

Resiliency post-Hurricane Helene: The role of Social Capital in Western North Carolina's
Community Food Organization Network

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Abstract

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Purpose:

This study investigates and describes the network of community food organizations in Western North Carolina post-Hurricane Helene by applying a social network analysis: Aims were: 1) What did the collaboration network of existing community food organizations in Western NC look like after Hurricane Helene? 2) How did the network structure hinder or facilitate a food organization's ability to distribute aid? And 3) Which organizations were the key actors in the network?

Background:

Hurricane Helene provided a useful context for examining how community food organizations collaborated after Western North Carolina's largest food bank warehouse was

destroyed. Community food organizations are usually on the frontlines after a climate disaster, distributing food to the affected population.

Methods:

Survey data collected from community food organizations that distributed food in Western North Carolina after Hurricane Helene was used to generate and analyze a collaboration network. We used a social network analysis to investigate the social capital, relationships formed, and the resources shared within a network of community food organizations that do not usually experience large-scale disasters. This study looked at bridging across structural holes in the network; degree and betweenness centrality; and brokerage roles for organizations to identify key actors.

Results:

The resulting network contained 130 organizations, two-thirds of which were well established in North Carolina at the time Hurricane Helene landed. The network was disconnected and was made up of distinct clusters. Organizations tended to collaborate within their respective counties and among organizations that were a different type than their own. Three key actors were identified; these key actors were highly connected, acted as bridges across clusters that would otherwise be isolated, and brokered exchanges primarily within their respective counties among organizations of a different type than their own. Food distribution after Hurricane Helene was correlated with high degree and betweenness centrality and cumulative brokerage scores.

Conclusion:

This study shed light on how rural community food organizations collaborated in an area that does not usually experience large-scale disasters. While the resulting network is largely disconnected, key actors worked to connect to smaller clusters. Highlighting the importance of

community food organization collaboration with other organizations before a disaster, to improve community resiliency after a disaster.

Dedication

This work is dedicated to the people of western North Carolina. Without you I would not be where I am today.

“And I am lost in memories

Of carefree days gone by.

Of loving faces, who never more

Will hear the pine trees sigh.

Oh, beautiful Blue Ridge Mountains,

Your magic has captured me.

Again and again I must return,

From your spell I can never be free.”

Glenna Wallace Moles, *Hymn to the Blue Ridge*

Acknowledgements

I want to first thank the organizations that took the time to participate in this study. I hope this work assists you in your dedication to a food secure North Carolina.

To my committee; thank you for the time and effort you gave me throughout this journey. To Pia Chaparro, thank you for being behind me to give me the push that I needed, for your guidance, and patience. To Emma Spiro, thank you for supporting this work and dedicating time out of all the great things that you do, to help with this project. I will carry the things you both taught me for the rest of my life.

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Lastly, thank you to my cohort who, every time we met asked how this project was going. You all inspire me and I am incredibly thankful to have met you. I will miss each and everyone of and cannot wait to see what you accomplish.

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Introduction

In 2023, 15% of households in North Carolina (NC) were food insecure, amounting to more than 1.6 million people struggling to put food on their table.¹ Climate disasters can exacerbate food insecurity, whether it be in the weeks or years to follow.²⁻⁴ Under a non-disaster setting, a food system is “adaptive,” “comprised of a set of diverse, autonomous actors whose work is interdependent and connected to ensure community food needs are met.”⁵ Post-disaster, the inability to access food in a commercial grocery setting can be affected by damaged buildings, electrical grids, and water systems.⁵ Further, the destruction of physical infrastructure, like roads, can make it difficult for community food organizations to deliver food to the affected community.⁵ This links food security post-disasters to the ability of the affected community to be resilient and recover faster.^{2,6,7}

Despite the challenges, community food organizations are usually on the front lines after a climate disaster, coordinating, planning, and distributing food to the affected population.^{6,8,9} While these organizations specialize in long-term continuous aid programs, they have built-in capabilities that allow them to pivot to emergency response when needed.⁹ Still, community food organizations experience an increased need for food post-disasters and can struggle with the increased demand, underscoring the need for a more resilient and collaborative food system.⁶ Social networks within communities are important to increase resiliency in disaster-affected populations, with previous research showing that populations with strong social networks recover from disasters faster.^{7,10-12} Relationships that develop between organizations, individuals, or groups within social networks can improve communication and coordination that promotes resiliency.^{7,11} Active participation in the network generates benefits termed social capital.^{7,11,13} This can show up as resources an organization can bring into the network, the relationships, and trust for the organization.^{7,11,13,14} In

theory, the more relationships a community can access and leverage post-disaster, the more resilient they are likely to be.^{7,10,12}

On September 27, 2024, Hurricane Helene hit Western NC, far surpassing rainfall records set 108 years prior in a region historically susceptible to flooding and mudslides.¹⁵ Small rural mountain towns were inundated by rising rivers.¹⁶ The flooding was so severe that the NC Department of Transportation essentially closed all roads in Western NC.¹⁷ Hundreds of thousands of people were left without power, and 74% of the mobile wireless communication network was out of service.^{18,19} The region's largest food bank, run by the Mountain Area Nutritional Needs Alliance (MANNA), was destroyed.²⁰ In a non-disaster setting, food banks act as warehouses to store a surplus of food that is distributed to other organizations or partners that are client-facing. Of MANNA's 220 partners, more than 100 operated at some capacity immediately after the storm, and within one month, partners were functioning in the 16 counties MANNA serves.²⁰ Despite losing its food supply, from October 2024 to March 2025, MANNA was able to distribute 10.2 million pounds of food to the communities affected by the storm, which amounted to a little over half its total distribution the year before.²¹

NC has the second-largest rural population in the United States.²² While Eastern NC is more rural than Western NC, the population largely resides in rural areas.²³ Compared to Eastern NC, Western NC is less frequently affected by hurricanes. Thus, previous research on NC community food organizations post-disaster has focused on the eastern portion of the state.^{8,24,25} Hurricane Helene provides an opportunity to investigate and describe the network of community food organizations in Western NC post-disaster. In particular, this study seeks to answer the following research questions by applying a Social Network Analysis: 1) What did the collaboration network of existing community food organizations in Western NC look like after Hurricane

Helene? 2) How did the network structure hinder or facilitate a food organization's ability to distribute aid? And 3) Which organizations were the key actors in the network?

Social network analysis (SNA) is one way to investigate the social capital, the relationships formed, and the resources shared within a network of community food organizations after a large-scale disaster.^{7,26} Examining the connections between community food organizations in Western NC by using SNA can reveal strengths and weaknesses of the connections, exclusion of organizations, and levers for change.²⁷

Methods

Participants and Data Collection

Participants for this study were community food organizations that distributed food aid in Western NC to communities affected by Hurricane Helene between September 27th, 2024, and September 27th, 2025. For the purposes of this study, “community food organizations” are defined as any organization that operates at the community level and distributes food to Western NC, including, but not limited to, food banks, food pantries, soup kitchens, mobile pantries, food hubs, and meal programs. Even though food banks act as warehouses, they were included in this study because they are an integral part of coordination in the network, with their main focus being to alleviate food insecurity. Food coalitions were excluded because their primary focus is on food policy changes and not the distribution of food to communities.²⁸ Because this study also used snowball sampling, the final analytical sample includes organizations outside of the above-defined community food organizations.

