TITLE: The role of collaborative governance network for building adaptive capacity in the Galapagos small-scale fishing sector.

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KEYWORDS: Adaptive Capacity; Social Network Analysis; Small-scale fisheries.

ABSTRACT

Collaborative forms of governance have a key role in building adaptive capacity in small-scale fishery systems. However, governance systems' structures and features are usually ignored, reducing opportunities to improve collaboration among multiple actors to cope with adverse drivers of change and enlarge trust in decision-making. This study used a social network analysis approach, based on descriptive statistics and exponential random graph models (ERGMs), to examine specific network patterns and configurations that may strengthen collaboration links in the Galapagos small-scale fishery governance system. We explored four main research questions: how do the collaborative ties in the Galapagos small-scale fishing governance system interact, which are the central and bridging organizations and agencies within the Galapagos small-scale fishery governance system, what are the organizational links of the Galapagos small-scale fishery governance system and their frequencies, and is there a tendency toward reciprocity, popularity, and sender-and-receiver network formations in the Galapagos small-scale fishery governance system? Our findings suggest a cross-level and cross-sectoral interaction between various organizations and agencies in the Galapagos small-scale fishery system. We identified central and well-positioned actors and network configurations whose interactions might be fundamental to strengthen the small-scale fishing sector's adaptive capacity to face future crises caused by novel pandemics, climate change or other anthropogenic and climate drivers of change.

1.1 INTRODUCTION

Small-scale fisheries are complex socio-ecological systems that evolve according to human behaviours and attitudes, environmental and development conditions, and other circumstances. An increasing number of natural and human-induced drivers of change, such as climate change, globalization, novel global pandemics such as COVID-19, illegal fishing, economic crises, and overexploitation of resources, are causing unprecedented consequences throughout small-scale fisheries in Latin America and the Caribbean, pushing them into socio-economic situations never before experienced (Escobar-Camacho et al., 2021). The dynamics and interactions of small-scale fishery systems are continually changing, particularly during a period where multiple drivers of change coincide (DeWitte et al., 2017; Lubell and Morrison, 2021). This reality triggers various rapid and transboundary management problems derived from different geneses charged with uncertainty and complexity, involving actors from several sectors, governance levels, and geographical scales. Consequently, it becomes increasingly challenging to align the governance structures scale to the problems they are meant to address (Bodin, 2017; Epstein et al., 2015; Kininmonth et al., 2015; Rijke et al., 2012) and build adaptive capacity.

Building adaptive capacity in small-scale fishery systems largely depends on the coordination, collaboration, and interdependencies between diverse actors, including resource users, managers, scientists, and non-governmental organizations (Johnson et al., 2020). The lack of communication and collaboration among these actors, together with a limited alignment (fit) between governance systems and socio-ecological dimensions, often results in a series of detrimental effects on small-scale fisheries (Bodin et al., 2014; Pahl-Wostl, 2009; Pittman et al., 2015). These effects include overfishing of fishery resources, habitat fragmentation, and biodiversity loss, which affect fishers' livelihoods, giving rise to "the tragedy of the commons" (Hardin, 1968). Disregarding governance systems' structures and features exacerbates the problem of alignment fit in complex socio-ecological systems. Consequently, building adaptive capacity also becomes increasingly challenging.

Collaborative network approaches may offer possible solutions to building adaptive capacity in small-scale fisheries (Berkes, 2010; Levy and Lubell, 2018) through participation, connectivity, and experimentation across actors, sectors, scales, and levels (Guerrero et al., 2015). This research and management approach bolsters opportunities for communication (Barnes et al., 2019), the creation of social learning (Bodin, 2017), trust-building (Bodin et al., 2020; Mcallister et al., 2017), the co-production of knowledge (Crona and Bodin, 2006; Kowalski and Jenkins, 2015), institutional building (Armitage et al., 2009; Berkes, 2009), and conflict resolution (Hahn et al., 2006), among other central elements for building adaptive capacity in socio-ecological systems. In this paper, we argue that unveiling the structure of governance systems' networks enables practitioners and decision-makers to understand the institutions and actors comprising those governance systems and their interactions. This allows, among other things, for planning actions strategically and revealing options for improved collaboration between governmental institutions, fishers, and civil society to cope with adverse drivers of change and build trust in the decision-making process, e.g., facilitating and accelerating the provisions of support and the delivery of mitigation measures in times of crisis (e.g., during pandemics) and the diffusion of crucial information and knowledge in governance systems.

The configuration of a governance system network relies on several historical, environmental, cultural, economic and social factors whose interactions might give rise to various network configurations, different connections, and, consequently, likely diverse interpretations (Groce et al., 2018; Lusher et al., 2012). The social network analysis represents an analytical framework to represent, capture, and unveil relationships and interdependencies in social and ecological environments (Borgatti et al., 2009; Ingold et al., 2018; Sayles et al., 2019). In this paper, we used a social network analysis approach to examine specific network patterns and configurations that may strengthen collaboration links in the small-scale fishery governance system of Galapagos. Such knowledge could be used by decision-makers as input to design and implement management actions and strategies to improve the adaptive capacity of the Galapagos small-scale fishery sector against multiple drivers of change.

Our social network analysis is based on descriptive statistics (centrality measures) and exponential random graph models (ERGMs), a statistical approach for assessing if certain network configurations are more prevalent or not in a network than would occur by chance alone according to the presence or absence of links among actors, actors' attributes, and network parameters in an observed network (Bodin et al., 2014; Bodin and Tengö, 2012; Guerrero et al., 2015; Kininmonth et al., 2015; Lusher et al., 2012; Pittman and Armitage, 2019; Shumate and Palazzolo, 2010). We followed this approach to explore: (1) central and bridging organizations and agencies within the Galapagos small-scale fishery governance system, (2) the frequency and organizational links of the Galapagos small-scale fishery governance system, and (3) the tendency toward reciprocity, popularity, and sender-and-receiver network formations within the Galapagos small-scale fishery governance system. To analyze network configurations, we used the term "nodes" to refer to those organizations and agencies connected to the Galapagos small-scale fishery sector through different links or ties, represented by actions of coordination, communication and work among organizations. On the other hand, the term "connectivity" refers to the links or ties of one organization to other organizations and agencies. We used both terms to describe the Galapagos small-scale fishery governance system as a governance system network.

In response to the growing need for decision-makers and policymakers to act during unexpected and rapid changes, the concept of adaptive capacity has gained popularity in policymaking and public policy discourses to illustrate ways to make a governance system more robust to adverse shocks. Adaptive capacity refers to the conditions that enable a system of interest to anticipate and respond proactively to diverse shocks, reduce the adverse consequences, recover and take advantage of new opportunities (Cinner et al., 2018; Engle, 2011; Folke et al., 2002; Whitney et al., 2017). Here, we argue that governance systems often represent the structures by which public and private institutions solve societal problems and build societal opportunities (Kooiman, 2003). Therefore, the study of governance systems structures and their features become increasingly necessary to bolster the capacity of complex socio-ecological systems to adapt (Armitage and

Plummer, 2010a; Emerson and Gerlak, 2015; Folke et al., 2005; Gupta et al., 2010; Pahl-Wostl, 2009).

Solving wicked problems spanning complex social-ecological systems such as small-scale fisheries governance systems requires multi-level cooperation to deliver appropriate policy solutions for complex social-ecological issues (Lubell and Morrison, 2021). Collaborative approaches are platforms to foster participation from various actors, providing expertise, flexibility, and experimentation from multiple sectors, and levels in light of rapid changes and uncertainty (Bodin, 2017). Although it is often hard to coordinate various organizations to manage common-pool resources because of social-ecological systems' socio-economic and political realities, impacting the future of a shared resource requires an initial understanding of how actors and stakeholders from various sectors, scales, and levels tend to interact within governance systems to propose actions, policies and strategies. Disregarding the latter might limit the cross-sectoral and cross-level interactions required to make decision-making structures operational and, therefore, strengthen the adaptive capacity of a system of concern. In Olsson's (2006) terms, the problem's elements correspond to the preparatory efforts to achieve a desirable social-ecological system state.

