Title:

Science-to-Management Pathways for Collaborative Herring Stock Survey Data: Using network analysis to track information flow and potential influence in fisheries management.

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Abstract:

Herring in the Northwest Atlantic are not overfished and overfishing is not occurring. However concerns for the potential of localized depletion and negative impacts on other fisheries and economic sectors have led to a sequence of management plans and amendments in the U.S. in recent years. Stock assessments have been vital in these management deliberations and there are several sources of herring stock survey data in the Gulf of Maine and Georges Bank, including a collaborative industry-science acoustic survey and government-administered trawl surveys. A joint U.S.-Canadian technical committee of scientists conducts the stock assessment from these data. We first describe the stock survey approaches, including the outcome of a 2005 external peer review of the collaborative acoustic survey, and examine their use in the assessment process. Second, we use a network analysis methodology to map the communication patterns among participants in the development of a fisheries management plan (FMP). Individuals (nodes) and their connections (links) are spatially arranged in a network map based upon the communicative relationship among all individuals. We track the pathways through which the collaboratively-derived stock survey data flow into the stock assessment (science) and the FMP decision-making (management) process. We compare pathways for their communication efficacy in feeding stock survey information into science and management. The resulting map shows participants in the collaborative survey well connected to the stock assessment and fisheries management process, although not institutionalized and dependent upon key individual participants serving as bridgers between informational resources.

Keywords: collaborative research, stock assessments, fisheries management, network analysis

1. Introduction

Atlantic Herring is a critical fish in the ecosystem and economy of the Northwest Atlantic. It sustains a directed fishery, is bait for the lucrative lobster fishery, provides essential food for marine mammals, birds, and other fish species, and consequently, supports extensive economic and community activity. Herring in the Northwest Atlantic are not currently overfished and overfishing is not occurring. However concerns for the potential of localized depletion and negative impacts on other fisheries and economic sectors have led to a sequence of management plans and amendments in recent years. Stock assessments have been vital in these management deliberations and there are several sources of herring stock survey data in the Gulf of Maine and Georges Bank, including government-administered trawl surveys and a collaborative industry-science acoustic survey. A joint U.S.-Canadian technical committee of scientists conducts the stock assessment from these data, which in turn is used to set harvest allocations by the fisheries management agencies in the U.S. and Canada.

Fisheries management in the U.S. is a multi-stakeholder process, involving commercial and recreational fishing interests, conservation organizations, state and federal governments, and other interested parties—it has been criticized for being slow, co-opted, and ineffective because of this structure as well (e.g., Heinz 2000, Okey 2003, Rosenberg 2003), although others have concluded that there are considerable successes (e.g., Hilborn 2007; Witherell 2004). Given the large number of participating stakeholders, fisheries management has been conceptualized as a governance network (Gibbs 2008). Governance networks are non- hierarchical and self-organizing groups of individuals or organizations working together toward a common outcome (e.g., generation of a fishery management plan); they use communication and organizational tools of coordination (e.g., regular meetings, formal communication procedures, coordinating staff or leaders), defined decision-making procedures, and division of labor or responsibilities and expectations (Agranoff 2007). This multi-party network provides parties with access to the fisheries management decision-making and with the opportunity to influence the process or outcome (Betsill and Corell 2008, Verschuren and Arts 2004).

This research applied network analysis strategies to map and compare the access pathways for collaborative industry-science acoustic survey data into the Atlantic herring stock assessment (science) and fishery management plan (management) development processes. Below we briefly review the social science literature on the science-to-management process (i.e., the flow of scientific information into the resource management process) and how information influences decision-making, followed by details of the Atlantic Herring case study. The methods for conducting network analysis are discussed and the resulting maps presented and analyzed—the comparisons of information flow pathways show that participants in the collaborative survey are well connected to the stock assessment fisheries management process and decision-makers; however, the acoustic survey is not institutionalized into the primary source of scientific advice in U.S. fisheries management (stock assessments) and are dependent upon key network bridgers to ensure the acoustic survey information is available to managers.

1.1 Science-to-management and influence in decision-making

The social process that integrates scientific information and knowledge into resource management and decisions is not well understood and has not been comprehensively analyzed (McNie 2007). The literature is composed primarily of tips emerging from individual case studies. In particular, research has shown the effectiveness of decision support frameworks that define a systematic procedure for making science-based decision. (Liu, et al. 2008; Jacobs 2005)

Scientific research is not always framed or conducted on a scale relevant to the jurisdictional scope of management, nor is research often communicated in venues used by managers. Thus, decision support frameworks help because they focus the discussion on management-relevant problem definition and approaches to analyze the problem (Lui, et al. 2008) and reframe the scientific research questions to address a suite of pragmatic management and social needs—including appropriate scale of the research, perceived credibility of the information, and realities of communicating the findings (Jacobs, et al. 2005). Lackey (1998) examined one type of fisheries management decision support framework (risk assessment models) and concluded that they promote science-to-management because they guide the policy debate toward narrow issues of risk.