Feeding America, the largest hunger and disaster relief network in the United States,^{29,30} lists eight food banks that are a part of their network in NC, which in turn distribute food to the client-facing community food organizations. Potential participating organizations were compiled from these eight food banks' websites using the "Find Food" function. This function generated a list of organizations that are either within the Feeding America network and/or are partners that the eight food banks distribute to. The initial list contained 1,334 potential participating organizations. Duplicates and organizations based outside of NC were removed (n=271). Contact information, such as emails, was gathered for the remaining 1,063 organizations. Organizations that did not have emails listed or another way of contacting them were removed (n=335). This resulted in 728 community food organizations that were initially contacted to participate in this study. As part of the data collection, organizations were asked to name other organizations, if any, that they collaborated with; this resulted in n= 123 additional organizations not in our original list. Of these organizations, 59 were contacted after removing duplicates and gathering email information, representing a one-step snowball sample. The snowball sample of organizations were not limited to community food organizations in order to capture how community food organizations utilize the broader disaster response network.

Organizations were asked to complete a survey with questions consisting of organization demographic information, Hurricane Helene preparedness, organization operation pre- and post-Hurricane Helene, food distribution pre- and post-Hurricane Helene, and collaboration between organizations. A copy of the survey can be found in **Appendix 1**. Initial emails with a link to a Qualtrics survey developed for the study were sent on January 8th, 2026. Of the initial 728 emails sent, 71 bounced back, and 44 organizations opted out. Of the 59 potential snowball participant organizations contacted, three emails bounced back, and four organizations opted out. Reminders

to all contacted organizations were sent each Tuesday of the week following initial contact, totaling four reminders over the course of data collection. The survey was closed February 18th, 2026. A total of 71 responses were collected; three of the responses were blank, and 38 answered the specific network questions. The final analytical sample comprised 130 organizations that included participants who answered the network-specific questions and the organizations that were named.

Analysis

Organization characteristics

Descriptive statistics (averages and standard deviation) were calculated for how long organizations went without power and water, food distribution 1-2 weeks after Hurricane Helene landed, food distribution up to one year after Hurricane Helene landed, and new partnerships organizations made during collaboration.

Organizations were grouped into NC regions³¹ based on their addresses, obtained from the organization list, and verified during data collection. For organizations that were named on the survey but did not answer the survey, addresses were found on either the organization's website, Facebook Page, or Google Maps. Address information was also used to determine which organizations were located in a designated disaster area based on the Federal Emergency Management Agency's (FEMA) disaster declarations.³² Counties were assigned to organizations based on their zip codes using a zip code database to find the corresponding county.³³

Non-community food organizations listed as part of the sample network in the survey were categorized into the following organization types: Education (E_1, E_2...), including local schools; Emergency Services (ES_1, ES_2...), including local Emergency Management Service

(EMS) and police; Government (G_1, G_2...), including the National Guard and social services; Healthcare (H_1, H_2...), including nursing homes and a crisis pregnancy center; Non-profit (NP_1, NP_2...), including the Red Cross and United Way; Private (P_1, P_2...), including national food companies and restaurants; and Religious (R_1, R_2...), including churches. Community food organizations included in the sample and not aggregated were Food Banks (FB_1, FB_2...), Food Hubs (FH_1, FH_2...), Food Pantries (FP_1, FP_2...), and Soup Kitchens (SK_1, SK_2...).

Network methods

SNA was used to examine the pattern of relationships between community food organizations and the ways in which the structural configuration of the network might have aided or hindered food distribution post-Hurricane Helene. The primary data object examined is the social network of relationships among community food organizations – made up of nodes (entities) and edges (relationships).³⁴ For this study, nodes are the organizations that participated in the survey (n=38) or were named on the survey by other organizations but did not participate in the survey (n=91). The edges represent which organizations requested help with resources from another organization. Because sending requests and receiving requests for resources were captured, the network is directed, meaning arrows on the edges between organizations show which organization sent or received a request for resources.

One network was generated and analyzed using R Statistical Software.³⁵ Several specialized analysis tools are available in R to perform social network analysis, various of which are used in this study. The threshold used to assess statistical significance was $p < 0.05$. It should also be noted that the sample of organizations in the data does not represent the full network of community food organizations. This is a limitation of the study. The analysis here may be sensitive

to missing data about both the organizations and relationships among them. The results should not be generalized beyond the sample of organizations observed.

Krackhardt connectedness measures the extent to which a network is connected into a cohesive component – meaning that all organizations can reach other organizations via some path of relationships.³⁶ A Krackhardt connectedness score was generated for the network and compared against a baseline of 1,000 randomly generated networks to determine if the observed connectedness deviated from what would be expected based on the global pattern of relationships between two nodes (dyads). This procedure is called a Conditional Uniform Graph (CUG) test, which was run conditioned on the dyad census using the R ‘sna’ package.³⁷ Other descriptive statistics used to characterize the network include the degree distribution and component sizes. The degree distribution captures the range of activity among the organizations, illustrating when some have more connections and act as “hubs” within the network. Component sizes show the distributions of connected groups within the network. To show how likely organizations were to report connections based on organization type, a mixing matrix was generated, providing the within- and cross-group relationships and density in the network. Network density measures the proportion of actual connections to the total possible connections within a network.¹³

In a directed graph, reciprocity measures the percentage of connections that are reciprocal. When an organization contacts another organization for resources ($A \rightarrow B$), and then the other organization contacts the original organization for resources ($A \leftarrow B$), that is a reciprocal connection called edgewise reciprocity. To assess if the network’s edgewise reciprocity was higher than what might be expected by chance, a CUG test conditioning on the edges was performed.

Bridging

A structural hole forms in a network when clusters of organizations are not directly connected but instead connected via a third party or bridge in the network.^{13,34} When these clusters are connected, this is considered bridging. Organizations that bridge across structural holes in a network have an advantage (i.e., social capital) over resource distribution, meaning they are essential in getting resources to parts of the network that may otherwise be left isolated.¹³ To assess which organizations acted as bridges, Burt's Constraint measure was calculated for each organization in the network.^{13,38} Burt's constraint measures the extent to which an organization's connections are redundant. The lower an organization's constraint score, the more bridging over a structural hole. A constraint score is considered low when $X < 1$.

Centrality

Organizations can be viewed as influential in a network because of their access and possible control over resources.³⁹ An organization that has control over resources mediates access to those resources by all others in the network. To measure this influence, we used two measures of centrality for each organization in the network. Degree centrality measures the total number of direct connections any given organization has.⁴⁰ Betweenness centrality measures the extent to which an organization lies on short paths between other organizations and therefore, is a central or important actor for mediating resources that flow along network ties.⁴⁰ Degree centrality and betweenness centrality scores were calculated for each organization in the network by using the R 'sna' package.³⁷

Permutation tests using a modified cor.test function from the R 'stats' package⁴¹ were used to test for correlation between an organization's degree centrality score and an organization's preparedness before Hurricane Helene; the organization having a disaster plan in place before

Hurricane Helene landed; physical damage the organization sustained during Hurricane Helene; the distribution of food 1-2 weeks after Hurricane Helene landed; and distribution of food up to one year after Hurricane Helene landed. The same permutation tests were run for betweenness centrality.

Brokerage

An organization can mediate resource exchange between two distinct groups, known as brokerage. Five brokerage roles were considered, as proposed by Gould and Fernandez⁴²; these include: 1) Coordinator. 2) Gatekeeper. 3) Representative. 4) Itinerant. 5) Liaison. The five brokerage roles are based on the organizations' (node) affiliation or membership. A Coordinator facilitates resource exchanges among two other organizations within the same group.⁴² A Gatekeeper can decide to grant access to or accept resources from an outsider, someone not in the broker's group, and allow those resources to flow into the group.⁴² A Representative takes resources from the group and attempts to share them with outsiders.⁴² An Itinerant acts as a mediator between two organizations that belong to the same group, while the organization acting as broker does not.⁴² In a Liaison role, all three organizations participating in the resource exchange belong to different groups from one another.⁴²

Two brokerage analyses were run on the network based on county to examine whether organizations brokered resource exchanges within or between affected counties, and organization type to examine which organization type was brokering resource exchanges. Each brokerage role score and cumulative brokerage roles (the total of all five brokerage roles) were calculated for each organization in the network. Permutation tests using the modified cor.test function were used to assess the significance of the correlation between an organization's cumulative brokerage score and an organization's preparedness before Hurricane Helene; the organization having a disaster

plan in place before Hurricane Helene landed; physical damage the organization sustained during Hurricane Helene; the distribution of food 1-2 weeks after Hurricane Helene landed; and distribution of food up to one year after Hurricane Helene landed.

