Using Social Network Analysis to Identify Communication Patterns among Albemarle-Pamlico National Estuary Partnership Partners

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Abstract

As one of the original "estuaries of national significance" designated by the Clean Water Act of 1987, the Albemarle-Pamlico National Estuary Partnership (APNEP) works to protect and restore the valuable resources of one of the largest estuary systems on the Atlantic coast. In order to accomplish its mission with a limited budget, APNEP engages in cooperative projects with partners from federal and state government agencies, environmental non-profits, academic institutions, and municipal planners. As APNEP moves forward with the implementation of its 2012 Comprehensive Conservation and Management Plan, communicating with existing partners, accessing potential partner organizations, and encouraging information sharing between environmental professionals in the region is crucial to efficiently accomplishing management plan objectives.

In order to assess how APNEP interacts with its partners and the larger environmental community in the Albemarle-Pamlico watershed region, a social network analysis was developed to map individuals and organizations that regularly communicate about environmental issues in the area. Using snowball survey methodology to identify individuals and organizations that are involved in watershed management issues, regional social network maps were created using the statistics program R. The social network maps include representations of communication links between sectors, network connectedness, the relative importance of specific individuals within the network, and a geographic representation of the connections between environmental professionals in the region. Analysis of the network maps identified geographical and organizational gaps in APNEP's outreach efforts, as well as key individuals whose network position could be leveraged to improve the efficiency of information transfer among the larger network. The structure of the various network maps provided implicit recommendations for APNEP to improve its outreach efforts to establish new partnerships and exchange information with the regional environmental community. As a long-term project, social network analysis can help APNEP target its limited communications resources to increase collaboration and share information efficiently with stakeholders.

Introduction

The Albemarle-Pamlico Estuary System

The Albemarle-Pamlico estuary encompasses eight sounds in North Carolina and Virginia. The Albemarle and Pamlico Sounds are the two largest bodies of water in the estuary, but the system also includes the smaller Back, Bogue, Croatan, Currituck, Core, and Roanoke Sounds[1]. The Albemarle-Pamlico estuary covers a land area of 28,000 square miles, including 2 million acres of estuarine water, and 10,000 miles of streams and rivers[2]. Its headwaters extend into the mountains of Virginia and the North Carolina piedmont and wind through wetlands, forests, farmland, and cities that affect the water quality of the downstream estuary[3]. Biophysical resources of the Albemarle-Pamlico estuary include the fresh, brackish, and salt water found in the watershed, and the plants, animals, and other organisms living in the waters and surrounding land area. The estuary also provides ecosystem services such as transportation of runoff and waste water, water filtration by shellfish, carbon storage in estuarine plants, and food resources for humans in the form of fish and shellfish.

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[1] (2012). Comprehensive Conservation and Management Plan. The Sounds. Raleigh, NC, Albemarle-Pamlico National Estuary Partnership.

[2] (2012). Comprehensive Conservation and Management Plan. The System, Albemarle-Pamlico National Estuary Partnership.

[3] Ibid.

Many stakeholders use the resources of the Albemarle-Pamlico estuary system. About 3.8 million people live, work, and play within the Albemarle-Pamlico watershed area[4]. Residents and visitors in both states depend on the estuary for environmental services, recreational opportunities, seafood, and a cultural connection to historic traditions such as fishing, hunting, and sailing[5]. Tourism operators also use the resources of the estuary as the foundation of their livelihoods, with coastal tourism in North Carolina contributing approximately $15 billion per year to the state's economy[6]. Conservation organizations that advocate for the protection and restoration of the estuary's natural resources, educational institutions such as universities, visitor centers, and public aquariums that teach people about the ecology and heritage of the Albemarle-Pamlico region, and municipal land use planners that develop regulations for areas within and around the estuary are other key stakeholder groups that influence watershed use[7].

Problem Definition and Project Motivation

The Albemarle-Pamlico National Estuary Partnership (APNEP) is a federal-state cooperative effort whose mission is to restore and protect the valuable environmental, economic, and social resources of the Albemarle-Pamlico estuary system. APNEP works to influence a network of varied stakeholders, manage a watershed boundary crossing North Carolina and Virginia, secure funding from federal and state agencies, and establish partnerships with over 150 NGOs, academic institutions, and local municipalities. The complex stakeholder structure, combined with APNEP's lack of direct authority to regulate behavior, has impacts on how efficiently and economically APNEP is able to achieve its mission and management plan

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[4] Hawhee, J. (2013). "Demographics and Density." Soundings.
[5] (2012). Comprehensive Conservation and Management Plan. The Sounds. Raleigh, NC, Albemarle-Pamlico National Estuary Partnership.
[6] (2011). 2011 Visitor Spending Fast Facts. Raleigh, NC, North Carolina Department of Commerce.
[7] (2012). "Albemarle-Pamlico National Estuary Program Partners."

objectives. Shared responsibilities layered over multiple government agencies and between non-profit, academic, and private sectors occasionally result in failure to convey important information to stakeholders in a timely, inclusive, and coordinated manner[8].

Although there is good reason for APNEP to act as a communications hub among stakeholders, given its ecosystem-based management approach that connects conservation projects and partners from the watershed's headwaters to the coast, there is no clear directive for how APNEP should implement the current management plan's call for increased engagement, efficient information exchange, and coordinated conservation efforts[9]. In order to implement the management plan's objectives, APNEP is working to maximize the efficiency of information transfer between APNEP and its project partners, using both its communications strategy and a formal analysis of the regional partner network[10]. A better understanding of how relevant watershed-related information flows across the Albemarle-Pamlico region can prevent redundancy of effort among partner organizations, and help APNEP identify the people and organizations that would be most helpful to implement a given project[11]. Solutions to improve the efficiency of APNEP's communications efforts are crucial to keeping within funding limits and achieving management plan objectives.

Background

Creation and Management of the Albemarle-Pamlico National Estuary Partnership

The Albemarle-Pamlico Estuary is one of 28 designated estuaries of the National Estuary Program established in Section 320 of the Clean Water Act of 1987 to recognize the

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[8] Hawhee, J. (2012). Questions about APNEP. K. Brogan. Beaufort, NC.
[9] (2012). Comprehensive Conservation and Management Plan. Component D: Engage. Raleigh, NC, Albemarle-Pamlico National Estuary Partnership.
[10] (2012). Communications Strategy 2012-2014. Raleigh, NC, Albemarle-Pamlico National Estuary Partnership.
[11] Urban, D. (2012). Social Network Analysis- Where to Begin. K. Brogan. Durham, NC.

environmental, cultural, and social importance of nationally significant estuarine resources[12]. At that time, the Environmental Protection Agency funded the initial Albemarle-Pamlico Estuarine Study (APES) to contribute to a national goal of restoring and protecting the water quality and ecological integrity of significant estuarine areas.

The National Estuary Program legislation is intentionally broad, designed to address a range of influences on estuarine health and to engage local communities in managing their estuaries[13]. The Estuaries and Clean Water Act of 2000 updated the National Estuary Program legislation with directives to strengthen monitoring and research through technological innovations associated with the National Estuarine Research Reserve System[14]. The update ensures that restoration projects are based on sound science and the best available data-gathering techniques[15].
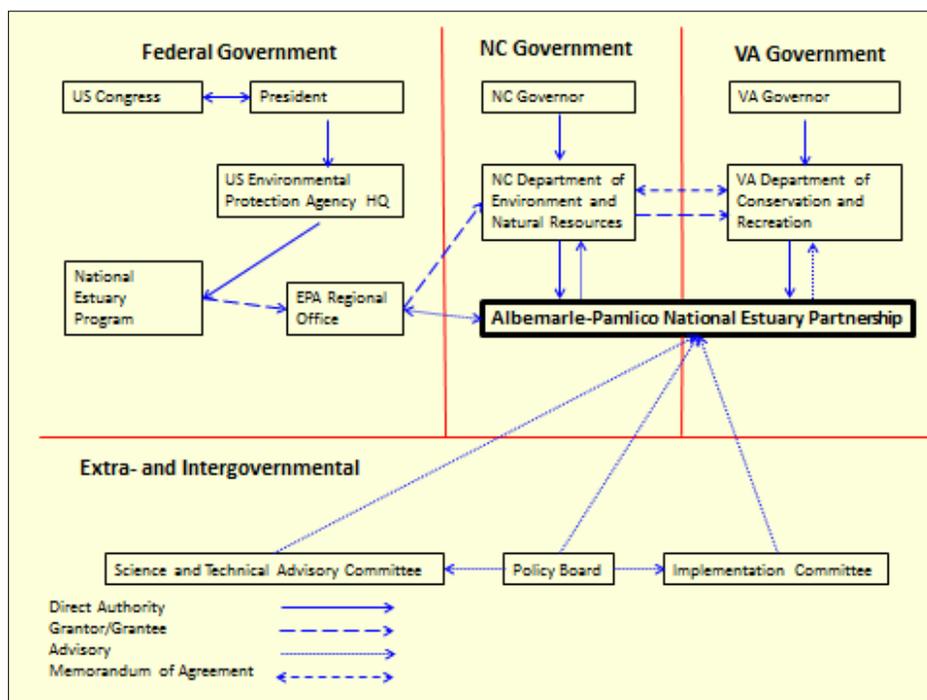
One reason social network analysis is applicable to APNEP's policy stems from its complex governance structure and position within federal and state agencies. At the federal level, the

[12] (1987). Federal Water Pollution Control Act. 320(f)(2). U. S. Congress. Washington DC.
[13] (2012). Estuaries and Coastal Watersheds: National Estuary Program Overview. E. P. Agency. Washington DC.
[14] (2000). Estuaries and Clean Waters Act of 2000. 835. U. S. Congress. Washington DC.
[15] Ibid.

United States Congress is responsible for authorizing the budget for the Environmental

Protection Agency (EPA), which in turn funds the National Estuary Program[16]. For APNEP, this

federal funding is granted to the North Carolina Department of Environment and Natural

Resources (NCDENR)[17]. NCDENR is responsible for hosting the North Carolina staff of

APNEP with office space and administrative support[18]. The Virginia Department of

Conservation and Recreation (VADCR) is subject to a memorandum of agreement with

NCDENR regarding the structure of the program, and an APNEP staff member located in

Virginia is paid through EPA grant money administered by NCDENR[19]. Municipal governments

in North Carolina and Virginia are also responsible for enacting and enforcing policies related to

the health of the estuary that affect residents and visitors to specific localities[20].

Comprehensive Conservation and Management Plan

Section 320 of the Clean Water Act mandates that each National Estuary Program

develop and implement a long-term Comprehensive Conservation and Management Plan

(CCMP, hereafter referred to as "management plan" or simply "plan") for their estuary,

containing specific actions to address water quality, habitat, and living resource challenges[21].

