Archetypical structures of social-ecological transformation and environmental governance in the Ciénaga Grande de Santa Marta (Colombia)

Three insights on social-ecological identity

Sebastián Restrepo Calle

Doctoral Thesis in Environmental and Rural Studies

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A la memoria de mi padres Alba Lucía Calle y Jaime Restrepo que dieron todo y más por nuestra educación y bienestar

A mi familia que es todo

A Julita y Tote que son mi motor en la vida

A las comunidades locales de la Ciénaga Grande que no dejan de enseñarnos qué se adaptan y transforman para seguir siendo resilientes

Best Gains -- must have the Losses' Test --
To constitute them -- Gains –

Las mejores ganancias
deben sufrir la prueba de la pérdida
para hacerse ganancias

Emily Dickinson

We need to interpret interpretations more than to interpret things

Necesitamos interpretar las interpretaciones más que intepretar las cosas

Michel de Montaigne

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Abstract

We live in a time of extraordinary social-ecological transformations, where it is more evident than ever that our chances to deal with change are seriously limited by our capacity to understand it. The social-ecological transformations we currently face entail an uncertainty associated with feedback cycles between causes and effects and how policies and management actions intervene in reality. This uncertainty poses limitations to navigate environmental management and sustainability challenges, making the misfit between social and ecological systems more evident. Even though governance is starting to recognize the dynamic, multi-level nature of social-ecological systems (SES), as well as the need to manage their changes in an adaptative, sustainable way, its impact to mitigate the consequences of unexpected, unpredictable changes, or adapt to new environmental conditions, is still limited. The identity of a system is a subjective, non-arbitrary concept which is defined by the nature of its components, the interaction among them, and the maintenance of their temporal and spatial continuity. This dissertation outlines three *insights* on social-ecological identity, deepening the definition of archetypes structures of transformation and governance in a strongly degraded coastal lagoon in the Neotropics: The Ciénaga Grande de Santa Marta -CGSM (Colombia). First, I defined the archetype structures of social-ecological transformation of the CGSM over the last four decades, revealing continous structural patterns between drivers of change, socia-ecological changes, and ecosystem services. Then, I explored the structural patterns of the governance network formed by state and non-state actors that explain the social-ecological system's interactions, change trajectories, and transformations. Finally, I studied the social mechanisms explaining collective action at the local level in a social-ecological system, centering on the interaction patterns between small-scale fisheries co-ops in the CGSM. The three *insights* on the identity of the CGSM made sense when I saw them together as lines of evidence explaining the social-ecological transformation process of this Neotropical coastal lagoon: the governance network patterns that describe conflict and cooperation interactions at different levels are strongly linked with the structures that explain the historical social-ecological transformation of CGSM. The results of this dissertation delivered relevant understandings to inform more adaptive governance proposals in the CGSM.