The U.S. fisheries management plan (FMP) development process is convoluted but explicitly lays out a science-based decision framework (Heinz 2000; Weber 2002)—see detailed discuss below of the Atlantic herring FMP process. The adequacy of the science, the responsiveness of management to scientific information, and the effectiveness of the interaction between science and fishery management in the U.S. has been hotly debated (e.g., Crockett 2005; Rosenberg 2007; Witherell 2005). While decision support frameworks may lay the groundwork for a science to management process and seek to frame the public debate, fisheries management takes place within a human context of conflict among competing ideas, values and knowledge and the application of political behavior and negotiation in a governance system (e.g., Hilborn 2007; Orbach 1989). Nonetheless, Lee (1993) found that the interplay of science and politics can lead to the integration of science into resource management decisions—what Lee called a blending of scientific idealism and political pragmatism—although it is a long-term process of social learning.

In sum, fisheries management is undertaken through a science-based decision support framework that remains inherently political, but likely facilitates the influence of scientific information through framing the problem and approaches to analysis, setting the agenda, and fostering social learning. However, influence is a challenging social phenomenon to study—identifying the significance of one piece of information, or the actions of one individual or organization relative to others in a public decision making process has not been thoroughly examined by social scientists. Influence is different from power, which is commonly associated with a capacity and a structural phenomenon (e.g., position in an organization, resources, authority), whereas influence is a relational variable related to an incident of impact. Influence would arise from the use of power, not the mere possession of power. The science-based decision support framework in fisheries management puts science in a position of power; however, science and the individuals who possess scientific knowledge would influence a decision-making process only if their particular science is used by decision-makers.

Much of the current literature has sought to define and operationalize influence (e.g., Arts and Verschuren 1999; Betsill and Corell 2001). Verschuren and Arts (2004) have segmented the process of influence into stages, starting with access to the decision-making process—a power-related factor considering the position of an individual in the decision-making structure. Once access is available, individuals need to make his or her information or preferences known to other participants, and the other participants need to be exposed to or hear the information and preferences put forth. Last, participants need to correctly understand the information and preferences in order for any action they take is influenced by the information and preferences.

In this study of Atlantic Herring stock survey data derived from collaborative research, network analysis produces greater understanding of three stages of the influence process—

access, making information known, and exposure by others to the alternative forms of stock survey data. While more research would be needed to more fully assess relative influence of these two stock survey data sources, particularly related to whether the scientists and managers correctly understand and act upon acoustic survey data, this study takes unprecedented steps toward understanding the influence of collaborative industry-science stock survey data.

2. The Case of Atlantic Herring

Atlantic herring are a small, oily schooling pelagic fish distributed along the North American Atlantic Coast from Cape Hatteras, North Carolina in the United States to the Canadian Maritime provinces. The Atlantic States Marine Fisheries Commission (ASMFC) reported “herring may be the most important fish in the North East United States because of its vast role in the ecosystem and its importance to the fishing industry” (ASMFC 2007a, 1). 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 (NEFMC 2003). Atlantic herring feed on zooplankton and serve a critical food web position between lower and upper trophic levels.

Herring are an important commercial fishery, providing bait for lobster, blue crab and tuna fishermen. The fishery developed in the late 19th century, stimulated by the simultaneous development of a canning industry and lobster fishery. In the early 1960s a foreign fishery contributed to a collapse of the offshore herring industry in the U.S., having increased the average annual landings from 60,000 metric tons through 1940s and 1950s to a peak of 470,000 metric tons in 1968 (ASMFC 2007a). The weir was the predominant gear used in the herring fishery until the 1940s when stop seines became more prevalent. Today, purse seines and mid-water trawls (mobile gears) are the gear of choice (ASMFC 2007a).

2.1 Atlantic herring management

The ASMFC and the New England Fishery Management Council (NEFMC) jointly regulate herring in state and federal waters in the U.S., respectively. The National Marine Fisheries Service (NMFS) in the National Oceanographic and Atmospheric Administration (NOAA) manages marine fisheries resources in the U.S. through the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson), which was first enacted in 1976 and amended in 1996 and 2007. In addition, NMFS applies the Marine Mammal Protection Act, Endangered Species Act, Coastal Zone Management Act, and National Marine Sanctuaries Action, along with international fisheries agreements, in their management of fisheries, including Atlantic Herring.

Magnuson established eight regional management councils, comprised of voting representatives from state agencies and citizens representing recreational and commercial fishing interests, conservation organizations, and other important stakeholder groups. There are non-voting representatives often from coordinating agencies. The Councils develop recommended fishery management plans (FMPs) for fish stocks, including specific management measures (e.g., regulations for gear restrictions, fishing seasons, quota limits, licensing strategies, etc.); NMFS has the final approval. FMPs must comply with the ten national standards in Magnuson, aimed at preventing overfishing, achieving optimal yields, making use of best scientific information, minimizing by-catch of non-target species, and considering fishing communities.