The management plan must recommend:

"Priority corrective actions and compliance schedules addressing point and nonpoint

sources of pollution to restore and maintain the chemical, physical, and biological integrity of the

estuary, including restoration and maintenance of water quality, a balanced indigenous

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[16] (2012). Estuaries and Coastal Watersheds: National Estuary Program Overview. E. P. Agency. Washington DC.
[17] Hawhee, J. (2012). Questions about APNEP. K. Brogan. Beaufort, NC.
[18] Ibid.
[19] (2001). Memorandum of Agreement for Albemarle-Pamlico National Estuary Program. N. C. D. o. E. a. N. Resources and V. D. o. C. a. Recreation.
[20] (2012). "Albemarle-Pamlico National Estuary Program Partners."
[21] (1987). Federal Water Pollution Control Act. 320(f)(2). U. S. Congress. Washington DC.

population of shellfish, fish and wildlife, and recreational activities in the estuary, and assure that the designated uses of the estuary are protected"[22].

The plan is considered the primary guiding document for each federally designated National Estuary Program. The Clean Water Act amendments of 1987 mandate that each national estuary program detail its plan to improve the designated estuary, but the programs are non-regulatory and do not have legal authority to change individual behavior[23]. The first management plan for APNEP was approved in 1994, with a major goal of "engaging the public to make connections between the natural environment and services provided by the [estuary] system"[24]. The most recent APNEP management plan was approved by the Policy Board in 2012, and is designed to be reviewed and updated over its ten-year timeframe as part of an adaptive management approach.

The role of relationships and partnerships between APNEP and relevant stakeholders is an important focus of the 2012 management plan as emphasized in the opening pages of the document:

"As a [National Estuary Program], much of APNEP's work is achieved through collaborative partnerships and leveraged resources with others interested in environmental and natural resource management in the region. Many of the objectives and actions in the CCMP rely on involvement from key governmental, non-profit, and other partners. In a time of growing

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[22] Ibid.
[23] Ibid.
[24] (2012). "APNEP's History."

austerity, the continued success of our program is dependent on the success of these partnerships"[25].

The CCMP forms the basis for cooperation and collaboration among implementing partners for the ten year period covered under the plan. While it is clear that initiating and fostering partnerships and collaborative activity with a wide range of stakeholders involves substantial information transfer and communication between APNEP and partner organizations, the management plan is less specific about the role and responsibility of APNEP as an information and data resource and channel for communications between stakeholders.

Social Network Analysis as a Communications Solution

To improve its outreach and communications capacity to connect with partners and share relevant information with key stakeholder groups, APNEP must better understand which individuals and organizations are active in Albemarle-Pamlico watershed management, and how these entities are connected to each other and to APNEP. While APNEP staff have a thorough qualitative understanding of key individuals and organizations working in the region, social network analysis can help APNEP rigorously and objectively examine the structure of the Albemarle-Pamlico estuary stakeholder network. Social network analysis creates a network map focused on the connections and interactions between people, and can provide useful information about information transfer and professional relationships within the region. APNEP would like to build a social network analysis framework to monitor and study the relationships between individuals and organizations that work with APNEP to achieve its mission. The goal of my Master's Project is to create a preliminary map of APNEP's social network to provide a better

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[25] (2012). Comprehensive Conservation and Management Plan. <u>Executive Summary</u>. Raleigh, NC, Albemarle-Pamlico National Estuary Partnership.

understanding of the players involved in watershed conservation and management at the regional level, and provide initial recommendations based on the analysis that identify key players in APNEP-related information transfer, as well as areas of weak communications and outreach where APNEP can focus its improvement efforts.

Social network analysis uses network and graph theory to describe actors and relationships using a structure of nodes and edges. Nodes are the actors, individuals, or organizations that interact with other nodes in a given network. Connections between any two nodes in a network are symbolized by edges, which can be characterized as relationships, communication, or joint action[26]. The combined collection of edges and nodes denoting the connections between individuals or organizations through a specified criterion creates a network map illustrating how the various contributors to the network interact. In social network analysis, actors are described by their relationships, not by individually identifiable characteristics such as gender or age, making the relationships that connect the actors just as important as the actors themselves[27].

The formal study of social networks began in the 1930s, and the past decade has seen an increase in scholarly attention to how individuals and organizations fit into larger webs of human interaction[28]. Social network analysis is based on several key principles. One underlying principle is that network structure matters. In network analysis, the location of an individual node on the network map has implications for the outcomes or characteristics of that node[29]. Second, studying how individual connections form patterns within the larger network is important to the

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[26] Stephen P. Borgatti, A. M., Daniel J. Brass, Giuseppe Labianca (2009). "Network analysis in the social sciences. ." Science **323**.

[27] Robert A. Hanneman, M. R. (2005). Introduction to Social Network Methods. Riverside, CA, University of California Riverside.

[28] Stephen P. Borgatti, A. M., Daniel J. Brass, Giuseppe Labianca (2009). "Network analysis in the social sciences. ." Science **323**.

[29] Ibid.

understanding the full network structure[30]. Social network analysis also aims to characterize different types of ties that define interaction between nodes, with common ties being "similarities, social relations, interactions, or flows"[31].

The results of a social network analysis focusing on connections among regional conservation practitioners in coastal Oregon were recently reported in the journal *Conservation Letters*[32]. Researchers used a snowball method where 47 original survey respondents identified 297 other conservation collaborators to form the core of the network. Analysis of the network identified groupings by ecosystem or business type (i.e. private industry, government, non-profit), collaboration among groups, and key players that connected different groups. The components of the network highlighted communication successes and challenges within the region. Using their findings, these researchers were able to educate people about the regional conservation network structure, introduce actors who may have common conservation objectives, and solicit ideas for collaborative projects between previously unconnected network partners. A preliminary network analysis will provide APNEP with similar information to guide communication and outreach strategies and form the basis for long-term social network monitoring and actions to improve the efficiency of the network to meet management objectives specified in the 2012 management plan.

Centrality is the primary social network analysis metric that is relevant to APNEP's project goals. *Centrality* is the position of a node in the network, and can be described by several properties. In APNEP's case, a node (individual) with high centrality is connected to many other

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[30] Robert A. Hanneman, M. R. (2005). Introduction to Social Network Methods. Riverside, CA, University of California Riverside.

[31] Stephen P. Borgatti, A. M., Daniel J. Brass, Giuseppe Labianca (2009). "Network analysis in the social sciences. ." Science **323**.

[32] Ken Vance-Borland, J. H. (2011). "Conservation stakeholder network mapping, analysis, and weaving." Conservation Letters **00**: 11.

people in the network, with better access to information and communication than those with

lower centrality rankings[33]. One important measure of centrality is *between-ness*, or the node

property of "frequently lying along the shortest paths between pairs of nodes"[34]. A high between-

ness measure for an individual indicates the potential power inherent in that node's position in

the network to disrupt, slow, or distort information flow that will affect large portions of the

network[35]. Another measure of centrality is *degree centrality*, which is the number of ties an

actor has to other actors, providing an advantage in the amount of information and resources they

are able to utilize within the network, and making them less dependent on a single source of

information or communication[36]. A third measure of centrality is *closeness*, defined as the path

length connecting two nodes. Actors with shorter path lengths to other actors in the network are

considered better positioned to reach others with information and interaction, and be easily

contacted by other actors in return[37].

In the preliminary analysis, APNEP will also be trying to identify key players within the

regional network of professionals. Key players are those individuals with high degrees of

centrality through measures of between-ness, degree, and/or closeness, and thus occupy highly

influential positions in the network[38]. Two considerations are useful when determining the

influence of a particular node in a network. One measure is the reduction in the cohesiveness of

[33] Reid, N. and B. W. Smith (2009). "Social Network Analysis." Economic Development Journal **8**(3): 48-55.

[34] Stephen P. Borgatti, A. M., Daniel J. Brass, Giuseppe Labianca (2009). "Network analysis in the social sciences. ." Science **323**.

[35] Ibid.

[36] Robert A. Hanneman, M. R. (2005). Introduction to Social Network Methods. Riverside, CA, University of California Riverside.

[37] Ibid.

[38] Long, J., F. Cunningham, et al. (2012). "Network structure and the role of key players in a translational cancer research network: a study protocol." BMJ Open **2**(3).

the network if the node was to be removed, referred to as the Key Player Problem/Negative[39]. This is useful to decipher the impact of individual actors, their roles in the larger network, and the network impact of that actor exiting the system. The second measure considers the extent to which a node is fully embedded in their respective network, known as the Key Player Problem/Positive[40]. It is useful when deciding which people or group of people are maximally connected to all other nodes, and can thus transfer information to surrounding nodes most efficiently.

The preliminary social network analysis of APNEP's regional network examines basic measures of centrality to identify key players that have the potential to serve as communications gateways for APNEP's outreach efforts. In addition, the network structure also identifies geographical and organizational "gaps" in communication efforts, where APNEP's outreach can be improved to yield more efficient information sharing and perhaps new project and partnership opportunities.

Methods

Data for the preliminary social network analysis were obtained from an online survey distributed to environmental practitioners working on watershed issues in the Albemarle-Pamlico watershed region using a protocol approved by Duke University. In accordance with common practice in the social network literature[41], a snowball survey method was used to elicit initial responses from one contact from each partner organization identified by APNEP, who in turn identified additional contacts that they communicated about watershed issues with, which created

[39] Borgatti, S. P. (2006). "Identifying sets of key players in a social network." Computational and Mathematical Organization Theory **12**(1): 21-34.

[40] Ibid.

[41] Moody, J. Introduction to Social Network Analysis. Durham, NC.

a respondent-generated network of professionals that regularly communicated about environmental issues in the Albemarle-Pamlico region. Snowball sampling is useful because the respondent is responsible for generating the next group of potential responses, and can name potential respondents that may have been over-looked by the researchers[42]. A snowball sampling methodology may fail to capture the complete network if respondents fail to report ties or ties do not exist to a subgroup of relevant individuals or organizations[43]. For example, if none of the initial respondents specified by APNEP indicated that they spoke with individuals at the North Carolina Coastal Land Trust (NCCLT) about Albemarle-Pamlico watershed issues, but the Land Trust was still actively involved in these issues, then the snowball sampling method would fail to capture the complete regional network structure. Although a complete census of environmental professionals working on Albemarle-Pamlico watershed issues is the ideal data set for performing a social network analysis, time and financial constraints dictated a more limited approach, described below.

