compliance to reduce the incidental catch of non-target species or marine mammals.

In recent years, the issue of fisheries monitoring, particularly for the Northeast multispecies groundfish fishery, has emerged as a major concern for both fisheries managers and fishers in these stakeholder negotiations. Scientists and managers use monitoring data for scientific stock assessments and to ensure compliance, but fishers are expected to handle the administrative and, at times, the costs associated with monitoring programs implemented by the government. Since 1989, the NOAA Northeast Fisheries Science Center has managed the Northeast Fisheries Observer Program by training and deploying human observers on fishing vessels in multiple fisheries throughout the New England and Mid-Atlantic regions (NOAA Fisheries 2019a). Observers in the Northeast Fisheries Observer Program collect data on catch, gear, fishing effort, and biological information about species in order to inform scientific assessments of the health of fishery stocks and protected species.

In 2010, the New England Fisheries Management Council adopted Amendment 16 to the groundfish fishery management plan, which created new rules requiring human observers to become independent of the Northeast Fisheries Observer Program (NOAA 2010). This new initiative, known as the At-Sea Monitoring program, placed at-sea monitors to collect information on catch, both landings and discards (i.e., the portion of catch not retained and thrown back into the ocean for various reasons), and to verify areas fished by species and gear type for the purpose of monitoring groundfish sector Annual Catch

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Entitlements. Amendment 16 also left open the possibility of using electronic monitoring in place of human at-sea monitors, arguing that the "technology is deemed sufficient by the National Marine Fisheries Service for a specific gear type and area fished" (NOAA 2010). Electronic monitoring refers to the use of digital video cameras and data storage devices aboard commercial fishing vessels to collect information on areas fished and species caught (NOAA Fisheries 2017).

Since 2006, NOAA Fisheries has distributed more than US$27 million to support the development of electronic monitoring technologies, including at least 30 different pilot projects to test various equipment and address practical problems in implementation (NOAA Fisheries 2019b). Electronic monitoring testing and implementation has taken place in multiple fisheries across the country. In the Northeast region, NOAA Fisheries has partnered with commercial fishing industry organizations, environmental advocacy organizations, and electronic monitoring technical service providers to test multiple electronic monitoring pilot programs in groundfish and herring/mackerel fisheries (NOAA Fisheries 2018). These investments in electronic monitoring pilot programs dovetail with the development of Amendment 23, first proposed in 2017 to the fishery management plan, which would allow electronic monitoring to be used as an alternative monitoring and management tool (NEFMC 2020). Electronic monitoring efforts have generated enthusiasm among some, but not all, stakeholders in the commercial fishing industry about the possibility of improving catch data for scientific assessments while providing fishers with a cost-effective, flexible alternative to human observers (Mirarchi et al. 2015, NOAA Fisheries 2019b).

Electronic monitoring pilot programs are based on arguments that cooperative fisheries management can have practical utility for scientists and managers who are pursuing solutions to complex problems. However, the structure of cooperative arrangements, including the characteristics of how organizations interact with one another, are not well understood. While prior research has assessed the nature and outcomes of various stakeholder group interactions in fisheries management (Pomeroy and Berkes 1997, Lane and Stephenson 2000, Grafton 2005), few studies offer a systematic analysis of the social networks that exist between stakeholder organizations. Without this deeper knowledge, we suggest that the power dynamics that inform electronic monitoring development and implementation will remain poorly understood, with significant implications for how Amendment 23 may affect fisheries management as it moves to implementation in the 2022 fishing year.

Our research seeks to fill these gaps by interrogating connections between Northeast fisheries stakeholders engaged in discussions about electronic monitoring-related management initiatives (e.g., Amendment 23). We focus on stakeholder interactions pertaining to electronic monitoring as a tool for fisheries management as they have played out in social media interactions. We hypothesized that fisheries stakeholders demonstrate varying levels of engagement and interaction in the social media ecosystem, and that levels of interaction may correspond to their influence within broader networks of fisheries stakeholder organizations beyond social media. We further hypothesized that governmental and environmental advocacy organizations have substantial influence in these networks given their historical cooperative efforts.

To assess these interactions, we use social network analysis and qualitative content analysis to examine electronic monitoring-related posts from Twitter accounts associated with Northeast U. S. fisheries stakeholders over a period of 2 years. Social network analysis is an analytical method of researching networks of human relationships and connections by identifying patterns using statistical analysis of the structure of those networks (Hansen et al. 2011). These analyses can identify which fisheries organizations have the greatest influence on the conversation about electronic monitoring, how these organizations interact on the topic of electronic monitoring, and where echo chambers may exist among discussions about electronic monitoring between these organizations in a social media environment. We investigate three interrelated questions in our analysis: (1) What is the structure of the network(s) of interactions between stakeholder groups in a social media environment (i.e., fisheries industry organizations, academic and government institutions, and environmental advocacy organizations) on the topic of electronic monitoring? (2) Which stakeholder organizations emerge as influential network actors? and (3) What are the characteristics of these actors and their relationships to other organizations that help explain their positions within the network?

In this line of inquiry, we aim to understand how interactions between stakeholder organizations vary over time, as well as which significant events (i.e., public meetings, workshops, or other catalysts for interaction between stakeholders) explain cross-boundary collaboration, network formations, or expansions. In doing so, we explore whether and how co-management strategies have evolved with the emergence of the social media ecosystem and new opportunities for information sharing and social networking. We have found that a range of fisheries stakeholders are engaging in electronic monitoring-related Twitter debates at varying levels, and that these interactions point toward a genuine desire for co-management-oriented partnerships. However, we have also found significant gaps in who is represented in these discussions and on what topics.

While not fully reflective of how stakeholders interact across all venues, we argue that analyzing social media ecosystems offers an opportunity for rapid assessment of informal interactions in co-management decision-making environments. We conclude by suggesting how these findings can assist research on examining power dynamics beyond social media, and describe how we are using findings from this first phase of our research to inform additional research on Amendment 23 as it moves through the regulatory process toward implementation in 2022.