Connecting organizations and agencies from different sectors and administrative levels—often with opposing views and interests—is challenging (Baird et al., 2019; Mcallister et al., 2017). However, strengthening the capacity of a complex social-ecological system to adapt is more a matter of learning, collaboration, cooperation, conflict resolution, and flexibility than prediction and control (Armitage et al., 2007; Bodin et al., 2020). Therefore, unveiling collaborative governance network patterns and configurations are significant—not only to contribute to, anticipate, and respond to multidimensional and uncertain changes that may occur across sectors, geographical scales and administrative levels—but also for equilibrating institutional objectives, strategies, and power distribution between the individuals we deem central figures in building adaptive capacity (Armitage and Plummer, 2010b; Keskitalo and Kulyasova, 2009; Morrison et al., 2019).

2.1 RESEARCH CONTEXT

Our study focuses on the small-scale fishery sector from the Galapagos Marine Reserve (GMR), Ecuador. In this multiple-use marine protected area, research efforts have often centred mainly on biological and ecological perspectives over human and social dimensions, ignoring the role of existing collaborative approaches in building adaptive capacity (Barragán Paladines and

Chuenpagdee, 2015; González et al., 2008; Quiroga, 2013; Watkins, 2008). The Galapagos Islands, known for being the natural laboratory in Charles Darwin's research on the theory of evolution, are located 1200 kilometres off the Ecuadorian coastline (Figure 1). Tourism and fishing are the main economic sectors in the archipelago. Both have encouraged human population growth (approximately 30,000 people) and tourism growth (271,238 tourists annually before the COVID-19 pandemic) (DPNG, 2021). Large-scale fishing was prohibited in 1998 when the GMR was created. Since then, local small-scale fishers were allocated exclusive access rights to Galapagos fishery resources.

The Galapagos small-scale fishery sector plays an essential role for the economy and food security in the Galapagos Islands, being a food supplier for the local population, hotels and vessels operating in Galapagos (Barragán P., 2015; Cavole et al., 2020). Today, 1100 fishers are registered in the Galapagos National Park fishing record, of which approximately 400 are active fishers (Burbano and Meredith, 2020). Although the fishing sector has been significant in the development of the Galapagos since the occupation of the islands, the Galapagos marine exploration has brought different social and ecological conflicts that have led to the establishment of diverse public and private organizations and agencies at various geographical and jurisdictional scales and levels (Castrejón et al., 2014). The expansion of the spiny lobster fishery, the Chinese market's growing demand for shark fins, the collapse of the sea cucumber (*Isostichopus fuscus*) fishery in the 1980s and 1990s, together with the adoption of the so-called Galapagos Special Law (GSL) to protect the marine resources of the islands in 1998, eventually prompted the establishment and presence of various governmental, scientific and non-governmental organizations, for either management and control, conservation reasons or commercial ends in Galapagos (Castrejón et al., 2014).

Today, five artisanal fishing cooperatives operate in the Galapagos Islands, known by their Spanish acronyms COPROPAG, COPESPROMAR, COPESAN, COPAHISA and ASOARMAPESBAY. Artisanal fishing cooperatives target more than 68 marine species, including sailfin grouper (*Mycteroperca olfax*), locally known as "bacalao"; camotillo (*Paralabrax albomaculatus*); brujo (*Pontinus clemens*); red spiny lobster (*Panulirus penicillatus*); green spiny lobster (*P. gracilis*), and slipper lobster (*Scyllarides astori*). Several governmental organizations have influenced the management of the GMR, mainly the Galapagos National Park Directorate (Spanish acronym DPNG) and Galapagos Special Regime Governing Council (Spanish acronym CGREG). Furthermore, diverse private organizations, non-governmental organizations (NGOs), and research agencies have played a significant role in the assessment and management of Galapagos small-scale fisheries, such as the Charles Darwin Foundation (CDF), which has served as a scientific adviser for the Ecuadorian Government since the 1960s (Castrejón et al., 2014).

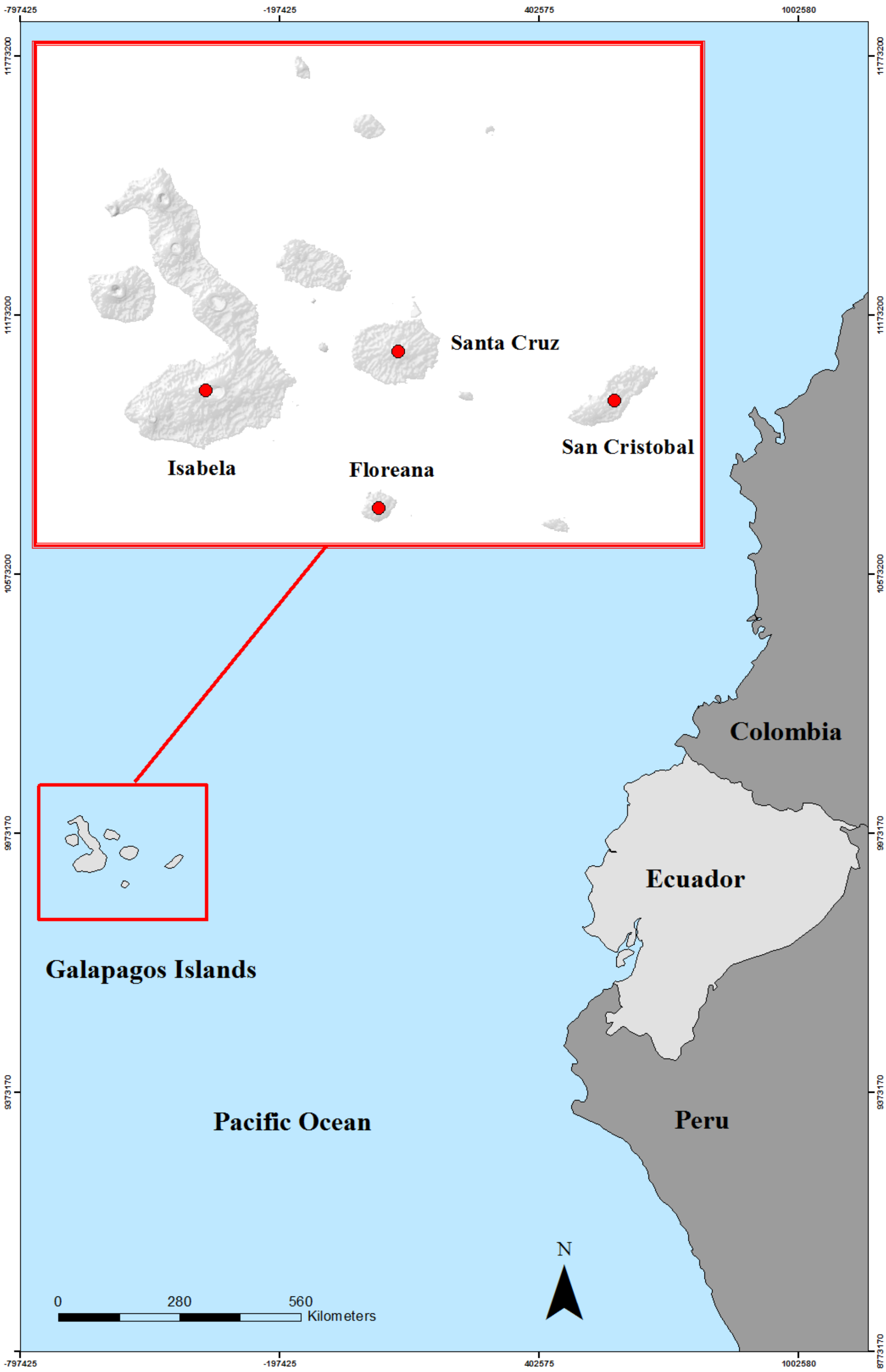


Figure 1. Location map. Red square indicates the Galapagos Islands. While red circles indicate inhabited Islands.

3.1 METHODS

3.1.1 Data Collection

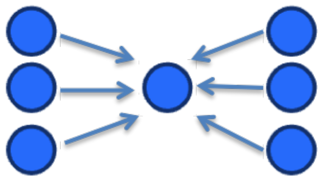
The data collection coincided with the COVID-19 pandemic. Therefore, we limited face-to-face research involving human participants. First, we created an online survey using Qualtrics software, version 7.2020 (Copyright © [2020] Qualtrics). The survey served to input a series of open-and closed-ended questions on the organizations' connectivity to other organizations and agencies involved with assessing and managing the Galapagos small-scale fisheries sector and store the answers of respondents of our study in the same database. Then, we undertook an extensive literature review to examine the history, management, and interactions in the Galapagos small-scale fishery system. Through this review, we created a list of public and private organizations frequently associated with assessing and managing the Galapagos small-scale fishery sector (in pre-COVID-19 pandemic conditions on the Galapagos Islands), including fishery cooperatives, governmental organizations, NGOs, private organizations, municipal and parish governments, and academic and research organizations. We used this list to interview representatives and officials of these organizations (n = 38).

