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Social cohesion and self-governance arrangements among small-scale fisheries in Puerto Rico

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In small-scale fisheries that suffer from weak formal governance, fishers use a variety of institutional strategies to self-govern. These self-governance arrangements may or may not be forms of collective action, yet they rely on informal institutions (such as norms of reciprocity) in generating social cohesion among users so that common rules can be agreed upon. Social network perspectives have been used to understand the cohesiveness of fishers operating with different gear types or in different communities, yet less is known about how social cohesion differs between fishers that operate through formal cooperative arrangements, such as fishing associations, and independent fishers who operate solely at the community level through informal cooperation. Using mixed methods, we compared the social cohesion of commercial fishers arising from information-sharing and work-support networks in four fishing communities of north-eastern Puerto Rico, as they coped with prolonged hurricane recovery and the COVID-19 pandemic. A series of exponential random graph models (ERGMs) were applied to untangle the drivers of cohesion emerging from fisher's information-sharing patterns. Fisher's communication was driven not just by operating at the same landing site or using the same primary gear type, but also by choosing to organize their fishing under the same self-governance arrangement. Specifically, fishers that were members of fishing associations mostly communicated among themselves, while independent fishers talked across arrangements, indicating the role of fishing associations in fostering social cohesion. However, associated fishers were less likely to receive information than independent fishers, suggesting the need for targeted communication strategies within each group. Moreover, independent fishers had more work support ties and a greater diversity of supporting actors across the supply chain, suggesting their need for higher levels of linking social capital. Multiple social factors explained whether fishers choose

to be members of fishing associations or remain independent, including trust in leaders and agreement on membership rules. These findings highlight the importance of knowing the cohesiveness of cooperation networks among small-scale fishers.

KEYWORDS

small-scale fisheries, fisheries governance, social cohesion, ERGM, cooperation, social capital, Caribbean, sustainability

1 Introduction

Small-scale fisheries (SSFs) contribute to food and income security around the world (FAO, 2015). However, many SSFs face resource overexploitation and precarious livelihoods, often because of weak formal governance (Chuenpagdee & Jentoft, 2015; Marschke et al., 2020). SSFs are governed through an interplay of both formal and informal institutions that incentivize ways in which resources are extracted (Cinti et al., 2014). Formal institutions prioritize management rules (i.e., laws, regulations, and sanctions) implemented by agencies to control access and extraction of fisheries, while informal institutions rely on values and social norms to influence the behaviors of a group of fishers (Chuenpagdee & Song, 2012; Ertör-Akyazi, 2019; Pellowe & Leslie, 2020; Quintana & Basurto, 2020). An important consideration for understanding how SSFs can be sustainable and resilient to socio-environmental shocks is to diagnose whether these communities would benefit from adjustments in their formal or informal management rules.

In many SSFs, a lack of effective enforcement and perceived illegitimacy of formal rules undermine fisheries governance (Begossi, 2010; Hauck, 2011; Oyanedel et al., 2020). Whether through co-management agreements or self-governance, this shifts the responsibility of management of SSFs on to local users (Alexander et al., 2018). Thus, fishers need to self-organize (i.e., determine their own rules) as they interact with other actors (Schlüter et al., 2021), and do so by employing social norms and by utilizing their social capital (Crona & Bodin, 2010; Basurto et al., 2013b; Cinner & Barnes, 2019). Social norms are the unwritten rules of behavior formed through the experiences shared by groups of individuals (Ajzen, 1991; Lin, 2000), such as through peer communication (Geber et al., 2019). More broadly, social capital at the community level refers to the social processes that facilitate cooperation among individuals, as well as the strength and patterns of these social relationships (Grafton, 2005). In this sense, social capital includes norms that facilitate trust, reciprocity, and the exchange of information, knowledge, or resources in a community (Dacks et al., 2020). There are different types of social capital. "Bonding social capital" is characterized by horizontal connections between individuals within a similar community, such as identity, familial, or neighborhood groups, while linking social capital is characterized by vertical links with formal or informal organizations (Ramirez-Sanchez & Pinkerton, 2009; Bodin & Crona, 2009). Importantly, understanding what creates social capital for the benefit of a local fishing community is key to identifying management opportunities (Chuenpagdee & Song, 2012; Barnes et al., 2015; Kosamu, 2015; Diedrich et al., 2017; Pellowe & Leslie, 2020; Quintana & Basurto, 2020), such as designing more legitimate conservation rules that are accepted and enforced by the community (Alexander et al., 2018).

While the self-governance of fishers can lead to desirable social-ecological outcomes (Basurto, 2005; Crona et al., 2017; Quintana et al., 2021), these community-based institutions are vulnerable to collective action problems, notably the Tragedy of the Commons (Ostrom, 1990; Lindkvist et al., 2017; Kamiyama et al., 2018; Schlüter et al., 2021). For example, communication among small-scale fishers has been demonstrated to build trust and cooperation, reduce resource extraction (Ghate et al., 2013; Barnes et al., 2019), and improve income equality (Ertör-Akyazi, 2019). However, group relationships are both cooperative and competitive (Stadtfeld et al., 2020), especially among small-scale fishers (Basurto et al., 2016; Bodin et al., 2020) who are embedded in a social-ecological system prone to group fragmentation (Basurto et al., 2013b; Cox et al., 2016; Alexander et al., 2018). These factors increase the difficulty of sustained collective action in SSFs (London et al., 2017; Pellowe and Leslie, 2020). Therefore, in SSFs that need to self-organize (i.e., those without strong formal or top-down management institutions), cooperation is more effective in tight-knit communities (Sultana and Thompson, 2007; Speranza et al., 2014; Gehrig et al., 2019).

Cohesive communities, that exhibit high bonding social capital, facilitate the development of cooperation (Coleman, 1990; Righi & Takács, 2018) and enforcement of social norms (Horne, 2001). Social cohesion is the degree to which individuals are held together through social relationships (Friedkin, 2004). While excessive social cohesion can lead to a rigidity that hampers collaboration and adaptability in complex groups (Gargiulo & Benassi, 2000; Bodin et al., 2006), social cohesion

is required to build shared perceptions and is known to facilitate the development of in-common norms and sanctions to govern fishery resources at the community level (Nunan et al., 2018; Alexander et al., 2018). For example, resource users may bond more with each other to later leverage damages to another user's reputation as a penalty for defecting on rules to manage a common access resource (Berardo, 2014). Indeed, gossip can be used to enhance the reputation of cooperators or denigrate that of free-riders (Smith, 2010). Enforcing in-group rules through social ostracism is another way to maintain cooperation in SSFs (Tilman et al., 2017). Community cohesion also aids in the design and adoption of more formal governance arrangements, such as co-management between agencies and communities (Gutiérrez et al., 2011; Villasante & Österblom, 2015; Rivera et al., 2021).

Despite social cohesion's facilitating role in outcomes for SSFs, there remains a need to better understand which social processes contribute to the emergence of desirable and undesirable structures in cooperative networks (Barnes et al., 2017; Alexander et al., 2018). The structure of a network influences the system's outcomes by facilitating or impeding processes such as information sharing (Bodin & Prell, 2011; Cumming, 2011). For example, in a centralized network of fishers, the central fisher carries more credibility and influences resource extraction more than if the network was decentralized (Mantilla, 2015). In addition, empirical evidence is lacking on the social cohesion of fishers who choose different social institutional arrangements (i.e., ways of organizing), and how this relates to collective action outcomes.

Throughout the Caribbean, SSFs tend to be both ailed by weak state-led governance and organized either through informal arrangements or through formally constituted fishing associations and cooperatives (de Oliveira Leis et al., 2019; Botto-Barrios & Saavedra-Díaz, 2020; Rivera et al., 2021). This is the case for Puerto Rico, a territory of the United States, where a lack of enforcement and little participation from fishers in decision-making have characterized fisheries management as predominantly top-down (Pérez, 2005; Arocho-Montes, 2017). Most Puerto Rican fishers continue to have negative perceptions of fisheries governance and do not believe decisions about fishing regulations are fair (Partelow et al., 2020). Moreover, recent hurricane impacts, and a fiscal crisis have fueled societal distrust of government institutions (Seara et al., 2020; Agar et al., 2020; Straub, 2021; Méndez-Tejeda et al., 2021; Rodríguez-Cruz et al., 2021). At the same time, Puerto Rico's commercial fishers arrange their operations either through incorporated fishing associations or as independent fishers relying on informal cooperation with others. This binary designation (i.e., associated, or independent) for how fishers identify and self-organize is influenced by the legacy of state development programs that incentivized the incorporation of fishers into associations to manage fishing centers (*Villas Pesqueras*) in coastal communities (Valdés-Pizzini, 1990; Pérez, 2005). These associations have produced both social unity and fragmentation. For example, associations have allowed lobbying of fisher's interests, such as proposing and opposing marine reserves (Hernández-Delgado et al., 2014; Griffith & Valdés-Pizzini, 2002). Nevertheless, associations also led to political conflict (Valdés-Pizzini, 1990; Griffith & Valdés-Pizzini, 2002; Pérez, 2005). While membership in associations has dropped throughout the past decades (Valdés-Pizzini, 1990; Matos-Caraballo & Agar, 2011; Del Pozo, 2012), some have been resilient to hurricane shocks and continue to be successful at assisting their members (Ramos-García, 2018; Agar et al., 2020).

The persistence of Puerto Rico's split between associated and independent fishers suggests their cooperative relationships are likely not only driven by geographic (i.e., infrastructure and market access across fishing landing sites) or knowledge (i.e., gear usage) commonalities, as has been explored in the past for SSFs (Griffith et al., 2007; Alexander et al., 2018; Crona & Bodin, 2006; Nunan et al., 2018), but also by the different characteristics of the two forms of institutional arrangements (i.e., rules of fishing associations and social norms of both groups). Here we draw on collective action theory to conceptualize cooperative relationships of commercial fishers as indicators of informal institutions that can diagnose the capacity for community-based fisheries management, and which can be leveraged to design more effective fisheries governance (Ostrom, 2009; Alexander et al., 2018; Schlüter et al., 2019; Basurto et al., 2020). More precisely, this study was underpinned by the premise that the structure of cooperative networks among resource users plays a determinant role in conservation outcomes (Bodin & Prell, 2011; Barnes et al., 2017; Alexander et al., 2018). We sought to answer the following research questions (RQs):

- (RQ1) Is an independent fisher more or less likely to exhibit bonding social capital when sharing information with other fishers in comparison to fishers who are members of associations?
- (RQ2) How does linking social capital in the form of work support from across the supply chain differ between associated and independent commercial fishers?
- (RQ3) Do fisher's explanations for their contrasting self-governance arrangements reveal trade-offs in how they cooperate?

