Solutions for Inclusive Green Development
Soluciones para el Desarrollo Verde Inclusivo

2022

ACADEMIC MASTER'S THESIS

Applying the SES Framework to Coral Reef Restoration Projects on the Pacific Coast of Costa Rica

Nohelia José Palou Zúniga

TROPICAL AGRICULTURAL RESEARCH AND HIGHER EDUCATION CENTER

DIVISION OF EDUCATION

POSTGRADUATE PROGRAM

Applying the SES framework to coral reef restoration projects on the Pacific Coast of Costa Rica

Thesis submitted for consideration by the Division of Education and Postgraduate Program as a requirement to qualify for the degree of:

MAGISTER SCIENTIAE

in Economy, Development and Climate Change

Nohelia José Palou Zúniga

Turrialba, Costa Rica

2022

This Master's thesis has been accepted in its present form by the Division of Education and the Graduate School Program of CATIE and by the advisory committee of the student, considering that it fills the requirements necessary for the student to present the final defense as well as participate in the final exam

***MAGISTER SCIENTIAE* IN ECONOMY, DEVELOPMENT AND CLIMATE CHANGE**

SIGNATORIES:

Róger Madrigal, Ph.D.
Thesis director

Juan José Alvarado Barrientos, Ph.D.
Member of the Advisory Committee

Achim Schlüter, Ph.D.
Member of the Advisory Committee

Roberto Quiroz, Ph.D.
Dean of the Graduate School

Nohelia José Palou Zúniga
Candidate

Dedicatory

To my parents, José Guillermo and Juana Elia, for their love and unconditional support.

Acknowledgements

To Roger Madrigal, for the guidance and for motivating me throughout the process.

To Achim Schlüter, for the support, helpful insights on understanding Ostrom and for his great hospitality during the short-term research stay. Gracias a Cordula también!

To Juan José, for opening me the doors to coral reef restoration projects in Costa Rica and for his attention, kindness and support.

To all the people working in the projects and living in the communities for sharing their time and knowledge to make this research possible and making me more curious about the all the wonders in the sea and the different challenges faced in coastal marine communities.

To EDCC, Lixis and Bombones for all the support and unforgettable moments throughout these 18 months.

To Adiska, Ben, Connie, Debbie, Hudu, Khady and Wiebke at ZMT for your great reception and sharing your research experiences and your cultures with me.

To DAAD scholarship program, for providing me this valuable opportunity to live incredible experiences and improve my knowledge.

To my professors and colleagues at CATIE for all the discussions that allowed me to understand and be more curious about the environmental and social challenges and opportunities in Latin America.

INDEX

Tables Index

Figures Index

List of Acronyms

AMPR: Marine Area of Responsible Fishing

CIMAR: Centro de Investigación en Ciencias del Mar y Limnología

ETP: Eastern Tropical Pacific

ICT: Instituto Costarricense de Turismo

INA: Instituto Nacional de Aprendizaje

GIZ: German Corporation for International Cooperation

MINAE: Ministry of Environment and Energy

MPAs: Marine Protected Areas

PTGP: Polo Turístico Golfo de Papagayo

RCCR: Raising Coral Costa Rica

RNVS: Refugio Nacional de Vida Silvestre

SESF: Social-Ecological Systems Framework

SINAC: Sistema Nacional de Áreas de Conservación

UCR: University of Costa Rica

WHSs: World Heritage Sites

Abstract

Global and local stressors have led to rapid declines in coral reef health. The high rates of coral degradation have motivated restoration initiatives worldwide. Evaluation of these initiatives has provided valuable information regarding coral restoration techniques and limitations phased by projects. However, most of the literature is focused on evaluating metrics related to fragment survival rate and growth, leaving a gap in understanding how social aspects such as governance structure affect project outcomes.

The present paper applies the Social-Ecological Systems Framework to identify social and ecological factors contributing to the success of three coral reef restoration projects in Costa Rica. Data was gathered from 50 semi-structured interviews with project members, volunteers, tour operators, fishers, and related community and government organizations.

Despite each case's specific ecological and governance characteristics, research results show that three main steps have contributed to project success. First, the importance of locals having a positive perception of coral reef and project benefits; second, the use of network structure to obtain adequate financial and human resources and third, the importance of compliance with a regulatory framework to create enabling environments for reef restoration.

Results show there are no universal solutions for coral reef restoration projects. Project managers must understand the ecological and social context of the restoration site to boost the benefits that reef restoration projects can provide, such as an increase in local stewardship, income generation, and the creation of more resilient communities.

Keywords: Reef Restoration; Costa Rica; Social-Ecological Systems; Governance

Resumen

Acciones antropogénicas y naturales a nivel global y local han llevado a una rápida disminución de la salud de los arrecifes de coral. Las altas tasas de degradación de los corales han motivado iniciativas de restauración en todo el mundo. La evaluación de estas iniciativas ha brindado información valiosa sobre las técnicas de restauración de corales y las limitaciones de los proyectos. Sin embargo, la mayor parte de la literatura se centra en la evaluación de métricas relacionadas con la tasa de supervivencia y el crecimiento de fragmentos, lo que deja un vacío en la comprensión de cómo los aspectos sociales, como la gobernanza, afectan los resultados del proyecto.

El presente documento aplica el Marco de Sistemas Socio-Ecológico para identificar los factores sociales y ecológicos que contribuyen al éxito de tres proyectos de restauración de arrecifes de coral en Costa Rica. Los datos se recopilaron a partir de 50 entrevistas semiestructuradas con miembros del proyecto, voluntarios, operadores turísticos, pescadores y organizaciones comunitarias y gubernamentales relacionadas.

A pesar de las características ecológicas y de gobernanza específicas de cada caso, los resultados de la investigación muestran que tres puntos principales han contribuido al éxito del proyecto. Primero, la importancia de que los locales tengan una percepción positiva de los arrecifes de coral y los beneficios del proyecto; segundo, el uso de la estructura de la red para obtener recursos financieros y humanos adecuados y tercero, la importancia del cumplimiento de un marco regulatorio para crear entornos propicios para la restauración de arrecifes.

Los resultados muestran que no existen soluciones universales para los proyectos de restauración de arrecifes de coral. Los administradores de proyectos deben comprender el contexto ecológico y social del sitio de restauración para impulsar los beneficios que pueden brindar los proyectos de restauración de arrecifes, como un aumento en la administración local, la generación de ingresos y la creación de comunidades más resilientes.

Palabras clave: Restauración coralina; Costa Rica; Sistemas socio-ecológicos; Gobernanza

1. Introduction

Coral reefs cover 0.2% of the earth's surface; however, almost 50% of coral reef live coverage has been lost in the last 30 years (Burke et al., 2011; Souter et al., 2020). Loss of coral coverage decreases ecosystem services such as recreational use, tourism development, fish biomass production, coastal protection, and carbon sequestration, causing direct effects on the livelihood of people living near coastal zones (Moberg & Rönnbäck, 2003; Eddy et al., 2021).

The global decline in coral reef ecosystem services has motivated restoration initiatives worldwide (Edwards & Clark, 1999). Most of the coral reef restoration literature is focused on evaluating only the ecological aspects of projects (Bayraktarov et al., 2019). The most common indicators for project success are coral colony level metrics related to corals survival rate and growth (Hein et al., 2017), leaving a knowledge gap related to the understanding of the social and economic factors that impact restoration project's performance, such as the influence of livelihoods, governance, local capacity building, and community participation on project's efficiency and sustainability (Kittinger et al., 2012; Hein et al., 2017). France (2016) highlights that governance has seldom been discussed in the marine restoration literature and argues that this type of project should be evaluated based on a combination of ecological and social criteria that are proportionate to the local context where the project is inserted.

This study aims to contribute to the knowledge of coral reef restoration projects through a social-ecological perspective by applying the Social-Ecological System Framework to identify the main social and ecological factors contributing to the successful outcomes of three restoration projects on the Pacific coast of Costa Rica. The research analyzes the role of perception in increasing local participation, the enabling conditions that allow access to technical and financial capacity, and how compliance with the existing regulatory framework contributes to project success. Special emphasis is given to the influence of different governance structures on projects successful outcomes, by comparing projects led by an NGO, co-managed community and technical government institution and co-managed by local university and a tourism private developer.

Ecological restoration can be defined as the process of assisting in the recovery and management of the ecological integrity of an ecosystem (van Diggelen et al., 2001) following four fundamental principles: increasing ecological integrity, benefiting and involving society, long-term sustainability, the past should inform initiatives and the future (Suding et al., 2015). These principles can be used as pillars for evaluating project performance. Coral reef restoration initiatives started in the 1960s with artificial reefs when coral reef degradation became more visible, and laws for protecting marine habitats were introduced (Rinkevich, 1995). In the early 2000s, efforts started eradicating invasive species and outplants from nurseries (Goergen et al., 2020). In 2016, emphasis was given to increasing efficiency and scale using micro-fragmentation and larval propagation. During this last wave, efforts have been accompanied by the commercialization of initiatives for touristic purposes (Meyers, 2017). Evaluation of projects conducted in the previous 60 years has helped identify the importance of site selection, accessibility (Quigley et al., 2022), water quality, eradication or control of threats (Shaver et al., 2020), public support (Frey & Berkes, 2014), adequate human and financial resources (Wenger et al., 2017), effective governance (Cinner et al., 2012), and straightforward legal mandate (Christie & White, 2007) as factors to consider for effective restoration initiatives.

Project assessment has also helped identify limitations and how different initiatives have dealt with these limitations. For example, Hein et al. (2019) evaluated vital stakeholders´ perspectives of coral reef restoration efforts in four restoration projects in Thailand, Maldives, Florida Keys, and the US Virgin Islands. Their findings show most common limitations to restoration success are lack of technical capacity, no connection between the project and local actors, the scale of threats outweighs solutions, lack of partnerships, and lack of science behind efforts. Boström-Einarsson et al. (2020) reviewed 362 cases evaluating restoration knowledge related to methods, success, and failures. The primary limitations identified relate to poor project design, lack of experimental control, short temporal scale, and lack of appropriate and constant monitoring. Human and coral reef interactions positively and negatively impact coral reef restoration, making it necessary to analyze reef restoration from a social-ecological perspective (Uribe-Castañeda, 2018). Very often, social and ecological aspects are seen as separate elements, ignoring interactions between different cultural, political, social, economic, ecological, and technological components (Resilience Alliance, 2010). Oversimplifying these interactions and applying one-size-fits-all solutions to ecosystem management have led to failures such as lack of stakeholder involvement, capacity to control causes of degradation, or lack of long-term sustainability (Wyborn & Bixler, 2013).

To address the gap from a holistic perspective, our research uses the Social-Ecological Systems Framework (SESF) as a diagnostic tool to deepen the analysis of social and ecological interactions affecting coral reef restoration performance. A *framework* is a comprehensive structuring tool that allows the depiction of an empirical situation. The SESF was explicitly created to understand social-ecological systems (Schlüter & Madrigal, 2012), allowing us to assess which variables across the ecological and social realm influence human behavior causing different outcomes in particular resource systems throughout time (Ostrom, 2007). For achieving a holistic perspective, the framework distinguishes eight categories for analysis: 1) social, economic, and political settings, 2) resource systems, 3) resource units, 4) governance, 5) actors, 6) interactions, 7) related ecosystems, and 8) outcomes. These categories are subdivided into second-tier variables identified in the literature to be relevant for common pool resources management (Ostrom 2007, 2009). These variables supply a common language for comparing cases by analyzing each case's ecological, economic, social, and policy characteristics and outcomes (Ostrom, 2007; Delgado Serrano & Ramos, 2015).

The SESF has helped to determine factors influencing sustainable management in coastal and marine ecosystems (Schlüter & Madrigal, 2012; Basurto et al., 2013; Leslie et al., 2015; Torres-Guevara et al., 2016; Partelow et al., 2018). Fewer studies have been made regarding applying the SESF to coral reef management; most refer to Marine Protected Areas (MPAs) containing coral reefs. For instance, Cinner et al. (2012) used the framework to measure the success of coral reef co-management across five countries. Their results show that successful co-management is related to critical institutional designs, knowledge of human agency in the ecosystem is high, and people have a history of being involved in co-management. Palomo and Hernández-Flores (2019) applied the framework to a marine natural protected area in Mexico by analyzing the key elements to achieve sustainable use in multiple resource systems such as coral reefs. Findings show that governance systems within a community change depending on the type of economic activity performed by the population, and governance complexity is related to the equity level of the actors. It also highlighted how community-based governance helped people get skills in conservation and increase stewardship.

Some studies have not applied the SESF directly but have linked social and ecological data to understand how these interactions influence outcomes and have helped identify relevant variables for understanding human-coral reef dynamics. Pollnac et al. (2010) evaluated 56 marine reserves in the Philippines, Western Indian Ocean, and the Caribbean, finding that fish biomass was influenced by human population density and compliance with rules. Cinner et al. (2016) evaluated 2,500 reefs worldwide; their results show that bright fish spots were linked to high dependence on marine resources, levels of local engagement, marine tenure, cultural taboos, and beneficial environmental conditions. On the other side, dark spots were linked to intensive capture, storage capacity access, and recent environmental stress events history. Conclusions from this study highlight the importance of strengthening participation and property rights in fisheries. These results help identify what social variables have been influential in other cases. Rogers et al. (2015) evaluated how the structure of coral reef communities may change in the future due to climate change and overfishing by considering structural complexity and primary productivity. Their findings show that the efficacy of management depends on biophysical characteristics and reef state, making marine reserves more effective with high structural complexity and restoration more effective for low complexity reefs.