## BACKGROUND: FISHERIES CO-MANAGEMENT

In natural resource management, co-management is generally defined as a power-sharing approach to resource governance between government institutions and resource users, or stakeholders (Berkes et al. 1991, Carlsson and Berkes 2005). However, a number of alternative definitions and conceptual frameworks for co-management have been proposed over the past three decades. Some view co-management as the combination of decentralized decision-making at the local level with facets of state control (Pinkerton 1994, Singleton 1998). In this idealized model, the relative power of stakeholders falls on a continuum of greater or lesser control, emphasizing the strengths of each while minimizing their weaknesses. Others see co-management as emerging from a series of continuing interactions, from information sharing between resource users and managers to more formalized public–private partnerships (Pomeroy et al. 2001, Carlsson and Berkes 2005). The concept of co-management has also been received with some skepticism, with critiques often hinging on arguments about human nature. For instance, the dominant perspective of fisheries economists and policy-makers is one of rational choice, where people are assumed to be egoistic and relate to each other and to rules and regulations in an "instrumental, strategic, and cost-benefit manner" (Jentoft et al. 1998:425). For Northeast groundfish, specifically, the rational choice perspective has been used to explain some of the factors that contributed to the failure of the fishery to meet its co-management objectives, which included a lack of incentives for conservation behavior, a "top-down" approach to management, and a loose network of heterogeneous fishing operations without shared purpose (Acheson 2011).

Despite debates in the literature about the practical feasibility of co-management structures, many attempts have been made to implement co-management at various scales throughout the world, from artisanal fisheries in developing nations to large commercial fisheries in developed nations (Lane and Stephenson 2000, Hall-Arber 2005, Cinner and Huchery 2014, Alexander et al. 2015). A foundational principle for a co-management structure to be effective is the decentralization of decision-making powers and influence. In these orientations, delegation and devolution of authority are typically found in small-scale fisheries where Aboriginal or Indigenous peoples' local knowledge, rights, and claims to land are at stake, such as Canadian fisheries and wildlife agreements with Indigenous groups in northern Quebec (Pomeroy and Berkes 1997) or the information-sharing agreements between state officials and native Alaskan subsistence whalers (Meek 2013).

In the United States, opportunities for fisheries co-management are embedded within the legal frameworks of federal fisheries management but vary by region depending on social, economic, and cultural factors at the local level. The Magnuson-Stevens Fishery Conservation and Management Act of 1976 is the primary law covering the management of marine fisheries in federal waters in the United States (NOAA 2006). Among the most critical components of the law is that it establishes eight regional fisheries management councils to develop, implement, and revise fishery management plans. Part of the charge to councils for the handling of fishery management plans is to ensure stakeholder participation in fisheries management and to consider the social and economic needs of states in each region affected by federal fisheries management policies. Regional councils typically include individuals affiliated with the commercial and recreational fishing industry, and frequently those with experiences as actual commercial or recreational fishers. Additionally, regional councils have advisory panels—composed largely of industry stakeholders and resource users—on topics related to proposed rules or rule changes. Finally, councils provide opportunities for public comment and feedback at multiple points throughout the management process, including in regulatory scoping hearings and general council meetings. However, some industry stakeholders view the council process as not truly participatory and ultimately just another form of hierarchical management in practice (Hall-Arber 2005, Henry and Olson 2014).

Though criticisms of the council process abound, there are also instances where co-management, at least in a limited sense, has had noticeable impact on the outcomes of fisheries management policies. For example, Hall-Arber (2005) chronicled the development of Amendment 13 to the Northeast groundfish fishery management plan and found that industry stakeholder organizations played the key role of "policy entrepreneurs" by iterating on the design of groundfish stock rebuilding strategies in coordination with an "institutional leader," the director of the National Marine Fisheries Service at the time of the amendment's development. Perceptions of the fairness and inclusivity of the management process have also been bolstered by collaborative research and workshops between scientists and fishers. Jentoft et. al. (1998:434) observed that fishers "do not easily accept the command and control" style of management, and that collaborative efforts may help explain increased acceptance of management outcomes. Of note, industry stakeholders see outcomes in management as more credible when backed by collaborative research efforts (Hartley and Robertson 2009).

## METHODS

A sizable body of research in the social sciences addresses stakeholder interactions in commercial fisheries management. These studies tend to focus on organizational characteristics, behavior, and social capital (Pomeroy and Berkes 1997, Jentoft et al. 1998, Lane and Stephenson 2000, Grafton 2005). Other studies demonstrate the usefulness of social network analysis in understanding the structure of connections between fisheries management stakeholders and how it influences sustainable fisheries discourse (Mueller et al. 2008, Barnes-Mauthe et al. 2014, Stevens et al. 2015, Nenadovic and Epstein 2016). However, this literature historically relies on qualitative interviews and workshops (NOAA Fisheries 2020), self-report surveys (Henry and Olson 2014, Pollnac et al. 2015, Russell et al. 2018), and census data and NOAA Fisheries commercial fisheries databases (Jepson and Colburn 2013). This body of literature has yet to recognize social media ecosystems as an important data source, and as a result, may overlook potential pathways for interrogating cross-boundary communication and collaboration.

A considerable body of research also examines how groups use social media as tools for facilitating collective action (Obar et al. 2012, Jost et al. 2018), advancing dialogue (Lovejoy and Saxton 2012, Lovejoy et al. 2012, Saxton et al. 2015), and building epistemic communities (Greenberg and Macaulay 2009, Brown et al. 2017). Social media sites, such as Twitter and Facebook, have been found to be a primary source of news information for some demographics (Broersma and Graham 2013, Pennycook and Rand 2019). Academic and government science institutions have also increasingly turned to social media platforms for science communication (Claussen et al. 2013, Davies and Hara 2017). Recent evidence even suggests that U.S. federal science-based agencies increasingly use social media for information dissemination in lieu of direct interactions with stakeholders and the general public (Lee and VanDyke 2015). We suggest that social media can provide useful data for researchers to further examine interactions between individuals and groups who share common interests in fisheries management issues. We leverage social network analysis to offer a novel exploration of how co-management strategies emerge in this empirical space.