The first question builds on how patterns in communication among fishers in the Caribbean have been explained by the presence of a community leader (Alexander et al., 2018), but not by more explicit differentiation of self-governance arrangements. Bonding social capital between fishers that are members of a common fishing association is expected to be stronger than between independent fishers, given the social benefits described for formally cooperative arrangements in other Latin American SSFs (de Oliveira Leis et al., 2019; Basurto et al., 2013a). In other

words, cohesion is likely strengthened through fishers' associations, since sharing the same work organization facilitates the formation of relationships (Jasny et al., 2019; Oh et al., 2004) and trust (Becchetti et al., 2013). However, cooperation among independent fishers incurs lower commitments and transaction costs than rules devised by fishing associations since they don't require sustained cooperation among a larger group (Lindkvist et al., 2017) and may have increased community cohesion among independent fishers. Meanwhile, the second and third research questions contextualized these differences to cooperative relationships across the supply chain given their prominence in the literature (Pedroza-Guitiérrez & Hernández, 2017; González-Mon et al., 2019; Basurto et al., 2020) and to narrated explanations not readily captured through the quantitative networks (Valdés-Pizzini, 1990; Del Pozo, 2012; Basurto et al., 2013a; Barclay et al., 2017). No a-priori hypothesis was expected for the latter two questions, given their grounded-theory approach.

2 Materials and methods

2.1 Study site

The northeast marine region of Puerto Rico provides a social-ecological site useful to explore the research questions stated above. First, the fishing communities in this region have been historically considered the second most productive in the archipelago (Suárez-Caabro, 1979). Second, the north-east region hosts a diversity of habitats (Kågesten et al., 2015) and commercial fisheries, including the three most valuable and popular fisheries in Puerto Rico: the deep-water snappers (*Lutjanidae* spp. and *Etelis oculatus*), the queen conch (*Aliger gigas*), and the Caribbean spiny lobster (*Panulirus argus*) (Agar et al., 2017). Third, it is a region with a similar number of independent and associated fishers (Matos-Caraballo & Agar, 2011).

This study selected *a-priori* five landing sites in north-eastern Puerto Rico whose social characteristics have been well-researched (Figure 1; Griffith et al., 2007; Del Pozo, 2012). Landing sites are places where commercial fishers have access to the sea to launch or moor their boats. They may also store gear and sell their catch at landing sites. The chosen landing sites were Culebra (CUL), Maternillo (MAT), Las Croabas (CRO), Sardinera (SAR), and Húcares (HUC). These were chosen due to their following characteristics: 1) history of fishery development programs, 2) access to fishing grounds and markets, and 3) current self-organization arrangements.

The landing sites shared a similar history of state interventions. All communities chosen benefited from small-scale fishery development programs from the 1950s throughout the 1970s (Pérez, 2005), including the 1963 Program for Minimum Facilities in Fishing Villages of the Puerto Rican Department of Agriculture, which built infrastructure to land and process catch (Suárez-Caabro, 1979). In 1976, the Agency for Community Action established subsidy and technical assistance programs for fishing associations in Culebra and Húcares (Suárez-Caabro, 1979). Furthermore, all landing sites utilize similar fishing grounds and often fish in waters around Culebra Island due to the high productivity in that area (Griffith et al., 2007). However, the landing sites have differing degrees of access to fishing markets. Contrary to the geographically isolated community in Culebra, all other landing sites were on the main island of Puerto Rico and have easier access to bigger and more diverse markets (Griffith et al., 2007; Del Pozo, 2012).

Each landing site had a unique self-governance arrangement at the time of sampling. Húcares has one association, with a recent history of high collective action. While Las Croabas and Maternillo have fishing associations, previous studies suggest that these associations have not been successful in recent years, due to a combination of leadership disputes, ecosystem degradation, and hurricane impacts (Del Pozo, 2012; Cruz-Torres et al., 2019). Both Las Croabas and Maternillo exhibit a combination of informal (independent fishers) and formal (associations) arrangements. At Sardinera there is no fishing association since Hurricane María in 2017 and at Culebra the fishing association collapsed in 2012. Since then, these two landing sites have organized informally, without any formal institutions (i.e., fishing associations). Association P1 was based in Húcares. Association P2 was based in Las Croabas, and Association P3 was based in Maternillo.

2.2 Data collection and analysis

Qualitative and quantitative methods were used to understand the interplay of social cohesion and community-based organization in small-scale fisheries. Qualitative interviews with fishers contextualized the reasons for cooperation, as well as their socio-economic reasons for their preferred self-governance arrangement. Building on these insights, quantitative social network analysis untangled how the information shared and the work support received by commercial fishers varied across social drivers.

2.2.1 Interviews

Semi-structured interviews, with an average length of 1 hour, were carried out to contextualize social networks through qualitative analysis. Nineteen initial interviews occurred with resource managers, academics, and fishing community leaders between March-August 2020. These initial interviews informed the design of a quantitative social network survey for commercial fishers. Due to COVID-19 health concerns and social distancing regulations at the time, these interviews were performed through web-based platforms or phone calls,

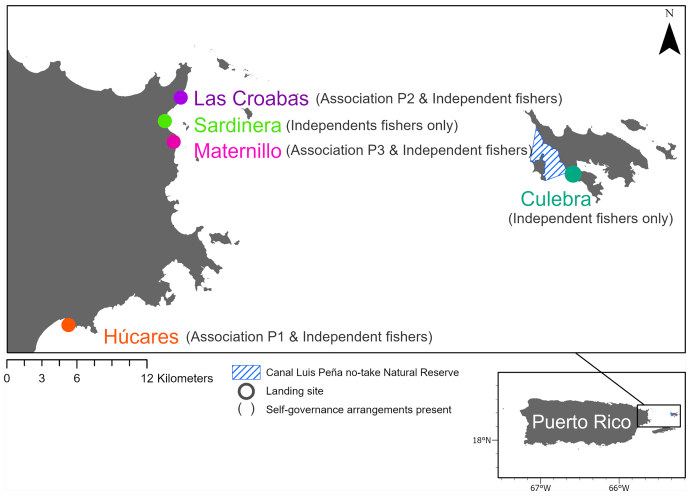

FIGURE 1
Map of the study site in north-eastern Puerto Rico highlighting the commercial fisher's self-governance arrangements (fishing associations vs. independent fishers) found in each landing site. While all sites have independent fishers operating in them, Las Croabas (CRO), Húcares (HUC), and Maternillo (MAT) also have fishing associations. Culebra (CUL) and Sardinera (SAR) only have independent fishers. Although associations sometimes had members who operated in other landing sites, their fish shops and administration were based on one of the landing sites. Association P1 was based in Húcares. Association P2 was based in Las Croabas, and Association P3 was based in Maternillo.

depending on the participant's preference. Between August 2020-January 2021, an additional 21 semi-structured interviews were conducted face-to-face or through phone calls with commercial fishers (Supplementary Table 1).

Informed consent and assurance of confidentiality were acknowledged verbally before all interviews; following protocols approved by the Institutional Review Board (IRB) of Oregon State University. All interviews were conducted in Spanish; the audio was recorded, transcribed, anonymized, and analyzed using NVivo qualitative analysis software. Initial coding themes were derived from the research questions and included current fishing problems and opportunities, drivers of these issues, and trends in social capital among fishers and other sectors. Responses on recurrent themes were compared between fishers from different communities and gear types. The second round of coding re-grouped codes based on emergent explanations for the self-governance arrangements of fishers and the reasons for sharing information and working with each other. Eight interviewees were re-contacted to check for the validity of specific answers. Salient emergent topics and supporting quotes were translated into English.

2.2.2 Social network survey

A social network questionnaire was administered to 61 fishers using an exponentially snowball sampling technique that allowed for the elicitation of names and ties with other fishers and non-fisher supporters. In response to health risks imposed by the pandemic, the questionnaire was carried out through a combination of modes: in-person (45.9%), phone (39.3%), or a combination of in-person and phone (14.7%). See Supplementary Material for details.

This social network survey generated data on several forms of bonding and linking social capital about types of self-governance, gear use, targeted fisheries, and markets. Two name generator questions were used, one for an information-sharing network and another for a work-support network. The first asked "*With which fishers do you share information about fishing?*" and the second network was created from the responses to "*Think of several people you work with to be able to fish. Tell me their names and I will ask you some questions about the support that is shared between you*". A name generator consists of a question that asks the subject to produce from memory a list of individuals (i.e., free list protocol). Name generator questions have been developed for hard-to-access populations and have been posed as reliable survey questions to capture stable social structures (Heckathorn, 2002; Robins, 2015). Each of these questions was followed by several name interpreter questions. At each landing site, eligible fishers were surveyed from one initial participant. Each participating ego (i.e., fisher nominating other) had unlimited referrals (i.e., alter nominees). Each new referral then provided more referrals (Etikan et al., 2016). A weight was placed on each tie by asking "How valuable is the information you share with this person?" in categories of "little, "moderate"" and "a lot"). See Supplementary Table 5.

For the information-sharing network, flows were unidirectional from ego to alter except when two fishers independently mentioned each other (i.e., reciprocal nomination). This bypassed the problem of having to

arbitrarily select whether to include or delete duplicated or contradictory ties. Meanwhile, the question for the work-support network implied the support received by egos.

Only the information-sharing network was used to determine the network boundaries. Fishers had to meet two criteria to be included in the network: 1) land catch in one of the chosen landing sites 2) be nominated as a commercial fisher by at least two 2 nominees. Fishers that were nominated by only one participant were excluded from the snow-ball sampling and social network analysis to avoid transitory or infrequent fishers in each landing site. See Supplementary Material, Sections 2.2 and 2.3 for details. Sampling recruitments stopped when the remaining alter fishers refused to participate, when they could not be reached after three outreach efforts, or when the sampling period ended without being able to obtain their contact information.

Small-scale fisheries in Puerto Rico include an ever-changing number of fishers, and existing records are often incomplete or outdated. Therefore, two forms of checks were used to validate whether the network was complete. The first was the total number of licensed commercial fishers for each landing site during 2019 (Supplementary Table 2). Since this restricted the network to only registered fishers complying with regulations, the boundaries were also checked using the total number of members in each fishing association (Supplementary Table 3). In Culebra, this was not possible due to a lack of formal self-governance arrangement, yet the small population size facilitated a complete local network. Eighty-nine percent (61/68) of the total network was surveyed when considering the records by the Department of Natural and Environmental Resources (DNER) for these landing sites.

