Fachhochschule Köln
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UNIVERSIDAD AUTÓNOMA
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UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ
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PROGRAMAS MULTIDISCIPLINARIOS DE POSGRADO EN CIENCIAS AMBIENTALES

AND

COLOGNE UNIVERSITY OF APPLIED SCIENCES
INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

RESILIENCE IN SANTA CRUZ DEL ISLOTE: SUSTAINABILITY OF A SOCIAL-ECOLOGICAL SYSTEM IN THE COLOMBIAN CARIBBEAN

THESIS TO OBTAIN THE DEGREE OF

MAESTRÍA EN CIENCIAS AMBIENTALES
DEGREE AWARDED BY
UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

AND

MASTER OF SCIENCE
TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS
IN THE SPECIALIZATION: RESOURCES MANAGEMENT
DEGREE AWARDED BY COLOGNE UNIVERSITY OF APPLIED SCIENCES

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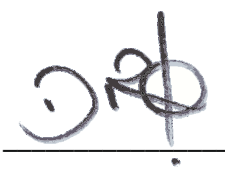
Unterschrift / *Firma*: 

RESILIENCE IN SANTA CRUZ DEL ISLOTE:

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A Papá y Mamá

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ABSTRACT

Santa Cruz del Islote situated in the Colombian Caribbean Sea embodies the tight coupling and interdependence between strong social and ecological sub-systems in a day-to-day context. While internal whole system relationships appear dynamic, where both components benefit and/or harm each other in a seemingly balanced manner, small but crucial events could threaten the whole system and trigger absolute failure.

The key components of this Social-Ecological System or SES are a remote, deep-rooted fishing community and an endangered ecosystem complex in the ocean and surrounding islands, upon which this community depends. Their interaction is mainly driven by human appropriation of the goods and services provided by the ecosystem and the environmental impacts caused by their use.

This is distant to what collective imaginary dictates an island in the Caribbean should be like; this islet exhibits at a small scale what alarms the world at a global scale today: destruction of coastal and marine ecosystems, slum settlements, food insecurity, loss of social cohesion, vulnerability of coastal communities to climatic events and conflicts over commons; and what alarms Colombia specifically: extreme poverty, loss of sovereignty, unemployment and illegal drug trade.

A resilience assessment was conducted to understand how capable this complex system is in maintaining its functions and identity under the influence of external disturbances; how much it can reorganize and learn; how close it has been to thresholds of radical change and what strategies can be adopted to move to and maintain the system in a desirable state - if it is at all possible.

From said assessment it was possible to conclude the SES is highly complex and is currently in a phase of rigidness (K phase); proximate to a threshold of collapse. However, the components of the system are resilient enough to induce a controlled breakdown and reorganize structure and interactions in a renewed, more desirable regime.

KEYWORDS: Resilience assessment; Social-ecological systems; isolated communities; Sustainability; Thresholds.

RESUMEN

Santa Cruz del Islote, situado en el Mar Caribe Colombiano, representa el acoplamiento y la interdependencia entre un sub-sistema social y uno ecológico en un contexto diario. Aunque las relaciones sistémicas internas son aparentemente dinámicas, donde ambos componentes se benefician y/o perjudican mutuamente en una manera balanceada; un evento pequeño pero crucial podría amenazar al sistema con la degradación total.

Los componentes claves de este Sistema Socio-Ecológico son una remota comunidad pesquera de gran arraigo; y los ecosistemas amenazados en el océano e islas circundantes, de los que la comunidad depende. Dicha interacción es regida especialmente por la apropiación de bienes y servicios provistos por los ecosistemas y los impactos causados por el uso.

Aunque alejado de lo que el imaginario colectivo dicta sobre cómo debe ser una isla en el Caribe; el islote representa a pequeña escala problemas que alarman al mundo de hoy: la destrucción de ecosistemas marinos y costeros, los asentamientos informales, la inseguridad alimentaria, la degradación del tejido social, la vulnerabilidad de comunidades costeras a eventos climáticos y los conflictos sobre los comunes; así como a Colombia específicamente como la pobreza extrema, la pérdida de soberanía, el desempleo y el narcotráfico.

Una evaluación de la resiliencia se llevó a cabo con el fin de entender cuán capaz es este sistema complejo de mantener sus funciones e identidad a través de las perturbaciones, qué tanto puede reorganizarse y aprender; cuán cerca está de un umbral que lo empuje a una trasformación radical y qué estrategias pueden usarse para moverlo y mantenerlo en un estado deseable, si es que ello es del todo posible.

De dicha evaluación fue posible concluir que el Sistema Socio Ecológico es altamente complejo y se encuentra actualmente en una fase de rigidez (o fase K); próximo a un umbral de colapso. Sin embargo, los componentes del sistema son lo suficientemente resilientes para inducir un colapso controlado y reorganizar la estructura e interacciones en un nuevo y más deseable régimen.

PALABRAS CLAVE: Evaluación de resiliencia; Sistemas Socio-Ecológicos; Comunidades aisladas; Sustentabilidad; Umbrales.

INTRODUCTION

A Social Ecological System (SES) is the coupling between a social and an ecological sub-system that feedback on each other as a natural result of their interaction. SESs belong to the category of complex systems; they show characteristics of non-linearity, emergent properties, cross-scale interactions and self-organization (Berkes & Folke 1998, Berkes et al. 2003). The feedbacks between the two sub-systems make the system highly dynamic such that it becomes hardly predictable. Some of them can make the system vulnerable while others may give it permanency in time or sustainability in a broad sense of the term. This responds to the existence of a system property called resilience (Holling, 1973, 1996; Gunderson, 2000; Gunderson et al. 2002; Berkes et al. 2003; Folke, 2006; Walker et al. 2006, 2008; Resilience Alliance, 2007, 2010; Folke et al. 2010; Cumming, 2011;)

System resilience is a fundamental property of complex systems. It refers to the capacity of a system to **buffer changes caused by external disturbances without losing its structure, functions and feedback mechanisms; that is to conserve its identity within a range of biophysical, social, economic and cultural options** (Resilience Alliance, 2007, 2010). It means not to become static but stable, and ultimately coming to be sustainable. Whether being exposed to sudden shocks and/or surprises or to sustaining incremental shifts, trying to preserve resilient system characteristics requires management strategies that increase diversity and thus future options.

Islands have always been considered laboratories for analysis and observation thanks to their obvious spatial delimitation; thus presenting certain advantage to follow up on different processes occurring within their boundaries; however from a SES approach these boundaries become fuzzy because islands, especially small and remote ones rely heavily on all kinds of subsidies to maintain their functions. The islands in the Archipelago of San Bernardo, Department of Sucre in the Colombian Caribbean are socially interconnected with tight links that go very far in history, probably for the distance that keep them remote to mainland; making them interdependent both in ecological and social terms.

In that sense, in order to assess the resilience of a SES, all main components must be included in the study. Therefore, while the main focus of this research is on the artificially enlarged islet: Santa Cruz del Islote, considered the most important socio-economic and demographic center for natives on the Archipelago; two more islands are included: Múcura and Tintipán. These are taken into consideration as their ecosystems strongly support the fishing community living in the area, together with the marine ecosystems surrounding the three emerged lands. These four elements will be termed in this research **The Santa Cruz Complex** (SCC-SES) to differentiate it from the islet.

The SCC-SES has proven up until today that it possesses the ability i) to support an ever-growing population; ii) to show enough flexibility to adapt to critical changes like becoming part of a Protected Marine Area; iii) to face numerous challenges for resources management; and iv) to thrive far from the mainland being ignored by the central Colombian government. However, considering sea level is rising, oceans acidifying and warming, climate changing, biodiversity declining, pollution increasing, urbanization and globalization expanding at rapid rates and human interactions focusing more and more on telecommunication, it is important to try to detect how much of these disturbances the SCC-SES can buffer before crossing a threshold to a point of no return.

TERMINOLOGY

Some terms used throughout this document are also commonly used in other disciplines to designate different concepts. These are defined below as used for the study of SESs in order to set a general common background and avoid misinterpretations.

Adaptability (or adaptive capacity): "The capacity of actors in a system to influence resilience" (Folke et al., 2010).

Basin of attraction: It is equivalent to a system regime, a stability domain or the configuration where the system is stable. In the basin of attraction "the dimensions are defined by the set of controlling variables that have threshold levels" (Folke et al., 2010).

Desirable regime: "The way society (in general or a particular segment) regards the flows of goods and services from one regime of a system in contrast to an alternative regime. One segment of society may regard a particular regime as desirable while another may not". For induced transformations of the SES it is necessary to establish first what the desirable regime is. (Resilience Alliance, 2007)

Global change: "It refers to the remarkable change in the human-environment relationship that has occurred over the last few centuries (...) in a wide range of global scale phenomena: population; the economy, including magnitude and distribution; resource use, especially for production of energy; transport and communication; land use and land cover; urbanization; globalization; coastal ecosystems; atmospheric composition; riverine flow; the nitrogen cycle; the carbon cycle; the physical climate; marine food chains; and biological diversity. It is important to note that the linkages and interactions between these various changes are also part of global change and are just as important as the individual changes themselves. Another feature of global change is that many changes do not occur in linear fashion but rather exhibit strong nonlinearities" (Steffen et al. 2004).

Scenario: "It is not a prediction of the future. It is a possible, plausible future that might arise under certain circumstances. A set of scenarios that bracket the range of possible futures is a useful tool for examining the kinds of processes and dynamics that could lead to a SES developing along particular trajectories" (Resilience Alliance, 2007).

Regime and regime-shift: "Regime is the set of states that define a domain of attraction (Scheffer and Carpenter 2003). In a regime the system has the same essential structure, function, feedbacks and, therefore, identity (Walker et al 2004). A regime shift occurs when a system crosses a threshold into an alternate domain of attraction" (Resilience Alliance, 2007).

Transformability: "Capacity to transform the stability landscape itself in order to become a different kind of system, to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable". Induced and active transformation is not the same as forced transformation which is not "introduced deliberately by the actors" (Folke et al., 2010).

STRUCTURE OF THIS DOCUMENT

The following document will be divided into seven chapters:

Chapter 1 Project Basics will give the reader a general understanding of the central issue of the research, that is the process of assessing the level of resilience of the SCC-SES; why is important to assess it and the methodology used here to do it.

Chapter 2 Theoretical and conceptual frameworks describes in depth how SESs work linking their purpose to Fundamental Human Needs; it gives basic notions of the Resilience Theory, reflecting on how it is connected to the Sustainability paradigm and building from it a conceptual structure to assess resilience in the study case.

Chapter 3 Case study presents the area under study and makes a general description of the conflicts inside the SCC-SES.

Chapter 4 Definition of the emerging system introduces the first part of the results of the research by defining the boundaries of the SES, describing spatial scales and the variables of concern for the actors. A diagnostic of the interactions crossing hierarchical spatial scales is developed to detect the level of coupling between sub-systems.

Chapter 5 Dynamics of the emerging system presents a temporal analysis identifying the drivers and disturbances detected for the system in different eras of its history as well as the patterns of change observed.

Chapter 6 Assessing resilience in the Santa Cruz Complex shows an analysis of resilience indicators applicable in this study; an assessment of said indicators and the conclusion about the type of management strategy the system requires according to the resilience thinking.

Chapter 7 Conclusions will present a discussion on the data analyzed and interpreted, answering the research questions and describing the suggested bases for future work.

CHAPTER 1
PROJECT BASICS

SECTION 1

GENERAL CONTEXT

Apparently Santa Cruz del Islote is the most densely populated island in the world (See Chapters 3 and 4 for details). This is very difficult to establish due to the high mobility and seasonal fluctuation of its population; even though the high density of its slum-like dwellings is clearly visible. With no beach and no vegetation the islet appears to be what it is called (See Fig. 1), but this does not mean a record like that would be a general known fact to Colombians.

Fig.1 Santa Cruz del Islote, Archipelago of San Bernardo. Source: https://sites.google.com/site/grupoecologicodelislote/ubicacion-geografica-del-islote

Just as recent as 2006, wide-reaching media like SOHO Magazine (Caparrós, 2006), National Geographic Magazine (Rubiano & Olson, 2010) and the national cultural television channel Señal Colombia in 2010 (La lleva, 2010), published reports on the islet, that were followed later on by several more articles in internet blogs and mainstream national and international media. The history of this settlement however, dates back to 1820 (La Gran Colombia) and around the mid-nineties the original huts were upgraded to more durable materials transforming approximately into the settlement it is today.

Additionally, it is closely surrounded by touristic islands and since 1996 it is part of the National Natural Park Corales del Rosario and San Bernardo. Why then, was this peculiarity on the Caribbean so unknown until recently?
Perhaps the answer lies again in the worst face of the Colombian reality: armed conflict and illicit drug trade. After a decade (1990-2000) of increasing terror on the population with a civil war that included direct attacks on rural and urban civilians (See Fig. 2). It is not surprising that tourism in Colombia both national and international was one of the worst economic activities to be developed at the time.

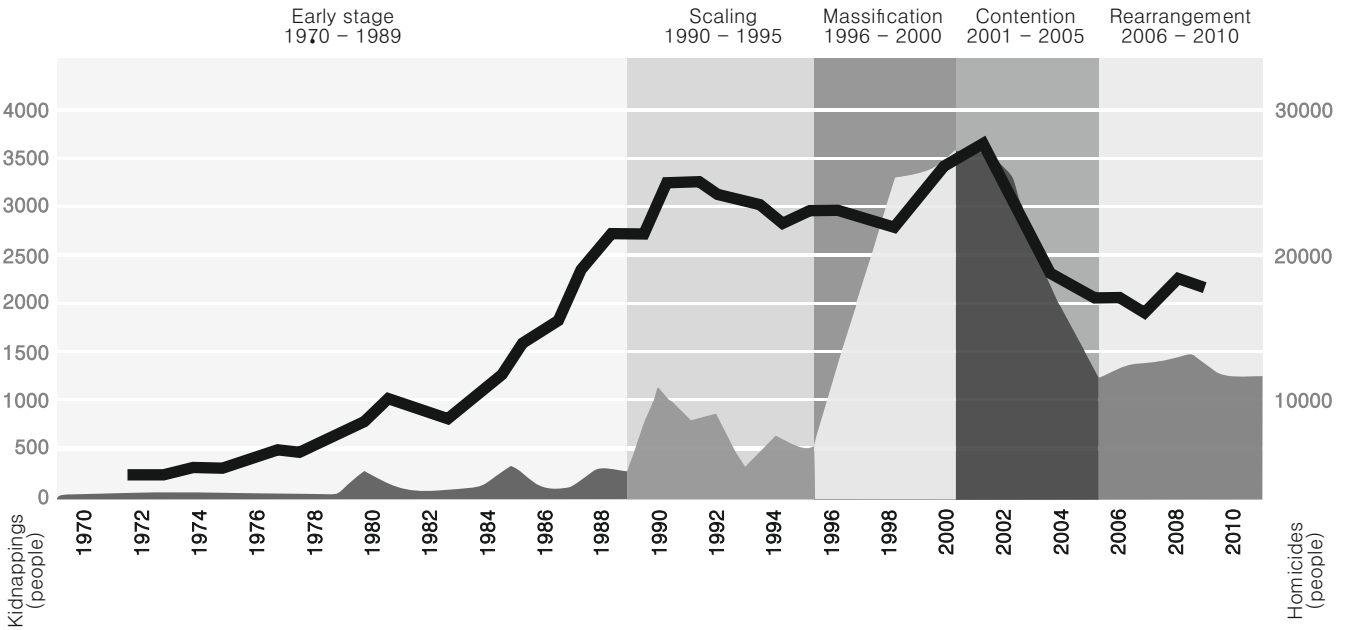


Fig.2 Kidnappings (areas) and homicides (line) in Colombia from 1970 to 2010. Five eras are identified for kidnapping which correspond positively with figures about homicides. Sources: Adapted from CNMH 2013, Carranza-Romero et al. 2012

The conflict which is still a crude reality, made strategies like Alvaro Uribe's "Seguridad Democrática" (MDN, 2003); the supposed demobilization of paramilitary groups and the intense advertising campaigns, help in restoring some confidence for travelers, without really reducing violence but making it more discrete. This had direct repercussions on the National Natural Parks as "eco-friendly" destinations (See Fig. 3) and consolidated the Caribbean coast –with Cartagena leading the market- as one favorite destination for international visitors.

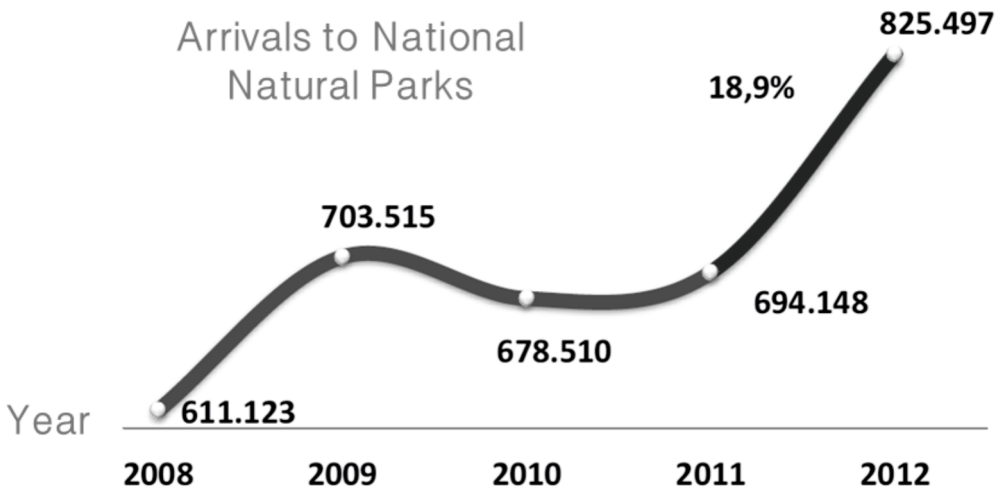


Fig.3 Evolution of visitors to National Natural Parks from 2008 to 2012. In 2012 the National Natural Park Corales del Rosario and San Bernardo hosted 420.492 visitors. Source: Informe turismo Abril 2013. (MinCIT, 2013)

The result of this new confidence directly affected the SCC-SES. The higher inflow of tourism to the area approximately since 2008 created new jobs and market possibilities which typically increased immigration from some communities in the Caribbean coast, as well as a higher demand for fishing products (MinCIT, 2013). All this **can** improve the local economy of the community, just as the increase of external values to the natives **can** change the social structure and heavy transit through a Marine Protected Area **can** have an effect on the coral reefs; new tourist developments **can** severely change the ecosystemic dynamics; and all these possibilities **can** become desirable or undesirable, it depends on **how** it is done. A resilience assessment in this case tries to clarify in which of those two directions the system is moving; how much is too much and what can these sudden processes mean for the people already perceiving the stark reduction on marine catches and the local effects of a global climate change.

SECTION 2

JUSTIFICATION OF A PROJECT IN THE AREA OR WHY NOT "JUST" MOVE THEM?

From the previous section someone can easily jump to the conclusion the native community or social sub-system of the SCC-SES is heavily impacting on its ecological counterpart while becoming increasingly vulnerable; thus the clearest possibility for them or for actors with a higher decision-making power is just moving them to a larger, safer, not-ecologically-threatened/protected area.

However, the results of studies in this area could contribute to the understanding of specific issues of this local SES that are tightly coupled with global change like the abrupt transformations of overpopulation, urbanization, land use, mangrove and tropical forest cover, marine trophic networks and diversity, sea level rise and warming, and the interdependencies of a globalized economy.

On the other hand, removing the community is also discouraged by Colombia being the country with more internally displaced persons[1] in the world with around 5 million people due to an internal conflict of 6 decades[2] still developing today; an alarming figure that yields the commitment towards the prevention of any more violations to the dignity and peace of mind of an already disrupted population. Additionally, this particular community

1. From Global Statistics of the Internal Displacement Monitoring Center. Last data at December 2012

2. The Armed Conflict or Colombian Civil War is understood as the conflict between paramilitaries, guerrillas and the government which started around 1960; however the decade of 1950 was also marked by conflict between the only two political parties at the time; this time is called "La Violencia" and gave origin to the first guerrillas.

identifies itself as an afrocolombian[3] traditional community, hence the importance of safeguarding their cultural values as part of the ethnic diversity of the country.

3. Descendent from enslaved Africans with common genetic, ethnic, cultural and spiritual values, recognized by the Colombian Constitution as ethnic group with individual and collective rights. In Colombia 29% of the population is considered Afrocolombian established mainly on the Departments of the Pacific and Atlantic (Caribbean) Coasts

From an academic perspective, most research developed in the area has focused on only one of the two sub-systems (see Research background) while the ones with a wider approach that consider both sub-systems have a strong proclivity towards conservation of the National Natural Park; mainly seeing communities as polluters and destructors of the ecosystems, who should at least learn about environmental protection. From the resilience thinking and assessment approach, it is necessary to develop case studies such as this one to promote reflections on the subject and conceptual discussions on the terminology; to help operationalizing the assessment and improving suggested applications.

SECTION 3

CORE OBJECTIVE AND RESEARCH QUESTIONS

The core objective behind this research is to **understand the behavior of a complex and adaptive Social-Ecological System through a resilience approach**; therefore the study will be mainly qualitative and the research questions addressing this central goal are the following:

A. Which **alternative states** has the SCC-SES adopted without losing identity, structure and function? How has the SES evolved regarding the coupling of its two sub-systems?

B. What have been the **main drivers** for the shifting between states?

C. What is the **level of resilience of the current state** of the SES? How close is it to a potential threshold? What it is its approximate position in an adaptive cycle?

D. What are the **adapting abilities and capacities** for learning and self-organizing that explain current and potential resilience of the SCC-SES?

E. How can the concepts of resilience, adaptive cycles and transformability be used to **stimulate the sustainability** of the SCC-SES?

SECTION 4

RESEARCH BACKGROUND

The field of resilience thinking has grown strongly on the last decade, especially applied to social-ecological systems as a novel approach to the issues that naturally arise from the fast feedbacks that tightly link human societies with their biogeographical context, in a changing global system (Walker & Salt, 2006). The urgent need for systemic analyses and flexible approaches allowing a more holistic view of the complex subjects has slowly developed in specialized literature with some inertial tendencies towards one field or the other. In the social side, applications have been directed to the reduction of vulnerability and disaster risks as well as climate adaptation; whereas in the environmental area the focus has persisted in the conservation of heavily pressured ecosystems like coral reefs and tropical forests. (Garschagen et al. 2010)

The term has gained as much force as to become a central paradigm of development which could replace sustainability, apparently for its higher operability and tangibility. This makes it more accessible to decision-makers, facilitating communication and consequently transforming it slightly more rapidly into actions (Béné et al. 2012). The cause for the success of the concept is precisely the systemic approach which considers covariance between sub-systems; processes happening across scales and dynamics of feedbacks. It is all condensable in the mental image of "bouncing back", but the concept of "back to what?" is difficult to clarify given the wide understanding of the engineering definition of resilience. In the case of SES resilience, the "what" is a state of balance or stability and not a previous configuration of the system (Holling, 1996)

Naturally, the theory has received criticism over key aspects. It is evident for example, the strength of natural science finding measurable indicators for ecosystemic elements and even the most complex ecosystemic processes, has led resilience to be seen as rather weak in its application within the social sciences. Experts find resilience thinking does not account for concepts like power and democracy when it proposes to re-centralize agency (Folke, 2006);a concept which would put the social sub-system as a group of individuals capable of driving their own lives, choosing and controlling their actions and responses, including its own resilience. Additionally, not only the **level** of resilience must be assessed but also the **type**; particularly in social sub-systems where a community can be very resilient under undesirable

conditions. This is the case of slum dwellings and informal, unregulated settlements. The difficulties of measuring the complex and unpredictable behaviors of the social sub-system, make the differences between the two traditional approaches to appear larger, slowing down the applicability of the concept (Béné et al. 2012)

Nevertheless, the Resilience Alliance has developed a framework to assess resilience in a qualitative way, based on concepts like the adaptive cycle (Holling, 2001) and the interactions of the Panarchies (Gunderson & Holling, 2002); which will be described in more detail in the theoretical framework. Through this methodology it is possible to recognize the phase a SES is located at different moments of its history. Four phases are acknowledged: two of them are analogical to ecological terms of reproductive strategies; **r** represents a phase of fast growth and **K** the phase of conservation of the energy and slow growth. The other two phases form the "bouncing back" stage or backloop, here **Ω** phase represents a release of the energy, while phase **α** the re-accommodation or reorganization stage when the SES goes into a different regime. (See Resilience Alliance, 2007; 2010)

Based on this representation many SESs have been analyzed and it is possible to find examples by the Resilience Alliance on its website (www.resalliance.org). An example is the case of The Annapurna Conservation Area (ACA) in Nepal, where it was concluded that the system of a protected area with a community based management, had until 2010, successfully avoided alternative undesirable states by exerting adaptive resilience and intended to apply transformative resilience to navigate the system to an even more favorable state. It contrasts with the case of the Tongass National Forest in Alaska (USA) which also by 2010, still remained in a collapsed state, unable to reorganize its energy thanks to great levels of rigidity originated in its resistance to adapt to new environmental protection policies; globalization of the timber markets and institutional reforms at the US Forest Service, which limited the forestry management. The entire process resulting in a strong decrease of the economic conditions on the area, as well as a degraded forest ecosystem.