Resumen

Vivimos un tiempo de transformaciones socioecológicas extraordinarias, en el que es más evidente que siempre que nuestros chances para lidiar con el cambio están seriamente limitados por nuestra capacidad para entenderlo. Las transformaciones socioecológicas que actualmente enfrentamos implican una incertidumbre asociada con los ciclos de retroalimentación entre sus causas y efectos, y en cómo las políticas y acciones de manejo intervienen en la realidad. Esta incertidumbre impone limitaciones para nevegar el manejo ambiental y los retos de la sostenibilidad, haciendo eviente el desajuste entre sistemas sociales y ecológicos acoplados. A pesar de que la gobernanza ha empezado a reconocer la naturaleza dinámica y multi-nivel de los sistemas socioecológicos, así como la necesidad de manejarlos de una forma sostenible y adaptativa, su impacto para mitigar las consequenicas de cambios inesperados e impredecibles, o de adaptarse a nuevas condiciones ambientales, es todavía limitado. La identidad de un sistema es un concepto subjetivo pero no arbitrario que se define por la naturaleza de sus componentes, las relaciones entre estos y el mantenimiento de su continuidad temporal y espacial. Esta disertación esboza tres miradas sobre la identidad socioecológica, profundizando en la definición de estructuras arquetípicas de transformación y gobernanza en una laguna costera fuertemente degradada en el Neotrópico: la Ciénaga Grande de Santa Marta -CGSM (Colombia). Primero definí las estructuras arquetípicas de la transformación socioecológica de la CGSM a través de las últimas cuatro década, revelando patrones estructurales continuos entre impulsores de cambio, cambios socioecológicos y servicios ecosistémicos. Luego, exploré los patrones estructurales de redes de gobernanza formadas por actores estatales y no estatales, las cuales explican las interacciones del sistema socioecológico, el cambio en sus trayectorias y transformaciones. Finalmente, estudié los mecanismos que explican la accion colectiva a nivel local en el sistema socioecológico, enfocándome en los patrones de interacción entre cooperativas de pesquerías artesanales en la CGSM. Las tres miradas sobre la identidad de la CGSM hicieron sentido cuando juntas definen lineas de evidencia que explican el proceso de transformación socioecológica de esta laguna costera Neotropical: los patrones de las redes de gobernanza que describen conflicto y cooperación a diferente escalas están fuertemente articulados con las estructuras que explican la transformación histórica de la CGSM. Los resultados de esta disertación entregarón entendimentos importantes para informar propuestas de gobernanza más adaptativas en la CGSM.

List of contributions

Original manuscripts

Paper 1. **Restrepo, S.**, Rey, D., Castillo, D. & C. Ortiz-Guerreo. Dot to dot: unravelling archetypical patterns of social-ecological transformation in a Neotropical Coastal Lagoon through press releases. (2022). To submit to Ecology and Society.

Paper 2. **Restrepo, S**., Ortiz-Guerrero, C., Castillo, D. & S. Vilardy. (2022). Conflict and cooperation within a Neotropical coastal lagoon governance network: Is there self-organization potential to prompt collaborative governance? To submit to Ocean and Coastal Management.

Paper 3. **Restrepo, S.**, Vargas, A., Ortiz-Guerero, C. & D. Castillo. (2022). Behind cooperation networks in Small-Scale Fisheries: Structural patterns and social tie formation in a Colombian Coastal Lagoon. To submit to International Journal of the Commons.

Other related contributions

Rivillas-Ospina, G., Maza-Chamorro, M. A., **Restrepo, S**., Lithgow, D., Silva, R., Sisa, A., ... & Rudas, D. (2020). Alternatives for recovering the ecosystem services and resilience of the Salamanca Island Natural Park, Colombia. Water, 12(5), 1513.

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Restrepo, S., Ortiz-Guerrero, C. & D. Castillo. (2019). Behind cooperation networks in Small-Scale Fisheries: Structural patterns and social tie formation in a Colombian Coastal Lagoon. XVII Biennal IASC Conference 'In Defense of the Commons: Challenges, Innovation, and Action'. Lima (Perú). July 1st-5th.

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Introduction

We live in a time of extraordinary social-ecological transformations, where it is more evident than ever that our chances to deal with change are seriously limited by our capacity to understand it. The human population has tripled in the last 60 years, favoring a fast growth of the economy and material consumption (Steffen et al. 2007, 2011), which derives into unprecedented ecological changes in terms of scale, rate, and intensity (Ellis 2015). As a result, more than three-quarters of the earth's land surface has been transformed in areas of human use (Foley et al. 2003, McGill et al. 2015, Seddon et al. 2016), driving abrupt changes in ecosystem patterns and processes, with unquestionable implications for biodiversity and human wellbeing (Millennium Ecosystem Assessment 2005, Nelson 2005, Rockström et al. 2009, Biermann et al. 2012, Steffen et al. 2015). Paradoxically, despite increasing knowledge on ecosystem change patterns and trends and their implications for society, limitations persist to effectively integrate such changes in environmental governance (Folke et al. 2005, Newig and Fritsch 2009, Abson et al. 2017).