Yeemin et al. (2006) highlighted that prevention of causes of degradation should be prioritized before starting restoration projects to reduce the costs of restoring large areas. Also, projects in limited demonstration areas are easier to manage for different purposes, such as education, tourism, or research. Trialfhianty and Suadi (2017) assessed projects in North-west Bali, analyzing the relationship between community perception and participation in restoration activities. They found that the level of community participation depends on how related their livelihood is to coral reefs and the importance of local leadership as bridges between science and local awareness. Community participation is assessed in several studies; Kittinger et al. (2016) showed that projects that increase community awareness, participation, and shared responsibility achieve long-term results. Notably, Kittinger found that restoration projects helped develop a skilled workforce, improve economic benefits through job creation, increase the capacity of community organizations to act on threats to reefs and watersheds, revitalize Native Hawaiian cultural practices, and innovate on using invasive algae as compost for farmers. Hein et al. (2019) found that community participation is retributed through jobs, education, stewardship, and increasing recreation opportunities.

Financing restoration projects is complex and limited, one of the biggest impediments to scaling up interventions (Bayraktarov et al., 2019). Most of it has been in-kind or NGO sector financing (Goreau & Hilbertz, 2008). Recently, the private sector has been increasingly funding restoration activities, especially hotels and dive operators (Bottema & Bush, 2012; Okubo & Onuma, 2015; Meyers, 2017). Understanding how governance structure and types of financing influence project outcomes are relevant for decision-making at the legal and practical levels. Bottema and Bush (2012) analyzed private sector-led marine conservation. Their results highlight the private sector's ability to create awareness both in tourist and local communities, generate income, and the capacity to support financial restoration activities. When government support is lacking, other reef users need help to guarantee compliance; for this to occur, trust is required. In their study, the private sector gained legitimacy by investing in education and employment programs. In the same direction, Okubo and Onuma (2015) analyzed commercial restoration projects in Okinawa, where diving tours have incorporated restoration activities. Results show it is appealing to tourists and creates environmental awareness. However, they highlight that this commercial project lacks long-term ecological integrity emphasis.

Bayraktarov et al. (2020) and Boström-Einarsson et al. (2020) found there is a knowledge exchange gap between projects conducted in Spanish-speaking countries in the Caribbean and the Eastern Tropical Pacific (ETP) and the rest of the restoration community. Most of the coral reef literature comes from the Indo-Pacific region, even though six of the eleven UNESCO marine World Heritage Sites (WHSs) that contain coral reefs are located within the ETP (Abdulla et al., 2014). Manzello (2010) highlights that ETP's unique oceanographic conditions act as a natural laboratory to understand coral reef reactions to changing environments, making it an important region to study to provide evidence for the conservation of reefs worldwide (Alvarado et al., 2017). Costa Rica is part of the ETP; the country has 970km^2 of coral coverage, representing a 0.34% of total world coverage (Spalding et al., 2001). Fifty-nine species have been reported in the country, contributing to 7.4% of the entire coral biodiversity (Cortés et al., 2003; Alvarado et al., 2006). Restoration initiatives in the country started around 2014[1] involving multisectoral partnerships, motivated by the loss of coral coverage by up to 77% (Burke and Maidens, 2004). Besides filling the gap about social variables contributing to restoration projects, this study aims to bridge the gap between restoration activities in Spanish-speaking countries from the ETP.

2. Context

Three study cases were chosen to analyze social and ecological enabling conditions for success (Figure 1). These three cases are on the Pacific Coast of Costa Rica, part of the ETP. They share ecological characteristics related to topography, oceanographic dynamics strongly influenced by low latitude trade winds, and inter-annual climate variation associated with ENSO. The Northern part of the coast has a dry tropical forest with a dry season from December to April when the upwelling season occurs; meanwhile, the southern part has tropical rainforest, with rain all year round, which decreases from December to April. High mountains in the central and southern areas prevent coastal upwelling (Cortés & Jiménez, 2003). Also, reefs in the ETP are built by a few coral species and have a discontinuous distribution (Reyes-Bonilla et al., 2020).

Regarding social and economic aspects, the Pacific Coast has experienced economic growth through tourism due to the country's political stability and infrastructure development, such as airports and roads (Honey et al., 2010), the existence of sources of pollution due to coastal development and/or forestry and agricultural plantations has threatened coral health (AIDA, 2012). The following sections briefly describe the location where projects are being conducted and project history and results. Table 1 summarizes the project description and results.

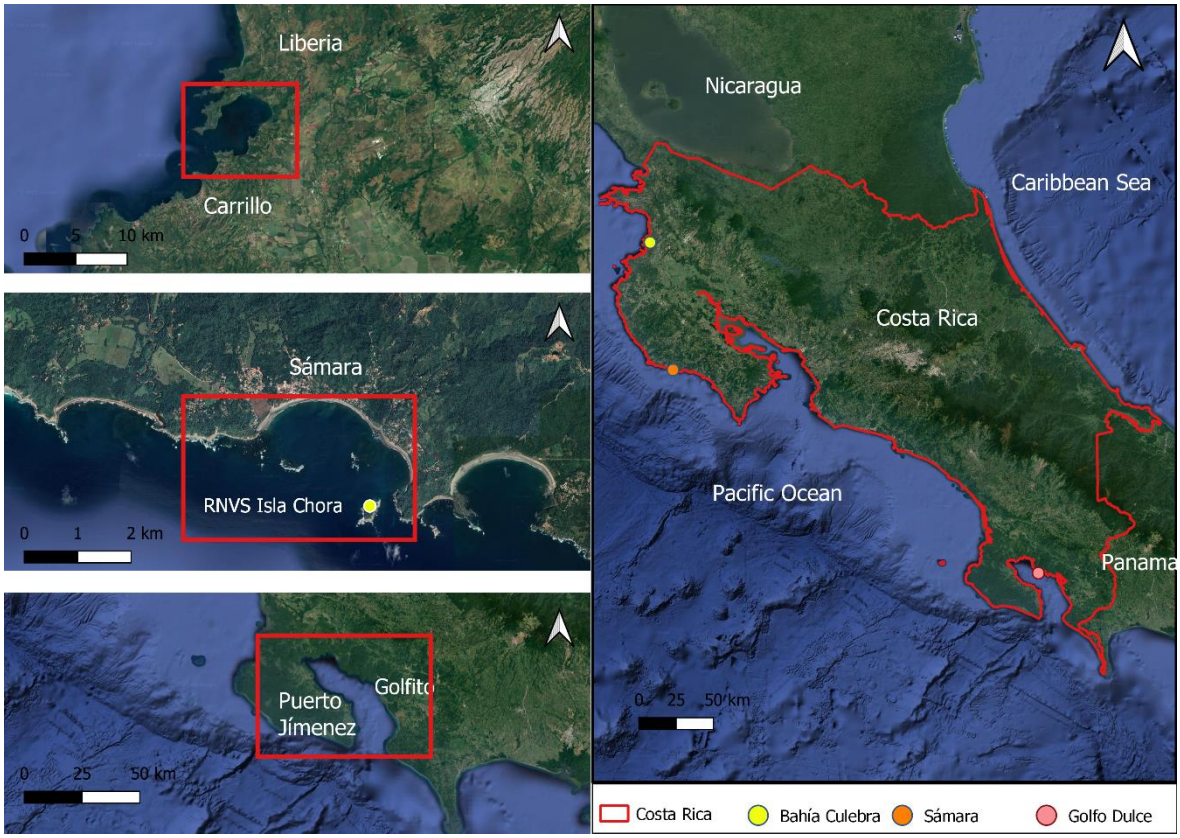
Table 1. Summary of project relevant information took from interviews with project´s members. Data was taken during fieldwork conducted from February to June 2022.

Organization	Managed by	Funded by	Starting Date	# of trasplanted corals	% survivance	Species
Asociación Proyecto Corales	Community and Government institutions	Personal donations, citizen science events, public sector (Govt institution) funding	2017	600	64%	*Pavona gigantea, Psammocora stellata, Porites lobata , Pocillopora elegans*
Raising Coral Costa Rica	NGO	International cooperation and personal donations	2016	1600	90%	*Pocillopora spp., Pavona frondifera Pavona gigantea, Psammocora stellata*

[1] Alvarado, J.J. January 14th, 2022. Email. San José, Costa Rica, CIMAR

Culebra reef gardens	Private sector and Academia	International cooperation, Private and public sector (University) funding	2019	265 +4,000	83.20%	*Pocillopora spp., Pavona clavus, Pavona gigantea, Porites lobata*

Figure 1. Location of three coral reef restoration projects working areas (Bahía Culebra, Sámara, and Golfo Dulce)



2.1. Sámara

Sámara (9.869220°N-85.515304°W) is located in the Nicoya canton in the Guanacaste Province. The estimated population for 2022 is 4,685 habitants (INEC 2011). The primary income sources are tourism, fishing, and agriculture (CREST 2013). Unlike other areas of the Guanacaste Province that follow a high-volume tourism strategy with resort-type hotel infrastructure, Sámara has small and medium infrastructure focused on ecotourism. The Refugio Nacional de Vida Silvestre (RNVS) Isla Chora is located in Sámara bay. The bay has a 3km extension. Most popular touristic activities include snorkeling, diving, kayaking, dolphin, whale, and turtle watching, horseback riding, and sport fishing. The region has a small *Pocillopora* or *Porites lobata* reef patch (Cortés & Jiménez, 2003); however, these reefs have been affected due to gravel and clay sedimentation carried by the Mala Noche and Lagarto rivers (Armstrong et al., 2010). Anthropogenic and natural threats have reduced live coral cover to 5%[2].

In 2016, the Ministry of Environment and Energy (MINAE) requested the Instituto Nacional de Aprendizaje (INA) to evaluate the feasibility of conducting a coral reef restoration project in Samara Bay. The feasibility analysis allowed us to determine sites for the nursery near RNVS Isla Chora and transplant sites in Cangrejal. The project started officially in 2017

[2] Perez Reyes, C. February 21st, 2022. Personal communication. Sámara, Costa Rica

when INA approached local tour operators and tour guides to participate in coral gardening training to create a group of local volunteers.

The project is co-managed by Asociación Proyecto Corales Sámara and INA. Asociación Proyecto Corales is a community organization with seven active volunteers, mainly from the tourism sector. INA provides technical knowledge and performs ecological monitoring. The project cost for Asociación Proyecto Corales is around US$28,000 per year, including equipment, nursery materials, and transportation. This money is collected from volunteer donations, local businesses' material donations, and a citizen science monthly event in partnership with tour operators. INA has funded around US$12,547[3], including the working hours of 3 INA staff members, equipment, and materials. The project is working in approximately 0.04ha and aims to transplant 10,000 fragments with the help of the local community. Until February 2022, the project has transplanted 600 fragments with a 64% of survival.

2.2. Golfo Dulce

One of four tropical fjords in the world (Quesada-Alpízar et al., 2006), Golfo Dulce (8.612352°N -83.291639°W) is in Puntarenas Province, between Golfito and Osa cantons (Figure 1). Golfito and Puerto Jimenez are the two most important cities surrounding the gulf. Results from the demographic census made in 2011 estimate population between both cities would be 24,703 habitants in 2022 (INEC 2011). Historically, the economy near Golfo Dulce was dictated by agriculture and gold mining. Nowadays, rice, livestock, tourism, commerce, artisanal, commercial, and sport fishing account for the most significant activities in the zone (Roman & Angulo, 2013).

Golfo Dulce covers an area of 750 km2. The gulf is surrounded by two National Parks, a forest reserve, and a Marine Area of Responsible Fishing (AMPR) (Fargier et al., 2014). Tidal forces, wind, freshwater entry into the system, upwelling subsurface water, and basin topography influence water mixing and circulation in the gulf, (Morales-Ramírez, 2011). Coral reefs and communities found in the gulf can be divided into two main groups: the ones located in the inner section of the gulf and those from the outer section (Cortés, 1990). Most common species found were *Porites lobata*, *Pocillopora damicornis* and *Psammocora stellata*. The inner gulf has low coral diversity (1-8%) and high topographic relief. Meanwhile, the outer gulf has a higher live coral coverage (29-46%) and low topographic relief (Cortés & Jiménez, 2003).

The restoration project started as a research initiative of two coral reef experts, with access to funding and technical knowledge for conducting the project. One of the coral reef experts was linked to the Costa Rica University (UCR) and the Centro de Investigación en Ciencias del Mar y Limnología (CIMAR), which facilitated access to local marine experts. The restoration initiative began in 2015 as part of a master thesis (Villalobos-Cubero, 2019). In 2016, NGO Raising Coral Costa Rica (RCCR) was created in partnership with UCR, and in 2019 the NGO got its independent status. The cost of implementing the project for RCCR is around US$100,000, which includes day of work payment for volunteers, equipment, materials, and transportation. Funds come 84% from international cooperation, 15% from personal donations, and 1% of citizen science events[4].

[3] Perez Reyes, C. December 21st, 2021. Informe final 2021. San José, Costa Rica
[4] Raising Coral Costa Rica, 2021, Executive Summary

RCCR intervenes approximately 0.5ha in Golfo Dulce. Objectives are defined annually; for 2022, the goal is to transplant 2,000 corals. One thousand four hundred corals have been transplanted with a 90% survival. RCCR has three major restoration sites in Playa Nicuesa, Mogos, and Sandalo. NGO structure is vertical, with two project managers specializing in marine biology and coral reef restoration and seven local coral gardeners.

2.3. Bahía Culebra

The bay has an extension of 7km, located inside the Papagayo Gulf (10.619357°N - 85.655315°W) in the northern Pacific of Costa Rica. The bay has seasonal upwelling from December to April, having colder and nutrient-rich waters and decreasing water temperatures (Alfaro & Cortés, 2012). Bahía Culebra is characterized by having rare and unique coral communities and reefs. Pocilloporid corals are the primary reef builders in shallow waters, and *Pavona clavus*, *Psammocora* spp., and *Leptoseris papyracea* are primarily found in deeper waters. Branching corals such as *Pocillopora damicornis* and massive such as *Pavona clavus* account for 42% and 30% of live cover (Cortés & Jiménez, 2003). Jiménez (2001) states dominance of species in the bay might be influenced by coral thermal tolerance and exposure to cool upwelling waters during the dry season. Corals in this area have been affected by siltation, fishing, and touristic activities, El Niño, extraction for the aquarium trade, macroalgal proliferation, and red tides (Cortés et al., 2010).