On systems more similar to our own study case, Zolli and Healy (2012) remember the process of the Jamaican coral reefs that went from millenary healthy and diverse ecosystems providing plenty of food to local fishing communities; to "vacant algal wastelands" in the lapse of two or three years. Poor understanding of the tight feedbacks developed between the social and

the ecological sub-systems during almost forty years of history (1950 to ca. 1990) and the pressure of an increased population on the island, caused that in 1970, fishers started to technify their methods and to extend their captures from large predators to include small herbivores. The result was a dominance of sea-urchins that no longer had to compete with fishes for algae. The ecosystem reduced its diversity so much that, after 1983 when an unidentified pathogen caused a mass mortality of the urchins, all that could thrive on the reef, were algal communities that slowly caused the death of corals by covering 92% of the surface area.

A second case recalled by the same authors is the one of the once prosperous California sardine industry from the 1950s that fell in a 98% also in short time period of 20 years. This came as a surprise because the Maximum Sustainable Yield strategy (MSY) –which was later proved to be highly risky (Larkin, 1977), but remains today as a paradigm for resource management- was being successfully applied at the time. It was established later that the catch of too many adults made the juvenile population, which was also being stressed by the cooling of the water caused by La Niña currents; unable to reproduce. It showed once more that overlooking feedbacks in scales and time added to non-linear behavior and high levels of unpredictability and uncertainty, can be disastrous for the SES, accelerating its collapse or making it stuck on a rigid, fragile or static phase.

For the area of San Bernardo and the Santa Cruz Complex or even for single islands, no resilience assessment has been conducted; however, many ecological studies have been developed; some with emphasis on different key species like corals, mangrove, turtles or fish (López-Victoria y Díaz 2000, Báez et al. 2002, Flórez y Etter 2003, Rincón-Díaz et al. 2004, Bejarano et al. 2004, Ballesteros et al. 2007, Navas-Camacho et al. 2010, García et al.2011, INVEMAR 2012). Some more, include a social component from a management of the resources perspective (MinAmbiente 2000, Lizarazo & López 2007, Bolaños et al. 2009, Díaz et al. 2010, DNP 2010, Gómez-Rozo 2011, INVEMAR 2011); and to a lesser extent, there are studies about the communities mainly focusing on the social dynamics of Santa Cruz del Islote (Durán 2009, Leiva, 2012a, 2012b), which has also received a lot of attention from different national and international media.

SECTION 5

METHODOLOGY

The methodological structure designed for this research is shown on Fig. 4. The main method applied was the Resilience Assessment (Resilience Alliance 2007, 2010) supported by a **literature review**: books, papers, maps, laws, documentary films, published news and other documents available about the SES, including records of local institutions and data collected on the field.

On the SCC-SES site a total of 30 semi-structured **interviews** were conducted on natives, tourists, immigrants and experts about subjects like basic information of the community, history of the settlement, use of the space, resources management and connectivity with other places and communities. Other activity was the observation of a **decision-making group** with the participation of the Community Council of the islet, the population of Chupundún (Native settlement in Múcura) and representatives of the IPSE[4]; to detail a project of 24 hours of electricity for the two communities.

4. Instituto de Planificación y Promoción de Soluciones Energéticas para las Zonas No Interconectadas.

A **field journal** accompanied by photographs and videos was developed to record personal impressions on the observed daily activities of the communities; as well as **visual records** of the mangrove and coral communities as evidence for further verification of ecological reports on the area.

Finally a **census** of the population on the islet at the time of the visit was started, to be finished and reported later on by a group of natives mostly composed by women.

For the analysis of the data, the Resilience Assessment workbooks were used as main guidelines and complemented with other methods found compatible both conceptually and operationally like the 9 windows[5] (Savransky, 2000) and the Matrix of fundamental needs (Max Neef, 1993).

5. Also called System Operator. It is one of the tools of the innovation methodology TRIZ developed by Genrich Altshuller. See Savransky, 2000

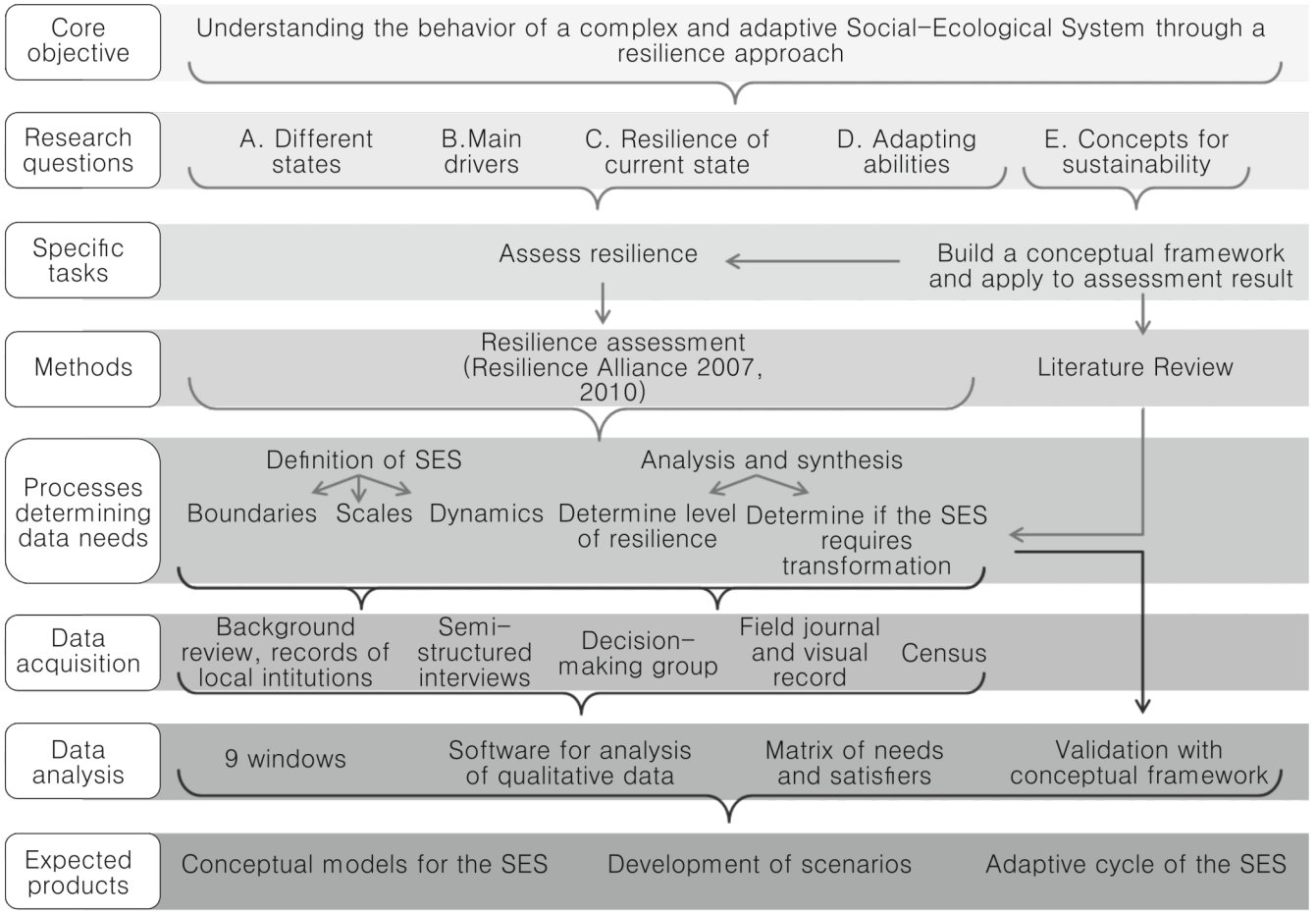


Fig.4 Methodological framework developed for Resilience in Santa Cruz del Islote: sustainability of a Social-Ecological System in the Colombian Caribbean. Source: Developed by author.

CHAPTER 2
THEORETICAL AND CONCEPTUAL FRAMEWORKS

SECTION 1

HUMAN NEEDS AND SATISFIERS

Every system has a main function to fulfill (Altshuller, 1961), which is the same to say that a main result for a confluence of factors acting within the system can be identified. For the function to be carried out, the system requires energy, matter and/or information, typically acquired from some larger system or super-system and it also needs internal components or sub-systems to convert those inputs into a function-satisfying instrument.

In the case of SESs, we propose that for analysis purposes, a main function is represented with the Fundamental Human Needs (Max-Neef 1993), since they partly drive the interactions between the social and the ecological sub-systems, in the sense that most ecosystemic elements are considered "resources" or "services". It means humans use a wide set of transformation processes to convert ecosystem components into the Satisfiers of their needs. The interaction can be conceptually modeled as seen in Fig. 5 (Max-Neef, 1993).

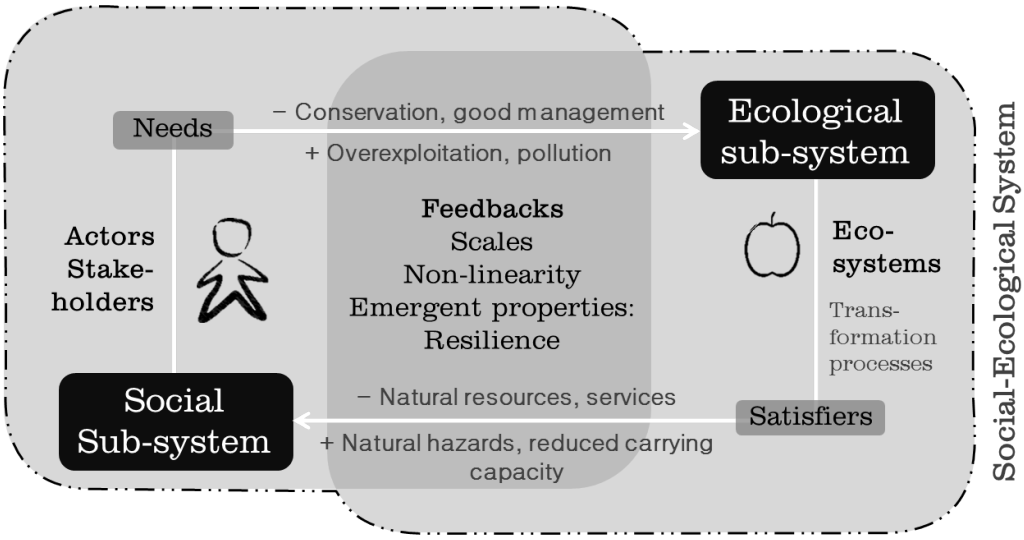


Fig. 5 Conceptual model of Social-Ecological Systems from the fundamental needs perspective. Needs will drive the two sub-systems to interact and couple into a larger and even more complex system. In this interaction the feedbacks between sub-systems can be negative (-): self-regulating and controlling for the whole system, or positive (+) amplifying and destabilizing. Source: Developed by author based on Max Neef, 1993; Chapin et al. 2011

The Human Scale Development perspective identifies nine axiological and non-hierarchical categories of fundamental needs namely: **subsistence, protection, affection, understanding, participation, leisure, creation, identity and freedom**. A person can fulfill these needs by being, doing, interacting or having "something" that Max Neef calls a Satisfier, which at the same time can have five types of behavior (Max-Neef 1993).

As a violator or destroyer the satisfier will have a paradoxical effect and will destroy the possibility of other needs to be satisfied; an example of this is censorship as an answer to the need of protection. A pseudo-satisfier will create the fabricated sensation of satisfaction, as charity is to subsistence. An inhibiting satisfier will usually over-satisfy a need making it difficult for the person to pursue the fulfillment of other need; like paternalism is to protection. Singular satisfiers will have a positive effect on just one need, becoming neutral for other needs, like gifts are for affection; and finally synergic satisfiers will fulfill or help to fulfill several needs in a positive way like popular education stimulates the needs of protection, participation, creation, identity and freedom, while fulfilling the need it was originally intended to: understanding (Ekins & Max-Neef, 1992).

The use of this particular approach responds to the interest of avoiding hierarchical views and the concept of "things" being understood as needs, when these are merely the materialization of a satisfier and as such can be replaced with other "things", processes or concepts; thus facilitating the analysis by making it more objective. The evaluation of how much the community of the SCC-SES is depending on the ecological sub-system to fulfill their fundamental needs and how the chosen satisfiers can be classified according to their behavior, will help explain how the two sub-systems interact; and what are the dynamics beneath these interactions.

SECTION 2

SOCIAL-ECOLOGICAL SYSTEMS

The concept of Social-Ecological Systems appeared in the past decade (Berkes et al. 2001, 2003; Becker, 2010) to define the association between a geographically or functionally defined ecosystem unit and a group of social actors. It means that by the interactions between the two subsystems, a new complex, adaptive, interdependent, constantly co-evolving system emerges. The study of SESs (Redman, 2004) began with an increasing awareness of the little effectiveness of separate studies to approach sustainability issues. Coupled systems such as these, are characterized by their high complexity and unpredictable feedbacks at different scales. Components are asymmetric in importance and information; there are high levels of uncertainty and sometimes, the objectives of the stakeholders or actors differ significantly (Holling, 2001).

Living in the Anthropocene (Crutzen, 2002; Steffen et al. 2007) or the era when humankind has become a force of nature, it has come to be very important to study the human-nature binomial (Glaser et al. 2012) with an integrated trans-disciplinary perspective. Fig. 6 shows an example of the interaction between the two sub-systems in the creation of a new conceptual systemic category.

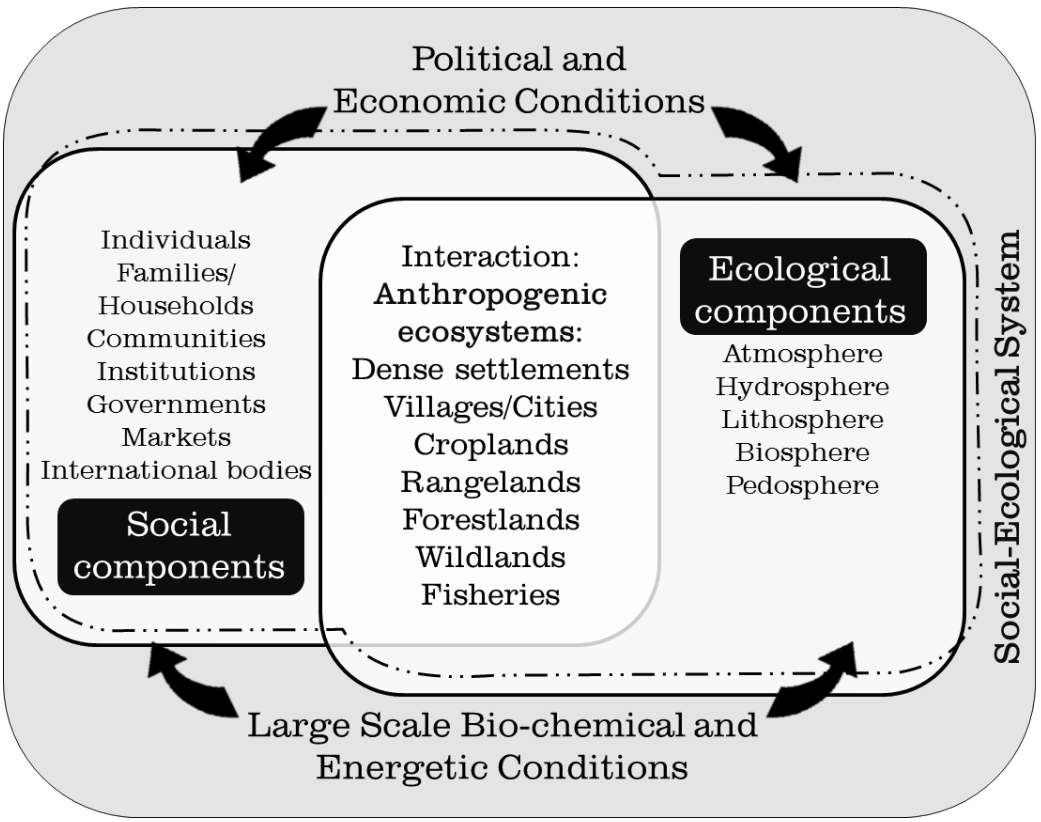


Fig. 6 Social-Ecological System. Example of the interaction between the social and the ecological sub-systems in the configuration of anthropogenic ecosystems. Source: Adapted from USDA 2013 in Walthal et al. 2012 and Chapin et al. 2011

The accelerating rate of change in ecosystems across the world, more visible for almost 60 years now is, according to the Millennium Ecosystem Assessment performed in 2005, driven by anthropogenic processes that increase pressure on ecosystems to meet human needs, especially for food, water, some materials and obviously fuel (MEA, 2005). The social sub-system generates a strong impact which not only reduces the ability of the ecological sub-system to recover, but also feeds back amplified effects on human societies.

COMPLEXITY IN SES

As Ostrom (2007) asserts in her paper about possible sustainable Social-Ecological Systems, there is no simple way to understand SESs. It can even be proven futile to model them mathematically or simplify them to the level of prescribing panaceas for all of them or for all the conflicts rising from resource management processes, given their high level of complexity and dynamicity.

Complexity in SESs can be described with some specific observed characteristics (Holling, 1998, Ostrom 2007, Cumming 2005), starting with the **unpredictable behavior** of the sub-systems. When studying or managing SESs, researchers and practitioners must not only deal with ecosystem interactions which can be anticipated just to some degree; but they must also keep in mind social interests, cultural backgrounds, preferences, power level, capacities, abilities, variability and so on. Such diversity in both sub-systems creates the impractical -however necessary- condition of designing specific analysis and customized management strategies for every SES.

SESs are **multi-causal** and **non-linear**, which means the output of the system will not be proportional to the input and that there can be several sources of said input. An example is the relation between food and population in an ecosystem or a human settlement; where at low population density, a certain amount of food will be sufficient for individuals to subsist and reproduce, thus having a positive effect on the population growth. However, if the population crosses a given **threshold** and becomes too large with respect to a given food supply; food limitation will have a negative feedback on the population, limiting its growth (Berkes et al. 2003; Walker et al. 2004).

Local SESs are influenced by a large number of external drivers at different scales, both in space and time; suggesting that potential interactions among drivers may trigger **feedbacks** to their context (super-system), as well as to their components (sub-systems); while having considerable lag effects and becoming rather unpredictable. Biomagnification can exemplify these processes: when the effect of certain chemicals is accumulated across trophic levels (spatial scale), the critical consequences may appear in different moments and places (temporal scale). It is also evident in governance problems, which usually go across local, regional, national or even international levels (Berkes et al. 2003; Walker et al. 2004).

SESs evolve and change dynamically; **self-organize** after a disturbance event; and display **emergent properties** from interactions between components; meaning new characteristics not present on the sub-systems will appear with the exchange.

All these characteristics will have a repercussion on the management of SESs: In order to respond to constantly changing systems, actors must be able to learn and adapt -sometimes with urgency- to new conditions and managers have to try to understand how does the system work, has worked and could work in the future; imagining possibilities for all its scales. These processes are certainly more time-and-resources consuming than just being reactive or applying panaceas and expect them to work; but more practical solutions represent a higher risk when the rate of change is high and they could end up doing more damage than anticipated (Resilience Alliance, 2007; 2010).

SECTION 3

SES-DYNAMICS: RESILIENCE AND LOSS OF COHESION

Part of the complexity of a SES lies on its high dynamicity. A theoretical framework for SESs has been built by researchers like Holling, Gunderson, Walker and Meyers within the last decade with a special emphasis on the phenomenon of **change** and how SESs respond to it.

In the description of the Adaptive cycle (Holling, 1973) (see Fig. 9), systems are found to grow on a base of available resources creating a structure that fulfills a main function. The early stage of this growth is known as the **r phase**, as an analogy to ecological reproductive strategies. This phase is highly dynamic because energy, information and matter are still building up. Slowly, the system reaches a phase of conservation also known as **K phase**, where all the energy accumulates in a more rigid state. Specialization, connectedness and stability are high while dynamicity and diversity decrease.

The rigidness of a mature SES will lead to **collapse;** a threshold where amassed energy is released by falling of its own weight; or by being induced earlier if the state of the system is untenable. Collapsing means the system cannot absorb change any more and after this point there are two roads the SES can transit: **one characterized by different levels of resilience and other by the loss of cohesion**.

COLLAPSE

While resilience, expressed by properties like adaptability, dynamicity and agility, allows the system to maneuver within the boundaries of its own identity adjusting to changes and absorbing them; collapsing implies a loss of consistency among the main components of the SES. Literature on the matter recognizes two approaches on collapse (Frantzeskaki et al. 2008):

The resilience approach is based strongly on the ecosystem concept of succession; it states that after collapse, a SES can become reorganized and renovated. While this does not necessarily mean the new state is a desirable one, it implies the system does not perish or can indeed find in collapse the opportunity to navigate into a more convenient state. In this approach the concept of collapse represents a **threshold** or the tipping point where the confluence of several characteristics of the system, push it into significant change.

In the vulnerability approach conversely; collapse, as the expression of a dynamic property is understood as a **state** of the system and the process leading to said state. It occurs **after** a threshold is crossed and it implies the ruin of the SES. This approach, which is more human centered, is compatible with what Diamond describes as indicators of collapse: environmental degradation, climate change, hostile neighbors, loss of friendly commercial allies and the response of the social sub-system to its own environmental problems (Diamond, 2005). The fatal combination can finish a community deeply dependent on natural resources and should be in consequence, avoided by increasing the coping capacity of the SES. This approach is widely applied in studies related to climate change; assessing hazards, risks and vulnerability of communities to such events (Garschagen et al. 2010)

Fig. 7 shows a summarizing classification (Frantzeskaki et al. 2008), where three out of six forces of change are capable of inducing collapse in a SES: crises, critical exogenous events or developments and institutional failures.

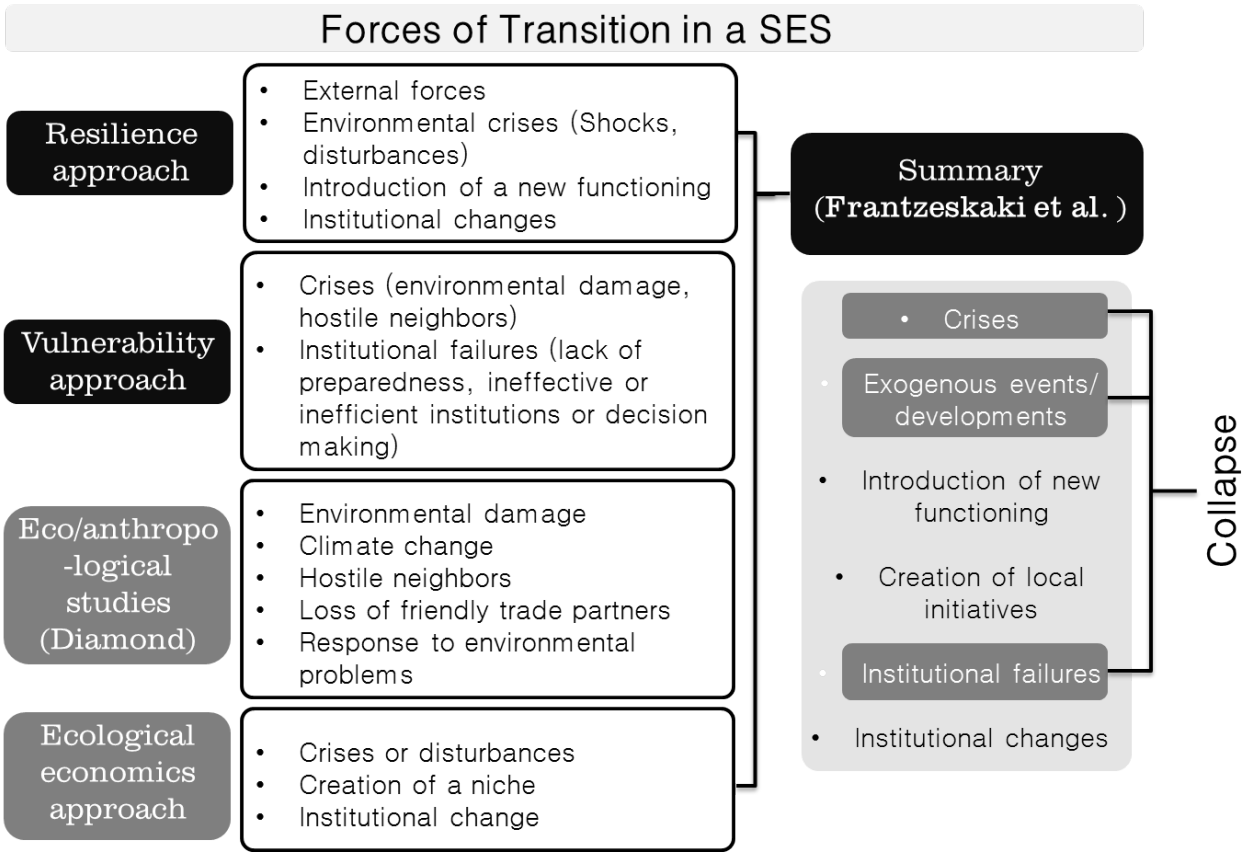


Fig. 7 Forces of Transition in a SES. On the left, four approaches towards the characterization of the forces needed to induce transformation. Based on these four approaches, Frantzeskaki et al. (2008) developed a new classification shown on the right, finding six Forces of Transition; three of them conducive to collapse, seen as a negative change.