The other survey questions generated data on fisher's attributes. Although other questions were asked, this analysis only considered fisher's primary gear type, and primary landing site, asked as categorical, closed-ended questions. A fisher's self-governance arrangement was asked as an open-ended question. These answers treated as node (i.e., actor) attributes, as encouraged by Van Der Gaag and Snijders (2005).

Several quantitative statistics of social cohesion were used in the information-sharing network. The degree centralization of a network is a normalized measure of how evenly ties in the network are distributed among the actors (Freeman, 1979). Low degree centralization values mean most fishers had a similar number of ties, whereas high values (closer to 1) mean ties were concentrated among a few, highly connected actors. Density was also calculated as the proportion of ties in a network compared to all possible ties. A high-density network is conceptually synonymous with a cohesive one. However, since density is not a scale-free measurement (e.g., bigger networks tend to have lower density simply because of the limited number of relationships actors can manage), combining density and degree centralization illustrates a more accurate representation of community cohesiveness (Bodin & Prell, 2011, p.40). To compare different factors, separate networks were created for each landing site, each self-governance arrangement, and each gear type.

The types of work support received were diverse, and twelve emergent edge attributes were created from responses to account for this. The work support network was split to assess only the two-mode (i.e., bipartite) interactions of sampled fishers and the institutional actors they received support from. The quality of these work relationships was assessed by comparing fishers by the frequency of ties representing "difficult cooperation", which was constructed by asking "*How easy it is to work with this person*?", categorized as "easy" or "hard".

2.2.3 Exponential random graph modeling

Factors accounting for the presence or absence of ties in the information-sharing network were tested using Exponential Random Graph Models (ERGM). ERGMs are statistical models that predict the maximum likelihood for tie formation, given nodal, edge, structural factors, and co-variates (Robins et al., 2007; Robins et al., 2009; Lusher et al., 2013). In other words, these models predict the probability that relationships among actors will occur given specified combinations of actor and edge attributes and how the empirical relationships are structured in the network. ERGMs have been used effectively in the past to understand the drivers of community cohesion among small-scale fishers (Alexander et al., 2018; Scaggs et al., 2021; Cáceres et al., 2022).

ERGM development followed a theoretically and hypothesis-driven approach in which possible drivers of communication (or lack thereof) were informed from previous 1) empirical research on small-scale fishing communities, 2) network approaches to natural-resource dependent communities or 3) qualitative insights from the semi-structured interviews of this study (Table 1). Although the survey included questions eliciting various attributes of fishers (e.g., gear diversity, market diversity, prices, costs, effort), only the attributes known for all fishers (egos and alters) were tested for in the ERGM. Although the network lacked ties that would have been obtained if all alters had been sampled, the network provides partial information on the population graph since the number of nodes is known and thus ERGMs are still able to make reasonable inferences (Robins et al., 2004; Pattison et al., 2013).

The ERGM used the directed information-sharing network, where information flowed from egos (fishers surveyed) to their nominated fishing peers (i.e., alters). Estimated parameters in the table are log odds but converted to odd ratios when reporting in the text to aid interpretation. Models were run in the sequence outlined in Table 1 to partition the effects of terms representing the possible place-based, knowledge-based, or organizational factors driving the formation ties. Note that two fishers from an association from another region of Puerto Rico (Association P6) met the network boundaries. They were included in the

TABLE 1 Descriptions of the sequential exponential random graph models (ERGM) developed for the information-sharing network among commercial fishers, expanding on the hypothesis explored by Alexander et al., 2018.

Model	Description and Justification	Purpose
Model 1: Random model	The random model suggests that ties are both random and uniformly distributed across all fishers (Bernoulli model). It only includes the edge configuration.	Baseline
Model 2: Model 1+ Reciprocity 	Builds on Model 1 by testing whether the inclusion of reciprocity contributes to the formation of communication ties among small-scale fishers. Norms of reciprocity have been highlighted as important in PR fisheries (García-Quijano, 2009).	Test the extent to which reciprocity explains the network structure.
Model 3: Model 2 + Self-governance arrangement homophily  + Associated sender effects  + Associated receiver effects 	Builds on Model 2 by testing whether the inclusion of different self-governance arrangements chosen by fishers drives the establishment and maintenance of cooperative communication ties among themselves. These terms account for literature highlighting the role of formal and informal institutions in shaping cooperation in SSFs (Basurto et al., 2013a; Lindkvist et al., 2017). No empirical work to date has tested this through ERGMs. Homophily refers to the formation of social ties between individuals who share a common attribute.	Test the effects of each fisher's overall self-governance arrangement membership to a specific association or as independent fishers. Also tests if associated fishers are more likely to send or receive information in comparison to independent fishers.
Model 4: Model 3 + Gear homophily 	Builds on Model 3 by including several gear types, and testing whether using the same gear types contributes to the formation of cooperative communication ties among fishers. Gear homophily is common in SSFs, but not for all gear types (Crona & Bodin, 2006; Cox et al., 2016; Alexander et al., 2018).	Accounts for knowledge-based communities.
Model 5: Model 4 + Landing site homophily 	Builds on Model 4 by testing whether geographic proximity *via* a shared landing site drives fisher's cooperative communication ties, which has only been empirically tested by Alexander et al., 2018). The geographical distance between fishing organizations is known to mediate the quality of communication between them (Adán et al., 2020).	Accounts for place-based communities.
Model 6: Model 5 + Triadic Closure 	Builds on Model 5 by testing whether bonding social capital in the form of triadic closure contributes to the formation of cooperative communication ties among cohesive sub-groups of small-scale fishers (Burt, 2005). Triadic closure refers to the likelihood that a fisher shares information with the friend of a common friend and has been noted as important for SSFs (Alexander et al., 2018).	Tests the extent to which cooperative tie formation leads to social cohesion while accounting for factors in previous models.

sender/receiver effects of the ERGM as associated fishers, but they were omitted when testing the homophily between associated fishers, since the sampling protocol limited the data obtained on the majority of members in Association P6, given they typically used a different landing site.

The goodness of fit of the different models was assessed by comparing a set of observed network statistics with the range of the same statistics obtained by simulating many networks from the fitted ERGM (Hunter et al., 2008a). First, a calibration assessment compared the observed and the simulated networks, to know how well the model reproduced each term. Then, a validation assessment was done to identify structural phenomena of data that were not explicitly modeled. Convergence was also assessed for every model by assessing whether the Markov chain Monte Carlo (MCMC) mixed well and converged to the target value. This network resulted in the formation of 604 triangles (from the 335 ties between the 76 fishers). Therefore, a triadic closure term was added in the ERGM to test how likely it was for a tie to form between two fishers connected indirectly by a shared information exchange partner. Triadic closure is a property among three nodes and is commonly measured through transitivity, a measurement of the number of closed paths between actors. The presence of multiple triangles (closed ties between three actors) is akin to cohesive subgroups (Hunter & Handcock 2006). Specifically, the directed version of geometrically weighted edgewise shared partnership (d-GWESP term) was tested, using outgoing two-path (OTP), also known as a transitive shared partner, as the default vertex type. In order words, this tested the likelihood of fisher *Juan* sharing information with fisher *Luis* if *Carmen* receives information from *Juan* and *Carmen* also shares it with *Luis*. Including directionality added a layer of complexity mirroring real-world interactions that may influence the cohesiveness of actors. For example, if the information was related to a coordinated action among a community of fishers, (such as letting a depleted fishing ground recover), having the redundant communication of both *Carmen* and *Juan* communicating this reality to *Luis* may be critical for the later to trust and cooperate in the agreed-upon change. The decay value used to determine how much weight to place on ties with multiple shared partners was conservative (0.25), as chosen by Goodreau et al. (2008). Other decay values (0.5 and 0.75) were explored but did not allow model convergence. All quantitative analysis was done in R software, version 3.6.1. Network processing and exploratory analysis were done in the *network*, *sna*, *igraph*, and *GGally* packages (Csardi & Nepusz, 2006; Butts, 2007; Butts, 2008; Schloerke et al., 2018). The *statnet* and *ergm* packages were used for the ERGM modeling (Handcock et al., 2008; Hunter et al., 2008b).

3 Results

3.1 Insights from interviews

The 21 fishers interviewed expressed multiple reasons for sharing information among themselves (Table 2). The most frequent reason was sharing insights about benthic environments and the weather (66.6% of participants). Most fishers (57.1%) also shared where they fished to receive assistance in case of emergencies at sea. Communicating to mitigate territorial conflicts by knowing how to avoid where other people fish was also stated by 14.2% of fishers as a reason to communicate with their peers. This was especially true for trappers, who shared their fishing areas with trusted fishers so that these peers could monitor their traps and minimize the risk of gear vandalism. In this scenario, the reputation of a communication partner was voiced as important since the receiver might abuse the knowledge. Yet being cautious about information-sharing with regards to reputation may have been a broader norm to avoid being perceived as affiliated with poachers, traffickers, and other less reputable actors. Similarly, the opportunity to improve their own and others' catch opportunities were mentioned by 19.0% of fishers as a reason for sharing information, especially among independent fishers targeting deep-water snappers. The social differences between fishers that operate in landing site different from their own, or that operate with different gear type, were also stated by 28.6% of fishers as contributing to their reluctance to share information.

Meanwhile, the explanations given by interviewed fishers for the work support they share were more diverse in the types of actors and the types of codes. Most (61.9%) responded that they shared gear (including going out in the same boat but also sharing equipment) as examples of the support they receive from other fishers. To a lesser extent (28.6%) fishers recognized the

TABLE 2 Emergent explanations from commercial fishers for their cooperative behaviors (n = 21).