We reached out the representatives and officials of public and private organizations (n = 38) via Zoom Video Communications Inc. (Zoom version 5.0.5) (n = 5), phone calls (n = 6), and emails by sending the links of our online survey to the individuals' institutional email addresses) (n = 27). We read to the representatives and officials the open-and closed-ended questions that we input in our Qualtrics survey during phone and Zoom interview calls, and we input their answers into the database. Responses from the links sent to the individuals' institutional email addresses were stored automatically in the Qualtrics database when respondents opened and completed the open- and closed-ended questions of the online survey. We obtained verbal consent from the participants at the beginning of each interview on Zoom and phone call. Informed consent was obtained from the study participants, who were contacted through their institutional email addresses when they opened the online survey. The study data were collected between June 2020 and November 2020. This study received ethics approval from our university's research ethics committee (ORE #41927).

3.1.2 Data Analysis

Representatives from the public and private organizations noted in the data collection section were asked to identify from the list: (1) the organizations they coordinate, communicate, or work with regarding management and organization of the Galapagos small-scale fisheries sector, (2) how often the interviewee's organization collaborates with the selected organizations—(a) frequently, (b) occasionally or (c) rarely— (3) what organizational ties link the interviewee's organization with selected organizations—(a) information exchange (e.g., regarding observations of environmental change, coral reef condition, invasive species, water quality), (b) management (e.g., mandatory organization and coordination of illegal fishing, monitoring, or user conflicts), or (c) collaboration (e.g., joint projects, technical expertise, finances, or human resources) (see, the organizational ties approach we based on in (3) in Alexander et al. (2017), and (4) the level and sector of the interviewee's organization (local, national or international) / (public or private) (see Appendix 1). We followed a snowball approach to conduct the interviews. Therefore, the respondents were asked to suggest other organizations or groups (not listed in our list) with which they coordinate, communicate, or work regarding the management and organization of the small-scale fishing sector's activities.

We drew on a set of social network techniques to illustrate and elucidate the interactions of the Galapagos small-scale fishing governance system. We used Gephi network visualization 0.9.2 software (Bastian et al., 2009) to (a) employ centrality measures to explore central nodes (in-degree centrality), (b) visualize the frequency of institutional relationships between organizations and agencies (frequent, occasional, or rare) and the nature of the relationship (information exchange, management, or collaboration), and (c) employ centrality measures to identify bridging nodes (betweenness centrality). We utilized PNet software to conduct an ERGMs analysis (Wang et al., 2009). We used ERGMs, also known as p* models, to explore whether or not specific network patterns are prevalent in the Galapagos governance system network using a building block approach. Figure 2 further explains this approach by presenting a series of building blocks and a brief description of their associated governance challenges (hypotheses).

Building blocks	Hypotheses	Governance processes
	**Hypothesis 1:** Do organizations and agencies tend to reciprocate institutional links in the Galapagos small-scale fishing governance system?	**Reciprocity effects:** Mutual interaction between organizations and agencies (A ↔ B). From a governance perspective, mutual interaction between actors represents network structures that facilitate sharing information, expertise, resources, and common objectives in a governance network and provides the baseline for the evolution of collaboration links in a governance network.
	**Hypothesis 2:** Do organizations and agencies tend to direct organizational links to a popular node in the Galapagos small-scale fishing governance system?	**Popularity effects:** propensity in which links tend to direct to popular organizations and agencies in the network. From a collaborative governance perspective, popularity effects may facilitate coordination, the flow and spread of information within the network (Andrachuk et al., 2019).
	**Hypothesis 3:** Do organizations and agencies from the public sector tend to send more organizational links compared to others in the Galapagos small-scale fishing governance system?	**Sender effects:** propensity to send more links than others due to actors' attributes. From a governance perspective, tendencies to send more organizational links from the public sector than other economic sectors illustrate network configurations in which the public sector plays a predominant role in the management and organization in the governance system.
	**Hypothesis 4:** Do organizations and agencies from the public sector tend to receive more organizational links compared to others in the Galapagos small-scale fishing governance system?	**Receiver effects:** propensity to receive more links than others due to actors' attributes. From a governance perspective, a tendency in which organizations and agencies from the public sector tend to receive more organizational links than others illustrates an active involvement of the public sector in the governance network.
	**Hypothesis 5:** Do organizations and agencies from the public sector tend to have organizational links with actors from the same sector in the Galapagos small-scale fishing governance system?	**Homophily:** propensity to be attracted to those with similar network features. From a governance perspective, homophily based on the public sector illustrates network configurations that often represent obstacles for cross-level communication and collaboration as they hamper interactions across administrative levels.

	**Hypothesis 6:** Do organizations and agencies from the local level tend to send more organizational links than others in the Galapagos small-scale fishing governance system?	**Sender effects:** propensity to send more links than others due to actors' attributes. From a governance perspective, a tendency to send more organizational links than others from the local level illustrates network configurations in which local priorities, social memory, local knowledge and experience from the local level organizations and agencies probably circulate in the governance network.
	**Hypothesis 7:** Do organizations and agencies from the local level tend to receive more organizational links than others in in the Galapagos small-scale fishing governance system?	**Receiver effects:** propensity to receive more links than others due to actors' attributes. From a governance perspective, a tendency in which organizations and agencies from the local levels tend to receive more organizational links than others illustrates network configurations in which local-level organizations and agencies contribute and are considered in the management and organization of activities in the governance network.
	**Hypothesis 8:** Do organizations and agencies from the local level tend to have organizational links with actors from the same level in the Galapagos small-scale fishing governance system?	**Homophily:** propensity to be attracted to those with similar network features. From a governance perspective, homophily based on local levels illustrates network configurations that often represent obstacles for cross-level communication and collaboration across administrative as they limit horizontal and vertical linkages between the government and local resource users.

Figure 2. Building blocks and their associated hypotheses used when estimating the propensity toward reciprocity, popularity, and sender-and-receiver network formations within the Galapagos small-scale fishery governance system. The building blocks represent well-defined network patterns linked to specific governance concerns (hypotheses) (Bodin et al., 2014, 2016). These building blocks help to disclose how frequent they are in a more extensive network of analysis (Bodin and Tengö, 2012). ERGMs provide a platform where the hypotheses can be statistically examined (Lusher et al., 2012). Building blocks associated with hypotheses 1 and 2: blue nodes represent organizations and agencies within the Galapagos small-scale fishery governance. Building blocks associated with hypotheses 3 to 5: red nodes represent organizations and agencies from the public sector, and blue nodes represent organizations and agencies from the private sector in the network. Building blocks associated with hypotheses 6 to 8: green nodes represent organizations and agencies from the local level, and yellow nodes represent non-local level nodes in the network. See also the discussions regarding "building blocks," also called "motifs" in Milo et al. (2002) and their use in theoretical frameworks presented in Barnes et al. (2019); Bodin et al. (2014); Bodin and Tengö (2012); Guerrero et al. (2015); Kininmonth et al. (2015) and Pittman and Armitage (2017a)).

To estimate the presence of the building blocks presented in Figure 2 in the Galapagos small-scale governance network, we first created an adjacency matrix from the interviewees' responses stored on

Qualtrics (i.e. a matrix of zeros and ones that indicates if nodes are connected (1) or not (0) (Koskinen and Daraganova, 2012). In this matrix, using the representatives' and officials' answers [noted in (1) in the data analysis section], a value of 1 indicated the existence of a link, and a value of 0 indicated the absence of a link. Furthermore, we created two attribute matrices according to the nodes' attributes from the interviewees' responses [noted in (4) in the data analysis section], i.e. a matrix that indicates the presence (1) or not (0) of an attribute of a node (Lusher and Robins, 2012a). In the first matrix, the public sector nodes were set as 1, and the non-public sector nodes were set as 0. In the second matrix, local level nodes were set as 1, and the non-local level nodes as 0.