In the present study, collapse is understood as a threshold or limit configuration and not as a permanent state; however, the three forces of transition identified by Frantzeskaki et al. (2008) are found valid as collapse drivers. The collapse threshold is also found in the analysis of historical collapses in ancient states by Butzer (2012). In this case, collapse is defined by an advanced breakdown; characterized by processes of fragmentation of the State, subsistence crises, militarization, fracture of social order, population decline, loss of cultural memory, etc. And after such a threshold; two separate paths again: **recovery, reconstruction and reconstitution; or complete sociopolitical devolution**. This pattern, shown in Fig.8 is consistent with the representation of the adaptive cycle by Holling; thus based on this analysis, it is concluded the SES adapts to disturbances to the limit of its capabilities and after reaching this frontier of collapse, it can be followed either by progressive loss of cohesion or by the induction of innovations that lead the SES to renewal.

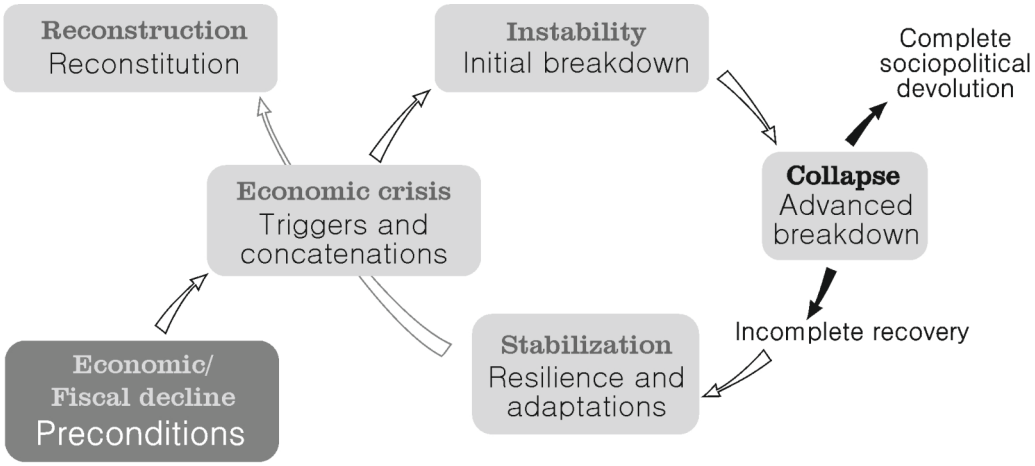


Fig. 8 Model of historical collapse. From the preconditions the system finds triggers and concatenations or cascading feedbacks like economic crises Upper path following triggers and concatenations responds to negative or buffering feedbacks while lower path represents positive or cascading feedbacks. Fragmentation of the State, subsistence crises, militarization, among others. Source: Adapted from Butzer, 2012

BEYOND COLLAPSE

As stated before, there are two paths a SES can follow after collapse: one characterized by the exhibition of different levels of **resilience** and other by progressive **loss of cohesion**.

If the SES continues losing its identity (Cumming, 2011; Collier & Cumming 2005) and allowing the reduction of consistency between its parts; it will cascade into an advanced breakdown; finally falling into what is proposed here as a c**omplete social-ecological failure** (Fig. 9, 4a). This is analogous to the complete sociopolitical devolution of Butzer, and it means the coupling between the two sub-systems is lost. Typically it is the social sub-system that must leave the geographical setting, since the ecosystems no longer provide enough resources and/or services for the sustenance of the community. A complete social-ecological failure, like desertification or the total abandonment of the land by the community is what Diamond (2005) describes for the ancient society of Easter Island where deforestation led to war and mass deaths.

If on the other hand, the system exhibits resilience, it can adjust its components in three ways according to its response to disturbance (Walker et al. 2004). While facing light disruption the resilient SES should have enough **resistance** or absorptive coping capacity to avoid significant change and persist; in greater disturbance the system should be able to **adapt and be flexible** obtaining only incremental adjustments; but under unviable or unsustainable conditions the system should move towards strategies of **transformability.** Therefore it is not just a matter of **if** the system shows resilience but how this happens and at what scale.

To continue with the description of the Adaptive cycle (Holling, 1973); after the threshold of collapse is crossed, two more phases occur. The first one is a period of release of the energy known as the Ω phase, where the components of the SES loosen their feedback mechanisms to rearrange them in the following phase of innovation, known as the α phase. These two periods make the backloop, which can be faster than the foreloop (first two phases of the cycle) and also sets novel founding conditions that allow a new cycle to begin.

A threshold opposite to collapse known as **regime shift** is crossed to start a growth phase in a different configuration of the system. These new conditions can be very similar to the "original" or totally different; however, the coupling of the sub-systems remains. A new regime can be the changed dominance of macro algal population where coral species used to dominate in a reef; it can also be the conversion of a tropical dry forest into a coconut plantation, or of a mangrove forest into a sandy shore. It can also be the shift of dominance between sub-systems, like the conversion of a patch of forest into a fully equipped urban development (Walker et al. 2004).

The cyclic behavior of SES is assumed, based on the observation of several cases; however, like most things in nature there is no fixed law about it: Systems in a K phase can return to r; or from r, skip the conservation phase and fall directly into Ω; or maybe what happens is the force of renewal can be too weak; in which case the system would fall back from α to Ω (Walker et al. 2004).

Additionally, there is the matter of scale and dimensionality: firstly, the SES is not cycling alone: larger scales or super-systems and smaller components or sub-systems have cycles of their own and are constantly interacting with each other (this is explained in detail in the Panarchies section). Secondly, when a SES starts a new regime, it can never go back to the initial conditions of the previous regime, regardless of how similar they may appear; this happens because of the very dynamic nature of SESs. Therefore, it is important to recognize the dimensionality of the loop to avoid stubborn attempts of "recovery" of the "original" state in management strategies. In other words, a particular state cannot be the reference to measure managing or recovery plans and policies. Fig. 9 depicts a representation of the Adaptive Cycle (Holling, 2001) expressing the concepts related to the different thresholds and phases while Fig. 10 explains the three-dimensional nature of regime shifts.

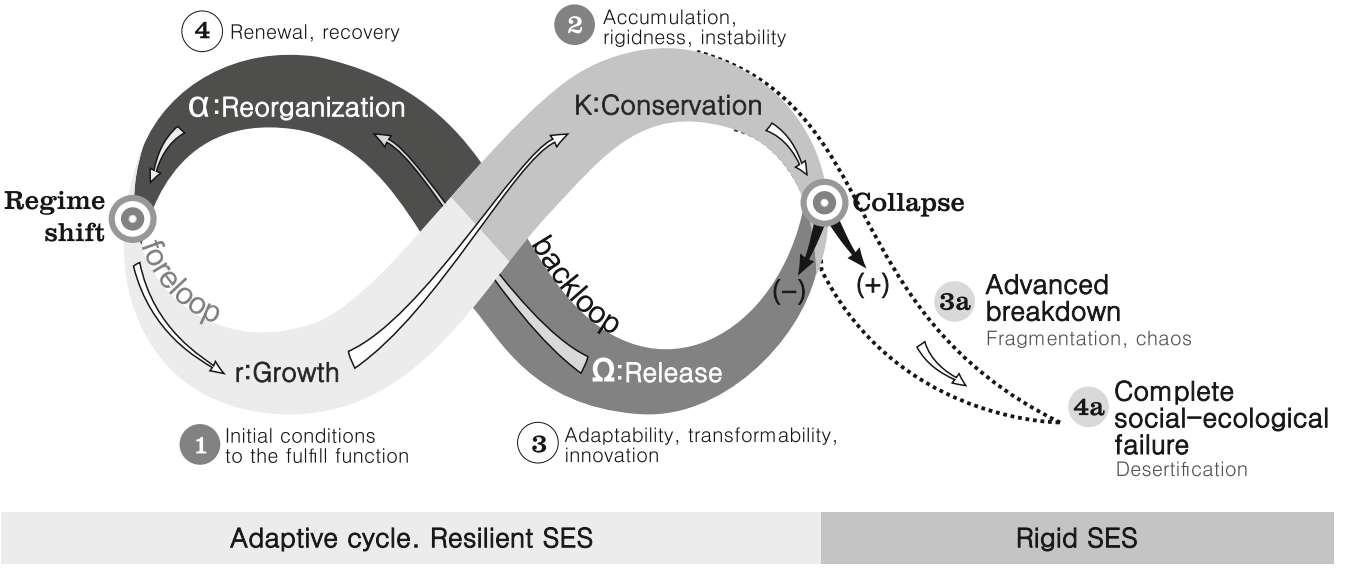


Fig. 9 Adaptive cycle of a SES. The SES grows from an initial configuration by accumulating matter, energy and information, building a structure that is specialized in the fulfillment of the main function, while accommodating the changes and disturbances it is capable of. At the peak of this accumulation it becomes too rigid to absorb more changes and adapt to them. At this phase centripetal forces breaking cohesiveness like ecosystem degradation or social conflict push the SES into a collapse. After the collapse threshold the system either releases energy to reorganize (negative feedbacks) or it continues losing identity (positive, cascading feedbacks). Source: Adapted from Holling 2001; Chapin 2011; Butzer 2012, Cumming 2011, Frantzeskaki 2008 and the key concepts of the Resilience Alliance available online: www.resalliance.org

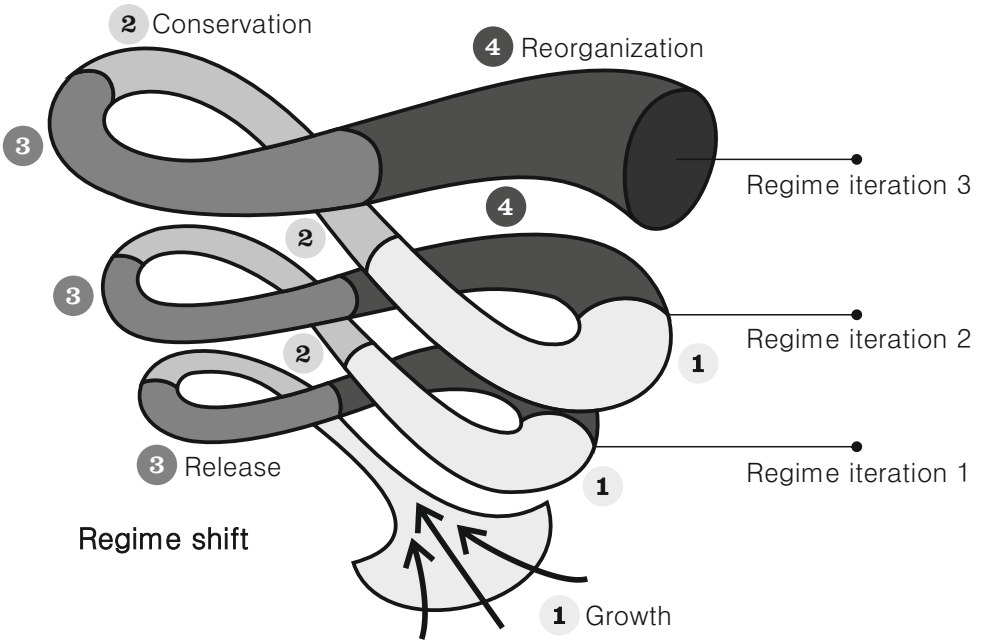


Fig. 10 Regime shifts: the SES begins a new adaptive cycle after the induction of an omega (3) and alpha phase (4). Coral reefs and marine ecosystems are today the typical image of regime shifts when after loss of herbivory, algal species become dominant over coral species. A regime shift is a rearrangement of the dominant attractors (Scheffer et.al. 2001), without losing identity, functions or feedback mechanisms.

RESILIENCE IN SOCIAL-ECOLOGICAL SYSTEMS

> **"**A resilient ecosystem can withstand shocks and rebuild itself when necessary. Resilience in social systems has the added capacity of humans to anticipate and plan for the future**".**
>
> Resilience Alliance, 2005

The Stockholm Resilience Centre detected a set of nine global thresholds or Planetary Boundaries (Rockström et al. 2009); that once crossed –three of them already have[6]- could make survival and wellbeing for humankind almost impossible to achieve. Such complex and challenging issues revealed the need of new inputs from transdisciplinary strategies and non-traditional perspectives in order to develop abilities to avoid collapse or to adapt to possible states of the system.

6.Climate change, natural flow in Nitrogen cycle and rate of biodiversity loss are already exceeding acceptable limits; Land system change, global freshwater use, ocean acidification and the natural flow on Phosphorus cycle are rapidly approaching thresholds. Stratospheric ozone depletion is the farthest to the dangerous limit while atmospheric aerosol loading and chemical pollution are not yet quantified.

In this context, the paradigm of Social-Ecological resilience defines the capacity of a SES to adapt to changes without losing cohesion of its components; the concept first introduced by Holling (1973) determines, a resilient SES is capable of keeping its identity by conserving its main function, its structure and feedbacks and the abilities to self-organize and learn, in spite of the strong forces of transition being applied to it (Gunderson, 2000; Folke, 2006; Scheffer, 2009).

The notion of resilience is important in the conceptualization of SESs because it is not a static feature; the term has long ago parted ways with its engineering equivalent by accepting there is no fixed state to return to after disturbance and that SESs are adaptive and continuously transforming. It also differs to some extent from the ecological definition since it must include the unpredictability within the social sub-system.

It is not easy however, to understand the flexibility and dynamicity within the concept of resilience and less so to operationalize it because the social sub-system; which is nowadays the typical driver of abrupt changes on the SES (Crutzen, 2002), has a historical tendency to pursue linear growth,

accumulation and rigidness. Collapse as a concept has a negative connotation and even the firmest conservationists have fallen for the trap of avoiding periodic fires in a mature forest[7]. "Pristine" nature/cultures are romantically viewed as a fixed state to return to and human-made systems like cities have a fast metabolism, with processes of high speed and complexity (Bettencourt et al., 2007); thus the more sophisticated human systems grow, the more rigid they have to become in order to maintain control over changes and to increase efficiency.

7. It is well known now the avoidance of periodic small fires allows the accumulation of enough fuel to produce mega-fires. See FAO, 2011

A SES can have different levels of resilience for every type and magnitude of disturbance; some combination of variables and some interactions of the sub-systems can get the system to respond in a sustainable way–a positive use of the resources, a suitable response to disruption-; while others are conducive to resources depletion or social loss of cohesion (Ostrom 2007). Knowledge of the variables structuring the SES and the speed of their change rate, supports management strategies; whether it is to **avoid** failure; to **maintain** a desired configuration; or to **induce** transformation for SESs that are resilient on undesirable conditions (Walker et al., 2004)

This means resilience in a SES, especially after collapse rarely comes natural. It requires persistence, adaptability and transformability, to take the system to back-loop (See Fig. 9) into "potentially more favorable stability domains" (Resilience thinking, See Folke et al. 2010). Some principles of resilience associated with rigidness and fragility **reduction** are tight feedback loops, dynamic reorganization, built-in counter-mechanisms, decoupling, modularity, simplicity, swarming, clustering, diversity and innovation (listed by Zolli and Healy 2012).

SECTION 4

PANARCHIES FOR SUSTAINABILITY

The concept of Panarchy[8] (Holling et al. 2001) refers to the interactions of adaptive cycles of hierarchically embedded (See Fig.11) systems across different scales resulting in both predictable and unpredictable outcomes. The idea behind the term is to grow conceptually apart from the top-down nature of the term hierarchy, which is typically more rigid and unaffected by interactions. It is represented in Fig.12 highlighting the structure of interactions among nested adaptive cycles considering space (scales) and time (cycles).

8. From the universal god of nature Pan, according to Greek mythology.

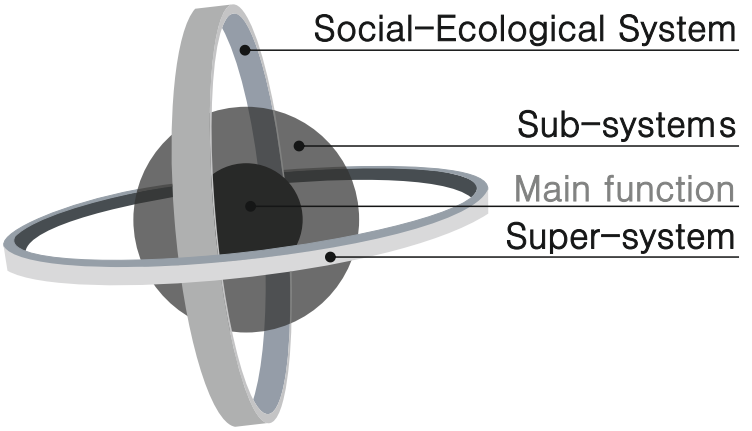


Fig. 11 Spatially nested nature of a SES. Every SES is like a dynamic Matryoshka doll composed by several elements organized in two sub-systems: Social and Ecological, revolving around a main function. All these elements are deeply affected by the contexts or larger scale they are embedded into (super-system). However, like the dolls, super-systems are always components of even larger scales; and sub-systems have components of their own and additionally every scale moves at different speeds. This is one of the principles behind Panarchy theory. Source: Developed by author based on Altshuller (1961) and the concepts of Panarchy (Holling et al. 2001)

Two types of connections between phases of adaptive cycles at different hierarchies are essential to the concept of sustainability of the SES: **revolt and remember**. The first is the capacity at lower levels to innovate, since it is easier for them to experiment and react fast to changes. While the second is the ability of higher levels to accumulate a memory of past successful experiences, thus controlling and stabilizing lower levels.

Transformability at smaller scales generates resilience for the whole panarchy and vice versa (!) (Folke et al. 2010). This looping interaction creates the need for breaking down resilience in the case of an undesirable state -preferably from the lower scales- to build resilience in a renewed, more desirable state of the panarchy. The sole awareness of this notion, gives actors a way to approach adaptive management of a SES, thus increasing its probabilities of becoming sustainable.

Panarchy means SESs are typically “creative” while conserving; innovative while being history-conscious. This links the concept of panarchy to the paradigm of sustainability understood as the “capacity to create, test and maintain adaptive capability” by the combination of “learning with continuity” (Bunnell, 2002). An example of the link between multi-scalar analysis and sustained environmental protection is listed by John (2006 as cited by Ostrom 2007) with top-down government regulation, bottom-up grassroots governance, and middle-out civic environmentalism for the protection of the commons.

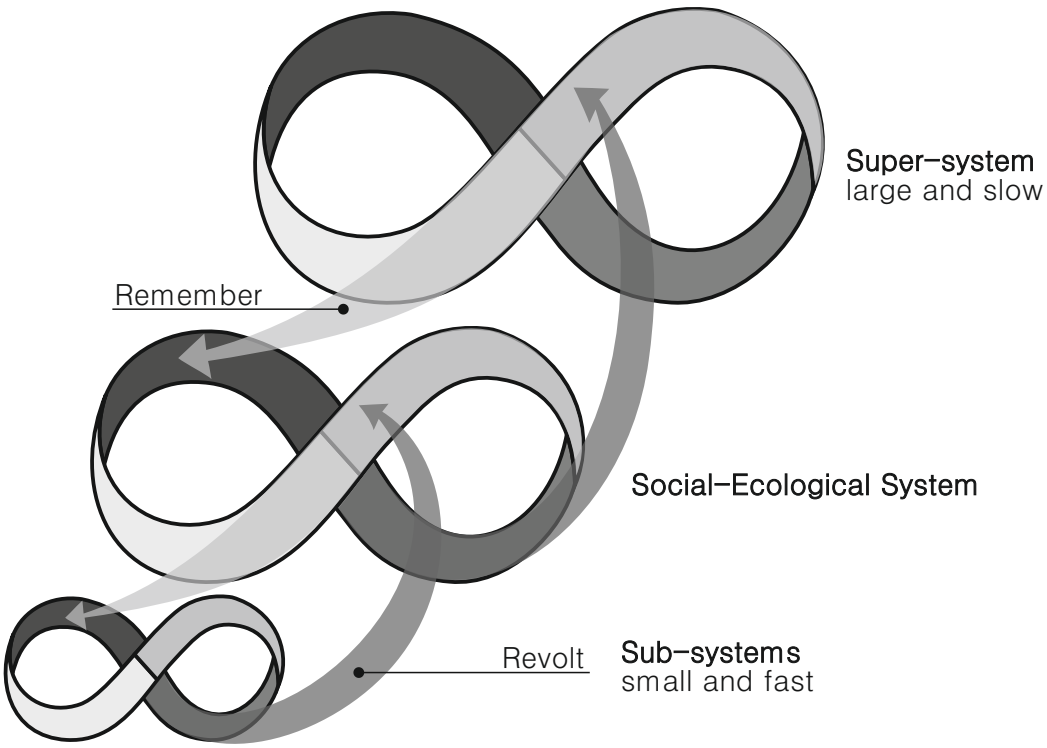


Fig. 12 Panarchy in adaptive cycles. It shows the unpredictable nature of Social-Ecological Systems exhibiting constant adaptive evolution of the system itself, the supersystem symbolized by everything representing a context for said system and all the components of the two sub-systems: social and ecological . Although it is depicted with a size gradient, the concept of Panarchy has been developed to avoid the rigidness of hierarchies showing that even when the systems are nested, the interactions between levels can deeply affect a higher or lower scale and in different moments in time. The agility of lower levels allows them to experiment and innovate; while larger levels store the memory of past experiences. Source: Holling 2001

SECTION 5

CONCEPTUAL FRAMEWORK: HOW TO DETECT RESILIENCE

Although it is very difficult to establish quantitative measures for the resilience of a SES due to the complexity of its nature, it is essential to find qualitative indicators to develop an assessment; keeping in mind resilience does not mean conservation; it is not necessarily a positive state or a goal in itself, but the property of a system which it can display in both, desirable and undesirable conditions; and if transformation is required, “old” resilience must be broke down in order to induce a new configuration of the system which should be fed at the same time with “new” resilience.

Bahadur et al. (2010) have condensed from a wide review of published literature on the subject, a list of ten characteristics of a resilient system. The recovered items show a tendency towards the social aspect of resilience giving emphasis to the role of local communities and social empowerment:

1. **High diversity**, of functional groups, drivers, activities, partnerships or resources; in sum a wide range of possible paths and tools the system can look to when disturbances are too great to uphold.

2. **Effective governance**, institutions and/or control mechanisms that guarantee the balance of power between the community and larger scales exerting control over them.

3. **Acceptance of uncertainty and change** means not trying to conserve a fixed state of the system, thus increasing adaptability.

4.**Community involvement** and inclusion of local knowledge, co-management of the resources, participation of the community in the decision-making about the resources.

5. **Preparedness, planning and readiness**, as well as being able to partially or gracefully fail, acknowledging worst-case scenarios in order to avoid catastrophic falls.

6. **High degree of equity**, with distributed wealth and assets throughout de community as well as a high level of justice.

7. **Social values and structures** with an ultimate purpose of having cooperation, coordination, trust and respect, the sharing of ethical standards to an improved management of the resources.

