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Integrating local knowledge for climate change adaptation in Yucatán, Mexico

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Abstract

The importance of local knowledge and traditional practices is now recognized by disaster risk reduction specialists, particularly in the aftermath of the tsunami in the Indian Ocean in 2004. However, these frequently used practices by local populations are not yet recognized by all actors involved in disaster prevention. This research seeks to identify local traditional practices which are connected to hydro-meteorological phenomena and climate change in the coastal areas of the Yucatán Peninsula in the Rio Lagartos Biosphere Reserve. The identification process requires observation, documentation, validation and categorization of local traditional knowledge. The traditional practices (mainly by fishermen as well as some farmers) examined specifically among the coastal populations relate to their habitat, natural resources, and fishing practices. Recognizing and valuing traditional knowledge will help improve resilience to the impact of disasters and the effects of climate change among coastal populations.

Keywords: Local knowledge; Hurricanes; Fishing communities; Adaptation; Climate change

1. Introduction

According to the 2010 census, 77.8% of the Mexican population lived in urban or urbanized zones (INEGI, 2011), as opposed to just 43% in 1950. In the Yucatán, in 2010, this urban population represents 84%. In the past four decades, two phenomena have combined along the Yucatán coast: the coastal population is growing at the same time as category five hurricanes are becoming more frequent in the Gulf of Mexico. Communities have suffered increasing financial losses over the past 40 years, despite prevention policies and projects by NGOs (Saldaña-Zorilla, 2014). Hurricanes are having greater impacts not only on infrastructure but also on human settlements and livelihoods. Poverty and lack of resilience are major vulnerabilities in the face of hurricanes. Although risk mapping exists in Mexico, insufficient attention is being paid to the mapping of social and financial vulnerabilities at a local level.

In Mexico, risk and disaster policies are centralized at a federal level by SINAPROC and CENAPRED[1] and their

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[1] National Civil Protection System (SINAPROC); National Disaster Prevention Center (CENAPRED).

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impact at a local and municipal level is limited; therefore, government disaster responses are poorly adapted to local communities. No federal instrument exists to take into account local knowledge and to allow people to use and bolster their own traditional knowledge.

Since the first decade of the twenty-first century, various pieces of research have studied local knowledge and its relevance to adaptation to the effects of climate change such as extreme hydro-meteorological events (Galloway McLean, 2010; Green and Raygorodetsky, 2010; Salick and Ross, 2009). Following the 2004 tsunami in the Indian Ocean, local knowledge helped communities to survive the aftermath (Hiwasaki et al., 2014). As a result, researchers have since paid closer attention to this topic. But it is only very recently that researchers and civil protection experts have focused on traditional practices to strengthen the resilience of communities to the effects of climate change.

Specialist studies (Hiwasaki et al., 2014) consider that the resilience of communities can be increased by combining new and old knowledge and techniques. Through the integration of scientific knowledge, adaptation and prevention strategies can become more successful.

A key question arises out of these considerations: How can local knowledge of hydro-meteorological threats be integrated into science and technology? The coastal populations of the Yucatán Peninsula, in common with their counterparts in Indonesia, are exposed to the impacts of climate change. In this article, we will attempt to identify the local knowledge and skills found among coastal populations, particularly those in the Río Lagartos Biosphere Reserve, in order to increase their resilience. Another question also stems from these same issues: How can society's community participation be incorporated into policies by using local knowledge?

2. Traditional knowledge about climate variability

The issue of traditional local knowledge is not new in the field of human sciences. Anthropologists and sociologists have developed theories since the 1930s and 1940s, for example in the case of Redfield's "folk-urban continuum" concept (1944). What is more recent is the fact that knowledge is being taken into account for the prevention and mitigation of phenomena linked to climate variability, such as flooding, droughts, and hurricanes. Therefore, over the past decade studies have sought to integrate local knowledge in disaster risk reduction (Hiwasaki et al., 2014; Walshe and Nunn, 2012). Various studies have also focused on the local perception of hurricane risks (Krishnamurthy et al., 2011; Sánchez-Cortés and Lazos Chavero, 2011). Furthermore, adaptation strategies based on traditional knowledge have been identified by various authors for preventing floods (Mavhura et al., 2013) and droughts (Bright Chisadza, 2013).

Integrating local knowledge as part of disaster risk reduction (DRR) has been proposed by Walshe and Nunn (2012) in the case of the 1999 Vanuatu tsunami, after an examination of people's responses to a tsunami focused on local knowledge rather than the early-warning system. The extremely low number of victims was due to people's ability to recognize warning signs of the tsunami, and this skill is attributed to tradition-based indigenous knowledge (*Kastom* stories) and myths. Hiwasaki et al. (2014) have also suggested integrating traditional knowledge in DRR in the case of Indonesia's coastal populations. The study showed that coastal communities on small Indonesian islands have robust local knowledge to predict hydro-meteorological threats through observations of the sky, sea, clouds, animals, plants and insects.