Results

Organization characteristics

Characteristics of the community food organizations included can be found in **Table 1**. Twenty-six (66.7%) organizations had served North Carolina for 11+ years, 9 (23.1%) for 6-10 years, 3 (7.7%) for 2-5 years, and 1 (2.6%) was out of state. Organizations reported whether they had prepared for Hurricane Helene (43.6%), had a disaster plan (41%), and had physical damage (18%) and/or food loss due to the hurricane (28.2%). Organizations were also asked if they went without power (33.3%) and water (18%) after the hurricane. On average, organizations went without power and without water for 1.08 (SD=0.28) and 2 (SD=1.15) weeks, respectively. Average food distribution before Hurricane Helene landed was 23,592.85 (SD=38,626.72) lbs per month. Average food distribution 1-2 weeks and up to one year after Hurricane Helene landed was 100,396 (SD=397,875.9) and 121,780.35 (SD=306,389.6) lbs per month, respectively. Organizations reported new partnerships made post-disaster; 10 organizations made new partnerships when sending requests for resources, for an average of 1.8 new partnerships per organization, and 14 organizations made new partnerships when receiving requests for resources, for an average of 2.21 new partnerships per organization.

The total sample (n=130) was grouped into regions: Coastal (3.1%), Inner Coastal (11.5%), Piedmont (50%), Mountains (30.8%), and Out of State (4.6%). Eighty-eight organizations (67.7%)

were located in FEMA-designated disaster areas. Community food organizations included in the sample were Food Banks (6.1%), Food Hubs (1.5%), Food Pantries (31.5%), and Soup Kitchens (4.6%). Non-community food organization types included were Education (1.5%), Emergency Services (3.1%), Government (4.6%), Healthcare (5.4%), Non-profit (19.2%), Private (10%), and Religious (12.3%).

Table 1: Organization Descriptive Statistics

	N (%)	Mean (SD)
<i>Time serving NC (Years)</i>		
2-5 Years	3 (7.7%)	
6-10 years	9 (23.1%)	
11+	26 (66.7%)	
<i>Out of State</i>	1 (2.6%)	
<i>Prepared</i>	17 (43.6%)	
<i>Had Disaster Plan</i>	16 (41%)	
<i>Damaged (physical)</i>	7 (18%)	
<i>Loss of Food</i>	11 (28.2%)	
<i>New Partnership</i>		
<i>Sending request</i>	14 (36%)	
<i>Receiving request</i>	10 (25.6%)	
<i>Loss of Power (Weeks)</i>	13 (33.3%)	1.08 (0.28)
<i>Loss of Water (Weeks)</i>	7 (18%)	2 (1.15)
<i>Food Distribution</i>		
<i>1 Year before</i>	33 (84.6%)	23592.85 lbs/month (38626.72)
<i>1-2 weeks after</i>	25 (64.1%)	100396 lbs (397875.9)
<i>1 Year after</i>	26 (66.7%)	121780.4 lbs/month (306389.6)
<i>FEMA County*</i>		
Yes	88 (67.7%)	
No	42 (32.3%)	
<i>Region*</i>		
Mountain	40 (30.8%)	
Piedmont	65 (50%)	
Inner Coastal	15 (11.5%)	
Coastal	4 (3.1%)	
Out of State	6 (4.6%)	
<i>Organization Type*</i>		
Education	2 (1.5%)	

<i>Emergency Services</i>	4 (3.1%)
<i>Food Bank</i>	8 (6.1%)
<i>Food Hub</i>	2 (1.5%)
<i>Food Pantry</i>	41 (31.5%)
<i>Government</i>	6 (4.6%)
<i>Healthcare</i>	7 (5.4%)
<i>Non-profit</i>	25 (19.2%)
<i>Private</i>	13 (10%)
<i>Religious</i>	16 (12.3%)
<i>Soup Kitchen</i>	6 (4.6%)

*Note: These measures are taken from the total sample (n=130)

Network structure

The resulting network (**Figure 2**) consists of 130 organizations that distributed food in Western NC after Hurricane Helene, colored-coded by the region the organization resides in. From the CUG test, we found that the network is more disconnected than what we would expect (p-value < 0.001) based on the number of actors and overall level of collaboration (i.e. activity) in the network. While the network is disjointed, not well connected, and made up of groups or clusters, organizations tend to group themselves by region. For example, organizations located in the Piedmont region (blue) had more connections with organizations that are also located in the Piedmont region.

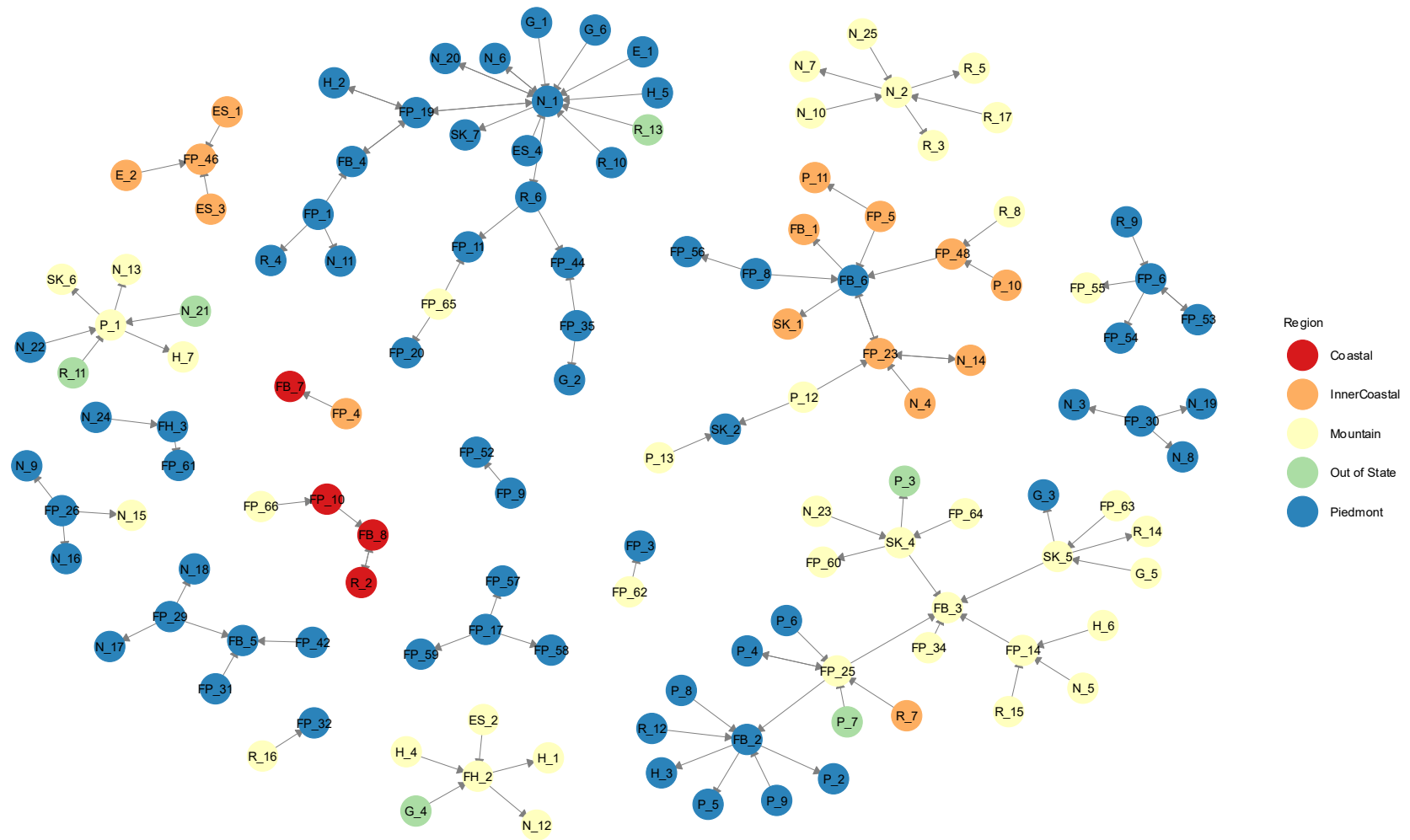


Figure 2: The Network of Community Food Organizations in Western North Carolina After Hurricane Helene. Colored by the region the organization resides in.