The Councils establish Plan Development Teams (PDTs) for particular species, comprised of scientists and staff from NMFS, Council staff, state agencies, and research institutions. PDTs review stock assessment and other scientific findings prior to drafting regulatory measures and developing recommendations for the species-specific oversight committee, comprised of a sub-set of the Council members. Advisory Panels (AP) are formed for each fishery among recreational and commercial fishermen, charter boat operators, buyers, sellers, consumers, and other knowledgeable and interested stakeholder groups to provide advice and input. The oversight committee presents management strategies and measures to the full Council for approval and formation of a final FMP, which are then presented to NMFS for final approval.

Individual states are responsible for managing fisheries in state waters (within three miles offshore), although they must be consistent with federal rules. Established in 1942, the ASMFC is comprised of three Commissioners from fifteen Atlantic coast states from Florida to Maine, along with the director of the state's marine fisheries agency, a state legislator, and an appointed knowledgeable and interested individual. Each state has one vote. The ASMFC adopts FMPs for coastal fisheries, although with limited regulatory authority, it works cooperatively with state regulatory agencies on interstate fisheries management, research and statistical analysis, fisheries science, habitat conservation, and law enforcement.

Atlantic herring is managed as one stock throughout its range in the Gulf of Maine and on Georges Bank. Nonetheless, there is evidence of three distinct stocks existing in the region, which have different spawning times, locations and biological characteristics, but the lack of quantitative data on relative stock sizes has led to difficulties in assessing their individual stock status (ASMFC 2006, Overholtz et al. 2006).

A federal FMP became effective in January 2001 comprised of a quota system with Total Allowable Catches (TACs)—when 95% of the annual quota is caught in a single management area, the area is closed until the start of the following fishing year. There were four management areas established, and the FMP required vessel, dealer, and processor permits, reporting requirements, and restrictions on vessel sizes. Later modifications in 2002 and a joint Federal-State modification in 2007, adjusted management areas, established greater gear restrictions, limit access to the fishery, and adjusted quota calculations. (NEFMC 2002, NEFMC 2006)

In this study, we were particularly interested in the 2007 FMP decision-making process. A joint NEFMC-ASMFC PDT was established with fifteen members from NMFS, state agencies, universities, and staff from both NEFMC and ASMFC. On the federal side, there were an eight member oversight committee comprised of Council members and one Councilor from the Mid-Atlantic Fisheries Management Council, and a NEFMC AP comprised of fifteen industry groups ranging from New Jersey to Maine. The ASMFC Atlantic herring technical committee consisted of nine individuals, five of whom also served on the joint PDT. The ASMFC Atlantic herring AP consisted of thirteen members, eight of whom also served on the NEFMC Atlantic herring AP.

2.2 Stock survey data sources

There are multiple sources for data on Atlantic Herring stocks in the Northwest Atlantic. Foremost, the U.S. and Canadian federal governments administer trawl surveys. The U.S. federal government has conducted annual acoustic surveys offshore on Georges Bank and Nantucket Shoals for over forty years. Further, the herring fishing industry and scientists at a private research institution conduct collaborative acoustic survey research inshore on spawning beds.

The Northeast Fisheries Science Center (NEFSC) conducts four bottom trawl surveys a year: 1) autumn survey that has been ongoing since 1963; 2) a spring survey initiated in 1968; 3) a winter survey started in 1991; and 4) a Northern Shrimp survey. The spring and autumn bottom trawl surveys supply synoptic coverage of continental shelf waters from Cape Hatteras, North Carolina to the Scotian shelf in Canadian waters. The winter survey provides opportunistic coverage from Cape Hatteras to the southern border of Georges Bank. Each survey contributes data to the long-term relative indices of abundance, distribution, and biomass for finfish and key marine invertebrate species (Stauffer 2003). The Canadian federal Fisheries and Oceans department (DFO) conducts similar bottom trawl surveys in Canadian waters.

U.S. and Canadian bottom trawl surveys have been used to model herring stock trends and abundance, although there have been noted challenges and limitations. For example, environmental factors, altered herring behavior, and changes in survey gear or timing have been associated with significant annual variability. Further, the U.S. trawl survey data from the winter, spring and autumn have proven difficult to interpret because during these seasons and in the areas sampled, the stock complex is mixed and disaggregation is difficult. (Overholtz, et al. 2006).

In part to address some of these limitations, acoustic survey designs have been discussed, refined, and implemented in the Northwest Atlantic. The acoustic survey designs and protocols were developed in part through a series of workshops among state and federal agencies, academic and research institutions, and the fishing industry in the late 1990s and early 2000s (Michael and Yund, 2001). In 1998 an acoustic research and monitoring survey was established by NMFS to assess pre-spawning herring offshore on Georges Bank, followed in 1999 by a collaborative science-industry acoustic survey covering inshore, spawning components of the stock along the Maine—New Hampshire—Massachusetts coast.