8. **Non-equilibrium system dynamics**, following natural systems which are in a constant transient state and never in equilibrium, a characteristic reserved only for individual components of the system. The system must be able to "cope with, adapt to, and shape change" (Folke, 2006).

9. **Learning** and having flexibility to apply new knowledge into guidelines of the system, being able to reflect on different events and adjust actions based upon this.

10. **Cross-scalar perspective**, acknowledging interconnectedness and transcending scales of space and time, having connections between the local and the global and with equivalent systems in the same scales

On the other hand Walker & Salt (2008) describe how a resilient world might look like, stressing the importance of ecosystem characteristics and concluding the nine key aspects would be: i) biological, social, economic and every possible sort of **diversity;** ii) embracement of natural ecological **cycles and variability**; iii) **modularity** of components to avoid over-connectedness; iv) acknowledgement of the **slow controlling variables** configuring the SES; v) a balanced tightness of **feedbacks** or the rapid detection of consequences for determined actions in order to avoid thresholds; vi) well-developed social networks where **trust,** leadership and adaptability are highly developed; vii) emphasis on **innovation**, based on learning and experimentation and the embracement of change; viii) **redundancy** in governance structures, mixing common and private property and finally ix) consideration of ecosystem un-priced **services** when creating proposals and assessments.

In summary and also building on the paths of resilience compiled in the work of Zolli and Healy (2012), **a resilient system must behave agilely in the face of change while keeping up with the interactions it has in temporal and spatial scales**. The temporal cross-scaling demands from the SES to remember, learn, imagine and innovate; while for the interaction with the larger context or super-system, the SES must be selective: if the influences from slow controlling variables are positive, meaning they contribute to the sustainability of the system; the SES should learn and use all the tools the super-system is providing. Whereas if such influences are negative, the system should promptly react discarding or protecting from them. In the relation with sub-systems, it is important to maintain and/or increase diversity, a modular structure –which would require a level of simplicity- with just enough redundancy and embedded counter-mechanisms to be prepared for disturbance; and for all these principles to be fulfilled, the system should have enough dynamicity to constantly reorganize and balance between coupling and decoupling. It means the SES should be coupled enough to perceive feedbacks or consequences of determined interactions; but decoupled enough to avoid dependencies or to be able to fail partially and not completely.

CHAPTER 3
CASE STUDY

SECTION 1 STUDY AREA
SECTION 2 OVERVIEW OF THE CONFLICT

SECTION 1

STUDY AREA

Santa Cruz del Islote is an islet in the Colombian Caribbean; together with nine other islands they form the archipelago of San Bernardo as high relief of the coralline platform in the Colombian northern coast (Flórez, 2003). In 1996, by the Resolution 1425 (MMA, 1996) that redefined the boundaries of what then was the National Natural Park Corales del Rosario, seven of the ten islands in San Bernardo were included in the first -and for many years only[9]- submarine National Natural Park of the country (See Fig. 13); however, only two of these islands, Maravilla[10] and Mangle are protected areas as such. The reason for the conservation status of the area was a highly diverse and extensive coral reef complex and the mangrove forest communities (PNN, 2006).

9. The National Natural Park Corales de Profundidad (Deep-Sea Corales) located 32 km in front of the Caribbean coast - west to the NNP Corales del Rosario y San Bernardo- was created in May 2013.

10. This latter, originally represented an important bird sanctuary but today, according to reports of the native community, it is disappearing due to tidal erosion.

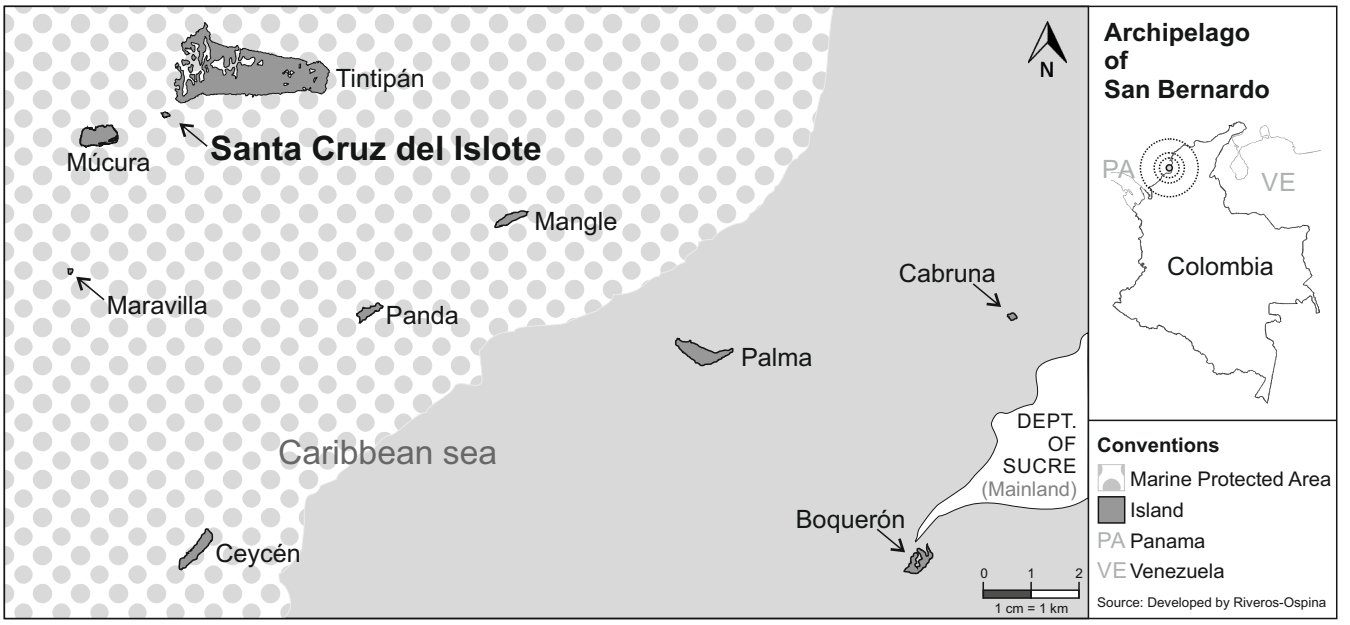


Fig. 13 Map of the Archipelago of San Bernardo (9°40´ 9°50Ń; 75°43´ 75°56Ẃ): Ten islands in the Colombian Caribbean Sea: Gulf of Morrosquillo. The dotted area shows the boundaries of what in 1996 became National Natural Park Corales del Rosario and San Bernardo. The only islands considered conservation area are Maravilla and Mangle. Source: Developed by author

The Archipelago, located northwest of the Gulf of Morrosquillo, Department of Sucre in Colombia; has an extension of 21,300 ha (Díaz et al. 2000). It consists of the shallow waters of the Caribbean Sea and the islands, which cover 450 ha. Two of these islands are better described as islets for their small size (less than 2 ha): Maravilla and Santa Cruz del Islote. The archipelago consists of 10% karstic depressions and islands, with altitudes ranging between 80 cm to 2 m (INVEMAR et al. 2002); 30% shallow platforms and 60% reef formations (López & Díaz, 2000). Islands have developed vegetation of dry tropical forest and mangrove forest, while the ocean is composed of hard coral reefs, algal populations and seagrass meadows (INVEMAR, 2011).

The climate is tropical (Aw in Köppen climate classification) with an average annual temperature of 27°C and total annual precipitation of ca. 1000 mm, distributed in two hydric stations: dry/windy from December to April and rainy/calm from May to November (Patiño & Flórez, 2000). The ocean presents superficial currents going from east to west in front of the continental platform; intensified during the dry season with trade winds, which cause erosion of the islands on windward areas. Rainy season brings the countercurrent of Darién, moving from Panama towards east, along the entire Caribbean coast (Flórez & Etter, 2003).

The archipelago has a very mobile population. It is composed of natives in the highest proportion; immigrant workers from coastal townships; and the owners of several vacation houses and lodges built on islands and cays coming mainly from the Colombian Department of Antioquia (Leiva, 2012a). Native population has settled mainly on the islands of Múcura, Ceycén, Tintipán and Santa Cruz del Islote (or simply El islote) (Leiva, 2012a), with the population of the islet being the highest (715 persons)[11] and densest (71,500 persons/km2) of the entire archipelago. These communities identify themselves as afrocolombians and their main economic activities are artisanal fishing and tourism.

11. From census applied during research

SECTION 2

OVERVIEW OF THE CONFLICT

"...y vinieron a decir que habíamos hecho una cabaña en el parque! Ellos hicieron un parque sobre la casa de nosotros!"

Valentín de Hoyos[12]

12. "And they (Officers from National Natural Parks) came to say we had built a cabin in the park! They made a park on top of our house!". Native fisherman and tourist guide about a cabin built around 1982 in the now Protected Marine Area. Extracted from the documentary film "Tantos tan invisibles" (All the invisible) (Beltrán et al. 2011)

Beginning in 1991 with the "green" political Constitution where 30 articles make reference to the protection of the environment: as an obligation of the State and of individuals; as collective right and duty; and as a determining factor of the economic model, which should be driven by Sustainable Development; Colombia has been developing a legal framework[13] to become a leading country in the natural resources management and under this context the figure of Natural National Park[14] was adopted.

13. See for example: Constitutional articles 8, 49, 58, 63, 67, 69, 80, 81, 88, 95, 339, 340, 360; the Environmental code, the legislation of the Ministry of Environment (MinAmbiente); Law 99 of 1993; Law 115 of 1994; Solid waste policy of 1997; National Policy of Environmental Education of 2002.

The Natural National Park Corales del Rosario y de San Bernardo was created in 1977, but only in 1996 it reached its current area of 120,000 ha by the redefinition of the boundaries. Today, the protected area contemplates the Archipelago of Nuestra Señora del Rosario and a portion of the Archipelago of San Bernardo, however, only two islands are protected as such: Maravilla and Mangle (See Fig.13). Other islands in San Bernardo are considered buffer zones. The park belongs to the jurisdiction of the Tourist and Cultural District of Cartagena de Indias, Department of Bolívar; however, the Archipelago of San Bernardo is located in the Department of Sucre.

14. An NNP is an area of exceptional value for the legacy of the Nation given its natural characteristics. In benefit of the entire population this area is reserved under this special figure of the SINAP (Sistema Nacional de Áreas Protegidas); declared by the Ministry of Environment (MinAmbiente) and administered by the National Natural Parks NNP (Artículo 329 del Decreto Ley 2811 de 1974)

For the National Natural Parks office (NNPO), the area has seven assets subject to conservation: coral reefs, seagrasses meadows, mangrove forests, coastal lagoons, sandy and rocky shores, tropical dry forest, and sedimentary seafloors. The strategies of the NNPO to achieve conservation are by improving governance, increasing knowledge about the assets, reducing pressures by fishing and tourism and by promoting environmental education (PNN, 2006).

However, the park has many environmental problems including 1) pollution by domestic and industrial (mainly agricultural from mainland) waste; 2) sedimentation originated by the Canal del Dique and the Sinú River; 3) Climate change inducing sea temperature rise and thus affecting the corals;

4) Marine resources overexploitation; 5) Use of inappropriate methods of extraction such as dynamite, trawling and small meshes; 6) Poorly managed tourist activities; 7) Few income alternatives for fishing communities; 8) Key species extraction (Mendoza et al. 2008).

The native community is well aware of their obligations to protect the Marine Protected Area and more importantly, they directly feel the impact of overexploitation combined with global change effects; however, measures for conservation have been rejected and in many occasions, disregarded by them. The conservation strategies of the NNPO have posed a series of restrictions on the traditional fishing communities with more than 150 years living on and from these islands; abruptly requiring them to stop commercial and artisanal fishing, hunting, logging and coastline filling[15] without effective alternatives for subsistence.

15. Natives build palisades to retain a filling of boulders, seashells, dead (?) coral, sand and other solid waste (Flórez & Etter, 2003) to stop tidal erosion of the coastlines.

A lot of this conflicting actions and perceptions are related to what the history of the establishment of a National Natural Park has been in Colombia. It is important to note that when a territory was to be transformed into a Park the State would have had to pay for the "improvements" on the land, owned by the communities, causing an immediate increase of said "improvements" to receive a higher retribution. This only meant more deforestation and agricultural transformation in territories that were originally wanted for their preserved conditions of a "close-to-pristine" nature (Durán, 2009).

Sometimes, the State did not have enough economic resources to claim the territories and the population was forced to displace massively; however, the communities that did remain on a Park became the target of persecutions and pressures to impose strict conservation norms that completely modified the traditional use the communities had been making of the resources (fishing, farming, hunting, etc.). In that sense the human component of the conservation was secondary from the beginning and the effects on the protection were limited (ibid).

With the Political Constitution of 1991, the Nation acknowledged indigenous and afrocolombian minorities; their traditional territories and practices of production, recognizing them as ethnic actors and compelling the State to negotiate any decision concerning their ancestral territories. By 1993, with the creation of the Ministry of Environment (MinAmbiente); the NNPO started creating mechanisms to improve environmental governance, like sustainable development of the communities; processes of participation;

environmental education and ecotourism. However, the recognition of the different social groups was varied; the law favored indigenous communities over Afrocolombians and small traditional farmers, giving the firsts greater participation on the management of the resources (ibid).

The policy of "Parques con la gente" or Parks with the people, a program of social participation for conservation was created to reduce conflicts on the Parks and their buffer areas by empowering all the actors involved including members or cooperatives from the communities, NGOs and the private sector. However one of the main problems the strategy encountered was the fight over the control of territories by illegal armies and drug lords due to a number of reasons: sometimes the guerrilla or the paramilitary group defines the norms of conservation to avoid deforestation, pollution or fishing with dynamite for example; also determining the associated punishments that go from forced work to executions, excluding the communities from participatory processes. In other cases the territories of the Parks are destined for illegal crops or as ports for international drug traffic, changing land use, creating pollution and reducing even more the control of the local community; and sometimes they become places of violent confrontation with the national army (ibid).

Another source of conflict has been the revenues generated by Ecotouristic activities in the protected areas that typically go to private investors with the excuse of increasing budgets for conservation by the concession of rights of use. This leaves the communities with the choices of becoming employees, contractors or the weakest competitor in the market. Additionally, publicity of the areas often shows the locals as exotic, ecologic savages. This contributes to an image of them that just as well as the ecosystems can be merchandised or used to keep them in a subordinate condition in respect of their political and economic participation (ibid).

All the clashes between different actors; found in the country in general and in the SCC-SES specifically have only left as a result two deeply vulnerable sub-systems. The resilience assessment of this SES attempted to give qualitative answers to how long can this situation be sustained before the entire system collapses; what is the most probable way the system would inertially follow after such an event; and if it is somehow possible to induce transformation towards a more desirable state of the system, ideally benefiting both sub-systems.

CHAPTER 4
DEFINITION OF THE SYSTEM

SECTION 1 SETTING BOUNDARIES
SECTION 2 SPATIAL SCALES
SECTION 3 DIAGNOSTIC OF THE INTERACTIONS

For assessing the resilience of the system (Resilience Alliance 2007, 2010), the methodology defines four main phases, 1) definition and understanding of the system; 2) conceptual models of the dynamics, interactions and evolution paths of the system; 3) implications of possible management interventions, and 4) synthesis of the understanding achieved about the resilience of the SES concluding among other things if transformation is necessary.

SECTION 1

SETTING BOUNDARIES

At the beginning of this research the focus was entirely on the small islet called Santa Cruz del Islote; however it became obvious that people of this community was daily moving through the Archipelago. As mentioned before native population is concentrated on four islands Múcura, Ceycén, Tintipán and Santa Cruz del Islote today considered "the capital" of the Archipelago for being the most significant economic and demographic spot of the area (from interviews with natives confirmed by Leiva, 2012). However, El Islote has no natural resources on its surface, providing only a mosquito-free space to build as many houses as can fit. Then as Leiva mentions there is a sense of apropriation of the space with different categories for each other island depending on what they provide for the "isleños" [16].

16. By isleños we mean natives exclusively from Santa Cruz del Islote

Fig. 14 shows the places detected during fieldwork as having a strategic value **for the islet**. The connection varies in type and strength: sometimes it is more political like with Sincelejo or Islas del Rosario, -capital of Department of Sucre and co-protected area respectively-; and sometimes it is more historical like with Barú and Isla Grande, thought to be the origin of the first human settlement on these islands. Some relations are more economy-based like with Palma which mainly provides income for tourism workers and some connections are rich combinations of economy, politics, culture, history, family ties, and recreation like the ones with Cartagena and Rincón del Mar.

Múcura additionally provides space for walking and playing; a native source of work for both El Islote and Chupundún –the native settlement of this island- with a tourist beach owned by "isleños"; an external source of work with the hotels and recreational cabins, and in a small proportion it is a source of food with the coconut plantations and the mangrove forest as well as a –bad- source of freshwater with an internal lagoon. Tintipán offers more

natural resources with the high diversity and extension of its mangrove forests, its intricate lacunar complex; the groundwater wells administered by isleños and the storages for rainwater on the recreational cabins guarded by them. It offers fewer jobs than Múcura, in lodges and cabins; and the space for the native graveyard.

For analysis purposes the three islands are so close geographically, socially and ecologically, they become axial components of a single system thanks to the strength and variety of their interactions; thus the SES under study will be limited to these three islands and their area of impact in the ocean; termed here as the **Santa Cruz complex** or SCC-SES as the object of the resilience assessment.

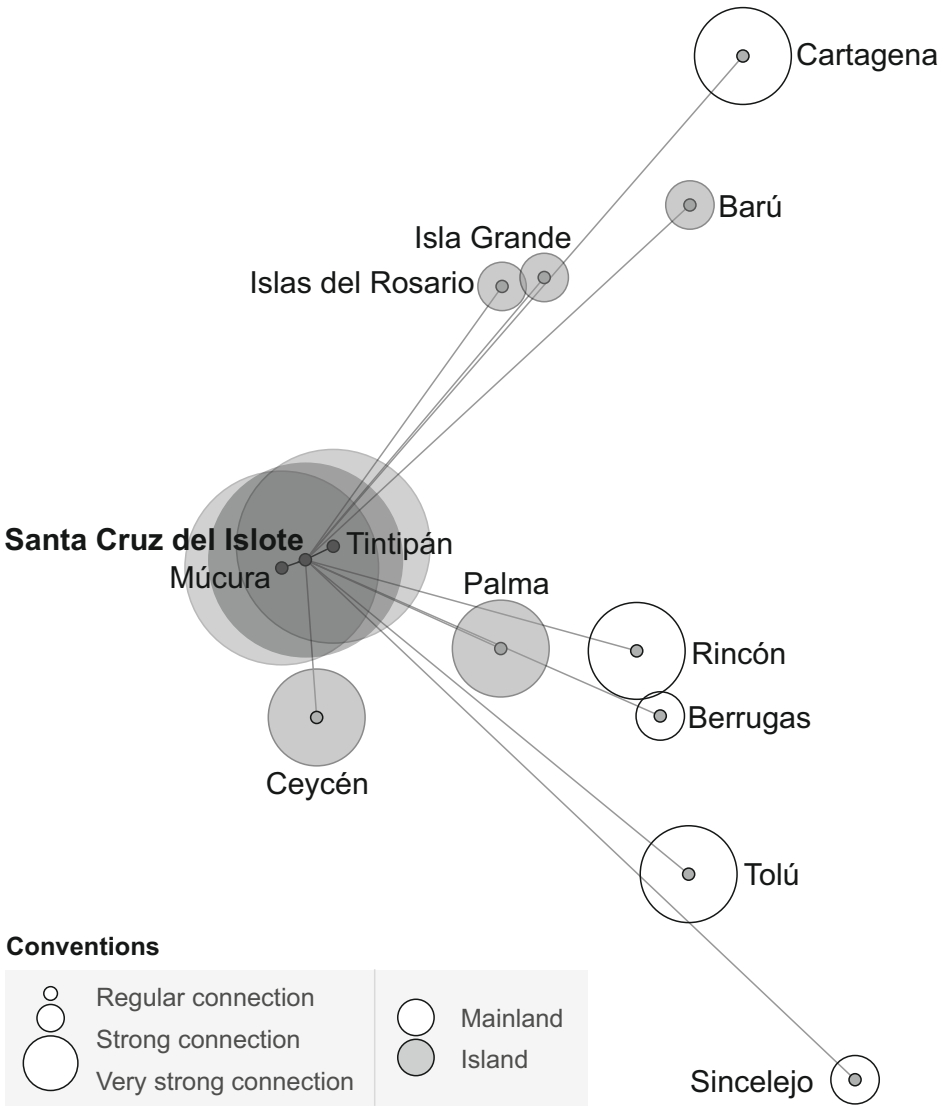


Fig. 14 Preliminary map of connectivity between Santa Cruz del Islote and other key settlements. Length of the lines are scaled geographical distances. The size of the circles indicates the strength of the connection based on the amount of appearances in the discourse of the natives and on literature on the archipelago. Source: Developed by author based on Flórez & Etter, 2003; IESCI, 2011; INVEMAR 2002, 2006, 2009, 2011, 2012; Leiva, 2012a; Lizarazo et al. 2007; Mendoza et al. 2008; PNN, 2006. For the complete document of quote compendium of the interviews, refer to the digital folder of this research: Citas de las entrevistas.docx

THE SANTA CRUZ COMPLEX

The SCC-SES consists of the islands Tintipán, Múcura and Santa Cruz del Islote and represents the focus for the resilience assessment. Their geographical proximity and historical development has created a strong interdependency between among them such that they can be –for the purpose of this research- considered one single system. Each has developed a specialized sub-function that contributes to the main purpose of the system; which is for the **native community to remain healthy**[17] **in the area**; a conditioned state that requires both the social and ecological sub-systems to be sustainable. The main role of Tintipán is to provide natural resources, while of Múcura space and economic entries and of Santa Cruz the center of the social network of the three. Fig. 15 shows the location of the complex, while Box 1 and Table 1 compare some of the main features of these islands.

17. Healthy is understood here as of having the nine axiological categories of human needs satisfied by synergic satisfiers (See also Table 2).