From the degree distribution we observe in **Figure 3** that most organizations (65%) have few connections (degree=1). A few organizations have many connections; these organizations can be considered “hubs,” where there is a lot of sending and receiving. The component size distribution, **Figure 4**, shows that there are three clusters that are highly connected within themselves. For example, component 15 is made up of 16 connected nodes.

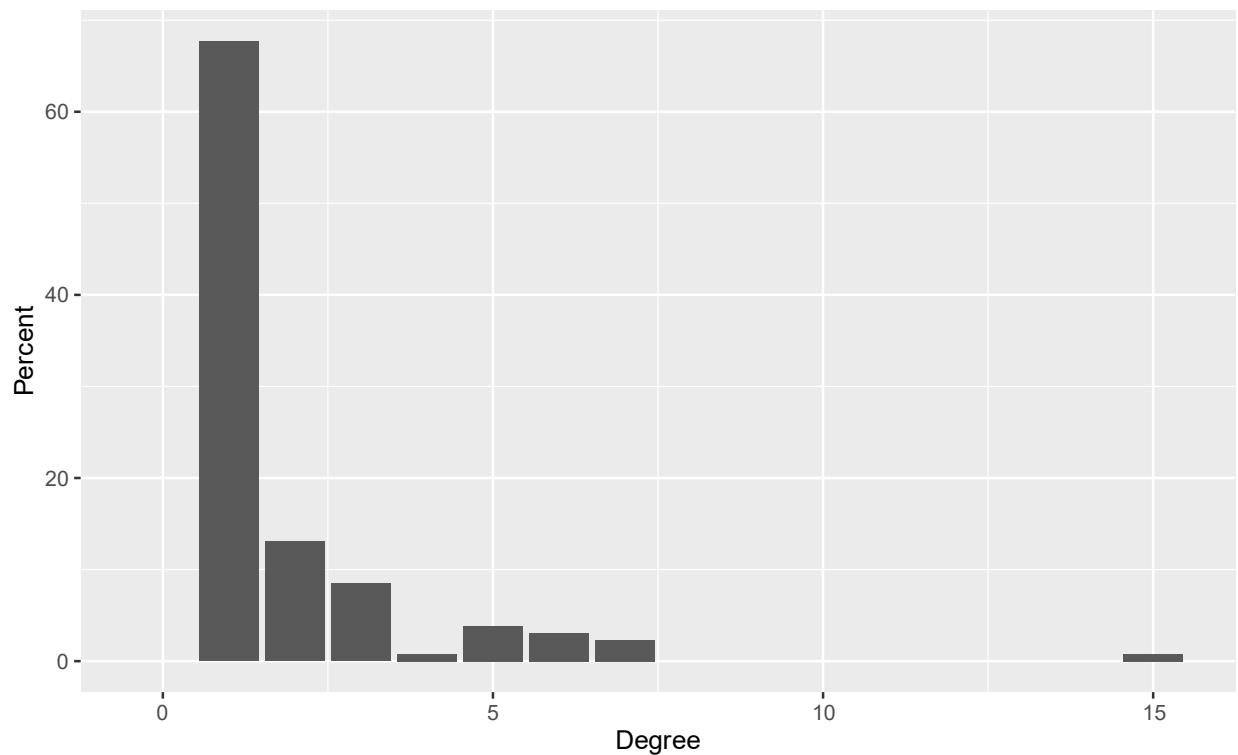


Figure 3: Histogram of the degree distribution showing how many organizations have a specific number of ties. Most organizations have few connections, but there is a long tail with a few organizations having a high degree. The y-axis is the percentage of the sample, and the x-axis is the degree (number of connections per node).

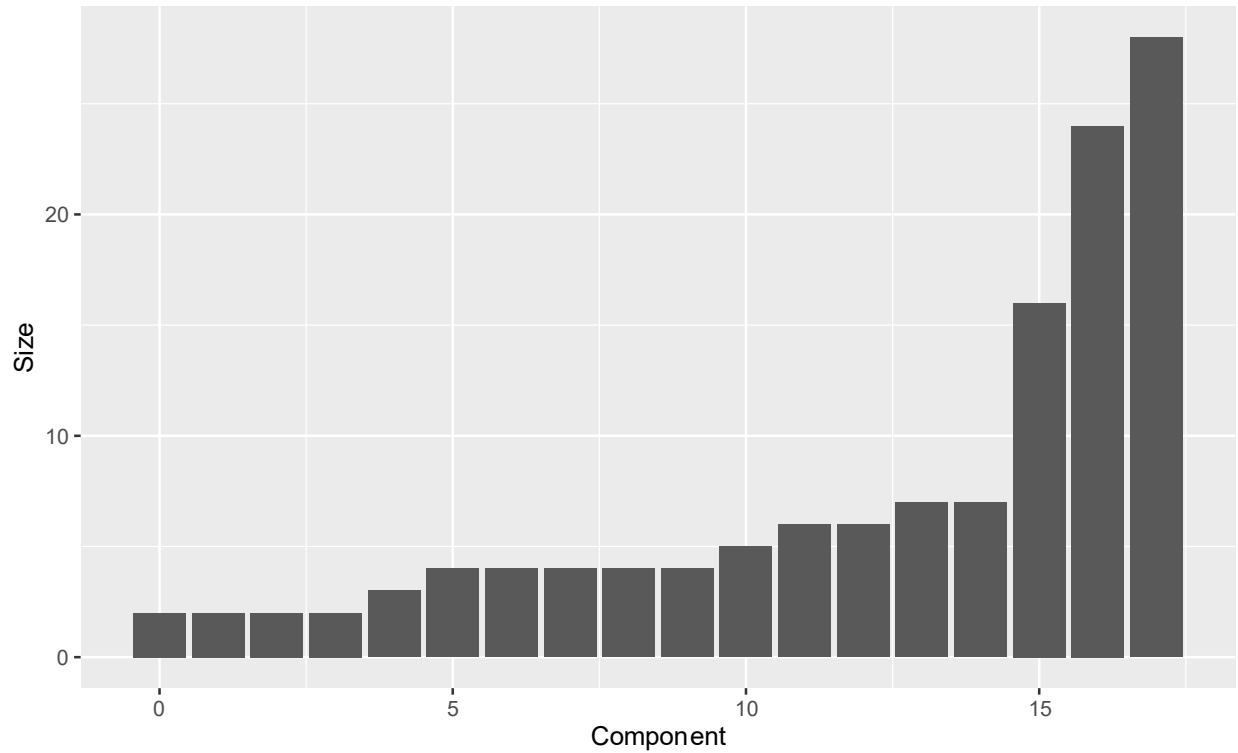


Figure 4: Histogram of the component distribution of the network. Each component is assigned a number (x-axis) and 'size' (y-axis) is based on the number of connected nodes in the component.

An analysis of the mixing matrix rates (**Figure 5**) between organizations of different types showed that food pantries and soup kitchens were more likely to send requests for resources to food banks. Government organizations and emergency services were more likely to send requests for resources to food hubs. Non-profits were more likely to request resources from other non-profits. Religious organizations and education were neither more likely nor less likely to send requests to any other type of organization.