Using the matrices described above and setting structural parameters and actor attribute parameters (see PNet parameters described in Figure 2 and Table 2), we estimated the tendency toward reciprocity, popularity, and sender-and-receiver network formations within the Galapagos small-scale fishery governance system (hypotheses/building blocks of Figure 2). We ran two models on PNet software (see Table 2). We combined attribute parameters and structural parameters in our models to include actors' attribute effects in the models (exogenous processes). We tested the fit by assessing if our model parameters converged (t-statistic < 0.1) and had a good fit (goodness-of-fit (GOF) < 0.1 (Robins and Lusher, 2012).

4.1 RESULTS

Our results are divided into two parts. In the first, we present the Galapagos Islands' small-scale fisheries network structure, connectivity, and organizational links by employing network statistics (in-degree centrality, betweenness centrality) and connectivity tools. In the second, we present the Galapagos Islands' small-scale fisheries network structure and connectivity by estimating parameters (ERGMs).

4.1.1 Galapagos Islands' artisanal fisheries network

Our results show that our interviewees identified 257 organizational links—comprised of 43 public and private organizations at various levels and scales—connected to the Galapagos' small-scale fishery sector (Figure 3) through management, exchange of information and collaboration. Often, the organizations and agencies link to others through more than one organizational tie (Figure 4, Table 1). Of these 257 links, 101 associations were frequent, 123 were occasional, and 33 were rare (Figure 5, Table 1). Although visually, the network initially appeared centralized (i.e., the network is organized around a central node), our results indicate that diverse organizations and agencies with high in-degree centrality were present in the network (i.e., nodes receiving more institutional links than others in the network, which means influential nodes in the network, considered by us as central nodes) (Figure 3). These were: the governmental organizations GO02 and GO01, the fishing cooperative FC01, the governmental organization GO03, and the fishing cooperatives FC02, FC03 and FC04, respectively. Our analysis of betweenness indicated that actors with high betweenness were present in the network (i.e., nodes often on the shortest paths between nodes in the network, meaning well-positioned nodes, deemed by us to be bridging nodes (Freeman, 1977)). These were: the governmental organization GO01, the non-governmental organization NGO01, the municipal government MG01, the fishing cooperatives FC02 and FC01, and the governmental organizations GO04 and GO02, respectively (Figure 6).

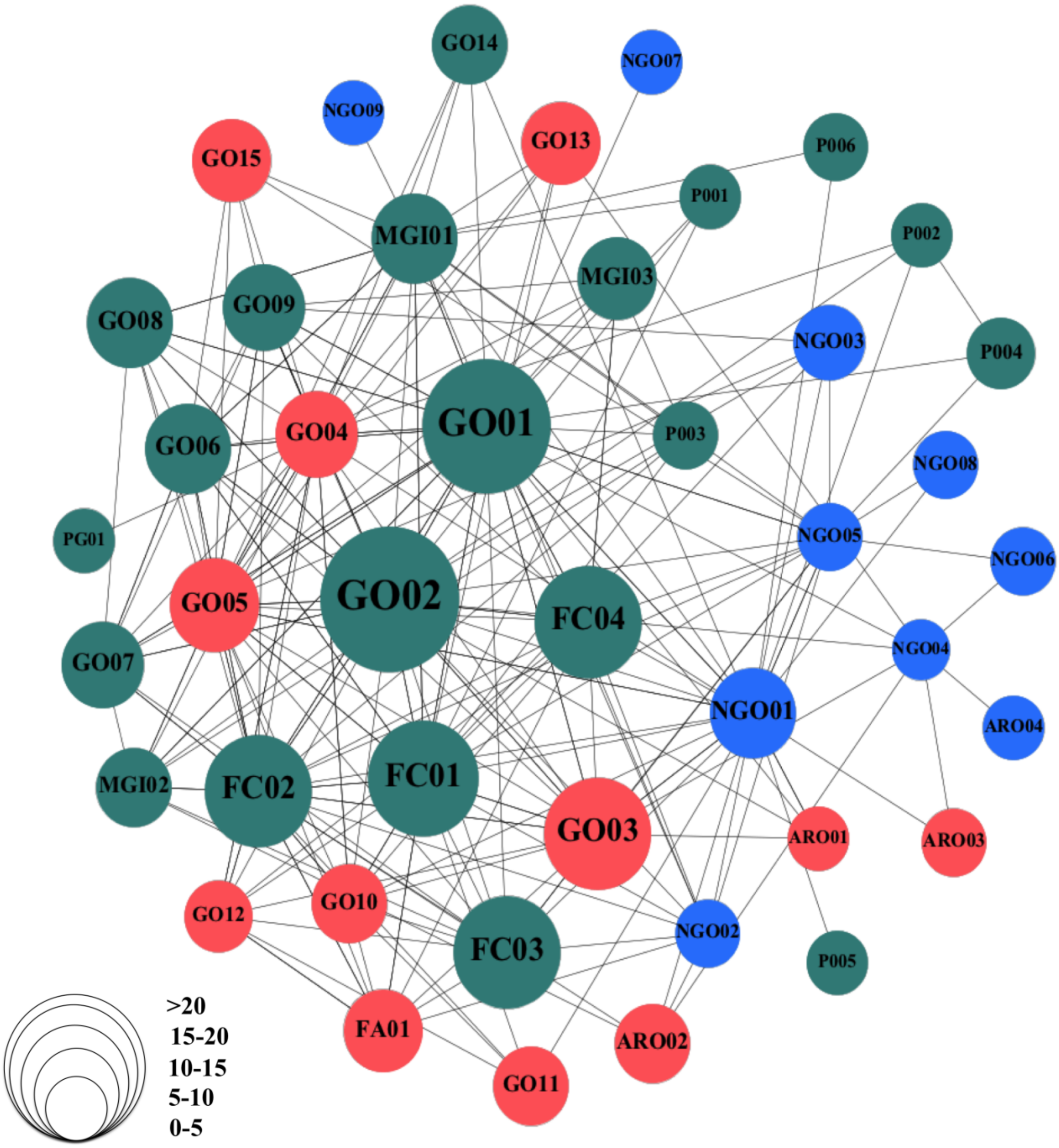


Figure 3. Central organizations of the Galapagos small-scale fishery governance network

Nodes indicate the organizations and agencies within the Galapagos small-scale fishery sector (GO = governmental organization, PO = private organization, FA = fishery association, NGO = non-governmental organization, MG = municipal government, PG = parish government, ARO =

academic and research organization). Node size indicates in-degree centrality. As the nodes' dimension increases, it means that those nodes receive more organizational links than others in the network, defined by us as central nodes. Node colour indicates level (green nodes = local level, red nodes = national level, blue nodes = international level). Links indicate ties between organizations and agencies linked with the Galapagos small-scale fishery sec