The social network survey was designed primarily to obtain information about individuals that respondents interacted with concerning Albemarle-Pamlico watershed management, both within and outside of the respondent's organization. The primary question used to construct APNEP's social network map asked respondents' to identify up to three people within their organization and up to five people outside of their organization with whom they regularly "share information about environmental topics related to, occurring within, or influencing the Albemarle-Pamlico region of North Carolina and Virginia" (Appendix I). The number of contacts that a respondent could name was limited to N=8 to avoid "survey fatigue", which occurs when surveys are too long or involved for a respondent to complete easily, as well

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[42] Ibid.
[43] Ibid.

as concern about processing survey data from a large number of respondents[44]. The responses to these questions formed the basis of the node and edge lists that generated the social network structure. The survey also asked respondents for the physical address associated with their position in order to identify regional key players and geographic holes in the network where outreach could be improved.

Duke University's institutional license with the survey software program Qualtrics provided the survey design, formatting, and collection platform. The survey design was approved by the Duke University Institutional Review Board (Appendix II), and also took into account APNEP's policies regarding federal and state freedom of information regulations. Precautionary measures were taken to inform respondents about how their responses would be used in data analysis and the final project presentation, as well as who would have access to both the data and final products of the research project (Appendix I). Opt-out responses were provided for all initial privacy questions, and data collected from incomplete and exited surveys was not used in analysis. Each survey recipient was sent an email cover letter explaining the research project goals, and providing information about how to access the final products online. Offering free access to the social network maps and communications recommendations encourages recipients to respond by providing a product that partner organizations may also find useful for their own outreach.

The initial group of survey recipients was chosen by APNEP staff to reflect one representative from each partner organization as listed on APNEP's partner website[45]. These individuals represent connections between APNEP and the larger environmental community in

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[44] Ibid.
[45] Partnership, A.-P. N. E. (2013). "APNEP Partners." from http://portal.ncdenr.org/web/apnep/partners.

North Carolina and Virginia, and served as the focal nodes to begin the snowball sampling method[46]. However, the strength of these ties to APNEP was variable, as some organizations are APNEP's regular project collaborators, while other institutions, such as municipal governments, do not have frequent contact with APNEP. In the case of most municipal governments in North Carolina and Virginia, the survey and explanatory email were directed to the town manager. APNEP provided a list of 240 contacts, representing one individual at each partner organization, which served as the initial survey distribution group. The selection of these 240 survey recipients also helped create the theoretical boundaries for the network. Because boundaries of social networks are based on connections of interest to the researcher, they are inherently theoretical and not representative of absolute network boundaries[47]. Selecting 240 primary contacts within the Albemarle-Pamlico region of interest provided both geographical and social theoretical boundaries for the network system based on the parameters of interest to APNEP.

After the initial survey distribution to APNEP's 240 primary contacts, each professional contact listed by a respondent was sent an email explaining the purpose of the research project and a link to the Qualtrics survey. The survey remained opened for approximately 70 days, and was closed December 31, 2012.

Once the survey data was collected within the Qualtrics software, it was exported to Excel to serve as the primary data source for the node and edge lists that ultimately dictate the social network structure. The node list is a representation of every individual named in the survey, including both the respondents and the professional contacts named in each survey response. The node list consisted of each individual's name and agency, as well as a Personal

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[46] Moody, J. Introduction to Social Network Analysis. Durham, NC.
[47] Ibid.

Identification Number (PIN) assigned by automatic numbering. The final node list included 374

individuals that became the nodes in the social network analysis structure.

The edge list identifies every connection between the 374 nodes by creating a list of

"from" and "to" links between individuals according to who respondents identified as their

primary contacts for watershed-related issues. Connections between respondents and contacts

within and outside of their organization were included in the final edge list of 521

communications ties.

Each respondent was asked to provide the physical address of their office. To identify

geographic areas of strong and weak outreach efforts, addresses were transformed into X-Y

coordinates and entered into the social network analysis software. Supplemental location

information was obtained from online research of network organizations and their associated

office sites. Volunteers, private citizens, or professionals working from home were assigned to a

city rather than a specific street address to respect privacy concerns.

APNEP staff reviewed the node and agency address list to resolve incomplete agency

affiliation and agency address information. Due to APNEP's knowledge of regional

environmental institutions, staff members were able to locate individuals to specific field offices

and agency sub-divisions, which added greater detail to the network analysis. The result featured

node and edge lists that were faithful to the survey responses and provided a level of institutional

detail that would be understandable and useful to APNEP and partner organizations.

The Social Network Analysis (SNA) package in the statistical analysis software program

R was used for data analysis due to its design simplicity and comprehensive user manual. Several

key commands in the SNA package helped generate the network structure (Appendix III). First,

the node list was read into the software program, including the PIN, agency identification (AID),

employment sector (NGO, state agency, federal agency, regional organization, university

program, educational institution, city, and county government) and the names of the individual

nodes. Then the edge list was added into the program, in the form of a "from" and "to" column

populated with the PIN for each individual that was part of a tie. The node and edge column-

based list were then transformed into a matrix, which is the appropriate data format for

generating a social network graph, using the "elist2mat" command (Appendix III). Finally, the

"gplot" command was used to plot the node and edge matrix in two-dimensional space[48]. The

digraph mode was selected for this particular analysis to reflect the directionality of the survey

responses, where one person could claim communication ties to another individual, but the

connection was not considered reciprocal[49]. Some arguments associated with "gplot" can be

manipulated to highlight different aspects of the network structure. Figure 1 illustrates the

original network plot, with the nodes color-coded to reflect the sector affiliation of the

individual. To obtain information about the different components present in the network, which

can show outliers that are outside the major connection hubs, the "component.dist" function was

utilized (Figure 2). The between-ness scores (Figure 3) and degree centrality scores (Figure 4)

were plotted to analyze where potential information flow could be affected by key players.

In order to identify regionally influential individuals in the network, a geographic

representation of the stakeholder network was created by incorporating the latitude and longitude

coordinates for each node into the "gplot" function. The geographically anchored network

structure was then overlaid on a regional map of eastern states from Maryland to Georgia to

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[48] Butts, C. T. and A. Montgomery. "Gplot SNA: Two Dimension Visualization of Graphs." Retrieved February 22, 2013.

[49] Moody, J. Introduction to Social Network Analysis. Durham, NC.

identify areas of stakeholder density and key players whose connectedness could be leveraged to improve communications efficiency between partners and organizations in North Carolina and Virginia.

Results and Recommendations

Social network graphs focusing on sector distribution, network connectedness, the relative importance of individuals in the network, and a geographic representation of the network were analyzed to provide information about how environmental professionals in the Albemarle-Pamlico estuary region interact and exchange information. Each network structure provides insight into the challenges associated with effective transfer of information through the network. The analysis for each network graph therefore discusses the inefficiencies inherent in the network structure, as well as APNEP's potential role in addressing those efficiency challenges.

Sector Representation in the Social Network

The first graph structure, representing individuals in the network color coded by their sector affiliation (Figure 1), illustrates several concepts that APNEP should consider when engaging with different stakeholder groups. First, North Carolina and Virginia tend to occupy separate clusters of the network, visually confirming the lack of integrated planning and participation in regional environmental initiatives.

Recommendation #1

As an agency responsible for coordinating conservation projects in both states, APNEP can work to facilitate collaboration between relevant organizations for inter-state projects. APNEP's knowledge of environmental initiatives in both states positions APNEP staff to effectively connect interested organizations to come together and cooperate on multi-state projects. This will

further APNEP's goal of integrating Ecosystem Based Management into their management and policy decisions by facilitating projects that span the entire ecosystem area.

Recommendation #2

Second, the sector- defined network graph also reveals a separation between state agencies and NGOs in the region, particularly in North Carolina, where state agencies are color-coded black and NGOs are color-coded red. The lack of connections between state agencies and NGOs represent possible missed opportunities for collaboration, funding, and knowledge sharing.

APNEP can play a role in matching state agencies and NGOs that have similar objectives and/or projects. Establishing stronger connections and communication between these two sectors can create opportunities for more robust interactions about environmental issues from different professional perspectives, and can help APNEP most efficiently accomplish project tasks by engaging well-qualified partners from both sectors.

Recommendation #3

Third, academic and educational institutions are also relatively isolated from the larger network. Universities, particularly in NC (colored blue), and educational institutions such as museums, aquariums, and primary schools (colored pink), occupy distinct clusters in the social network, with limited connections to professionals working in other sectors. The significant research budgets of universities are a resource that APNEP and its partners would like to target for project funding and monitoring efforts. APNEP should work to connect the financial resources of their university affiliates with the data needs inherent in monitoring, researching, and managing one of the largest estuary systems in the country. Additionally, because museums, aquariums, and other educational institutions act as a primary interface between environmental

issues and the general public, they provide a significant potential source of volunteer engagement and community support for APNEP initiatives. Ensuring that educational institutions are aware of current conservation and restoration projects in the region, and working with the institutions to communicate effectively about Albemarle-Pamlico watershed issues, can increase volunteer participation in APNEP projects and public support for APNEP and its partners.

Network Connectedness

The network component function in the SNA package of the R software program determines the connectedness of the network as a whole. In a fully connected network, there exists a connection between every pair of nodes[50]. However, in a disconnected network, there may be multiple components representing subsets of node pairs that are not connected to the other subsets of the network[51]. Network components are useful for identifying organizations and individuals that are isolated from the larger network of communication and information transfer about environmental issues in the region.

Seven distinct components of the regional network of environmental professionals were evident from the survey data (Figure 2). The largest, most connected part of the network is represented by the nodes colored black (Figure 2). The other components, composed of six different small groups or individuals, are essentially excluded from communication and information transfer occurring within the larger network. In the smaller groups of nodes, communication only flows between the few individuals within the component group. The individual isolates represent survey respondents that did not list any professional contacts or

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[50] Wasserman, S. and K. Faust (1994). <u>Social Network Analysis: Methods and Application</u>. New York, NY, Cambridge University Press.
[51] Ibid.

interactions about regional environmental issues, and therefore had no "edges" to connect them to other nodes in the network.

Recommendation #4

Being able to identify these six outlying component groups presents an opportunity for APNEP to integrate additional organizations and individuals into the larger regional network. Outreach to the isolated network components and the distribution of regular communications from APNEP and partner organizations should serve to inform the isolates of regional environmental initiatives, and provide opportunities to become involved in projects and knowledge sharing. Engaging with the isolated components also allows staff to assess these groups' capability and willingness to partner with APNEP on activities of mutual interest and expertise.

Prior to devoting time and resources to developing stronger relationships with isolated network components, APNEP should evaluate the role and mission of each component, and determine whether partnerships or even involvement in regional environmental communications is appropriate or useful. For example, agencies or institutions with limited budgets, research capabilities, and project scope may not have much to contribute to APNEP initiatives. In this case, while it would appropriate to involve such an organization in regional environmental communications, it would not be efficient for APNEP to pursue a significant partner relationship. Background information on the capabilities and priorities of isolated components should be considered before APNEP takes any significant outreach action.