To develop a collaborative research program to collect fishery dependent acoustic data, an initial feasibility project was conducted and revealed that relatively inexpensive scientific-grade acoustic systems could be added to commercial fishing vessels to collect substantial acoustic data in the course of normal fishing operations (i.e., fishery dependent data). However, performing fishery independent scientific surveys with commercial herring vessels proved substantially more difficult (Scheirer et al., 2005). A full-scale fishery independent acoustic survey was conducted with more success in 1999, using a commercial groundfish vessel. Since its inception, the program has experienced irregular funding certainty, periodic staff turnover, inconsistent commercial vessel participation from groundfish and herring fisheries, and a shift in lead scientific responsibilities between a State marine resource agency and a private research institution. Further, new acoustic systems were tested and deployed. Nonetheless, nearly a decade of annual surveys have covered coastal waters from Eastern Maine to Cape Ann, Massachusetts to assess distribution, abundance and biomass of spawning Atlantic herring (Salerno 2007). After the first six years of full-scale collaborative industry-science acoustic surveys, an independent peer review of the project was undertaken to certify the results and receive recommendations for standardized design and operations. (Scheirer et al., 2005)

In March 2005, the Northeast Consortium funded and facilitated an independent peer review of the herring acoustic survey. The review panel concluded that acoustic surveys are an appropriate way to survey herring in this area and recommended that this technique be continued in the inshore Gulf of Maine due to the lack of knowledge about the timing and locations of the significant spawning events for herring in this region. It also recommended that future surveys focus on estimating biomass using a broad-scale systematic survey approach, as well as developing an annual sentinel acoustic survey of the important spawning grounds. Results of the peer review were presented to the federal and state fishery management entities (NEFMC and the ASMFC) in May 2005 and were adopted in subsequent acoustic surveys (Salerno 2007).

2.3 Stock assessment process and use of survey data

Converting survey data into an overall stock assessment of abundance, distribution, and biomass and scientific advice on quotas takes place through scientific peer review processes. Given the U.S.—Canada transboundary nature of Atlantic herring and the fishery, there are joint U.S. and Canadian stock assessment processes in place. Since 1998, the Transboundary Resources Assessment Committee (TRAC) has reviewed stock assessments and projections necessary to support management activities for shared resources across the U.S.—Canada boundary in the Gulf of Maine-Georges Bank region. These assessments provide advice to the federal and state resource managers on the status of fish stocks and likely consequences of management alternatives. The TRAC co-chairs (one DFO and one NMFS appointee) identify co-experts (one from DFO and one from NFMS) responsible for coordinating the data preparation, leading the analysis, facilitating the working paper production and presentation, and inviting independent peer reviews. The TRAC drafts scientific consensus stock assessment reports and presents the results to U.S. and Canadian fisheries managers. (DFO 2009)

The TRAC produced 2003 (Overholtz, et al. 2004) and 2006 (DFO and NMFS, 2006) reports, referencing several sources including NMFS winter, spring and autumn bottom trawl surveys, Canadian winter bottom trawl surveys, U.S. and Canadian larval herring surveys from U.S. 1971—1994 and Canada 1987—1995, the U.S. acoustic surveys on Georges Bank, and inshore herring acoustic surveys done by a State agency in coordination with industry (i.e., fisheries independent data) (Overholtz, et al. 2004). The fisheries dependent data from the collaborative acoustic survey research have not been regularly used, although prior to the 2005 peer review of the collaborative industry-science survey, data from the acoustic survey had been cited by Overholtz, et al. (2004) and in the NMFS Stock Assessment and Fishery Evaluation

(SAFE) reports for Atlantic herring (Northeast Consortium 2006). Since the 2005 peer review of the collaborative acoustic survey concluded that the survey to date could not be considered a consistent time series of stock assessment data, the data has been used more qualitatively by the TRAC (Northeast Consortium 2006).

To further assess the influence of the collaborative acoustic survey research data, we conducted a network analysis on the 2007Atlantic herring FMP decision-making process. It provides additional insights into the access of and exposure to the collaborative survey research by the TRAC (scientific stock assessment) and PDT (fisheries management).

Methods

Social network analysis gathers and analyzes data from individuals or organizations regarding the links or connections among the individuals or organizations (i.e., actors). Social networks can assess a wide range of resources, authority, information, and levels of interdependence among actors and it has utility in illustrating the structure of formal and informal networks and resource flow (Scott 2000). The links and the relationships are of primary analytical interest rather than the actors. Communication network analysis is a social network analysis sub-field that focuses on the characteristics of specific communication pathways and the patterns of connections that communication produce (Monge and Contractor 2003). Rather than examining broader social structure (e.g., resources, authority, information, and levels of interdependence among actors), communication network analysis concentrates on the flow of data, information, knowledge, images, symbols and other forms of communication among network actors.

Surveys and interview protocols are used to gather data for communication network analysis. Software (in this study, InFlow, www.orgnet.com) is readily available to analyze and graphically represent 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.

A 1—5 Likert scaled frequency of communication is a common network analysis measure (Scott 2000; Monge and Contractor 2003), and a critical factor in social capital (Putnam 2000) and multi-party planning (Forester 1999, Innes 1998), although there are other measures used to access the value and significance of connections.

A questionnaire was administered (web-based, hard copies mailed or handed to participants, and phone interviewed) among a list of 249 participants identified in the public records as participating in the Atlantic herring FMP process, and confirmed as participants by key informants (i.e., lead government staff). The individuals participating in the collaborative industry-science acoustic survey and the TRAC stock assessment process were noted so that their location in the network map could be overlaid onto the maps. Standard survey data collection procedures and quality control standards were used in the design and administration of the questionnaire (Dillman 1999).