The bay's economic development intensified in the '90s due to the Polo Turístico Golfo de Papagayo (PTGP), which promotes sun, sea, and sand tourism. The PTGP is managed by the Instituto Costarricense de Turismo (ICT), which grants concessions to investors from luxury hotels. Main touristic activities in the bay include sport fishing, diving, snorkeling, and water ski rides (Jimenez, 2001; Sánchez-Noguera, 2012).

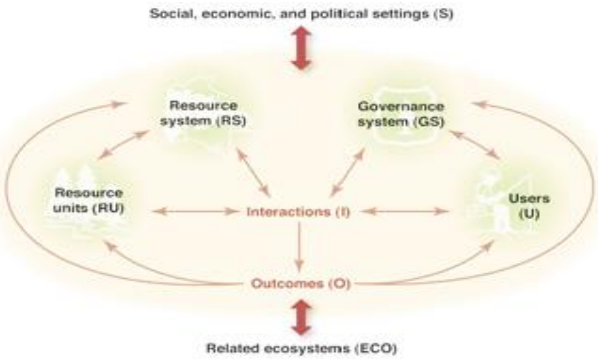
The restoration project started as a coral gardening pilot in 2019. It is managed by a private-public partnership between Sistema Nacional de Áreas de Conservación (SINAC), CIMAR, German Corporation for International Cooperation (GIZ), Peninsula Papagayo, and RCCR. In 2020, the project was officialized to implement an in-situ coral gardening program and promote responsible touristic activities in reefs and nurseries in Bahía Culebra. CIMAR's role is to lead ecological monitoring and provide technical knowledge. Meanwhile, Peninsula Papagayo contributes by managing volunteers to clean the structures. Both organizations make financial contributions to the project. In the case of CIMAR, they contribute US$76,000 per year, including equipment, staff, and materials. The relationship between both actors is ruled by a cooperation agreement of three years which will be evaluated by the end of the period. Project goals are to transplant 5,000 corals in 5 years, recover 30% of coral cover, increase biomass and fish diversity by 50%, establish a responsible tourism program with three local enterprises, create environmental awareness in the local community, propose marine spatial planning for productive activities related to coral reefs in the zone. The project covers around 0.09 ha in Güiri-Güiri, Islas Pelonas y Playa Blanca. Two hundred sixty-five coral fragments have been transplanted, and 4,000 fragments of *Pocillopora* spp. are meant to stay in the spider and A structures that are already growing. The project has an 83.2% of coral survival.

3. Methods

This research follows a qualitative approach by comparing three case studies using the SESF as a diagnostic tool (Figure 2) (Ostrom, 2007; McGinnis & Ostrom, 2014). The diagnostic process means asking a series of questions on a specific system and elaborating on more

specific questions based on the responses provided by previous questions, allowing it to go from general to particular (Frey & Cox, 2015).

Figure 2. Social-Ecological Systems Framework including first and second- tier variables (DeCaro and Stokes 2013).



Social, economic, and political settings (S)
S1 Economic development. S2 Demographic trends. S3 Political stability.
S4 Government resource policies. S5 Market incentives. S6 Media organization.

Resource systems (RS)	*Governance systems (GS)*
RS1 Sector (e.g., water, forests, pasture, fish)	GS1 Government organizations
RS2 Clarity of system boundaries	GS2 Nongovernment organizations
RS3 Size of resource system*	GS3 Network structure
RS4 Human-constructed facilities	GS4 Property-rights systems
RS5 Productivity of system*	GS5 Operational rules
RS6 Equilibrium properties	GS6 Collective-choice rules*
RS7 Predictability of system dynamics*	GS7 Constitutional rules
RS8 Storage characteristics	GS8 Monitoring and sanctioning processes
RS9 Location	
Resource units (RU)	*Users (U)*
RU1 Resource unit mobility *	U1 Number of users*
RU2 Growth or replacement rate	U2 Socioeconomic attributes of users
RU3 Interaction among resource units	U3 History of use
RU4 Economic value	U4 Location
RU5 Number of units	U5 Leadership/entrepreneurship*
RU6 Distinctive markings	U6 Norms/social capital*
RU7 Spatial & temporal distribution	U7 Knowledge of SES/mental models*
	U8 Importance of resource*
	U9 Technology used
Interactions (I) → Outcomes (O)	
I1 Harvesting levels of diverse users	O1 Social performance measures (e.g., efficiency, equity, accountability, sustainability)
I2 Information sharing among users	
I3 Deliberation processes	
I4 Conflicts among users	O2 Ecological performance measures (e.g., overharvested, resilience, biodiversity, sustainability)
I5 Investment activities	
I6 Lobbying activities	O3 Externalities to other SESs
I7 Self-organizing activities	
I8 Networking activities	

Related ecosystems (ECO)
ECO1 Climate patterns. ECO2 Pollution patterns. ECO3 Flows into and out of focal SES.

Multilevel frameworks such as the SESF facilitate the diagnosing task because it orders a set of variables that have been proven relevant for understanding resources' sustainable use (Ostrom, 2009). First-tier variables help design the general questions, and then second-tier variables can be chosen depending on the system's characteristics and the information provided through the data collection.

The case selection method used was most similar cases (Seawright & Gerring, 2008), which requires the identification of key variables of interest that should be similar across cases and variables that should vary meaningfully (Nielsen, 2016). For this study, similar variables are successful ecological outcomes with survival rates above 50% (Harriot & Fisk, 1988), projects that have been sustained for more than 18 months, and similar ecological characteristics for being part of the ETP. This similarity, especially regarding

ecological variables, allows us to focus on the impact of varying variables such as governance structure or being surrounded by touristic poles, land protected areas, or no special management zone may have on project success with the aim of understanding if governance structure is an influential variable for successful outcomes in coral reef restoration.

3.2. Data collection

Data was collected using semi-structured interviews and participant observation. Interviews followed a diagnostic procedure (Ostrom, 2007; Cox, 2011) which consisted of broad semi-structured questionnaires designed for each actor group based on the SESF first and second-tier variables (Figure 2) to ensure the information during cases would be comparable for the analysis. Using second-tier variables allows for identifying more specific details of the resource system management. Also, a literature review from similar studies helped identify relevant questions for designing the interview protocol. Questions were divided into 1) project data which included questions regarding motivation to start the project, goals, criteria for species and site selection, number of transplanted fragments, survival rate, monitoring schedule, and actors involved. 2) Perception segment included questions on reef benefits, reef state, significant threats, time living in the community, knowledge about project existence, project benefits and limitations, and the presence of conflicts between reef users. 3) The technical knowledge, financial capacity, and social capital section included questions on quantity of cleaning and monitoring activities performed per month, type of funding, key partners, how project information is shared with different stakeholders, the number of training received and by who, how decision making is made, level of trust in different actors, participation in community organizations. 4) Regarding rules compliance, questions were directed to the application of the AMPR, touristic pole, or the lack of management and what benefits or challenges they identified from the type of management in each zone. Data regarding ecological systems and socioeconomic context was mainly obtained from management plans, monitoring reports, thesis, and published articles.

All primary data was collected between February 2022 to June 2022 through 50 semi-structured interviews in Spanish (Table 2). Following literature related to coral reef restoration projects (Frey and Berkes, 2014, Okubo y Onuma, 2015; Kittinger et al., 2016; Hein et al., 2017), individuals were chosen based on their proximity to sea-related activities and the information they could provide due to their role in the community or workplace.

Table 2. Semi-structured interviews were conducted during field research to identify relevant SESF variables for successful project outcomes

Study area	Total interviews	Project Members/volunteers	Fisherman	Tour operators	Hotels	Community or govt. organizations
Samara	20	4	4	6	3	3
Bahía Culebra	11	1	1	6	1	2
Golfo Dulce	19	4	3	6	2	4
Total	**50**					

Sampling was done according to the type of actor. For critical informants, who included project members and representatives of community and government institutions, purposive sampling was selected (Bernard, 2006; Maxwell, 2009). For other groups, snowball sampling was used, aiming for a balanced sample of gender and age. Information from interviews was cross-checked with other individuals until a saturation point related to specific topics was reached. Data was also collected through participant observation, mainly by participating in restoration activities, watching people interact with restoration sites, and

living in each community for at least three weeks, providing the perception of the daily reality of each project.

2.3. Data analysis

Data were analyzed applying qualitative content analysis using MAXQDA software. The analysis consisted of classifying data from interviews using systematic coding classification that allowed the identification of themes and patterns (Hsieh & Shannon, 2005). First, transcribed interviews were analyzed, and relevant data based on the research questions were highlighted. Afterward, deductive category application (Mayring, 2000) was used by applying SESF first and second-tier variables to determine coding schemes and the relationship between codes. Partelow´s (2018) definitions and indicators of SESF variables were used as a codebook. Data that could not be coded using SESF first and second-tier variables were highlighted and labeled either as a new category or subcategory. In the case of perception-related questions, codes are derived directly from data. Data was triangulated by gathering information from different sources to validate their context (Creswell, 2014). Data were segmented by cases, involving constant comparative techniques (Strauss & Corbin, 1990). Once all data was coded, comparison tables were developed depicting how each variable was present in each case and identifying their positive or negative effect on the project's ecological outcome. Information regarding positive or negative impact was crosschecked with previous studies of collective action theory (Olson, 1965; Ostrom, 2009; Poteete & Ostrom, 2014) and coral reef restoration research (Yeemin et al., 2006; Kittinger et al., 2012; Frey & Berkes, 2014; Okubo & Onuma, 2015; Cinner et al., 2016; Kittinger et al., 2016).

3. Results

Results show that despite peculiarities to each case, they follow similar routes for success. Three main factors were present in all cases:

- Role of positive perception of benefits from coral reefs and restoration project
- Role of network structures to achieve adequate human and financial resources
- Role of compliance with regulatory frameworks

The coding process with variables shown in Figure 2 displays that these three main factors were possible due to the interaction of the following SESF variables: network structures (GS3), constitutional choice rules (GS7), leadership/entrepreneurship (U5), norms, trusts, social capital (U6), investment activities (I5), knowledge of SES (U7), information sharing (I2), operational choice rules (GS5), monitoring activities (I9), location (RS8), economic value (RU4), the importance of resource dependence (U8), predictability of system dynamics (RS6), distinctive characteristics (RU6), history or past experiences (U3), (S5) markets. Other SESF variables were also identified during the coding process. However, the variables were chosen due to the frequency of their appearance as relevant factors during the coding process, as shown in Figure 3, Figure 4, and Figure 5, and their relationship with collective action and coral restoration literature.

Figure 3. Graph representing frequency of codes related to Resource System and Resource Units set of second-tier variables that were identified during the analysis of interviews.

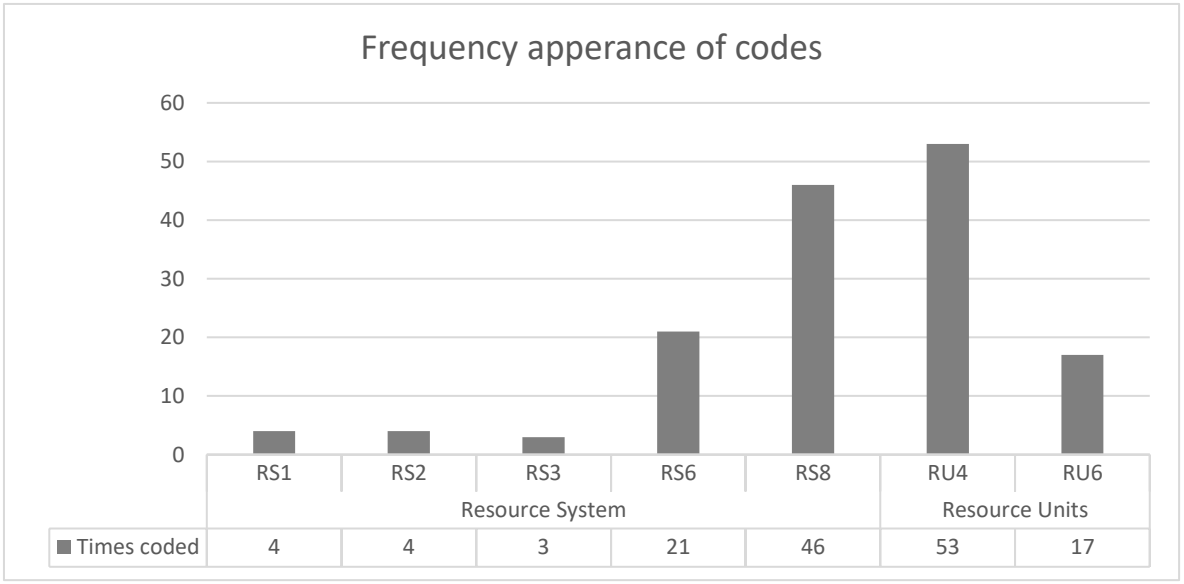


Figure 4. Graph representing the frequency of codes related to Governance system and Actors set of second-tier variables that were identified during the analysis of interviews

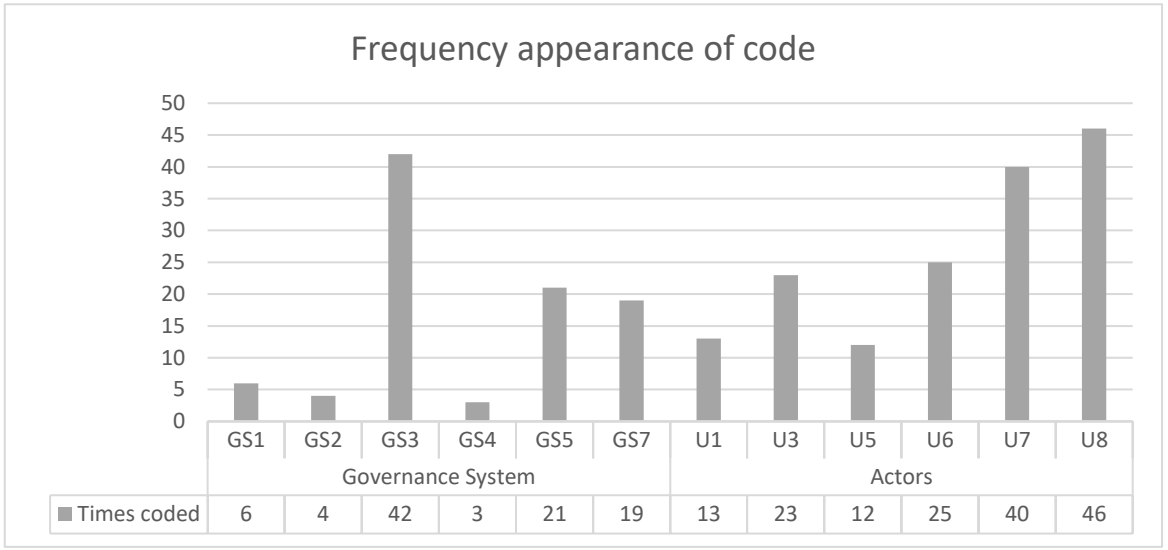


Figure 5. Graph representing frequency of codes related to Social, Political and Economic Settings and Interactions set of second-tier variables that were identified during the analysis of interviews.