Type of cooperation	Salient themes	% of individuals mentioning theme	Translated representative quotes
Info-sharing	Environmental conditions	66.6	"In the mornings, when going out 'Hey, how clear is it to this place, how is the current over there … did the lobster move?' That is what we say. It's not that we know where the fish are, and we stay quiet to get it just yourself … no. We always tell each other." –HUC, associated
	Maritime safety	57.1	"We always tell each other where we are going to fish that day and that way, we help each other. If I do not come back in the afternoon, they know where to look"–CUL, independent
	Reluctance to share	28.6	"What happens is that fishing in CRO and HUC is very different. For example, the fishers from HUC focus on conch, are divers, while those in CRO also catch lobster and conch, but also the deep-water snappers. And sometimes the [fishers in the east] do not have a common interest, and that limits our communication" –, HUC, independent "I am jealous of my knowledge because I've invested my life in obtaining it!" –CUL, independent
	Catch opportunities	19.0	"We, the … the ones that go out for the deep-water snappers, try to help each other out so we make fewer mistakes. There is help. Sometimes I am at 400 fathoms, and they tell me 'We are fishing good at 700 fathoms.' That way I can move and fish better" –CRO, independent
	Conflict mitigation	14.2	"I tell them where I fish so that there aren't problems. The depth: if the bottom is muddy or rubble [then] that communication protects me. This way I have friends too. I communicate with [fisher] so he looks out for my traps; he is respected and is my cousin. But you have to be careful with whom you talk to [and avoid] those with a bad reputation. Even with family!" –CRO, associated
Work-support	Sharing Gear*	61.9	"We combine boats. We give one month to my partner's boat, then another month for my boat and we trade the percentage [from earnings for whoever shares the boat] too. When it's your turn, we take it out, paint it, change motors, whatever it needs. That way we don't overwork the boat and we protect the motors. And the percentage is good. Depending on the catch, it can be 200 to 300 extra a week" –HUC, associated
	Fishing with others	28.6	"I am pretty autonomous, but always need support because the sea is a struggle! Right now I don't fish with more people because I need a bigger boat, but if your boat is broken, I will go with you[.] I am a fisherman, but I go as a deckhand too." –CUL, independent
	Reciprocity	23.8	"I also have a friend here, who finds me bait. Squid for the queen snappers. He also knows a bit about mechanics and gives me hand with that. And I give him fish from time to time. Today I help you, tomorrow you help me." –CRO, associated.

*Includes codes "Finding lost gear", "Sharing boats" and "Sharing equipment".
The landing sites the fishers operated in were Culebra (CUL), Las Croabas (CRO), Húcares (HUC) and Maternillo (MAT).

TABLE 3 Commercial fisher's reasons for choosing self-governance arrangements emergent from coding and analyzing semi-structured interviews (n = 21).

Self-governance arrangement	Theme	% of individuals mentioning theme	Translated Representative Quotes
Independent	Sense of community	71.4	"I don't have anything bad to say about the association … but it's just not the same comradeship as with my independent friends."
	Negative perception of association leadership	52.4	"The problem with the associations is that those who manage them are not fishers and don't know how we suffer out there … and that is why they put their interests first and conflicts occur."
	Lack of cooperation	42.8	"Unfortunately, fishermen are not organized. We do not support each other. The fisher sees the other fisher as the enemy because you are the person stealing from me! And since you are the one that robs me, I won't ally myself with you!"
	Patron-client relationships	23.8	"We already have a selling commitment with [R5]. There is nothing in writing, but since they have never failed us, well you have to be loyal to those that are loyal to you. And we sell to [R5]" "The restaurant [R5] buys lobster at $7.5, and even though there are restaurants [in a neighboring town] buying it at $8.5, I have to go deliver it there. Do you know what it is to come from fishing, clean the boat, take a shower, and then take them the lobster? And then they give you a check and you have to go to a bank to deposit it and then wait three days. So, even though [R5] buys them from me for less, they are my stable buyer. I have less work, and they pay me cash! [.] One day a diver came with lobster to [R5] and asked how much he would be it for. [R5 owner] answered $7.75 the pound. 'Oh, I'll sell it all for $7.50' And [R5 owner] answered 'I can't buy it from you because I already have my fishers.' That's what he said. [R5 owner] did not want to mess up the price. I am with [Association P3] now, but that's why I still want to sell to [R5]"
	Improved prices	33.3	"It's not the same for a fish shop to pay you $6 for lobster when a business can buy it for 7 or even 8 dollars."
	Market limitations	33.3	"The factor with CUL is that business is very limited. We need to export. If the people here show up, I don't have any problem selling to a fishing association."
	Disagree with association rules	28.5	"The other problem had is that sometimes I would get there and the fish shop didn't want to buy me all the catch. They only wanted to buy the nice fish, but the third-rate I had to find somewhere else to sell it. And so I said, 'If they are not going to help me, why would I stay [a member]?"
Associated	Trust leadership	76.0	"[I am associated] because there is not a war in the association, over who fishers better. Also, [the leader] is always attentive to our needs"
	Leverage political interests	66.6	"We in the association don't stay quiet!" "Having an association allows me to have more validity … to receive help" "I hope that through the association [the government] helps us all, not just a few. That is my objective in being a member of the association … because here there is a monopoly over the [subsidized] trap mesh"
	Sense of Community	52.4	"Maybe I have a dollar less selling to the association, but it benefits us in the long run because when there are needs, there is strength in union. … and if I go independent and go sell in another place, the fish shop where we organize ourselves will collapse. We will make progress if we cooperate."
	Receive paperwork assistance †	52.4	"It is convenient for us, [P2 leader] helps us fill out catch reports and help us with the licenses"
	Stable selling opportunities.	38.1	"The fish shop calms things around here. It unites us, because they not only buy to me but to him too, at the same price. It helps make sure we sell our catch"
	Less effort*	19.0	"They buy all of my catch, whether it's quality or not. That saves me a lot of work."
	Access to infrastructure	19.0	"To support, but also for the benefits, like the Access to the ramp and having a place to sell. Because I don't have a freezer in my house."

*Requires less post-harvest effort than independents.
† Aid with catch reports, permits, and fisheries aid.

need to fish with others, rather than alone. Norms of reciprocity in work support were explicitly mentioned by 23.8% of fishers. The actors mentioned in these codes included association leaders, bait collectors, and buyers, but mostly referred to fishers (a mix of captains and deckhands).

When fishers shared their reasons for their social arrangements, the responses were mainly related to social relationships and not economic factors (Table 3). Most associated fishers (76%) voiced favorable opinions of their leaders, and about half (52.4%) expressed they associate because of the community and support from other fishers in the association. Most associated fishers (66.6%) also mentioned that the opportunities to leverage their interests through the association was a benefit to them. Some associated fishers (19%)

also expressed how they had the benefit of knowing their association's fish shop would buy their catch and spare them the effort of cleaning the fish. Associations also had different membership agreements which were voiced as part of their reasons to associate with them. All three associations provided the service of cleaning catch to their members. Although Association P3 did not have a functioning fish shop (an important location where fishers gathered), these agreements were confirmed by their members. Association P1 did not force its members to always sell all their catch to the association and allowed members to sell or give away catch to others, thus facilitating fisher's need to maintain other relationships and minimize instances when the association had more catch than demand. Association P2 did not have this as a rule because of its few members for whom it depended on a stable fish supply.

Meanwhile, most independent fishers (71.4%) also commented favorably on the community provided by their relationships as non-associated fishers. Half (52.4%) of independent fishers also expressed their dislike of the association's leadership, while a sizable percent (42.8%) referred negatively to their perceived lack of cooperation among members of associations. A lesser number of independent fishers expressed disagreement with association rules (28.5%). For example, Culebra's fishers expressed how their previous negative experiences with associations made them want to stay independent. Some independent fishers cited lack of support from historical associations and alleged corruption by its leaders, while others recognized that fishers were not willing to follow the association's rules and preferred to sell elsewhere at better prices, undermining the association's viability. Several (23.8%) independent fishers referred to their stable relationships with patrons as a reason for their informal arrangement.

3.2 Insights from the social network survey

3.2.1 Information-sharing network

Information sharing among fishers provided a more complete sense of bonding social capital and the factors influencing social cohesion. Therefore, this was the central focus when analyzing community cohesion. A total of 335 ties were recorded for this network, for an average of 2.23 (± 1.47 SD) ties per fisher. Note that these values consist of the ties inside the network boundaries, and do not include ties with fishers at landing sites not included in this study. Associated fishers had an average of 2.45 (± 1.41 SD) ties, though this varied by association. Members of Association P1 had an average of 2.84 (± 1.09 SD) ties each, followed by Association P2 with an average of 2.24 (± 1.66 SD) ties for its members, and lastly, members of Association P3 had an average of 2.22 (± 1.48 SD) ties each. Meanwhile, independent fisher had an average of 2.49 (± 1.66 SD) ties. Therefore, the number of ties did not initially seem to vary greatly across self-governance arrangements. However, information sharing spanned diverse themes that assisted in uniting or dividing social groups. Sharing information about harvesting was the most frequent type of information-shared, accounting for 38.8% of all ties. This was followed by 18.7% of ties communicating about post-harvest matters and 16.2% about problems. Information-sharing related to pre-harvest topics and opportunities within the sector each accounted 11.5% of these ties.

Culebra had the highest density and the highest degree centralization, followed by Húcares. Meanwhile, Las Croabas and Maternillo had comparable low values for both statistics. Regarding self-governance arrangements, Association P3, based in Maternillo, exhibited the highest degree of centralization, followed closely by Association P2 in Las Croabas and Association P1 in Húcares. Independents had the lowest degree of centrality of all arrangements (Table 4). This suggested how associations had more highly connected fishers than those operating under independent arrangements. Association P2 was the densest, followed by Association P1 and then Association P3. Independents were the arrangement with the lowest density.

The influence of primary landing sites, primary gear types, and each fisher's organizational arrangements in the network structure was glimpsed through qualitative network analysis and pointed to the overlapping roles of place-based, knowledge-based, and organizational communities in driving community cohesion among fishers (Figure 2). Information-sharing was treated as a single network across all landing sites due to the significant cross-landing site operations and membership of fishers. For example, Las Croabas fishers were associated with Association P3 in Maternillo and vice versa. This overlap highlighted the need to treat self-governance arrangements as a distinct factor from landing sites.

3.2.2 Exponential random graph models

Quantitative analysis through ERGMs tested the likelihood of information-sharing ties through factors representing hypothesized knowledge-based, place-based, and organizational social processes (Table 5). The Akaike information criterion (AIC) improved with every model (Akaike, 1973). Model 6 had the lowest AIC and thus was the most efficient model in explaining the variation in the network structure. While results from all stepwise models are provided in the supplementary material (Supplementary Table 7), only results from the best fitting model are discussed here.

First, a positive and significant estimate for the reciprocity parameter suggested that a tie was 2.20 times more likely to exist when there was an information tie flowing in the opposite direction, compared to when there was no reciprocating tie. The baseline probability of a tie was 5.8%, but when a tie flowed from fisher A to fisher B, then the probability of a tie from fisher B to fisher A increased to 46.9%.