Our study began with preliminary investigations of the nature of interactions between fisheries regulators, scientists, advocacy organizations, and industry stakeholders in social media related to sustainability fisheries management in the Northeast region, which later evolved into a case study of interactions pertaining to the development and implementation of electronic monitoring technologies. To test our hypothesis that fisheries stakeholders demonstrate varying levels of engagement and interaction in the social media ecosystem, and that these shape influence within broader networks of fisheries stakeholder, we first used social network analysis. It is a method for interrogating the structural connections of relations between "nodes" (individuals, groups, institutions, etc.) and the network that emerges from such relations (Scott and Carrington 2011). This approach allows researchers to investigate outcomes that result from influences in networks, or alternatively, what kinds of networks result from important events. In all cases, social network analysis puts emphasis on interactions, as opposed to focusing only on the actors, individuals, or groups themselves. Social network analysis is generally used to examine two types of networks: directed and undirected. Our study focuses on directed networks in which all "edges" are tweet interactions between Twitter accounts, where interactions have a known source and a target. Each Twitter account is, thus, a "node" that interacts with other nodes through tweets, retweets, mentions, likes, and replies. When one node tags other nodes in a tweet, directed edges are established that go from the tweeter to the nodes that were tagged. Network structure is then determined by tracing the paths connecting the nodes.

The structure of a social network can be analyzed based node or edge characteristics. They form the basis of the statistics used to measure important aspects of network connectedness, such as degree centrality, betweenness centrality, and eigenvector centrality. Degree centrality simply represents the number of edges connected to a node, or the number of links one node has to other nodes. Betweenness centrality represents how well a node passes information through the network, or how much a node is in-between other nodes. It uses an algorithm that calculates the frequency of shortest paths between nodes, and each node is a given a score that reflects how many shortest paths pass through it to other nodes (Golbeck 2015). Eigenvector centrality represents how much influence nodes have over the network, or how connected nodes are to other highly connected nodes. It is determined for a given node by using a matrix calculation that takes into consideration the degree centrality of other nodes that are connected to the given node (Golbeck 2013, Hansen et al. 2011). The global network, meaning all edges and nodes within the data set, can be analyzed using these calculations. The network can also be subdivided into partitions of nodes or edges to analyze sub-groups, interactions between particular stakeholders, or interactions within discrete time periods.

Statistical analysis was conducted using Gephi social network analysis software tools for each 1-month period of the data set, which resulted in 36 different time-dependent sub-networks. The network was further partitioned to show only interactions between nodes belonging to each primary stakeholder category. New sub-networks were then constructed, representing all two-stakeholder combinations (i.e., only government and individual nodes, or only environmental non-government organization and media). Networks with high average degrees and those with high centralities were then identified for additional analysis. Social network analysis can also identify "echo chambers" within a network. This is evidenced by a group of highly connected nodes organized around a particular topic that have no edges connecting them to other groups. One can also find "broadcast" accounts that post information but do not engage in two-way conversations. These anomalies can be equally important as finding a well-connected network. Identifying isolated groups and broadcast-only accounts may reveal opportunities for future interventions by bringing together disconnected stakeholders and conversations. Twitter was selected as the platform of choice for practical reasons. Social network analysis software tools used to sample social media data have limited access to Facebook's application programming interface due to restrictions imposed on third-party platforms by Facebook in the wake of the Cambridge Analytica data breach in 2018 (Facebook 2018).

In addition to analyzing the structure of interactions using social network analysis, we also used qualitative content analysis to examine the content of the discourse between Northeast fisheries organizations on the topic of electronic monitoring in the social media environment. We used this additional layer of analysis to characterize what topics were of primary and secondary importance within stakeholder interactions, and to identify dissonances in the priorities expressed by different stakeholder groups. To accomplish this, the full data set of Twitter activity was imported into MAXQDA text analysis software. The text of tweets was qualitatively analyzed and systematically coded for emergent and recurrent keywords, topics, and concepts related to the discourse on electronic monitoring technologies, monitoring, and fisheries co-management. Qualitative coding of tweet content in MAXQDA used grounded theory, a method that allows for themes to emerge from the data (Charmaz 2006). Qualitative coding was conducted in three passes in order to construct a hierarchy of keywords, topics, and concepts. Two members of the research team independently coded segments of the qualitative content, and the full research team reviewed the coding structure to ensure that codes had face validity and were applied consistently, and that there was a consensual interpretation of the qualitative content contained within the tweets.

## RESULTS

Data collection began by identifying 113 stakeholder organizations that were prominent in debates about fisheries management, science, and sustainability, or were major players in the region's seafood industry. Sample selection was informed largely by the direct knowledge of the primary investigator's familiarity with groundfish management actions over the last decade. Stakeholders were then categorized into eight primary types based on their stated affiliation in Twitter account bios. Secondary affiliations indicated if they were employed by other stakeholders. For instance, Brett Alger has an individual account (@lgerbrett) but is the NOAA Fisheries National Electronic Technologies Coordinator. The primary stakeholder categories were defined as follows:

- Academic (ACAD): colleges and universities (and associated labs or centers) or not-for-profit think tanks and scientific research institutes
- Community non-profit organization (CNPO): not-for-profit organizations promoting or supporting local seafood

consumption and/or the well-being of coastal and fishing communities

- Environmental non-governmental organization (ENGO): non-governmental organizations that focus on environmental issues (typically but not strictly not-for-profit)
- Fishing industry (FI): commercial fishing industry organizations and organizations representing commercial fishing business interests
- Government (GOV): federal or state government agencies or affiliated programs
- Individual (IND): nodes with no stated affiliation to an organization; these were assigned secondary affiliations if additional information could be found
- Media (MED): news media, trade journals, and specialty magazines
- Tech industry (TI): companies in the electronic monitoring device industry, satellites, or other technology support services for the industry or government

An initial scrape of Twitter data was conducted 3 January 2020, using NodeXL software tools. Data collection captured tweets, retweets, mentions, likes, and replies associated with our initial 113 stakeholder organizations. The resulting global network spanned a timeline of November 2008 to January 2020. This data set was then limited to 12 January 2017 to 27 December 2019 based on the subset of Twitter data that contained conversations related to electronic monitoring activities and Amendment 23 in the Northeast United States. This final data set accounted for the activities of 210 stakeholders across the eight primary stakeholder categories (Table 1). Of the 84 individuals (IND), 54 were found to have secondary affiliations.