Local perceptions of hurricane risk among the local communities in El Zapotito in the state of Veracruz have been studied by Krishnamurthy et al. (2011) and the study showed how local perceptions can be integrated into risk management. The model used in this study is based on the local community's perception. Research in the state of Chiapas in a Zoque community (Sanchez-Cortés and Lazos Chavero, 2011) revealed that the local perception of climate change has enabled people to alter the agricultural calendar for planting and harvesting. The Zoque community had observed changes in the annual rainfall patterns, rising temperatures, and different durations of "northers".

A study by Mavhura et al. (2013) in Muzarabani, Zimbabwe, showed that local communities have in place prevention and mitigation strategies to prevent flooding for various purposes: to protect belongings, houses, crops, and to conserve water and food. In another community in Zimbabwe, Bright Chisadza (2013) observed various traditional indicators used to predict droughts in the Msingwane Catchment zone, such as trees and plants; insects, birds and animals; and wind, the moon and the sun at different times of the year. Most indicators are observed shortly after the winter and at the beginning of the rainy season.

All of the aforementioned experiences tend to support the thesis put forward by García Acosta (2014): "community experiences have made it possible to develop practices and methods as well as various habits which, over time, have helped consolidate effective risk and disaster prevention strategies." In the Yucatán, we have also found adaptive practices to cope with hydro-meteorological phenomena. However, these practices have been gradually modified and many of the authors cited do not take into account social and cultural shifts that have been altering such customs.

In this context, practices and observations based on populations' local knowledge has necessarily changed and sometimes disappeared. Even so, we will propose in our working hypothesis that some elements of this traditional knowledge continue to exist.

3. Conceptual framework

The study of local knowledge in connection to hydro-meteorological events involves handling some key disaster risk reduction concepts such as:

3.1. Vulnerability

This concept has various strands, and involves various types of vulnerabilities, integrating aspects of sociology (social vulnerability), economics (financial vulnerability), physical considerations (architecture and construction), and anthropology (cultural and organizational vulnerability). This concept is currently still in the process of being constructed from a theoretical and methodological perspective, though it is frequently used in specialist studies and in the design of public policies. It involves various actors, from the communities themselves to the state and civil society and even homes and individuals. Nevertheless, as pointed out by Terry Cannon (2008, 2), the concept is confusingly used and overused. People connect it to poverty and marginalization, and it has connotations of victimhood, whereas in fact people have skills as well as vulnerabilities, with the latter concept always being used as something negative. It is important not to consider people as "victims", but rather as people who have the capacity for resilience and who also have their own resources. According to T. Cannon (2008, 2), there are five interrelated components found in vulnerability:

- The means of subsistence and resilience.
- The welfare state (food, education and health).
- Self-protection (safe homes).
- Civil protection (by the government) and
- Governance.

In this study we will use the concept of vulnerability applied to the communities that are the subject of our work. In other words, we seek to identify the different kinds of vulnerability found in the fishing communities in question, but without disregarding their adaptive capacity.

3.2. Resilience capacity

Resilience is a capacity: the capacity of a community or system to return to a prior state. Vulnerability is also predictable. It is possible, based on the characteristics (vulnerability, adaptation capacity) of the community being studied, to identify their resilience capacity. Once again we refer to Cannon (2008, 10) who argued that if communities had high levels of resilience they would not be vulnerable. Inversely, severe vulnerability would imply low resilience. Cannon (2008, 10) identified five components of resilience and vulnerability:

- Methods of subsistence based on strong and resilient activities.
- A healthy community with good nutritional levels.
- Well-protected and resistant belongings.
- Efficient civil protection system.
- Strong institutions and governance.

Social inequalities can also be very relevant in terms of resilience, yet various governments do little to address this issue. Within communities, not all families are equal: some are richer, some are poorer, and not all families are vulnerable and resilient in the same way. In order to understand a community's vulnerability, the community must not be seen so much as a harmonious place with shared risks but rather as somewhere with an unequal distribution of risks and vulnerabilities.

3.3. Adaptive capacity

Adaptation is a process, similarly to housing, that has been progressively conceptualized both by academics and in international organizations such as the United Nations and the IPCC.[2] The IPCC (2007) gives the following definition for adaptation: "The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects". This is a broad definition; however, it is worth adjusting to the local level when considering specific populations. A given population may or may not have the capacity to adapt to the effects of climate change. This will depend on various socioeconomic and technical factors that will allow such a population to make changes in order to limit its vulnerability to said effects. In fact, over time, communities have been able to adapt to different climates and their effects, both in terms of habitat and agriculture. The quality of traditional homes corresponds to certain kinds of climates and the presence of local materials. The adaptive capacity is therefore the ability of a system or group to face some changes to the climate's impacts and in particular its extremes. Adaptive capacity is considered as a fundamental mechanism to reduce vulnerability.