Centrality Measures

Two primary measures of centrality, or the relative importance of an individual within a network, were analyzed using the survey and network structure data. Although there are several measures of centrality that focus on different aspects of an individual node's position within the network, measures of between-ness and degree centrality provided the most contrast among nodes within this particular network, and were thus the most useful centrality measures to evaluate for management purposes. Key players were identified for each measure of centrality based on their between-ness and/or degree centrality values, extending the idea that key players are important because of their position in the network structure and their ability to control information flow to other individuals in the network.

Between-ness

Between-ness is a measure of centrality that considers where an individual node falls along the paths between other nodes in the network[52]. If a node is situated along many of the shortest paths between other pairs of nodes, that node is in a powerful position to control information flow to the other nodes along those short pathways[53]. The "scores.btwn" function calculated the between-ness value for each node, and the "node.btwn" and "gplot" functions were used to generate a network graph with node size corresponding to between-ness score (Figure 3). Between-ness values in the network ranged from 0-3590.33, with higher scores indicating greater relative importance within the network structure. The key players in the social network were those with the highest between-ness values, with the twenty highest scoring individuals included in Table 1.

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[52] Robert A. Hanneman, M. R. (2005). Introduction to Social Network Methods. Riverside, CA, University of California Riverside.
[53] Ibid.

The most influential players in the network based on between-ness values are illustrated in Figure 3. Individuals from APNEP, the UNC Coastal Studies Institute, and the North Carolina Sea Grant office had some of the highest between-ness scores in the network, which is intuitively logical given those organization's roles in project facilitation and collaboration in the region. The high between-ness values of two individuals from APNEP speak to its role as a regional communications hub and partnership facilitator, and validate its position as a key player in the region's environmental management dialogue.

Recommendation #5

APNEP can use the between-ness values of network members to assist in identifying key players whose connectedness in the network could be leveraged to improve communications to a particular constituency. Highly connected, and therefore presumably influential, individuals in the network could also be considered for inclusion on APNEP's advisory committees and policy board to provide a broadly-connected perspective of regional environmental issues.

Degree Centrality

Degree centrality is based on the idea that individuals with the most connections are the most important, and is essentially a measure of the number of ties directly connected to a given node[54]. Individuals with high degree centrality scores are considered influential in the network due to their ability to transfer information directly to a larger number of other actors. The "scores.degree" function calculated the degree centrality value for each node in the network, while the "node.degree" and "gplot" functions generated a network graph with node sizes scaled to represent degree centrality scores. Degree centrality scores in the network ranged from 0,

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[54] Moody, J. Introduction to Social Network Analysis. Durham, NC.

indicating an individual isolated from network communications (these are the three individual isolates in Figure 2), to 18 direct ties. The fact that 229 individuals had only one direct connection in the network emphasizes the importance of highly connected nodes in transferring information through the network. The key players in this network representation would include individuals with the highest degree centrality scores, with the twenty highest-scoring individuals listed in Table 2.

A representation of the social network based on each node's degree centrality value is illustrated in Figure 4, with the larger node dots corresponding to individuals with the highest degree centrality scores. By comparing Table 2 and relative size of the dots in the network graph, it is apparent that an individual from APNEP is again considered a key player in the network based on degree centrality values. The individual from APNEP, along with the other highly connected key players, fill a crucial role in transferring communications within the network, and are able to reach a significant number of individuals directly with information.

Recommendation #6

APNEP should focus on delivering relevant policy and project information to these key players, and ask them to pass along the information to their professional networks to increase the efficiency and range of APNEP communications' distribution. By leveraging the connectedness of degree centrality key players, APNEP will be able to reach larger portions of the network through direct contact, which can alleviate some of the time and resource pressures associated with trying to distribute information widely through less direct channels.

Recommendation #7

Some individuals qualify as key players using measures of both degree centrality and between-ness. The 13 individuals who co-occur in Table 1 and Table 2 are well positioned along network paths and have many direct connections to other individuals in the network.

APNEP should consider these individuals to be the best prospects for outreach engagement within the social network, and work to communicate regularly with them about APNEP projects and involve them in projects, advising roles, and/or committees.

Geographic Network Analysis

Because APNEP's programmatic boundaries cover areas in both North Carolina and Virginia, and the state-federal structure of the program involves communication between government agencies located in several areas along the east coast, a geographic analysis of the social network is necessary to understand where stakeholders are situated within the region and how information flows through geographic space. Mapping nodes in geographic space, while maintaining the original connections, provided some insight into how APNEP could best address the challenges of regional communication about projects and watershed management.

Naturally, the network of individuals involved with Albemarle-Pamlico estuary issues is concentrated in North Carolina and Virginia (Figure 5). Within those two states, clusters of activity can be seen in the coastal regions of both states, as well as North Carolina's capitol Raleigh, where many relevant state agencies and APNEP itself are headquartered. Roanoke and Virginia state capitol Richmond, as well as the area around UNC Asheville, are also areas with clusters of network players that could influence information transfer.

Outside of North Carolina and Virginia, node clusters can be found primarily in the Washington DC area where APNEP's federal partners NOAA and the EPA are headquartered, as

well as around NOAA regional office locations in Charleston, SC and the EPA Region 4 office in Atlanta, GA. Because federal funding and partnerships are crucial for the success of APNEP projects, it is important to maintain strong communications links with these geographic regions. Although outside APNEP's program boundary, the federal agencies in these regions provide critical support for APNEP's efforts, and resources should be devoted to ensuring efficient information sharing with these unique geographic groups.

Given the lack of information sharing and collaboration across state boundaries (Figure 1), key players in a geographic representation of the network would be those nodes that have edges extending to individuals in both North Carolina and Virginia. Theoretically, this would allow the node to connect their professional contacts from both states, and foster communication between individuals that previously did not occur due to the lack of information exchange between North Carolina and Virginia. Having connections to individuals and organizations in both states indicates that this geographic key player could serve as a bridge to bring potential partners and project ideas from different states together to maximize efficiency and impact. However, there are a limited number of nodes that meet the criteria for being considered a geographic key player by connecting to individuals in both North Carolina and Virginia.

The most visually obvious key player in this network is the green node in the southern-central region of Virginia, with connections in both coastal North Carolina and the Roanoke/Blacksburg region of Virginia. This individual is Chuck Peoples of The Nature Conservancy's Halifax, VA field office. His connections to stakeholders in both states, and his central geographic location within the region create opportunities for him to bring individuals from both states together for projects and collaboration.

Recommendation #8

APNEP should involve Mr. Peoples in regional planning and outreach activities to facilitate inter-state cooperation. Aside from this individual, there are several other nodes with inter-state connections between the coastal regions of North Carolina and Virginia. Although the nodes were too clustered for individual identification, APNEP can utilize this visual confirmation of interaction among coastal stakeholders to foster information exchange opportunities between the states. Holding meetings and workshops in areas convenient for both coastal Virginia and North Carolina stakeholders, and publicizing these events through outreach in both states, should bring a variety of interested parties together and foster collaboration between attendees from different areas and organizations.

Using Social Network Graphs to Inform Strategy

APNEP should use the geographic analysis to inform its outreach strategy, with a focus on bridging the communications gaps between North Carolina and Virginia, as well as identifying and communicating with areas that are currently left out of wider regional activity. Areas in northwest Virginia and North Carolina are relatively under-represented in the geographic analysis, and could be important areas of outreach for APNEP given the watershed dynamics and the impacts of upstream activities on estuary health.

Analysis of several network graphs provides information for APNEP to consider when taking management and/or outreach actions. Fully utilizing the influence of key players can result in more efficient information transfer between APNEP and the larger environmental network, while targeting isolated network components and geographic areas can create opportunities for more stakeholders to become involved with APNEP initiatives. Ultimately, the network analyses and

graphs can guide APNEP actions towards efficient use of time and staff resources, while helping APNEP play an important role as a regional facilitator of partnerships and projects.

Considerations for Long-term Social Network Analysis

Although the preliminary graphs generated by this analysis capture the network structure at a specific point in time, long-term study of a social network can reveal structural changes that reflect shifting network interactions[55]. Conducting repeated and regular social network analyses creates an opportunity to "track the actual details of change and how local- level decisions might produce large-scale structural transformations"[56]. Long-term analysis of the regional stakeholder network provides an opportunity for APNEP to monitor individuals and organizations' participation in regional environmental initiatives over an extended time period, and track partnership opportunities as groups begin or discontinue watershed-related projects[57]. APNEP can also validate the success of programmatic outreach initiatives by assessing changes in the network structure that may be connected to various management actions[58]. For example, targeting outreach actions to address the communications challenges outlined in the discussion of Figure 1 should lead to future network structures where isolated clusters of academic institutions are better integrated into the network, more individuals have connections in both North Carolina and Virginia, and there are more communications ties between state agencies and NGOs.

Social network analysis is a data hungry and technically advanced method for studying stakeholder connections and communications actions. Given APNEP's limited budget and the various additional responsibilities of program staff, efficiency in conducting social network

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[55] Scott, J. (1991). Social Network Analysis. Thousand Oaks, CA, Sage Publications Ltd.
[56] Ibid.
[57] Carpenter, D. and J. Hawhee (2012). APNEP Social Network Analysis: Project Scoping Meeting. K. Brogan. Raleigh, NC.
[58] Ibid.

analysis over the long-term must be a priority consideration as APNEP moves forward with ongoing network analyses. The following are some brief recommendations for APNEP to consider for future social network analysis initiatives.

Technical Capabilities

There are several software programs with social network analysis capabilities. Each program offers varying combinations of design simplicity, a user-friendly interface, and output capability. Additionally, some software programs have associated purchase and licensing costs[59]. Although a discussion of several software programs occurred during preliminary meetings with experts prior to this initial APNEP analysis, the R software package was selected primarily because of the project advisor's familiarity with the interface. It is worth noting that the EPA is currently refining the social network capabilities of its Decision Analysis for a Sustainable Environment, Economy, and Society (DASEES) tool. Use of this software program for APNEP's social network analysis could provide a useful tie-in with similar federal-level initiatives, and give APNEP an opportunity to contribute to the development of this tool. In the future, APNEP should research and test several software programs to determine which program best suits APNEP's unique expertise and data-processing needs. A general idea of what types of graphs and products would be most useful to guide APNEP's management actions should also guide the selection of an appropriate software program, perhaps using the graphs provided in this preliminary analysis as a starting point for future analysis needs.

Formatting, inputting and analyzing data within the R software program constituted a significant portion of researcher effort during the initial social network study. Whether APNEP

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[59] (2013). "UCINET software."

staff assume the responsibility for conducting long-term social network analysis in house or use students or partners to perform the data analysis, the software users should be well-versed in software scripting and coding. Due to the technical requirements of performing social network analysis using statistical computing software, significant staff time and resources will likely be dedicated to this aspect of long-term network study. Efficiency can be maximized by selecting the software program that best corresponds to APNEP's product requirements and staff programming capabilities.