The social-ecological transformations we currently face entail an uncertainty associated with feedback cycles between causes and effects and how policies and management actions intervene in reality (Biermann et al. 2012). This uncertainty poses limitations to navigate environmental management and sustainability challenges (Knight 2015), making the misfit between social and ecological systems more evident (Young 2002, Folke et al. 2007, Galaz et al. 2008a, 2008b, Epstein et al. 2015). Even though governance is starting to recognize the dynamic, multi-level nature of social-ecological systems (SES) (Armitage et al. 2009, Brondizio et al. 2009, Schultz et al. 2015), as well as the need to manage their changes in an adaptative, sustainable way (Dietz et al. 2003, Folke et al. 2004, 2005, Lebel et al. 2006, Carpenter et al. 2009), its impact to mitigate the consequences of unexpected, unpredictable changes, or adapt to new environmental conditions, is still limited (Olsson et al. 2004, 2006, Schultz et al. 2015, Chaffin et al. 2016). Failures of governance to deal with change have shown to increase SES vulnerability (i. e., decreasing their resilience), but they also evidence how policy resistance negatively impacts processes of transition towards sustainability (de Gooyert et al. 2016).

The dynamics of social-ecological systems as complex adaptive systems involve diverse ways to respond to change and disturbance (Levin et al. 2013), and it is often challenging to establish differences between endogenous and exogenous dynamics (Cumming 2014). Nevertheless, evidence suggests that critical transitions or regime shifts are becoming more common in the context of current transformations (Rocha et al., 2015, 2018). Regime shifts can be understood as substantial rearrangements in social-ecological structure, function, and feedback cycles (Scheffer et al. 2001, Scheffer and Carpenter 2003, Walker et al. 2004), which may be driven by a cumulative change in slow system variables, external disturbance, or stochastic shocks (Rocha 2015). Regime shifts are challenging for governance as they cannot be easily predicted or reverted (Crépin et al. 2012, Rocha et al. 2015), suggesting that management actions should be aimed to increase system resilience, decreasing the risk for these shifts to happen, and at the same time building adaptive capacity (Crépin et al. 2012). The chances to anticipate regime shifts depend on the knowledge of the social-economic system and its function and system's responses to both disturbances and management actions. In contexts where systems face continuous, accelerated shifts, this task would involve differentiating which factors remain constant (Cumming and Collier 2005), understanding system trajectories, adjusting different management measures, or even managing collapses (Cumming and Peterson 2017).

Although regime shifts and critical transitions have been studied in a wide variety of ecosystems, marine and coastal ecosystems are perhaps one of the most threatened globally but also those with the best evidence on co-occurrence patterns between different types of drivers, regime shifts, and their implications for key ecosystem services (Möllmann et al., 2015; Rocha et al., 2014; Yletyinen et al., 2016). Among these ecosystems, coastal lagoons are remarkable for being highly dynamic and productive ecosystems, and at the same time facing frequent environmental disturbances and fluctuations (Kjerfve 1994), which in turn reflect the interactions and dependencies between social and ecological systems (Nayak and Armitage 2018). Coastal lagoons face rapid transformations driven by aspects such as land claim, agriculture, urbanization, and overfishing (Millennium Ecosystem Assessment 2005), and also by phenomena such as climate change, sea-level rise, local subsidence, sediment flux change, and ocean acidification (Liu et al. 2018). It raises concern that the global extent of coastal wetlands does not surpass the 10% of existing wetland areas

globally (Davidson and Finlayson 2018, 2019). In addition, coastal wetlands have lost more than 60% of their areal extent during the twentieth century, raising further concern (Davidson 2014). Endogenous and exogenous dynamics in coastal lagoons, together with the strong transformation processes they face, particularly in the Neotropical region (Esteves et al. 2008), illustrate the evident need for reference points that allow interpretations of their changes and effectively adapt their governance.