3.4. Social engagement

The participation of society is also a process through which community members intervene either directly or through their representatives on decisions connected to different aspects of their community's life. Social engagement requires a certain level of social organization because in a community that is unorganized or poorly organized only a limited participation in decision-making is possible. When actors from outside the community take actions without taking into account existing types of social organization, they are highly unlikely to achieve their objectives. People's participation is considered a key element in the processes of reducing risk and vulnerability. Below we will see how traditional practices cannot be separated from the organization of society and from the participation of all community members.

3.5. Disaster risk reduction (DRR)

Disaster risk reduction requires an understanding that risk is a social construct and therefore risk reduction can

[2] IPCC: Intergovernmental Panel on Climate Change.

only be achieved through a social process as opposed to a technical, engineering-based process.

DRR also involves accepting that disasters are not natural and that in most cases they are products of actions taken by societies and their representatives. It is also widely recognized that disasters are consequences of a lack of development. DRR will therefore include actions that encourage economic and social development such as a participative planning of local and sector-based development. Thus risk management becomes a component of social and economic development planning. Disaster risk management is a complex social process designed to reduce risk, and must take into account human, territorial and economic development, environmental protection and sustainability.

4. Methodological issues

4.1. Data collection and analysis

The data collection method involves participant observation on location in the three study periods spent in the field (November 2013, November 2014, and August 2015). The interviews were unrestricted and based on a script of questions. Around 20 people were interviewed in the three locations, with subjects including fishermen, municipal officials and women.

The analysis essentially consists of four stages:

(1) Analysis of the vulnerability patterns of homes, including habitat, productive resources, exposure and sources of income. We have analyzed vulnerability in six types of resources: human capital, social capital, political capital, built capital, natural capital and economic capital.
(2) Analysis of local resilience capacities and local practices oriented toward habitat, fishing and farming. For each action we considered the type of practice (family, institutional, individual) and the type of measure taken.
(3) Analysis of the communities' observations in order to predict and interpret hydro-meteorological events. We considered indicators associated with the wind and clouds; indicators associated with birds; indicators associated with temperature: and indicators associated with water currents. The interviews were mainly carried out with fishermen since they are mainly the people with this type of knowledge.

5. Description of the area in question

The Río Lagartos Biosphere Reserve (created on June 26, 1979) is located in the Yucatán Peninsula and is 74 km long. The state has a 378-km stretch of coastline in total, and it therefore represents 19.6% of the entire coastal area (see Fig. 1). The reserve is affected by different patterns of atmospheric circulation due to its geographical location and proximity to the sea, such as prevailing trade winds, modified polar air masses ("northers") and convection currents which cause precipitation. Two clearly definable rainy seasons exist: the first from June to November represents 70% of the total annual rainfall, the remaining rain (30%) falls during the dry period from December to May. "Northers" happen in September–October and March–April. In the Río Lagartos Reserve, the total annual rainfall is 550 mm. The Reserve is considered a high-risk zone, since it is located along the path of hurricanes originating in the Caribbean and in the Gulf of Mexico. In the past 88 years, 12 tropical hurricanes have made a strong impact on the peninsula.

The Río Lagartos reserve is home to four populations who live in three municipalities: San Felipe, Río Lagartos and Tizimín; the communities within the reserve are as follows (Table 1):

Fishing is the most important activity for the Economically Active Population (EAP) in the reserve, with the following totals per community (1996):

San Felipe: 67.4% EAP
Río Lagartos: 63.8% EAP
Las Coloradas: 21.5% EAP
El Cuyo: 3% EAP.

Fishing is carried out by cooperative fishing groups, rural fishing associations, community organizations, license holders and independent fishermen. People normally fish along the coasts or informally, with the use of small boats with outboard motors and in the area of the Gulf of Mexico near to the coast. The different communities have the following number of boats:

San Felipe: 211 boats
Ría Lagartos: 328 boats
Las Coloradas: 56 boats
El Cuyo: 243 boats
Total: 838 boats

Hardly any farming takes place within the reserve; the *milpa* is the most important traditional type of farming method in the region; the reserve is in the state's main livestock area, and cattle farming is therefore a major activity, both on community-owned *ejidal* lands or in privately owned ranches.

The original permit granting rights to exploit the salt flats of Las Coloradas was issued in the late-1930s. However, salt has been taken from this area intermittently since colonial times; the concessional area spanned approximately an area of 1000 ha, along a 16–20 km stretch of coastline. At that time the production totaled a maximum of 3000 tons per year. Currently, the company generates jobs to provide a livelihood to 100 families in the area (INE, 1999).

