Marine Policy 34 (2010) 1060–1067

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Fishery management as a governance network: Examples from the Gulf of Maine and the potential for communication network analysis research in fisheries

Troy W. Hartley *

Virginia Institute of Marine Sciences, The College of William & Mary, Gloucester Point, VA 23062, USA

ARTICLE INFO

Article history:
Received 11 February 2010
Received in revised form
11 March 2010
Accepted 12 March 2010

Keywords:
Fishery management
Governance network
Communication network analysis

ABSTRACT

It has been suggested that the fisheries management process with multiple, informed stakeholders and socio-economic, political, and scientific complexity can be considered a governance network. This exploratory study applied communication network analysis (CNA) measures and methods to assess two cases of US federal fishery management in the Northwest Atlantic—Atlantic herring and sea scallop. Through questionnaires and interviews, CNA maps were constructed and quantitative measures of network structure and function (density, weighted average path length) and centrality measures for individual network members (degree, betweenness) were derived using InFlow software. The results show that fishery governance networks are horizontally and vertically integrated across levels of government and public–private–nonprofit sectors. The findings validated existing understanding of fisheries management as a contested, competitive management context among stakeholders, and provided new insights about the effectiveness of information sharing across the network and the critical role of bridgers connecting disparate subgroups. Fisheries management can be conceptualized and analyzed as governance networks, and the paper discusses additional research questions, refinements needed for application of the research methods, and ramifications for managers (e.g., can resource managers manage networks).

1. Introduction

Fisheries management is scientifically, socio-economically, and politically complex, i.e., a so-called “wicked” problem in policy studies [1,2]. Wicked problems present challenges for governance, and two US national ocean commissions concluded that the current marine resource and ocean management system in the US is fragmented and unable to meet those challenges [3,4]. To improve coordination among these fragmented components of governance, Ekstrom et al. [5] suggested that we first need a better understanding of existing governance and presented an organizational mapping protocol to assess jurisdictional and functional overlaps in agencies, laws and regulations, i.e., the institutional dimensions of the ocean governance network. Gibbs [6] suggested that fisheries management could be thought of as a governance network too, given the large number of participating and informed stakeholders in the fisheries management process. The broader public policy and administration fields have also considered networks and the management of governance networks in tackling wicked problems [7].

The study reported here is a first step toward testing this conceptual and analytical approach by conducting communication network analysis (hereafter called CNA) on fisheries management examples from the Gulf of Maine in late 2006/early 2007. Communication network maps were constructed, measured, and compared for Atlantic herring and Gulf of Maine scallop fishery management plan (FMP) development in the Northwest Atlantic. After a brief overview of the network governance and network analysis literature and short descriptions of the two fisheries cases, the CNA research methods are presented, followed by the network structure and function results for each fishery management case. The paper concludes with a discussion about what assessing fisheries management as a governance network tells us, what method refinements are needed for application of this research approach, and what considerations fisheries governance networks raise for resource managers.

2. Governing by networks

Research on governance as a network explores the position individuals (or organizations) maintain in a network of relationships and how that position contributes to their influence, attitudes, behaviors, and the development of trust and information [8,9]. Interaction and communication frequency are common

* Tel.: +1 804 684 7530; fax: +1 804 684 7161.
E-mail address: thartley@vims.edu

0308-597X/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.marpol.2010.03.005

measures of social capital in a network and contributes to building trust, establishing credibility, conducting resource exchange, creating motivations and other dimensions of strong social capital [10]. For example, Hartley et al. [11] found that US coastal community networks with close, frequent links among credible, trustworthy actors, which in turn influenced the acceptance and use of information from those actors. Schneider et al. [12] found that networks in communities with US federally funded National Estuary Programs bridged more levels of government, contained more experts, built stronger links among stakeholders, and established greater credibility in the fairness of local decision-making procedures.

Governance networks are self-organizing, non-hierarchical, yet contain leaders and managers within the network [13,14]. Agranoff [13] defined networks as including: some degree of permanence; regular meetings; formal communication procedure; and identified leaders and members. Further, networks include; defined decision-making procedures; division of labor and process for assigning tasks; and clear partners. Some governance networks are sanctioned with binding charters; some less formal (e.g., memorandum of understanding, bylaws) than others (e.g., legislation or executive branch order) [13].

Network structures enable or inhibit various groups and individual functions. Coleman [15] showed that many links in a network (i.e., high density) contributes to the sense of belonging and group identity. Bodin et al. [16] concluded that density is an indication of the strength of trust and the potential of social control among a group. Networks with bridgers (i.e., an individual linking otherwise less connected clusters) to diverse resources function in more adaptive and creative manner than networks with high density and many tight links [17]. A bridger has access to a wide range of information that is specific to the individual clusters of actors (e.g., stakeholder interest groups). This in turn permits a bridger to synthesize a large pool of knowledge, and learn about the organizational dynamics and interests of those subgroups, and thus provides advantages in identifying whom to connect to and how [18].

An individual's position in a network and the communication links that they sustain can be an indicator of their management of information flow and their access to decision-makers. Friedkin's [19] research in organizational behavior identified a horizon of observability, i.e., a network threshold where information becomes inaccessible. Information or resources within two links of a network member is readily available and considered in decisions. In the range of 2–3 links away from the network member, she may be generally aware of the information and its availability; however the information is less clear and network member is less conscious of its availability. Information becomes beyond a network member's horizon of observability at 3–4 links away and greater.