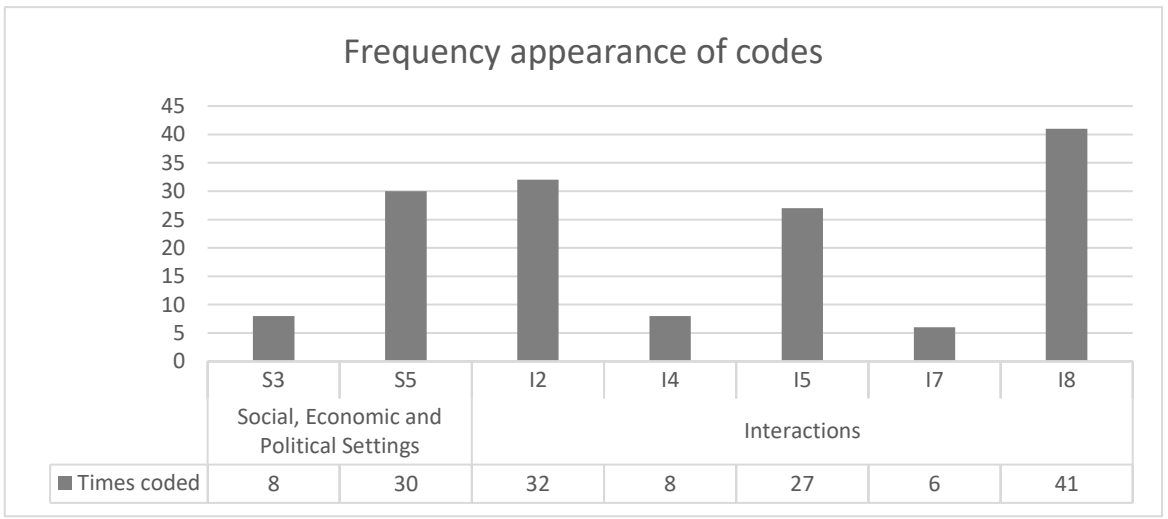
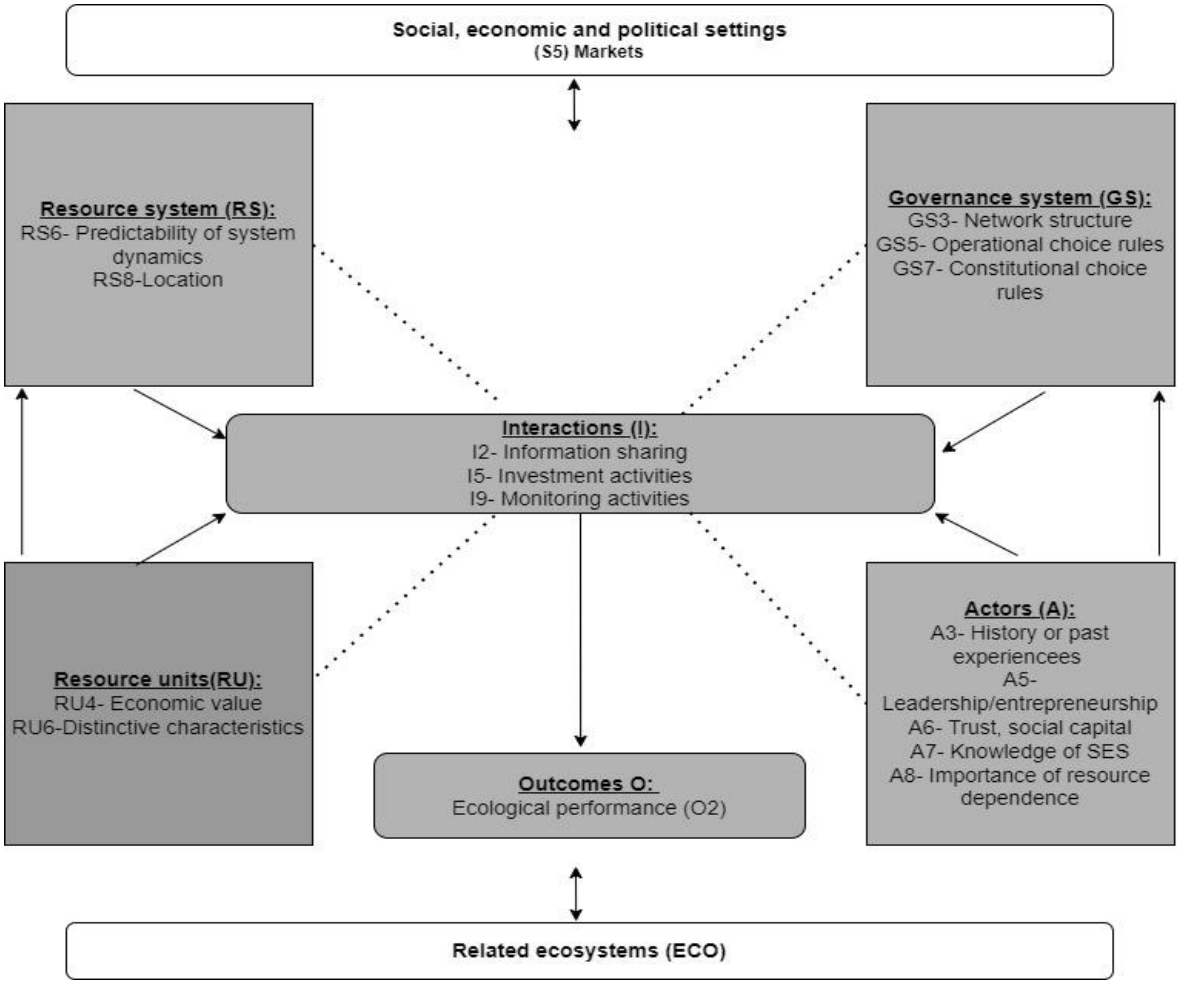


Figure 6 shows an adaptation of the SESF diagram showing how the salient variables interact to produce positive perception of benefits, obtain adequate financial and human resources, and achieve enabling environment for coral reef restoration.

Figure 6. SES Framework with more salient variables for coral reef restoration success identified through the coding process.



3.1. Role of positive perception of benefits from coral reefs and restoration projects

During the interviews, people were asked to mention up to three benefits they perceived from coral reefs and restoration projects. Results regarding the perception of benefits from these two elements show that in all three study cases (Figure 7 and Figure 8), people positively perceive coral reefs as home to marine biodiversity, justifying that without corals, there would be no fish, lobsters, or turtles in the zone. The second, most important benefit identified was tourism attraction, which seems to relate to the first option because perception is that people are attracted to coral reefs due to the number of animals they can see, as expressed by a key informant in Golfo Dulce and a tour operator in Bahia Culebra.

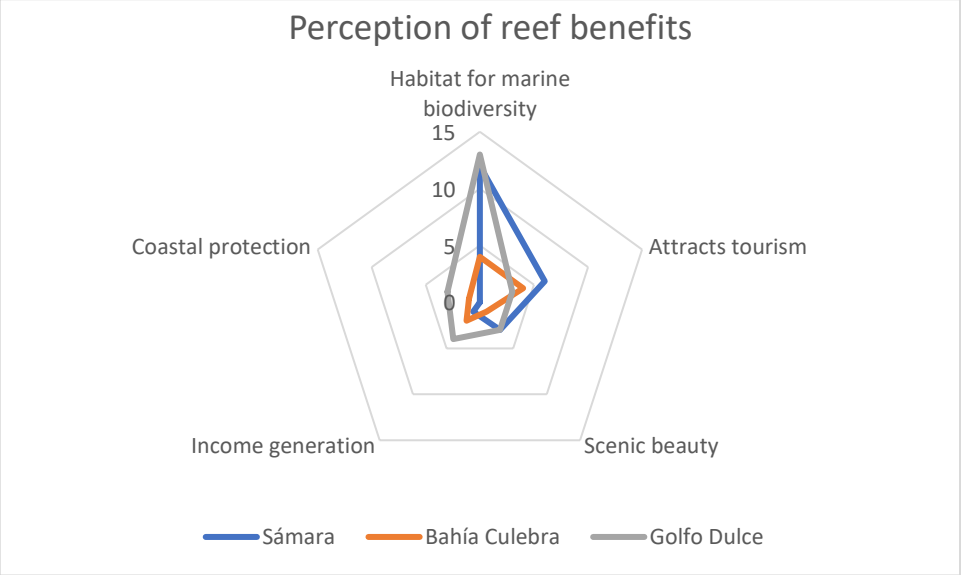
Golfo Dulce Key Informant 1*: "They are the marine ecosystem engineers; where there are coral reefs, we see life and food."*

Bahía Culebra Tour Operator 3: *"it's a huge touristic attraction, locals like it, and foreigners come from all over the world to dive here, and that is really good for us; more corals, the better."*

There is a difference between results from Sámara and Golfo Dulce compared to Bahía Culebra mainly because there were less people interviewed in this zone than on the other

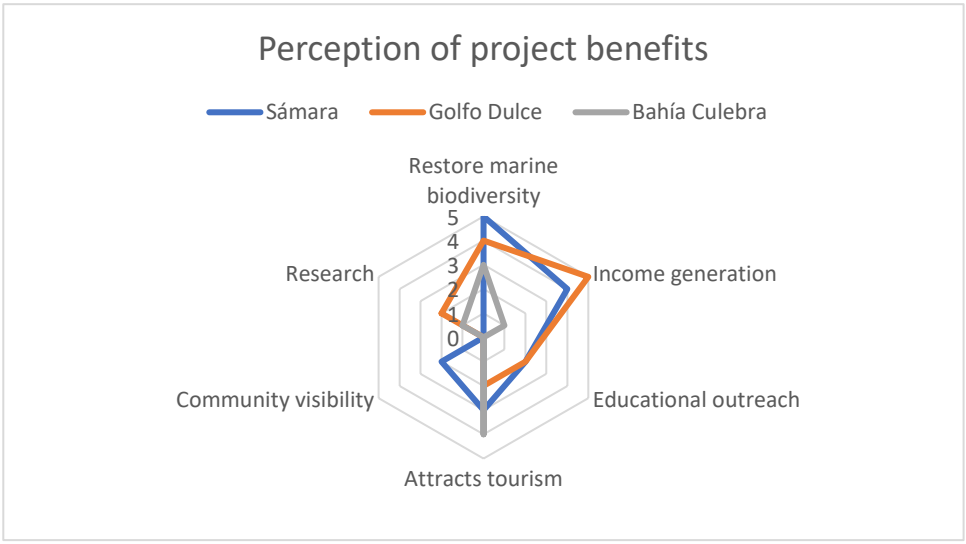
two due to less community involvement. Also, perception of most interviewees was Papagayo gulf did not have many coral reefs.

Figure 7. Results from interviews regarding reef benefit perception in Sámara, Golfo Dulce and Bahía Culebra.



Results from reef benefits are aligned with those perceived as project benefits. When asked about project benefits, restoring marine biodiversity was the most mentioned. A volunteer from RCCR expressed how changes are becoming noticeable in a short period of ***Golfo Dulce Volunteer 1:*** *"The change in a variety of fish, seahorses, and lobsters that we now see is big. In places where everything was dead before, after 4 or 5 months, we start to see a change."*

Figure 8. Results from interviews regarding project benefit perception in Sámara, Golfo Dulce and Bahía Culebra.



Income generation was the second most mentioned benefit. It is perceived directly and indirectly, as explained by a key informant from Sámara. ***Sámara Key Informant 2****: "We are seeing jobs being created just to receive this type of tourism; people now come to the city and have one more tourist activity to do, so hotels, restaurants, tour operators, and everyone benefits from it.*

This positive perception motivated people to support project activities. However, there is a difference in motives to participate in the project between the groups interviewed, which is caused by the type of economic activity performed by the individual. People related to touristic activities were more willing to contribute to the project since they perceived short-term benefits from their contribution due to the possibility of generating income from the project as a touristic attraction, which gave them a higher *economic value* perception. On the other side, fishers who perceived benefits related to the increase of marine biodiversity see it as a long-term benefit that did not cause a significant motivation to participate in restoration activities, as expressed by a fisher from Golfo Dulce. ***Golfo Dulce Fisher 1:*** *"I know the project will benefit because more corals mean more fish, but the problem is the change takes time. It could be months or years until we see the number of fish we used to have, and I need money and food to take back home. I can´t just take a day off work. I live from what I earn every day, and, in the sea, we never know if it´s going to be a good day but not going to fish is not an option."*

Projects have also conducted educational awareness campaigns to reach locals and tourists about the importance of reefs; this has caused an impact on the perception of corals and project benefits. Most of these educational outreach activities target youth from schools and social media.