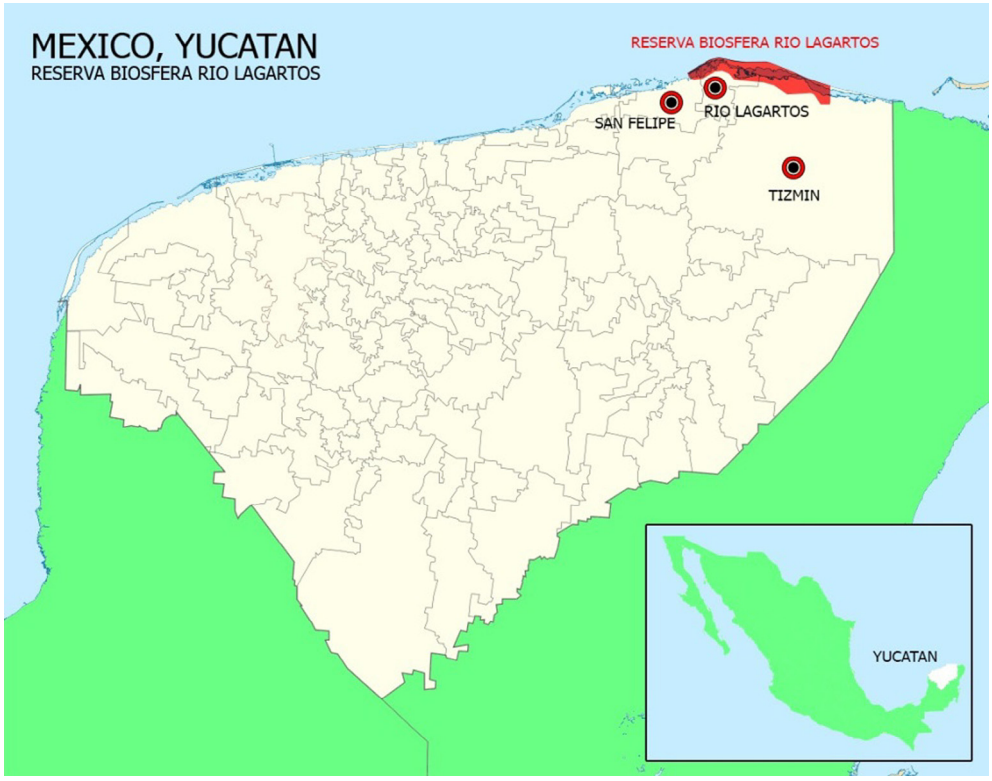

Fig. 1. Location of the area in question.

Table 1
Total population in 1995 and 2010.

Communities/years	1995	2010
San Felipe	1,610 inhab.	1,839 inhab.
Río Lagartos	2,844 inhab.	2,218 inhab.
Las Coloradas	1,300 inhab.	1,151 inhab.
El Cuyo	1,162 inhab.	1,748 inhab.
Total:	6,916 inhab.	6,956 inhab.

Sources: INEGI, 1996, and 2011.

6. Vulnerability and risk mapping (Río Lagartos, San Felipe and Las Coloradas)

The methodology used led us to analyze six types of vulnerability, based on the different resources presented by the communities.

6.1. Human capital

Human capital is characterized by the type of education received and the family's external resources. Generally speaking, in the three communities in the study no family member has had to emigrate to the United States or Canada, and therefore the families cannot rely on the support of remittances. On the one hand this represents a vulnerability, but on the other, it also indicates that to date there has been no need to emigrate abroad as found in other states in Mexico, since "there are no migratory processes caused by hurricanes" (Soares et al., 2014, 90).

As mentioned by T. Cannon, access to education is an important variable in terms of reducing human capital's vulnerability. At schools, no courses are available to inform people about hydro-meteorological events. However, when there is the threat of an imminent hurricane (September–October) in San Felipe, the community is informed that they must take preventive and emergency measures (boarding up their homes' windows and roofs) (Notification is given by the Director of Civil Protection, Don Feliciano Montoya Bello). In Las Coloradas, the same approach is apparently taken before a hurricane (Mayra Navarro, interview subject). At schools, and despite the magnitude of previous disasters (Hurricane Gilberto and Isidore), disaster risk reduction has not been incorporated into the school curriculum. The only training provided is for those working for civil protection unit, and the knowledge they acquire is not usually passed on.