Not all network links are equal [20]. Some network connections may be more relevant to securing and transmitting financial resources, while others more central to directly making the policy or management decision. Networks are dynamic systems, adjusting over time. Networks with great diversity and capacity to bridge to disparate groups can advance innovation and adaptation [16,17], but inhibit group cohesion and effective social control that come from tighter and more dense networks [21,15].

In summary, governance networks are self-organizing and non-hierarchical, and they have structures and functions that enable and inhibit group and individual action. While many of the basic network principles have emerged from organizational behavior research in the private sector, the study of governance networks in a public policy setting has emerged in the past 5–10 years. However, the organizational network principles related to group cohesion, trust, and control, innovation and adaptation, and information flow and knowledge management are relevant in governance networks and fisheries management.

3. Fisheries management examples

While the three cases in this research have the same institutional context (i.e., US federal fisheries management undertaken by the New England Fisheries Management Council (NEFMC)), they also provide sufficient contextual variability to generally assess the application of governance network frameworks. Below are brief overviews of two fisheries and their management—Atlantic herring and sea scallops.

3.1. Atlantic herring: Federal Amendment 1 and State Amendment 2

Atlantic herring are a small, oily schooling pelagic fish distributed along the North American Atlantic Coast from Cape Hatteras, North Carolina in the US to the Canadian Maritime provinces. Herring are the foundation forage fish of the food web for marine mammals, seabirds, sharks, and over twenty fish species throughout the Mid-Atlantic and Northeast. Atlantic herring feed on zooplankton. Thus, Atlantic herring serve a critical food web position between lower and upper trophic levels [22].

While herring in the Northwest Atlantic are not currently "overfished" and "overfishing" (i.e., US regulatory standards), concerns for localized depletion and negative impacts on the lobster fishery and economic sectors resulted in significant management attention. US Federal FMP Amendment 1 established a limited access program and included the following measures: an open access incidental catch permit; a change in the management area boundaries; establishment of a purse seine/fixed gear-only area; and the establishment of a maximum sustainable yield (MSY) proxy. Amendment 1 established: an approach to determining the distribution of area-specific Total Allowable Catches (TACs); a multi-year specifications process; and a research quota set-aside for herring-related research. Still further, it created: a set-aside for fixed gear fisheries; a change in the midwater trawl gear definition; and additional measures that could be implemented later through a quicker framework adjustment process [23].

State Amendment 2 governs the Atlantic herring in state waters (within three miles of shore) and revised management area boundaries, biological reference points, and the specification process. Amendment 2 created research set-asides, specified processing operations, and established measures to address fixed gear fisheries. Amendment 2 sought to complement the Federal Amendment 1, but differed in regards to its effort control program and spawning restrictions. Specifically, the effort control program was based on a "days out" provision, which allowed the fishery to be harvested throughout the season by closing one or more days each week. The Amendment 2 is then used by the states in the herring fishery to guide the implementation of state regulations [24].

In summary, Atlantic herring is a valuable fish to the ecosystem and fishery to the economy. There are many stakeholders participating in a large, complicated, duel Federal—state FMP process. Amendment 1 was completed by the NEFMC in May 2006 (and published by the National Marine Fisheries Service in March 2007), while Amendment 2 was issued in August 2006.

3.2. Gulf of Maine scallop: Amendment 11

A marine bivalve mollusk, scallops are harvested primarily through the use of scallop dredges and trawls. Area closures in New England and the Mid-Atlantic and above-average recruitment resulted in increased scallop biomass throughout the early 2000s. The scallop is managed as a single unit throughout its range but five stock components are recognized: eastern Georges Bank, the Great South Channel, the Gulf of Maine, the New York Bight and the waters adjacent to Delaware, Maryland and Virginia. Over the past several years, the sea scallop resource has maintained a highly profitable commercial sea scallop fishery [25].

The NEFMC's scallop FMP was implemented in 1982. In 1994 Amendment 4 established an open access "general category" permit for vessels that did not qualify for limited access that was applied to the directed scallop fleet. Eligible vessels could apply for a general category permit and land up to 400 pounds of scallops a day. At the time, this possession limit was deemed suitable and sufficient to accommodate scallop bycatch on long trips and sporadic small scale scallop fishing near shore by non-qualifying vessels [25].

Since 1999, there has been considerable growth in general category fishing effort and landings, among a diverse fleet. Some general category vessels fish for scallops seasonally, while another component of the fleet lands scallops above incidental levels while fishing for other species. Still others are full-time day boat vessels that target scallops year round. This additional effort has been a contributing factor to why the FMP has been exceeding the fishing mortality targets [25].

Amendment 11 added measures to control capacity and mortality in the general category scallop fishery, including a limited access program with an individual fishing quota for qualified vessels. Amendment 11 contained a specific quota allocation for the general category scallop fishery. Amendment 11 was finalized in April 2008, over eight months after the communication network analysis data collection was initiated [26].

In summary, general category sea scallop fishery is a diverse fishery, although smaller in number of impacted stakeholders than the Atlantic herring fishery. The FMP Amendment was narrow, applying to general category scallop fishers, although it was just getting initiated at the time when the research began.

4. Methods

Social network analysis gathers and analyzes data from individuals or organizations regarding the links or connections among the individuals or organizations (i.e., nodes, also called actors). Social networks can assess a wide range of resources, authority, information, and levels of interdependence among actors and have utility in illustrating the structure of formal and informal networks and resource flow [27]. The links and the relationships are of primary analytical interest rather than the actors. Frequency of interaction is a common measure in the field of social network analysis, because of the role of frequent connections in generating and sustaining social capital [28,10].

