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Improving a resilience observatory with a post cyclonic event resilience assessment: Application to the 2010 OLI cyclone in three Pacific islands

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A B S T R A C T

French Polynesia is a territory extremely vulnerable to climate change and associated risks. Among these risks, the cyclonic risk impacts regularly and durably the Polynesian territory. The concept of resilience is particularly relevant in a dynamic of adaptation of territories and populations facing the increase of risks and uncertainties. However, it is complex to operationalize and measure. The methodology presented in this article is part of a larger project to design a spatial decision support system, built in the form of a risk and resilience observatory. This observatory is built around several bricks, one of which is intended to acquire various forms of data, and the other to involve local actors in the adaptation of their territory to climate risks. This paper develops a methodology to assess the social, technical and urban resilience during and after Hurricane Oli. It was built around qualitative data, acquired through interviews and questionnaires with inhabitants and local actors of three islands: Tubuai, Rurutu, Bora-Bora. This approach allowed us to identify different levels of resilience over the long term and according to the actors involved in the experience of cyclone Oli. Finally, this approach allowed for the long-term involvement of stakeholders in the evaluation and implementation of more resilient risk management strategies, both at the individual and collective levels.

1. Introduction

According to the IPCC, climate change will increase the intensity of tropical cyclones (Campbell, 2018; Collins and Sutherland, 2019; Gemenne et al., 2019; Nurse et al., 2014). While the frequency of cyclones is not expected to change, the projections estimate that category 4 and 5 tropical cyclones will increase significantly (Knutson et al., 2020), and that the average intensity of cyclones will increase by about 10% with a 2 °C warming scenario. In addition, precipitation during these cyclones will increase by at least 7% per degree of warming. Finally, sea level rise will increase storm surges which will be considerably higher during these events (Collins and Sutherland, 2019) with severe impacts on societies, urban infrastructure and ecosystems (Deo et al., 2022). However, the tropical cyclones are the costliest and the most harmful disasters (Geiger et al., 2018, 2021), in terms of financial and human costs (Deo et al., 2022). Over the last 20 years, these cyclones reach 29 $ billion and impacted 22 millions of people each year (Geiger et al., 2018). In 2019, the average annual losses, linked to risks, in Pacific islands reach 1.075 $ billion (United Nations, 2020). It is estimated that tropical cyclones represent 49,6% of this cost (United Nations, 2020). The number of people affected varies according the different islands (United Nations, 2020), but the very high exposure areas in Pacific are French Polynesia, New Caledonia, Samoa, Solomon Islands, Tonga, Vanuatu and Papua New Guinea (United Nations, 2020). This extreme exposure is due to increased vulnerability in the Pacific Islands and the confrontation to multiple stressors (McCubbin et al., 2015; Serre and Heinzlef, 2022). This vulnerability is linked to geological and geographical conditions (seismic zones, atolls, volcanic islands, geographical dispersion) but also to socio-economic conditions (Magee et al., 2016). The Pacific Islands are confronted with numerous challenges, such as aging and small populations, limited resources, dependence on international trade and commerce, geographical remoteness, fragile ecosystems, etc (Serre and Heinzlef, 2022). The climate change (Leal Filho, 2017) and the increasing cyclone risk, is then the "*greatest threat to the livelihood, security and wellbeing of Pacific people*" (Gemenne et al., 2019).

Among the Pacific nations, French Polynesia occupies a special position. First of all, geographically, French Polynesia covers 5 million km^2, which is the size of Europe (Fig. 1). Divided into 5 archipelagos, 118 islands and 4200 km^2 of land, Polynesia has a diversity of territories, resources but also extremely numerous and diverse issues. Composed of high volcanic islands and coral atolls, Polynesia is located in the intertropical zone and on the Pacific ring of fire, exposing it to the passage of atmospheric depressions, cyclones, tsunamis or even floods and land movements (Heinzlef and Serre, 2019; Jessin et al., 2022). On the political level, Polynesia has a hybrid status. Legally, according to the first