Social-ecological identity is a subjective, non-arbitrary concept defined according to the properties in which the researcher is interested (Cumming and Collier 2005, Cumming and Peterson 2017). However, the idea is helpful to understand what remains constant within a continuously transforming system. The identity of a social-ecological system is defined by the nature of its components, the interaction among them, and the maintenance of their temporal and spatial continuity (Cumming and Collier 2005). Even though it is well known that adaptive governance needs to distinguish the identity of a social-ecological system to influence its resilience positively (e.g., Folke, 2016; Folke et al., 2010), few studies have dealt with this concept practically. This dissertation outlines three *insights* on social-ecological identity, deepening the definition of archetypes structures of transformation and governance in a strongly degraded coastal lagoon in the Neotropics: Ciénaga Grande de Santa Marta -CGSM (Colombia). In this document, I present the theoretical focus, provide an outline of this work, and lastly, the conclusions of my research. Afterward, an appendix is given with the three research papers derived from this work, together with their respective supplementary materials.

Theory: An archetypical approach to deal with identity and change in SSE

The identity of a social-ecological system is a property associated with the maintenance of its key components, the relationships between them (networks), and their continuity through time and space (Cumming et al., 2005; Cumming & Collier, 2005). In highly dynamic contexts, identity is a reference point that allows to assess change in a complex system and address the study of its resilience empirically. Resilience is understood as the ability of a system to maintain its key components and relationships as it faces internal changes, as well as external shocks and disturbances (Cumming et al., 2005). Identity is a

problematic concept due to its subjectivity (Cumming & Peterson, 2017). However, its definition is far from being whimsical. It is constructed based on systems previously defined by an observer who has built a domain, setting limits from which reality is interpreted. In practical terms, identity may be understood through: (a) elements that define the system, such as objects, species, or people, (b) relationships that imply interactions and processes in which the components are constantly tied, (c) continuity sources interpreted as those factors (mechanisms) maintaining the resilience and identity of the system, and (d) innovation sources that may be endogenous or exogenous factors that introduce novelty to the system and may condition its response-ability in the face of change (Cumming et al., 2005). In agreement with Andrachuk & Armitage (2015), understanding identity is essential to assess if the system has crossed its threshold and understand the magnitude of its changes. Under this point of view, the concept of identity becomes relevant to study the trajectory changes in its transitions and assess its social-ecological transformations. In short, identity allows understanding the structural and functional change level beyond which one given system has transformed into another.

In the identity of a social-ecological system, the tension between its transformation and persistence becomes clear. This tension is particularly evident in the change of local patterns of interaction between critical components, explaining the resilience and adaptive capacity of the system through time (Andrachuk & Armitage, 2015). These dynamics of change affect ecological and social domains in those systems and influence interdependencies such as those existing between governance systems and ecosystem dynamics (Dietz et al., 2003; Folke, 2007; Folke et al., 2005, 2010). In this way, these interdependencies evidence a fit problem relative to how governance system characteristics align with the processes of ecosystems (Brondizio et al., 2009; Cox, 2012; Folke et al., 2007; Galaz et al., 2008). These fit problems affect the effectiveness of management decisions (Treml et al., 2015) and, in the long term, transform resilience as an essential quality of social-ecological systems, which may favor or condition its ability to adapt and transform (Anderies et al., 2006; Andrachuk & Armitage, 2015; Scheffer & Westley, 2007; Walker et al., 2004).