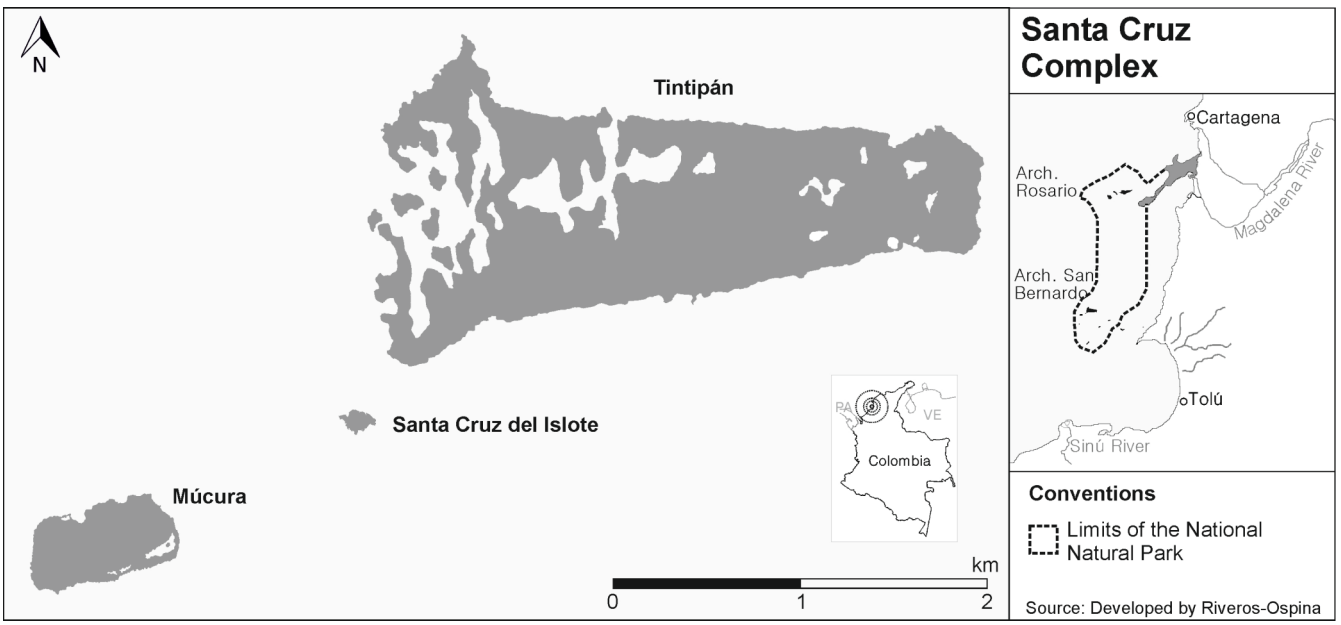
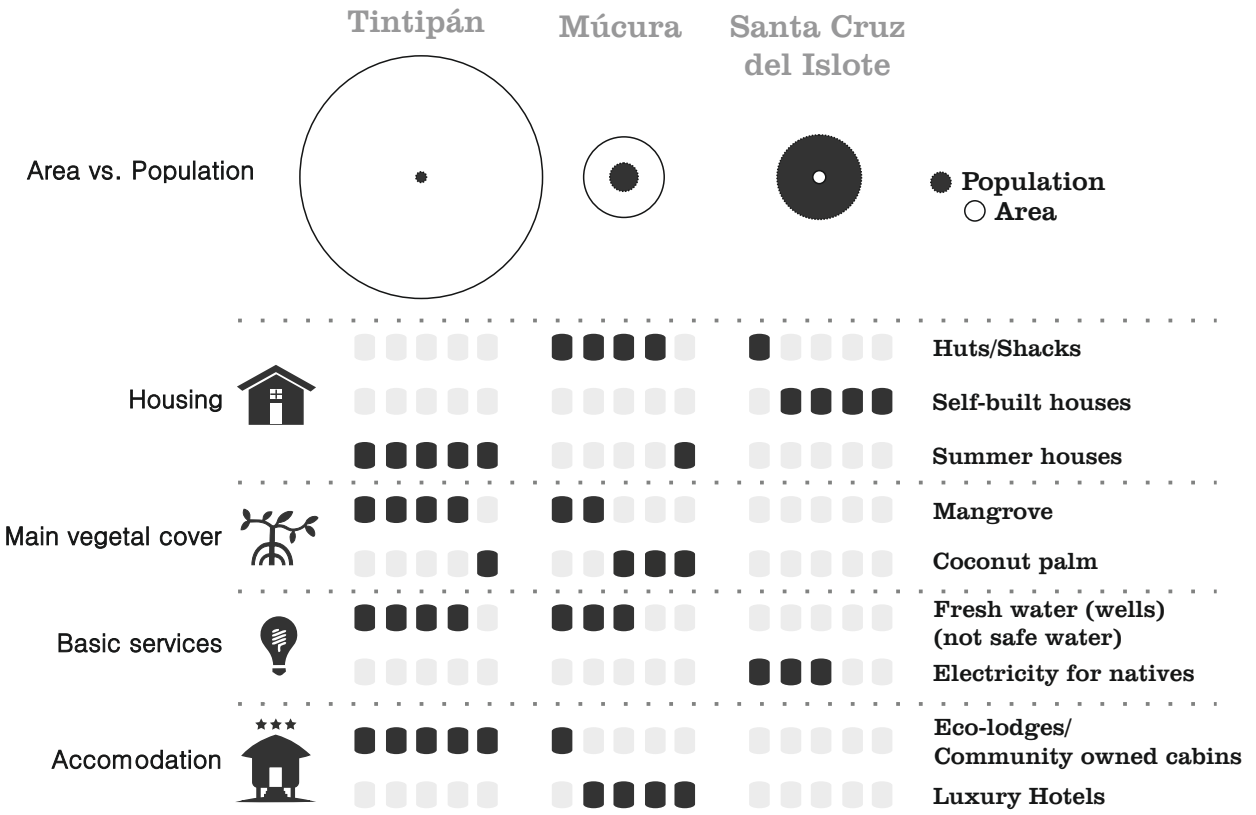


Fig. 15 Map of the Santa Cruz Complex: Santa Cruz del Islote, Múcura and Tintipán



Box 1: Comparative analysis of some key aspects of the SCC-SES.

Sizes of the circles represent the ratio of population vs. area in each island, evidencing the overpopulation of the islet. Additionally if the cause of the initial settlement in the islet was the presence of sandflies, it is possible to see a correlation between mangrove forest cover, presence of sandflies and amount of population.

For the following four categories, five squares indicate the proportion in which the items in the right column are found in each island (grey squares are blank, black ones indicate presence of the item). In the case of housing, three items can be found in the islands: huts or shacks made of wood, palm leaves and asbestos sheet roofs; an upgrading of former shacks turned into cement self-built houses and luxury summer houses where natives work stewarding.

For the vegetal main cover there is a clear dominance of mangrove forest in Tintipán, of coconut plantation in Múcura and of none in the islet. As for basic services, the availability of freshwater and electricity for natives was evaluated. In the category of tourism accommodation, there are two sorts in the islands: eco-lodges or luxury hotels.

Source: Developed by author based on field observation, Flórez & Etter 2003, Leiva 2012, INVEMAR 2006.For supporting data, see Table 1

Table 1 Basic data from the islands. Source: Field observation, Flórez & Etter 2003, Leiva 2012, INVEMAR 2006.

	Tintipán	Múcura	Santa Cruz
Population (persons)	90	227	715
Population in high seasons (persons)	200	500	1087
Native houses	0	38	94
Hotels/Summer houses	21	3	0
Area (ha)	331,5	36,7	1
Population density (persons/km2)	27,1	648,5	71500

SECTION 2
SPATIAL SCALES

ECOLOGICAL SUB-SYSTEM

The islands in the archipelago are characterized by three main ecosystem types: coastal lagoons, mangrove forests surrounding them, and dry tropical forests (INVEMAR, PNNCR y SB , NOAA, 2006); coral reefs and seagrass beds colonize the oceanic platform.

Ocean waters in this area are relatively clear with steady temperature (29°C) and salinity (35 ppt). Occasionally the archipelago receives waters from the Sinú River, whose outlet is located 30 km to the south (López-Victoria and Díaz, 2000) or from the Magdalena River, which is the source of the largest input of continental waters to this coastline, especially when trade winds move them south to west. This has degraded the quality of the water by an overestimated capacity of the ocean to absorb pollutant discharges. Coral reefs are extremely sensitive to this degradation because i) reef organisms have a very narrow physiologic tolerance, ii) interactions among key species (plant-herbivorous) are highly vulnerable and iii) toxicity of certain pollutants increases with high temperatures (INVEMAR, 2009)

In San Bernardo, coral reefs (mainly of *Montastraea* spp., *Porites porites, Agaricia tenuifolia*) act as a barrier reducing wave impact and strong currents, thus helping the creation of sedimentary substrates for seagrass and mangrove ecosystems to establish. In turn these two act as sedimentary

traps, improving water transparency, which favors the development of the reef. Additionally mangrove forests serve the functions of nursery for coral fish communities, habitat for mammals, birds, reptiles and amphibians, regulation of local temperature, winds and precipitation, protection of the coastline from erosion, retention and fixation of soils, protection of the islands from hurricanes and storms, recycling of nutrients and carbon fixation while also representing a good source of construction and industrial materials, landscape and recreation (Flórez & Etter, 2003).

The loss of algal endosymbionts in coral communities, also known as coral bleaching is a state of difficult recovery with drastic consequences for the coral in its function as biodiversity source. However a dominance of algae is also a sign –although not a cause - of coral mortality and low levels of herbivory which can prevent coral recruitment and recovery (Rodríguez-Ramírez et al. 2010b, Cinner et al., 2012).

The karstic processes present at the formation of the archipelago are responsible for the heterogeneity of the seabed with the formation of deep bottoms (up to 40 m depth) and internal brackish lagoons like the ones characteristic to Tintipán. Beyond that, the area has shallow waters (5 m depth) and the islands have from 80 cm to 2 meters of elevation (INVEMAR et al. 2002)

Tintipán and Múcura are composed of four geomorphological units (Fig. 17), namely tidal channels (70%), dissection slopes (0,5%), summits of the coralline terrace (19%) and coralline beaches (10,5%). 73 plant species (63 genus and 43 families) were identified on these two islands with Fabaceae (6 spp.), Rubiaceae (6 spp.), and Euphorbiaceae (4 spp.) as the most diverse families. Tintipán is mostly dominated by red mangrove (*Rhizophora mangle*.) (77,8% of island surface). In Múcura the domain is exerted by coconut plantations (*Cocos nucifera*) with ground vegetation and a patch of Mangrove covering 36,2% of the island (Flórez & Etter, 2003).

According to Flórez & Etter (2003), Múcura could have established in the past far more developed forests than the ones in Tintipán due to morphological aspects like its continuous coralline summit; and geographical aspects: Tintipán protects Múcura from erosion of the trade winds. They find evidence in the vegetation differences between the two islands and the tall tree relicts in Múcura, now almost covered with coconut monoculture.

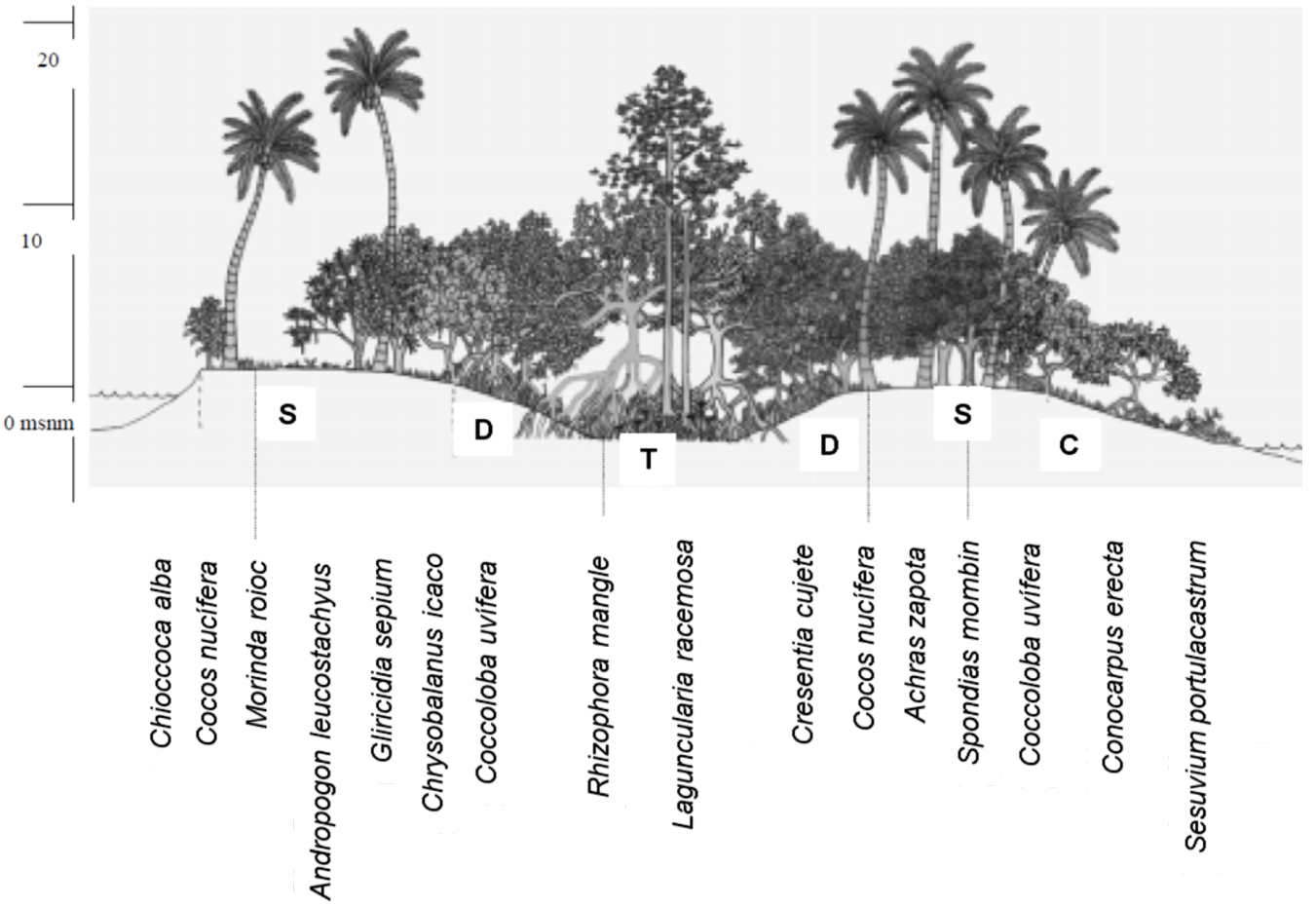


Fig. 16 Topographic and vegetation profile of Tintipán. S (Summits of the coralline terrace), D (Dissection slopes), T (Tidal Canals), C (Coralline beaches). msnm (meters above sea level). Source: Flórez & Etter, 2003

Múcura and Tintipán have mobile beaches, coastlines under erosive processes, and dynamics of accumulation of boulders or mangrove development. It means there are alternation periods between erosion and reconstruction by sedimentation (Flórez & Etter, 2003). Erosive processes of the Colombian Caribbean accelerated in the 1970s and 1980s with the development of coastal cities and cities like Medellín, Bogotá, Cali and Bucaramanga which severely impacted the waterbasin of the Magdalena River. In the Archipelago, the rate of erosion is medium with 2-3 m/year (1986-2006).

From measurements between 2006 and 2011, a small recovery of the coral cover was observed in San Bernardo after a severe episode of bleaching in 2010. However, diseases like the Dark Spot Disease (DSD) have notoriously increased in the last years (INVEMAR, 2012). See Fig.17.

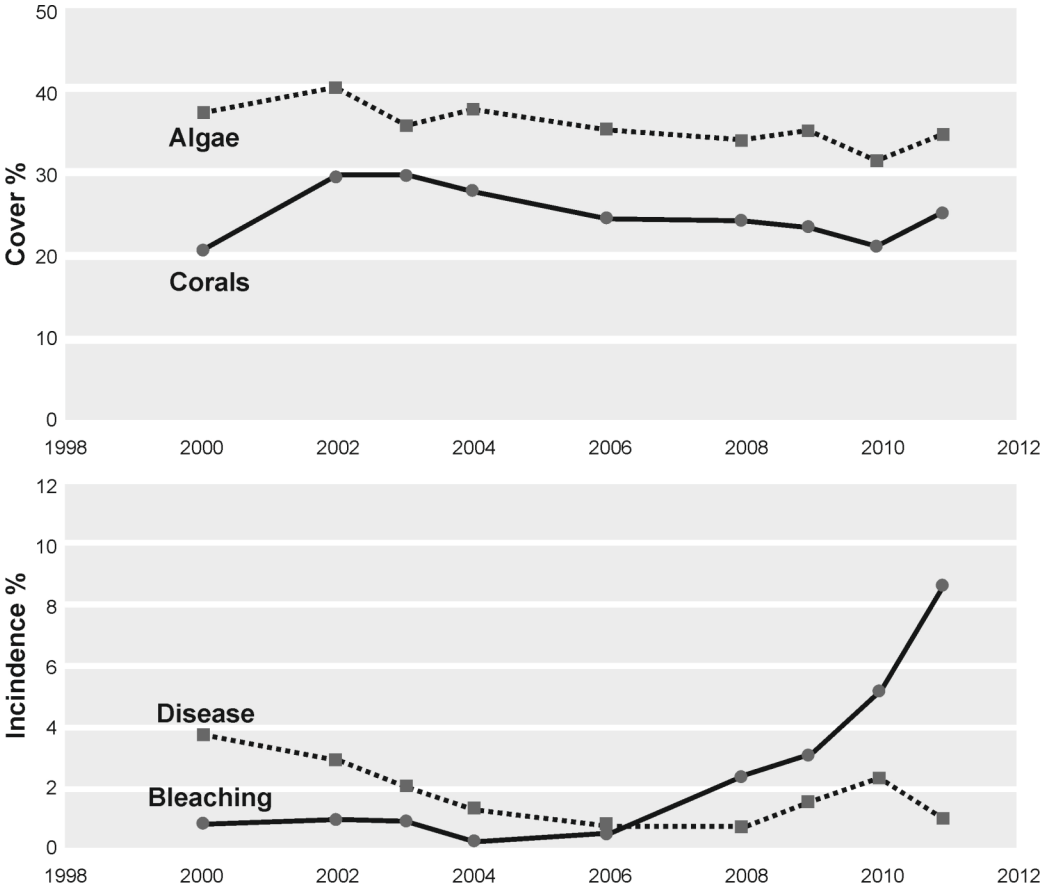


Fig. 17 Corals in San Bernardo. Evolution of coral cover vs. algal cover and incidence of coral disease and bleaching through the period of 1998 to 2012. Source: INVEMAR, 2012

In general, overfishing of species of economic interest like snappers (pargos) (*Lutjanidae*), groupers (meros y chernas) *(Epinephelinae)* and grunts (roncos) (*Haemulidae*) (Díaz et al., 2001); as well as Lobsters (*Palinuridae*) crabs and seashells, particularly *Strombus gigas*[18]; has produced changes in the dynamics of the ecosystems of the entire area of the NNP, also increasing populations of algae (INVEMAR, 2009). Other critical or threatened species in the area are the Atlantic goliath grouper (*Epinephelus itajara*), Hawksbill turtle (*Eretmochelys imbricata*), Green turtle (*Chelonia mydas*) and Olive Ridley Turtle (*Lepidochelys olivácea*) (INVEMAR, 2009). Therefore, the NNPO has determined the species requiring special protection are Grouper (*Epinephelinae* spp.), Parrotfish *(Scaridae* spp.), Elkhorn coral (*Acropora palmata*), Staghorn coral (*Acropora cervicornis*), Lobster (*Palinuridae* spp.), Crab, Starfish, Sea urchin, Hawksbill sea turtle (*Eretmochelys imbricata*), Queen Conch (*Strombus gigas*) and Octopus spp. (PNN, 2006)

18. Threatened species according to CITES with abundance of < 4 individuals ha-1 for the area of the Park (INVEMAR 2009)

SOCIAL SUB-SYSTEM

Native communities of the islands identify themselves as Afrocolombians, which gives them special rights for belonging to an ethnic minority including better chances of guaranteeing land tenure. Isleños have started in 2011 a legal action to be declared an *Afrocolombian community*[19]. This status as ancestral population would give them the right to obtain collective ownership of the islet, which is currently considered just as Múcura and Tintipán, a vacant land (terreno baldío) owned by the State. However, both El Islote and Chupundún have all the characteristics to be categorized as slums or shanty towns (UN-HABITAT, 2003; UN-HSP, 2003): inadequate access to safe water; inadequate access to sanitation and other infrastructure; poor structural quality of housing; overcrowding; and insecure residential status.

19. This means they have an african-colombian origin, a culture of their own; they share a history and have their own traditions. They preserve this identity which differentiates them from other ethnic groups (Ley 70 de 1993: Congress of Colombia)

Main economic activities are artisanal fishing and ocean-related (eco)-tourism, both led almost exclusively by men. The role of women is stronger on the islands where they work at the hotels and decide about households, children upbringing, religious, cultural and administrative matters like fee collecting and management of resources like water and electricity. As a strategy to resist bad fishing seasons the communities practice aquaculture of best-selling species like lobsters. Nevertheless, reaching mainland markets is expensive for the required fuel; therefore locals make the best income when they sell the products directly to tourists or local hotels.

Isleños are the descendants of the first Afrocolombian fishing community that settled in San Bernardo and for this reason they feel a very strong tie and identity with the islet as the center of the native life in the archipelago. Múcura has the second largest population but most of them are immigrants from coastal areas; tourism in this island is developed through high profile hotels but also by a beach made and "owned" by isleños where the native community has more power and influence. The combination Ceycén as fishing station, Múcura as agricultural and tourist area and Tintipán as source of ecosystem services creates a relation of tense cooperation between the two communities also because much of the attention and subsequent government interventions have been drawn by the islet, resulting in even more disregard of the native communities of Múcura and Ceycén. There is no native settlement in Tintipán; all the natives living there are isleños that work guarding and working on summer houses or lodges. (Leiva, 2012a; Flórez & Etter, 2003)

There is no electricity infrastructure in any of the three islands. Hotels and vacation houses have private power plants of different capacities, and the islet uses a diesel plant to provide six hours of electricity to contributing users. The population is used to a shared and/or time-restricted use of appliances, which is more cost-efficient. The capacity of this plant exceeds the demand of the population, thus making it very expensive to operate.

The territory of Santa Cruz del Islote is entirely built with 96 houses[20] connected by narrow streets and alleys. The periphery of the islet constitutes a series of docks and "patios" (small aquaculture lots), leaving no room for natural resources or a beach. Furthermore, most of the territory of the islet is the result of an artisanal technique called "calce" in Spanish, consisting in the filling of the shore with shells, rests of coral and solid waste, pressed and covered with concrete in the last stage of the process.

20. No more than three stories edifications that sometimes perform double services which include some groceries stores, a school, a health center, a church, discos, a restaurant and a cockfighting arena.

Dwellings are self-built and they are an improvement of previous sheds; today with one and two stories concrete houses and some small wooden huts in the islet; while in Múcura the majority of the settlement is built with wood and palm leaves. Running water and sewer systems are only found in hotels; however the islet and some eco-lodges have self-made differentiated ducts for rain and sea water.

There is a relatively new (8 years) one-room school in Múcura offering elementary education (all levels simultaneously) for the children in Chupundún, and subsidiary to the school in the islet which offers up to the 8th grade (IESCI, 2011), this one has received donations to make it larger –it is actually the tallest building on the islet- and better equipped. After the 8th grade some kids go to mainland cities to finish schooling but many drop out at even lower levels and join their relatives fishing or working with tourism.

Birth rates are high with 5 to 10 births per year while mortality is very low with 1 death every 2 to 5 years (Known from interviews, official registrations do not exist). Morbidity is related to skin, respiratory and digestive problems associated with consumption of unsafe water, long exposure to sunrays and bad waste management (IESCI, 2011); additionally fishing accidents are common. However, they are in general healthy, physically fit, strong, long living people. Today it is possible to find a doctor and a nurse at the healthcare center located on the islet and in charge of the entire Archipelago, on a daily basis[21]; however this is a Primary Attention Unit (UPA in Spanish) which means patients must be taken to mainland for emergencies.

21. This service is provided by the ESE (Government Social Enterprise) of Cartagena.

Conflicts are solved within the communities, although symbolic positions for general security are filled by natives. Known long history of drug trafficking through the area have brought economic welfare but also the threat of consumption. Globalized information accessed through satellite television and internet in the islet has made young people eager to go out of the islands or to wish for their kids *the life they never had* and *more opportunities* outside the archipelago[22]. Life in the islands is described as monotonous and party is always welcome; sexual activity is started early and polygamy in men is tolerated by women and admired by other men. Young women use now birth control to avoid having as many children as their predecessors.

22. For the complete document of quote compendium, refer to the digital folder of this research. Citas de las entrevistas.docx

From the observation of a decision-making process for the solar/fuel 24 hour electricity generation project, in a session in Múcura; it was perceived that strategic decisions like the conformation of the coordinating committee, the selection of the 12 hours of the day when electricity was mostly needed in this island, for a trial experience; and the selection of the public place within the settlement of Chupundún, to locate the generating plant and the solar panels; were taken in consensus with the participation of nearly the entire population, within a couple of hours. A sign of adaptability that is probably due to the necessity of fast reactions characteristic to life in the islands with the interaction with the sea and the high scarcity of rain.

SUPER-SYSTEM

The archipelago has multiple administrative entities: some islands belong to the Department of Sucre and some to Bolívar; some are within the boundaries of the Natural Park as buffering areas, controlled by the Touristic and Cultural District of Cartagena. Some islands are outside said boundaries and some are protected areas themselves. This creates a diverse identity for natives that see themselves as *isleños* (from Santa Cruz del Islote) or islanders (from any other island), *costeños* (from the Caribbean coast), *cartageneros* (from Cartagena, where they also own properties or have close relatives) and *afrocolombians* (Leiva, 2012). This creates a strong attachment from the community to the area, but it also produces difficulties to manage the archipelago as a unit, hindering conservation strategies.

Threats coming from the larger scale are fast coastal development, urbanization and population growth: Colombian northern coast has been one of the preferred destinations not only for workers and entrepreneurs from the interior but also for people displaced by the long-running armed

conflict (León, 2013). Industrialization has made this area a key port for marine commerce and commercial cruises and an established route for legal and illegal trade with Central and North America and in the last years with Europe (Mantilla, 2011). Additionally, it is exploited industrially by national and international fishing, natural gas and oil companies.

More aspects of the Supersystem influencing the SES were described in Chapter 3.

SYNTHESIS OF THE PANARCHICAL STRUCTURE

Nine windows[23] of a SES give an integrative perspective of time and scale having as a base a system in present time which is serving a main purpose or function and for that it arranges certain components and relates to certain contexts. In the case of the SCC-SES the main function is identified as the **community remaining healthy**[24] **in the area**, which makes it compulsory for both the social and ecological sub-systems as well as their interactions to be sustainable.