L*ocation* also influences perception and collective action in three ways:

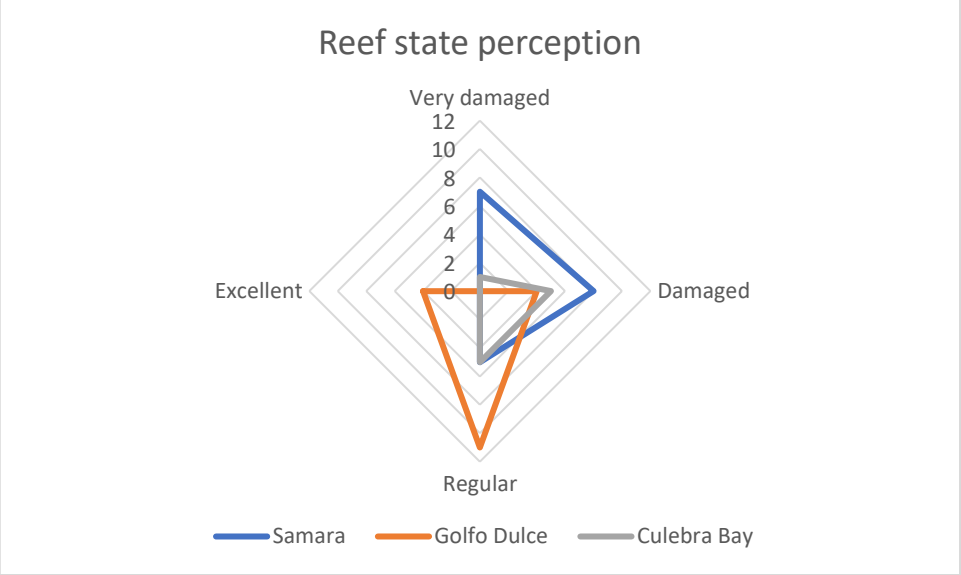
- Projects were in sites of easy access to communities, as in the case of Sámara, or in the area of influence of local businesses, as in the case of the hotels in Golfo Dulce and the private developer in Bahía Culebra, it was easier for people to perceive benefits and stewardship was increased.
- Accessibility to restoration sites also reduces transaction costs related to transportation.
- All three projects were in zones with no previous conflict between reef users.

In the case of Sámara, in the beginning, the project faced sabotage from local fishers because of a lack of communication of project objectives and benefits from the project to the local community. Fishers feared the project would take their fishing rights in the area. The problem was solved with meetings to inform about project goals, how it would benefit fishers regarding the provision services of reefs, and by defining in conjunction restoration site in which the project would not be affected, and fishers could continue with their activities. An example was given by a fisher, a member of the Samara fisher association. ***Sámara Fisher 2:*** *"They focus mainly on tourism, which is fine, but they should not leave out the fishers. For example, where they wanted to make the nurseries was a place on the fishing route. So, I told them no, you could not put it there because you will affect us; you must use common sense. They probably would have set up the project there if they had not invited me to the meeting, which could have caused conflicts. We know it is a good project, but it must be good to everyone, not just a few."*

Interviews with project volunteers in Sámara and Golfo Dulce showed that the duration of living in the community is essential for increasing collective action. People who lived in the community where restoration took place and knew how coral reefs changed through time were more willing to contribute. When asked about what will motivate them to participate in the project, we saw that people with a negative perception of the reef state due to local threats, such as sewage water or sedimentation (Figure 9), were more willing to participate than those that had a regular perception and perceived global threats, such as climate change because they saw their actions could not stop the original problem. This difference in perception of reef state and threats was one of the most significant contrasts between local

actors interviewed in Sámara and Golfo Dulce, projects with greater community participation. For instance, a member of the local water organization in Sámara told us about how teak plantations damaged corals and the actions they have been conducting to reduce this type of threats. ***Sámara Organization 2:*** "*I have lived in Sámara all my life, and I have seen how we have been losing our reefs, especially 30 years ago when the teak plantations started. We are doing our best to restore the riparian buffer and help give better conditions for corals to survive. I also participate in the project because it´s important for our community."*

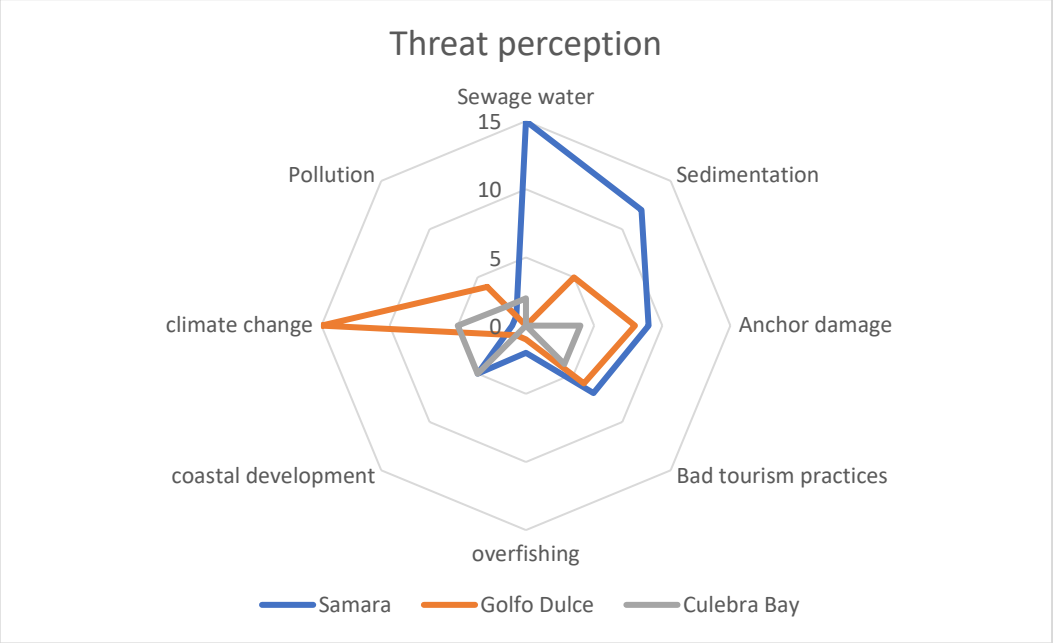
Figure 9. Results from interviews regarding reef state perception.



In Sámara, reefs are mostly perceived as very damaged (Figure 9). People interviewed in Golfo Dulce considered reef stats primarily regular, and in Bahía Culebra, perceptions were divided between regular and damaged. However, in Bahía Culebra, when we asked about coral reefs' state or benefits, most people said the zone doesn't have coral reefs or just some small patches, but they did not seem to recognize them as an essential ecosystem in the zone.

In the case of Golfo Dulce, the major threat perceived is climate change (Figure 10), as explained by this tour operator ***Golfo Dulce Tour Operator 3***: *"It´s difficult because Golfo Dulce is very protected, and we can see coral reefs are in a good state. We have events such as El Niño and red tides that affect them, but there is nothing we can do; that´s nature and climate change. I don´t participate directly in project activities, but I help corals by keeping tourists from damaging them during our tours."*

Figure 10. Results from interviews regarding perception of significant threats to coral reefs.



3.2. Role of network structures to achieve adequate human and financial resources

Project members were asked about limitations they perceived from restoration projects; project funding and access to a workforce with diving skills were among the most mentioned. All three projects relied on network structures between local and external actors to obtain adequate human and financial resources. These partnerships were possible due to two main factors; first, positive perception of *economic value* from local businesses such as tour operators, private developers, and hotels that motivated them to participate in restoration activities. Second, *trust and social capital* were built through previous social and institutional interactions, allowing organizations to have a good reputation between the community and their partners. For example, in Asociación Proyecto Corales, most active project members have participated in other community organizations. Peninsula Papagayo performs social outreach activities focused on education and employment for the community. In the case of Golfo Dulce, RCCR has focused on educational outreach activities and providing jobs to locals.

Also, external actors were relevant in the three cases to obtain technical knowledge and access adequate human resources. These external actors were trusted due to their historical presence as community public education service providers. Technical knowledge transferred from external actors to local actors has allowed the building of local capacities, which has helped increase the number of project members. Coral gardeners' contribution varies in each case. For example, in Sámara, they are volunteers; in Golfo Dulce, they are also volunteers, but they receive a US$35 per day of work retribution; and in Bahía Culebra, the permanent staff includes workers from Peninsula Papagayo and CIMAR. RCCR estimates that certifying someone in diving and coral gardening costs US$1,200. The issue projects have with paying for volunteer certifications is that many starts with the course, but after getting their certification, not everyone continues actively participating in the project. The project loses its investment because no rules bind certified volunteers to contribute to the project for a certain amount of time. For example, Asociación Proyecto Corales, INA trained 30 volunteers in 2018; by February 2022, the group only had seven active volunteers. To reduce costs and still access the skilled workforce, projects have implemented volunteer programs in which people pay and access equipment, training, or supervision from project members. People that participate from these volunteer programs are either members of the diver

community in Costa Rica or tourists. Costa Rica reputation of being an ecotourist destination with well-known diving spots (Valverde Sanchez 2018) is an advantage projects have when implementing these type of volunteer programs. These programs have been strengthened through *information sharing*, especially on social media. Social media has also been used to report on project results and crowdfunding. Information sharing also contributes to building network structures because it reduces the chance of conflict, as mentioned before in the Sámara case.

External actors also contributed to backing restoration efforts with science. This helped establish *operational choice rules* regarding the site, species selection, and monitoring activities, contributing to more efficient projects. Scientific knowledge transferred by external actors allowed them to know about season and weather variability, *giving predictability of system dynamics* to determine rules for restoration sites and activities such as choosing nursery sites without the presence of coralivorous fish, sandy bottom, good water quality, presence of live coral coverage, selecting species that have had a presence in or near the restoration site, choosing structures that fit in *distinctive characteristics* of each species cleaning restoration sites at least twice a month, and monitor changes in fish biomass.

Most of the scientific knowledge external actors have comes from official guides established by international coral reef organizations based on international reef restoration experiences. Also, projects had two and half year's experimental phase, where tests regarding the correct type of species with specific structures were made. In the case of Bahía Culebra, knowledge on how to start the project was transferred from RCCR through a partnership.

3.3. Role of compliance with regulatory frameworks

Costa Rica banned trawling fishing in 2013 (Sentence No. 2013-10540). Project members and fishers identified this fishing method as one of the most extensive threats corals had and perceived that the prohibition helped improve the environment for coral reefs. In general, interviewees highlighted compliance with this legal framework and a positive perception of its effects on marine biodiversity. ***Sámara Fisher 1:*** *"I have been living here for more than 40 years, and I remember when I was a kid, my father would capture many fishes, and with time, the quantity of fish decreased. Trawlers were the worst thing that happened to the seas; they destroyed everything. Now we see a change, but still, more time is needed to see a difference. We as fishers must fight for the sea, the government wanted to allow trawlers again, and we fought against it because we know how bad it is."*

In 2019, MINAE, through decree N° 41774, established the promotion of restoration and conservation initiatives for recovering coral reef ecosystems. This decree is the first regulatory framework in Costa Rica to address coral reef restoration projects by stipulating the creation of a multilevel governance structure to facilitate cooperation for restoration initiatives and creating an official restoration protocol (SINAC 2020). This protocol gives the guidelines on submitting a restoration project, including the rules that a biologist or natural resources manager must lead each project proposal. Projects must last a minimum of two years to guarantee at least one year of monitoring. Restoration proposals are approved by research departments from the Conservation Area where the project belongs. Key informants from Sámara and Golfo Dulce shared insights into how they have contributed and benefited from this legal framework:

Golfo Dulce Key Informant 1: *"Due to our experience in coral restoration, the governmental conservation institution ordered us the design the official coral restoration*

protocol for Costa Rica. There we stated biological differences between the Pacific and Atlantic coast corals, specified rules for starting a project, and how to monitor them."

Sámara Key Informant 1: *"I am in charge of assisting with the Coral Council meetings. When the project started, we received technical assistance through this committee."*

As seen before, water quality is an essential element for effective coral reef restoration. This study shows positive water quality results from compliance with *Constitutional choice rules*. Golfo Dulce is surrounded by National Parks, Forest Reserve and is an AMPR. Protected areas were not created taking into consideration the link between land and sea, as stated by a member of the government institution in charge of protected areas Golfo Dulce, ***Golfo Dulce Organization 1:*** *"First protected areas were created to stop deforestation; throughout time, studies have been made that show the importance of protecting marine environments due to the species that live there, but we are still in an amateur stage regarding Marine Protected Areas. However, here in the Gulf, we see the importance of working together on terrestrial and marine protected areas. Here we see deforestation was reduced since we started protecting the zone in the 70s."* A key informant from Golfo Dulce also expressed that marine protection is still not well developed in Costa Rica. Still, land-related activities have had a positive impact, ***Golfo Dulce Key Informant 2:*** *"There is not much being done by the government to protect the oceans, it´s still something new, but we can´t deny national parks have helped reduce deforestation and provide a good environment for corals."*

Fournier et al (2019) evaluated anthropogenic impacts from plantations near the Coto Colorado river, which covers 95% of the agricultural area and drains into the gulf. Their results show the importance of the 2,100 ha of mangrove to cushion the impact of land-based pollution. Another study by Cortés (1990) demonstrates that corals have natural regeneration rates; for example, at Punta Nicuesa, Cortés (1990) reported a 45.9% increase in live coral cover in 1985/1988. Alvarado et al (2015) report an 83.4%live coral cover for the same zone. The project Manager from RCCR also says their monitoring shows natural regeneration rates and greater resistance to stress events such as changing water temperatures.

In Bahía Culebra, the legal document establishing rules in the Touristic Pole is the Management Plan approved in 1995 by the ICT board, which includes regulations on conservation of protected areas, reduction and control of possible pollution sources, wastewater, and solids recycling, among others. An employee from one of the hotels located in the PTGP highlighted compliance to the management plan, ***Bahía Culebra Hotel 1:*** *"Our business complies with requirements to operate in the touristic pole. We treat 100% of the water we use, and none is thrown to the sea; we reuse it to water our golf camps."*

4. Discussion

By applying the SESF, we have identified three critical enabling conditions for achieving successful restoration:

1. Positive perception of benefits both from coral reefs and projects to achieve collective action
2. Network structures to get adequate financial and human resources
3. The importance of compliance with an existing regulatory framework to create enabling environments for projects development and coral reef ecology.