Privacy Concerns

Because APNEP is housed within a state agency and is part of a federal-state partnership, there were natural concerns about how the personal information required to construct the social network would be shared with partners, government agencies, and the general public. Because this analysis is part of a Duke University Master's Project, the results are required to be published online through the Duke University Library. Additionally, the project's focus on human-subject research required approval by the Duke Institutional Review Board to ensure appropriate protocols were followed for collecting sensitive or personal data. APNEP and North Carolina Department of Environment and Natural Resources (DENR) legal staff also reviewed the research protocol to ensure compliance with federal and state privacy regulations.

In future studies, APNEP should continue to work with the DENR legal team and, if necessary, university affiliated review boards to address privacy concerns and compliance with applicable policies. Because the results of a social network analysis could have professional implications for individuals in the network, there are obvious concerns about personally identifiable material being made available to the public or even an individual's professional

superiors. APNEP can address these concerns by maintaining open lines of communication with individuals and organizations that raise privacy concerns, providing information about current privacy regulations at the federal, state, and university level, and always maintaining an "opt-out" exit option throughout the survey process. In order to avoid the perception that APNEP is using this information "behind closed doors" to determine management strategies, a significant portion of the social network analysis results should be available to partners and other interested parties, either through general distribution of the analyses to partner organizations or at the request of an interested group.

Network Representation

Although privacy concerns and personally identifiable information should be a primary consideration for APNEP moving forward, it is also important for APNEP to maintain and even increase the representation of stakeholders in the network analysis to better reflect the full range of individuals and organizations involved in environmental activities in the region. Due to the user-dictated survey sampling method, it is clear that relevant individuals, organizations, and even geographic areas are un- or under-represented in the final network structure of 374 individuals due to a lack of mention in survey response forms. Expanding the representativeness of the network structure in future studies can provide APNEP with more accurate data about relevant actors and activities in the watershed region.

Increasing the survey response rate would help APNEP attain more comprehensive information about the true nature of the stakeholder network. The response rate for the preliminary survey distribution was about 20%, which is lower than the 42% response rate cited in Vance-Borland and Holley's 2011 social network analysis of environmental professionals in

coastal Oregon[60]. APNEP can work to improve the response rate by providing incentives for completing the survey, which could include a monetary or other award for completing the survey, or a system of follow-ups as a reminder to complete the survey.

Due to concerns about survey fatigue and the potential of an overwhelming number of survey responses to process, the number of professional contacts a respondent could list in the survey form was limited to eight individuals. However, if stakeholders are really speaking with more than eight contacts about regional environmental issues, limiting the number of contacts has the potential to exclude relevant individuals from representation in the network structure. This issue could be addressed in future survey iterations by increasing the number of spaces to list professional contacts or leaving a blank space for respondents to list as many contacts as they feel are necessary.

Evaluation Metrics

If APNEP takes a management or outreach action based on this preliminary social network analysis, there should be metrics in place to evaluate the success of that action. This will allow APNEP to build records of outreach actions and corresponding results, and will provide insight into the usefulness of social network analysis for guiding communications strategy. The evaluation process could be as simple as tracking network-based outreach actions and their corresponding results in a database, or as complex as correlating changes in future social network structures to specific management actions. The presence of new connections between individuals and organizations, a more geographically balanced network structure, and more even between-ness scores could all be considered as indicators of evolution in APNEP and the larger

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[60] Ken Vance-Borland, J. H. (2011). "Conservation stakeholder network mapping, analysis, and weaving." Conservation Letters **00**: 11.

community's communications strategies. However APNEP chooses to assess the outcomes of various outreach actions, establishing clear evaluation metrics can help APNEP determine how to best allocate resources to accomplish its communications objectives.

Future Master's Project Opportunities

Given the significant constraints on staff time and financial resources, a periodic assessment of the regional social network structure would be an ideal project for Duke graduate students working in partnership with APNEP staff. Social network analysis is a useful tool for a variety of professional applications, and the project builds technical as well as communications knowledge, which make it a valuable opportunity for students looking to enhance those skill sets. Additionally, working for a client provides experience in addressing real-world environmental challenges and delivering a useful and comprehensive final product. APNEP can benefit from working with student groups to complete network analysis projects by acting in an advisory role rather than having to tackle each step of the process independently, utilizing the technical expertise of faculty and computing facilities associated with research universities, and building a strong relationship between university research and regional data and analysis needs. As illustrated in Figure 1, universities are relatively isolated from the larger environmental network, and involving students in APNEP projects can create a strong foundation for future collaboration and further involvement of university partners in the region's environmental activities.

Conclusion

In an era where financial resources are limited and environmental issues span political boundaries, cooperative regional efforts are absolutely necessary to advance conservation and protect the valuable environmental, economic, and social assets of one of the largest and most

important estuary systems in the country. Regular social network analysis, whether completed by APNEP or future student groups, can reflect changes in how stakeholders are engaging and communicating with each other about regional environmental initiatives. As a facilitator of partnerships and projects, this type of social interaction information is invaluable to APNEP as it works to most efficiently allocate its time and resources to achieve the objectives outlined in the 2012 management plan. Social network analysis can guide APNEP's efforts to engage a variety of stakeholder groups, facilitate new partnerships to accomplish more comprehensive restoration and conservation projects, and share environmental data and policy information with resource users, researchers, and decision-makers. Analysis of the regional stakeholder network can ultimately help APNEP "do more with less", and advance management strategies and activities that will improve both the human and environmental dimensions of the estuary ecosystem.

Figure 1. Network representation coded by employment sector
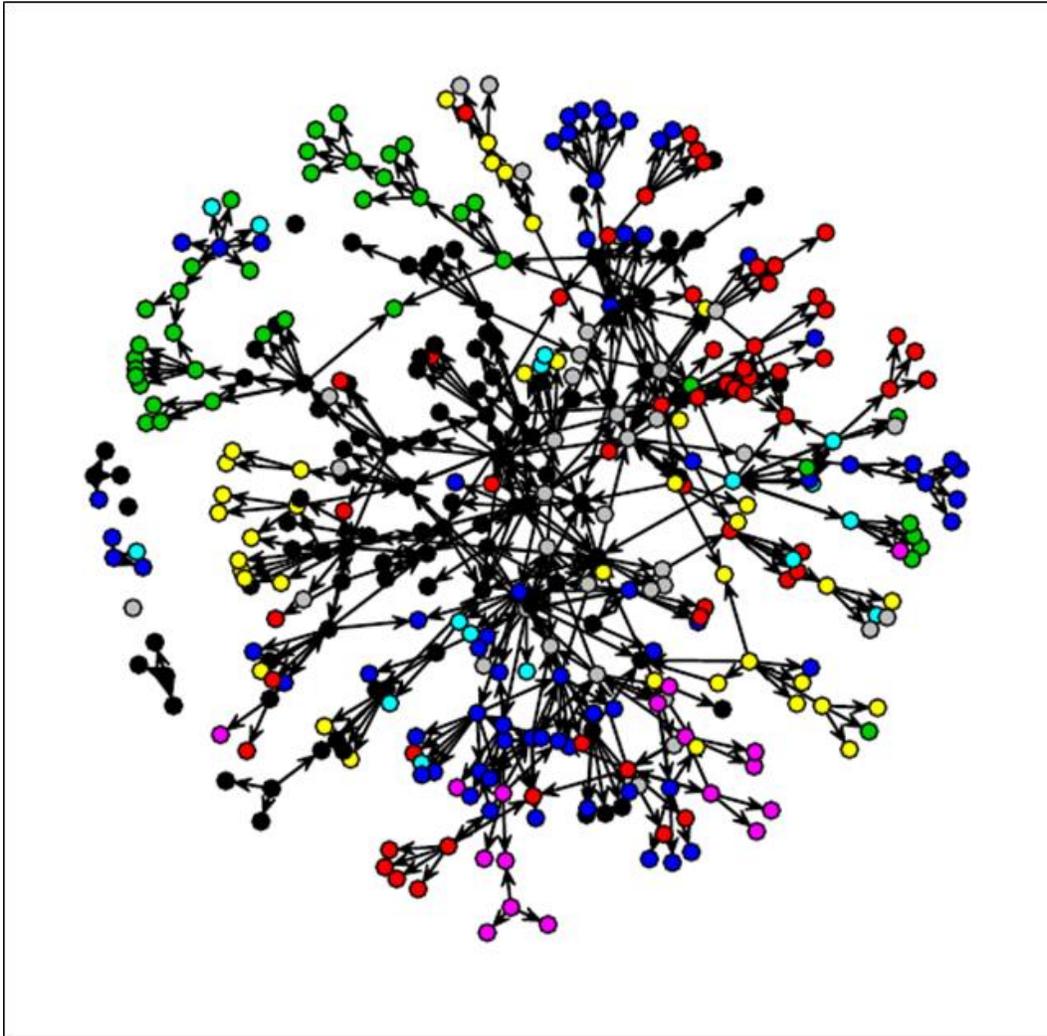
- ● North Carolina NGO
- ● Federal government
- ● North Carolina university
- ● North Carolina educational institution, Virginia private sector business
- ● North Carolina state government
- ● Virginia state government, Virginia NGO, Virginia municipal government
- ● Virginia university, Virginia county government
- ● Federal government (office in North Carolina), Virginia regional government organization