From the analysis developed in this section, Fig.18 shows only the spatial scales found in the SCC-SES, identifying main components, actors, and institutions related to the system under study.

23. Also called the system operator, the 9 Windows are one of the tools of the innovation methodology TRIZ developed by Genrich Altshuller. See Savransky 2000.

24. Healthy is understood here as of having the nine axiological categories of human needs satisfied by synergic satisfiers (See also Table 2).

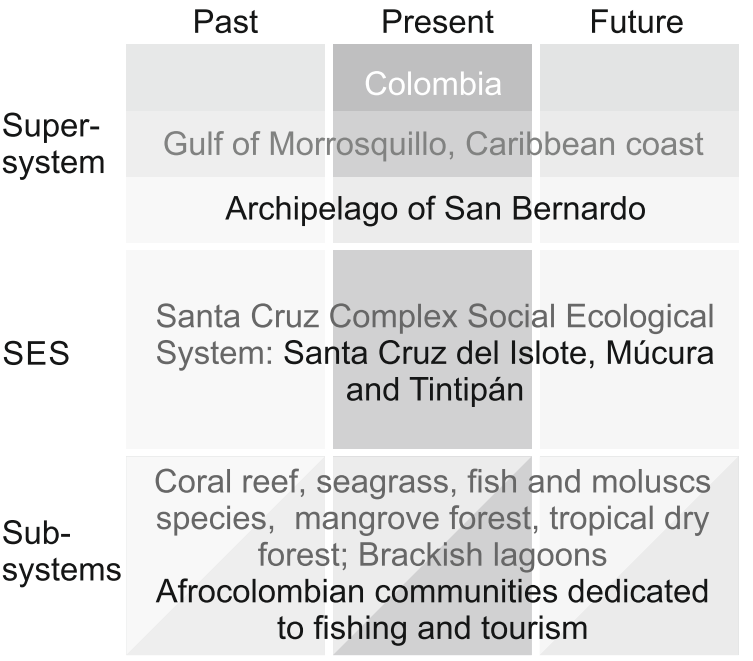


Fig. 18 Preliminary view of the Nine windows for SCC-SES. Scalar analysis serves the purpose of clarifying Panarchies: Larger scales have the ability to protect and control smaller scales while these latter can innovate and experiment thanks to their higher dynamicity. Source: Developed by author based on Chapter 4: Definition of the SES

SECTION 3

DIAGNOSTIC OF THE INTERACTIONS AND LEVEL OF COUPLING

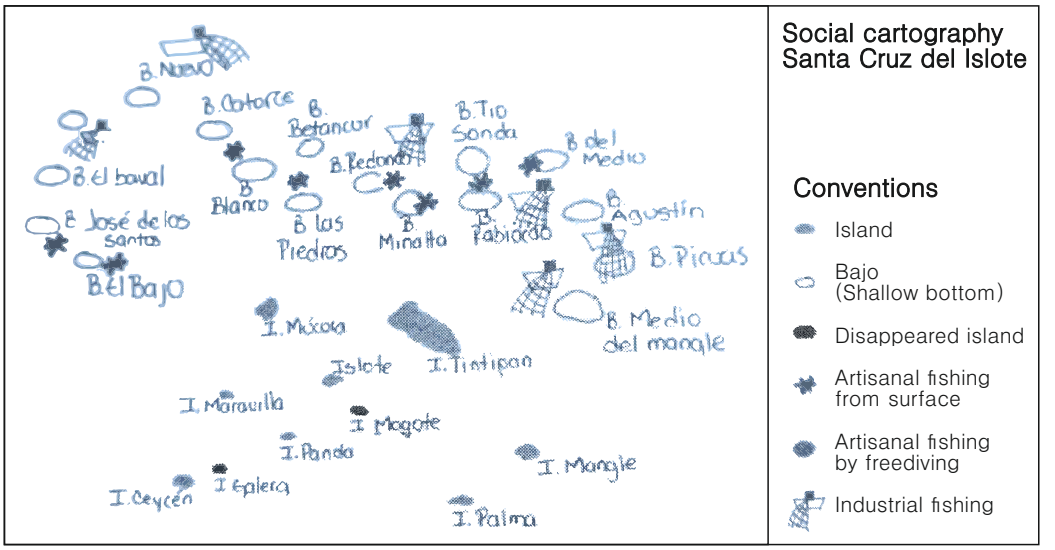


Fig.19 Social cartography of the archipelago by the community of the islet. Exercise with the communities where 65 people from several group of actors (fishingmen, artisans, hotel owners, tourist guides, community leaders, teachers, elders and young natives) were consulted on the location of the islands and the areas for fishing; identifying the most used "bajos" or shallow shoals such as Minalta thought to be the most productive one; TioSolda, Rabiorcao, las Piedras and Blanco. Additionally the presence of industrial fishing is detected within the boundaries of the protected area and two disappeared islands are remembered. Source: Modified from Mendoza et al. 2008.

As previously described, human communities (social sub-system) satisfy their most fundamental needs directly and indirectly with ecosystemic products and services (ecological sub-system). In the SCC-SES the community has developed tight interactions with the natural resources evidenced in the conversion of fish products and vegetation to elements of their economy. Fig.19 shows for example the perceived importance of areas that for the casual observer are just "more ocean", but for the communities are the key of their subsistence.

Furthermore, from the revision of the concept of satisfiers for the islands, Table 2 shows the satisfiers natives give to their needs, highlighting the ones they get in the most obvious way from their biophysical context, or those that have been developed by the long struggle with it. From the observed in seven out of nine categories the link of the community to the insular environment is direct and it can be concluded that the SES is highly coupled which means there is a common "fate" for both sub-systems.

Table 2 Matrix of needs for the community in the SCC-SES. The highlighted satisfiers are the ones directly obtained or developed by their relation with the insular ecosystems. Some satisfiers are destroying or inhibiting other needs, some are singular satisfiers and some are synergic. Source: Developed by author based in Max Neef, 1992

	Being Attributes	**Having Institutions/ Mechanisms**	**Doing Actions**	**Interacting Space/time**
Subsistence	Adaptability, resourcefulness, solidarity, complicity	Methods of fishing, fish market, tourism strategies	Fishing, guiding, collaborating with illegal trading, buying water	Island ecosystems, coral reefs, ocean, communities, mainland
Protection	Adaptability, Hard-work, distrust	Shelter, health system, minority rights, family, tight personal links	Filling coastline, building, cooperating, discharging waste water and solid waste to the ocean and lagoons	Dwellings
Affection	Warmness, solidarity, tolerance, passion, sense of humor, generosity, promiscuity	Friendships, family	Sharing, expressing, having children	Schools, homes, public spaces. Nights (with electricity)
Under-standing	Curiosity, communication	Teachers, fishing "masters"	Instructing, giving example, observing	Fishing journeys, schools
Participation	Organization, receptiveness, respect, solidarity	Community action board	Communicating, protesting	Meetings, internet, families
Leisure	Relaxedness, communality, flexibility	Celebrations, games, addictions	Talking , dancing, playing, partying	Ocean, forests, beaches, playing and dancing spaces
Creation	Imagination, boldness	Skills, work, effort	Inventing	Free time, lack of resources
Identity	Deep sense of belonging, differentiation, discrimination	Religions, language, traditions, gender differentiated groups, habits, sexuality	Integrating, bragging, committing, staying	Daily routines
Freedom	Tolerance, illegality	Tight personal links	Choosing, disobeying	Daily routines

Based on this analysis it becomes clear that some satisfiers do not behave in a synergic manner which increases the rigidness for the whole system; however it is important to remember that the selection of these particular satisfiers represents culture for this portion of the society (Max Neef, 1993); therefore if a transformation of the interactions between the two sub-systems is needed, the process to do so will be very challenging and will have a deep social impact.

What is also visible from this analysis is that some needs could be fulfilled with a base of ecosystem elements but currently are not satisfied. Safe drinking water or solar energy for subsistence, are examples of this. This creates dependencies to external actors, also reducing dynamicity of the system by restricting participation and power to make decisions about the management of the resources.

CROSS SCALE INTERACTIONS

The jump of causes and effects between scales shows the complexity and non-linearity of the SES. To give an example, Fig. 20 illustrates among others, the case of the increase of fishing effort. As tourism on the area (SES) is intensified, job opportunities create migration to the islands or permanence of the young people which causes overpopulation especially on the islet (subsystem). A higher population –also increased by tourists- rises the demand of fish products hence increasing the fishing effort; however this also happens due to the competition for the resource between natives and the fishing communities from the coast (supersystem); while said resource is at the same time the stock left (not caught) by industrial fishing boats (supersystem) still working in the area despite of its conservation status. As consequences of the increased fishing effort there are losses on the coral and mangrove populations since the techniques used have to be more aggressive and even dangerous for the fishers; and this loss of habitat for the species of interest naturally cycles back into the effort required to catch.

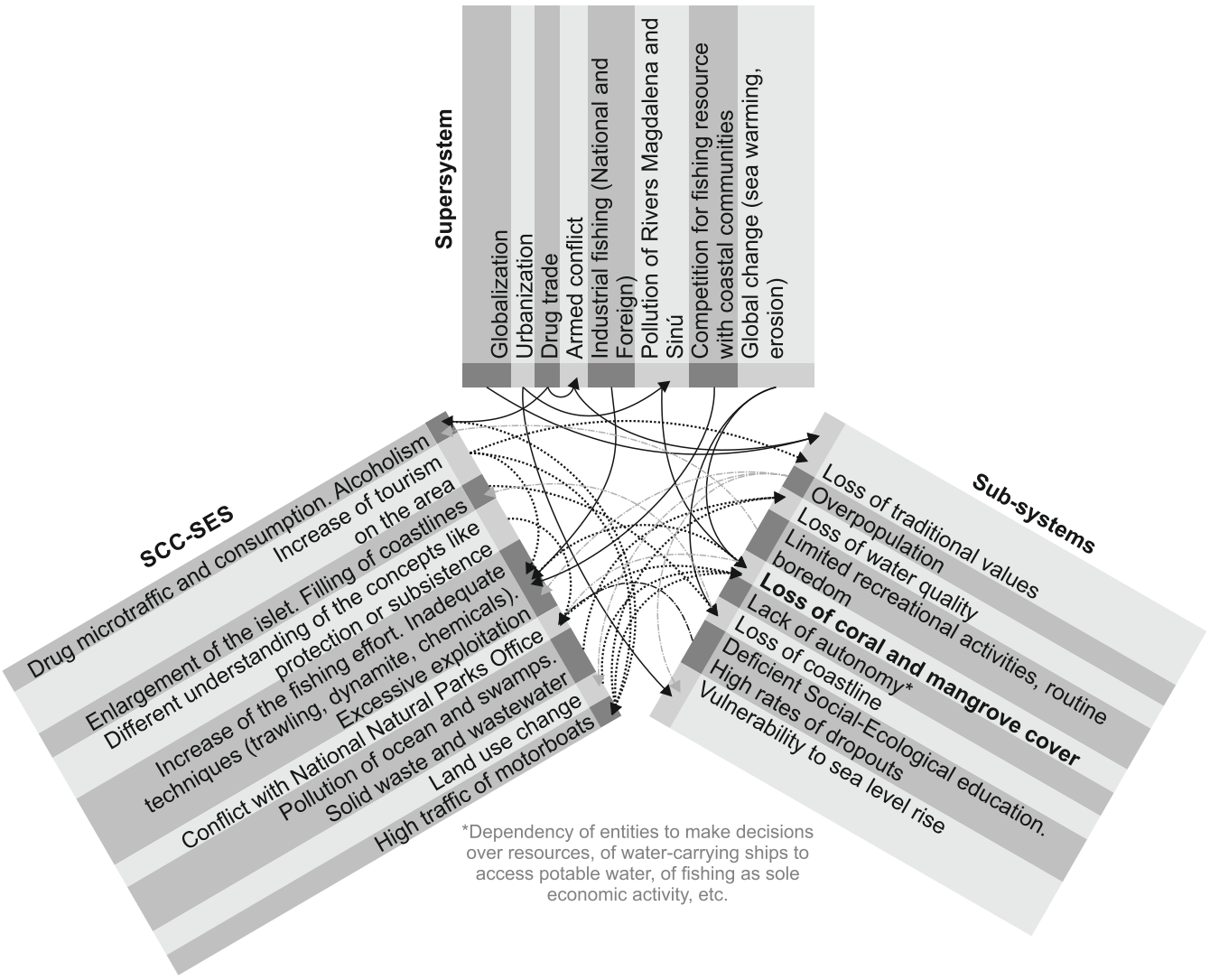


Fig.20 Disturbances on the SCC-SES: Issues cascading and crossing the three spatial scales

CHAPTER 5
DYNAMICS OF THE SYSTEM

SECTION 1

TEMPORAL ANALYSIS

Interactions between different scales are crucial to the development of events within the SES. Table 3 shows three different scales: the larger (L) scale represents the super-system: the country, the Caribbean Region in Colombia and the Archipelago of San Bernardo. At the medium (M) scale events in the SCC-SES level are registered, and at the smaller (S) scale, the evolution of Santa Cruz del Islote: "capital" of the archipelago and social axis of the complex, is described.

Table 3 Timeline for the Santa Cruz Complex. Sources: INVEMAR, 2003; Leiva 2012; Flórez and Etter 2003; Interviews with the community

Year	Scale	Event
Paleoindian - 1300 (ca.)	M	It is thought that the culture of the Mocans and then the Carex and Mahates used the islands for **fishing**. This would connect native Americans, African slaves and modern communities around this activity.
1589	L	Islands in the archipelago of San Bernardo are considered till today vacant land and property of the Nation; however since Spanish colony false royal charters and property titles on the island of Múcura have been used to occupy it. These negotiations will create conflicts between alleged owners (original and successive buyers as well as heirs) and the State until today.
1593	L	The island of Barú (former Peninsula of Barú separated by the Canal del Dique) on the Archipelago of Rosario (Colombian Caribbean coast) is granted to Spanish colonizers as private property
1603 (ca.)	L	In the pacific and Caribbean coasts escaped slaves settled in rebel communal towns called palenques, with their own socioeconomic organization
1820	M	Natives begin exploratory travels from the communities of Barú to the archipelago. The richness of the ecosystems makes the fishing very successful but very far from home. Fishing men establish fishing stations on the islands for the winter months but discover mangrove covered islands are greatly inhospitable because of the mosquitoes and sand flies;
1851	L	Slavery is completely abolished in Nueva Granada
1860	M	Immigration to the islet starts. Natives settle their homes as they bring along their families in Santa Cruz del Islote: a tiny cay without any important vegetal cover; but rely on the resources on other islands. Some of them clear the land and build small coconut farms in Múcura and Tintinpán
1875-1885	L	Boom of the coconut trade throughout the coast. The islands produce also hawksbill shells, other turtles and fish
1887	L	94 commoners buy from their Spanish master the Hacienda Santana (Santa Ana) in Barú
1900 (ca.)	M	Deforestation of the Mangrove forests for charcoal production causes the disappearance of the islands Caracolillo, Salamanquilla, Juan de Jesús and islets Galeras and Mogote due to tidal erosion.
1920	M	The "*porroca*" -a coconut disease- kills the island plantations. Natives sell some lots they had cleared by slash-and-burn in Múcura to outsiders. The production of the islands shifts with the increased demand of red mangrove as charcoal in Cartagena

1930	M	Maritime trade starts with Panama where coconut was still on demand and this brings along smuggling of merchandise
1960	L	The first National Natural Park is created in Huila-Caquetá Smuggling from Panamá is reduced with a stronger control from authorities. Charcoal commerce with Cartagena crashes for the improvements to the electricity supply in the city which shifts the economic activity of the islands for fishing
1960	S	Trade of agricultural products like yucca, corn, plantain, mango and watermelon between the islet and Cartagena, Tolú, Rincón and Berrugas increases for the impossibility of crops other than coconut on the islands
1963	S	Settlement in Santa Cruz burns to the ground. Natives camp for about a week in Tintipán and then returned to re- build the houses.
1966	L	Department of Sucre is created from a division of the Department of Bolivar, getting the administration of the islands on the archipelago
1969	L	The State recognizes the royal charters declaring Barú private property
1970	L	From this decade on, drug traffickers increasingly gain access to islands on the Colombian Caribbean and Pacific coasts to facilitate the movement of drug shipments to Central America, The United States and Europe
1970	M	The Island El Mogote disappears due to tidal action
1973	M	Chupundún: the native settlement in Múcura begins to develop
1977	L	National Natural Park Islas del Rosario is created under the jurisdiction of Cartagena
1977	M	According to senior fishers by this time the fishing started
1980	L	Year until which the state of the coral reefs in the Protected Area is considered satisfactory Industrial fishing starts
1984	L	The State discards royal charts which make natives rightful owners of several terrains in Barú, says the island vacant land which is State property, ready to sell to big tourism companies
1985	S	The materials of the dwellings on the islet are upgraded to concrete and asbestos roofs but still no basic services are provided
1985	M	Tourism boom gets natives to sell new cleared terrains on the islands, reducing

SECTION 2

ALTERNATE REGIMES: ERAS IN THE SCC-SES

Based on the analysis of temporal and spatial scales, five eras for the SCC-SES can be identified as seen in Fig. 21.

The first phase of modern **colonization** starts with a thriving fishing activity which activated migration to the islands, bringing with it, land conversion which peaked at the second era of full **exploitation.** In this phase the communities already settled enjoyed of a buoyant charcoal market with Cartagena. Charcoal was produced from mangrove trees and coconut, wiping out the mangrove forest - in Múcura especially- and creating coconut farms instead.

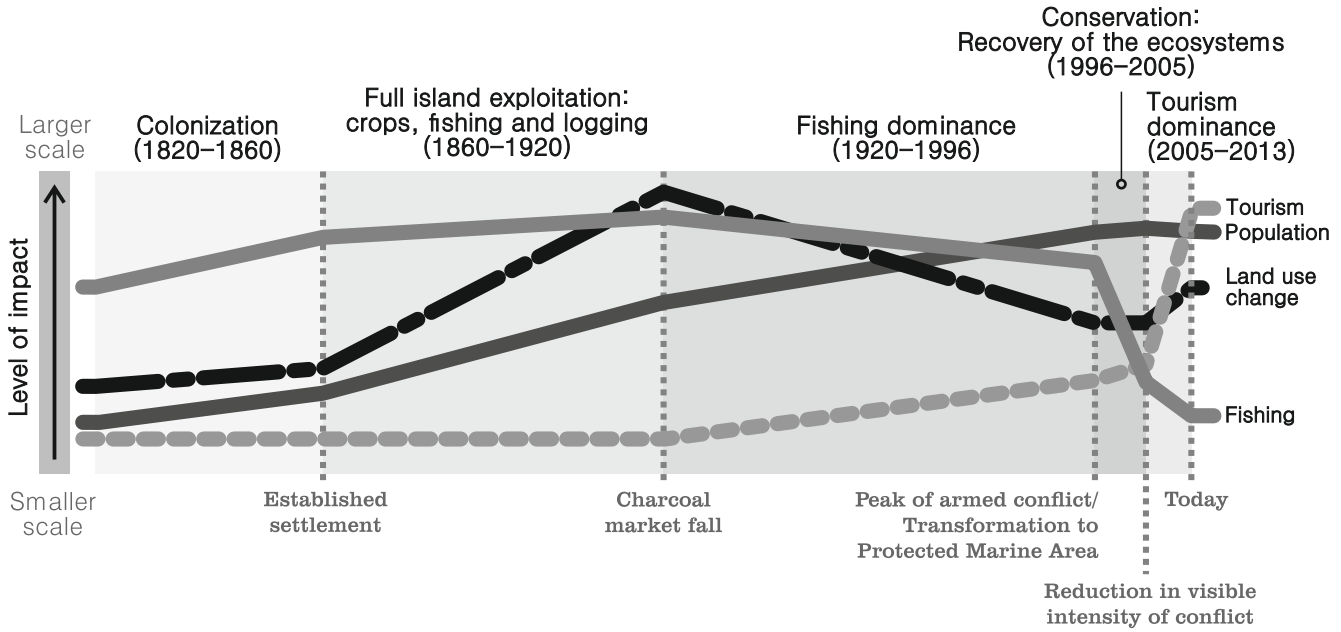


Fig. 21Conceptual model of the eras of the SCC-SES based on temporal and disturbance analysis. Dotted lines represent tipping points where the system moved to another era. Source: Developed by author based on timeline analysis

A third phase is defined by the dominance of **fishing** as main economic activity, very abundant at the beginning with profuse catches of turtles, lobsters and conches and slowly declining due to years of heavy exploitation. It started with the crash of charcoal market due to the arrival of electricity to the cities and finished with a double threshold: the peaking of the armed conflict which paralyzed tourism and mobility in general in the country; and the conversion of the area in a Marine Protected Area and National Natural Park. This phase called **conservation** resulted in a small recovery of the ecosystems. In the final phase of **tourism** as new dominant activity observed until today, fishing has continued declining while tourism has increased with offers of traditional beach tourism and eco-tourism.

From this analysis it is interesting to note the behavior of the population has constantly increased after an initial migration to the islands, even though two basins of attraction already have changed: the SCC-SES has no longer a logging, charcoal producing economy; nor is fishing its only or stronger strategy. It shows the community has been able to adapt to new regimes displaying high levels of flexibility.

In that sense, if the SES was to be analyzed with a simplification of its structure it would be different for every era as shown in Fig. 22; remembering the main function of the SES is for the community to *remain healthy in the area*. Under the assumptions that ecosystems would be the local source of

energy/matter/information to perform different tasks of the SES and that the object of the main function or the entity obtaining benefit from this main function would be the community; it is clear that the main driver has changed for every era, but additionally this visualization helps to grasp for example that only since the main driver is tourism women have gained strength as main actors. This is probably associated with a gain of decision-making power and a better access to information, visible in their larger participation in the economy and their new family planning attitude.

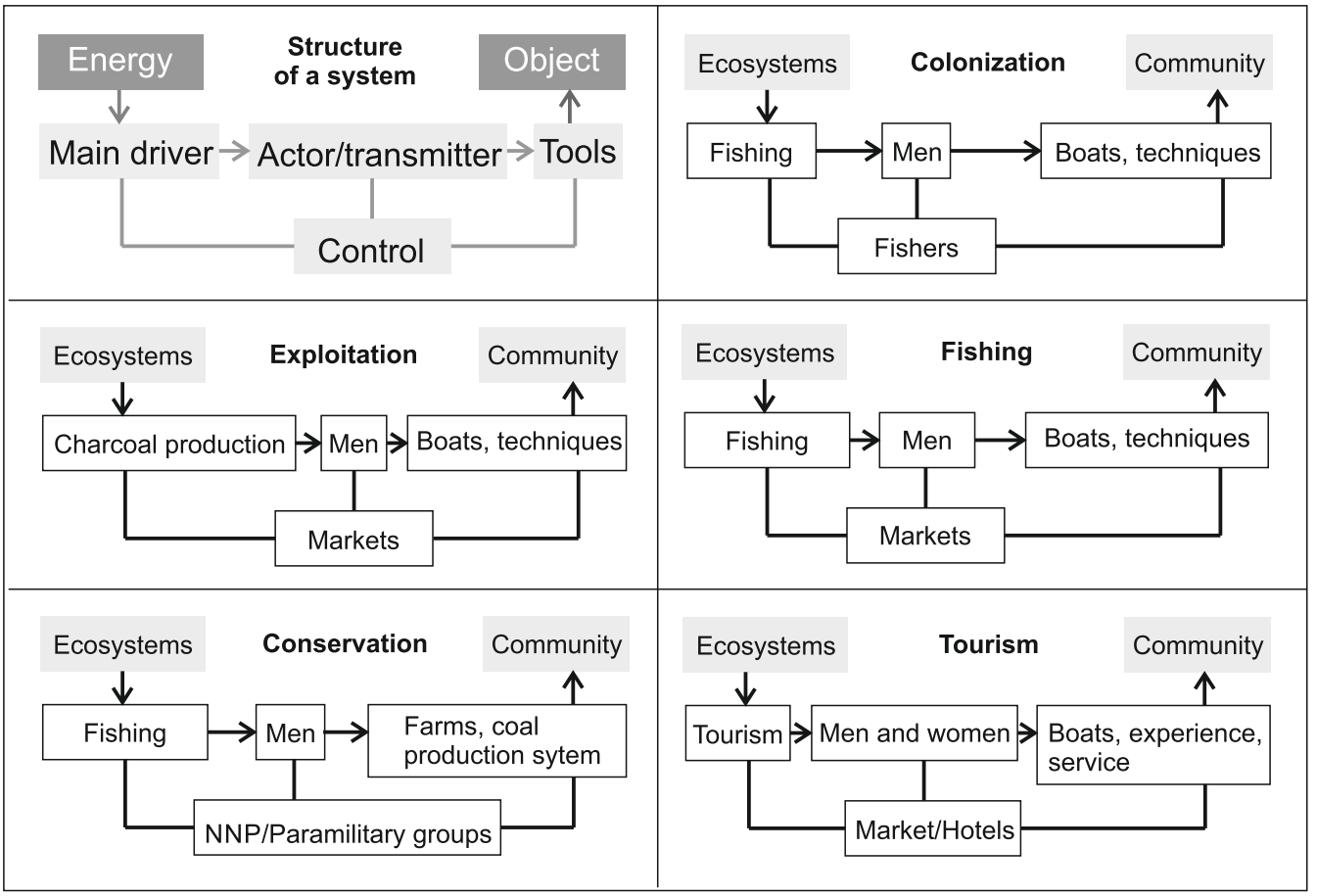


Fig. 22 Configuration of the system in every era. In the SES, the energy to perform the function is mainly obtained from ecosystems to be used by the community: main actors will use different tools according to the main driver that varies with each era. This relation will determine the type of institution, group or structure exerting the control over the system.