Second, a set of parameters modeled the homophily, sender, and receiver effects of self-governance arrangements. When testing for how likely a type of arrangement was at receiving information, independent fishers were 1.72 more likely to receive

TABLE 4 Descriptive metrics for the information-sharing network, disaggregated across homophily effects, indicative of different drivers of social cohesion.

Category	Node attribute	Number of fishers	Number of ties	Density*	Degree Centralization†
Total Network:		76	335	0.059	0.12
Shared landing site ‡	Culebra	15	69	0.329	0.363
	Húcares	14	53	0.291	0.244
	Las Croabas	27	91	0.130	0.213
	Maternillo	17	28	0.103	0.202
Shared self-governance arrangement §	Association P1	12	46	0.348	0.291
	Association P2	5	9	0.450	0.292
	Association P3	17	51	0.188	0.460
	Independents	40	117	0.075	0.231
Shared primary gear ||	Fish trappers	16	56	0.233	0.267
	Lobster trappers	6	8	0.267	0.65
	Gillnet	4	2	0.167	0.333
	Handline	13	10	0.064	0.170
	Mechanized deep-water hook and line	7	19	0.452	0.533
	SCUBA diver	21	41	0.098	0.113
	Skin divers	7	16	0.381	0.40
	Rod and Reel	1	0	0	N/A

*Density calculated from directed networks.
† Normalized degree centralization for the directed networks, where a score of 1 indicates all ties are centered around one actor, and a score of 0 reflects a network where all actors have the same number of ties (Freeman, 1979).
‡ In Sardinera (SAR), the fish shop was closed after internal conflict and hurricane damages that led to members' secession. Only three fishers remained and so the landing site was excluded from further analysis.
§ The two fishers from Association P6 were outside this scope of analysis.
|| The following gear types were not reported as the primary ones for any of the fishers: trammel nets, cast nets, beach seine, troll lines, and long-lines. The gear type for the alter fisher A66 was unknown.

information than associated fishers ($p = 0.0203$). Conversely, associated fishers were not significantly more likely to send information than independent fishers ($p = 0.5806$). Regarding homophily effects, independent fishers were 1.21 times more likely to share information among themselves, but this difference was not statistically significant ($p = 0.5214$). This suggested that independent fishers were equally likely to share information with both associated and independent fishers and thus did not exhibit significant homophily among themselves. Because it was expected that fishers within an association shared information more often with one another than with fishers in another association, homophily was estimated separately for each association. Fishers from all associations were significantly more likely to share information with each other than with fishers outside their association. Members of Association P1 in Húcares were 1.92 times more likely to communicate among themselves, while those of Association P2 in Las Croabas and P3 in Maternillo were 5.91 and 2.78 times more likely, respectively ($p < 0.001$).

Next, the effects of sharing information among the same primary gear type were used as a proxy for how specialized knowledge brings people together. The parameter estimates for all seven gear types were positive, but only some were significant. Fishers whose main gear type was mechanized deep-water hook and line were 5.48 times more likely to share information with each other ($p<0.001$). Meanwhile, fish trappers and lobster trappers were 2.75 ($p<0.001$) and 2.28 ($p<0.05$) times more likely to share information with fishers whose primary gear was the same as their own, respectively. This trend varied for divers. Skin divers were 1.99 times more likely to share information among themselves ($p<0.05$), which was expected given the requirements of a dive buddy when practicing apnea spearfishing. Lastly, SCUBA divers were 1.66 more likely to share information among themselves and not with other gear types ($p<0.01$). Handline fishers did not significantly share information exclusively among their same primary gear type. Despite not being significant in previous models, in the best-fitting model gillnet fishers were 5.29 times more likely to share among themselves ($p = 0.02$). Only one fisher expressed rod and reel as their primary gear, and thus homophily could not be tested for this gear type. Overall, this suggested that gear-based homophily contributed to tie formation among most, but not all, gear types.

Consecutively, the influence of geographic distances was tested through landing site homophily. Fishers from all landing sites exhibited a positive and significant tendency to form information-sharing ties when they operated at the same landing site ($p<0.01$). This social mechanism was more

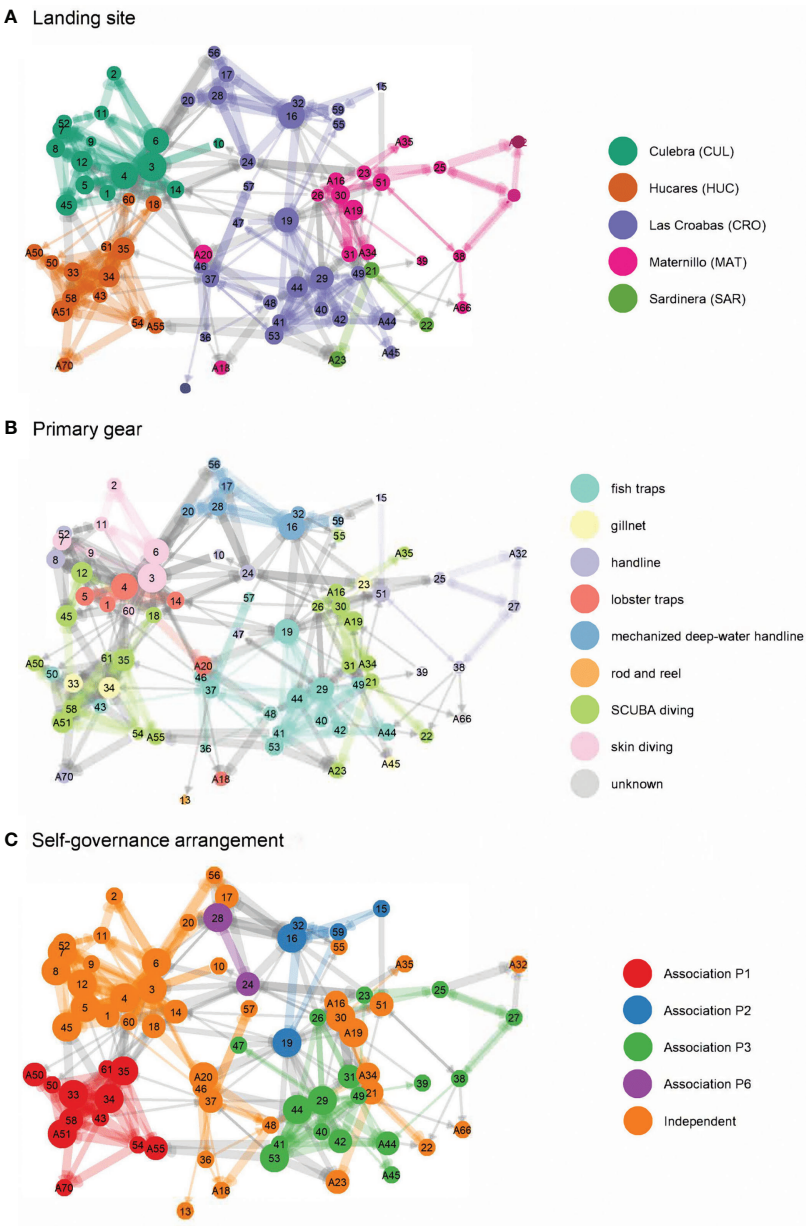

FIGURE 2
The information-sharing network among commercial fishers of north-eastern Puerto Rico, highlighting key attributes used to compare **(A)** place-based communities as defined by landing site, **(B)** knowledge-based as defined by the common use of a primary gear type, and **(C)** organizational communities based on the same self-governance arrangement. Each circle (node) is a unique fisher whose identity is anonymized. Each fisher is represented by a number if they were surveyed (egos) or by a combination of a letter and number if not sampled (alter) but still inside the network boundaries. The layout uses a spring-embedder algorithm (Fruchterman & Reingold, 1991), which places high-degree centrality nodes in the center of the plot, so that fishers that are more connected to each other, are closer together and less connected fishers are farther apart. Node size displays degree centralities, a measure of the number of ties connecting an actor. The direction of communication is denoted by arrows. The width of ties represents the value placed by the fisher on the information shared (Little, Moderate, or A lot). Ties are colored if they share node homophily to highlight possible cohesion effects.

enhanced for some sites compared to others. The fishers from Culebra, all operating independently, were 3.76 times more likely to share information with each other ($p<0.001$), which was not surprising given its isolation. On the other hand, the landing site composed mostly of fishers associated with P1 (Húcares), was 3.73 times more likely to form communication ties among fishers operating there ($p<0.001$). Fishers operating in Maternillo were 2.83 more likely to form communication

TABLE 5 Results from the best-fitting nested exponential random graph model for the information-sharing network among commercial fishers.

Factor	Parameter	Node attribute	Estimate parameter (Standard Error)
Observed network	Edges	–	-4.50 (0.30)*
Reciprocity	Mutual	–	0.79 (0.24)*
Self-governance arrangement	Homophily	Independent fishers	0.20 (0.31
		Association P1	0.66 (0.39)*
		Association P2	1.78 (0.46)*
		Association P3	1.02 (0.234)*
	Sender	Associated fishers	0.14 (0.26)
	Receiver	Associated fishers	-0.53(0.23)*
		Fish-traps	1.01 (0.19)*
		Gillnets	1.67 (0.73)*
		Handline	0.40 (0.26)
		Lobster traps	0.83 (0.36)*
Primary gear type	Homophily	Mechanized deep-water hook & line	1.70 (0.29)*
		Scuba divers	0.51 (0.16)*
		Skin divers	0.69 (0.29)*
		Culebra	1.33 (0.19)*
Landing site	Homophily	Húcares	1.32 (0.31)*
		Las Croabas	0.50 (0.17)*
		Maternillo	1.04 (0.14)*
Social cohesion	Transitive path closure (OTP)	–	1.03 (0.11)*
Model fit	AIC (BIC)	–	1837 (1970)

*Reject null hypothesis of parameter = 0, $p<0.05$.

ties which each other compared to when fishers from other landing sites ($p<0.001$). Meanwhile, fishers operating in Las Croabas were 1.64 times more likely to communicate among themselves ($p<0.01$). A homophily term for fishers from Sardinera was not included due to its low population (two egos and one alter), a consequence of not being operational during sampling.