Perceptions can be used as evidence for assessing environmental outcomes to understand stakeholders´ conception of social and ecological outcomes of a specific initiative and the social acceptability of conservation or restoration governance (Bennet, 2016). Our study found that positive perceptions of coral ecosystem services and project benefits influenced collective action to restore the coral reef. In the three projects, we found a positive perception of both coral and project benefits related to resource dependence, the high economic value of reefs, duration of living in the community, knowledge of the human agency, project location, and information sharing. Studies made in México and Indonesia about perceptions of coral reefs and restoration projects show wealth (Cinner & Pollnac, 2004) and local leadership involvement, degree of interaction with the project, and overall project results (Trialfhianty & Suadi, 2017) also influence perceptions.

Depending on the group of reef users being studied, the resource's type, use, and governance vary (Palomo & Hernández-Flores, 2019). Tour operators and fishers in the three cases seemed to perceive coral reefs and project benefits positively perceive coral reefs and project benefits. However, the willingness to participate in the project was greater among tourism-related actors than among fishers. The main difference is that fishers' positive perception is related to increasing fish biomass which is a long-term benefit that doesn't seem to compensate for using their time to contribute to the project because of economic reasons. Cinner and Pollnac (2004) used Maslow's hierarchy of needs to show the relation between wealth and involvement in environmental activities in a coastal community in Mexico. Wealthier residents were able to meet basic needs and have more economic security for contributing to environmental conservation, which is related to a fulfilling sense of belonging. Their study recommends that for involving fishers' alternative livelihoods should be implemented. In our research, tourists-related actors were more willing to participate because they perceived the short-term benefits of restoring coral reefs. Diedrich (2007) found similar results with a positive correlation between tourism and coral reef conservation awareness in Belize.

Analyzing the type of governance structures and motivations to start a restoration project matters because it affects project design, stakeholder participation, monitoring, and long-term ecological integrity. Even though the three cases have different governance structures, they all share similarities of being projects with a biotic rationale, which means their main goal is to recover lost aspects of local diversity (Clewell & Aronson, 2006). Throughout time an idealistic motivation has been developed for social and cultural reasons (Clewell & Aronson, 2006). These types of inspiration seem to be a tendency in the region, as shown by Bayraktarov et al. (2020) review of coral reef restoration projects in Latin America, where 42% of projects have biotic motives, followed by an 8% with idealistic and pragmatic motives.

Reviews of projects implemented in the Caribbean, Western Atlantic, and Indonesia highlight the importance of partnerships for having adequate scientific, logistical, technical, institutional, and interpersonal skills (Johnson et al., 2011; Lamont et al., 2022). In the case of Latin America, Bayraktarov et al. (2020) showed that NGOs and foundations are the most common type of project leaders. They establish partnerships with universities, conservation management bodies and regulators, local associations, national and international business partners, international environmental NGOs, tourist operators, private donations, international grant schemes, and local community groups. These partnerships are established mainly to fill funding gaps and provide a skilled workforce. This is the case of the project in Golfo Dulce, led by an NGO (RCCR), created specifically to work with coral reef restoration, that has received support from academia; it´s mainly funded by international cooperation grants and involves community members as coral gardeners. Goreau & Hilbertz

(2008) highlight that NGOs or foundations financed by international cooperation grants are the most common governance structure for reef restoration projects. Lirman & Schopmeyer (2016) and Hesley (2017) identified the dependence on grants as the main cause of long-term failure of coral restoration led by NGOs because these funds usually last between 1-3 years. In that perspective, the fact that RCCR primary mission is working with coral restoration helps to focus all resources on this work, unlike the other case studies where organizations leading do not deal exclusively with coral reef restoration or depend totally on volunteer work. However, if we evaluate long-term performance, RCCR may have a more significant challenge in maintaining stability than the other two cases because their main workforce depends on the payment workers receive. They will also have to reduce critical activities such as continuous monitoring if they fail to diversify funds other than grants.

Besides motivation, the three study cases share the involvement and funding of activities from the public sector through external actors such as the local university or technical learning government institution. These external actors have enabled science efforts backing restoration activities, which has allowed projects to have experimental phases to determine what species and structures work best for the specific ecological conditions in the zone and provide continuous monitoring. This experimental phase is present in the three cases. It has allowed the projects to use small-scale pilot projects to demonstrate success and build relationships with key stakeholders to contribute to scaling up. A review of restoration projects in Thailand recommends pilot projects as a good management practice for successful restoration (Yeemin et al., 2006). Nonetheless, it is not the case in many projects, as shown by the Boström-Einarsson et al. (2020) review, where 60% of projects out of 362 lack standardized monitoring, with the median of projects performing less than 18 months of monitoring. Also, external actors have had an essential role in building local capacities through the implementation of workshops on coral gardening and providing educational benefits to local communities (Bottema & Bush, 2012; Okubo & Onuma, 2015; Hein et al., 2019).

However, science-related actors by themselves would not be able to perform all the work. Transferring knowledge is essential to success because it builds local capacities, increasing local stewardship (Hein et al., 2019). It´s the case in Sámara, where the project is being co-managed by community and government institutions. The local organization makes decisions regarding cleaning or fundraising activities; meanwhile, the public sector institutions support technical decisions and monitoring. We found that community involvement is influenced by past experiences, trust, social capital, and benefit perception. These variables depend on who is leading the project and the history of the restoration site. Sámara is being led by locals who participate in other community organizations, allowing trust and social capital to be developed (Pretty, 2003). Similar results regarding the importance of social capital and trusted leaders have been found in projects evaluated in Indonesia by Frey and Berkes (2014) and Partelow and Nelson (2020). In the case of the local community interviewed in Bahía Culebra, they were less likely to participate in the restoration project because:

1. They perceived Peninsula Papagayo as a powerful actor that already had all the resources needed to conduct the project,
2. It´s their responsibility to compensate for the damage caused by the building of the touristic pole, and
3. Locals feel excluded from possible benefits that could be obtained from the project due to difficulty accessing restoration sites.

Bottema and Bush (2012) analyzed private restoration initiatives conducted in Indonesia and found similar challenges in getting acceptance and participation from locals. They

recommend state support for private initiatives to create lasting institutional arrangements. In Golfo Dulce, the project started as a research initiative, and project managers are not locals, affecting community participation. Also, past experiences of exclusion in the decision-making process of land and marine regulations (National Parks and AMPR) (Fargier et al., 2014) have left local groups, such as fishers associations, suspicious that more conservation activities will affect their property rights. RCCR has been working since 2019 to address the lack of information about the project goal and increase community involvement through local workshops and educational outreach activities with schools. Strengthening local communities' governance, such as property rights, seems to have an impact on coral reef conservation (Cinner et al. 2016)

The private sector, through tourism-related businesses, has also been critical for funding and scaling up restoration activities. Meyers (2017) highlights the positive use of tourism to get a skilled workforce and funding for restoration. However, if not well-planned commercial projects may negatively impact coral reef restoration (Westoby et al., 2020). Okubo and Onuma (2015) research on Okinawa commercial projects presents three significant problems derived from profit-driven projects. The first has to do with the use of fragments from natural coral colonies that are already deteriorated and the effect it may have on natural processes corals are having. Second is the lack of genetic or species diversity used. Projects tend to use *Acropora*, which has a commercial interest because of its beauty and faster growth rates. The third increase in market restoration activities could cause scarcity of donor fragments, increasing costs of restoration, which could increase poaching and thus lead to even more deterioration. The level of involvement of the private sector varies in each case for our study. For example, in Bahía Culebra, there is an agreement to co-manage the project between the local university and private developer, and responsibilities between both sides are established under a written agreement. In Sámara, we identified private touristic-related owners participating from the local community organization and donating equipment, hotel rooms, and their time as volunteers. Also, Sámara partnered with a local tour operator for the citizen science event. In the case of Golfo Dulce, private support comes mainly for "house reefs" (Liburd & Becken 2007) and hotels located near restoration sites. In the three cases, decision-making is not profit-driven; instead, decisions are managed by science-related actors to improve ecological integrity by using lessons learned from other projects' best practices in scientific or grey literature and through experimental phases.
Private partnerships are mainly used to establish volunteer programs through citizen science. Volunteer programs help projects obtain funding and a skilled workforce, which is more difficult for reef restoration than shore-based activities such as mangrove restoration because diving or boating skills are less common (Hesley et al., 2017). The main difference in volunteer programs between projects is that funding from the private sector in Bahía Culebra covers most of the expenses from volunteers compared to the other two, which allows for a more constant list of volunteers.

Results from our study highlight the importance of compliance with regulatory frameworks to reduce coral causes of degradation. All official restoration guides state that effective restoration must first control the causes of degradation (Goergen et al., 2020; Shaver et al., 2020; Quigley et al., 2022). Coral reef restoration should complement other conservation strategies such as sustainable fishing practices and marine spatial planning (Lirman & Schopmeyer, 2016). Good water quality is critical for choosing restoration sites (Goergen et al., 2020; Shaver et al., 2020). In Golfo Dulce, good water quality is possible due to the protection of forests surrounding the gulf through the declaration of national parks and forest reserves. The existence of mangrove forests in the zone (Fournier et al., 2019) goes up to 2,100ha. A study in the Caribbean supports incorporating habitat diversity, including mangroves and seagrass meadows, to reduce threats to coral reefs (Mumby et al., 2004). In

the case of Sámara, almost all the mangrove forest has been deforested, so sedimentation from teak plantations in the mountains directly affects coral reefs. Besides that, sewage water is not being treated, thus affecting water quality. The community water association is trying to treat water with cost-effective solutions such as bioplanters and recover riparian buffers.

Sánchez-Noguera et al. (2018) present a study from 2010-2011 on water quality in Bahía Culebra. Using the geometric average of FC/100mL, Bahía Culebra obtained <1.8, corresponding to excellent water quality classification. The study concludes that Bahía Culebra has a high degree of sanitary quality in its coastal waters, which has been constant over time. In Bahía Culebra, the regulatory frameworks contributing to water quality come from the Touristic Pole Management Plan, which determines wastewater and solids recycling rules. However, the study highlights the importance of monitoring and access to information regarding compliance with the Management Plan.

There is a global gap in environmental policies for coral reef restoration projects (Westoby et al., 2020). Australia is now leading the path in this subject (Fidelman et al. 2019). Nevertheless, regulatory frameworks play a crucial role in translating scientific knowledge into basic restoration standards, mobilizing financial resources, and enabling environments for cooperation. Coral reef restoration legislation in Costa Rica is still in an initial phase but has effectively facilitated best practices and knowledge to restoration stakeholders.

5. Conclusions

We applied the SESF to identify the multiple social and ecological factors that potentially contribute to the successful ecological outcomes of three study cases evaluated on the Pacific coast of Costa Rica. The framework provided a structured way to compare factors across cases. To our knowledge, this is the first study to use this diagnostic tool on coral reef restoration projects. SESF proved relevant to studies that aim to explain how sustainable outcomes are achieved because it connects real issues related to the system of interest to the decision-making process at multiple levels.

Over the past eight years, Costa Rica has gathered much technical knowledge of coral reef restoration. However, most of this valuable knowledge, specifically regarding social aspects of project success projects, has not been shared with the scientific community. This study aims to contribute to the knowledge on coral reef restoration conducted in the ETP by analyzing three case studies. These projects were chosen due to their successful survival rates of coral fragments, project lifetime surpassing 18 months, and the active participation of local actors.

Our results show that even though projects have differences in governance structures, they have followed similar paths for achieving successful outcomes. Results illustrate that there are no universal solutions for effective restoration efforts. Critical enabling conditions for successful outcomes include local's having a positive perception both of coral reefs and project benefits to increase collective action and legitimate project governance. Positive perception can be built through educational outreach activities and locating projects near groups that are dependent of corals. Also, establishing network structures with both local and external actors aiming for a balance between science-related actors and community or commercial actors contributes to reducing project costs, increasing fragments in nurseries, and providing a skilled workforce for accurate ecological monitoring. Last, results showed that it is necessary to comply with a regulatory framework to control the causes of coral degradation and provide an enabling legal environment for coral restoration. These three factors have allowed the building of local capacities, increased environmental awareness,

and established responsible tourism activities that have helped generate local direct and indirect income while monitoring the ecological integrity of the coral fragments.

Regarding long-term sustainability challenges, we identified global ones, such as changes in the predictability of system dynamics due to climate change, which could affect survival rates. For projects to be prepared for these challenges, technology like under water temperature sensors and constant in-field monitoring is necessary to understand how corals react to stress events and what species or fragments are more resilient so they can be used as donors. National challenges include narrowing university or technical learning government institutions' funding, which could broadly compromise the ecological and technical monitoring of the restoration programs, especially in Bahía Culebra and Sámara. Projects must communicate their results in social and economic terms for high-level decision makers to understand the importance of funding this activity. Relevant metrics could include the number of jobs created or the revenue gathered through tourism or restoration activities.

Finally, at the local level, we found the challenge of reducing local causes of degradation, which requires interinstitutional coordination between the community, private sector, and government through marine spatial planning. Other challenges are more context- or governance-dependent; for example, science or NGO-led initiatives typically guarantee ecological integrity but fail to create local stewardship. For community and NGO-led initiatives, it´s important to diversify their funding to avoid failing to continue their activities. For all three projects, monitoring and researching which techniques or species are working better for their specific environmental conditions and the importance of sharing these results with the entire restoration community are essential. Also, for scientific purposes, the country should standardize the results reporting so that results can be comparable, which is an issue not only in Costa Rica but in the entire restoration community (Goergen et al., 2020; Shaver et al., 2020).