SECTION 3

SCENARIOS

The following scenarios are built upon the data and impressions gathered of the SCC-SES during literature review and fieldwork, linked to the concepts studied in the theoretical and conceptual frameworks. All the references can be found on the sections of definition and dynamics of the SES.

EVICTION

As the intuitive alternative to protect ecosystems within the SES, evicting the community from the natural park with a business-as-usual tendency in the larger system, would not only be difficult for their status of Afrocolombian actors or the lack of State budgetary resources to come to an economic agreement on the "improvements" (See Overview of the conflict section); but it would also be quite pointless: the ties of blood, culture and economy would make them move to already populous coastal towns and cities, following the trend of other communities displaced from their original rural contexts in Colombia. In the new places, traditionally fishing people would find little to do and it is highly probable they never find the quality of life they enjoy and take pride of, nowadays in the islands, thus increasing unemployment rates and consequent poverty and criminality. Additional to the possible psychological effects this lack of freedom and frustration can have on a person.

Increased population in the place of their destination would increase pressure on resources, space and infrastructure, as well as unregulated occupation of the land. Local -and national, if the same happens to similar communities- fishing production would fall, thus increasing dependencies on imports and industrial fishing monopolies. Also, since they are not historically, culturally or economically attached to the new place, their participation in social and political processes would be restricted.

On the other hand, with the islands "free of natives" two possible paths are detected: one is the lack of presence of the State in the form of rural population and its connections to institutions of governance, would increase the power of illegal armed actors for the strategic position of the islands losing even more sovereignty for the country. The second is the government would be able to use the lands as it intended to do with the island of Barú and

the Hacienda Santa Ana (See timeline) giving concessions to private touristic developments; both paths producing an even greater deterioration of the ecosystems. In conclusion eviction for conservation would probably be detrimental for both sub-systems; the SCC-SES would lose its identity completely and the process would even have negative impacts on the super-system.

TRADITIONAL TOURISM

A second possibility would be to actually follow the current tendency of development of the SCC-SES: increase traditional massive beach tourism disguised as "eco-tourism" for the lack of proper infrastructure. Also, work with private investment which does not really profit local communities or conservation initiatives. This is straightforward another pessimistic scenario that might benefit the social sub-system for a while but is likely to fall rapidly thanks to the interlinkages between the two sub-systems. Land use change to build more comfortable and relaxing environments like beaches and sports courts, micro-climate change from urbanization, pollution and high traffic deteriorate island and oceanic ecosystems, which would be followed closely by a decline of the touristic attractive of the islands.

BACK TO A SUBSISTENCE FISHERY

The third alternative would be for the community to reinforce subsistence -not artisanal- fishing activities, leaving tourism and fish products commerce aside. While seemingly an ideal option for the NNPO, the resource is extracted by not only the SCC-SES but international, national and regional competitors with every level of fishing techniques in spite of the conservation status of the area. As a consequence this alternative would require a massive intervention to the super-system to be viable for the small fishing community; otherwise subsistence fishing or the use of fishing rods and small nets would have null power to compete against trawlers, seiners, line vessels or trap setting boats, even if in general the fishing fleet of the Caribbean in Colombia is smaller than the one in the Pacific. On the other hand; even successful subsistence fishing only satisfies –as the name suggests- a single category of the human fundamental needs and not precisely in a synergic manner, leaving the community with small options for other areas of development.

GLOBAL CHANGE

It is out of the reach of the present study to understand in detail every possible impact on the SCC-SES from the very wide range of possibilities within the global change. However, there are at least four aspects for which it is possible to imagine an outcome: sea level and temperature rise, globalization, urbanization and overpopulation. These three latter have a bigger impact on the social sub-system: globalization could lead to a loss of traditional values, producing a desire on younger population to leave the islands in search of "better opportunities", deteriorating the culture of transmitting fishing-related knowledge from generation to generation. Urbanization which is already a tendency at least on the islet, changes micro-climate increasing the need of climate control and thus the electricity consumption, which today is a 6-hour condition but with new projects of hybrid generation (solar and fuel) will become a permanent reality. Overpopulation is also a reality on the islet and the community has vast experience managing issues of space, trust and sharing; however increasing population has a direct impact on the ecosystems which provide resources and process waste.

On the other hand, issues related to the ocean are highly uncontrollable. Quite evidently, a rise of few centimeters of the Global Mean Sea Level would cover most of, if not entire, islands and there would be no SES to assess or evolve since the social component would be removed from the complex. This is also true for the ecological counterpart: if water temperature raises thus killing corals by bleaching, triggering a collapse of the trophic chain, increasing erosion by losing their function as tidal barriers and breaking the sediment traps for the establishment of mangrove forest; the coupling between sub-systems would bring the SES to collapse.

There is little the specific SES can do to stop such global processes, other than managing for their own sustainability to the best of their capacities. However if remaining in a vulnerable position is the choice of this community; prevention, adaptation and preparedness measures could be taken to avoid at least the collapse of the social component.

AN OPTIMISTIC APPROACH

In a more hopeful development of events, since the community is well aware of the negative impacts damaged ecosystems, or at least fish deployed areas can have on their own subsistence and on the tourist appeal; they could make a clean transition towards real eco-tourism which requires for the ecosystems to be healthy and providing resources for the increased populations of high seasons. In that sense, carrying capacity of the islands would be known and respected, and low touristic seasons could be a time for fishing techniques less and less aggressive as well as for learning. Additionally, if projects like the use of solar energy and the collective ownership of the land are well managed, they could increase independence from external actors and empower the community to control external competition. The communities already have the tools to make ecological and community tourism; and both could include education or in-formation for the tourist. These activities could strengthen the participation of women in the income generation, broadening their current scope of just the service area.

SECTION 4

SYNTHESIS OF THE TEMPORAL STRUCTURE

From the analysis developed in this section, Fig.23 shows only the temporal scales found in the SCC-SES, identifying main eras, current state of the system and possible future scenarios

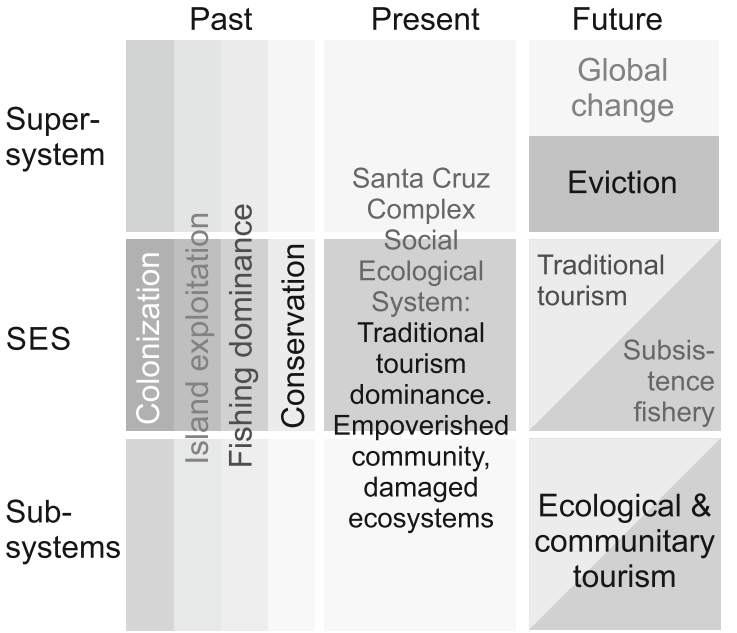


Fig. 23 Temporal scales in the Nine windows: definition of the past is useful to identify moments when the system has shown indicators of resilience –or non-resilience-. Revision of tendencies helps developing possible scenarios and imagining desirable future states in case transformation is required. Source: Developed by author based on Chapter 5: Dynamics of the SES

CHAPTER 6
ASSESSING RESILIENCE

SECTION 1 RESILIENCE INDICATORS
SECTION 2 ASSESSMENT OF INDICATORS
SECTION 3 POTENTIAL MANAGEMENT STRATEGIES

SECTION 1

RESILIENCE INDICATORS

In reference to the developed theoretical and conceptual frameworks, a matrix of six resilience indicators was applied in the analysis of the SCC-SES considering the three components of resilience related to the response to disturbances: **resistance, adaptability** and **transformability** (Walker et al. 2004). These indicators were valued in the three spatial levels of our Panarchy, with a grading scale of five qualifiers of performance for each one. These qualifiers are: Very good, good, tolerable, poor and very poor and they are used here to give a sense of location of each component on the Adaptive cycle.

RESISTANCE

- **Diversity:** it evaluates the amount and quality of options a SES possesses to resist change: the tool kit, the economic alternatives, the biodiversity, the varied cultural backgrounds, the use of a wide spectrum of resources, etc.
- **Synergy of the satisfiers:** it is the use of holistic elements to satisfy fundamental needs, the involvement of all actors, the freedom to choose and participate, the equity and the trust.

ADAPTABILITY

- **Dynamicity:** It assesses the agility to change, the modularity of the components which could build up in different arrangements or remain separated according to the configuration needed; its opposite would be a high level of coupling and rigidness that restricts movement with the high interdependencies of the components.
- **Learning:** It is the ability to remember past errors and successful experiences, as well as having a broad vision of the behavior of larger and smaller scales or analogic SESs elsewhere and modify its own performance in accordance.

TRANSFORMABILITY

- **Preparedness:** Evaluates the capacity of responsiveness, including velocity and quality of the response; the ability to manage feedbacks, reflect and act on them as well as a balanced level of redundancy and "dormant" elements which activate to respond to scarcity.
- **Innovation:** or the ability to come up with new ideas and developments in the face of disturbance; the level of initiative; the capacity to embrace change and to manage in non-equilibrium states and uncertainty.

SECTION 2

ASSESSMENT OF INDICATORS AND PHASES OF THE ADAPTIVE CYCLE

DIV Diversity
SYN Synergy
DYN Dynamicity
LEA Learning
PRE Preparedness
INN Innovation

ASSESSMENT IN SUPER-SYSTEM

The supersystem considered in the assessment is the Caribbean region in Colombia, which for the communities also represents "mainland"; and to a larger extent, the country itself. The supersystem is also a SES; therefore it includes all the interactions between people and nature. See Table 4

Table 4 Assessment for Super-System: Caribbean region and Colombia. For further information see: PNUD, 2011 and León, 2013

	Indicator	Assessment of the indicator
Resistance	DIV Very good	Colombia is one the most biodiverse countries in the world; historically has a high ethnic diversity, culturally, economically and politically it accepts many different activities, opinions and beliefs.
	SYN Very poor	In general the satisfiers chosen by many communities in the larger level, national industries and government institutions do not have a synergic behavior. A few examples are the receptivity to open-pit mining and biofuel production, vast extensions of monocultures, intensive industrial fishing, as excuses to satisfy the need of subsistence. Armed conflict to satisfy the need of protection or identity; "Druglord" culture for participation and leisure.
Adaptability	DYN Poor	Extreme coupling has kept the country in general, and the Caribbean region specifically, lagging its social development, with vast impoverished regions and a conflict that has lasted for generations.
	LEA Poor	Even in the most obvious manifestation of learning which is education, Colombian governments have concentrated national investment in armament and "security" strategies, creating large portions of uniformed mass.
Transformability	PRE Tolerable	Colombia is not a country characterized by its readiness in the face of disturbance. It is more a system that takes measures after the problems if at all. However, and regardless of their effectiveness there are plans of disaster preparedness, institutions, protocols and infrastructure to prepare the system for unexpected changes.
	INN Poor	There are no evident innovations resulting in benefits for the Caribbean coast or the country in general; not in economic, social, cultural, ecological or political development.

Adaptive cycle in the SUPER-SYSTEM is in a peaking K phase: conservation; energy has been accumulated and sequestered.

Perhaps its high diversity in so many aspects, especially from the natural resources perspective, has allowed the country to resist and persist in an undesirable configuration of the system; however in none of the other categories the system exhibits a dynamic behavior or to have learned from so many years of a stagnant situation; nor to be prepared or to be ready to innovate.

ASSESSMENT IN SUB-SYSTEMS

DIV Diversity
SYN Synergy
DYN Dynamicity
LEA Learning
PRE Preparedness
INN Innovation

Assessing the resilience of sub-systems separately is a real challenge because human beings are at all times part of ecosystems. This constant interaction results in ecosystems also becoming part of human individual and social systems. It means the distinction described below can only be made at a conceptual level, but it will be useful later for contrasting purposes, with the Social-Ecological coupling. See Tables 5 and 6.

Table 5 Assessment for the Social Sub-System. For further information see: Sub-section of the Social sub-system and Boxes 2 to 7

	Indicator	Assessment of the indicator
Resistance	DIV Poor	Population of the islands is mostly afro-descendent and mainly fishers. People from other ethnic groups are perceived as outsiders/tourists.
	SYN Good	Synergy seen as cooperation and team work is highly rated in the islands. Daily life is very challenging far from the infrastructure provided by mainland in terms of electricity, sanitation, safe water, education, health, communication, etc. even more in the past than now; and they have managed to succeed by building trust and taking care of each other.
Adaptability	DYN Good	Locals have proved they have high agility to adapt to changes. Historically adopting quickly new technologies, new economic activities, new political status and today implementing elements like internet or satellite television, converting to the religion whose practice is available for them in the islands, etc. Additionally they have built a network with communities in mainland. It is probably the sustained relation with the families the first settlers left behind to go to work and live in the islands, but it is so strong, natives belong too to those communities in Cartagena, Tolú, etc. This increases their dynamicity by giving more choices of places to live in case they had to leave the SCC-SES.
	LEA Tolerable	Communities are able to remember past social errors or successful experiences from larger or analogous systems; for example, times or places of extreme violence, good business, nice cultural environment, etc. and can modify its own performance in accordance. However, since they are remote communities there can be a big role in subjective interpretation or gaps in the information, what makes the vulnerable to manipulation.
Transformability	PRE Poor	Remoteness and little diversity of activities make the community poorly prepared to act on a variety of social disturbances like the adoption of imported cultures brought by tourism or drug trading. These are potentially highly detrimental for the communities, whether they remain in the islands or migrate to mainland.
	INN Poor	Long dated lack of diversity is also a sign of little innovation, showing more adaptability to new conditions than novelty.

Adaptive cycle in the SOCIAL SUB-SYSTEM is in a advanced r phase: growth; energy is starting to accumulate and sequester.

Dynamicity in the communities supports the flexibility of the social sub-system. People are proud of their identity as islanders, of their abilities to survive and very especially of the peaceful environment they have achieved comparing themselves to mainland communities. Nevertheless there is a high dependency on external drivers to induce transformation and innovation which makes them vulnerable and little prepared for disturbances coming from the same source

Table 6 Assessment for the Ecological Sub-System. For further information see: Sub-section of the ecological sub-system

	Indicator		Assessment of the indicator
Resistance	DIV	Good	Coral reefs and mangrove forests are two of the most biodiverse ecosystems on the planet, giving origin to some of the most complex and varied trophic network existent. However, their current state is deteriorated .
	SYN	Very good	Natural ecosystems fulfill their needs in a way that waste is used by other organisms as useful input thus representing the best model for synergistic collaboration.
Adaptability	DYN	Tolerable	Trophic networks in diverse ecosystems are highly dynamic since the energy moves fast among trophic levels. However, the loss of some key species, which leaves absent niches, has reduced this dynamicity.
	LEA	Tolerable	Learning in ecosystems can be understood as the stimuli collected in every level of biological organization, including species, individuals and molecules; which leads to adaptations and adjustments. In this case the velocity of these reactions can be very slow and could be obstructed by ecosystem degradation.
Transformability	PRE	Poor	If disturbance is natural: a hurricane, a change on the temperature or pH of the water, etc. mangrove and coral communities have strategies like redundancy, dormancy, adaptation of the ecological niche, etc, helping them to resist change or to create new regimes of the system without collapsing. However this decreases significantly when disturbance has a human origin.
	INN	Tolerable	Innovation in ecosystems is evolution. Some species can display for example phenotypic plasticity as a strategy to innovate; however, this adjustments happen at extremely slow velocities.

Adaptive cycle in the ECOLOGICAL SUB-SYSTEM is in a peaking r phase: growth; energy is starting to accumulate and sequester.

The current state of the sub-system is deeply influenced by the human factor, exhibiting high coupling and dependency. Although ecosystems naturally have high resistance, adaptability and transformability, the state of the ecological sub-system has been conditioned by the interaction with the social-sub-system. The key concept here would be the difference of velocity of change of each component.

DIV Diversity
SYN Synergy
DYN Dynamicity
LEA Learning
PRE Preparedness
INN Innovation

ASSESSMENT IN SOCIAL-ECOLOGICAL SYSTEM

The assessment at the Social-Ecological level reflects the interactions between smaller and larger scales. Since SESs are complex systems with non-linear behavior, the assessment does not represent just a sum of the results obtained by its components; it rather describes the relation of provision /use/impact, earlier depicted in Figs. 6 and 7, between the two Sub-systems while being influenced by the Superystem.

In that sense, it was necessary to know first-hand the perception of the communities about said interactions and contrast this information with data collected in literature as reported in Chapter 4 and 5 Definition and Dynamics of the system. The following boxes show a selection of quotes taken from 28 interviews in the communities of Santa Cruz del Islote, Chupundún (Múcura) and Tintipán, made in April 2013[25]. These show absence, presence or quality of each of the six resilience indicators and are classified accordingly.

In the discourse of the interviewees, there are references to **diversity** of resources and activities, basically showing its scarcity. They talk about having few economic activities to develop in the islands and that they have been performing them their entire lives. There are also several mentions to the fishing having strongly declined, both in quantity and quality:

Box 2 Quotes for diversity

- "Yo me siento un poco cansado. (…) Yo ya quiero cambiar de vida. **Todo mundo quiere cambiar ya de vida**". (Adult man)
- "¿Usted sabe lo que son **50 años usted en el mismo trabajo**? Sacándole agua a un pozo. En 50 años ¿qué? Lo seca. ¿Sí o no? Esa es la razón de la palabra" (Elderly man)
- "Pero como todo aquí, **la única fuente de trabajo, y todo lo que tiene que hacer uno es con la pesca**, **nos lo acabamos**. No ve que el producto del caracol, lo compran. La langosta, la compran. El pescado lo compran. Y ese es el trabajo de uno. Tiene uno que cogerlo. Matarlo si o no?" (Handyman)
- "Está bien malísima la pesca. Anteriormente (…) traía uno 30, 40, 50 kilos de pescado. Y hoy sale uno a pescar y de regreso trae uno la pura liga (cantidad de subsistencia). Esto está inundado de puro trasmallo

25. For the complete document of quote compendium, refer to the digital folder of this research. Citas de las entrevistas.docx

(…) **Así que la pesca ha mermado aquí el ciento por ciento**" (Elderly man)

- "Bueno, yo ya tengo mis dos hijos (...) Trabajando para ellos, dándole duro para ellos; a donde no llegué que lleguen ellos. Que tengan una buena vida, mejor que la mía. **Que no se queden por acá, que busquen un futuro mejor**" (Young man)

The category of **synergy** is related to the quality of the elements chosen to satisfy the fundamental needs or satisfiers. In the interviews there are signs of wellbeing, peace and trust as a result of living in these communities. However, there are also complains about detrimental or non-existent satisfiers. The ambiguities respond to the complexity of the SES and give an idea of vulnerability:

Box 3 Quotes for synergy

- "Como todos nos hemos criado aquí juntos. Llevamos una tesis muy buena que no pelea el uno con el otro ni disgusto. **Hermandad. Ha hecho que perdure la isla en el tiempo**" (Elderly man)
- "Uno está en el aire libre. El agua. Tranquilo. Uno no ve ruido. Uno para comer tiene que estar chequeando uno. Porque si no cualquiera pasa por ahí, le daban un tiro a uno, sin uno saber. Entonces uno vive mal así. **Aquí uno vive muy sabroso**" (Adult man)
- "Ellos viven felices, se conocen en lo más íntimo, han luchado mucho por ampliar el territorio, hay como 4 apellidos. **Son como una familia que lucha por el territorio**" (Church minister)
- "Hay **demasiado tiempo de ocio**, consumismo y occidentalización (…) Hay una esperanza en la recreación del islote para eliminar los vicios". (School teacher)
- "Siempre le hacen la misma pregunta ¿Cuál es la necesidad más grande de la isla? La respuesta es **todas las necesidades**" (Community leader)

In the case of **dynamicity,** the SES level appears to be in a transition from a historical high dynamicity that has allowed the settlements to endure; to exhibiting signs of rigidity. It can probably be associated with increased

restrictions from external actors, which are also related to the loss of diversity. In the face of some disturbances the communities are extremely agile; for some they are very reluctant to change; or they are willing to make adaptations that result in a conflict with the ecological sub-system and thus with the entity in charge of its protection: the NNPO.