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. We solicited respondents to the questionnaire through a series of email and solicitation letters throughout 2007. In November 2007 and January 2008 the researchers conducted face-to-face interviews with five key participants.

Data on the links (i.e., Likert scaled frequency measures) and the nodes (i.e., demographic identifiers for the individuals) were entered into a database for importation into the InFlow software to generate communication network maps and run the network connectivity measures. An algorithm from mathematical graph theory is applied by most network analysis software; the algorithm in InFlow spatially orients nodes in a map based upon their relationship with each other. Once the network is mapped, we ran connectivity metrics that measure what is mapped. Several measures of network structure and operation are available, although this study was focused on connectivity and specific pathways between individuals involved in the stock assessment and fisheries management processes. Thus, network size, density, and path lengths were analyzed, along with measures of an individual's network connectivity (degree, betweeness, closeness). Preliminary findings and communication network maps were presented to and discussed with NEFMC staff in November 2007 and the Atlantic herring PDT in August 2008, aiding interpretation (e.g., further qualitative characteristics of communication links and network function) and enabling further data gathering.

Results

Overall, the communication network map of Atlantic herring fisheries management (Figure 1) reflects a snap shot in time (winter/spring 2007) among 146 individuals communicating on a weekly basis, consisting of state agencies from Maine to North Carolina, U.S. and Canadian federal fisheries agencies, several industry sectors (e.g., directed herring fishery, lobster fishery, hook and line sector), and four non-governmental organizations. The network had low density (1%) illustrating limited interaction across all parties. Certain individuals had higher centrality measures than others—for example, the node located in the center of the Figure 1 map demonstrated four times more links to others (degrees) than the next highest member of the network and thus illustrates a high overall activity level in the network. He was among the highest in closeness scores reflecting access to many others in the network, and had betweeness scores three times higher than the next ranked network member, illustrating control over information flow across the network. Nonetheless, the weighted average path length (2.5) of the entire network reflects a network that is compact given its' size, i.e., on average any two individuals in the network are less than three links away from each other.

Figure 1. Weekly Communication Network, Atlantic Herring FMP process, 2007.