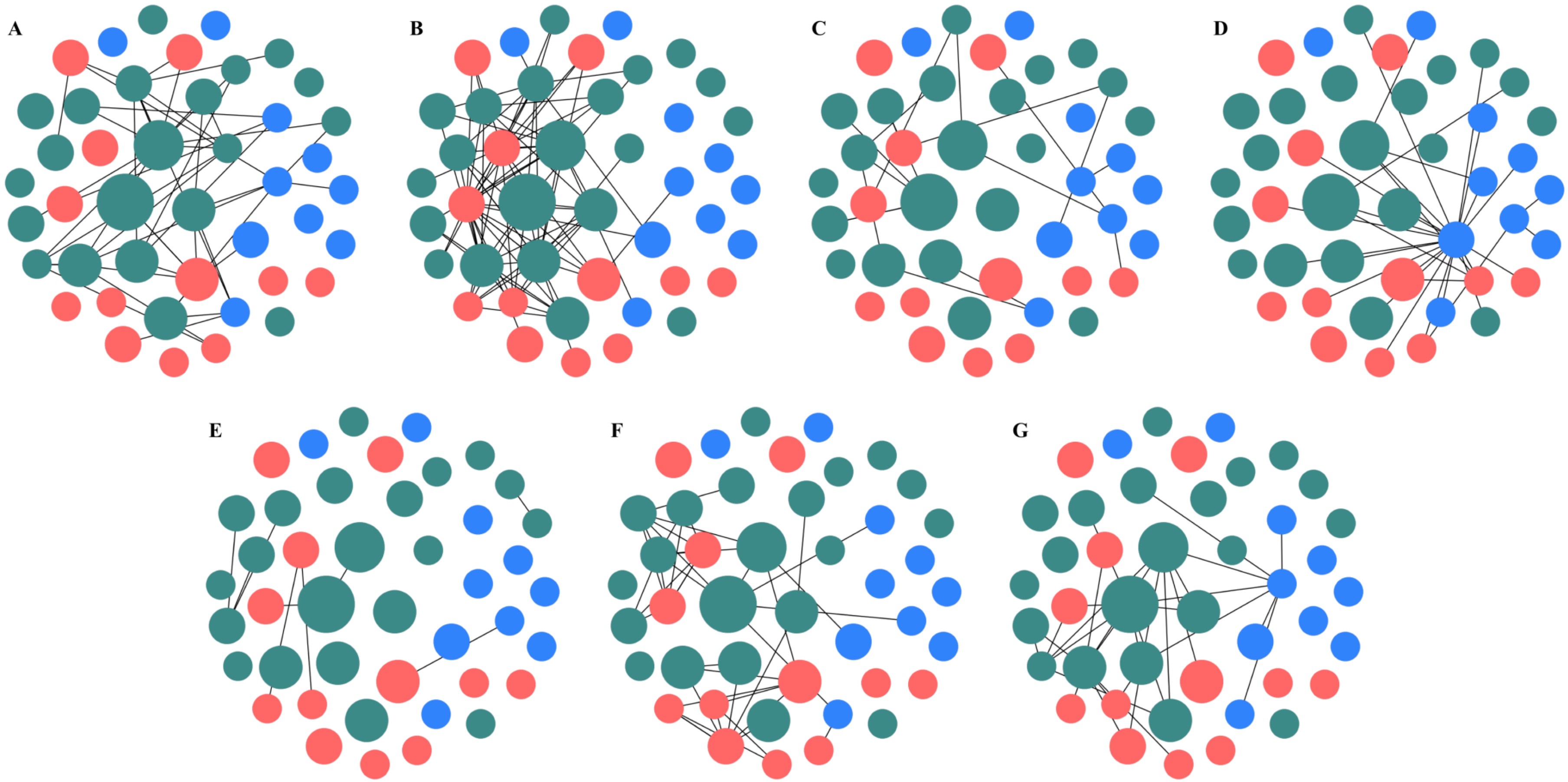


Figure 4. Type of organizational ties of the Galapagos small-scale fishery governance network

Nodes indicate the organizations and agencies within the Galapagos small-scale fishery governance system shown in Figure 3. Node colour indicates level (green nodes = local level, red nodes = national level, blue nodes = international level). As the nodes' dimension increases, those nodes possess higher in-degree values than others in the network (see, Figure 3). The link colour indicates the organizational links between organizations and agencies linked with the

Galapagos small-scale fishery sector. 4A indicates links due to links due to collaboration. 4B indicates links due to management. 4C indicates links due to information exchange. 4D indicates links due to information exchange and collaboration. 4E indicates links due to information exchange and management. 4F links due to information exchange, management and collaboration nad 4G inidcates links due to managament and collaboration.

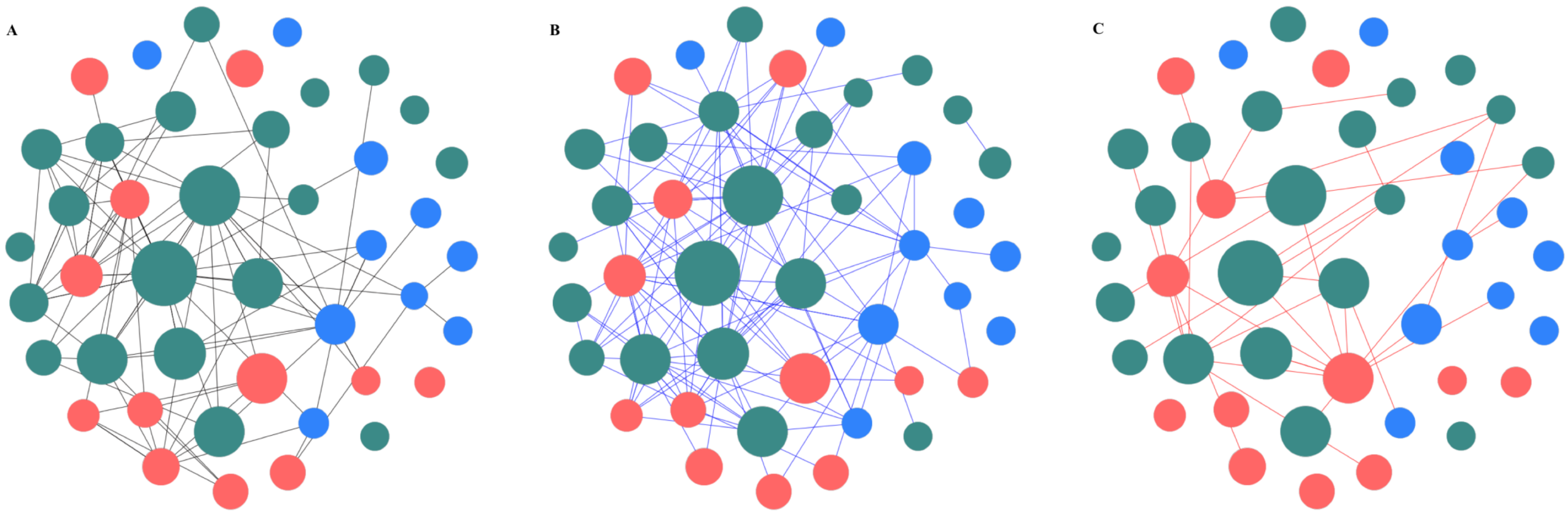


Figure 5. Frequency of organizational ties of the Galapagos small-scale fishery governance network

Nodes indicate the organizations and agencies within the Galapagos small-scale fishery governance system shown in Figure 3. Node colour indicates level (green nodes = local level, red nodes = national level, blue nodes = international level). As the nodes' dimension increases, those nodes possess higher in-degree values than others in the network (see, Figure 3). The link colour indicates the frequency of organizational links between organizations and agencies linked with the Galapagos small-scale fishery sector. Black links in 5A represent frequent organizational links. Blue links in 5B represent occasional organizational links. Red links in 5C represent rare organizational links.