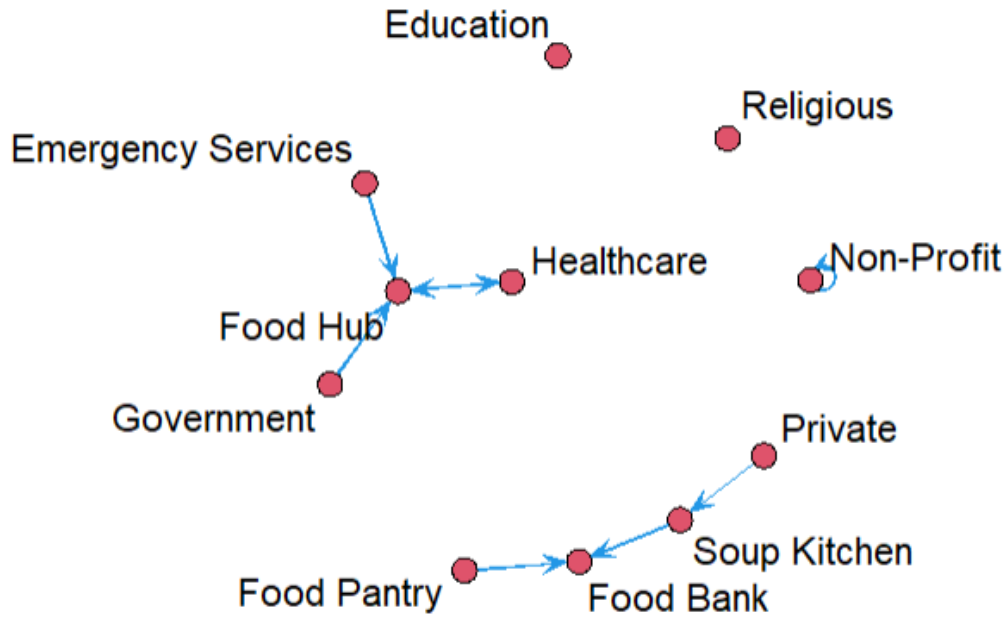


Figure 5: Mixing rates by organization type show the connections that exist between organizations of different types. Blue connections represent relationships that are more frequent than what you would expect given the number of organizations of that type and the overall activity level in the network.

Network density was 0.007; this value indicates that the network is sparse with few connections. The rate of edgewise reciprocity was 16.4%. Based on the CUG test, the rate of reciprocal connections was higher than what we would expect given the low density of the network (p -value < 0.001). For this reason, the nodes were not aggregated.

Bridging

Thirty-three organizations had low constraint scores ($X < 1.0$), indicating that these organizations work to bridge (i.e., connect) what would otherwise be disconnected clusters to the rest of the network. For example, in **Figure 2**, N_1 (constraint score=0.09) bridges two smaller clusters by having connections to FP_19 and R_6.

Centrality

Twenty percent of organizations in the sample had a degree centrality score of 3 or more, indicating that they were “highly” connected. The rest of the sample (80%) had a degree centrality score of 1 or 2, indicating that they had very few connections. A moderate to strong, positive, and statistically significant association between a node’s degree centrality and distribution of food 1-2 weeks after Hurricane Helene landed was found (Observed = 0.403, permutations = 5000, $n = 26$, $p\text{-value} = 0.002$). This indicates that organizations that had more connections immediately after Hurricane Helene landed were able to distribute more food. A moderate, positive, and statistically significant association between a node’s degree centrality and distribution of food up to one year after Hurricane Helene landed was also found (Observed = 0.353, permutations = 5000, $n = 27$, $p\text{-value} = 0.05$), showing that an organization’s connections continued to influence their ability to distribute food up to one year after the event. No statistically significant association was found between a node’s degree centrality and preparedness before Hurricane Helene landed (Observed = -0.103, permutations = 5000, $n = 39$, $p\text{-value} = 0.598$); the organization having a disaster plan in place when Hurricane Helene landed (Observed = 0.076, permutations = 5000, $n = 39$, $p\text{-value} = 0.718$); and physical damage sustained during Hurricane Helene (Observed = -0.166, permutations = 5000, $n = 18$, $p\text{-value} = 0.621$).

For betweenness, nineteen (14.6%) organizations had a betweenness centrality score greater than zero, with 10% having a betweenness centrality score of 6 or more, which indicates they acted as “hubs.” From the correlation tests, a positive and statistically significant moderate association between a node’s betweenness centrality and distribution of food 1-2 weeks after Hurricane Helene landed was found (Observed = 0.375, permutations = 5000, $n = 26$, $p\text{-value} = 0.046$). This shows that organizations acting as a mediator distributed more food 1-2 weeks after

Hurricane Helene landed. No statistically significant associations were found between an organization's betweenness centrality and preparedness before Hurricane Helene landed (Observed = -0.086, permutations = 5000, n=39 p-value = 0.733); the organization having a disaster plan in place when Hurricane Helene landed (Observed = 0.055, permutations = 5000, n=39, p-value = 0.838); physical damage sustained during Hurricane Helene (Observed = -0.203, permutations = 5000, n=18, p-value = 0.644); and distribution of food up to one year after Hurricane Helene landed (Observed = 0.251, permutations = 5000, n=27, p-value = 0.114).

Brokerage

A total of 19 organizations participated in some type of brokerage. When grouped by county, the most frequent role observed for these 19 organizations were the Gould and Fernandez Coordinator role, indicating that organizations that acted as brokers were exchanging more resources with other organizations within the same county. Around half of the organizations participating in some brokerage (n=10) had multiple brokerage roles, indicating that these organizations brokered resource exchanges within their county and between counties. **Figure 6** shows cumulative brokerage scores when grouped by county in the network graph.