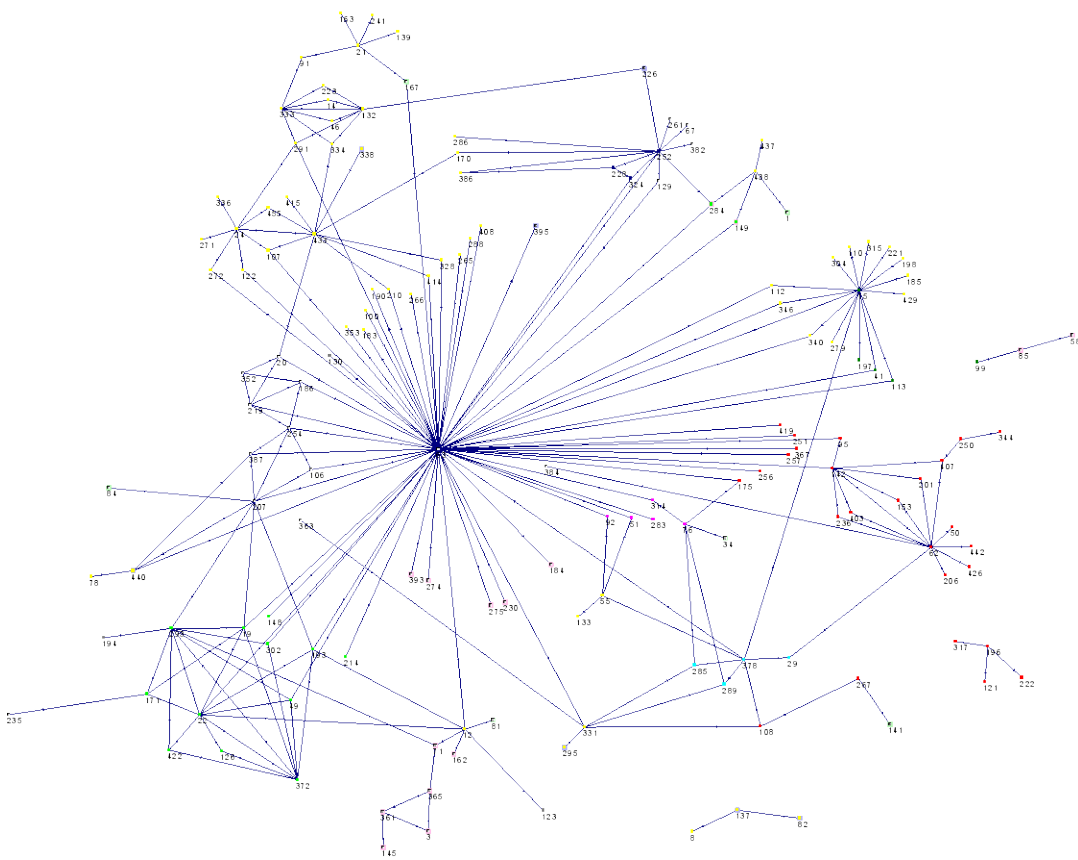
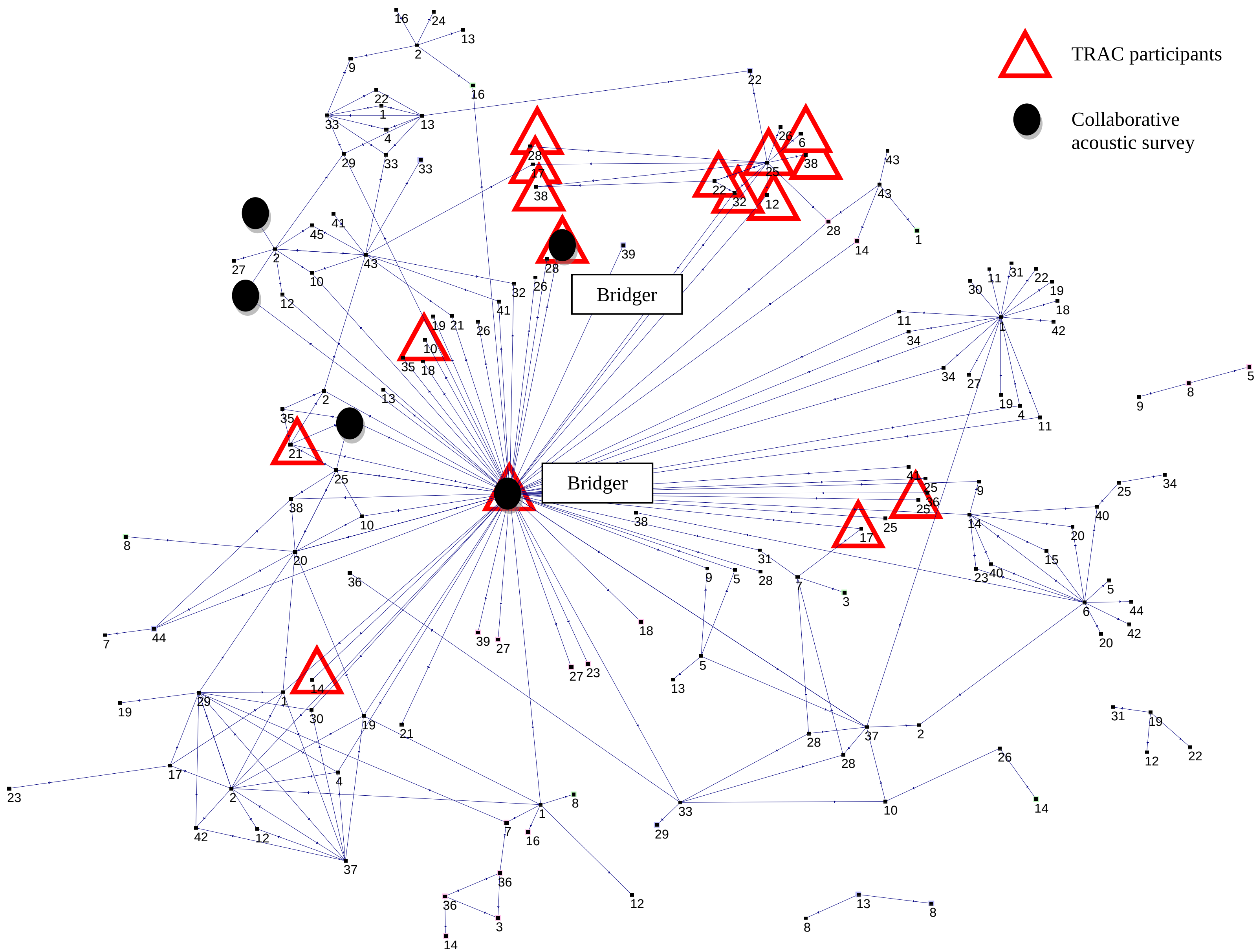


Figure 2 below overlays the participants in the collaborative acoustic survey research and the participants in the TRAC stock assessment process onto the overall Atlantic herring FMP network to assess the connectivity between collaborative researchers and the primary scientific advisory committee on stock assessment to management. Five of the twenty-four participants in the collaborative acoustic survey research (21%) participated in the herring FMP process at a weekly frequency, whereas fifteen of the twenty-eight TRAC participants (54%) were parties to the herring FMP process. Two individuals, one from industry and one from a state regulatory agency, participated in both the collaborative acoustic survey and the TRAC, thus contributing a bridging function. The weighted average path length for the sub-group of TRAC plus collaborative acoustic survey participants is 2.4, and thus this sub-group alone has the potential to share information across its parties broadly within a week. Therefore, the sub-group of TRAC and collaborative acoustic survey researchers function like the overall Atlantic herring FMP network—sufficient access and exposure across participants to enable influence; yet dependent upon the bridgers to achieve connectivity.