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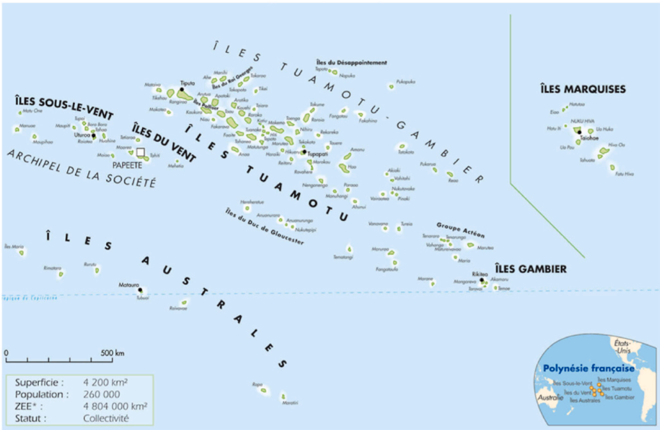

Fig. 1. French Polynesia territory. Source: https://monplanvoyage.com/destinations/polynesie-francaise-pays.

article of the law n° 84–820 of September 6, 1984, the territory of French Polynesia constitutes "*an overseas territory with internal autonomy within the framework of the Republic*"(Haut-Commissariat de la République en Polynésie Française, 2019). In this, the French State keeps the authority on the regalian missions (such as: nationality, civic rights, electoral right, justice; foreign policy; defense; public security and order) while the Country (French Polynesia) and its local government can vote local laws (Haut-Commissariat de la République en Polynésie Française, 2019). This hybrid autonomy allows it to be a key territory in the Pacific. Finally, regarding the economic aspect, as a French overseas territory, Polynesia benefits from a higher standard of living than its neighbors, which allows it to implement regional adaptation strategies and to be a leader in terms of innovation in the Pacific (AFD, 2020). All these characteristics, geographical, legal, economic, make it an extremely rich and complex territory and all the more relevant in this perspective of adaptation to climate change (Lamaury et al., 2021).

Faced with many hazards, Polynesia is primarily impacted by tsunamis and cyclones (Dominey-Howes and Goff, 2013; Dutheil et al., 2020; Etienne, 2012; Jessin et al., 2022). Cyclones represent the second major coastal risk in French Polynesia (Larrue and Chiron, 2011; Schindelé et al., 2006). This risk is mainly present in the west of the territory (Fig. 2), impacting the archipelago of Australes (principally the island of Rurutu and Tubuai) but also the archipelagos of the society (mostly Bora-Bora, Maupiti, Tahaa and Raiatea) and the Tuamotu (Tikehau) (Canavesio et al., 2014; Jessin et al., 2022).

The last cyclone to date is the Oli cyclone which occurred in early February 2010. Initially a moderate tropical depression, Oli progressively strengthened to reach the stage of a tropical cyclone and passed 300 km from Moorea and Tahiti during the night of February 3 to 4 (average winds: 148 km/h) and then followed a south-east trajectory which brought it directly to Tubuai, in the heart of the Austral archipelago (Canavesio et al., 2014). Between Tahiti and Tubuai, the cyclone strengthened considerably from level 2 to level 4 (Saffir-Simpson scale) in only 6 h. When arriving on Tubuai, the average winds were estimated at 212 km/h, which makes Oli one of the five most powerful cyclones since 1970 in French Polynesia (Canavesio et al., 2014). If the human losses were null, the economic and material consequences were extremely heavy for the Polynesian territory. The damage was estimated at 68 million euros, 504 buildings in Bora-Bora were affected and 115 houses were completely destroyed. Finally, numerous environmental damages were recorded (Etienne, 2012).

This episode has profoundly questioned the capacity for climate risk management, adaptation and resilience in French Polynesia. In terms of forecasting only, the South Pacific and French Polynesia are considered as the "*poor cousins*" of the global forecasting system, with an extremely low coverage of the observation system (Canavesio et al., 2014). In a