CNA is a social network analysis sub-field that focuses on the characteristics of specific communication pathways and the patterns of information flow and connections that communication produces [29]. CNA concentrates on the flow of data, information, knowledge, images, symbols, and other forms of communication among network actors. That is, CNA is analyzing information flow, knowledge management and the related outcomes (e.g., knowledge integration, mutual understanding), whereas social network analysis is considering social capital, trust, and other broader social constructs.

Surveys and interview protocols are used to gather data for CNA. Software (in this study, InFlow, www.orgnet.com) is readily available to graphically represent and analyze maps of the quantitative data on the relationships and interactions within and between individuals and stakeholder groups in a network. Communication is defined as any formal or informal communicative act or contact (i.e., email, face-to-face, phone, ad hoc meeting, etc.). Network maps reflect a particular moment in time and are sensitive to the communication patterns emerging from particular activities underway at the time.

A 1–5 scaled frequency of communication is a common CNA measure [27,29]. Daily communication is a highly frequent level of interaction and typically reflects contact among close friends or colleagues. Weekly communication is often the operational level, illustrating a group regularly working together on a project, while monthly communication reflects a broader network of individuals who can connect as necessary. Thus, a weekly frequency is a measure of interest when considering the extent of coordination and regular information sharing among groups on a particular issue or activity. All communication events are significant and each contributes to the frequency, although all communication events may not be equal for other characteristics of the network link.

A questionnaire was administered (web-based, hard copies mailed or handed to participants, and phone interviewed) among a list of participants identified in the public records, and confirmed as participants by key informants (i.e., lead government staff). Standard data collection procedures and quality control standards were used in the design and administration of the questionnaire [30]. A project advisory group of marine and fishery scientists and managers, and fishermen, and two key informants involved in the Atlantic herring FMP process pre-tested the questionnaire. The questionnaire contained information on the study objectives, use of the results, and design of the study and questionnaire. It included participant consent certification and a definition of communication. The questionnaire contained a list of individuals from the public record and for each individual, asked "How often do you typically communicate with the following individuals? (You could communicate about anything, NOT only [Atlantic herring or sea scallop] FMP)." The question was on a 1–5 scale, (1: yearly, 2: quarterly, 3: monthly, 4: weekly, and 5: daily). A 0: never option was available and demographic measures were included (age, profession, years on job, level of education, and discipline). The questionnaire required up to 30 min to complete in hard copy, and slightly faster on-line, in person or by the phone (20 min), although duration varied depending upon how many individuals the respondent knew and communicated with.

In January and March 2007, the researchers observed FMP public meetings and planning sessions, and throughout 2006 and 2007, we gathered case documentation from the public record and individual participants. Data were imported into the InFlow software for the generation of network maps and the centrality measures of the network structure and function. An algorithm from mathematical graph theory is applied by most network analysis software; the algorithm spatially orients nodes in a map based upon the relationship nodes have with each other. In the last decade, the expanding computer power and graphics capabilities has enabled an explosion of network analysis software options.

Network size, density, and weighted average path lengths were analyzed, along with measures of an individual's network centrality (e.g., degrees, betweenness). Density is an overall network measure and is the ratio of actual links present to all links possible—if everyone was linked with everyone, density would be 100%. Weighted average path length reflects the shortest path between two points in the network, averaged across all participants—it is a measure of how easily everyone in the network can connect with everyone else. At the individual level, degree is the total number of links an individual has with other nodes and is a measure of activity level of the individual. Betweenness is a measure of connectedness, based upon a position of shortest path between other nodes in a network. Someone with high betweenness values is efficiently linking different individuals (e.g., an individual positioned between two clusters of nodes that are not otherwise connected, would have a high betweenness value) [27,31–33].

Preliminary findings and CNA maps were presented to and discussed with NEFMC staff and PDT members three times in the spring, summer and fall of 2008, aiding interpretation (e.g., further qualitative characteristics of communication links and network function) and enabling further targeted data gathering among key network participants who had not yet responded. Reporting questionnaire response rates are misleading, since the entire public record is the universe being sampled and all individuals are not equal in their network location and function. While response rates were 27% and 13% of the entire public records for Atlantic herring (192 individuals identified from the public record) and sea scallop (76), when consulting with key informants, the respondents in both cases exceeded 50% of those considered core participants by the key informants. Sampling and case boundaries are discussed further below.

5. Network analysis findings

Fig. 1 presents the weekly and monthly CNA maps for Atlantic herring and sea scallops fishery management through the NEFMC in the fall 2007. Below is a discussion of the Atlantic herring network map and centrality measures, followed by sea scallop, and then a short comparison.

5.1. Atlantic herring

The weekly Atlantic herring CNA map contained one large group of 146 individuals, consisting of members of state agencies from Maine to North Carolina, US and Canadian federal fisheries agencies, several industry sectors (e.g., directed herring fishery, lobster fishery, hook and line sector), and four non-governmental organizations. There were three additional smaller, isolated groups with three and four members that become part of a single group at a monthly communication frequency rate. The network's density was 1%, reflecting low level of interactions between all 146 members (i.e., all members are not sharing information with everyone else).

At the same time, the weighted average path length of the entire network was 2.5 (i.e., on average any two individuals in the network are fewer than three links away from each other). Thus more specialized functions and roles among individuals in the network are enabling information flow across the large network. The node located in the center-left of the Atlantic herring map (dark circle added in Fig. 1) possessed four times more links (degrees) to others than the next ranked member of the network. This individual's network position and function illustrated the highest overall activity level in the network. Further, he had the highest betweenness score (0.20), more than three times higher than the next ranked network member (0.06). High betweenness reflects a bridge between otherwise less connected clusters or nodes.