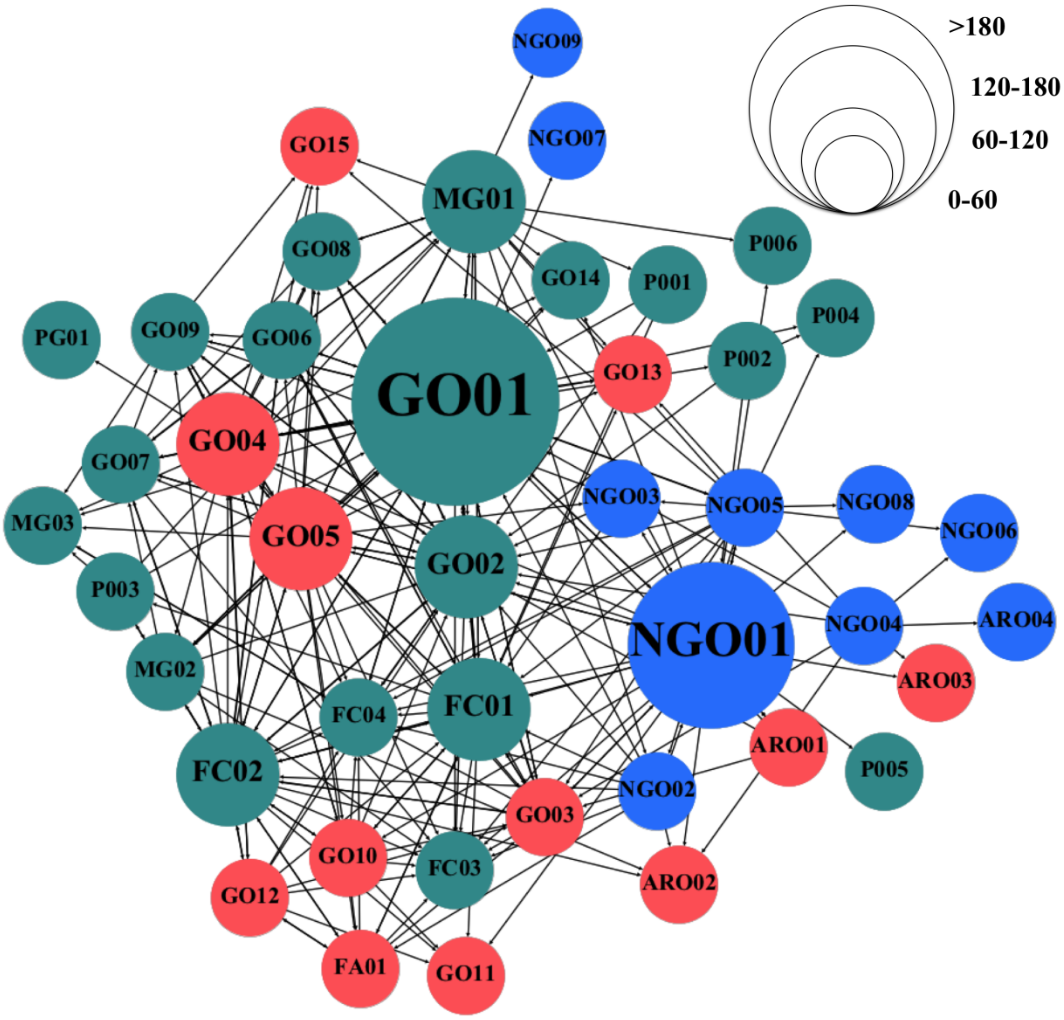


Figure 6. Bridging organizations of the Galapagos small-scale fishery governance network

Nodes indicate the organizations and agencies within the Galapagos small-scale fishery sector (GO = governmental organization, PO = private organization, FA = fishery association, NGO = non-governmental organization, MG = municipal government, PG = parish government, ARO = academic and research organization). Links indicate the connections between organizations and agencies within the governance system. Node size indicates betweenness centrality. As nodes' dimension increases, it means that those nodes are often on the shortest paths between nodes in the network, defined by us as bridging nodes. Node colour indicates level (green nodes = local level, red nodes = national level, blue nodes = international level).

Statistic	Value
Number of nodes	43
Number of links	257
Number of frequent organizational links	101
Number of occasional organizational links	123
Number of rarely organizational links	33
Number of nodes from the public sector	21
Number of nodes from the private sector	22
Number of nodes from local level	21
Number of nodes from national level	12
Number of nodes from international level	10
Percentage of links due to information exchange	7.0
Percentage of links links due to management	31.91
Percentage of links due to collaboration	17.9
Percentage of links due to information exchange, management and collaboration	15.56
Percentage of links due to information exchange and management	3.5
Percentage of links due to information exchange and collaboration	12.06
Percentage of links due to management and collaboration	12.06

Table 1. Overall network statistics description of the Galapagos small-scale fishery governance system. For interpretation purposes, the table breaks down the links and relationships between 43 organizations and agencies within the Galapagos small-scale fishery governance system network (a directed network, i.e. a governance system network in which all links do not necessarily have to be reciprocal). There are organizations and agencies connected to others through more than one organizational tie in the network.

4.1.2 Estimating parameters (ERGMs) to define network structure and connectivity artisanal fisheries in the Galapagos Islands

Our results indicated that the reciprocity between organizations and agencies was positive and statistically significant, suggesting that organizations and agencies are likely to reciprocate organizational links (hypothesis 1; Figure 2, Table 2). The AinS parameter (popularity) is positive and statistically significant, indicating there is a propensity to popular organizations and agencies in the network, which relates to the in-degree distribution of the network (hypothesis 2; Figure 2, Table 2). Estimates based on node attributes indicated that the public sector, and local level did not influence the formation of associations. We did not find evidence of homophily based on the nodes' attributes, either by the influence of the economic sector (public sector) or based on the local level concerning the organizations' choice of partners to manage the activities of the Galapagos' artisanal fishery sector (hypothesis 5 and 8; Figure 2, Table 2). There is a positive and significant sender effect based on the public sector attribute, indicating a tendency for public-sector organizations and agencies to send more organizational links, compared to others in the network (hypothesis 3; Figure 2, Table 2). We found no strong evidence that local organizations and agencies tend to send more organizational links than others in the network (hypothesis 6; Figure 2, Table 2). Additionally, we found no strong evidence that organizations and agencies from the public sector or local levels tend to receive more organizational links than others in the network (hypothesis 4 and 7; Figure 2, Table 2). All the parameters we used converged (t-statistic < 0.1) and had a good fit (goodness-of-fit (GOF) < 0.1) (Table 2).

Hypothesis	Parameter (PNet names)	Estimate	Standard error (ER)	T-statistics	Goodness-of-fit (GOF)
Model 1:					
-	Arc	-5.56	0.37	0.02*	-0.07
Hypothesis 1	Reciprocity	1.95	0.23	0.003*	-0.03
Hypothesis 2	AinS	1.69	0.21	0.01*	-0.07
Hypothesis 3	Sender (public sector)	0.66	0.23	0.09*	0.02
Hypothesis 4	Receiver (public sector)	-0.14	0.20	-0.04	-0.10
Hypothesis 5	Interaction/ Homophily (public sector)	0.19	0.25	0.01	-0.004
Model 2:					
-	Arc	-2.46	0.15	0.09*	0.04
Hypothesis 1	Reciprocity	2.01	0.24	0.04*	0.04
Hypothesis 6	Sender (local level)	0.23	0.22	0.09	0.06
Hypothesis 7	Receiver (local level)	0.20	0.21	0.05	0.05
Hypothesis 8	Interaction/ Homophily (local level)	0.21	0.26	0.05	0.05

Table 2. ERGM results. A t-statistic < 0.1 indicates a converged model. GOF indicates how well the model captured features of the data. GOF < 0.1 indicates a good fit. * Indicates a significant parameter. Positive or negative values indicate more or less than the network configuration, respectively. Arc parameter ($A \rightarrow B$) provides the baseline for the occurrence of associations (Lusher and Robins, 2012b; Robins and Lusher, 2012).

5.1 DISCUSSION

We argue that the extent of the effects of multiple and simultaneous drivers of change on social-ecological systems forces governance systems to explore ways of coping with unexpected drivers of change and building adaptive capacity. We argue that among the diverse factors contributing to building adaptive capacity in complex social-ecological systems, including financial support, technology, and local knowledge, an understanding of network configurations of governance systems is increasingly a factor to be considered in building adaptive capacity (Adger, 2003; Barnes et al., 2017; Cinner et al., 2018). Governance systems actors often determine and set, among other things, the legal rights to resources and support or compensation mechanisms in society (Kooiman, 2003). Therefore, the study of governance systems becomes a cornerstone component of analysis in solving different multi-scale social-ecological problems and consequently a significant determinant in building adaptive capacity in complex social-ecological systems (Angst, 2019) such as the Galapagos small-scale fishing system.

The adverse consequences of the COVID-19 pandemic are a vivid example of how unexpected and rapid changes can challenge the Galapagos governance system and suddenly affect people's wellbeing and livelihoods. The pandemic has pushed the Galapagos small-scale fishing sector into the worst ever socio-economic situation experienced in the history of this archipelago, making evident the necessity of a more holistic form of governance to deal with the complex social-ecological interactions spanning the fishery sector. We argue that those organizations responding to the wicked transboundary problems that the Galapagos small-scale fishing sector faces need to build an enabling environment to act during periods of change. No previous research has evaluated the small-scale fishing governance system network of the Galapagos Islands. Therefore, an initial understanding of how the collaborative governance network of the Galapagos small-scale fishing system behaves forms a vital baseline for enhancing the collective efforts, policies, and adaptive capacity in the fishery sector.

Illegal international fishing, climate change and the effects of the COVID-19 pandemic are the main drivers of change affecting the Galapagos small-scale fishing system. From a governance perspective, much of the effectiveness of problem-solving amidst multiple societal concerns rely on the governance system's ability to coordinate and establish rules and laws that prevent a misfit between the governance system and the societal problems that arise (Pittman et al., 2015). This capacity in the Galapagos co-management system currently depends on the system's ability to fit with environmental, biological, and ecological issues and various societal concerns and stakeholders' expectations (see also the arguments on achieving multiple socio-ecological institutional fits and social fit put forward by Ishihara et al. (2021) and Acton et al. (2021).