Social cohesion in the network was included in the model through the triadic closure term. It tested if the reason commercial fishers share information with each other was not only because of the previous factors but also because fishers shared common cooperation partners. Specifically, in each potential tie, it tested how many additional fishers were shared between two fishers in a tie. In other words, it tested if the information was shared between a fisher and two other fishers who also talked to each other (e.g., how likely is *Juan* to talk to *Luis* if both *Luis* and *Juan* already talk to *Carmen*). A significant, positive parameter estimate was found with directed triadic closure ($p < 0.001$). This indicated that a communication tie was 2.8 more likely to form when two fishers shared one or more information exchange partners than compared when two fishers did not share ties that close triangles among partners. The effect size for homophily by landing sites dropped when adding a term for triadic closure, suggesting there was a tendency for transitivity in information sharing within each landing site. Since many of the people in a triad also shared the same landing site, not including triadic closure attributed this pattern to landing site homophily, while including it was more precise about the influence of transitivity. While the likelihood for homophily in Culebra dropped from 11.8 to 3.8 times when accounting for triadic closure, the same likelihood in Húcares only dropped from 6.2 to 3.7, suggesting that fishers from Húcares exhibited stronger social cohesion (Supplementary Table 7).

3.3 Work support networks

The type of work support ties fishers received from their peers and institutional actors across the supply chain were diverse (Figure 3). Fishers mostly received support from other fishers in ways that allowed them to catch more than they could alone. The second most frequent support type between fishers was sharing gear, followed by support they attributed to being able to diversify their catch and expand their fishing range. Clarification confirmed the latter two support types were a product of the skills and equipment a partner contributes to shared fishing activity. Although improving maritime safety was stated by several fishers as important in the information-sharing network, this benefit from supporting each other at sea ranked the second lowest of support among fishers at sea. The lowest frequency of support at sea was finding lost gear, presumably

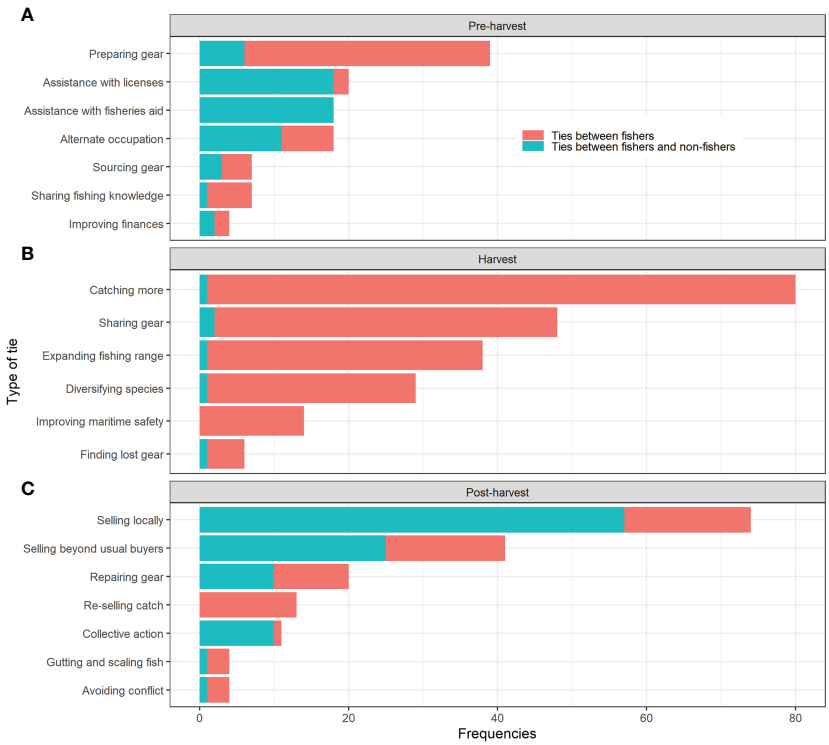

FIGURE 3
Frequencies of cooperative ties in the network of work support received by commercial fishers, grouped by supply chain phases. Frequencies are colored according to whether the provider was a fellow fisher (red) or if the support was given by other actors in the supply chain (blue), such as buyers, mechanics, and NGOs. Of these ties, 12 edge types emerged from responses. That is, they fit the a-priori classification of "other" in the survey but were grouped through interpretation guided by the semi-structured interviews. Definitions for these categories are provided in Supp. Table 6. **(A)** Cooperative ties related to pre-harvest activities. **(B)** Cooperative ties related to harvesting activities. **(C)** Cooperative ties related to post-harvest activities. Supply chain phases were defined according to reasonings by Basurto et al., 2020, who posit that access to capital (i.e., social, financial, cultural), physical means of production (i.e., gear, aid), and fishing property rights (i.e., licenses) are part of pre-harvest action situations, while collective action and conflict resolution mechanism are part of the post-harvest phase. Studies on Puerto Rico fishing show how occupational multiplicity is a needed condition for many fishers to operate (Griffith & Valdés-Pizzini, 2002) and thus conceptualized as a necessary precursor for viable fishing strategies.

since it mostly only applies to trappers. Additionally, fishers also played supportive roles in other fisher's pre-harvest and post-harvest activities, as can be expected from petty commodity producers. Fishers mostly supported other fishers before harvesting by preparing gear. After harvesting, fishers still supported each other by selling, re-selling catch, as well as repairing gear.

Fishers also received work support from non-fishers, especially on needs not related to harvesting (Figure 4). Visualizing these ties provided insights into linking capital among small-scale fishers at each landing site. These actors included buyers (e.g., restaurants, associated fish shops, middlemen, individual customers), pre-harvest supporters (e.g., mechanics, bait collectors, gear suppliers), and others whose assistance could span the supply chain (e.g., managers, NGOs). The type of support, its perceived value, and from what type of actors it came from, varied across the landing sites (Table 6).

Culebra's independent fishers received support from several restaurants that bought their catch. They also relied on several mechanics and hardware stores for access to gear and motor repairs. In contrast, Maternillo fishers were mostly supported by middlemen and the fish shop managed by Association P3. The average value of support from the fish shop was higher (2.5) than that of the middlemen (1). Fishers from Las Croabas and Húcares were supported by similar amount and type of actors. Although Association P3 is in Maternillo, it had members who only operated in Las Croabas. Meanwhile, Association P2 in Las Croabas supported both independent fishers and those in its membership. All fishers in Húcares were centrally supported by Association P1, yet some of its members received support from other buyers.

Differences in the work support network were also apparent between self-governance arrangements. Only four restaurants gave support to associated fishers, while independent received support from 13 restaurants. The restaurant R5 was a strong supporter of fifteen fishers, of which thirteen were associated.

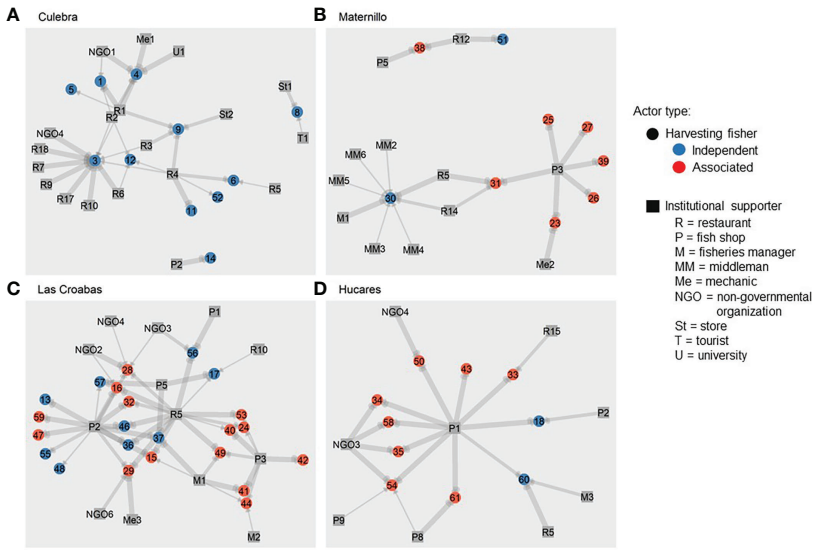

FIGURE 4
Support for work across the supply chain received by harvesting fishers from institutional actors. Support for work across the supply chain received by harvesting fishers from institutional actors (e.g. buyers, managers, gear suppliers, and non-governmental organizations), across landing sites of Culebra (CUL; panel **A**), Maternillo (MAT; panel **B**), Las Croabas (CRO; panel **C**), and Húcares (HUC; panel **D**). The network reveals differences in the type and quantity of supporters among self-governance arrangements. This network excludes ties among fishers and ties among institutional actors, and therefore it is a bipartite (i.e., two-mode) network. Tie width denotes the value placed by fishers on the support from that actor (Little, Moderate, A lot), with higher value ties represented by thicker lines. Node colors for fishers (circles) highlight whether their self-governance arrangement (i.e., associated, or independent), while institutional actors are represented by squares. The letter R denotes restaurants, the letter M denotes managers, while MM denotes middlemen. The letter P represents fish shops, including those run by Associations P1, P2, and P3. The acronym "Me" represents mechanics, while "St" represents hardware and fuel stores. Isolate fishers (those that did not report institutional support) were eliminated for clarity.

Independents also had 7 more pre-harvest supporters than associated fishers. Similarly, independents received support from 5 middlemen, while associated fishers had none. Independents also reported twice as many "hard to work with" ties than associated fishers. While associated and independent fishers received support from a similar amount of fish shops, the average value of their support was higher for associated fishers than independents.

4 Discussion

To understand the interplay of social cohesion and organization around SSFs systems facing weak formal governance and socio-economic precariousness, we studied the cooperative relationships among independent and associated Puerto Rican commercial fishers, as well as from their supporters across the supply chain. An information-sharing ERGM confirmed the co-existence and significant likelihood of multiple types of information-sharing ties among harvesting fishers, which lead to overlapping place-based, knowledge-based, and self-governance communities. This points towards the need of managers and scholars to evaluate the assumptions as to what drives the cohesion in the social networks of fishers. Our analysis provides insight on the factors explaining the social cohesion of small-scale fishing communities by adding nuance to the role of self-governance arrangements in the formation of cooperative communication relationships. While institutional differences between fishers have been explored through network models for other SSFs, it has been limited to testing the presence of a warden (a state-appointed ranger for a marine reserve and sometimes also a fishing co-op member) and not the diversity of fisher's ways of self-organizing (Alexander et al., 2018). Furthermore, relationships beyond the harvesting phases of fishing (i.e., pre-harvest and post-harvest) are critical in the development of cooperative and non-cooperative relationships in fishing communities (Basurto et al., 2020). These results address this by incorporating insights into fisher's relationships with their institutional supporters across the supply chain. While rich ethnographies exist (see Griffith et al., 2007; García-Quijano, 2007; Del Pozo, 2012), there are no quantitative descriptions of cooperative relationships among Puerto Rican fishers, leading to an understudied potential of informal institutions in fisheries governance.