Figure 2. Network components
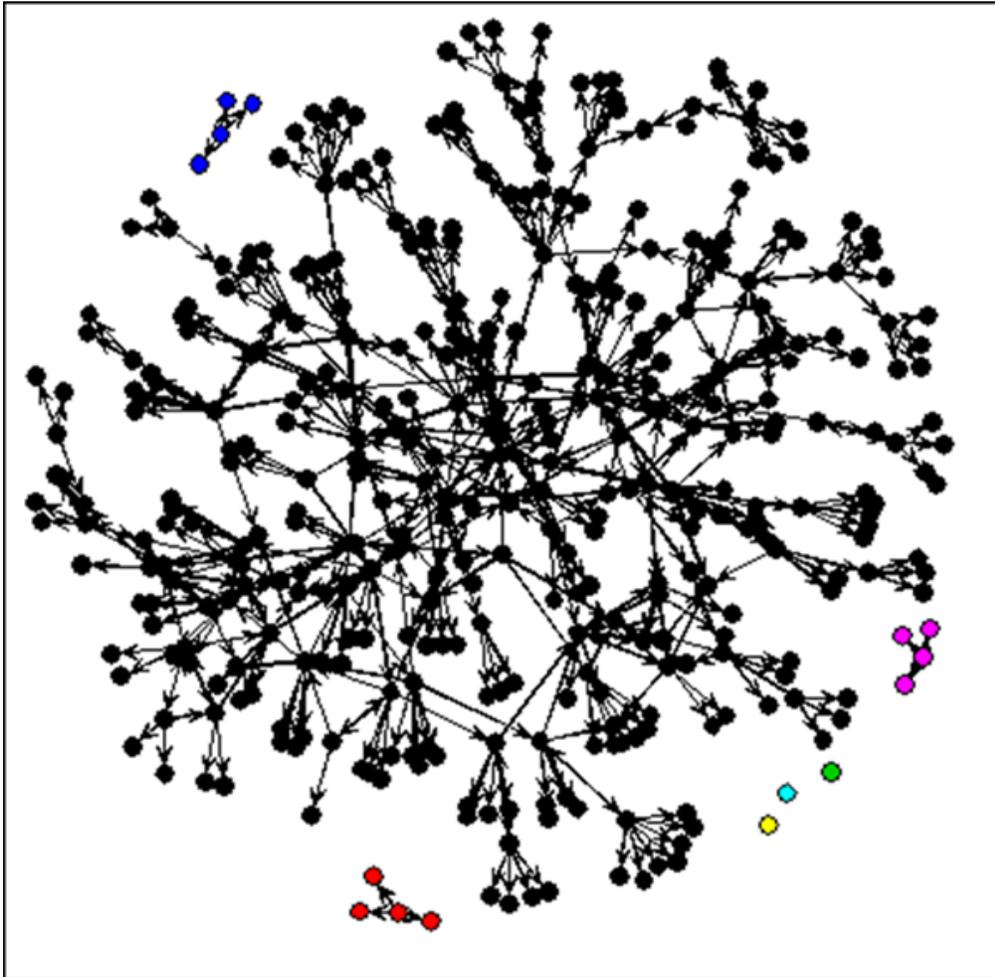
- ● Large network component
- ● Elizabeth City State University
- ● North Carolina Department of Transportation
- ● North Carolina Wildlife Resources Commission
- ● US Fish & Wildlife Service
- ● NCSU Extension Forestry program
- ● North Carolina Forestry Service

Figure 3. Network between-ness values
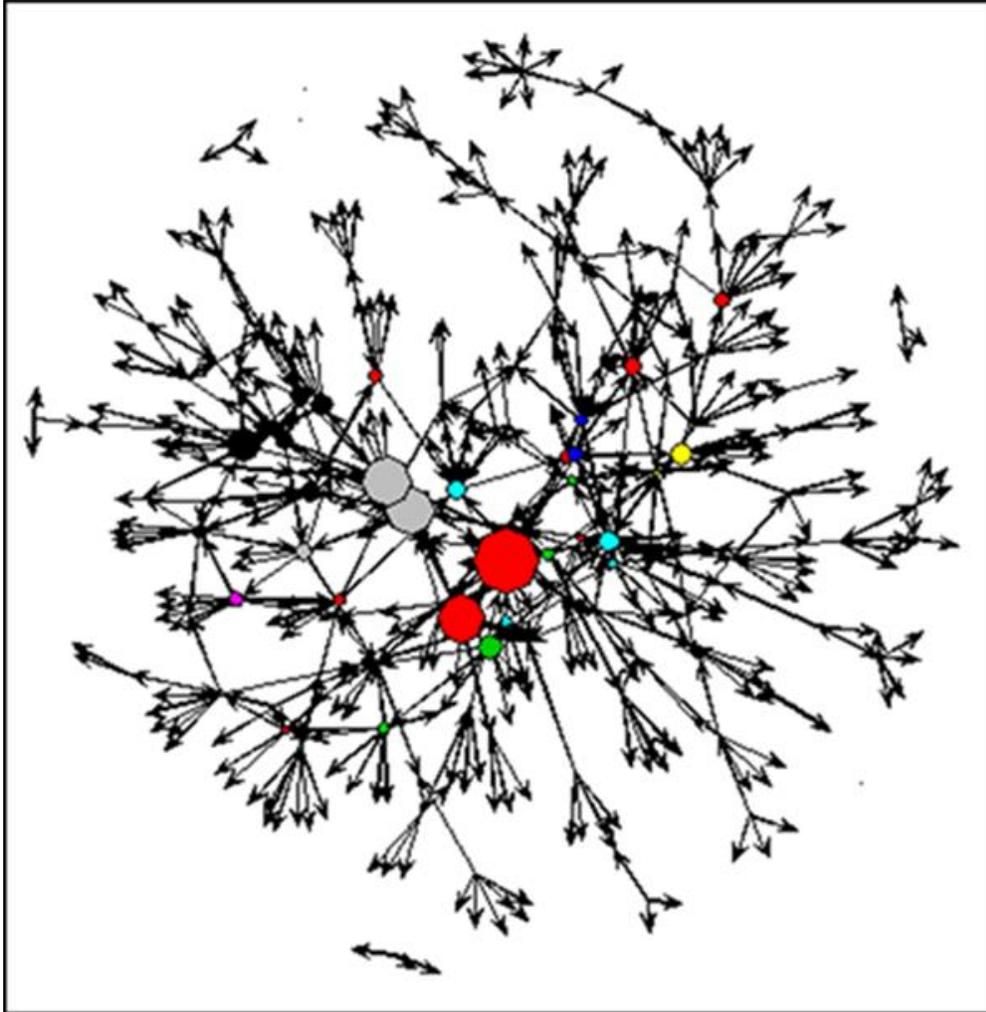
- 🔴 APNEP
- ⚪ UNC Coastal Studies Institute
- ⚫ North Carolina Sea Grant

Figure 4. Network degree centrality values
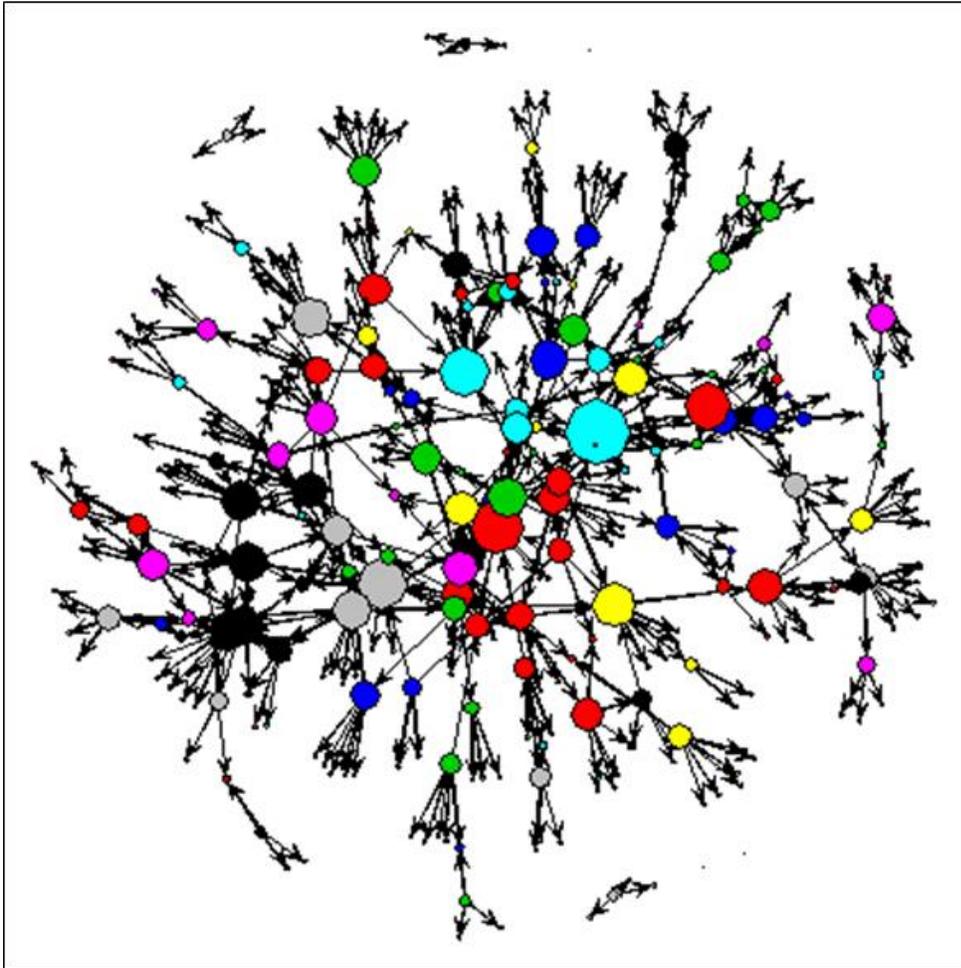
Legend for largest degree centrality scores:

- ● US Fish & Wildlife Service Raleigh (larger), Pamlico-Tar River Foundation (smaller)
- ● APNEP
- ● North Carolina Sea Grant

Figure 5. Geographic representation of the network.
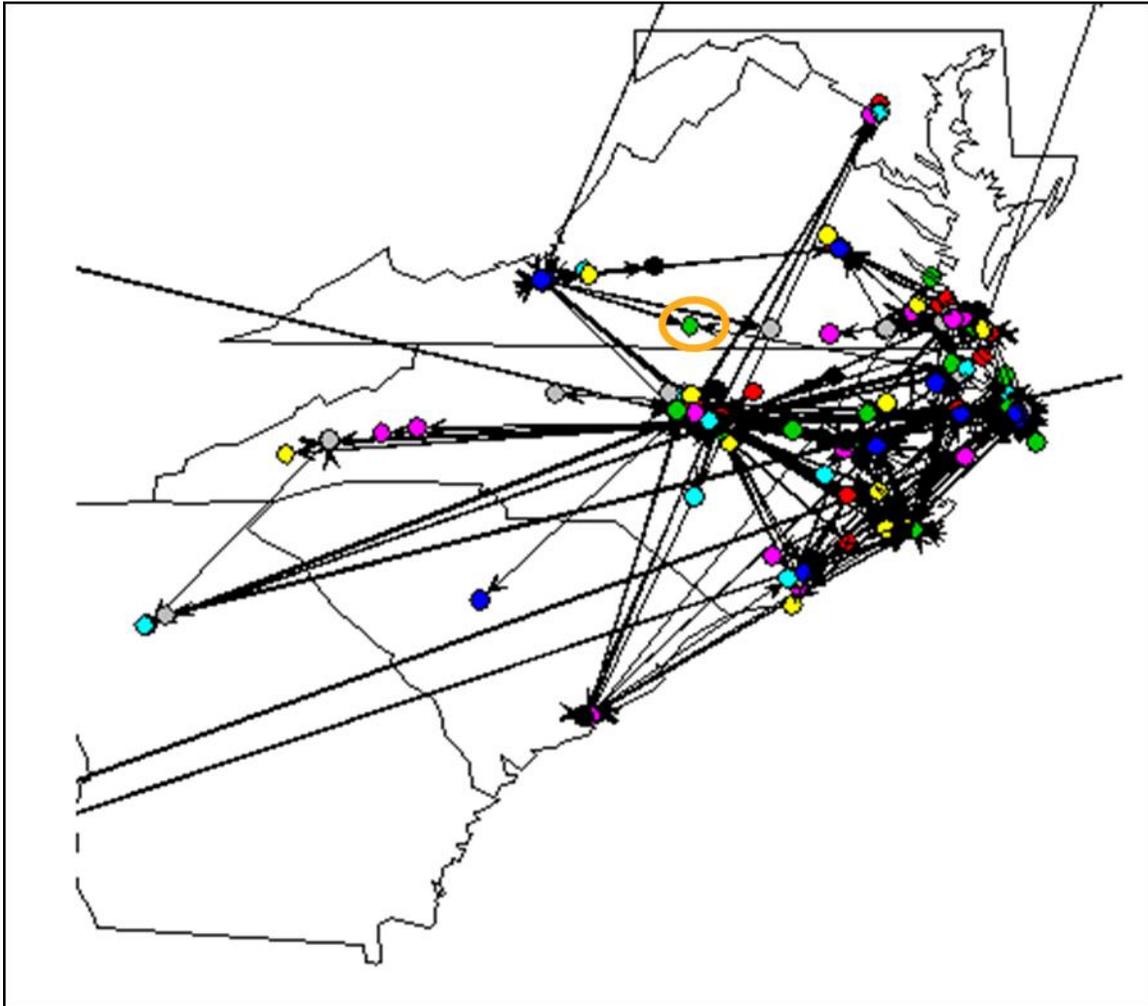
● Chuck Peoples, The Nature Conservancy, Halifax VA