Our results suggest that organizations and agencies within the Galapagos small-scale fishing governance system network interact through diverse organizational links emerging from the exchange of information, management, and collaboration (Figure 4, Figure 5, Table 1). Notably, our outcomes indicate that the organizations and agencies within the network often link to others through one or more organizational ties at once. Linkages associated with a) management, b) collaboration, c) information exchange, management and collaboration, d) information exchange and collaboration, and e) management and collaboration were the most prominent linkages in the network (Table 1). Although our centrality analysis focused on the whole network connectivity, regardless of the nature of organizations and agencies links, it must be noted that the local-level government organizations GO02 and GO01, the national-level governmental organization GO03, and the local-level fishing cooperatives FC03, FC04 and FC01, respectively, are central nodes in links emerging from management. The local-level governmental organizations GO02 and GO01, the local-level fishing cooperative FC01, the national-level governmental organization GO03 and the local-level fishing cooperatives FC03 and FC04, respectively, are central nodes in relations arising from the collaboration. The local-level governmental organization GO02, the national-level governmental organization GO03 and the local-level governmental organization GO01 are central nodes in links emerging from the exchange of information.

We consider these network configurations to be interesting characteristics of collaborative governance. Therefore, we argue that if these network features are seen and agreed upon more strategically between organizations and agencies according to their nature and needs, and are activated when social-ecological interactions and social concerns unfold, they are valuable benchmarks to align strategies, coordinate solutions, and harmonize policy-making processes in the sector, particularly in times of abrupt changes. This capacity is referred to in the literature as "sleeping nodes and links" (Janssen et al., 2005). Organizational links should strategically align more closely with the sector's social-ecological interactions and societal needs than with actors' institutional objectives and affiliations in the governance system. Addressing the adverse location-specific drivers of change that define the state of social-ecological systems (Smit and Wandel, 2006; Wisner et al., 2004) depends in part on the effectiveness of governance systems to reconfigure, adapt to change and approximate as closely as possible their management scale with the social-ecological interdependencies scale (Folke et al., 2007; Kininmonth et al., 2015; Pittman and Armitage, 2017b). Therefore, we argue that exploring the network interdependencies and patterns of collaborative networks more strategically would enable devising novel governance arrangements and updating joint efforts aimed towards a desirable future in the sector (Armitage et al., 2007).

Our ERGM's outcomes suggest a positive and significant tendency of organizations and agencies to reciprocate links (hypothesis 1; Figure 2, Table 2). We consider this an essential feature in the Galapagos small-scale fishery collaborative network, as mutual organizational links between organizations and agencies within governance systems play a significant role in sharing information, expertise, resources, objectives, and collaborative network links' evolution. Governance systems' adaptive capacity largely depends on their capacity to act collectively. Therefore, positive reciprocal effects in the network (A ↔ B) can potentially lead to the incorporation of a new third collaboration party (C) in reciprocal organizational links, giving rise to new strategic collaborative alliances. This means, in other words, that it is likely that a collaboration partner of my partner may become my collaboration partner (Pittman and Armitage, 2017b), making reciprocal action a significant condition to improve the Galapagos collaborative network and include organizations and stakeholder groups that often possess critical local knowledge and know beforehand what the local priorities, which facilitates building adaptive capacity in a location-specific context.

The results indicate a positive effect but nonsignificant for homophily and receiver effects, suggesting no solid statistical evidence of homophily (hypotheses 5 and 8; Figure 2, Table 2) and receiver effects (hypotheses 4 and 7; Figure 2, Table 2) based on the nodes' attributes, either by the influence of the economic sector (public) or based on the local level regarding the organizations' choice of partners to manage the activities of the Galapagos small-scale fishery sector. We argue that this can be perceived as an interesting feature for cooperation and building adaptive capacity in the Galapagos fishery sector if one considers the value of cross-level and cross-sectoral interaction (Carlisle and Gruby, 2019; Ostrom, 2010) and the principle of subsidiarity (Marshall, 2008) when managing common interests. Effective responses to rapid and transboundary multidimensional changes require the interaction of various actors at different levels – from the local to the international – in which all decision-making structures must take action within their mandates in a coordinated way to strategically cope with the effects of multidimensional problems facing socio-ecological systems (Armitage et al., 2007; Bixler et al., 2016). Acknowledging that local fishing communities have a close link with their environment – i.e. a link that allows them to capture what often cannot be perceived by the scientific community and decision-making structures – and that the subsidiarity principle ensures that decisions are made as close as possible to those whose livelihoods might be affected by decision-making, are crucial in adaptive capacity building.

Although we found no strong evidence that organizations and agencies from the local levels tend to send more organizational links than others in the network (hypothesis 6; Figure 2, Table 2), outcomes concerning sender effects suggest that organizations and agencies from the public sector are more likely to send organizational links than others in the Galapagos small-scale fishery sector (hypothesis 3; Figure 2, Table 2). This, from our view, may be interpreted to mean that the public sector plays a predominant role in defining management and organization in the Galapagos small-scale fisheries sector, reflecting the Galapagos' reality closely if we consider the dominant role that central and local governmental institutions have played historically in the policy implementation and coordination in the sector.

Our results also suggest tendencies for centralization (in-degree distributions) in the Galapagos small-scale fishing sector network (hypothesis 2; Figure 2, Table 2). This, from our perspective, may be seen as another important feature of analysis in the sector, bearing in mind that a popular position in a social network might signify a more considerable impact on social-ecological systems. Organizations and stakeholders involved in governance system structures can provide incentives to both ease changing conditions and increase them (Armitage et al., 2011). Thus, probably, some central and bridging organizations and agencies can potentially become significant catalyzers and intermediaries that connect actors and groups at different geographical and jurisdictional scales and levels in the network, which, with an understanding of the benefits of exploring multilevel interactions and polycentrism in times of abrupt and sudden changes, contribute to enhancing collaborative governance networks. On the one hand, improved connectivity and collaboration between such nodes might provide platforms in the network to foster participation and knowledge sharing that account for local priorities and social memory. On the other hand, improved connectivity and collaboration among important nodes in the network can provide platforms for building trust, and social capital that might serve to alleviate the frequent tensions and disputes that arise in Galapagos small-scale fishing management.

It is critical to recognize that managing complex social-ecological systems involving a few actors is a challenging, if not impossible, endeavour. This is particularly true in rigid co-management systems where actors are often stipulated and defined by policies and laws, limiting connectivity, flexibility and experimentation across sectors, levels and scales. Therefore, the initial idea of governance systems management based solely on collaboration (co-management concept) should be expanded in scope. This approach should echo the adaptive co-management approaches proposed by other research (Armitage et al., 2009; Clark and Clarke, 2011; Dietz et al., 2003; Folke et al., 2005). The multiple socio-ecological interactions that exist in small-scale fisheries in the Galapagos require cooperation and experimentation (learning by doing) that take place in different decision-making centres. Central and bridging organizations and agencies in the network (e.g. CGREG, DPNG, fishing cooperatives, CDF) that operate at local, national and international levels and possess connections to governmental organizations, NGOs, funding organizations and local resource-users play a significant role in this regard.

Bolstering the capacity of a socio-ecological system at the local scale to adapt is highly dependent on correcting errors by adjusting attitudes and behaviours (double-loop learning, i.e., adjusting errors through values and policies), for example, by building social capital rather than changing individual resource management strategies and actions (single-loop learning, i.e., correcting mistakes from routines) (Armitage et al., 2008). An example of the latter approach would be repetitive conflicts between conservationists and local fishers regarding fishing techniques. Management of common-pool resources requires nodes to provide leadership and vision among the stakeholders. Central and bridging nodes occupy important positions in social networks, making them significant actors for creating synergies among stakeholders in a network (Figure 7) (Berdej and Armitage, 2016; Olsson et al., 2006). Their influential positions in social networks enable them to not only bring together organizations and agencies from various sectors but also to link significant inputs such as knowledge, resources, technical expertise and best practices to deal with unexpected and rapid changes that occur at various scales and levels (Armitage et al., 2017; Bodin and Crona, 2009; Folke et al., 2005). In this context, the effect of central and bridging nodes goes beyond merely bridging together stakeholders and exchanging information and goals. Central and bridging nodes play a significant role in approximating as closely as possible the resource governance scale to the extent of social-ecological system dynamics and prevent a misfit between the social-ecological dimensions, social values and needs (Figure 8), see discussion in Olsson et al. (2007) and Ishihara et al. (2021). At the same time, they are essential catalyzers for building social capital and trust, access to information, co-production of knowledge, conflict resolution, the incorporation of local priorities and collaborative learning (Berardo and Scholz, 2010; Folke et al., 2005; Hahn et al., 2006), features that we deem critical in collaborative approaches to bolster the capacity of complex social-ecological systems to adapt.