The fit problems between governance systems and ecosystems are associated both to the spatial and temporal scales of management (Cumming et al., 2006) and to the lack of knowledge on the thresholds of the social-ecological system, as well as its possible cascade effects (Rocha et al., 2018). Several authors have addressed the problem of fit (e.g., Epstein et al. 2015), mainly from a spatial and temporal point of view (e.g., Bergsten et al. 2014), or in terms of the connectivity between governance system and ecosystem attributes (e.g., Guerrero et al. 2015 or Pittman & Armitage 2017). However, few studies have referred to how these decouplings explain drastic changes in the social-ecological system, particularly in the case of changes that affect interaction patterns that define system identity. In this context, attention must be given to those governance structures that relate to actors with a direct or indirect effect on the ecosystem, institutions, and the behavior of other actors, operating at and between different levels and scales (Basurto et al., 2013; Basurto & Coleman, 2010; Cash et al., 2006; Kininmonth et al., 2015). The study of such governance structures poses a knowledge challenge relevant for understanding how multilevel dynamics influence the effectiveness of ecosystem resource management (Armitage, 2007; Newig & Fritsch, 2009; Ostrom et al., 2007).

The changes in social-ecological systems result from structure and function rearrangement of the system (Folke et al., 2004; Scheffer et al., 2009); that is, they are a product of interaction patterns and processes of interaction between its components. Even though not all changes experienced by a social-ecological system imply severe transformations, in some cases, cumulative and historical reinforcement processes in slow system variables may cause critical transitions or critical regime shifts (Folke et al., 2004; Rocha et al., 2015, 2018; Scheffer et al., 2001; Scheffer & Carpenter, 2003). According to Lade et al. (2013), even those non-linear interactions between social and ecological subsystems, which are not regime shifts themselves, may lead to regime shifts in coupled social and ecological systems. Scheffer et al. (2012) suggest that in systems and networks with many components, those regime shifts may associate with particular aspects of their structure, which may be detected to anticipate such shifts. Consequently, the concept of regime shift may apply to social-ecological systems (Filatova et al., 2016), in which complex interactions associated with their structure and feedback mechanisms may favor the

transition from a stable regime to an alternate one (Kinzig et al., 2006; Sugiarto et al., 2015).

In this dissertation, we understand that social-ecological transformation depends essentially on social interaction processes that institutions mediate (Feiock, 2013; Koontz et al., 2015; Lubell, 2013; Ostrom, 2005) and configure governance regimes (Bennett & Satterfield, 2018; Berkes, 2017; Cox et al., 2016; Folke et al., 2005; Lebel et al., 2006; Lemos & Agrawal, 2006). The mechanisms explaining these social interaction patterns, and in turn those with ecological systems, emerge according to how social actors build decisions in the face of social dilemmas; that is, situations in which there is an evident interdependence between individuals facing choices in which maximizing self-benefit in the short term results in leaving other participants in conditions worse than in the initial alternative (Ostrom, 1998). Under this perspective, potential decisions taken by actors within a social dilemma are strongly influenced by their social capital, which implies considering those variables that mediate social interactions and explain collective benefits (Ostrom, 1995). In the practice of overcoming social dilemmas through collective action, this social capital may take concrete forms related to trust and reciprocity rules, networks, and other forms of social participation such as institutions (formal and informal rules) (Ahn & Ostrom, 2002).

Social capital, together with a set of explanatory variables regarding relationships of reciprocity, trust, and reputation between actors, explain diverging results in terms of cooperation and social benefits within a social dilemma (Ahn et al., 2004; Ahn & Ostrom, 2002; Ostrom, 2000). Nevertheless, results are not always beneficial. Conflict is likely when the causal relationship between collective action variables has positive feedback based on low social capital (Ostrom, 1995, 1998). Collective action dynamics lie at the heart of governance, understood as the ways and means by which society takes collective decisions through regulation processes, mechanisms, and organization dynamics between state and non-state actors (Duit & Galaz, 2008; Lemos & Agrawal, 2006; Nyborg et al., 2016; Rapp, 2020). As a result, governance is configured based on historical processes through which social actors interact at different levels and scales, generating changes in the state of social-ecological systems (Biermann et al., 2012; Schultz et al., 2015; Voß & Bornemann, 2011). In this way, governance structures and processes are related to the

identity and change of a social-ecological system: the chances for a system to transit between different states, even to the point of total transformation (Chaffin et al., 2016), is given by social capital and characteristic forms of interaction between social actors in social dilemmas and multifaceted action situations.