Table 1. Individuals with the highest between-ness values

Name	Agency	Location	Between-ness value
Dean Carpenter	APNEP	Raleigh NC	3590.333333
Michael Piehler	UNC Coastal Studies Institute	Morehead City NC	2645.333333
Jim Hawhee	APNEP	Raleigh NC	2628.333333
Gloria Putnam	NC Sea Grant	Raleigh NC	2543
Nancy White	UNC Coastal Studies Institute	Wanchese NC	1814.333333
Judith Ratcliffe	NC Natural Heritage Program	Raleigh NC	1320.5
Michelle Moorman	USGS NC Water Science Center	Raleigh NC	1196.666667
Reid Wilson Laney	US Fish & Wildlife Service	Raleigh NC	1124.5
Robert McClendon	UNC Coastal Studies Institute	Wanchese NC	1111.833333
Lindsay Dubbs	UNC Wanchese Campus	Wanchese NC	1042.833333
Heather Jacobs Deck	Pamlico-Tar River Foundation	Washington NC	1040.5
Michelle Covi	East Carolina University	Greenville NC	1034.333333
Kevin Dockendorf	NC Wildlife Resources Commission	Elizabeth City NC	941.8333333
Terri Kirby Hathaway	NC Sea Grant	Wanchese NC	901
Jack Thigpen	NC Sea Grant	Raleigh NC	894.6666667
Michelle Duval	NC Division of Marine Fisheries	Morehead City NC	846
John Gallegos	US Fish & Wildlife Service (Back Bay NWR)	Virginia Beach VA	798
Tom Stroud	Partnership for the Sounds	Columbia NC	781.3333333
Linda Rimer	EPA	Research Triangle Park NC	779.1666667

Table 2. Individuals with the highest degree centrality values

Name	Agency	Location	Degree Centrality Score
Reid Wilson Laney	US Fish & Wildlife Service	Raleigh NC	18
Dean Carpenter	APNEP	Raleigh NC	15
Gloria Putnam	NC Sea Grant	Raleigh NC	14
Heather Jacobs Deck	Pamlico-Tar River Foundation	Washington NC	14
Kevin Dockendorf	NC Wildlife Resources Commission	Elizabeth City NC	13
Michelle Moorman	USGS NC Water Science Center	Raleigh NC	12
Judith Ratcliffe	NC Natural Heritage Program	Raleigh NC	11
Matthew Godfrey	NC Wildlife Resources Commission	Beaufort NC	11
Michael Piehler	UNC Coastal Studies Institute	Morehead City NC	11
Nancy White	UNC Coastal Studies Institute	Wanchese NC	11
Paul Angermeier	Virginia Tech	Blacksburg VA	11
Terri Kirby Hathaway	NC Sea Grant	Wanchese NC	11
Tom Allen	East Carolina University	Greenville NC	11
Fritz Rohde	NOAA Fisheries Habitat Conservation	Beaufort NC	10
Jimmy Johnson	DENR Office of Conservation, Planning & Community Affairs	Washington NC	10
John Gallegos	US Fish & Wildlife Service (Back Bay NWR)	Virginia Beach VA	10
Linda Pearsall	DENR Office of Conservation, Planning & Community Affairs	Raleigh NC	10
Lindsay Dubbs	UNC Wanchese Campus	Wanchese NC	10
Michelle Covi	East Carolina University	Greenville NC	10

Appendix I. Qualtrics Survey

Social Network Analysis Survey

You are invited to participate in a research study by Kate Brogan, a graduate student at the Nicholas School at Duke University and Jim Hawhee, Community Specialist at the Albemarle-Pamlico National Estuary Program.

Purpose
The purpose of this project is to conduct a social network analysis to understand communication patterns about environmental affairs in the Albemarle-Pamlico region. Information gathered during this research project will be used to inform a Master's Project (MP) about the social network analysis and will contain recommendations for implementing routine social network analysis at APNEP.

Procedures
You will be asked to share information about your organization and its involvement with the Albemarle-Pamlico National Estuary Program (APNEP). You will also be asked to provide the names of people within your organization and outside of your organization with whom you share information about the APNEP or the Albemarle-Pamlico region.

Confidentiality
The information you provide will be used to analyze how you and your organization share information with APNEP and its partners. To do this, the data we analyze and report on will need to include your name, title, contact information, and your organization's name. Therefore, due to the social mapping nature of this project, identification of participants by name and organizational affiliation are necessary to understand the communications channels present among APNEP's partners. If you do not want your name, title, contact information, and your organization's name to be included in the research data and reports that is okay but we discourage you from participating.

APNEP would also like to access your name, title, contact information, and your organization's name for their purposes. It hopes to use your information to increase the efficiency of their communication initiatives and identify connections between organizations and people that will benefit from ecosystem-based management strategies. If you do not want your name, title or organization's name to be given to APNEP that is okay but we discourage you from participating.

You will have the opportunity to indicate how your information will be used when you complete the survey.

Voluntariness
This study is completely voluntary. You do not have to complete the survey if you do not want to. If you decide the complete the survey, you can skip questions or stop at any time for any reason. In addition, you will be given the opportunity to indicate how your information you provide can be used. If you have questions about your rights as a participant in this study, please contact the Duke IRB at ors-info@duke.edu.

Contact
If you have any questions about the survey, the research project or why you were asked to participate, please contact Kate Brogan at katherine.brogan@duke.edu or Dr. Cindy Van Dover at c.vandover@duke.edu.

If you would like to complete the survey, please click below to begin. If you would prefer a hard copy of the survey to complete, please contact Kate Brogan.

- ○ I have read the consent form and understand the conditions of participating in this survey. I would like to participate in the survey.
- ○ I would not like to participate in the survey.

Please indicate how the researchers can use your name, title, contact information and organization:
- ○ YES, I agree that the researchers can use my name, title, contact information and organization's name when they analyze and report their data for research purposes.
- ○ NO, I do NOT want the researchers to use my name, title, contact information and organization's name when they analyze and report their data for research purposes.

Please indicate if the researchers can provide your name, title, contact information and organization's name to the Albemarle-Pamlico National Estuary Program :
- ○ YES, I agree that the researchers can provide my name, title, contact information and organization's name to APNEP.
- ○ NO, I do NOT want the researchers to provide my name, title, contact information and organization's name to APNEP.

You also will be asked to identify individuals and organizations that you communicate with about environmental issues. We may contact the people you identify and ask them to indicate how their information can be used. They also may be asked to complete this survey.

Please provide your name.
_____

Please provide your primary organization's name. Be as specific as possible, listing your organization and then adding your division, unit, or program. For example, list DENR-Natural Heritage Program or City of Durham- Stormwater Services. For the remainder of this survey, "organization" listed in any question will refer to your answer to this first question.
_____

Is your position at your primary organization supervisory?
- ○ Yes
- ○ No

How many employees do you supervise at your organization?
- ○ 1-10
- ○ 10-25
- ○ 25-100
- ○ 100+

Please provide the physical address, city, and state where your office is located.
_____

Please list any secondary affiliations related to environmental affairs. These affiliations may include but are not limited to professional organizations, advisory bodies, or working

groups. Examples: NC Association of Environmental Professionals (NCAEP), SAV Partnership, Watershed Restoration and Improvement Team (WRIT)

Please list up to three people within your organization with whom you share information about environmental topics related to, occurring within, or influencing the Albemarle-Pamlico region of North Carolina and Virginia.
Click on the link for a map of the Albemarle-Pamlico region: http://portal.ncdenr.org/web/apnep/apnep-basins-and-counties

Contact 1	
Contact 2	
Contact 3	

Please list three or more people outside of your organization with whom you share information about environmental topics related to, occurring within, or influencing the Albemarle-Pamlico region of North Carolina and Virginia. Please list the name, organizational affiliation, and email (optional) of each contact.
Click on the link for a map of the Albemarle-Pamlico region: http://portal.ncdenr.org/web/apnep/apnep-basins-and-counties

Contact 4	
Organization	
Email	
Contact 5	
Organization	
Email	
Contact 6	
Organization	
Email	
Contact 7	
Organization	
Email	
Contact 8	
Organization	
Email	

What environmental topics do you communicate about with each person identified above? For each of the people you identified, please select the appropriate topics of communication. You may select as many topics as you wish.