**Table 1.** Stakeholders by primary affiliation category.

| Primary stakeholder categories | Sum |
|---|---|
| Academic (ACAD) | 19 |
| Community non-profit organization (CNPO) | 8 |
| Environmental non-governmental organization (ENGO) | 22 |
| Fishing industry (FI) | 14 |
| Government (GOV) | 27 |
| Individual (IND) | 84 |
| Media (MED) | 15 |
| Tech industry (TI) | 21 |
| Total | 210 |

**Social network analysis**

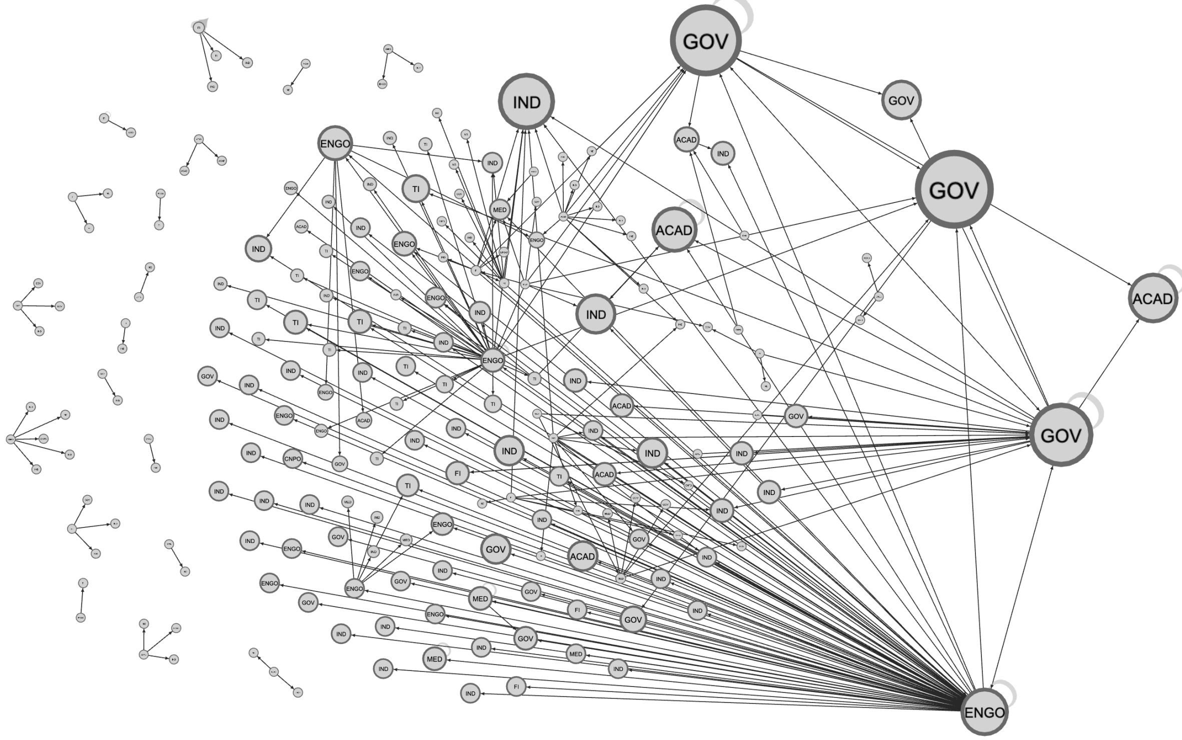
Our analysis resulted in a global network consisting of 210 nodes (Twitter accounts of fisheries stakeholder organizations) connected by 281 edges (interactions between these accounts) pertaining to tweets that discussed electronic monitoring in the Northeast United States from January 2017 to December 2019 (Fig. 1). We first analyzed the global network according to the eight primary stakeholder categories (Table 1). This allowed us to assess which stakeholders were interacting with each other (within their respective categories), as well as interacting across stakeholder categories. Overall, we discovered 47 interactions limited to within a single stakeholder category versus 234 interactions across stakeholder boundaries. This was an early signifier that cross-category interactions were widely present across the network. Only the top seven nodes had eigenvector centralities greater than 0.5, which suggested that there were a few highly connected fisheries stakeholder organizations on Twitter. However, the average betweenness centrality (14.595) and average eigenvector centrality (0.108) of the global network indicated that these fisheries stakeholder organizations had limited influence over their respective networks.

Government and environmental NGO Twitter accounts made up more than 50% of the top 10 accounts across multiple statistics from 2017 to 2019. The top environmental NGO was EM4fish, a "knowledge base and community of practice" supported by the Environmental Defense Fund, Kingfisher Foundation, National Fish and Wildlife Foundation, and Net Gains Alliance (EM4Fish 2020). EM4fish had the highest betweenness centrality (1381.767) of all nodes in the network, indicating it was the most highly connected fisheries stakeholder organization. EM4fish had the seventh highest eigenvector centrality (0.560) as well, and was the most influential environmental NGO according to these statistics. The Seafood and Fisheries Emerging Technology Conference (SAFET) and the National Fish and Wildlife Foundation were the next most dominant environmental NGOs across statistics. SAFET was the third most connected stakeholder organization, with a betweenness centrality of 370.35, while the National Fish and Wildlife Foundation was the 10th most influential, with an eigenvector centrality of 0.378. Other environmental NGOs in the top 20 organizations across statistics included Nature Conservancy, Pew Environment, and Ecotrust Canada. These are all large environmental non-profit organizations that cover a wide range of issues beyond those pertaining to electronic monitoring or Amendment 23.