When the focus changes to monthly communication frequency, the Atlantic herring map expands slightly in size (156 participants) but more substantially in number of links (density

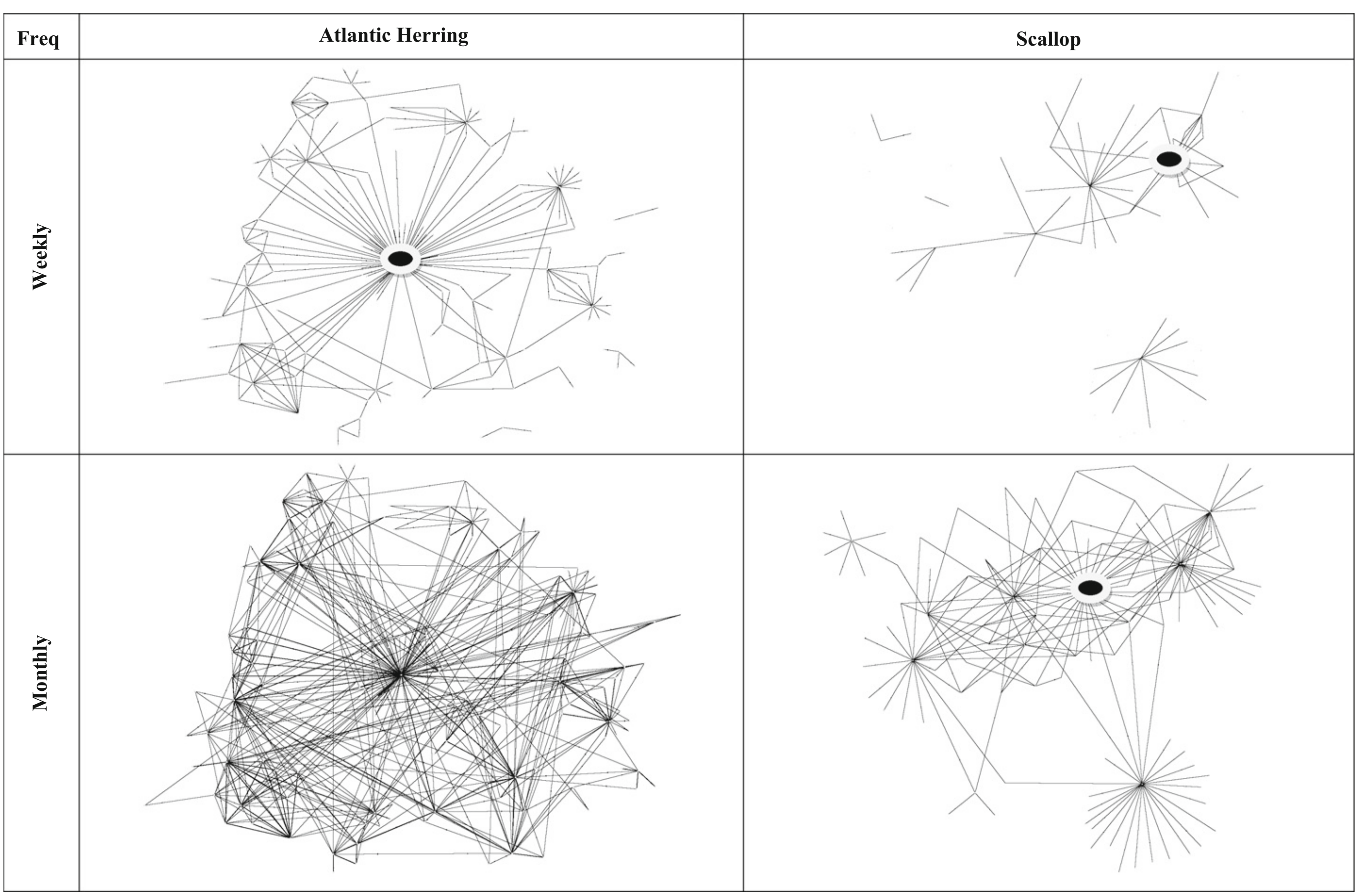

Fig. 1. Fall 2007 weekly and monthly CNA maps in Atlantic herring and sea scallop fishery management.

increases to 2%)—i.e., overall information flow between all members is slightly greater. At the same time, however, those ten additional individuals are connected peripherally and the weighted average path length increases to 3.5; the network does not share information as easily as it did at the weekly frequency rate. The same individual referenced above remains the highest rank in betweenness, but by less than at the weekly level. His betweenness value (0.45) is slightly larger than the next most effective bridging individual (0.30) followed by others with measures of 0.23 and 0.17.

The individual with the highest centrality measures (degree and betweenness) was the chair of the Plan Development Team (PDT), charged with drafting the Atlantic herring FMP Amendment 11. He was a scientist with a state marine resource agency. Other individuals with high degree and betweenness values—and who approached the PDT chair in bridging capacity at a monthly frequency—included the NEFMC staff assigned to the PDT, and a NEFMC member from a State very active in the herring and lobster industries.

5.2. Sea scallops

The weekly sea scallop CNA map contained a larger cluster of thirty-six individuals, plus sixty-five additional isolates and smaller clusters that become part of a single network at a monthly communication frequency rate. The thirty-six contained NOAA (39%), NEFMC or Mid-Atlantic Fishery Management Council staff or members (28%), industry members on NEFMC Advisory Panel (17%), state agency staff (11%), and a university-based scientist. The scallop network's density was 4%, demonstrating higher overall group activity than the larger herring network. Its weighted average path length was 1.5; on average any two individuals are less than two links apart.