Standardizing coral reef restoration project reports will contribute to make projects more comparable between them and knowledge regarding best techniques or structures for growing corals or species resilience to stress events would be available for the reef restoration community to learn of. The three projects evaluated in this study have differences in the number of corals transplanted and the coral genus used that can influence the overall survival rate. That is why we included other aspects, such as project durability and local involvement, to determine project success and not focus only in ecological outcomes, but project overall performance. Also, all three projects continue to be implemented and thus are evolving continuously to solve the different challenges faced. Results shown here are statical, in a sense they reflect a specific period of each project. Coral reef restoration initiatives are still recent in Costa Rica; findings from this study contribute to providing insights for future restoration project design and implementation strategies that can reduce transaction costs hence making projects more cost-effective and appealing to a more significant number of stakeholders, especially during these times when the United Nations declared the Decade on Ecosystem Restoration (2020-2030) (Fischer et al., 2021).

6. References

Abdulla, A., Obura, D., Bertzky, B., & Shi, Y. (2014). Marine World Heritage: Creating a globally more balanced and representative list. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *24*(S2), 59–74. https://doi.org/10.1002/aqc.2527.

AIDA. (2012). *Los Arrecifes De Coral En Costa Rica: Valor Económico, Amenazas Y Compromisos Legales Internacionales Que Obligan a Protegerlos* (Vol. 1, Issue 1).

Alfaro EJ, Cortés J. 2012. Atmospheric forcing of cool subsurface water events in Bahia Culebra, Gulf of Papagayo, Costa Rica. Revista de Biologia Tropical 60:173–186 DOI 10.15517/RBT.V60I2.20001.

Alvarado,JJ., Aburto Oropeza, O., Abad, R., Barraza, E., Brandt, M., Cantera, J., Estrada, P., Gaymer, C., Guzmán-Mora, AG., Herlan, JJ., Maté, JL. (2017). Coral Reef Consrvation in the Eastern Tropical Pacific. In Enochs, I.C., & Glynn, P.W. (Eds.), Coral Refs of the Eastern Tropical Pacific. 8, 291-314. https://doi.org/10.1007/978-94-017-7499-4.

Alvarado, JJ., Beita-Jiménez, A., Mena, S., Fernández-García, C., & Guzmán-Mora, A. G. (2015). Ecosistemas coralinos del Área de Conservación Osa, Costa Rica: Estructura y necesidades de conservación. *Revista de Biologia Tropical*, *63*(April), 219–259. https://doi.org/10.15517/rbt.v63i1.23105

Alvarado, JJ., Fernandez, C., Nielsen, V. (2006). Arrecifes y Comunidades Coralinas. Capitulo V. *In.* Nielsen-Munoz, V., Quesada-Alpíar, MA. Ambientes Marino Costeros de Costa Rica :1-221.

Armstrong, E., Degnall, E., Obasare, R., Scott-Solomon, E. (2010). *Sedimentation in Mangrove Forests in Sámara, Costa Rica*.

Basurto, X., Gelcich, S., & Ostrom, E. (2013). The social-ecological system framework is a knowledge classificatory system for benthic small-scale fisheries. *Global Environmental Change*, *23*(6), 1366–1380. https://doi.org/10.1016/j.gloenvcha.2013.08.001.

Bayraktarov, E., Banaszak, A. T., Maya, P. M., Kleypas, J., Arias-Gonzalez, J. E., Blanco, M., Calle-Triviño, J., Charuvi, N., Cortes-Useche, C., Galvan, V., Salgado, M. A. G., Gnecco, M., Guendulain-Garcia, S. D., Delgado, E. A. H., Moraga, J. A. M., Maya, M. F., Quiroz, S. M., Cervantes, S. M., Morikawa, M., … Frias-Torres, S. (2020). Coral reef restoration efforts in latin American countries and territories. *PLoS ONE*, *15*(8 August), 1–19. https://doi.org/10.1371/journal.pone.0228477

Bayraktarov, E., Stewart-Sinclair, P. J., Brisbane, S., Boström-Einarsson, L., Saunders, M. I., Lovelock, C. E., Possingham, H. P., Mumby, P. J., & Wilson, K. A. (2019). Motivations, success, and cost of coral reef restoration. *Restoration Ecology*, *27*(5), 981–991. https://doi.org/10.1111/rec.12977.

Bennett, N. J. (2016). Using perceptions as evidence to improve conservation and environmental management. *Conservation Biology*, *30*(3), 582–592. https://doi.org/10.1111/cobi.12681

Bernard, H.R. (2006) Research Methods in Anthropology. Qualitative and Quantitative Approaches. Altamira Press, Lanham.

Boström-Einarsson L, Babcock RC, Bayraktarov E, Ceccarelli D, Cook N, Ferse SCA, et al. (2020) Coral restoration – A systematic review of current methods, successes, failures and future directions. PLoS ONE 15(1): e0226631. https://doi.org/10.1371/journal.pone.0226631.

Bottema, M. J. M., & Bush, S. R. (2012). The durability of private sector-led marine conservation: A case study of two entrepreneurial marine protected areas in Indonesia. *Ocean and Coastal Management*, *61*, 38–48. https://doi.org/10.1016/j.ocecoaman.2012.01.004

Burke, L., & Maidens, J. (2004). Reefs at Risk in the Caribbean. *National Geographic*, 80. http://pdf.wri.org/reefs_caribbean_front.pdf.

Burke, L., Reytar, K., Spalding, M., Perry, A. (2011). Reefs at Risk Revisited. World Resources Institute, Washington, DC, USA.

Center for Responsible Travel. (2013). Un retrato de la realidad económica en Nosara y Sámara: Proporcionando las herramientas para el Desarrollo Sostenible. https:// www.responsibletravel.org CREST.

Christie, P., & White, A. T. (2007). Best practices for improved governance of coral reef marine protected areas. *Coral Reefs*, *26*(4), 1047–1056. https://doi.org/10.1007/s00338-007-0235-9.

Cinner, J. E., Huchery, C., MacNeil, M. A., Graham, N. A. J., McClanahan, T. R., Maina, J., Maire, E., Kittinger, J. N., Hicks, C. C., Mora, C., Allison, E. H., D'Agata, S., Hoey, A., Feary, D. A., Crowder, L., Williams, I. D., Kulbicki, M., Vigliola, L., Wantiez, L., … Mouillot, D. (2016). Bright spots among the world's coral reefs. *Nature*, *535*(7612), 416–419. https://doi.org/10.1038/nature18607.

Cinner, J. E., McClanahan, T. R., MacNeil, M. A., Graham, N. A. J., Daw, T. M., Mukminin, A., Feary, D. A., Rabearisoa, A. L., Wamukota, A., Jiddawi, N., Campbell, S. J., Baird, A. H., Januchowski-Hartley, F. A., Hamed, S., Lahari, R., Morove, T., & Kuange, J. (2012). Comanagement of coral reef social-ecological systems. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(14), 5219–5222. https://doi.org/10.1073/pnas.1121215109.

Cinner, J. E., and Pollnac, R. B. (2004). Poverty, perceptions and planning: Why socioeconomics matter in the management of Mexican reefs. *Ocean and Coastal Management*, *47*(9–10), 479–493. https://doi.org/10.1016/j.ocecoaman.2004.09.002

Clewell, A. F., & Aronson, J. (2006). *Motivations for the Restoration of Ecosystems*. *20*(2), 420–428. https://doi.org/10.1111/j.1523-1739.2006.00340.x

Cortés, J. (1990). The coral reefs of Golfo Dulce, Costa Rica: distribution and community structure, en Atoll Res. Bull. 344.

Cortés, J., & Jiménez, C. E. (2003). Corals and coral reefs of the Pacific of Costa Rica: history, research and status. In Cortés, J. (Ed.), Latin American Coral Reefs. (pp. 361-385). Amsterdam: Elsevier Science B.V

Cortés, J., Jiménez, C. E., Fonseca, A. C., & Alvarado, J. J. (2010). Status and conservation of coral reefs in Costa Rica. *Revista de Biologia Tropical*, *58*(SUPPL. 1), 33–50. https://doi.org/10.15517/rbt.v58i1.20022

Cox, M. (2011). Advancing the diagnostic analysis of environmental problems. International Journal of the Commons 5, 346–363.

Creswell, J. W. (2014). Research Design: Qualitative, Quantitative and Mixed Methods Approaches (4th ed.). Thousand Oaks, CA: Sage.

DeAngelis, B. M., Sutton-Grier, A. E., Colden, A., Arkema, K. K., Baillie, C. J., Bennett, R. O., Benoit, J., Blitch, S., Chatwin, A., Dausman, A., Gittman, R. K., Greening, H. S., Henkel, J. R., Houge, R., Howard, R., Hughes, A. R., Lowe, J., Scyphers, S. B., Sherwood, E. T., … Grabowski, J. H. (2020). Social factors key to landscape-scale coastal restoration: Lessons learned from three U.S. case studies. *Sustainability (Switzerland)*, *12*(3). https://doi.org/10.3390/su12030869

DeCaro, D. A., & Stokes, M. K. (2013). Public participation and institutional fit: A social-psychological perspective. *Ecology and Society*, *18*(4). https://doi.org/10.5751/ES-05837-180440

Delgado-Serrano, M. del M., & Ramos, P. A. (2015). Making Ostrom's framework applicable to characterise social ecological systems at the local level. *International Journal of the Commons*, *9*(2), 808–830. https://doi.org/10.18352/ijc.567.

Diedrich, A. (2007). The impacts of tourism on coral reef conservation awareness and support in coastal communities in Belize. *Coral Reefs*, *26*(4), 985–996. https://doi.org/10.1007/s00338-007-0224-z

Eddy, T. D., Lam, V. W. Y., Reygondeau, G., Cisneros-Montemayor, A. M., Greer, K., Palomares, M. L. D., Bruno, J. F., Ota, Y., & Cheung, W. W. L. (2021). Global decline in capacity of coral reefs to provide ecosystem services. *One Earth*, *4*(9), 1278–1285. https://doi.org/10.1016/j.oneear.2021.08.016.

Fargier, L., Hartmann, H. J., & Molina-Ureña, H. (2014). Marine Areas of Resposible Fishing: A path towards small-scale fisheries co-management in Costa Rica? Perspectives from Golfo Dulce. In Amezcua, F., & Bellgraph, B. (Eds.), *Fisheries Management of Mexican and Central American Estuaries*. (pp. 155-180). Dordrecht, The Netherlands: Springer Science + Business Media

Fidelman, P., McGrath, C., Newlands, M., Dobbs, K., Jago, B., & Hussey, K. (2019). Regulatory implications of coral reef restoration and adaptation under a changing climate. *Environmental Science and Policy*, *100*(March), 221–229. https://doi.org/10.1016/j.envsci.2019.04.016

Fischer, J., Riechers, M., Loos, J., Martin-Lopez, B., & Temperton, V. M. (2021). Making the UN Decade on Ecosystem Restoration a Social-Ecological Endeavour. *Trends in Ecology and Evolution*, *36*(1), 20–28. https://doi.org/10.1016/j.tree.2020.08.018

Fournier, M., Castillo, L., Ramírez, F., Moraga, G., & Ruepert, C. (2019). Evaluación preliminar del área agrícola y su influencia sobre la calidad del agua en el Golfo Dulce, Costa Rica. *Revista De Ciencias Ambientales*, *53*(1), 92-112. https://doi.org/10.15359/rca.53-1.5

Frey, J. B., & Berkes, F. (2014). Can partnerships and community-based conservation reverse the decline of coral reef social-ecological systems? *International Journal of the Commons*, *8*(1), 26. https://doi.org/10.18352/bmgn-lchr.408.

Frey, U. J., & Cox, M. (2015). Building a diagnostic ontology of social-ecological systems. *International Journal of the Commons*, *9*(2), 595–618. http://doi.org/10.18352/ijc.505

Goergen, E. A., Schopmeyer, S., Moulding, A. L., Moura, A., Kramer, P., & Viehman, T. S. (2020). *Coral reef restoration monitoring guide: Methods to evaluate restoration success from local to ecosystem scales. NOAA Technical Memorandum NOS NCCOS 279. Silver Spring, MD. September*, 145. https://doi.org/10.25923/xndz-h538

Goreau, T.J. & W. Hilbertz. 2008. Bottom-up communitybased coral reef and fisheries restoration in Indonesia, Panama, and Palau, p. 143-159. In R. France (ed.). Handbook of Regenerative Landscape Design. CRC, Boca Raton, Florida., USA.

Harriot VJ. & Fisk DA.(1988). Coral transplantation as a reef management option. Proceedings of the Sixth International Coral Reef Symposium, vol. 2. p. 375–9.

Hein, M., McLeod, I. M., Shaver, E., Vardi, T., Pioch, S., Boström-Einarsson, L., Ahmed, M., & Grimsditch, G. (2020). Coral reef restoration as a strategy to improve ecosystem services - A guide to coral restoration methods. *Ecological Engineering*, 345–364.

Hein, M. Y., Birtles, A., Willis, B. L., Gardiner, N., Beeden, R., & Marshall, N. A. (2019). Coral restoration: Socio-ecological perspectives of benefits and limitations. *Biological Conservation*, *229*(June 2018), 14–25. https://doi.org/10.1016/j.biocon.2018.11.014

Hein, M. Y., Willis, B. L., Beeden, R., & Birtles, A. (2017). The need for broader ecological and socioeconomic tools to evaluate the effectiveness of coral restoration programs. *Restoration Ecology*, *25*(6), 873–883. https://doi.org/10.1111/rec.12580

Hesley, D., Burdeno, D., Drury, C., Schopmeyer, S., & Lirman, D. (2017). Citizen science benefits coral reef restoration activities. *Journal for Nature Conservation*, *40*, 94–99. https://doi.org/10.1016/j.jnc.2017.09.001

Honey, M., Vargas, E., & Durham, W. H. (2010). Impact of Tourism Related Development on the Pacific Coast of Costa Rica. *Organization*, *April 2010*, 1–114. www.responsibletravel.org

Hsieh, H.-F., & Shannon, S. E. (2005). Three Approaches to Qualitative Content Analysis. *Qualitative Health Research*, *15*(9), 1277–1288. https://doi.org/10.1177/1049732305276687

Hughes, T. P., Graham, N. A. J., Jackson, J. B. C., Mumby, P. J., & Steneck, R. S. (2010). Rising to the challenge of sustaining coral reef resilience. *Trends in Ecology and Evolution*, *25*(11), 633–642. https://doi.org/10.1016/j.tree.2010.07.011

INEC. (2011). Costa Rica: Población total por grupos de edad, según provincia, cantón y sexo. https://inec.cr/estadisticas-fuentes/censos.