A subset of government nodes also dominated across multiple statistics. Three nodes were most common: NOAA Greater Atlantic Region Fisheries Office, NOAA Northeast Fisheries Science Center, and NOAA Fisheries. All three are operated by NOAA offices, and two are specific to the Northeast region. The NOAA Greater Atlantic Region Fisheries Office and NOAA Northeast Fisheries Science Center had the second and fourth highest betweenness centrality, with scores of 943.283 and 147, respectively, suggesting high connectivity across the global network. The four highest influences on the network were all government organizations as well. NOAA Fisheries had an eigenvector centrality of 1, meaning that NOAA Fisheries was connected to all other highly connected organizations in the network, followed by the NOAA Greater Atlantic Region Fisheries Office (0.899) and the NOAA Northeast Fisheries Science Center (0.789). An individual personal Twitter account (*lgerbrett*) with a secondary affiliation to a government organization (NOAA) had the fourth highest eigenvector centrality (0.59), which illustrates how personal accounts of federal employees can amplify government-related Twitter activity.

Our analysis then turned to identifying the prevalence of interactions among 28 pairings of primary fisheries stakeholder categories (Table 1) as a measure of engagement across stakeholder boundaries (Fig. 2). Six paired networks had more

**Fig. 1**. The global network of 210 nodes (stakeholders) connected by 281 edges (interactions) (ACAD: academic; GOV: government; ENGO: environmental non-governmental organization; IND: individual; MED: media; TI: tech industry; FI: fishing industry; CNPO: community non-profit organization).



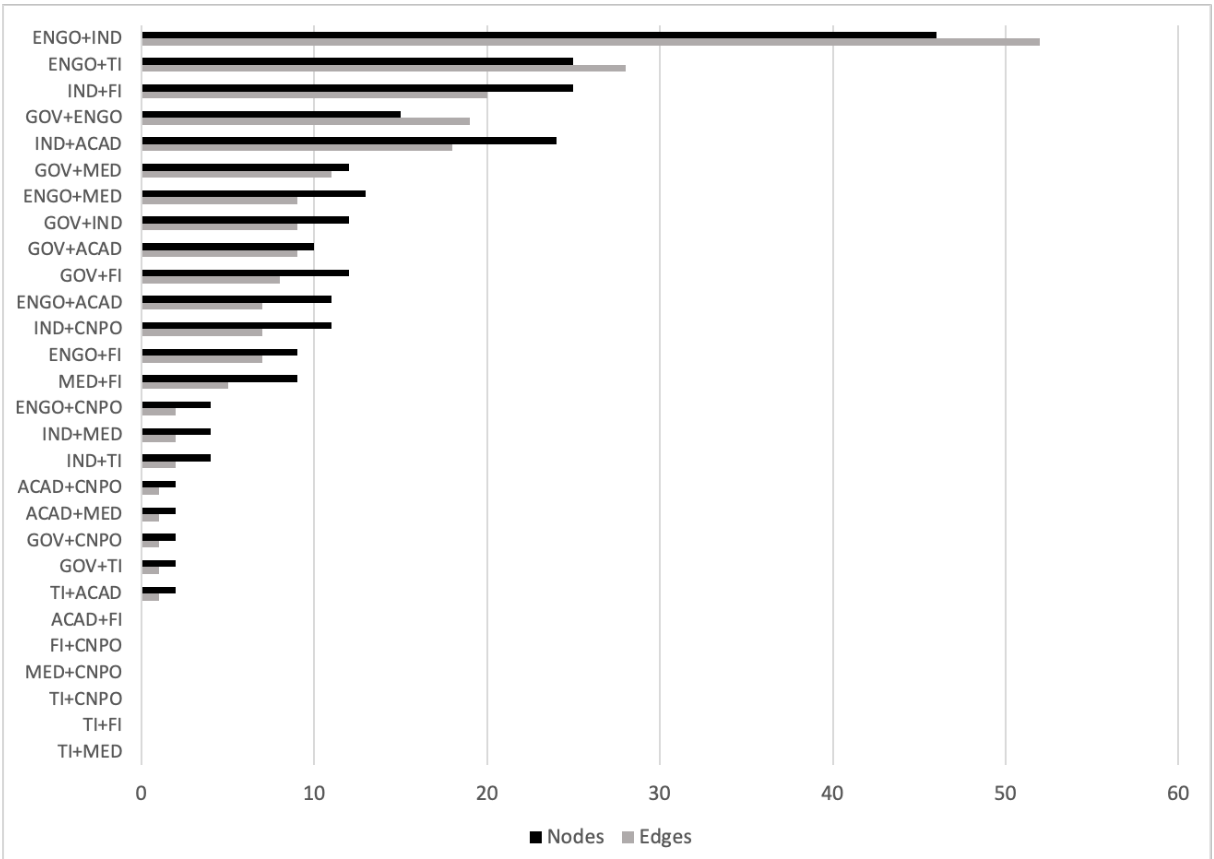

than 10 cross-boundary interactions between organizations over the 2-year period. At the highest level of connectivity, there were 52 interactions between environmental NGOs and individual personal accounts, which accounted for 15.8% of total interactions in the global network (including communications between stakeholders of similar category). The second-most connected cross-boundary pairing was between environmental NGOs and tech industry organizations, with 28 interactions (9.95%). Four paired networks had between 10 and 20 edges: individual personal accounts and fishing industry organizations (20, 7%), government and environmental NGOs (19, 6.7%), individual personal accounts and academic organizations (18, 6%), and government and media organizations (11, 3.9%). These findings suggest that while government and environmental NGO stakeholders were the most connected organizations in the global network, government organizations did not have an equivalent share of cross-boundary interactions to environmental NGOs. Additionally, neither government nor environmental NGOs had particularly high cross-boundary interactions with fishing industry organizations.

The most active paired network during the 2017–2019 time frame was between environmental NGOs and individual personal accounts. Accounting for interactions both within and between these two stakeholder categories, we found 106 accounts with 82 interactions between them. Among these, 52 consisted of bridged interactions between environmental NGOs and individual personal accounts, as noted. EM4Fish was the central environmental NGO in this network, with a betweenness centrality of 92.667, and was involved in 37 of the 52 interactions with other stakeholder categories.