Several individuals recorded higher levels of activity (degrees) than other network members, including two NOAA staff members, an industry member on the advisory panel, and an NGO representative on the NEFMC. The individual in the upper right of the scallop weekly communication network map (dark circle added)—a NOAA staff—showed a betweenness value (0.15) five times greater than the next highest individual (0.03), thus he is bridging between otherwise disparate groups more than others in the network.

When the focus is adjusted to a monthly communication frequency, the network structure and function changes. The network almost triples in size to 101 members. Density decreases to 2% and weighted average path length increases to 2.5; the network spreads out. The differences between the higher ranked bridger and others in the weekly communication network diminished at the monthly frequency level. The high number of active members' remains, but a different individual now shows the highest betweenness value (0.3) compared to the highest at the weekly frequency, whose betweenness measure is 0.2 at a monthly frequency. The NOAA staff member is surpassed at the monthly frequency in his bridging capacity by an industry representative who serves on the NEFMC's advisory panel. See the dark circle added to the monthly sea scallop network map in Fig. 1.

6. Discussion: Atlantic herring and sea scallop FMP as networks

The objectives of this study included testing the application of network analysis in fisheries management. The use of network concepts in other areas of public policy research has been criticized for being more conceptual and failing to use network analysis methods and measures [34,35]. Below the discussion first considers what a CNA tells us about Atlantic herring and sea scallop fishery management, then it shifts to an initial review of the strengths and limitations of the research method and measures.

While both cases exist within the same institutional context (i.e., FMP development in the NEFMC), the two cases were at different points in the FMP process, engaged multiple but different stakeholders, and had different individuals participating, although some overlap existed among NEFMC and NOAA staff members. Atlantic herring had completed the FMP amendment four months before data collection started, whereas sea scallop had only just initiated the process and an FMP amendment would not result in a year after data collection. Thus, variability in the network structure and function was expected and observed in the findings.

6.1. Network structure: group cohesion and information flow

The density measure for Atlantic herring's 146-member weekly network (1%) was smaller than the 36-member sea scallop weekly network (4%). High density may reflect a sense of belonging, group identity, and the potential for group cohesion and conformity [15,16]. While there are insufficient numbers of network maps on public policy and resource management cases to know what "high" or "low" might mean in this context, US fisheries management is considered highly contested and political [36,37]. Thus, densities of 1% and 4% are likely reflecting "low" densities among fairly diverse stakeholder groups. The network structure confirms the literature on the contested nature of fisheries management, in general, and a review of trade industry press coverage at the time confirms the contested nature of Atlantic herring and scallops in particular [38,39]. As one general category scalloper said reflecting on forming a coalition, "We're a small group trying to get more people to join. If we don't, we're just going to get walked right over" [39; 1A].

Nonetheless, both Atlantic herring and sea scallops exhibited individuals in bridging roles and low weighted average path lengths (2.5 for herring and 1.5 for scallops at a weekly frequency). Both of these networks fall within Friedkin's [19] horizon of observability (less than three links) and thus information flow and availability of knowledge is likely to be effective across the diverse herring and scallop management networks. The weighted average path length values suggest that all stakeholders are aware of each other and of knowledge being considered in the FMP.

While there are significant differences between universities and public sector decision-making where Friedkin conducted his research (e.g., public decisions typically require and government officials proactively seek public comment), a horizon of observability value likely exists in public decisions too, although the threshold value may be greater than Friedkin's three links. Replicating Friedkin's study in a fishery management or other coastal or marine resource management case would clarify the horizon of observability in this public policy and management context.

6.2. Network function: roles of individuals

Both the Atlantic herring and sea scallop weekly networks contained individuals with substantially higher betweenness values than other members—three times higher for herring and five times greater for scallop network. Higher betweenness values indicate bridgers, who are connecting otherwise disparate groups or nodes in the network. At a coordinating, weekly communication frequency, both networks depended upon bridgers to enable information flow throughout the network. These bridgers appear to be effective given the low weighted average path lengths. Research published elsewhere shows the vulnerability of the weekly coordinating network in Atlantic herring to the loss of the bridger [40]; however both of the individuals in herring and scallop saw their bridging capacity become more equalized with others at a monthly frequency rate. This suggests the potential to adapt to the loss of a bridger.

Networks with bridgers are thought to be more adaptive and creative [17,18]. Future research with more fisheries management network maps could consider whether there are correlations between the presence of bridgers and the degree of innovation in the resulting FMP. It would also be necessary to account for the variety of the information and knowledge structures among the participating groups to assess the extent and potential of knowledge integration and innovation available to bridgers. Johnson and van Densen [41] found greater opportunity for innovative fisheries management approaches as a result of cooperative research that bridged industry and science partners, and Wilson [42] drew similar conclusions regarding fisheries co-management.

Key players based upon their institutional roles also played key roles in their networks, although specific institutional roles did not pre-determine their network roles. For example on one hand, PDT chairs, NEFMC staff and members, NOAA, industry members on Advisory Panels all showed more links (degrees) and bridging capacity (betweenness) than other members of the networks. However, members from a state agency, NOAA, and industry all served leading bridging roles.

7. Discussion: analyzing management as a governance network

There are distinct qualitative and quantitative analysis benefits obtained from application of network analysis in fisheries management. Preliminary CNA maps were valuable tools during key informant interviews to identify targeted survey solicitation reminders and for case study documentation. Further, sufficient variability in network structure and function seems to exist with variability in contextual factors (e.g., timing in the fisheries management process, size and diversity of fishery, interested stakeholder groups, etc.); however, far more cases need to be analyzed with CNA methods to build further hypothesis about relationships between network structure and function and contextual factors or create theoretical frameworks.