Jiménez, C. (2001). Arrecifes y ambientes coralinos de Bahía Culebra, Pacífico de Costa Rica: aspectos biológicos, económico-recreativos y de manejo. *Revista de Biología Tropical*, 49 (Suplemento 2), 215-231.

Johnson, M. E., C. Lustic, E. Bartels, I. B. Baums, D. S. Gilliam, L. Larson, D. Lirman, M. W. Miller, K. Nedimyer, S. Schopmeyer. (2011). Caribbean Acropora Restoration Guide: Best Practices for Propagation and Population Enhancement. The Nature Conservancy, Arlington, VA.

Kittinger, J. N., Bambico, T. M., Minton, D., Miller, A., Mejia, M., Kalei, N., Wong, B., & Glazier, E. W. (2016). Restoring ecosystems, restoring community: socioeconomic and cultural dimensions of a community-based coral reef restoration project. *Regional Environmental Change*, *16*(2), 301–313. https://doi.org/10.1007/s10113-013-0572-x.

Kittinger, J. N., Finkbeiner, E. M., Glazier, E. W., & Crowder, L. B. (2012). Human dimensions of coral reef social-ecological systems. *Ecology and Society*, *17*(4). https://doi.org/10.5751/ES-05115-170417

Lamont, T. A. C., Razak, T. B., Djohani, R., Janetski, N., Rapi, S., Mars, F., & Smith, D. J. (2022). Multi-dimensional approaches to scaling up coral reef restoration. *Marine Policy*, *143*(June), 105199. https://doi.org/10.1016/j.marpol.2022.105199

Leslie, H. M., Basurto, X., Nenadovic, M., Sievanen, L., Cavanaugh, K. C., Cota-Nieto, J. J., Erisman, B. E., Finkbeiner, E., Hinojosa-Arango, G., Moreno-Báez, M., Nagavarapu, S., Reddy, S. M. W., Sánchez-Rodríguez, A., Siegel, K., Ulibarria-Valenzuela, J. J., Weaver, A. H., & Aburto-Oropeza, O. (2015). Operationalizing the social-ecological systems framework to assess sustainability. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(19), 5979–5984. https://doi.org/10.1073/pnas.1414640112

Liburd, J. J., & Becken, S. (2017). Values in nature conservation, tourism and UNESCO World Heritage Site stewardship. *Journal of Sustainable Tourism*, *25*(12), 1719–1735. https://doi.org/10.1080/09669582.2017.1293067

Lirman D, Schopmeyer S.2016.Ecological solutions to reef degradation: optimizing coral reef restoration in the Caribbean and Western AtlantiC.*PeerJ* 4:e2597https://doi.org/10.7717/peerj.2597

Manzello, D. P. (2010). Coral growth with thermal stress and ocean acidification: Lessons from the eastern tropical Pacific. *Coral Reefs*, *29*(3), 749–758. https://doi.org/10.1007/s00338-010-0623-4.

Maxwell, J. (2014). Designing a Qualitative Study. In *The SAGE Handbook of Applied Social Research Methods* (Issue July). https://doi.org/10.4135/9781483348858.n7

Mayring, P. (2000). Qualitative Content Analysis. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *1*(2). https://doi.org/10.17169/fqs-1.2.1089

Meyers, R. (2017). An aesthetics of resilience: design and agency in contemporary coral restoration. *Resilience*, *5*(3), 201–221. https://doi.org/10.1080/21693293.2016.1241477.

McGinnis, M. D., & Ostrom, E. (2014). Social-ecological system framework: Initial changes and continuing challenges. *Ecology and Society*, *19*(2). https://doi.org/10.5751/ES-06387-190230

Moberg, F., & Rönnbäck, P. (2003). Ecosystem services of the tropical seascape: Interactions, substitutions and restoration. *Ocean and Coastal Management*, *46*(1–2), 27–46. https://doi.org/10.1016/S0964-5691(02)00119-9

Morales-Ramírez, Á. (2011). La diversidad marina del golfo dulce, pacífico sur de costa rica: amenazas a su conservación. *Biocenosis*, *24*, 9–20.

Mumby, P. J., A. J. Edwards, J. E. Arias-González, K. C. Lindeman, P. G. Blackwell, A. Gall, M. I. Gorczynska, A. R. Harborne, C. L. Pescod, and H. Renken. 2004a. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature 427:533-536

Nielsen, R. A. (2016). Case Selection via Matching. *Sociological Methods and Research*, *45*(3), 569–597. https://doi.org/10.1177/0049124114547054

Palomo, L. E., & Hernández-Flores, A. (2019). Application of the Ostrom framework in the analysis of a social-ecological system with multiple resources in a marine protected area. *PeerJ*, *2019*(8). https://doi.org/10.7717/peerj.7374

Partelow, S. (2018). A review of the social-ecological systems framework: Applications, methods, modifications, and challenges. *Ecology and Society*, *23*(4). https://doi.org/10.5751/ES-10594-230436

Partelow, S., & Nelson, K. (2020). Social networks, collective action and the evolution of governance for sustainable tourism on the Gili Islands, Indonesia. *Marine Policy*, *112*(August), 0–1. https://doi.org/10.1016/j.marpol.2018.08.004

Partelow, S., Senff, P., Buhari, N., & Schlüter, A. (2018). Operationalizing the social-ecological systems framework in pond aquaculture. *International Journal of the Commons*, *12*(1), 485–518. https://doi.org/10.18352/ijc.834

Pollnac, R., Christie, P., Cinner, J. E., Dalton, T., Daw, T. M., Forrester, G. E., Graham, N. A. J., & McClanahan, T. R. (2010). Marine reserves as linked social-ecological systems. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(43), 18262–18265. https://doi.org/10.1073/pnas.0908266107

Poteete, A. R., & Ostrom, E. (2004). Heterogeneity, group size and collective action: The role of institutions in forest management. *Development and Change*, *35*(3), 435–461. https://doi.org/10.1111/j.1467-7660.2004.00360.x

Pretty J. (2003). Social capital and the collective management of resources. *Science (New York, N.Y.)*, *302*(5652), 1912–1914. https://doi.org/10.1126/science.1090847

Okubo, N., & Onuma, A. (2015). An economic and ecological consideration of precommercial coral transplantation to restore the marine ecosystem in Okinawa, Japan. *Ecosystem Services*, *11*(November), 39–44. https://doi.org/10.1016/j.ecoser.2014.07.009.

Olson, M. (1965). The Logic of Collective Action: Public Goods and the Theory of Groups. Harvard University Press, Cambridge, MA.

Ostrom, E. (2007). A diagnostic approach for going beyond panaceas. *Proceedings of the*

National Academy of Sciences of the United States of America, *104*(39), 15181–15187. https://doi.org/10.1073/pnas.0702288104

Ostrom, E. (2009). Collective Action Theory. *The Oxford Handbook of Comparative Politics*, *May 2018*, 1–26. https://doi.org/10.1093/oxfordhb/9780199566020.003.0008

Quesada-Alpízar, M.A., & Cortés, J. (2006). Los ecosistemas marinos del Pacífico sur de Costa Rica: estado del conocimiento y perspectivas del manejo. *Revista de Biología Tropical*, 54 (Suplemento 1), 101-145

Quigley, K. M., Hein, M., & Suggett, D. J. (2022). Translating the 10 golden rules of reforestation for coral reef restoration. *Conservation Biology*, *December 2021*, 1–8. https://doi.org/10.1111/cobi.13890

Reyes-Bonilla, H., Alvarado, J. J., Smith, F., Cortés, J., Zapata, F. A., Rivera, F., Ayala-Bocos, A., Friedlander, A., Quimbayo, J. P., Olivier, D., Martínez, P., Millán, A. M., Araya, T., Arriaga, A., Olán, M., Pérez-Matus, A., & Evie, W. (2020). Status and trends of coral reefs of the Eastern Tropical Pacific. *Status of Coral Reefs of the World: 2020*, 1–13

Rinkevich, B. (2015). Climate change and active reef restoration-ways of constructing the "Reefs of Tomorrow." *Journal of Marine Science and Engineering*, *3*(1), 111–127. https://doi.org/10.3390/jmse3010111

Rogers, A., Harborne, A. R., Brown, C. J., Bozec, Y. M., Castro, C., Chollett, I., Hock, K., Knowland, C. A., Marshell, A., Ortiz, J. C., Razak, T., Roff, G., Samper-Villarreal, J., Saunders, M. I., Wolff, N. H., & Mumby, P. J. (2015). Anticipative management for coral reef ecosystem services in the 21st century. *Global Change Biology*, *21*(2), 504–514. https://doi.org/10.1111/gcb.12725

Román, M. y Angulo, J. 2013. Panorama socioeconómico de los cantones de Osa y Golfito: tendencias y desafíos para el desarrollo sostenible. San José, Costa Rica: INOGO, Stanford Woods Institute for the Environment, Febrero, 2013.

Sánchez-Noguera, C. (2012). Entre historias y culebras: más que una bahía (Bahía Culebra, Guanacaste, Costa Rica). *Revista de Biología Tropical*, 60 (Suplemento 2), 1-17.

Sánchez-Noguera, C., Jiménez, C., & Cortés, J. (2018). Desarrollo costero y ambientes marino-costeros en Bahía Culebra, Guanacaste, Costa Rica. *Revista de Biología Tropical*, *66*(1–1), 309. https://doi.org/10.15517/rbt.v66i1.33301

Seawnght, J., & Gerring, J. (2008). Case selection techniques in case study research: A menu of qualitative and quantitative options. *Political Research Quarterly*, *61*(2), 294–308. https://doi.org/10.1177/1065912907313077

Sentence No 2013–10540. 2013. Constitutional Chamber of the Supreme Court of Justice. August 7th 2013.

Shaver, E. C., Courtney, C. A., West, J. M., Maynard, J., Hein, M., Wagner, C., Philibotte, J., MacGowan, P., McLeod, I., Boström-Einarsson, L., Bucchianeri, K., Johnston, L., & Koss, J. (2020). *A manager 's guide to coral reef restoration planning and design. NOAA Coral Reef Conservation Program. NOAA Technical Memorandum CRCP 36*.

128.

SINAC-GIZ. (2020). Protocolo para la restauración de arrecifes y comunidades coralinas de Costa Rica. San José, Costa Rica.

Spalding, Mark & Ravilous, C & Green, E. (2001). World Atlas of Coral Reefs. University of California Press.

Souter, D., Planes, S., Wicquart, J., Logan, M., Obura, D., & Staub, F. (2020). *Status of Coral Reefs of the World: 2020 Executive Summary INTERNATIONAL CORAL REEF INITIATIVE*.

Suding K, Higgs E, Palmer M, Callicott JB, Anderson CB, Baker M, Gutrich JJ, Hondula KL, LaFevor MC, Larson BMH, Randall A, Ruhl JB, Schwartz KZS (2015) Committing to ecological restoration. Science, 348, 638-640.

The Resilience Alliance. (2010). Assessing resilience in social-ecological systems: Workbook for practitioners. *Resilience Alliance*, *January*, 54. http://www.resalliance.org/3871.php.

Torres-Guevara, L. E., Lopez, M. C., & Schlüter, A. (2016). Understanding artisanal fishers' behaviors: The case of Ciénaga Grande de Santa Marta, Colombia. *Sustainability (Switzerland)*, *8*(6), 1–17. https://doi.org/10.3390/su8060549

Trialfhianty, T. I., & Suadi. (2017). The role of the community in supporting coral reef restoration in Pemuteran, Bali, Indonesia. *Journal of Coastal Conservation*, *21*(6), 873–882. https://doi.org/10.1007/s11852-017-0553-1

Uribe-Castañeda, N., Newton, A., & Tissier, M. Le. (2018). Coral Reef socio-ecological systems analysis & restoration. *Sustainability (Switzerland)*, *10*(12), 1–11. https://doi.org/10.3390/su10124490

Valverde Sanchez, R. (2018). Conservation Strategies, Protected Areas, and Ecotourism in Costa Rica. *Journal of Park and Recreation Administration*, *36*(3), 115–128. https://doi.org/10.18666/jpra-2018-v36-i3-8355

Van Diggelen, R., Grootjans, A. P., & Harris, J. A. (2001). Ecological restoration: State of the art or state of the science? *Restoration Ecology*, *9*(2), 115–118. https://doi.org/10.1046/j.1526-100X.2001.009002115.x

Villalobos-Cubero, T. 2019. Manejo integrado y restauración ecológica de los arrecifes y comunidades coralinas de Golfo Dulce, Pacífico Sur, Costa Rica. Tesis de Maestría Académica en Gestión Integrada de Áreas Costeras Tropicales, Universidad de Costa Rica, Costa Rica.

Wenger, A., Ahmadia, G., Álvarez-Romero, J. G., Barnes, M., Blythe, J. L., Brodie, J., Darling, E. (2019). Coral Reef Conservation Solution-Scape White Paper. https://doi.org/10.31230/OSF.IO/YD4ZG

Westoby, R., Becken, S., & Laria, A. P. (2020). Perspectives on the human dimensions of coral restoration. *Regional Environmental Change*, *20*(4). https://doi.org/10.1007/s10113-020-01694-7

Wildlife Conservation Society. (2022). Coral Reef Governance : Strengthening Community and Collaborative Approaches. February.

Wyborn, C., & Bixler, R. P. (2013). Collaboration and nested environmental governance: Scale dependency, scale framing, and cross-scale interactions in collaborative conservation. *Journal of Environmental Management*, *123*, 58–67. https://doi.org/10.1016/j.jenvman.2013.03.014

Yeemin, T., Sutthacheep, M., & Pettongma, R. (2006). Coral reef restoration projects in Thailand. *Ocean and Coastal Management*, *49*(9–10), 562–575. https://doi.org/10.1016/j.ocecoaman.2006.06.002