Environmental NGOs also had the most interactions across all paired networks, which were primarily with individual personal accounts, government, tech industry, and media organizations. Environmental NGOs were connected most strongly with tech industry (28 edges) and media (23 edges). In the 2-year period, environmental NGOs had only two interactions with community non-profit organizations on the topic of electronic monitoring. Our analysis showed that EM4fish, SAFET, and Nature Conservancy were significantly engaged with multiple stakeholder groups across these networks. EM4fish and SAFET had the first or second highest betweenness centralities and eigenvector centralities in all environmental NGO paired networks. This indicates that these organizations are well connected and have influence with multiple stakeholder groups.

As noted, government accounts had far fewer interactions across stakeholder partitions than did environmental NGOs. The most active government-paired network consisted of government and media accounts, represented by 11 interactions between organizations of different stakeholder category affiliations. NOAA Fisheries accounts were the most active and connected government accounts across all paired networks. Government

**Fig. 2.** Number of nodes and edges in 28 stakeholder category paired networks.




accounts consistently had the same level of interaction between 2017 and 2019 with fishing industry organizations (8 edges), academic organizations (9 edges), and individual personal accounts (9 edges). Saving Seafood was the media organization that was most connected with government accounts, with a betweenness centrality of 4 and an eigenvector centrality of 0.04. Among fishing industry organizations, Seafood Harvesters of America had the highest betweenness centrality (1), and the Commercial Marine Expo had the highest eigenvector centrality (0.289). Seafood Harvesters of America had an eigenvector centrality of 0.020.

Two individual accounts had the highest betweenness centralities and eigenvector centralities in the paired network of government and individual personal accounts: *20secs0fcourage*, with a government secondary affiliation, and *AaronOrlowski*, with a media secondary affiliation. The one interaction between government and community non-profit organizations was from the Port of New Bedford, a local port government, to Fishing Partnership, a New England-based fishing support services group. The Port of New Bedford, along with Northeast Ocean Data, a data portal website developed and maintained by several Northeast states' natural resource management agencies, were in the top 10 statistics within the government partitioned network but had low statistics with other paired networks, indicating they interacted primarily with other government organizations rather than across stakeholder groups.

**Tweet content analysis**

Topics and concepts arrived at through systematic coding of qualitative content were organized into common thematic categories and cross-tabulated by the primary stakeholder group categories. Our analysis of the textual contents within tweets revealed important insights into why interactions between stakeholders arose and what type of information had been shared by whom and with whom. Systematic coding in multiple passes to identify key themes resulted in a wide array of topics and concepts spanning the broad thematic areas of fisheries management, social values, science and technology, and several other topical subjects relevant to fisheries monitoring.

For the purpose of communicating our findings, we condensed codes into 12 major thematic categories. For example, the "monitoring" thematic category was composed of codes such as at-sea monitoring, observers, electronic monitoring, and other coded content that related to the monitoring of fisheries. In addition to the topic of monitoring, major themes emerged related to futures, communication, co-management, and appropriate technology, among others (Table 2). Within these themes, "futures" included mention of emerging technologies, improved data collection for future scientific assessments, data modernization, hope or optimism, and progress in general.

**Table 2.** Thematic categories of coded tweets by primary stakeholder group affiliation.†

| | ACAD (%) | GOV (%) | ENGO (%) | IND (%) | MED (%) | TI (%) | FI (%) | CNPO (%) | Total (%) |
|---|---|---|---|---|---|---|---|---|---|
| Co-management | 19.2 | 14.1 | 8.4 | 10.8 | 11.3 | 12.0 | 14.8 | 18.2 | 11.7 |
| Environmental justice | 5.5 | 11.8 | 3.0 | 2.7 | 5.7 | 0.0 | 7.8 | 22.7 | 5.5 |
| Scientific knowledge gaps | 6.8 | 3.5 | 2.2 | 0.0 | 3.8 | 0.0 | 3.5 | 0.0 | 2.8 |
| Appropriate tech | 6.8 | 7.1 | 11.9 | 16.2 | 13.2 | 8.0 | 10.4 | 9.1 | 10.8 |
| Resilience | 4.1 | 7.1 | 4.1 | 5.4 | 5.7 | 0.0 | 6.1 | 13.6 | 5.0 |
| Values | 2.7 | 2.4 | 2.4 | 5.4 | 3.8 | 0.0 | 4.3 | 9.1 | 3.1 |
| Futures | 8.2 | 4.7 | 21.1 | 8.1 | 7.5 | 16.0 | 8.7 | 4.5 | 14.1 |
| Cost/funding | 2.7 | 3.5 | 5.1 | 10.8 | 11.3 | 8.0 | 8.7 | 0.0 | 5.9 |
| Communication | 17.8 | 24.7 | 11.9 | 8.1 | 7.5 | 20.0 | 13.9 | 18.2 | 14.1 |
| Monitoring | 17.8 | 15.3 | 22.4 | 18.9 | 22.6 | 20.0 | 12.2 | 0.0 | 18.8 |
| Trust/credibility | 2.7 | 1.2 | 1.4 | 10.8 | 5.7 | 4.0 | 4.3 | 0.0 | 2.7 |
| Expertise/situated knowledge | 5.5 | 4.7 | 6.2 | 2.7 | 1.9 | 12.0 | 5.2 | 4.5 | 5.5 |
| SUM‡ | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| *N* = segments | 73 | 85 | 370 | 37 | 53 | 25 | 115 | 22 | 780 |

†ACAD: academic; GOV: government; ENGO: environmental non-governmental organization; IND: individual; MED: media; TI: tech industry; FI: fishing industry; CNPO: community non-profit organization
‡Column percentages based on the sum of coded segments

"Communication" included sharing of news articles that covered monitoring technologies and pilot projects, networking via conferences and stakeholder-organized events, and other stories or articles on electronic monitoring, artificial intelligence, or other monitoring technologies. "Co-management" included mention of collaboration on research projects and participation in management by stakeholders, and cooperation in general between parties across institutional boundaries. And "appropriate technology" included mention of issues related to data quality, safety, and challenges associated with electronic monitoring, as well as demonstrating fishers as stewards and the potential positive outcomes for the industry from technological innovations.