	${q://QID10 /ChoiceTextEntryValue/1}	${q://QID10 /ChoiceTextEntryValue/2}	${q://QID10 /ChoiceTextEntryValue/3}	${q://QID11 /ChoiceTextEntryValue/1}	${q://QID11 /ChoiceTextEntryValue/4}	${q://QID11 /ChoiceTextEntryValue/7}	${q://QID11 /ChoiceTextEntryValue/10}	${q://QID11 /ChoiceTextEntryValue/13}
Advocacy	☐	☐	☐	☐	☐	☐	☐	☐
Agriculture	☐	☐	☐	☐	☐	☐	☐	☐
Attractions, recreation, tourism	☐	☐	☐	☐	☐	☐	☐	☐
Coastal affairs	☐	☐	☐	☐	☐	☐	☐	☐
College education	☐	☐	☐	☐	☐	☐	☐	☐
Environmental consulting	☐	☐	☐	☐	☐	☐	☐	☐
Environmental law	☐	☐	☐	☐	☐	☐	☐	☐
Environmental restoration	☐	☐	☐	☐	☐	☐	☐	☐
Finance	☐	☐	☐	☐	☐	☐	☐	☐
Fisheries	☐	☐	☐	☐	☐	☐	☐	☐
Land conservation	☐	☐	☐	☐	☐	☐	☐	☐
Local government affairs	☐	☐	☐	☐	☐	☐	☐	☐
Planning	☐	☐	☐	☐	☐	☐	☐	☐
PreK-12 education	☐	☐	☐	☐	☐	☐	☐	☐
Public health	☐	☐	☐	☐	☐	☐	☐	☐
Regulatory policy	☐	☐	☐	☐	☐	☐	☐	☐
Research	☐	☐	☐	☐	☐	☐	☐	☐
Resource extraction	☐	☐	☐	☐	☐	☐	☐	☐
Water quality	☐	☐	☐	☐	☐	☐	☐	☐
Water quantity and supply	☐	☐	☐	☐	☐	☐	☐	☐

Appendix II. Duke University Institutional Review Board Survey Approval

[IRB]Notice of Protocol Approval

IRB ADMINISTRATOR [ors-info@duke.edu]

Sent: Tuesday, June 05, 2012 5:04 PM
To: Katherine Brogan; Van Dover, Cindy Lee [clv3@duke.edu]
Cc: Alejandro Martinez

Protocol : [B0158] Using Social Network Analysis to Identify Communication Partners among APNEP Partners

Researcher(s) :
Cindy Lee Van Dover(Advisor)
Katherine Brogan(Graduate Student Researcher)

Expiration Date : 6/4/2013
In conducting research under this protocol, the researcher agrees to:

- Secure approval before making any changes to the protocol, such as adding another subject population, revising procedures, modifying the informed consent process, or replacing or adding investigators.

  The form, **Request to Amend an Approved Protocol**, can be found at:
  http://www.ors.duke.edu/Research-with-Human-Subjects/forms

- Renew the protocol within twelve months.

  The form, **Request to Renew an Approved Protocol**, can be found at:
  http://www.ors.duke.edu/Research-with-Human-Subjects/forms

- Report any unanticipated risks to the research subjects or deviations from the procedures described in the protocol as soon as they are identified. Report to Lorna Hicks at lorna.hicks@duke.edu

- Notify the IRB staff at ors-info@duke.edu when the research is completed.

- As required by Duke policy, retain all research data and signed consent forms for at least five years after the completion of the study.

Appendix III. R script for network analysis[61,62]

```
# read in the people:
node.list<-read.csv("node_list.csv") # this is PIN, AID, Name

# find the dimensions (rows, columns):
dim(node.list)


# read in the links as edge list:
edge.list<-read.csv("edge_list.csv") # fromPIN, toPIN

# convert to a matrix:
source("elist2mat.R")
edge.matrix<-elist2mat(edge.list, dim(node.list)[[1]])

dim(edge.matrix)
edge.matrix[1:7,1:7]
sum(edge.matrix[edge.matrix==1])

# gplot defaults to a digraph, here with equal weights:
library(sna)
gplot(edge.matrix, label=node.list$PIN, displaylabels=TRUE,
label.cex=0.3, boxed.labels=FALSE, vertex.col=node.list$AID)

gplot(edge.matrix, label=node.list$PIN, displaylabels=FALSE,
vertex.col=node.list$AID)

components(edge.matrix)
component.dist(edge.matrix)
#doesn't have to be reciprocal connections, can be one way arrows
component.dist(edge.matrix, "unilateral")
comp.list <- component.dist(edge.matrix, "weak")
comp.member <- comp.list$membership
gplot(edge.matrix, label=node.list$PIN, displaylabels=TRUE,
label.cex=0.3, boxed.labels=FALSE, vertex.col=comp.member)

# next ...betweenness
node.btwn <- betweenness(edge.matrix)
#this betweenness works... identify larger nodes
gplot(edge.matrix, label=node.list$PIN, displaylabels=TRUE,
label.cex=0.3, boxed.labels=FALSE, vertex.col=comp.member,
vertex.cex=node.btwn*0.001)
```

---

[61] R Development Core Team (2011). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

[62] Carter T. Butts (2010). sna: Tools for Social Network Analysis. R package version 2.2-0. http://CRAN.R-project.org/package=sna

```
#export betweenness scores
scores.btwn<- cbind(node.list, node.btwn)
write.csv(scores.btwn, "scores_btwn.csv")
#geographic distribution of betweenness
length(node.btwn)help
summary(node.btwn)
quantile(node.btwn, probs=c(0.85,0.9,0.95))
plot(nodes.xy[,2:3], xlim=c(-84,-75), ylim=c(32,38), xlab="Longitude",
ylab="Latitude", col=node.list$AID)
points(nodes.xy[node.btwn>0,2:3], pch=19, xlim=c(-84,-75),
ylim=c(32,38), col=node.list$AID)
identify(nodes.xy, labels=node.list$PIN)


#degree centrality scores
node.degree<- degree(edge.matrix)
gplot(edge.matrix, label=node.list$PIN, displaylabels=TRUE,
label.cex=0.3, boxed.labels=FALSE, vertex.col=comp.member,
vertex.cex=node.degree*0.01)
scores.degree<- cbind(node.list, node.degree)
write.csv(scores.degree, "scores_degree.csv")
summary(node.degree)
#geographic distribution of degree centrality
length(node.degree)
summary(node.degree)
plot(nodes.xy[,2:3], xlim=c(-84,-75), ylim=c(32,38),
col=node.list$AID)
points(nodes.xy[node.degree>4,2:3], pch=19, xlim=c(-84,-75),
ylim=c(32,38), cex=node.degree/2, col=node.list$AID)
identify(nodes.xy[node.degree>4,2:3], labels=node.list$PIN, xlim=c(-
84,-75), ylim=c(32,38))


#closeness
node.closeness<- closeness(edge.matrix, tmaxdev=TRUE)
gplot(edge.matrix, label=node.list$PIN, displaylabels=TRUE,
label.cex=0.3, boxed.labels=FALSE, vertex.col=comp.member,
vertex.cex=node.closeness)
scores.closeness<- cbind(node.list, node.closeness)
write.csv(scores.closeness, "scores_closeness2.csv")
#geographic distribution of closeness
length(node.closeness)
summary(node.closeness)
plot(nodes.xy[,2:3], xlim=c(-84,-75), ylim=c(32,38),
col=node.list$AID)
points(nodes.xy[node.closeness>4,2:3], pch=19, xlim=c(-84,-75),
ylim=c(32,38), cex=node.closeness/2, col=node.list$AID)
identify(nodes.xy[node.degree>4,2:3], labels=node.list$PIN, xlim=c(-
84,-75), ylim=c(32,38))

#information centrality
node.infocent<- infocent(edge.matrix, rescale=TRUE)
```

```
node.info2 <- node.infocent*1000.0
gplot(edge.matrix, label=node.list$PIN, displaylabels=TRUE,
label.cex=0.3, boxed.labels=FALSE, vertex.col=comp.member,
vertex.cex=node.infocent*0.01)
scores.infocent<- cbind(node.list, node.infocent)
write.csv(scores.infocent, "scores_infocent.csv")
#geographic distribution of info centrality
length(node.infocent)
summary(node.infocent)
plot(nodes.xy[,2:3], xlim=c(-84,-75), ylim=c(32,38),
col=node.list$AID)
points(nodes.xy[,2:3], pch=19, xlim=c(-84,-75), ylim=c(32,38),
cex=node.info2, col=node.list$AID)
identify(nodes.xy[node.degree>4,2:3], labels=node.list$PIN, xlim=c(-
84,-75), ylim=c(32,38))


#geographic distribution
nodes.xy <- read.csv("nodes_xy.csv")
#("help(gplot)")
# use original gplot function, add in coord
gplot(edge.matrix, coord=nodes.xy[,2:3], xlim=c(-84,-75),
ylim=c(32,38), label=node.list$PIN, displaylabels=TRUE, label.cex=0.3,
boxed.labels=FALSE, vertex.col=node.list$AID)

map('state', region=c('virginia', 'north carolina', 'south carolina',
'georgia'))
points(nodes.xy$X, nodes.xy$Y, pch=19, col=node.list$AID,
cex=node.btwn*.001)
points(nodes.xy$X, nodes.xy$Y, pch=19, col=node.list$AID,
cex=node.degree*.25)
points(nodes.xy$X, nodes.xy$Y, pch=19, col=node.list$AID,
cex=node.closeness)
points(nodes.xy$X, nodes.xy$Y, pch=19, col=node.list$AID,
cex=node.infocent*0.25e13)

#map and gplot with add=TRUE
map('state', region=c('virginia', 'north carolina', 'south carolina',
'georgia'), add=TRUE)
```

Appendix IV. Commonly Used Acronyms, adapted from APNEP 2012 Comprehensive Conservation & Management Plan

APES- Albemarle-Pamlico Estuarine Study
APNEP- Albemarle-Pamlico National Estuary Partnership
CCMP- Comprehensive Conservation and Management Plan
COG- Council(s) of Governments
CSI- University of North Carolina Coastal Studies Institute
EPA- United States Environmental Protection Agency
IMS- University of North Carolina Institute of Marine Sciences
NC- North Carolina
NCCF- North Carolina Coastal Federation
DENR- North Carolina Department of Environment and Natural
Resources
NC-DMF- North Carolina Division of Marine Fisheries (NC-DENR)
NC-DWQ- North Carolina Division of Water Quality (NC-DENR)
NC-DWR- North Carolina Division of Water Resources (NC-DENR)
NC-EEP- North Carolina Ecosystem Enhancement Program (NC-DENR)
NCDOT- North Carolina Department of Transportation
NC-NCFS- North Carolina Forest Service
NC-NHP- North Carolina Natural Heritage Program (NC-DENR)
NC-NERR- North Carolina Coastal Reserve and National Estuarine Research
Reserve
NC-OCPCA- North Carolina Office of Conservation, Planning, and
Community Affairs (NC-DENR)
NC-WRC- North Carolina Wildlife Resources Commission
NGO- Non-governmental organization
NMFS- National Marine Fisheries Service
NOAA- National Oceanic and Atmospheric Administration
SAFMC- South Atlantic Fishery Management Council
SALCC- South Atlantic Landscape Conservation Cooperative
TNC- The Nature Conservancy
UNC- The University of North Carolina at Chapel Hill
USACE- United States Army Corp of Engineers
USFWS- United States Fish and Wildlife Service
USGS- United States Geological Survey
VA– Virginia
VA-DCR- Virginia Department of Conservation and Recreation
VA-DEQ- Virginia Department of Environmental Quality
VA-DGIF- Virginia Department of Game and Inland Fisheries
VA-VMRC- Virginia Marine Resources Commission