Third, Figure 3 below overlays the PDT participants with the TRAC and collaborative acoustic survey researchers onto the overall Atlantic herring FMP network, in order to assess the potential science-to-management impacts. Both the TRAC and the collaborative research participants have a single overlapping individual directly on the PDT, which provides direct access and a bridge between the TRAC and collaborative research information into the PDT deliberations. However, the combined TRAC, collaborative research, plus PDT membership, as a sub-group, is more diffuse than the overall Atlantic herring FMP network with a weighted average path length extending to 2.7, i.e., the membership have more communication links between individuals than seen in the previous two analyses. Therefore, these two bridging individuals, both scientists with a state regulatory agency, serve information sharing roles.



<u>Figure 2: Atlantic herring FMP network map: Overlay TRAC and Collaborative Stock Survey Participants</u>

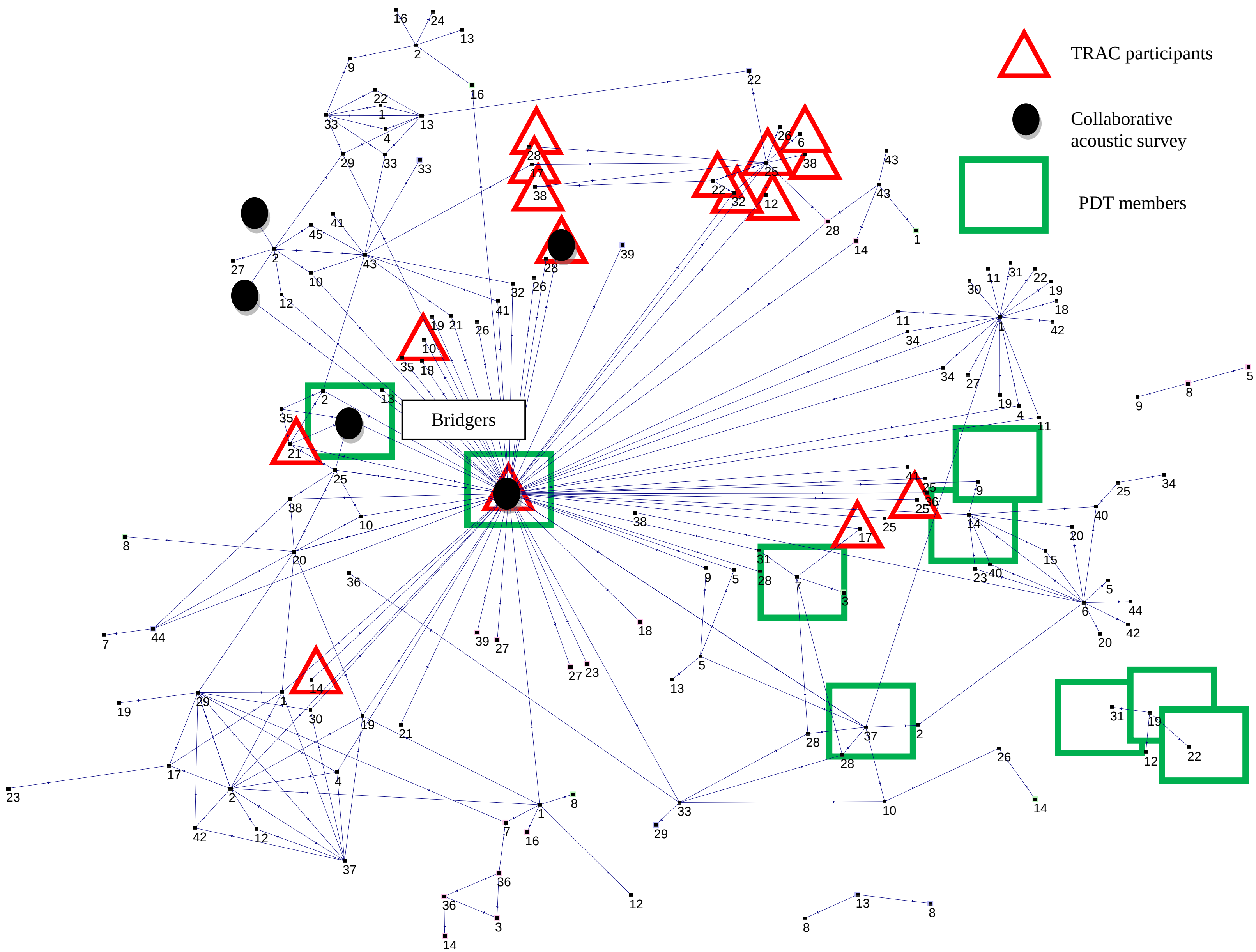


Figure 3: Atlantic herring FMP network map: Overlay TRAC, Collaborative Stock Survey, and PDT Participants

Discussion

The Atlantic herring FMP network displays strong connectivity across a wide array of stakeholders, with a weighted average path length of 2.5. Friedkin's (1983) study of organizational behavior identified the threshold number of links beyond which information becomes inaccessible to a network member. Information or resources within two links of someone is readily available and utilized in decisions. In the range of 2-3 links away, decision-makers may be generally aware of the information and its availability; however it becomes less clear and decision-makers are less conscious of its availability. At 3-4 links away and greater, the information is beyond a decision-maker's horizon of observability.