Other themes identified included environmental justice, scientific knowledge gaps, resilience, values, cost and funding, monitoring, trust and credibility, and expertise or situated knowledge. The theme of environmental justice referred to mention of disproportionate impacts of rules and regulations on marginalized communities but also included references to procedural justice (i.e., who gets a seat at the table of fisheries management) and distributive justice (e.g., rights to fish, access to fisheries). References to scientific knowledge gaps included uncertainties in stock assessments related to insufficient data or poor data quality. The theme of resilience identified references to environmental, economic, and social sustainability of the social ecological systems of fisheries, including mentions of stewardship, respect for the ocean, and support for fishing communities. Thematic content related to values included any display of values (social and/or environmental) through opinions, interest, or argumentation in favor of or opposed to electronic monitoring or monitoring in general. Cost/funding referred to any mention of the costs to industry associated with electronic monitoring, or the availability of government funding to offset costs of electronic monitoring to the industry. Monitoring is a general thematic category that captured any specific mention of fisheries monitoring, be it electronic monitoring or human observers. The thematic category of trust and credibility referred to mentions of trust or lack of trust in people, entities, and technology, or about gaining or maintaining trust in relationships between organizations and fishermen, including credibility, transparency, and accountability in achieving or hindering trust-building work. Finally, themes related to expertise and situated knowledge referred to mentions of respect (or lack thereof) for various forms of expertise or situated knowledge, including fishermen's experience. Table 2 shows the percentage of segments of Twitter content by each stakeholder group that were coded with concepts or terminology related to each of the broad thematic categories.

Our findings revealed significant differences in what stakeholders from different groups prioritized in their Twitter communications. Environmental NGOs and tech industry organizations most often engaged in discussions about futures, whereas academic, community non-profits, fishing industry organizations, and government agencies more often engaged in interactions related to co-management. Much of the discussion related to futures included hopeful or optimistic statements about the future of fisheries science and management based on developments in electronic monitoring and artificial intelligence technologies. For instance, one of the most well-connected environmental NGOs, EM4Fish, often shared or retweeted news and information from other environmental NGOS or government accounts that touted the successes of electronic monitoring pilot programs and the potential that electronic monitoring holds for improving outcomes in fisheries sustainability. Surprisingly, environmental NGOs were the least likely to engage in discussions that mentioned co-management, whereas academic organizations and community non-profits were the most likely. In the case of community non-profits, in particular, co-management discussions appeared tightly linked to environmental justice concerns, especially in light of industry consolidation and the accountability of larger, vertically integrated industry stakeholders. Government and tech industry organizations most often included some aspect of communication in their Twitter activity, which reinforced our social network analysis findings that suggested that these accounts served primarily a broadcast function to relay information to stakeholders.

Thematic categories were additionally analyzed for their co-occurrence in order to understand to what extent, and why, concepts arose in conjunction with one another (Table 3). The

**Table 3.** Frequencies of co-occurrence between thematic categories in coded tweets.

| | Co-mgmt | Env justice | Scientific know gaps | App tech | Resilience | Values | Futures | Cost/ funding | Comm | Monitoring | Trust/ credibility | Expertise/ situated know |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Co-management | 0 | 21 | 12 | 25 | 16 | 11 | 38 | 14 | 51 | 83 | 5 | 33 |
| Environmental justice | 21 | 0 | 1 | 9 | 11 | 7 | 7 | 10 | 14 | 19 | 3 | 5 |
| Scientific knowledge gaps | 12 | 1 | 0 | 4 | 4 | 2 | 8 | 4 | 9 | 14 | 1 | 3 |
| Appropriate tech | 25 | 9 | 4 | 0 | 10 | 13 | 68 | 16 | 23 | 95 | 8 | 2 |
| Resilience | 16 | 11 | 4 | 10 | 0 | 8 | 13 | 8 | 14 | 22 | 1 | 6 |
| Values | 11 | 7 | 2 | 13 | 8 | 0 | 5 | 2 | 8 | 12 | 8 | 2 |
| Futures | 38 | 7 | 8 | 68 | 13 | 5 | 0 | 11 | 60 | 163 | 7 | 11 |
| Cost/funding | 14 | 10 | 4 | 16 | 8 | 2 | 11 | 0 | 9 | 45 | 7 | 6 |
| Communication | 51 | 14 | 9 | 23 | 14 | 8 | 60 | 9 | 0 | 76 | 6 | 31 |
| Monitoring | 83 | 19 | 14 | 95 | 22 | 12 | 163 | 45 | 76 | 0 | 12 | 32 |
| Trust/credibility | 5 | 3 | 1 | 8 | 1 | 8 | 7 | 7 | 6 | 12 | 0 | 1 |
| Expertise/situated knowledge | 33 | 5 | 3 | 2 | 6 | 2 | 11 | 6 | 31 | 32 | 1 | 0 |

highest levels of co-occurrence were found at the intersection of codes related to monitoring/co-management, monitoring/futures, and monitoring/appropriate technology. Additionally, futures/appropriate technology, monitoring/communication, and communication/co-management also had relatively high rates of co-occurrence compared to other thematic areas. Our findings suggest that the dialogue between scientists, managers, and stakeholders in the social media space regarding fisheries monitoring focuses largely on why it will be beneficial to move toward electronic monitoring for the future of fisheries monitoring, but on the other hand, includes substantial emphasis on the need for meaningful participation of diverse stakeholders in the process.

Perhaps as revealing as the highest occurring and co-occurring themes within stakeholder Twitter interactions were the thematic categories that did not appear as frequently. In particular, scientific knowledge gaps, expertise or situated knowledge, and trust or credibility were among the least common themes. These themes implicate critical issues related to fisheries monitoring and data collection for scientists, managers, and stakeholders alike, such as how to address scientific knowledge gaps and recognize and produce solutions that account for tacit knowledge within the fishing industry, and the importance of trust in forming effective partnerships.