The CNA maps and quantitative measures for the Atlantic herring and sea scallop fishery management cases identified the most active coordinating participants and critical bridgers between disparate groups, which were facilitating, monitoring and controlling information flow. Both networks demonstrated effective information sharing across their networks' varied subgroups, although both networks were insufficiently dense to build any sense of cohesion or group identity—thus, they will likely continue to reflect competing interests and contested management processes.

The Atlantic herring and sea scallop networks were very diverse with multiple stakeholders that crossed state–federal government levels and public–private–nonprofit sectors. This has important ramifications for fishery management, as well as emerging integrated, multi-stakeholder, regional governance initiatives (e.g., coastal and marine spatial planning, ecosystem-based approaches to management, and integrative adaptive management). Fisheries, coastal, and ocean governance networks are not only horizontal, (i.e., the coordination of the >100 US coastal and marine federal agencies and organizations that were the focus of two federal ocean policy analyses [3,4]), but also vertical, crossing local–state–federal government boundaries, as well as across public–private–nonprofit sectors. In the US, governance networks reflect Federalism in practice and illustrate the vast array of players, levels, and rules at play in governance of coastal and marine resources.

While considering the nesting of governance systems across scales in an ecosystem-based management approach to connect fragmented coastal and ocean government, Sissenwine [43] suggested that a vertical and horizontal connectivity was needed—vertical connectivity promotes two-way links between lower and higher level policies and goals, while horizontal connectivity links adjacent ecosystem-based management projects to account for impacts on neighbors. Sissenwine used the term connectivity to conceptualize a different form of integrated and nested governance than currently existing ones. However, connectivity is also a CNA concept, referring to the suite of quantitative measures of network structure and individual function in the network (in this study, density, weighted average path length, degree, and betweenness). Thus, further CNA case studies in fisheries and other areas of coastal and marine resource planning and management will further our understanding of what sufficient vertical and horizontal connectivity looks like.

Further, understanding the network structure and function can provide practical advice on communication, outreach, and strategic activities. For example, knowing who are the most centrally located and connected individuals permits prioritization of limited outreach and communication services for maximum information diffusion. Maiolo and Johnson [44] used CNA to identify the well-connected leaders and members of the king mackerel fishery for targeted outreach. Corporations [45] and increasingly NGOs [46,47] are integrating strategic positioning into their operations, seeking to position their message deliberately in the existing network to generate and maintain visibility, mobilize constituents, and advance change. Measuring the actual network structure and function would enhance the effectiveness of strategic positioning.

7.1. Challenges: defining boundaries and expanding network link measures

While CNA of fisheries management both validated findings in the literature and produced new findings about the FMP process, there remain challenges to the research that will require further refinement of the methods for application in fisheries, coastal, and ocean management. Two in particular will be discussed here—boundaries and additional communication network link measures.

First, social network analysis calls for very high response rates, in the 85+% range ([27,48]) to accurately capture the network fabric and take full advantage of the quantitative measures. These response rates are impractical in most public policy survey research. Further, the boundaries of the fisheries, coastal, and ocean governance networks are fuzzy, crossing sectors, levels of governments, and other stakeholder groups—the public policy context is not a single private sector corporation with clear organizational units and boundaries. It is unclear where to define the boundary of a more narrower FMP network and thus know when a sufficient sample has been obtained. In practice, we found that after obtaining $\sim$25% response rate from those identified as core participants by key informants on each case, a sufficiently accurate communication network map emerged that was useful in follow-up interviews with key informants. These informants identified the additional key members to target for follow-up solicitation. When these new respondents were added, the resulting network grew in density (i.e., more internal links) from the preliminary CNA maps, but it did not expand substantially in the number of network members (i.e., few new members were added). Nonetheless, advances in less intrusive measurement instruments (e.g., with consent, electronic communication records such as email and phone records provide data; Virginia Sea Grant is integrating CNA into quarterly staff progress reporting) and more strategic applications of CNA (e.g., building preliminary network maps from multiple data sources, and then targeting further survey data collection and analysis on particular clusters of interest), may provide further opportunities. In addition, embedding CNA into case study methods would facilitate the examination of these important link values.

Second, not all network links are equal [20]. While frequency is an effective measure to track information flow, there are additional dimensions of information that are important in fisheries management. For example, salience (i.e., usefulness and relevance), credibility, and legitimacy (trustworthiness of the process that developed the information) can be critical to ensure scientific information influences fisheries management [49]. Influence is a complex factor and proven difficult to study. However recent advancements in the definition and operationalization of influence raise additional measures to consider related communication links and network structure and function [see 40,50]. Discussing similar characteristics to the influence framework, Weber and Khademian [7] identified the transfer, receipt, and integration of information and knowledge as central to network function.

7.2. Can resource managers "Manage" networks?

If fisheries management is a governance network, then can fisheries managers actually direct the network to achieve its public and societal goals? There is no consensus in the literature on this point. From a theoretical perspective, Kickert et al. [51] argued that the self-organizing, non-hierarchical nature of networks mean that managers are supporting players unable to lead the network; networks are not controllable by one party and the best that public managers can do is serve as facilitators and arbitrators of dispute. Nelson [52] concurred and extended the caution to strategic positioning. She argued that purposively building or breaking relationships could be counter-productive and potentially destructive, because the perception of coercing participation and manipulating the network would lead to a backlash that destroys the motivation, accountability, trust, and mutual benefits that the managers sought to create in the first place.