The low density (1%) of the Atlantic herring FMP network is due to the size of the network and the significance of bridgers, i.e., individuals connecting otherwise disparate groups in the network who are channeling information flow. Increasing density would reflect more individuals linking with one another and the network map would become an increasingly dense ball of links. The bridgers enable the network to efficiently share information broadly and quickly (within a week). Overall, all individuals in the Atlantic herring FMP network, including the collaborative acoustic survey researchers, can use the pathways in the network to access others and make others aware of their information in order to influence decision-making. Further research would be needed to determine whether the collaborative acoustic stock survey data is understood by members of the network and acted upon, once they have been made aware of it. Nonetheless, the network pathways exist through which influence could be achieved.

Second, when overlaying the collaborative researchers with the specific decision process for analyzing stock survey data and deriving stock assessments (i.e., the TRAC), again the collaborative researchers demonstrated sufficient access to ensure their information and data were available to the stock assessment scientists. Document review confirmed that the TRAC scientists were aware of the availability of the collaborative research acoustic survey data (Overholtz, et al. 2006). Further, two individuals (one industry leader and one state regulatory agency scientist) bridged the TRAC and collaborative research acoustic survey efforts. The effectiveness of the bridgers are enhanced by the potential credibility of an industry representative and a marine scientist in the state agency among the broad stakeholder interest in the larger Atlantic herring FMP network. Further, not all networks are equal; networks with bridgers to diverse resources function more adaptively and creatively than networks with high density and many tight links (Newman and Dale, 2005). Thus effective bridgers provide greater ability of the Atlantic herring stock assessment process to be creative and address the challenges that has been acknowledge in herring stock assessment (Overholtz, et al., 2006).

Third, the decision support framework of fisheries management establishes the primary role for the PDT in drafting the FMP for NMFS and fisheries management council approval, including reviewing stock assessment advice from the TRAC and other scientific findings prior to drafting regulatory measures and developing recommendations. Not all communication is equal; some have more significance in transmitting particular types of information or resources (Granovetter 1983), and thus, pathways to the PDT are also an important indicator of potential influence. Here too both the TRAC and the collaborative research acoustic survey have access through their members participating directly on the PDTs. Further, the bridgers have even greater significance as the sub-group of TRAC participants, collaborative acoustic survey researchers, and PDT members are more communicatively diffuse (weighted average path length of 2.7) than the overall Atlantic herring FMP network (2.5). A powerful 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 sub-groups, and thus provides advantages in identifying whom to connect to and how (Burt 2003).

In sum, the Atlantic herring FMP network structure and function supplied the level of connectivity needed to provide collaborative acoustic survey researchers with access to and awareness of their information in both the scientific stock assessment process (TRAC) and the management process (PDT). While the acoustic survey is not fully institutionalized, as demonstrated by its annual, but inconsistent implementation with funding uncertainty and partner turnover (Salerno 2007; Scheiner, et al. 2005), bridgers served critical roles to ensure potential influence. While bridgers serve important functions in the Atlantic herring FMP network and sub-groups analyzed in this study, bridgers proved slightly more important to achieving influence in the science-to-management arena than they are in the collaborative research-to-stock assessment context because the network path way distance is greater in the science-to-management context. Nonetheless, the dependent upon bridgers introduces vulnerability to the network function. If bridgers leave the network, considerable connectivity would be lost. This is particularly true for the connectivity of the collaborative acoustic survey data because one bridger is simultaneously a participant of the collaborative acoustic survey research, TRAC (stock assessment) and PDT (management) groups.

Conclusion

Gibbs (2008) suggested that fisheries management could be conceptualized as a network. This study analyzed Atlantic herring fisheries management process in the U.S. as a network in order to assess the integration of collaborative industry-science stock survey data into the stock assessment and fishery management processes. Specifically, do collaborative acoustic stock surveys have a pathway into fisheries science and management and do they make a difference? We took an important first step in researching these questions and found that the collaborative acoustic survey information did have access to both the science and management processes and that those participating in the science and management were aware of the acoustic survey information. To achieve this potential for influence in stock assessments and fisheries management, key individuals in the governance network had to serve critical bridging functions. In other words, only a few individuals channeled the collaborative acoustic survey information into the stock assessment and management processes, and thus there are some vulnerabilities to turnover which could severe the links that currently exist.

Collaborative science—industry research will be successful in having data and results used in stock assessment and fishery management only if the communication pathways exist to make the participants of the institutionalized mechanisms for stock assessments (in this case, a joint U.S.—Canada scientific panel) and fisheries management (in this case, a joint Federal—state plan development team) aware of the data and results. The communication pathways must also make those data and results available and contribute to increasing the understanding of it in order to influence stock assessments and fisheries management. The collaborative acoustic survey research on Atlantic herring has taken important steps toward achieving this level of connectivity in the stock assessment and fisheries management network.

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