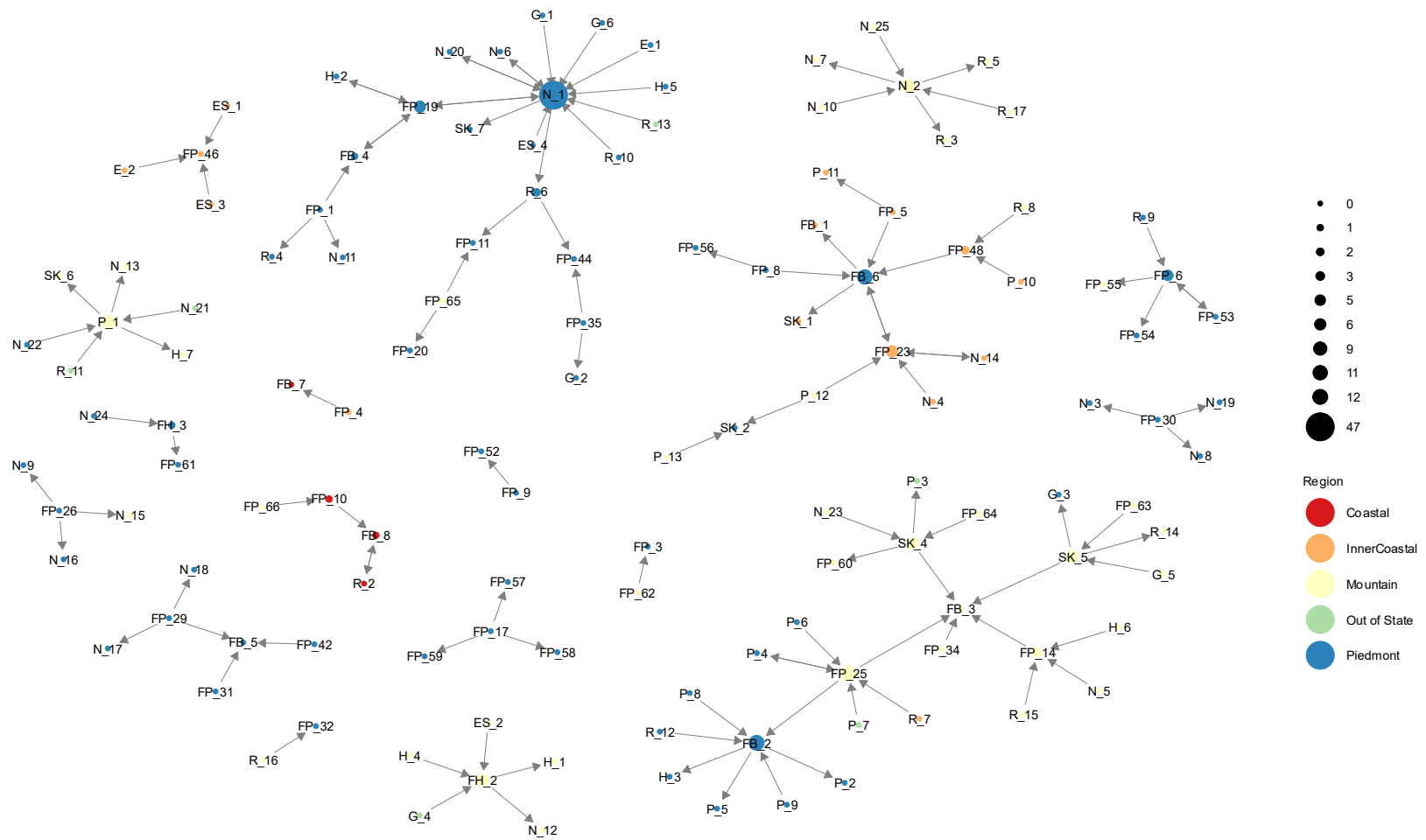


Figure 6: Network Graph of Gould-Fernandez Brokerage Analysis grouped by county membership. The size of the circle indicates a higher cumulative brokerage score. Broker type is not distinguished.

When grouped by organization type, organizations that participated in some type of brokerage mostly participated in the Gould and Fernandez Liaison role. This means that organizations that acted as liaisons were exchanging with organizations of a different type. Around half (n=11) had multiple brokerage roles, showing that these organizations brokered resource exchanges to organizations that were the same type and not the same type as their own. **Figure 7** shows cumulative brokerage scores when grouped by organization type in the network graph.

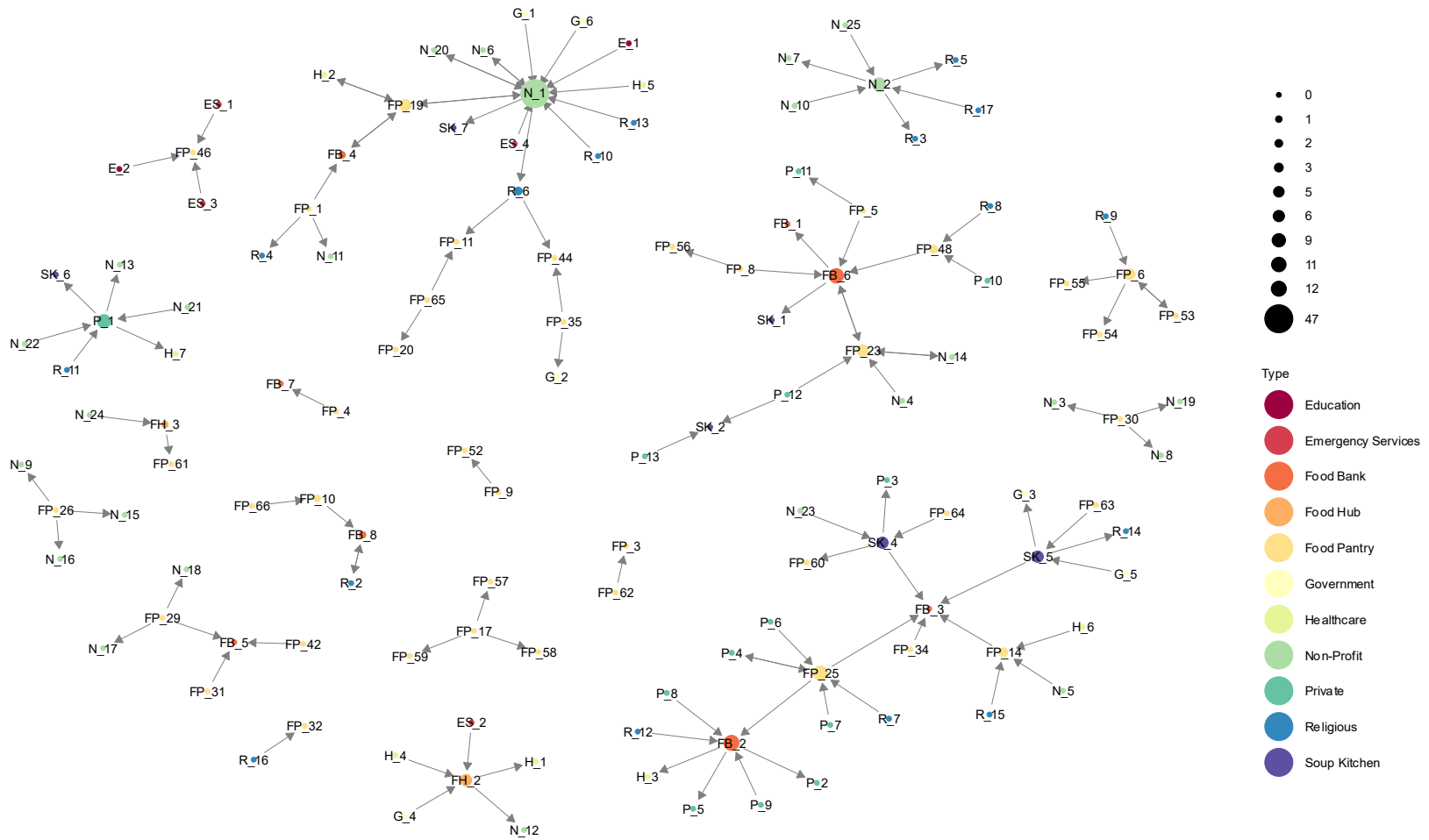


Figure 7: Network Graph of Gould-Fernandez Brokerage Analysis grouped by organization type. The size of the circle indicates a higher cumulative brokerage score. Broker type is not distinguished.

Correlation tests found a moderate-to-strong, positive, and statistically significant association between an organization's cumulative brokerage score and distribution of food 1-2 weeks (Observed = 0.532, permutations = 5000, $n = 26$, $p\text{-value} < 0.001$). A moderate, positive, and statistically significant association between an organization's cumulative brokerage score and distribution of food up to one year after Hurricane Helene landed was found (Observed = 0.392, permutations = 5000, $n=27$, $p\text{-value} = 0.042$). Organizations that brokered resource exchanges, regardless of brokerage role, were more likely to do so immediately after Hurricane Helene landed. No statistically significant association was found between a node's brokerage and preparedness before Hurricane Helene landed (Observed = -0.129, permutations = 5000, $n=39$, $p\text{-value} = 0.579$); the organization having a disaster plan in place when Hurricane Helene landed (Observed = 0.123, permutations = 5000, $n=39$ $p\text{-value} = 0.597$); and physical damage sustained during Hurricane Helene (Observed = -0.216, permutations = 5000, $n=18$, $p\text{-value} = 0.5766$).

Key actors

N_1 had the lowest constraint score (0.09), the highest degree centrality score (15), the highest betweenness centrality score (103), and the highest cumulative brokerage score (47). Combined, these scores indicate that this organization was central in the distribution of food while also acting as a bridge and a broker. As a broker, this organization acted primarily as a Coordinator when grouped by county (i.e., it interacted with organizations within their county) and as a Liaison when grouped by organization type (i.e., it interacted with organizations of a different type than their own). The organization reported a loss of power and water for one week after Hurricane Helene but did not report the pounds of food distributed before or after Hurricane Helene.