However, other scholars see managers as the conductor of an orchestra, possessing sufficient authorities and resources to position themselves in a central and guiding role in a network [13,53,54]. For example, they call for the use of innovative and emerging communication and information management tools to promote network function and serve roles facilitating information flow and managing knowledge. Further, negotiation and alignment of partners (e.g., self-selecting strategic partners) help resolve differences, solve problems, and impact network structure and function, while the development of decision-support frameworks can identify roles, niches, and operational guidelines that further effect network structure and function.

As a practical matter, networks exist and the awareness of networks enables the consideration of strategic positioning by managers, agencies, and any stakeholder within the network. Further, managers and other stakeholder groups will likely consider how they can alter the incentives and motivations of participants to promote engagement of a network toward achieving their goals. Far more research is needed to understand the governance network structure and function in fisheries and other coastal and marine resource management contexts; thus, currently there is not much practical guidance for fisheries managers on how to fulfill their objectives through their network position and roles [see 53,54].

8. Conclusion

Can fishery management be conceptualized and analyzed as networks? Yes. This study was an exploratory first step. It raised more questions than it answered—as all research does—but it provided additional lenses to conceptualize and analyze fisheries management. Networks are considered non-hierarchical and self-organizing, although their structure and function are somewhat mediated by prescriptive decision-making procedures, such as FMP development frameworks. This research found variability in FMP communication network structure and function in different fisheries cases within the same institutional setting. The CNA findings validated some existing literature (e.g., illustrating the network structure and function that underlies a contested FMP process among diverse stakeholders), thus enhancing CAN's validity as a useful analytical tool in fisheries. CNA produced new findings (e.g., quantitative measures of network function—i.e., weighted average path length—illustrated that FMP networks were effective at sharing information broadly across its diverse membership. It also raised new questions (e.g., role of bridgers and whether their presence may contribute to innovation in fisheries management). Nonetheless, managing a network to advance science-to-management, maximize influence, or more broadly to achieve public and societal value is not easy, but understanding how the network is structured and functions is an important first step.

Acknowledgment

This research was funded by New Hampshire Sea Grant from the National Oceanic and Atmospheric Administration, US Department of Commerce, Grant no. NA06AR4170109. I am extremely grateful to the participants in the study who responded to questionnaires and interviews, and the anonymous reviewers and the editors of Marine Policy for their constructive input.

References

[1] Jentoft S, Chuenpagdee R. Fisheries and coastal governance as a wicked problem. Marine Policy 2009;33:553–60.
[2] Browman HI, Stergiou KI. Theme section: politics and socio-economics of ecosystem-based management of marine resources. Marine Ecology Progress Series 2005;300:241–96.
[3] Pew Ocean Commission. America's living oceans: charting a course for sea change. Washington: The Pew Charitable Trust; 2003.
[4] US Commission on Ocean Policy. An ocean blueprint for the 21st century. Washington: US Commission on Ocean Policy; 2004.
[5] Ekstrom JA, Young OR, Gaines SD, Gordon M, McCay BJ. A tool to navigate overlaps in fragmented ocean governance. Marine Policy 2009;33:532–5.
[6] Gibbs MT. Network governance in fisheries. Marine Policy 2008;32:113–9.
[7] Weber WP, Khademian A. Wicked problems, knowledge challenges, and collaborative capacity builders in network settings. Public Administration Review 2008;68(March/April):334–49.
[8] Burt RS. Bandwidth and echo: trust, information and gossip in social networks. In: Rauch JE, Cassella A, editors. Networks and markets. New York: Russell Sage Foundation; 2001.
[9] Carrington PJ, Scott J, Wasserman S, editors. Models and methods in social network analysis. Cambridge: Cambridge University Press; 2005.
[10] Putnam RD. Bowling alone: the collapse and revival of American community. New York: Simon & Schuster; 2000.
[11] Hartley TW, Gagne M, Robertson RA. Cases of collaboration in New England coastal communities: an approach to manage change. Human Ecology Review 2008;55:213–26.