The fisher cooperative networks were interpreted through the lens of bonding (within groups) and linking (across hierarchical groups) social capital, as has been done in other small-scale fisheries (Ramirez-Sanchez & Pinkerton, 2009;

TABLE 6 Summary of the network of support received by fishers from institutional supporters.

Population	Number of supporters per fisher (Average tie value)						
	Restaurants	Fish shops	Middlemen	Pre-harvest supporters*	Conservationists†	Managers	Number of "hard to work with" ties
Culebra (n= 12)	0.92 (1.9)	0.08 (3)	0 (0)	0.25 (2)	0.25 (2.5)	0 (0)	7
Maternillo (n= 9)	0.33 (2.5)	0.22 (2.5)	0.56 (1)	0 (3)	0.11 (1)	0.11 (3)	2
Las Croabas (n= 22)	0.09 (2.52)	0.14 (2.3)	0 (0)	0.05 (3)	0.18 (1.5)	0.09 (2)	1
Húcares (n= 12)	0.17 (2.25)	0.33 (2.57)	0 (0)	0 (0)	0.17 (3)	0.08 (2)	2
Associated (n= 30)	0.13 (2.5)	0.2 (2.5)	0 (0)	0.03 (3)	0.17 (2.2)	0.07(1.6)	4
Independent (n=25)	0.52 (2.03)	0.1 (1.25)	0.2 (1)	0.32 (3)	0.2 (2.3)	0.08 (2.6)	8

*Hardware stores, gear suppliers, and mechanics not affiliated to fishing associations.
†Non-governmental organizations and university academics supporting through conservation projects.
It compares the amount of each type of supporter per fisher in each population (landing site or self-governance arrangement). In parenthesis, it also includes the average value reported by fishers for those ties (1 = low, 2 = moderate, or 3= high). Note institutional actors may support fishers from different landing sites and both organizational arrangements. Only 55 fishers (91% of those surveyed) answered this question.

Nenadovic & Epstein, 2016). Specifically, information-sharing was conceptualized as bonding social capital. The clustering of cooperative relationships among similar actors is a network representation of bonding social capital (Berardo, 2014). Meanwhile, the work support received from institutional actors was conceptualized as linking social capital, in alignment with previous definitions of network perspectives of social capital (Grafton, 2005; Barnes et al., 2015).

4.1 Overlapping drivers of bonding social capital

Fishers' explanations for their ways of organizing fishing activities revealed that a sense of community was important for both independent and associated fishers. The importance of these bonding relationships was evidenced during the recovery of Hurricane María, where commercial fishers pooled resources and disseminated information on relief opportunities (Agar et al., 2020). More broadly, the activation of these community-based social networks mirrors a trend in self-governance in Puerto Rico's recent years, where rural communities have relied on sharing resources and other forms of informal cooperation to fulfill their needs (Talbot et al., 2020; Roque et al., 2021). The different drivers of commercial fisher's bonding capital, and consequently, how they can be leveraged to foster community-based fisheries management, are contextualized below.

4.1.1 Reciprocity

Reciprocated communication between fishers was repeatedly expressed as fundamental to fisher's operations. This norm for reciprocity is known to extend to fisher's post-harvest intentions too, as giving away catch is often reciprocated in PR fisheries (Griffith et al., 2013). Although evidence for reciprocity was not repeatedly pointed out by interviewed fishers when describing whom they share information, the ERGM validated that reciprocity significantly explains these ties, suggesting the norm for reciprocity extends to these fisher's information sharing. This may be explained by the social gains of having a reputation for honesty (Smith, 2010). Since norms of reciprocity are an informal governance institution in SSFs known to lead to more cooperative management of common-pool resources (Ostrom, 1990), this highlights the potential to leverage its presence when designing interventions. Specifically, reciprocated communication can be strengthened by those seeking to increase the detection and consequences of breaking a community's commitments, as it amplifies the reputation damages of free-riders (Smith, 2010).

4.1.2 Shared self-governance arrangement

ERGM analysis of the information-sharing network showed members of fishing associations mostly communicated among themselves, while independent fishers talked across self-governance arrangements. This provides evidence of cohesive and isolated communication among fishers of associations. The higher number of average ties per fisher in two of the three associations (i.e., P1 and P3), when compared to independent fishers, indicate how some formal self-governance arrangements, structured around common rules and a leader, promote more cooperative communication, especially among themselves, than those fishers who have chosen informal and independent ways of organizing their fishing. These results confirm the importance of formally cooperative arrangements (e.g., cooperatives and associations) in promoting social capital and encouraging pro-sociality among fishers (Gutiérrez et al., 2011; Basurto et al., 2013a; Alexander et al., 2018). This is notable because, in contrast to cooperatives, fishers belonging to associations in Puerto Rico remain petty commodity producers with individual ownership over the means of production (Valdés-Pizzini, 1990), and arguably operate through less collectivist rules. Yet even

these associations provide bonding social capital to their members. With this result, the first research question was answered, confirming the expectation that associated fishers are more likely to exhibit bonding social capital when sharing information with other fishers, in comparison to independent fishers.

At the same time, this model also found how associated fishers were almost two times less likely to receive information from any fisher when compared to independent fishers, perhaps because independent fishers needed to source information from other fishers while those in associations could receive information from their leaders and other association partners. While this could be interpreted as associated fishers receiving less cooperation, it may also be because they require fewer information sources because of the coordination the associations provide. This is in line with previous observations noting how independent fishers bear a higher cost when sourcing information, in comparison to those collectively organized in cooperatives (Evans & Weninger, 2014).

Combined, these insights may be leveraged by fishing managers and scholars to design targeted communication for each group of fishers, such as the dissemination of regulations or announcements about participatory management opportunities. Specifically, they show that if managers just target associations, information is likely to stay within and not reach other fishing groups. This in turn would reduce the diversity of stakeholders in decision-making, and dimmish the efficiency of fisheries governance (Zetina-Rejón et al., 2020). Indeed, fishers' self-governance arrangement has been linked to their level of participation in formal governance (Nenadovic & Epstein, 2016). In other words, independent fishers may be key to bridging groups of fishers that choose opposite self-governance arrangements and therefore are information diffusers. Since associated fishers in PR are known to be sampled more in research studies than independent fishers (Partelow et al., 2020), this also points toward scholars' need to actively account for the representation of independent fishers in future studies. At the same time, not reaching out to associations may also leave them uninformed.

4.1.3 Knowledge-based communities

Knowledge-based communities built from fisher's use of different gear types also explained the communication network among fishers. These gear-based communications were characterized by the sharing of information on fishing territories. Previously, these gear strategies have been posited as the basis for "opposition to, or cooperation with, fishery management" (Griffith et al., 2007, p. x). Thus, homophily of gear and membership in associations may be useful proxies for niche knowledge of fishing practices and political tendencies which inform on internal conflicts and conflicts with fishery managers.

Similar to previous research (Crona & Bodin, 2006; Cox et al., 2016), sharing a gear type facilitated communication among Puerto Rican small-scale fishers. However, this was not true for all types of gears, as has been noted for Jamaican SSFs (Alexander et al., 2018). The estimated effect sizes for gear homophily were generally smaller than by homophily by association, although fishers using mechanized deep-water hook and line were an exception. Fishers whose main gear type was either mechanized deep-water hook and line or fish traps were the more likely to share information. This was congruent with qualitative interviews where these fishers (who target deep-water snappers) tended to share *via* radio and cell phone the environmental characteristics of their fishing grounds to improve each other's chance of success. Meanwhile, SCUBA divers had significant homophily, despite being known to also practice other fishing strategies (notably handlines) and despite requiring low capital investment, which facilitates entry into gear type (Agar & Shivlani, 2016). Yet homophily for SCUBA fishers may be explained by their tendency to be from a lower socioeconomic class (Griffith et al., 2007). Fishers that primarily used traps also had significant homophily, perhaps because they had a common need to source materials and watch out for fishers who steal and vandalize traps. Trappers expressed how the risk of theft solidified sharing information on where they set their traps so that trusted colleagues could monitor them. Overall, conflicts and specialized environmental knowledge seem to drive the homophily of communication among gear types. Significant homophily among fish trappers was also found in Jamaica (Alexander et al., 2018). In contrast, handline fishers in Puerto Rico did not share significant homophily, as was the case in Jamaica. Therefore, this tendency of handliners in Puerto Rico to share information with more gear types suggests their higher tendency of adopting new knowledge. Gear homophily was not significant for handlines, which fits with how this gear was rarely a fisher's only fishing strategy, since handline strategies are limited to certain moon phases or seasons and sometimes target second-rate fish (Griffith & Valdés-Pizzini, 2002). The rest of the time, handliners tend to switch to other gear, such as spearfishing, and thus contributed to a tendency to connect with fishers who used other gear types. While gear-based homophily has advantages in building specialized knowledge, it may impede the dissemination of knowledge relevant to viable livelihoods and collective arrangements (Crona & Bodin, 2006). In this case, only handliners and those who use gillnets may be significant bridges of the knowledge necessary for fishers to diversify their catch portfolio and better adapt to social and environmental change (Alexander et al., 2020; Robinson et al., 2020).

4.1.4 Place-based communities

Fishing communities based on the geographic proximity of landing sites are known to foster a sense of place and social

cohesion because these are places that facilitate repeated interactions among fishers (Brown, 2015; Alexander et al., 2018). Place-based communities have become less common as modernity facilitates communities made up of fishers who work together but live dispersed over several towns (Griffith et al., 2007). While we found evidence for the significant role of the landing site in driving the formation of information-sharing ties among commercial fishers, this mechanism was more enhanced for some sites compared to others. Despite the absence of an association, fishers on the small island of Culebra exhibited more cohesion than those operating in the other landing sites, which reflects how small groups are more likely to form ties than larger groups. Residents of Culebra are known for working within their close community ties to address perceived environmental challenges (Cubero, 2017; Pérez-Ramos et al., 2020).