Interaction dynamics between people and ecosystems configure complex social-ecological interdependencies that may be understood through relational or network approaches (Bodin et al., 2019). Seen as constructs, networks are theoretically based on the assumption that causes, effects, or associations between aspects can be conceptualized or modeled as interaction patterns through a process of representation and abstraction (Brandes et al., 2013). Network analytical perspectives, centered on analyzing patterns of interaction between social and ecological systems, their structure, processes, and results such as resilience (Janssen et al., 2006), have been influential in tying diverse fields of applied knowledge to the management of natural resources (Sayles et al., 2019). The regular use of these analytical approaches in social-ecological interaction has even derived in developing heuristics centered on the study of ecological and social connectivity and social-ecological adjustment (Bodin et al., 2014; Bodin et al., 2019; Bodin & Tengö, 2012). For example, suppose identity is defined from the continuity of key components and relationships of a system. In that case, it is susceptible to be addressed through a relational perspective in which characteristic, recurrent structures in the interactions within systems, either social or ecological, or their coupling processes.

Archetypes are generic structures and behaviors representing distinctive ties and characteristics of systems (Kok et al., 2016; Oberlack et al., 2019). Being recurring patterns in which minimal components (building blocks) are reiteratively appreciated (Eisenack et al., 2019; Lane, 2017), these may be considered as analysis units when studying the identity of a social-ecological system. Even though the perspective of archetype analysis has been growing in the last years, representing a significant contribution to addressing environmental problems with a social-ecological approach (Eisenack et al., 2019; Gotgelf et al., 2020; Hartel et al., 2018; Oberlack et al., 2019; J. Rocha et al., 2020; Sietz et al., 2019), still there are no knowledge voids where archetypes are explicitly addressed from a relational approach. This dissertation analyzes archetypes in social-ecological

transformation and environmental governance networks (archetypical structures). In the first case, archetypes result from understanding co-occurrence patterns between drivers of change, social-ecological changes, and ecosystem services affected through time. From a governance point of view, archetypes are associated with structural patterns and variables that explain the formation of social ties of cooperation and conflict. Our proposal considers both cases under the notion that those social-ecological transformations that determine a system's identity are tied to characteristic patterns in their governance structures.

Outline: Three *insights* on social-ecological identity

Our approach to the social-ecological identity of Ciénaga Grande de Santa Marta (CGSM) considered a relational perspective centered on identifying archetypical structures, that is, persistent, indicative patterns that represent both the process of social-ecological transformation and the characteristics of the governance acting on this system. Therefore, we built three insights, which allowed us to understand change dynamics in the CGSM by recognizing which elements can remain constant through time, providing a helpful narrative from the point of view of adaptive governance. In this dissertation, each insight is defined as an act of comprehension or a familiar event of understanding that happens readily and builds knowledge (Lonergan, 1957). Understanding social-ecological identity through archetypes was not an easy exercise in the analytic practice. However, it resulted in a fluent information assembling process centered on comprehending relationships through which meaning was found.

Insight 1: Social-economic transformations and identity

The analysis of social-ecological transformation was centered on reconstructing the history of social-economic changes of the CGSM through events reported in national and local press reports (paper 1). The intent of this paper was not to understand the change in a linear perspective from a well-preserved system to one that is degraded. Instead, this work aimed to determine persistent structures of the transformation process through four decades (1996 to 2020), which would inform us about what remains constant within a transformation process that has been accelerated. For this, we defined that social-ecological transformations implied recognizing the drivers of those changes reported by press reports,

identifying those social-ecological changes, and understanding the implications of such changes for ecosystem services key to the local well-being of different users of the CGSM. In addition, we use the database of regime shifts (Biggs et al., 2018), making clear that, due to the lack of reliability of the reported events, each finding was understood as a social-ecological change event and not as a regime change.