FB_2 had the second lowest constraint score (0.14), the third highest degree centrality score (7), the fifth highest betweenness centrality score (24), and the second highest cumulative brokerage score (12). This organization leveraged their connections to distribute food after Hurricane Helene landed and acted as a broker between the connections. Similar to N_1, their most prominent county-level brokerage role was a Coordinator, and their most prominent organization type brokerage role was a Liaison. FB_2 reported 960,000 lbs of food distributed in the year before Hurricane Helene, 200,000 lbs 1-2 weeks after, and 1,416,571 lbs up to one year after Helene. The organization reported no physical damages sustained because of Hurricane Helene.

FP_25 had the fifth lowest constraint score (0.18), the second highest degree centrality score (7), the sixth highest betweenness centrality score (23), and the third highest cumulative brokerage score (11). Unlike N_1 and FB_2, FP_25 acted more as a Liaison for both brokerage analyses, meaning that FP_25 interacted with organizations outside their own county and of a different organization type than their own. The organization reported distribution of 480,000 lbs of food the year before Hurricane Helene, 200,000 lbs 1-2 weeks after, and 1,200,000 lbs up to one year after Helene. The organization reported no physical damages caused by Hurricane Helene. While FP_25 was located in a different region from N_1 and FB_2, all three organizations were located in a FEMA-designated disaster area.

Discussion

In this study, we applied social network analysis to understand how community food organizations collaborated to distribute food to communities affected by Hurricane Helene in Western NC. We found that, after Hurricane Helene landed in Western NC, the overall network of community food

organizations was not well connected and was made up of clusters or groups. Organizations tended to share connections with other organizations within the same region. However, the few organizations that had many connections (high degree centrality) or collaborated in resource exchanges (brokerage) were more likely to distribute resources 1-2 weeks after and up to one-year after Hurricane Helene landed. This shows that brokerage continued to affect an organization's ability to distribute resources up to one year after Hurricane Helene landed. Organizations that mediated resource distribution (high betweenness centrality) were more likely to distribute resources 1-2 weeks after, but not one year after Hurricane Helene landed. The lack of organizations with a betweenness centrality score speaks to the disconnection of the network; for this reason, 10% of the organizations can be thought of as "hubs." Organizations tended to collaborate within their respective counties and among organizations that were a different type than their own. Despite being located in FEMA-designated disaster areas where infrastructure loss was more likely to occur, the three key actors identified played crucial roles in their respective clusters.

Two-thirds of the organizations that completed the survey were well established (11+ years) in NC at the time that Helene landed, having been in the area for more than a decade. Because social capital can also include the trust an organization has, this could explain why we observed organizations cluster by region. A study on the network of eastern NC community food organizations post-Hurricane Florence (2018) found that outsider organizations seeking to help were more likely to be turned away or were deemed untrustworthy.²⁵ However, if organizations have established relationships (i.e. trust) with those in different regions prior to a disaster, an organization can leverage that connection.^{25,43} Prior established relationships could explain why we observed some organizations collaborating across counties.

Almost half of the organizations that answered the survey prepared for Helene (43%) or had a disaster plan in place (41%); however, this did not make organizations more or less likely to collaborate after the disaster. The same was observed for organizations that experienced any physical damages (18%; i.e., experiencing damage was not associated with collaborating among organizations). Previous research has found that when community food organizations become inoperable after a disaster, they try to find ways to distribute food, for example by utilizing mobile pantries, or asking organizations close to them to take over distribution.^{8,25} MANNA's CEO reported in an interview that after Hurricane Helene landed in Western NC, the organization used its undamaged trucks to move resources to areas that needed it.⁴⁴ When Hurricane Helene landed, MANNA was also in the process of moving its warehouse to a different location.²⁰ The new warehouse allowed MANNA to quickly stage donated items and begin distributing.^{20,44} However, MANNA still had difficulties connecting with some of its partners.⁴⁴ This would explain why organizations that prepared for Hurricane Helene, but still experienced damages, were neither more nor less likely to collaborate.

Thirty-three organizations reported their monthly food distribution before Hurricane Helene landed, for an average of 23,592.85 lbs per month. While only 25 and 26 organizations reported food distribution 1-2 weeks and up to one year after Hurricane Helene landed, respectively, food distribution 1-2 weeks and one year after was 4.25 times and 5 times more, respectively, than the average before Hurricane Helene landed. Previous research has found that demand and donations go up during disaster recovery.^{8,25} This study's distribution increase post-disaster speaks to the ability of organizations to distribute resources despite the network not being well connected.⁹

Even though the network captured for this study shows isolated clusters or groups, we found that 33 organizations connected with organizations within clusters that would otherwise be isolated (i.e. they occupy structural holes). The participation in, and control of, resource distribution explains the social capital that bridging over what would be two isolated clusters or groups gives an organization.¹³ Burt¹³ describes that an organization which bridges between groups or clusters can tailor solutions to the specific needs of the organizations it is connected with, even replacing formal bureaucracy, and shifting solutions swiftly when needed. This bridging organization can know about, and can exercise control over, “more rewarding opportunities.”¹³ However, previous research found that optimal disaster networks include a combination of densely packed clusters or groups that are connected by an organization acting as a bridge.⁴⁵ While the network for this study does show bridging across structural holes, the network could be more robust by connecting the larger clusters or groups.

Three key actors were identified in the network, all having high degree and betweenness centrality: N_1, a non-profit organization, FP_25, a food pantry, and FB_2, a food bank. Butts, Acton, and Marcum⁴⁶ found in their study on the emergent multiorganizational network after Hurricane Katrina that organizations with high degree centrality could be considered “mass collaborators.”⁴⁶ These organizations have many connections compared to the rest of the network, facilitating the exchange of information and resources in the network.⁴⁶ Organizations that have a high betweenness centrality do not necessarily have to have many connections.⁴⁶ These high betweenness organizations bridge to other parts of the network that would otherwise be disconnected, sometimes represented by one connection between two organizations.⁴⁶ However, it is typical in SNA that those identified with a high degree centrality also have a high betweenness centrality.⁴⁶ Petrescu-Prahova and Butts⁴⁷ found that during 9/11, the organizations that acted as

“hubs” of communication were those with many connections (high degree) and those that bridged between many organizations (high betweenness).

The top three brokers for the network were the three key actors: N_1, FB_2, and FP_25. N_1 primarily took on a role that collaborated with organizations all located in the same county (Coordinator) but also had roles collaborating with other organizations between counties (Gatekeeper, Representative, Liaison). FB_2's collaboration role involved organizations all located in the same county (Coordinator) and between counties (Representative). FP_25's collaboration role involved primarily organizations outside of its respective county (Itinerant and Liaison). Among organization types, N_1 was a broker in each of the five brokerage roles, collaborating among organizations of the same type (non-profit organizations) and of a different type. On the other hand, FB_2 and FP_25 took on roles that collaborated with organizations of a different type than their own (Itinerant and Liaison). Lind et al.⁴⁸ found in their study after Hurricane Katrina that local organizations that held broker roles had existing (i.e., pre-disaster) connections. They also noted that national organizations, like FEMA, lacked trust from the local community, which made establishing contact difficult.⁴⁸ Trust among organizations could explain why organizations tended to broker mostly within their respective counties.