Nevertheless, conflict and cooperation are social processes that occur simultaneously among actors embedded in environmental governance, including resource users in SSFs (Basurto et al., 2016; Bodin et al., 2020). In this sense, geographic proximity has been hypothesized as a driver of community fragmentation as fishers avoid establishing ties with each other due to direct competition over nearby marine resources (Alexander et al., 2018). These results revealed the presence of inter and intra-landing site conflicts, with each landing site being influenced by its unique trajectory. Maternillo has a history of associations successful at advocating for fisher's interests and promoting environmental conservation (Del Pozo, 2012; Del Pozo, 2019). Yet hurricane María impacted the association's infrastructure. Soon after the leader passed away and the fish shop closed (Cruz-Torres et al., 2019). A new leader re-organized several, but not all, of the fishers into Association P3, and thus conflicts between the new management and independent fishers contributed to the fragmented communication of fishers in this landing site. Meanwhile, Las Croabas had a functioning infrastructure that attracted independent fishers from other landing sites whose docks and ramps were damaged by the hurricane. This contributed to few communication ties between the visiting and resident fishers at Las Croabas. Shifting landing sites was one of the most frequent post-hurricane adaptation strategies by commercial fishers (Agar et al., 2020). The fragmentation among fishers operating in Maternillo and Las Croabas, respectively, exemplifies how at certain landing sites, targeting self-governance or gear-based communities may be more effective when supporting local institutions.

However, the positive parameters for landing site homophily suggest social closeness outweighs these conflicts, especially in Húcares. Fishers from Húcares descend from tight-knit families passing on traditional seafaring skills, which influences their tendency for place-based community cohesion (Griffith et al., 2007). Our results show how this cohesion endures, despite the landing site having four fish shops. While one of these shops is managed by Association P1, the others are businesses that buy from fishers without formal benefits.

At the same time, landing site homophily could be indicative of inter-landing site conflicts, which may be a barrier to regional collective action (Alexander et al., 2015; Alexander et al., 2018). Nevertheless, fishers from the mainland sites often fish around and refuel in Culebra's waters, which linked communication from the most remote site to those in bigger markets. The presence of the region's only no-take marine protected area in Culebra, which is co-managed by a community board and PR's Department of Environmental and Natural Resources, may assist in regional cohesion among commercial fishers. While Culebra's lack of a fishing association may hamper the building of cooperative ties across landing sites (Gutiérrez et al., 2011), the communication between fishing organizations in other small-scale fisheries is also fragmented due to geographic distance (Adán et al., 2020), suggesting place-based interactions are still key to sustain cooperation.

4.1.5 Social cohesion

Social cohesion in the form of triadic closure has been highlighted as important for Caribbean artisanal fisheries (Alexander et al., 2018). This study advances the understanding of this phenomenon by testing to what extent self-governance arrangements drive this under the presence of other mediating social factors. The incorporation of triadic closure resulted in the best-fitting model of the information-sharing network. This phenomenon was indicative of social cohesion and bonding social capital (Burt, 2005; Alexander et al., 2018). Note how gillnet fishers did exhibit significant gear homophily once the triadic closure term was added, indicating transitivity might be a social mechanism that drives communication homophily for these net fishers. However, the significance and direction of other terms did not change when accounting for this phenomenon, confirming that the effects for institutional arrangements remain valid, even when taking into consideration the rest of the fitted factors. This evidenced how most fishers in the network, regardless of their self-governance arrangement, relied on shared communication partners to sustain their fishing enterprises. Despite independent fishers not sharing significant homophily, this suggests that in addition to the tightly knit associated fishers, at least some independent fishers exhibit cohesive communication with other fishers. This informal cooperation can facilitate their inclusion into associations or the formation of new collective arrangements (Basurto et al., 2020).

However, another outcome of these high levels of bonding social capital among fragmented networks such as this one, especially among independent fishers, is that they still include isolated clusters (such as those in Culebra), from which groups with competing interests may form (Bodin & Crona, 2009). This friction can lead to transaction costs when trying to foment new governance modes, such as co-management (Alexander et al., 2018; Rivera et al., 2021). In small communities such as Culebra, reciprocal altruism and other prosocial norms can survive better

than in larger communities (Dixit & Levin, 2017), yet the presence of other relatively small gear-based communities, may help sustain those social norms.

4.2 Differences in linking social capital

The formal and informal ways fishers organized were related to the quantity and type of linking social capital they leveraged from institutional actors across the supply chain. Most of these actors were their buyers and focused on the trade-offs of selling to fishing associations. Independent fishers mainly explained their arrangement in opposition to the problems of associations, not the benefits they received from being independent. This included procedural problems in rule-making for associations, and not necessarily opposition to pro-social interactions per se. The reasons were a mix of economic and social trade-offs, answering the third research question. These reasons contextualized how fishers perceived the social cohesion of their own or other fishers' chosen self-governance arrangements. For example, independent arrangements were perceived as requiring more time investment in relationships with several buyers, because of their need to find demand for their fresh catch, and the responsibility to distribute it. Meanwhile, associated fishers had the benefit of knowing their association's fish shop would buy their catch and (if the agreement existed in their association) spare them the effort of cleaning the fish. While independent fishers interviewed cited the advantages of patron-client relationships and improved prices (23.8% and 33.3%, respectively), a sizable portion (52.4%) of their reasoning was in juxta-positioning of the downsides of being associated. This has been noted in the past and highlights that being an independent fisher was not the default arrangement, but rather an alternative to associations (Valdés-Pizzini, 1990).

The management of fishing associations is highly variable across Puerto Rico (Griffith et al., 2007; Partelow et al., 2020). Therefore, studying several associations with different leadership contexts allowed for a more nuanced understanding of their benefits and drawbacks. The formal arrangement of Association P1 and the informal patron-client arrangement of restaurant R5 were voiced by fishers as highly beneficial. These cooperative relationships can be attributed to the actor's social norms. For example, the loyalty of fishers to buyers influences the success of self-governance arrangements that financial interventions cannot overcome (Schlüter et al., 2021). This is critical for associations, which depend on a self-reinforcing loop such that loyalty leads to less cheating (Schlüter et al., 2021), but it is also important in patron-client relationships (Lindkvist et al., 2017; Basurto et al., 2020). Reputation, which is built on credibility and trust, is also known to be critical in building social capital in buyer-seller relationships across the supply chains of SSFs (Pedroza-Gutiérrez & Hernández, 2017). We found evidence in the role of loyalty and trust in leaders who used to be commercial fishers before becoming fish buyers and consequently maintained close ties with numerous fishers. Restaurant R5 was not just a buyer, but a patron of fishers, who provided loans and access to stable markets, but only to loyal fishers. Similarly, members of P1 referenced their perceptions of fair rules and reputation of their leader as one of the main reasons for being associated. In contrast, other landing sites had leaders too but were not as trusted. Association P3 in Maternillo illustrates a less functional arrangement. Some members were concerned over a lack of experience by the leader in Association P3.Yet, P3 members also reiterated their support because it amplified their voices, and assisted in license renewal and other paperwork. This situation may explain how Association P3 had the second lowest likelihood in sharing information among themselves.

These results confirm how leadership is a key factor in shaping desirable outcomes for SSFs (Gutiérrez et al., 2011; Crona et al., 2017; Alexander et al., 2018). Specifically, it highlights the role of trust in leaders, which is known to be a crucial factor in determining the success of formal organizational arrangements among fishers (Griffith & Valdés-Pizzini, 2002; Basurto et al., 2013a; Lindkvist et al., 2017). In Puerto Rico, the success of associations is influenced by the capacity of its leaders to harness rhetoric that can lobby fisher's interests, while remaining neutral to political parties to mitigate conflicts (Valdés-Pizzini, 1990; Pérez, 2005). The benefits of associations extended to non-members too. Some associations also bought from or assisted with the paperwork of independent fishers. Conversely, independent fishers are known to support associations when posed with an external threat to their livelihoods (Valdés-Pizzini, 1990).

Meanwhile, repeated social support from other actors in the supply chain allows formal arrangements to survive despite having less reliability in their fishers than would have been needed without the social support (Schlüter et al., 2021). As in other fisheries in the Latin American and Caribbean (LAC) region (Schlüter et al., 2021), cooperative fishing arrangements in PR have been incentivized by NGOs easing up-front costs (i.e., time, financial and emotional costs of agreement on rules) for collective action, and often act as bridges between external funders and fishers. The viability of fisher's operations in this study was supported through the legitimization and support from partnerships with NGOs. This was evident in Húcares, where NGO3 had co-implemented conservation and fishery development projects with the fishers associated with P1, facilitating access to equipment, recovery aid, alternate sources of income, and information on fisheries policies. Indeed, NGOs act as effective information brokers between resource users and agencies in marine conservation across the Caribbean, including Puerto Rico (Smythe et al., 2019; Turner et al., 2020). However, other actors, such as those that provide access to numerous buyers, are critical for the viability of independent fishers. These

unorganized fishers required supporters for services usually provided by associations, such as providing access to bait, buying second-rate catch, and assisting with paperwork. Together, this provided evidence that linking social capital was higher among independent commercial fishers, thus answering the second research question.

5 Conclusion

The viability of commercial fishing in the fishing communities of north-eastern Puerto Rico, whether through associations or independent strategies, is reliant on cooperative ties. Bonding social capital driven by sharing landing sites, primary gear types, and formally cooperative self-governance arrangements (e.g., fishing associations) significantly explained patterns in social cohesion. Fishers that were members of fishing associations mostly communicated among themselves, while independent fishers talked across arrangements. Associated fishers received information from fewer partners than independent fishers. Together, these communication patterns suggest how information dissemination strategies from managers, researchers, or other fishers need to account for these distinct social groups. Meanwhile, independent fishers had more quantity of ties and diverse actors to support pre-harvest and post-harvest operations when compared to associated fishers, suggesting independent's need for higher levels of linking social capital. Multiple social factors explained whether fishers choose to be members of fishing associations or remain independent, including trust in leaders and agreement on membership rules. These findings contribute evidence on the cooperative outcomes of informal institutions in small-scale fisheries and how these may support collective action. Understanding the social relationships that hold SSF actors together could be leveraged to better disseminate information to resource users, and to design fisheries policies that consider community diversity.

Data availability statement

The datasets generated and analyzed for this study can be found in the Github repository: https://github.com/NicoGomezAndujar/Social_Cohesion_Small-scale_Fisheries-Puerto-Rico.

Ethics statement

The studies involving human participants were reviewed and approved by Human Research Protection Program and Institutional Review Board of Oregon State University. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

NG-A conducted the research sampling, analyzed the data, and wrote the manuscript. DG, FC, and JW contributed to the methodological design and wrote the manuscript. DG and JW contributed to the quantitative analysis. DG and FC contributed to the qualitative analysis. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2022.966309/full#supplementary-material

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