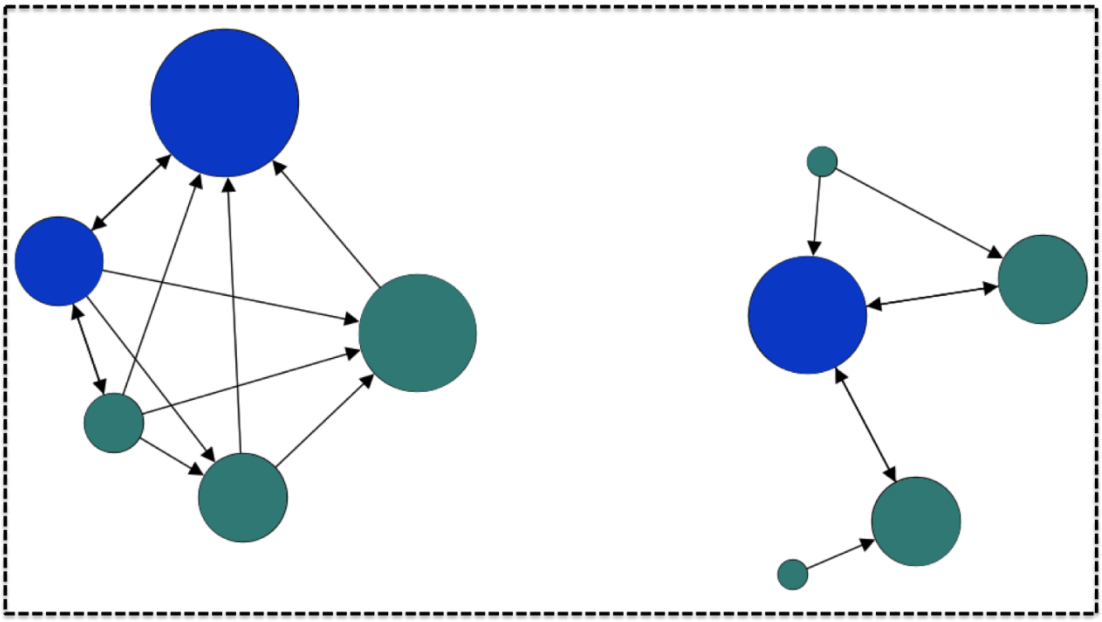


Figure 7. Central nodes and bridging nodes

The black dotted line indicates the governance system. Nodes indicate the organizations and agencies within the governance system. The arrows indicate the organizational links between organizations and agencies within the governance system. As the nodes' dimension increases, it signifies that those organizations and agencies receive more institutional links than others in the network (nodes with higher in-degree centrality values compared to the rest of nodes in the network), deemed by us as central nodes. The blue nodes indicate those organizations and agencies that are often on the shortest paths between organizations and agencies in the governance system network, deemed by us as bridging nodes (nodes with higher betweenness centrality values compared to the rest of nodes in the network). Linking diverse actors across geographical scales and administrative levels often poses one of the most significant challenges in managing common-pool resources. Bridging and central nodes usually contribute to having a more densely clustered collaboration network. Often, they serve as channels for communication and intermediaries to connect separated organizations and agencies across geographical scales and management levels in a governance system.

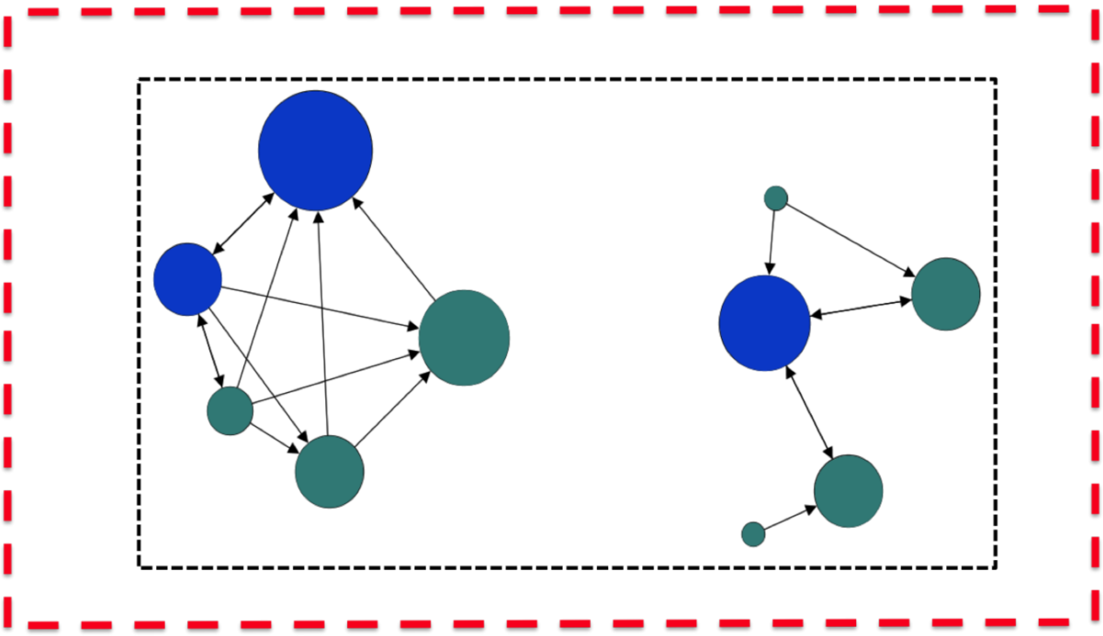


Figure 8. The problem of fit (based on Olsson et al. (2007)

The black dotted line indicates the governance system. The red dotted line indicates the geographical and functional scale spanning social-ecological dimensions. Nodes indicate the organizations and agencies within the governance system. The arrows indicate the organizational links between organizations and agencies within the governance system. As the size of the nodes increases, it indicates organizations and agencies receiving more organizational links, defined by us as central nodes. Blue nodes indicate organizations and agencies within the governance system on the shortest paths to all other nodes, defined as bridging nodes. A governance misfit often occurs because the spatial and functional scale of a social-ecological system (red dotted line) goes beyond the management scope of the governance system (black dotted line). Addressing the problem of fit from a governance perspective involves, among other things, addressing various complex social-ecological problems at the appropriate timing, geographical and functional scales. See the discussions regarding governance fit put forward by Pittman et al. (2015) and Epstein et al. (2015).

6.1 CONCLUSIONS

To our knowledge, this paper is the first study in the Galapagos Islands that aims at studying the collaborative governance system of the Galapagos small-scale fishery using a social network approach. The results presented in this paper highlight that the use of social network approaches through network statistics approaches and ERGMs are valuable tools when analyzing collaborative processes through social network analysis from place-specific perspectives. We argue that if the aim is to strengthen governance systems, both network statistics approaches and ERGMs enable decision-makers to make decisions. On the one hand, network statistics allow decision-makers to make initial decisions by understanding critical actors in the network, existing collaboration frequency and organizational links that occur in a network. On the other hand, ERGMs allow decision-makers to undertake more profound investigations by understanding more specific interdependencies occurring in a network by incorporating structural and attribute variables in the analysis, enabling a further explanation of a social network configuration and the formation of links.

Our results suggest that various organizations and agencies from different sectors and levels interact in the Galapagos small-scale fishing sector network. Therefore, considering the value of social network approaches in adaptive capacity research on socio-ecological systems, we suggest this paper may guide future theoretical frameworks that strengthen the Galapagos small-scale fishing governance network. We recognize the need to align the Galapagos small-scale fishery governance system presented in this study with the collaboration links, relationships and interdependencies formed during the COVID-19 pandemic in the sector. The unprecedented nature of the coronavirus variants must have accelerated the creation of collaboration links in the sector. Thus, we argue that the experience gained in responding to the COVID-19 pandemic would allow the formulation of additional inputs for enhancing the Galapagos small-scale fishing governance system network and the sector's scientific development from collaboration and social network analysis, in addition to opening further discussions on the governance system's capacity to align management with the complex social-ecological interactions occurring in the sector.

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