In this paper, we opted for a mixed methodological approach, in which we performed a content analysis on press news, searching for co-occurrence patterns between drivers, social-ecological changes, and ecosystem services, analyzed through four time periods (1986-1995; 1996-2005; 2006-2015; 2016-to present). These patterns were analyzed through network modeling techniques. First, we built a tripartite network between drivers, changes, and services. Then, we split it up into four one-mode networks for each moment: (a) drivers based on social-ecological changes, (b) social-ecological changes based on drivers, (c) Social-ecological changes based on ecosystem services, and (d) ecosystem services based on social-ecological changes with this, we tested hypotheses to compare the observed networks with randomly simulated networks, to verify if the observed patterns represented characteristic structures or were given by chance at each period. To understand network trajectories, we analyzed their changes in the network structure through each decade, comparing indexes focused on understanding how ties are created or lost within each period. Lastly, we made a compositional network analysis through the intersection of ensembles for nodes and ties within each network. In this way, we understood which structures of social-ecological transformation were persistent in the CGSM.

Insight 2: Conflict and cooperation patterns within a governance network

We analyzed multilevel and multi-layer governance structures associated with cooperation and conflict interactions in the assemblage of social actors that comprise the governance network of the CGSM (Paper 2). This paper aimed to understand the structural patterns of the governance network formed by state and non-state actors that explain the social-ecological system's interactions, change trajectories, and transformations. Our central assumption is that those patterns predicting the formation of social ties around conflict and cooperation persist in time and space and are directly related to the dynamics of collective

action and social capital that explain the history of transformation in the CGSM during the last 40 years. This understanding allows us to have better ideas on managing governance in a highly dynamic system where causes and consequences of change get mixed up over time. At the same time, the paper allows understanding if there is potential for self-organization that facilitates collaborative governance and improves adaptive abilities.

We also analyzed social networks, particularly combining a descriptive perspective and multi-layer exponential random graph models. The theoretical basis for exponential models was related to conflict and cooperation as driving forces in the construction of alliances within governance structures and with self-organization as a product of interaction between public and private actors under different power regimes. Thus, we tested two hypotheses with the model: (1) there are differences in assortative and relational mechanisms that form conflict and cooperation layers, acting on the potential to self-organization in the governance network, and (2) the governance network structure of the CGSM holds a pattern based on the multiplexity and reinforcement (restricted exchange) between conflict and cooperation ties that explain the governance network dynamics. In this way, the model analysis gives us network structures that, acting as interaction archetypes, represent the bases of the governance structure that explain social-ecological transformations of this ecosystem through time.

Insight 3: Collective action and cooperation mechanisms at the local level

We studied the social mechanisms explaining collective action at the local level in a social-ecological system, centering on the interaction patterns between small-scale fisheries co-ops in the CGSM (Paper 3). The essence of this article was to determine which factors explain cooperation between these co-ops. In particular, we inquired into how different drivers of the formation (observed interactions, co-op social attributes, and contextual factors) explain cooperation patterns at the local level. In terms of identity, this perspective is valuable as it allows us to understand, from the collective action, which structural patterns are characteristic of the interaction between fisher co-ops, and additionally how those factors are associated with social capital fluxes that may enhance social cohesion and coordination between different levels of a governance system in the CGSM.

We opted for building a nested exponential random graph model, which added layers of causal interaction on explanatory variables proposed in second-generation collective action theories (cooperation, trust, reciprocity, reputation) (Ostrom, 1998). We fed this model with data from a survey made on fisher co-ops in the CGSM, in which we characterized these organizations and their interactions with each other. In this way, we first made a descriptive exercise of network structure, both with network-based and node-based metrics. Then, in the nested model, we choose structural configurations associated with each explanatory variable of collective action and keep those related to co-op social attributes and context constant. Finally, we tested hypotheses to understand the structural configurations and the variables that better explained cooperation between fishers' co-ops.