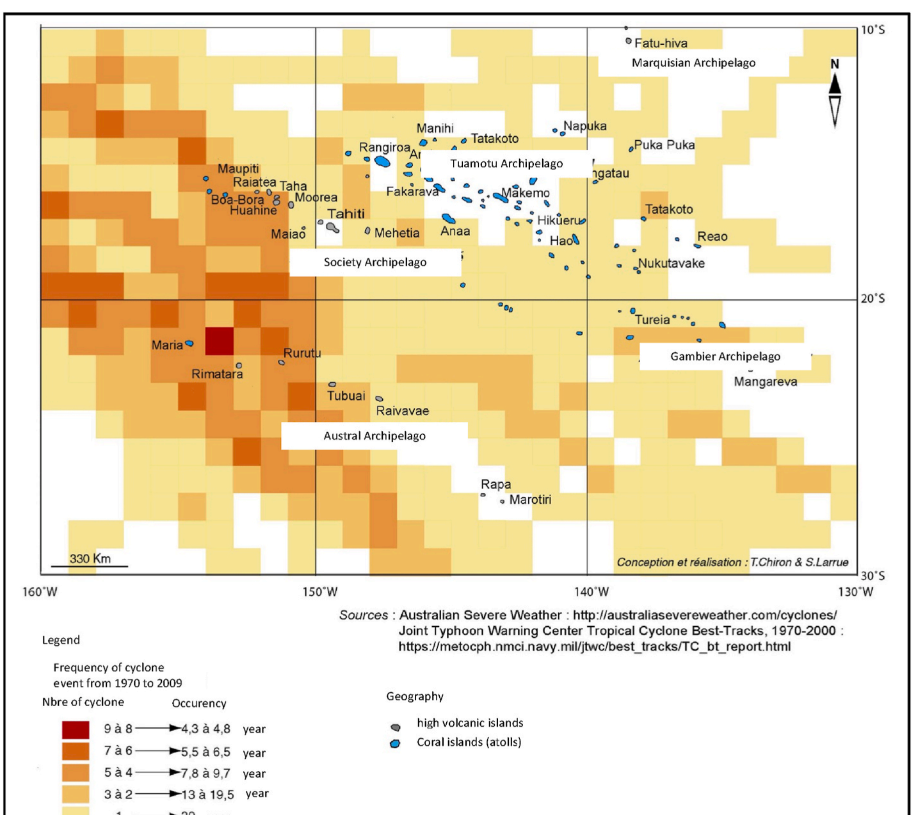

Fig. 2. Frequency of cyclone events from 1970 to 2009. Adapted from (Larrue and Chiron, 2011).

context of increasing cyclonic risks in terms of intensity, it is therefore urgent to reconsider the tools necessary to prepare, adapt and accompany French Polynesia in a risk management as resilient as possible.

Although resilience is now a key concept in risk management (Boin et al., 2010; Boin and McConnell, 2007; Cutter et al., 2010; Disse et al., 2020; Gallina et al., 2016), its application remains complex and uneven (Heinzlef et al., 2022; Serre and Heinzlef, 2022). Defined as the capacity of a system to adapt to disturbances and limit negative impacts in order to restore equilibrium in the face of shocks, resilience is intended to be the appropriate response to risks, climate change and related uncertainties (Alexander, 2013; Heinzlef et al., 2019, 2022; Jessin et al., 2022; Meerow et al., 2016). However, the application of the concept in terms of efficient strategies and adequate tools to the needs of local actors and decision makers is extremely complex and limited (Balsells et al., 2015; Heinzlef et al., 2020a, 2020b, 2022). One of the main reasons is the lack of understanding and ownership of the concept. Its multidisciplinary origin feeds a conceptual vagueness around its definition. As a result, resilience remains at the level of discourse and struggles to be anchored around effective strategies that are adapted to local needs (Heinzlef et al., 2022; Serre and Heinzlef, 2022). To address this operational limitation of the concept of resilience, countless approaches have attempted to develop indicators to measure and characterize resilience (Cutter et al., 2010; Gonçalves and Marques da Costa, 2013; Peacock, 2010; Renschler et al., 2011; Serre, 2018; Serre and Heinzlef, 2018; Suárez et al., 2016), models to visualize the concept (Heinzlef et al., 2022; Johansson et al., 2016; Kurwakumire et al., 2019; Lhomme et al., 2010; Robert et al., 2008; Yang et al., 2022), or participatory approaches to translate the concept into understandable terms (Heinzlef et al., 2019; Marschütz et al., 2020; Serre and Heinzlef, 2022; Toubin et al., 2015). Most approaches understand resilience in its technical dimension, assessing the capacity of urban networks or critical infrastructures to resist, absorb or recover from a disruption. In addition to the over-representation of the technical-functional dimensions of a territory, the methods mostly use quantitative data to evaluate resilience (Cutter et al., 2014; Johansson et al., 2016; Opach and Rød, 2013; Serre and Heinzlef, 2018; Wiréhn et al., 2017). For reasons of accessibility and ease of data processing, statistical data are therefore preferred (Serre and Heinzlef, 2018; Wiréhn et al., 2017). While all of these approaches are relevant and have in their own way made significant advances in operationalizing resilience, the multitude of these methods have also contributed to the fuzziness of the concept. Which methods to turn to? To which tool? Why this one rather than another? A unique tool, allowing to produce qualitative and quantitative data, to integrate and associate local actors, to evaluate and represent resilience is therefore a crucial element (Serre and Heinzlef, 2022). This tool is being developed in French Polynesia in the form of a risk and resilience observatory. Among the main tasks of this observatory, assessing resilience and involving stakeholders are two of the most important. This article seeks to contribute to the observatory and these two precise tasks, by producing qualitative data on resilience in the face of cyclonic risk, using Cyclone Oli as a case study.