6.2. Social capital

Social capital refers to the formal and informal relations between people in the same community. Pierre Bourdieu (1980) defined it as "the set of current or potential resources connected to the ownership of a set of relationships that are institutionalized to varying extents belonging to a group" and which can be mobilized for the benefit of the community and which imply long-lasting obligations. In the three communities we found mainly formal (cooperative) fishing organizations. Social capital is important

because this is how a community bounces back after hurricanes and strengthens its resilience. Some fishermen's cooperatives exist in San Felipe, Rio Lagartos and Las Coloradas, but not all fishermen belong to them. Some are independent (unaffiliated) fishermen, others are known as "license holders" as they are hired by some "fishing permit holders" and have the same rights as the others and can take more advantage of the government's program of benefits. Although cooperatives strengthen social capital, divisions can exist between fishermen belonging to different organizations. In San Felipe, various fishing cooperatives exist, two of the most important of which being *Pescadores Unidos de San Felipe* (119 members) and *Pescadores Legitimos de San Felipe* (83 members). In 2001 a cooperative of 14 fisherwomen was set up: *Mujeres Trabajadoras del Mar,* who fish for the "maxquil" crab (*Libinia dubia*) which is then used as octopus' bait (Astorga, 2014). Currently there is an overall decline in the fishing due to the increasing size of the fishing fleet and to the effects of climate variability which prevents people from fishing every day of the year.

6.3. Political capital

Political capital is related to the decision-making process, in this case on a state or municipal level. Soares' interviews (2014) confirm that the community of San Felipe has the lowest levels of political vulnerability, and its director of civil protection confirmed to us that, thanks to the experience acquired with Hurricane Isidore, the population and the Civil Protection unit are now prepared for the eventuality of another hurricane.[3] Four other teams have also been created: evacuation, search and rescue, first-aid, medical and clean-up. Temporary shelters are available in the community of Panabá, at a secondary school for the community of San Felipe.

Flags are used as an early warning system:

Blue: minimum danger
Green: low danger
Yellow: moderate danger, prepare for evacuation
Orange: evacuation
Red: impact

However, in Río Lagartos and Las Coloradas, the communities' relations with the local authorities are not good and in fact make it difficult to put into practice an evacuation or prevention process. Although all communities have received government aid after Hurricane Isidore (sheet roofing, food provisions, FONDEN houses[4]), San Felipe was the only community with a good relationship with the municipal authorities. The fact that Las Coloradas is just a department of the Río Lagartos municipality does not benefit the relationship. In none of the three communities, except San Felipe, are there proposals about how to cope with hydro-meteorological events. Following Hurricane Isidore, the UNDP[5] promoted a project called "local risk management" in the Yucatán, which provided training for local leaders in the areas of gender equality and risk management. One of the 17 "micro-regional emergency response units, (UMAC)" was set up in San Felipe, the existence of which may explain why San Felipe now has a risk management plan.

6.4. Built capital

Built capital consists of infrastructure and housing, as well as goods that make it possible to develop means of subsistence such as fishing boats. Most people who have wooden houses consider their homes to be vulnerable to hurricanes. Those with concrete-block houses consider their vulnerability to be low, except in the case of floods caused by hurricanes. On the whole, the FONDEN reconstruction program after Hurricane Isidore was gratefully received. But now, various families remarked that the constructions' concrete has been damaged by salt residues (4 × 6 m rooms) and some are now considering knocking them down. Therefore, these houses, after 12 years, show some structural defects. Wood is a well-adapted construction material used in coastal areas, and some houses are still built with this material in the three communities examined in this study. The wood used is either "pich" (*Enterolobium cyclocarpum*) or "zapote negro" (*Diospyros digyna*), both of which are resistant to woodworm and the salinity in the air.

No improvement program for wooden houses exists (in San Felipe 465 houses are wooden, and 271 are built with concrete block) which could otherwise help with the required maintenance for houses. However, a state program does operate, using funds drawn from CONAVI, Mexico's national housing commission, and this consists of providing the equivalent of 70,000 Mexican pesos in construction materials (concrete blocks, beams and flooring blocks, cement, sand, gravel and rebar) and the beneficiaries also receive a contribution toward labor costs, worth around 8000 Mexican pesos. This program was implemented in various communities in the Yucatán (Motul, Progreso, Chelem, etc.), including San Felipe. This program promotes, regardless of location, concrete block houses, and has also contributed toward destroying the traditional wooden houses in San Felipe (the program did not apply in Río Lagartos and Las Coloradas).

6.5. Natural capital

Natural capital refers to the available resources in a community or municipality. The area in question is highly

[3] Only the Director of Civil Protection in San Felipe has occupied the position since 2003; the other civil protection directors have been appointed every three years by the successive administrations and have therefore been unable to accumulate the necessary experience.

[4] FONDEN: National Development Fund.