[12] Schneider M, Scholz J, Lubell M, Mindruta D, Edwardsen M. Building consensual institutions: networks and the national estuary program. American Journal of Political Science 2003;47:143–58.
[13] Agranoff R. Managing within networks: adding value to public organizations. Washington: Georgetown University Press; 2007.
[14] Weiner ME. Human services management, 2nd ed.. Belmont: Wadsworth; 1990.
[15] Coleman JS. Foundations of social theory. Cambridge: Harvard University Press; 1990.
[16] Bodin O, Crona B, Ernstson H. Social networks in natural resource management: what is there to learn from a structural perspective?Ecology and Society 2006;11:1–8. http://www.ecologyandsociety.org/vol11/iss2/resp2/.
[17] Newman L, Dale A. Network structure, diversity, and proactive resilience building: a response to Tompkins and Adger. Ecology and Society 2005;10: 1–4. http://www.ecologyandsociety.org/vol10/iss1/resp2/.
[18] Burt RS. The social capital of structural holes. In: Guillen MF, Collins R, England P, Meyer M, editors. The new economic sociology: developments in an emerging field. New York: Russell Sage Foundation; 2003. p. 148–89.
[19] Friedkin NE. Horizons of observability and limits of informal control in organizations. Social Forces 1983;62:54–77.
[20] Granovetter MS. The strength of weak ties: a network theory revisited. Sociological Theory 1983;1:201–33.
[21] Borgatti SP, Foster PC. The network paradigm in organizational research: a review and typology. Journal of Management 2003;29:991–1013.
[22] New England Fisheries Management Council. The role of Atlantic herring, Cuplea harengus, in the Northwest Atlantic ecosystem. Woods Hole: Northeast Fisheries Science Center; 2003.
[23] US Department of Commerce. National Oceanic and Atmospheric Administration. Fisheries of the Northeastern United States, Atlantic herring fishery, Amendment 1, Final rule. Federal Register March 12, 2007; 72(47): 11252–11281.
[24] Atlantic States Marine Fisheries Commission. Amendment 2 to the interstate fishery management plan for Atlantic herring. Washington: Atlantic States Marine Fisheries Commission; March 2006. ⟨www.asmfc.org⟩.
[25] New England Fisheries Management Council. Scoping announcement summary. Newburyport: New England Fisheries Management Council; 2007. ⟨www.nefmc.org⟩.
[26] US Department of Commerce, National Oceanic and Atmospheric Administration. Fisheries of the Northeastern United States: Atlantic sea scallop fishery, Amendment 11, Final rule. Federal Register April 14, 2008; 73(72): 20090–20133.
[27] Scott J. Social network analysis: a handbook, 2nd ed.. Thousand Oaks: Sage Publications; 2000.
[28] Burts RS. The network structure of social capital. In: Sutton RS, Straws BM, editors. Research in organizational behavior: volume 22 New York: Elsevier Press; 2000. p. 345–423.
[29] Monge PR, Contractor NS. Theories of communication networks. New York: Oxford University Press; 2003.
[30] Dillman DA. Mail and internet surveys: the tailored design method. New York: John Wiley and Sons; 1999.
[31] Monge PR, Contractor NS. Theories of communication networks. New York: Oxford University Press; 2003.
[32] Freeman LC. A set of measures of centrality based on betweenness. Sociometry 1977;40(1):35–41.
[33] Chen C. Social networks at Sempra Energy's IT division are key to building strategic capabilities. Global Business and Organizational Excellence January/ February 2007; (DOI:10.1022/joe.20120):16–24.
[34] Rethemeyer RK. Conceptualizing and measuring collaborative networks. Public Administration Review 2005;65(1):117–21.
[35] Dowding K. Model or metaphor: critical review of the policy network approach. Political Studies 1995;43(1):136–58.
[36] Hilborn R. Defining success in fisheries and conflicts in objectives. Marine Policy 2007;31(2):153–8.
[37] Orbach M. Of mackerel and menhaden: a public policy perspective on fishery conflict. Ocean and Shoreline Management 1989;12(1):1–18.
[38] Plante JM. High stakes provoke intense herring debate: NE council endorses area 1A TAC reduction. Commercial Fisheries News 2006;34(November): 1B–3B.
[39] Stevens L, Kennedy S. General category scallopers form NE coalition. Commercial Fisheries News 2006;33(1A):12A–3A.
[40] Hartley TW, Glass C. Science-to-management pathways in US Atlantic herring management: using governance network structure and function to track information flow and potential influence. ICES Journal of Marine Science forthcoming.
[41] Johnson TR, van Densen WL. Benefits and organization of cooperative research in fisheries management. ICES Journal of Marine Science 2007;64(2007):834–40.
[42] Wilson DC. Fisheries co-management and the knowledge base for management decisions. In: Wilson DC, Nielsen JR, Degnbol P, editors. The fisheries co-management experience: accomplishments, challenges, and prospects. Dordrecht: Kluwer Academic Publishers; 2003.
[43] Sissenwine M. Globalization and scaling in ecosystem-based management. MEAM 2008:7–8.
[44] Maiolo JR, Johnson JC. Discovering communication networks in marine fisheries: implications for management. In: Thomas JS, Maril L, Durrenberger EP, editors. Marine resource utilization: proceedings of a conference on social science issues. MASGP-88-039. Mobile: Mississippi-Alabama Sea Grant Consortium; 1989.
[45] Njuguna JI. Strategic positioning for sustainable competitive advantage: an organizational learning approach. KCA Journal of Business Management 2009;2(1):32–43.
[46] The Accenture Foundation, International University, The Banyan, editors. Strategic research and political communication for NGOs: initiating policy change. Thousand Oaks: Sage Publications; 2009.
[47] Bischoff-Turner S. From strategic planning to strategic positioning. Conservation Impact January 2004:1–11. http://conservationimpact.com/wp-content/uploads/2009/12/article-booklet/strategicmarketingarticleCI.pdf.
[48] Burt RS. Studying statues/role-sets using mass surveys. In: Burt RS, Minor MJ, editors. Applied network analysis. Beverly Hills: Sage Publications; 1983.
[49] Wilson DC. The paradoxes of transparency: science and the ecosystem approach to fisheries management in Europe. Amsterdam: Amsterdam University Press; 2009.
[50] Verschuren P, Arts B. Quantifying influence in complex decision making by means of paired comparisons. Quality & Quantity 2004;38(2004):495–516.
[51] Kickert WJM, Klijn E-H, Koppenjan JFM, editors. Managing complex networks: strategies for the public sector. London: Sage Publications; 1997.
[52] Nelson L. Environmental networks: relying on process or outcome for motivation. In: Mandell MP, editor. Getting results through collaboration: networks and network structures for public policy and management. Westport: Quorum Books; 2001.
[53] Goldsmith S, Kettl DF, editors. Unlocking the power of networks: keys to high-performance government. Washington: The Brookings Institution; 2009.
[54] Argnoff R. Managing within networks: adding value to public organizations. Washington: Georgetown University Press; 2007.