Box 4 Quotes for Dynamicity

- "Bueno, **yo como al trabajo no le tengo miedo**. Que se acaba el pescado… yo voy y corto leña, y vendo. Jarreo agua y todo. No sé cómo me encontraron hoy aquí" (Elderly man)
- "Su suelo (del islote) es el producto del agrandamiento de una manera artesanal llamada Calce o calzar o aterrar. Esta técnica se realizó por medio de las técnicas de echar corral, es decir, formar una cerca de madera alrededor de la zona calzada. Nosotros **nos vemos en la necesidad de aterrar la isla periódicamente** debido a que la acción de las mareas nos hace perder una parte del terreno calzado" (Community leader reading a legal document for the land collective ownership)
- Para vender sin tener propiedad (lotes de relleno o de deforestación): "Los que estén en el lugar, eso es de él. (…) Mi casa es mía. La casa esa es del Uruguayo. El hotel es de Don Oscar. ¿Qué eso es del Estado? No! es de Don Oscar. Usted no puede entrar. Aquí en la punta también es un restaurante. Yo no puedo entrar. Tengo que respetar! (…) El que tiene sus cosas son de él" (Native businessman)
- "Después del incendio, nada más quedaron estas dos casas. (…) En Tintipán dormimos dos noches. A las tres noches nos pasamos otra vez aquí. Aquí armamos carpas. Y ya venía uno a dormir aquí a su carpa. Y a ir limpiando. Que saliera el fogaje, todas las cosas, las cenizas" (Elderly man remembering the biggest disaster in the islet)

The communities show abilities to **learn** from past or present-but-external disturbances and be aware of them but not necessarily having the tools to act on the issue; this is the case of the fish stock reduction or the coral degradation:

Box 5 Quotes for Learning

- "(…) El tamaño (del pescado) es casi igual. Claro que antes era más grande. Por la menos competencia. Porque se cogía menos, se crecía más. Pero como ahora se está atacando, crece menos, porque no hay" (Elderly man)
- "El coral sí tiene una cosa, es que el coral es vivo. Eso sí lo sé yo. El coral crece. Una piedrecita así, viva, viva, ya va creciendo y ya. (…) Al coral lo mata es el rayo del sol. Ese coral que blanquea y coge así, es que el rayo de sol le pega al agua y se la calienta mucho. (…) cuando pela con la marea, el rayo del sol lo mata. Eso es lo que pasa. En los arrecifes donde pela, hay más sol" (Elderly man talking about the increased exposure of the corals with low tides and increased temperature)

For **preparedness** there were quotes indicating a current positive level; an example would be them, expecting a specific month to collect rainwater and having protocols and an artisanal infrastructure for this moment. Another example is the network they have built with mainland; strong to the point that it is clear if they were to move out from the islands they would have an assured place to go. However for imminent disturbances like 24 hours of electricity or increased dependence on tourism activities the level of preparedness is unknown and requires attention:

Box 6 Quotes for Preparedness

- "El pozo del agua, es muy pequeño así que **no es suficiente lo que recolectan de lluvia** para los tiempos de sequía" (Colombian tourist)
- "…qué hace una persona de aquí, pescadora, que no está preparada para estar viviendo en Cartagena. Así le den 20 millones de pesos y una casa para vivir. Al año están pidiendo limosna. Se gastan la plata y no saben qué hacer (…)". (Adult man)
- Sí. Ahora meses nosotros nadábamos en el pueblo (islote). **Eso es normal** cada año. Eso es para octubre o noviembre. Es que sube la marea". Entonces ustedes todo el tiempo están cuidando que el mar no se lleve el terreno? "Sí. Esto está pegado ya. El calce éste. Va uno calzando y calzando" (Elderly man)
- "Sí, tenemos planta eléctrica y **estamos esperanzados** en la planta que

posiblemente ya en diciembre **tenemos planta de luz solar**. Mucha alegría porque la luz más cara del mundo es la luz de aquí. La luz más cara del mundo entero. Esto es duro duro!. Yo pago 12.5 millones anuales de luz" (Native trader)

- "Aunque el turismo es positivo económicamente, **llega "otro mundo"** a esta zona aislada y hay una pérdida de valores" (School teacher)
- "No, no. **No deseamos que se acabe** el turismo. La ayuda más grande que tenemos nosotros cuando el tiempo esta malo es el turismo que viene de Tolú. Eso sí sería lo último" (Fisherman)

Regarding **innovation,** there are some quotes showing improvements and adjustments already done that allowed them to accommodate better the island life. Others show some "revolts" in the sense of panarchy are required. Finally, some quotes talk about certain innovations that have been very good intentions but have been poorly planned and performed; this is the case of the very interesting and conflicting activity of "calce" or shoreline filling in the islet; as well as the case of the "Patio productivo" project in Múcura:

Box 7 Quotes for Innovation

- "**Direct TV** hay unas 50 antenas, funciona con recargas de $7,000 COP pa' unos días o se puede de $70,000 COP por la mensualidad. El **internet** cuesta $40,000 COP mensuales" (Adult woman)
- "No se pueden cumplir todas las normas de "Medio Ambiente". Por ejemplo, en el islote querían conservar (calzando) la isla de Maravilla (única isla protegida por ser refugio de aves) pero Parques dijo: "Si el mar la trajo, el mar se la lleva"" (Fisherman)
- "A los de Parques se les ocurrió la idea de ponernos a hacer "Patio Productivo" pero a quién se le ocurre! Mire ahí hay uno (señala caja con sembrado), dígame ¿De dónde sacamos el agua pa' las matas?. Cómo pretenden que vivamos de esa cajita de cebollín?! A mí me gustaría que el gobierno acoja a la comunidad, que nos ayude en forma de talleres (...) Ayudas pero seguidas" (Community leader)
- "Hay un beneficio que estamos perdiendo por falta de una acción comunal organizada que toque puertas. Se una con la promotora de

> turismo de Bolívar y (…) con la de Sucre. (…) Ellos vienen a explotarnos acá y no dejan beneficio. Y con esa plata se apoyaría el medio ambiente, porque se podría trabajar, no pescar y 6 meses pescar. (…) Que le hagan mes de pesca y especifiquen zona de pesca, (…) Bolívar tiene aquí bolicheros, trasmalleros de Sucre que están acabando con el pescado. Entonces uno que es nativo y que sale a pescar, no coge nada (…)" (Adult man)

In summary, through the qualitative analysis of data obtained in literature and field work; it is possible to assess six indicators of resilience for the SCC-SES. This condenses our understanding of the interactions between the sub-systems and the influence from the super-system:

Table 7 Assessment for the Social-Ecological System.

	Indicator	Assessment of the indicator
Resistance	DIV Poor	There are few economic activities besides fishing or tourism the community has been able to develop from the management of the natural resources. There are in fact very few activities in general to develop in the remoteness of the islands. Additionally; biodiversity is being reduced by human activities; and services like freshwater, electricity or sanitation are too scarce. See Box 2
	SYN Tolerable	Social-Ecological SystemSynergy here is related to the way the communities satisfy their needs with elements obtained from the ecosystems. Destruction of diversity as a result of overfishing or land use change talk about a poor choice of satisfiers. However, here it is important to recognize these communities have developed an exemplary management of scarcities, achieving for their own an ingenious, practical and peaceful life with very few resources, therefore the evaluation is not so good or so bad. See Box 3
Adaptability	DYN Poor	Communities have managed to remain in the area even when main drivers of economic activities collapse and shift (see eras); displaying a high level of dynamicity, perhaps because trophic networks in the Caribbean reefs are very complex, and this has allowed the fishing communities –and industry- to exploit this activity for many years. They have also adopted quickly new technologies, legal and political statuses and today they implement elements like internet or satellite television; they convert to the religion whose practice is available for them in the islands, etc. However, the reduction of large predatory species, evidenced with the blooming of species like parrotfish and algae; and even small herbivorous species for bait (INVEMAR, 2009), reduce dynamicity of the ecosystems, which at the same time increases the fishing effort and reduces the dynamicity of the SES altogether. Moreover a social overload is detected in the discourse of young parents that no longer want their kids to stay in the islands or adults that do not want to be fishers any more. See Box 4

Adaptability	LEA	Poor	Communities have learned almost everything from the interactions with ecosystems; having an enormous know-how on most animals, plants, climate and ocean phenomena, etc. surrounding them. However, they fail to make the most of this knowledge even when they know how to react and what to do with most disturbances; they have not yet fully applied this knowledge to preserve said interactions and consequently achieving their own preservation. See Box 5
Transformability	PRE	Poor	If disturbance has a human origin like deforestation or trawling; growth rates of mangrove or corals give almost no chance to redundancy, dormancy or any other strategy that could have been successful for natural disturbances; and the community has small chances of reversing these processes. Additionally, in their own words, their fishing background restricts their performance in different settings like a city in mainland or a massive tourism economy. See Box 6
	INN	Very poor	The SES has been able to manage in non-equilibrium states. However, innovation for the sake of ecosystemic rehabilitation or a more sustainable use of the resources has not been detected. The SES is very affected with the influences of the Supersystem and depends from it for some fundamental needs giving little space for initiatives. See Box 7

Adaptive cycle in the SOCIAL-ECOLOGICAL SYSTEM is in an advanced K phase: conservation; energy has been dangerously accumulated and sequestered. Close to a -probably necessary- collapse

Overfishing, land use change, water quality degradation, massive tourism, coastal development, climate change, social and political conflicts have caused a severe reduction in the resilience of the SES. Life in the islands has become increasingly difficult and globalization has brought new and not necessarily sustainability-inducing values to the community. Both, social and ecological sub-systems show signs of saturation.

DIV Diversity
SYN Synergy
DYN Dynamicity
LEA Learning
PRE Preparedness
INN Innovation

SYNTHESIS OF THE ASSESSMENT

As observed in Table 8, the best ratings a system can achieve, it does by isolating its components: that is, people without measuring their interaction with ecosystems; and these latter, without the severe impacts of people. However, as said before, this separation can only be conceptual, and it is nearly impossible to do for people: the configuration of any community is to a great extent given by its context.

When interactions are measured, the evaluation of each indicator falls; exhibiting the poor balance between components; both in large SESs like the super-system or in small ones like the SCC-SES. The assessment of the SCC-SES is the result of non-linear interactions between social and ecological sub-systems, including all their components, under the influence of super-systems; all growing like the roots and shoots of a tree.

This also illustrates how, approaching these issues from single disciplines without a systemic outlook is not only ineffective but also potentially dangerous. In the case of the ecological sub-system, it is also very vague to make a general assessment, because every ecosystem (mangrove forest, tropical forest, coral reef, seagrass meadow, etc.) can be in a very different position within the adaptive cycle. Further and more specialized, quantitative analyses would be required.

Regarding each property, it can be concluded that the super-system has exhibited resistance, but its capacities to adapt and transform have been hindered. The strength of the social sub-system could be its adaptability but not its transformability; while for the ecological sub-system, in its ideal or less degraded state; resistance is also the key; as well as adaptability to some extent. Now, the case of the SES shows, how non-linear and unpredictable these systems can be; since regardless of the good ratings in its components, its own performance can be reduced.

As an experiment to give an idea of the position of each panarchical level, in the adaptive cycle; it is possible to visualize said position, in a way that does not contradict the previous evaluation. If we replace qualitative describers (very poor to very good), with numbers (1 to 5) and grade the foreloop: 5, as the poorest qualification a system could obtain; would represent a state of collapse; and 30, as the highest, would represent a completely renewed system. Then, the position for each level would be as shown in Fig. 24. The

backloop, as a transitory state between collapse and renewal, -which usually happens very fast- is not considered in this particular grading.

Table 8 Summary of the assessment of resilience indicators

	Super system	Social sub-system	Ecological sub-system	Social-Ecological System
DIV	Very good	Poor	Good	Poor
SYN	Very poor	Good	Very good	Tolerable
DYN	Poor	Good	Tolerable	Poor
LEA	Poor	Tolerable	Tolerable	Poor
PRE	Tolerable	Poor	Poor	Poor
INN	Poor	Poor	Tolerable	Very Poor

DIV Diversity
SYN Synergy
DYN Dynamicity
LEA Learning
PRE Preparedness
INN Innovation

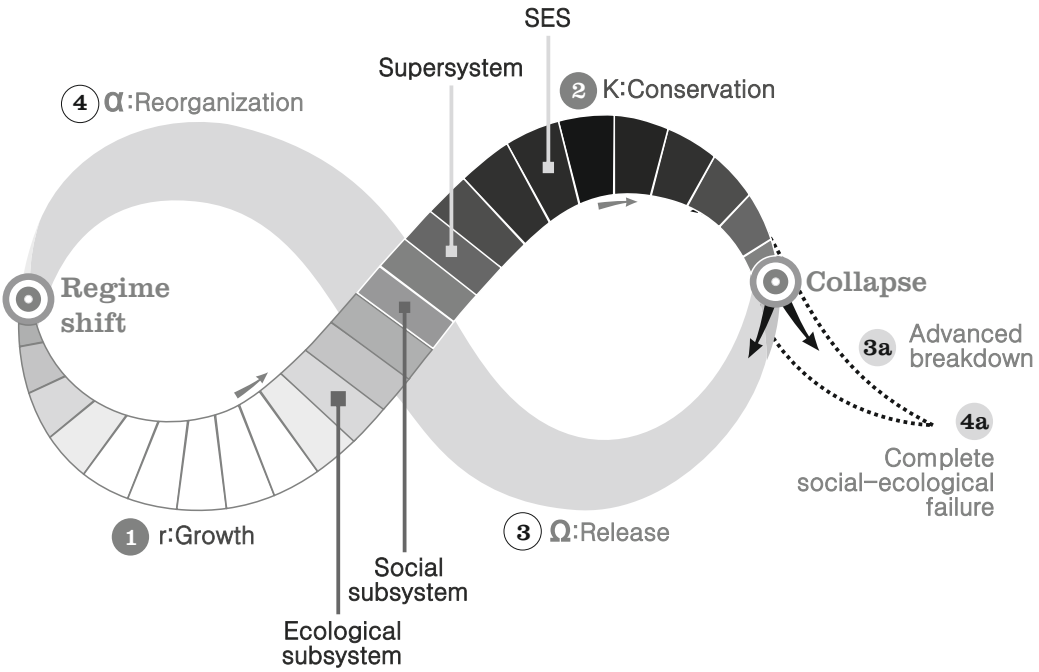


Fig. 24 Positions of every level in the adaptive cycle. If qualitative describers are replaced with numbers, it is possible to grade the foreloop and find a position for the four levels of the Panarchy. The SES would be the level closer to collapse with 12 points; the super-system would be in a late K-phase with 15 points; the social and ecological sub-systems would be in growth phases, with 17 and 20 points respectively, although the first would be in a more advanced stage. Source: Developed by author

SECTION 3

POTENTIAL MANAGEMENT STRATEGIES

In conclusion: SCC-SES has currently a l**ow level of sustainability-inducing resilience**. Its components isolated can exhibit higher levels of resistance, adaptability and transformability; but when they interact; the actual level of the complex system appears, and it is proximate to collapse. We have seen that responding to interactions and feedbacks, both components have been overloaded with energy: people are tired and ecosystems are fragile.

However, some of these "original" or isolated strengths in each level are useful to induce the navigation of the SES into a more desirable state: The high diversity in the Colombian Caribbean region and the country itself (supersystem). The synergy and dynamicity of the social sub-system, seen in an attitude of cooperation, agility and resourcefulness: the historical resistance of these fishing communities. And finally: the richness of the reefs; and forests of the Caribbean. It would be possible to exploit the memory of such properties to **dynamically reorganize** the SES in a new regime.

Once the resilience of the SCC-SES is assessed, it is possible to make a crosslinking with the developed scenarios (Chapter 5, Section 3) to analyze the management strategies available for the development of the system as follows:

Eviction by government and Global change are both scenarios of complete decoupling. In these cases it is not possible for the social sub-system to remain in the area. The first one is far enough from the reach of the SES, but the second is completely out of their control; therefore, the only strategy available is to prepare for transformation. In that sense foreloop type actions can be useful, improving education and fostering innovation.

If traditional tourism scenario comes into effect, the current level of resilience would make the SES accelerate ecological degradation and the entire system to collapse very fast. This would leave very few possibilities for the ecological sub-system to backloop without the community and the tourism industry having to leave first.

On the other hand, if the community tries –or is forced- to go back to a subsistence fishery; without a massive intervention on the super-system that

stops external influence to the SES, perceived in industrial fishing, coastal development, armed conflict, etc. both sub-systems would crash; first by accelerating ecosystem degradation due to the increased fishing effort and then by fostering a massive emigration from the islands. In this case, also without a deep-rooted community to exert environmental stewardship; backloop would also be very difficult to induce.

For the last scenario of eco-tourism/conservative fishing or any other combination of activities that promotes the recovery of the system; it is necessary to create controlled disturbances leading to a reorganization of the SES. A break-down of the K-phase, should allow a more balanced interaction between the sub-systems and new sustainability-inducing resilience would have to be built with an induced backloop; trying to avoid reaching again the current high level of dependency to the larger scale and the high impacts generated to smaller scales; that is, **decoupling** the scales to some degree.

In said scenario an adaptive type of governance and a synergic choice of satisfiers for human needs are needed; as well as autonomy in the production of energy, water and income. The community should be able to recover food-providing ecosystems using their traditional knowledge and legal status of protected community, exerting real conservational power; they should turn their waste into new resources, instead of just throwing it away to pollute; just like they have done with the coastline filling but with better technical information and long-term visualization. All this, supported by strong educative strategies that could be more effective than the ones applied today, by becoming closer to real local life. Fig. 25 describes the model of current states and possible transitions associated with the different management strategies and scenarios.

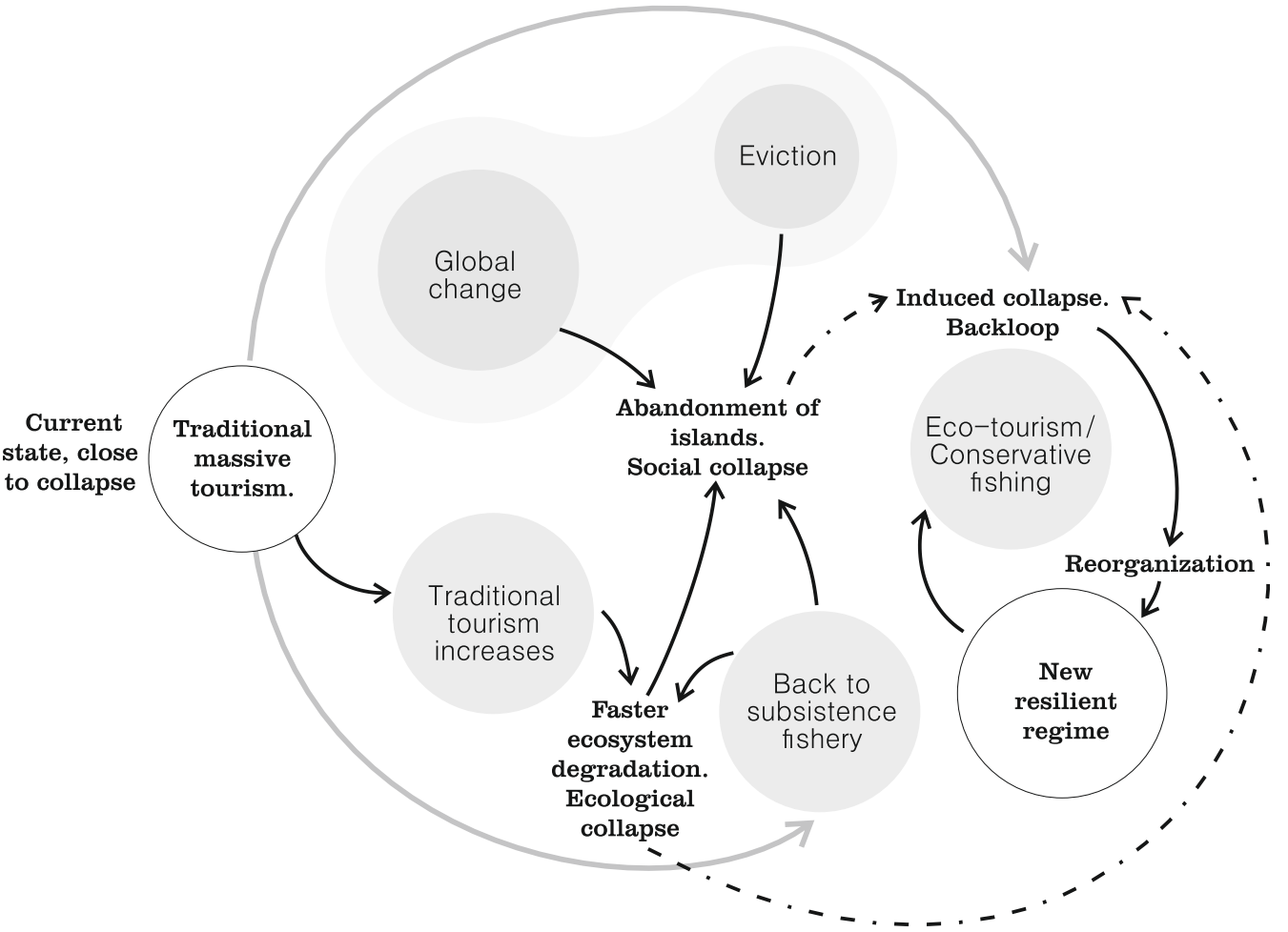


Fig.25 State and transition model of the SCC-SES. From a current state of traditional massive tourism and a low level of resilience; the activation of the five scenarios developed, would produce different outcomes for the SES. The two scenarios in the big gray area are out of the control of the SES, therefore the only possibility for the SES here, is to be prepared for the moment they HAVE TO abandon the islands. The increase of traditional tourism is a default scenario if the SES follows its tendency and no action is taken; this scenario would produce a faster degradation of the ecosystem and eventually for this reason, the communities would also have to leave the islands. Two actions can be taken: Go back to subsistence fishery and move to an eco/community tourism/conservative fishing model. In the first case, without a massive intervention to the super-system, a double social and ecological un-controlled collapse could happen, and from these states it would too late to induce controlling, reorganizing variables. For the second case and last scenario, it would be necessary to induce a controlled collapse first, to reorganize the SES in a renewed regime with sustainability-inducing resilience. Source: Developed by author

CHAPTER 7
CONCLUSIONS

ANSWERING THE RESEARCH QUESTIONS
LESSONS LEARNED
CHALLENGES OF THE RESEARCH
RECOMMENDATIONS

The core goal behind this research was to understand the behavior of the complex and adaptive SCC-SES through a resilience approach; and for this goal the conclusion would be that it is impossible to fully appreciate all the intricacies of such a system and certainly even more difficult to calculate accurately how its behavior in the future would be. However; general state, configuration, interactions and feedbacks were visualized in Chapters 3 to 6 allowing a holistic understanding of the SES.

The SES has had already four regime shifts, setting five eras or **alternative states** of its history, where configuration has been modified but identity has not been entirely lost. From colonization to a hard-core exploitation of the natural resources, which decreased in the era of fishing dominance; this latter turned into a conservation phase, ironically enough with the escalation of war in the country; and finally the current era of alternation of fishing and tourism where this last one has a dominance.

The main drivers in each era have been fishing and marine resources most of the times, and some other times, charcoal production or tourism (See Fig. 23). However; the **main forcers driving the shifts** have been: i) the capacity of an established settlement to produce massive quantities of charcoal from mangrove and coconut palm covered islands; ii) the fail of a market the SES depended on; iii) the reduced dynamicity of the Super-system brought by conflict and conservation laws, blocking or slowing economic and social flows down; iv) the reduced fish stocks and increased population mobility that facilitated tourism to become a new option for development.

The SCC-SES is currently in a late **K phase of conservation in the adaptive cycle**, **exhibiting a low level of resilience**; energy has been dangerously accumulated and sequestered by an increasing loss of diversity, synergy and dynamism evidenced in overexploitation and degradation of both sub-systems. **The SES is found to be close to a -probably necessary- collapse**; and from the contrast with scenarios **an intended regime shift** is recommended. For that purpose, resilience must be reinforced to make sure the system goes into a renewal phase and not into a cascading loss of cohesion that ends up in a complete social-ecological failure.

It was interesting to learn from an initial assumption of the SES being unintentionally self-damaging with a blind poor management of the ecological sub-system; that not only the community is fully aware of how coupled the two sub-systems are, but also the larger scale has a very strong

influence on the behavior of the community in spite of the geographical distance between them. Thus they are innovative but in a potentially damaging way and have become very restricted in their own decision-making power

Evidently, some external drivers like sea level rise and other factors within the global change are well out of the control of the SES scale; however, before the worst case scenario comes to be a reality, this particular system needs to implement the best combination of top-down government regulation, bottom-up grassroots governance, and middle-out civic environmentalism, it can achieve by its own capacities. In that sense, the biggest challenge for the SES could be to obtain the protection from the larger scale at the country level or even to loosen the tight feedbacks between them; but there is already a will to work from the NNPO; attention from national and international media drawn by the peculiarities of the islet; a cross-sector network with at least one actor from academy, industry and government; and most importantly a history of resistance and adaptive capacity, supporting the processes for **sustainability of this SES**, even if they are weak at the moment.

One of the biggest lessons of this "Paradox of the Caribbean" and the tiny "capital" in the middle of the sea, is the importance of avoiding pre-conceptions, or partial and uninformed opinions coming with overspecialization and a non-panarchic approach: temporal and spatial scales are vital to understand the behavior of a SES, thus they are key to its resilience-building and sustainability. This also implies having an impartial view of the community, without idealizing their exotic closeness to nature and ancestral traditions; nor condemning their use of resources and space. It is important to remember poverty and wellbeing are highly relative and subjective.

The challenges encountered by this research were many. On the one hand there was the need to build clear and applicable theoretical and conceptual frameworks that captured the essence of resilience thinking; which, being a dynamic area of study, was continuously adapting to new information and level of understanding. Additionally, the object of study in itself is a complex and adaptive system that behaves non-linearly, with interactions jumping scales, and constantly giving ambiguous signs of presence and absence of resilience. Likewise, in order to have a holistic approach the scope of analysis had to be quite broad since all the scales had to be considered.

On the other hand, there were technical issues like the lack of complete official information on the area, both current and historical; and the remoteness of the study which required advanced logistics. Budget restricts heavily the time on the site and since the methodology for assessing resilience avoids giving cook-book recipes; it becomes a highly time-consuming process.

It is very important to note the ecological sub-system is composed by several ecosystems; in this case: coral reefs, mangrove and tropical dry forests, seagrass meadows, etc. Therefore, in order to reduce subjectivity, for future work it is recommendable to support the assessment of indicators in these "sub-sub-systems" or smaller components, which could be all in very different stages of the adaptive cycle; with more updated and specialized quantitative data, on a framework designed by the study.

Additionally, researchers should have as much visions on the subject as possible considering not only all the actors and stakeholders but a solid component of multi-, inter-, and transdisciplinarity. For applications in similar cases it is reasonable to remain in the spirit of the Resilience Alliance of avoiding a prescriptive technique and design a specific methodology according to each particular case, from the broad range of existent tools or creating new ones.

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