[5] United Nations Development Program.

biodiverse and was declared the Rio Lagartos Biosphere Reserve in 1979. Its status as a natural reserve implies various contradictions. Although most interview subjects believe that the reserve protects the natural environment, its protected status is also considered as imposing severe restrictions. The main conflicts between the local population and the reserve administrators took place in the early 1990s when the regulations for using and accessing the natural resources along the coast were established. For example, it is prohibited to cut down trees in the area and therefore the wooden houses made with local timber can no longer be improved or rebuilt. In order to rebuild a *guano* palm roof you have to request a permit in order to acquire the guano palm. In fact, the growth of local cattle farming has destroyed the forests that existed previously in the municipalities. Mangroves are one of the important natural resources that they have been gradually affected by housing construction. Since the early 1980s the natural reserve regulations hindered the growth of urban communities, and then the natural population growth was in turn affected by the same norms. New families could no longer find new plots of land where they might live because the existing plots are in areas of mangroves. One exception was made in San Felipe with the construction of a small subdivision of 55 houses on the outskirts of the town. In Las Coloradas and Río Lagartos there is no possibility for growth.

The natural capital most affected by hurricanes are fishes and fishing. After Hurricane Isidore in 2002, fishermen had to wait two months without being able to fish, and their catches were much smaller for a whole year.

Most people in the three communities consider that the climate has changed in the past 10 to 15 years, and think that the temperature has changed (becoming hotter) and that now it is difficult to know if it's going to be cold or hot. The locations of fishing grounds have also changed.

6.6. Economic capital

Economic capital consists of inhabitants' available financial resources. In San Felipe, 30.65% of the population is economically active, of which 53.94% mainly work in the fishing industry, 10.9% in the secondary sector, and 35.15% in the tertiary sector[6]; in the three locations in question, most of the economically active population are men who work in fishing: that is their main livelihood. In Río Lagartos, some fishermen also work in tourism especially in July and August. Fishing and tourism are the economic activities most sensitive to hydro-meteorological effects, and therefore these events have affected families' finances. Some work as cattle farmers and are less vulnerable. The main economic activity continues to be fishing, meaning that the three communities are very vulnerable to hurricanes and to "northers" because such phenomena cause both financial and job losses. Economic capital is therefore precarious.

[6] Source: INEGI, 2011, 2010 Population and Housing Census.

7. Analysis of local resilience capacities and local practices related to habitat, fishing and natural resources

The communities in this study have a certain degree of resilience and adaptive capacity to cope with natural phenomena such as hurricanes or floods. Different types of traditional practices and adaptation strategies exist, from time-honored family customs to institutionalized practices at a municipal level. In the table below we show traditional and institutional practices used to cope with climatic events in the communities of San Felipe, Río Lagartos and Las Coloradas (Table 2):

Hurricanes pose the main threats to habitats. Well-defined traditional practices are in place to protect houses from hurricanes, such as tying down roofs with ropes, boarding up windows, etc. Catholics pray before hurricanes. Before a hurricane, the civil protection authorities warned the general public through a weather warning "traffic light".

Fishing is subject to various threats, mainly hurricanes, which hit more or less every 10 or 15 years. The port authorities encourage fishermen to take off their boats' engines, and to safeguard their boats. Red tides are almost yearly occurrences, and they pose both a threat and an opportunity because at the beginning of the tide there is an abundance of fish to be caught, but this is followed by a lack of fish. Several climate-related threats mainly affect fishing. Every year, from October to November, northers prevent fishing when the port authorities issue a warning. In April and May, in some years, droughts have caused forest fires and there have been water shortages. Homes have already been flooded when hurricanes hit or due to atypical rainfall. Only one house in San Felipe is built on stilts, and it is currently not used. Various local inhabitants mentioned rising temperatures, and those least affected by these increases are those who live in wooden houses with guano palm leaf roofing.

8. Communities' observations about hurricanes

In the three communities—San Felipe, Río Lagartos and Las Colorados—interviews were conducted to find out the observations, mainly those made by fishermen, about phenomena that predict a variation in the climate and in particular that foretell an imminent hurricane. These observations are based on the local knowledge of winds, clouds, sky color, etc. These observations are presented in Table 3 below.

Fishermen are mainly the ones who make observations of certain phenomena prior to hydro-meteorological effects such as hurricanes. These phenomena predict hurricanes and the observations are mainly made about the wind and bird behavior. The fishermen's knowledge is not scientific but based on observations of the sky, clouds and wind,

Table 2
Traditional and institutional practices used to cope with climatic events.