## DISCUSSION

Analysis of Twitter behavior from January 2017 to December 2019 on electronic monitoring-related topics in the Northeast United States suggests the dominance of a small set of stakeholders. Environmental NGOs and government agencies were found to drive most interactions within the global network, through both their primary and secondary affiliation activities. Content analysis revealed that these groups drive a discourse that focuses primarily on hope and optimism for the future of fisheries sustainability based on the innovation of new management technologies in the Northeast region, specifically for the commercial groundfish fishery. However, participation in electronic monitoring-related conversations on Twitter also grew substantially across this timeline, with new Twitter accounts joining the conversation in 22 of the 24 months in our study. This growth may indicate that stakeholders are finding new reasons to engage in electronic monitoring-related debates as Amendment 23's approval looms, where Twitter is one representation of this trend.

NOAA Fisheries, as represented by the NOAA Greater Atlantic Region Fisheries Office and NOAA Northeast Fisheries Science Center, showed evidence of having significant influence in the global network. Despite the prominence of government organizations in the global network, paired network analysis revealed that government organizations interacted mainly with other government organizations, frequently with environmental NGOs, and infrequently with other stakeholder groups. The second most active government pairing was with media. Government interactions involved primarily sharing, or broadcasting, information by tagging tweets initiated by other stakeholders. This was underscored by the content analysis, which revealed that communication was the most common theme featured in government interactions. Information sharing, a prominent theme in government interactions in particular, also indicates the presence of activities identified in the co-management literature as a first step in a process that can later lead to more intentional cooperative partnerships (Carlsson and Berkes 2005).

Among environmental NGOs, EM4fish emerged as one of the most influential actors across all paired networks. This organization describes itself as a collective space for driving change in fisheries management by promoting emerging technologies (EM4Fish 2020). EM4fish is also composed of many influential individuals, such as NOAA Fisheries program coordinators, commercial fishing industry representatives, electronic monitoring technology industry executives, and representatives from multiple environmental NGOs. This highlights an unexpected finding in our study—the prevalence of individuals acting through private Twitter accounts—which suggests that communication and collaboration is unfolding through individual-level network interactions as much as, if not more often than, organizational-level interactions. As Hall-Arber (2005) observed, a small set of influential policy entrepreneurs across institutional and organizational boundaries can substantially alter the course of fishery management decisions. Similar patterns are emerging among electronic monitoring stakeholders, which may influence the outcome of electronic monitoring technology implementations.

We also sought to identify marginalized actors and discourses within electronic monitoring-related Twitter networks. We found a striking lack of interaction between the fishing industry and electronic monitoring technology providers. This reveals a critical gap between two stakeholder groups who perhaps are most in need of careful coordination given the logistical and economic challenges associated with moving the industry toward new business models. Also, the overall electronic monitoring discourse between all stakeholder groups was relatively devoid of what the researchers felt are important topics, such as addressing gaps in scientific knowledge for stock assessments, accounting for situated knowledge within the fishing industry, and building trust and credibility among stakeholders, scientists, and managers. These interrelated issues will prove fundamental to robust co-management partnerships. Environmental NGOs and government organizations, which have the largest influence within this social media network environment, should consider how trust and credibility with stakeholders can be achieved, in part, through the use of situated knowledge to help improve fisheries science for management purposes.

## CONCLUSION

The purpose of this study was to understand the structure and content of interactions among Northeast fisheries stakeholders engaged in a social media network discourse on the future of fisheries monitoring. There are notable limitations associated with social media network and content analysis, primarily that many important stakeholders (i.e., fishers themselves) may not have an online or social media presence and are therefore absent from our sample and analysis. This could have implications for our findings such that the perspectives of fishers may not be well represented in social media data and could be underrepresented in our analysis. While we recognize that our findings are likely not indicative of interactions across all spaces digital and physical, we do suggest that our examinations of social media and its importance in shaping fisheries discourse is novel and presents a meaningful structure for examining how stakeholder engagements in electronic monitoring development are unfolding in the Northeast United States.

Despite the dominance of a subset of actors, minimal connections between certain groups, the prevalence of broadcasting-type behaviors, and the absence of some critical discourses, our findings do suggest that a diverse range of fisheries stakeholders are engaging in meaningful electronic monitoring-related discussions in social media. However, our findings also suggest that there is much room to expand the global network of stakeholders and the substance of their interactions, in the interest of moving network interactions from information sharing to robust opportunities for fisheries co-management. Finally, our study indicates the need for additional research on how the concerns of regional fisheries stakeholder networks coalesce in social media spaces, and how those spaces reflect communications strategies found in other venues beyond social media, where patterns and differences may point to the function that social media plays in the broader strategies of co-management collaborations.

Our social media analysis is part of a larger mixed-methods project. The findings we have presented here presently inform the next phase of our study, which involves conducting qualitative interviews with individuals in stakeholder groups represented in the social media ecosystem. These interviews will examine why and how certain fishing industry groups develop collaborative partnerships with environmental NGOs and government agencies, and to what extent their cooperation determines the direction of Amendment 23. Findings from our social media analysis also informed how we might investigate why other industry organizations remain on the outside of these cooperative arrangements, and what can be done to increase participation to produce more equitable and inclusive co-management outcomes across the fishery. In doing this work, we argue that although it may be the case that investigating social media ecosystems may yield limited insight into co-management arrangements between fisheries stakeholders, scientists, and managers, these methods can help rapidly illuminate pre-existing relationships between stakeholders that can serve as the basis for deeper investigation through more traditional methods.

*Responses to this article can be read online at:*
https://www.ecologyandsociety.org/issues/responses.php/13474

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**Data Availability:**

*Social network analysis data that support the findings of this study are openly available at https://tinyurl.com/92sch7n4. Qualitative coding data are also available from the corresponding author, KJ, upon request.*

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