This study has strengths and limitations. One strength of this study is that when a disaster affects a community, informal networks tend to appear; SNA is one way to capture these networks and answer important questions in disaster research.⁴⁹ By using SNA, we were able to identify holes in the network that could lead to better collaboration of community food organizations for not only future disasters but also for the current recovery of Helene-made food deserts.⁵⁰ One major limitation of this study is the survey response rate. Organizations that did not answer the specific network questions could have connections that were not accurately captured. Furthermore,

the organizations that were named but did not answer the survey could have reciprocal or mutual connections that are not accurately represented. For example, the eight major food banks that are a part of the Feeding America network in NC did not respond to the survey; however, some were named on the survey and are included. Data collection took place during the 2025 government shutdown. This was an unprecedented time for food banks as they were trying to keep up with an increase in demand due to the Supplemental Nutrition Assistance Program (SNAP) benefit pause,⁵¹ which may explain the low response rate. Social network analysis methods in particular are sensitive to missing data, and therefore the results of this study should not be generalized beyond the sample of data observed. This approach, however, illustrates the importance of understanding the overall pattern of collaboration, particularly in disaster settings, and its impact on the effectiveness of response.

Conclusion

This study has shown the application of social network analysis to investigate a community food organization network after a large-scale disaster. As such, it adds to the ever-growing research on food security responses to disasters. This study also sheds light on how rural community food organizations collaborated in an area that does not usually experience large-scale disasters, despite losing one of its largest food banks.²⁰ The network of organizations identified in this study is not well connected, even though key organizations worked to bridge across smaller clusters. The network could be more robust by connecting the larger clusters. Research has shown that having community food organizations interact with one another *before* a disaster can improve collaboration efforts during the disaster response effort.^{7,25,43,48} The increase in interaction before

a disaster could improve connection within NC's community food organization network. Using a survey as a primary data collection tool can be a way to obtain information about a large sample relatively quickly.⁵² However, given the limitations when applied to SNA, future research could validate ties by using public online data, similar to what Butts, Acton, and Marcum⁴⁶ collected, such as situation reports, maps, advisories, press releases, and organizational website information. Given the observed frequency and intensity of climate disasters, research on food security responses is ever more important for the resiliency of communities.⁵³

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Appendix 1

The following questions are about **your** organization. There are **three required** questions in this section.

Q1 What is the name of your organization?

Q2 What is the zip code your organization is located in?

Q3 How long has your organization been serving North Carolina?

- ☐ 1 year
- ☐ 2-5 years
- ☐ 6-10 years
- ☐ 11+ years
- ☐ N/A (out of state)

Q4 Is your organization considered a:

- ☐ Food bank
- ☐ Food pantry
- ☐ Soup kitchen
- ☐ Meal program
- ☐ Other: _____

Q5 Was your organization in North Carolina at the time Hurricane Helene landed? (September 26th, 2024)

☐ Yes

☐ No

Q6 Did your organization take any steps to prepare for Hurricane Helene?

☐ Yes (*Display Q6A*)

☐ No

While this is not a full list of steps your organization may have taken, please fill it out to the best of your ability.

Q6A Please select all the steps your organization took to prepare for Hurricane Helene:

- ☐ Staged vehicles in secure location
- ☐ Topped off fuel in vehicles
- ☐ Identified alternative routes for potentially affected areas
- ☐ Identified secure location for other equipment
- ☐ Handed out an updated contact list of all staff
- ☐ Shared disaster preparedness materials with staff
- ☐ Contacted Feeding America for any staff support
- ☐ Developed a plan for staff that are unable to work
- ☐ Built stock of items for staff use (water, canned goods, personal care items)
- ☐ Built stock of disaster relief products

- ☐ Created physical inventory sheets
- ☐ Parked or stored food supply off-site
- ☐ Pre-positioned food supply (moved to higher shelves etc.)
- ☐ Pre-position perishable items
- ☐ Pre-made meals before disaster
- ☐ Identified partners to help with procurement support after the disaster
- ☐ Developed a list of partner agencies who would respond to the disaster
- ☐ Developed a list of community partners who would respond to the disaster
- ☐ Tracked weather patterns
- ☐ Provided alert warnings
- ☐ Developed a notification procedure to inform staff when it was safe to return to work
- ☐ Developed procedure to communicate to partner agencies with regards to operations status after the disaster

The following questions are about food distribution, partnership, and disaster coordination plans **BEFORE** Hurricane Helene landed in North Carolina on September 27th, 2024. Please answer to the best of your ability.

Q7 On average, how many pounds of food **per month** did your organization distribute to the public in the year **BEFORE** Hurricane Helene landed in North Carolina?

Q8 How many food banks, pantries, soup kitchens, meal programs, etc., did your organization partner with **BEFORE** Hurricane Helene landed in North Carolina?

Q9 Does your organization have a disaster coordination plan?

☐ Yes (*Display Q9A*)

☐ No

Q9A Would your organization be willing to share its disaster coordination plan?

☐ Yes (*Display Q9AA*)

☐ No

Q9AA Please upload your disaster plan here:

The following questions are about damages **your** organization experienced **AFTER** Hurricane Helene landed in North Carolina on September 27th, 2024. Please answer to the best of your ability.

Q10 Did your organization experience any damages or loss of food, power, or water **AFTER** Hurricane Helene landed?

☐ Yes (*Display Q10A-10F*)

☐ No

Q10A How many weeks did your organization go without power **AFTER** Hurricane Helene landed?

Q10B How many weeks did your organization go without running water **AFTER** Hurricane Helene landed?

Q10C Did your organization have to relocate in the **6 months AFTER** Hurricane Helene landed?

☐ Yes

☐ No

Q10D Did your organization have to relocate in the **1-year AFTER** Hurricane Helene landed?

☐ Yes

☐ No

Q10E Did your organization experience any loss of food because of Hurricane Helene?

☐ Yes

☐ No

Q10F Did your organization experience any damage because of Hurricane Helene? (Includes buildings, equipment, etc.)

☐ Yes

☐ No

The following questions are about how long it took your organization to start distributing food after Hurricane Helene landed in North Carolina on September 27th, 2024.

Q11 Did your organization distribute any food in North Carolina to communities or individuals affected by Hurricane Helene **up to 1-year AFTER** Hurricane Helene landed? (This does not include other organizations' requests for food)

☐ Yes (*Display 11A-11C*)

☐ No

Q11A When did your organization start distributing food to communities and individuals affected by Hurricane Helene?

- ☐ Day(s) after the hurricane landed
- ☐ 1-2 weeks after the hurricane landed
- ☐ 3-4 weeks after the hurricane landed
- ☐ More than a month after the hurricane landed

Q11B How many **total** pounds of food did your organization distribute to the public **1-2 weeks AFTER** Hurricane Helene landed? (Please use total poundage between September 28th, 2024 - October 11th, 2024)

Q11C On average, how many pounds of food **per month** did your organization distribute to the public up to **1-year AFTER** Hurricane Helene landed? (Please use total poundage between September 28th, 2024 - September 27th, 2025)

The following questions will ask you to name up to 3 organizations your organization **connected with** for help or supplies, and 3 organizations that **requested** help or supplies from your organization after Hurricane Helene landed in North Carolina on September 27th, 2024. Some questions will also ask if these organizations had established a partnership after Hurricane Helene. Please include the **full name** of each organization.

Q12 Name up to 3 organizations your organization **reached out to** for any help or supplies **AFTER** Hurricane Helene landed in North Carolina. Please include the **full name** of each organization. (If this does not apply to your organization, please leave blank)

Q12A How many of these organizations were **new** partnerships?

Q13 Did your organization **EXPECT** to get help from a partner or organization, but did not receive this help?

☐ Yes (*Display 13A*)

☐ No

Q13A If known, why could the partner not help your organization?

Q14 Name up to 3 organizations that **contacted your organization** for help or supplies **AFTER** Hurricane Helene landed in North Carolina: (If this does not apply to your organization, please leave blank)

Q14A How many of these organizations were **new** partnerships?

Q15 Was there any reason your organization could not help another?

☐ Yes (*Display 15A*)

☐ No

Q15A What was the reason, if known, why your organization could not help?