Threat	When	Type	Action Taken	Comments
1. Habitat				
Hurricane	Before hurricane	Family	Boarding up windows and taking out belongings	People fix up their house every 6 months (in July and December)
Hurricane	Before hurricane	Family	Prayers (Catholics)	At church
Hurricane	Before hurricane	Family	Tying down roofs with ropes	
Hurricane	Before hurricane	Institutional	Warnings to local population (weather warning "traffic light")	Civil protection
2. Fishing				
Hurricane	After hurricane	Individual	Remove engines from boats	Warnings issued by the port authority
Red tide	Each year in July, August	Individual	Abundant catches of fish in the beginning	Smaller catches of fish afterwards
Sea cucumber fishing		Individual	Dive fishing	22 men died while sea cucumber fishing
Pollution of the sea and sea inlet	All year	Institutional	Warning to population	Cleaning boat engines
3. Climate/environment				
Northers	October, November and December	Individual and institutional	No fishing	Warnings issued by the port authority
Droughts	In April and May	Institutional	Rain water harvesting program	Causes forest fires
Atypical rainfall	Variable	Individual	Unforeseen	Causes floods
Flooding	During/after hurricane	Family	Only one house on stilts in San Felipe	Some septic tanks overflow
Temperature rise	Variable	Family	No actions specified	People who live in wooden houses suffer less during temperature rises

Source: Based on interviews carried in 2014 and 2015.

as well as birds, similarly to a scientific process. This local capacity observing phenomena prior to hurricanes may increase the resilience of coastal communities. When warnings issued by the authorities (civil protection office) coincide with fishermen's observations, the time has come to include community participation in prevention policies using local knowledge. This "ethno-meteorological" knowledge has so far been infrequently taken into account and these observations prove that alternative warning systems can be designed on the basis of local knowledge. Municipal officials generally lack this type of knowledge unless they also happen to have experience as fishermen.

9. Conclusion

In each community in question, vulnerability and resilience capacity should be seen as two different areas. Different fishing communities have different adaptation methods. Similarly to other fishing communities, in India (Coulthard, 2008) in our cases communities seek adaptive capacity by diversifying their means of subsistence as a key strategy for adapting at a family level. For example, in San Felipe, people are diversifying their resources between fishing, arable and cattle farming; in Río Lagartos, they complement fishing resources with tourism (boat trips); in Las Coloradas, a part of the population is working in the salt mining company. In the three communities the main means of subsistence is fishing, a natural resource that is highly vulnerable to climatic effects (hurricanes, "northers"). The diversification of means of subsistence is a way of reducing vulnerability. Some years are good for fishing, but others less so.

Furthermore, authorities pay scant attention to this traditional knowledge. Civil protection and port authorities have their own early-warning systems in place. Fishermen are adept at predicting hurricanes and northers. If we want to understand communities' relations and interactions with their environment, and particularly with climate and climate change, we must take into account both popular practices and traditional knowledge about climatic threats.

Following the creation of the Río Lagartos Biosphere Reserve, the population faced the imposition of external regulations and restrictions on their activities, for example the prohibition of cutting down trees and guano palms, used for the construction of wooden houses and roofing. Julia Fraga (2006) points out that over a period of 20 years (1979–1999) the human aspect has not been taken into account in the protected area. People began to take an interest from the first decade of the twenty-first century, under pressure from academic groups and some NGOs. Communication between the Reserve's administrators and the local population is poor, except in the fishing sector where there is slightly more. Some efforts have been made to integrate local communities in the Reserve's conservation activities, but largely without success.

The traditional habitat faces the threat of disappearing, wooden houses are gradually being replaced by concrete block and slab constructions. Indeed, everything seems to be conspiring to bring about the disappearance of wooden houses:

Table 3
Communities' observations about hurricanes.

Type of Observation	When	Meaning	Remarks
Alerta María TV(Television Alert)	*Isidore* (September 21–26, 2002) *Wilma* (October 15–25, 2005)	Hurricane warning	In the case of Hurricane Gilberto there was no warning.
Smell of the wind	*Isidore* (September 21–26, 2002) *Gilberto* (September 8–20, 1988) *Wilma* (October 15–25, 2005)	Hurricane warning	Fisherman's observation
Change in noise made by birds	*Isidore* (September 21–26, 2002) *Gilberto* (September 8–20, 1988) *Wilma* (October 15–25, 2005)	Hurricane warning	Fisherman's observation
Change in wind direction	*Isidore* (September 21–26, 2002) *Gilberto* (September 8–20, 1988) *Wilma* (October 15–25, 2005)	Hurricane warning	Fisherman's observation
Change in birds' flight	*Isidore* (September 21–26, 2002) *Gilberto* (September 8–20, 1988) *Wilma* (October 15–25, 2005)	Hurricane warning	Fisherman's observation
Change in speed of sea currents	*Isidore* (September 21–26, 2002) *Gilberto* (September 8–20, 1988) *Wilma* (October 15–25, 2005)	Hurricane warning	Fisherman's observation
Red sky	*Isidore* (September 21–26, 2002) *Gilberto* (September 8–20, 1988) *Wilma* (October 15–25, 2005)	Hurricane warning	Fisherman's observation
Changes in weather (Clouds, fog)	*Isidore* (September 21–26, 2002) *Gilberto* (September 8–20, 1988) *Wilma* (October 15–25, 2005)	Hurricane warning	Fisherman's observation
Increase in wind speed	*Isidore* (September 21–26, 2002) *Gilberto* (September 8–20, 1988) *Wilma* (October 15–25, 2005)	Hurricane warning	Fisherman's observation
Birds begin to fly off (flamingos, pelicans, seagulls)	*Isidore* (September 21–26, 2002) *Gilberto* (September 8–20, 1988) *Wilma* (October 15–25, 2005)	Hurricane warning	Fisherman's observation
Birds make different noise	*Isidore* (September 21–26, 2002) *Gilberto* (September 8–20, 1988) *Wilma* (October 15–25, 2005)	Hurricane warning	Fisherman's observation
Changes in location of fishing grounds	Every July, August	Red tide	Fisherman's observation
Rise in temperature	In July and August	Climate change	Various interviewees made his same observation

Source: Based on interviews conducted in 2013, 2014 and 2015.

1. The biosphere reserve's regulation prohibits cutting down "pich" and "zapote" wood needed to maintain wooden houses.
2. The negative impact of reconstruction programs (FONDEN) and state project supported by CONAVI.
3. Insurance companies do not insure wooden houses against the threat of hurricanes.
4. No state program exists for improvements to wooden houses.

Few strategies are in place to protect wooden houses from hurricanes due to the lack of a specific housing program for the improvement of wooden houses. Local inhabitants, despite being aware that wooden houses are more comfortable to live in, better adapted to the tropical heat, think about rebuilding them with concrete blocks and roofs. Concrete block walls are highly susceptible to salt residues, as we have seen, but local inhabitants do not perceive this problem so clearly.

The three communities in this study perceive threats: those interviewed concur in their view that climate variations related to higher temperatures, and temperature drops during the "norther" season. If current hydro-meteorological events are hurricanes and "northers" associated with flooding. Changes in rain patterns were also mentioned. Red tides are not related to the climate, however it poses an almost yearly threat in the area and has an impact on fishing. It is reported that catches have decreased by 30% in the past five years, and therefore fishing is in the process of becoming a subsistence activity that creates little financial surplus.

The salt industry in Las Coloradas is not perceived as a threat to ecosystems because it has created over 100 jobs in the community. In fact, the industry is included within the Biosphere Reserve and does not seem to give rise to conflict. In September 1988, Hurricane Gilbert destroyed almost all the infrastructure in the field and the salt production plants in Las Coloradas, endangering the continued operations of the company, which nevertheless survived and recovered due to its resilience capacity.

The disaster risk reduction capacity in the three communities in question is not only in the hands of the population; in fact, the population hardly participates in risk prevention activities. There is a demand for new homes as a result of the population's natural growth, yet no suitable plots of

land are available for their construction. In San Felipe a small subdivision has recently been built in the outskirts of the town in an area of mangroves that has been filled in. This initiative does not take away the threat of flooding.

Community experiences in San Felipe as well as another local population has shown a dispersal of energies and initiatives related to the culture of participation, not so much due to the communities' social capital but more as a result of the differences created by the municipalities' political parties. Similarly, the distances that have marked the new generations of fishermen in front of the cooperatives, acting in a more independent way, have been a factor so that the climatic variability does not manage to settle in the preventive and participative culture.

Similar conclusions were reached in another ten case studies in a report funded by the European Union (FP7), Enabling knowledge for disaster risk reduction in integration to climate change adaptation (2015), coordinated by Scira Menoni et al. (2015). The key question is: How to integrate traditional knowledge into disaster risk-reduction activities? Local authorities receive hurricane warnings from the state's civil protection authorities, and then pass on the information locally without worrying whether fishermen have already been alerted thanks to their own knowledge. For instance, San Felipe's local civil protection director developed a risk map based on his own acquired knowledge, identifying other threats that help reduce the risk of disaster. The fact that various kinds of traditional, institutional and scientific knowledge exist, yet without being either understood or analyzed by other actors, is one of the obstacles in the way of better risk management. In the four municipalities in question we find little cooperation on the issue of risk management between the various actors, the fishermen's cooperative, the harbor master, and the municipal authorities, except in the case of Hurricane Isidore which hit in 2002. One of the difficulties preventing cooperation and communication among the various actors is not the information per se, but it is precisely the traditional knowledge, since it is understood as a socially constructed process that is recognized and shared within a community. Information about hurricane risks is not a social construct but scientific or institutional information that is communicated top down. Therefore, it is very difficult to integrate traditional knowledge as part of scientific or institutional risk-reduction activities. It is the community rather than risk-management systems that can decide on how to share or remind people about available knowledge, and to collaborate in creating new understanding based on both existing and new information, as shown by the integration of traditional knowledge in San Felipe's local civil protection risk map.

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