What was the level of resilience of territories and communities during the passage of cyclone Oli? What is the situation ten years later?

We will first present the structure of the observatory and the indicators constructed to assess the resilience of territories and communities to Cyclone Oli. In the second part, we will present the analysis of resilience on the islands of Tubuai and Rurutu (Australs archipelago) and on the island of Bora-Bora (Society archipelago), at the Oli period and 10 years later. Finally we discuss the lessons learned from this methodology and its integration into the risk and resilience observatory.

2. A risk and resilience observatory - how to assess polynesian resilience to cyclone risk?

2.1. Indicators

The necessity to develop an observatory of risks and resilience in French Polynesia is explained by several observations (Serre and Heinzlef, 2022). An observatory-based approach is useful to produce new forms of knowledge by creating a balance between actions and research. Observatories tools include collection and organization of diverse data, visualization, knowledge production, aid for decision-making and give the opportunity to debate, reflect and communicate (Caron et al., 2017; Heinzlef and Serre, 2020; Kurian et al., 2016, 2016, 2016; Mikoš et al., 2023; Serre and Heinzlef, 2022; Wehn et al., 2015).

On the French metropolitan scale, the national observatory of risks and the regional observatory of major risks do not integrate French Polynesia, its territory, the associated risks and the related stakes. Thus, no national tool integrates the specific problems of the overseas territories and does not bring any knowledge on risks, nor does it create and diffuse qualitative and/or quantitative data.

Moreover, in French Polynesia, it is difficult to develop efficient and relevant public policies for risk management because of a lack of scientific knowledge, but also and especially because of a scattering of this knowledge, of the professionals and persons in charge of risk management as well as a very weak structuring of the data. This is why it is essential to centralize data, models, approaches in a single tool in order to identify the production of knowledge, the data to be produced, the scientific research to be conducted, and to support local decision support (Jessin et al., 2022; Serre and Heinzlef, 2022).

This observatory is developed around 6 key actions (Jessin et al., 2022; Serre and Heinzlef, 2022).

1. Increase risk and resilience knowledge
2. Data collection and geovisualization modeling
3. Engaging stakeholders
4. Technical production of the observatory
5. Operation of the observatory over the long term
6. Experimentation and valorization of the observatory

The analysis of the resilience of Polynesian territories and communities to cyclone Oli was integrated in tasks 2 and 3 of the observatory, in order to integrate stakeholders (with interviews and questionnaires) and produce data on the resilience to cyclonic risk (Fig. 3).

When we talk about resilience and the operationalization of the concept, the notions of evaluation and measurement emerge (Bahadur et al., 2015; Gonçalves and Marques da Costa, 2013; Heinzlef et al., 2022; Prior and Hagmann, 2014; Tierney, 2009). For this, the use of indicators seems to be the most appropriate method to evaluate resilience (Cutter et al., 2010; Fox-Lent et al., 2015; Heinzlef et al., 2019; Lamaury et al., 2021; Peacock, 2010; Serre, 2018; Serre and Heinzlef, 2018; Suárez et al., 2016). Nowadays, many models and indicators exist, all of which attempt to characterize the notion of resilience through specific indicators. In this study, we used the urban, technical and social resilience indicators developed by (Serre and Heinzlef, 2018)). The main advantage of this method is providing a holistic reading of the territory, highlighting the systemic functioning between the population, the built environment, the infrastructure issues and the economic dynamics. In this case study, we will retain as a definition of resilience the whole of the "*aptitudes and capacities of a territory and its population to implement before, during and after a disruptive event in order to limit its negative impacts*" (Heinzlef, 2019).

An adaptation of the initial indicators was made, particularly because of the relevance of the sub-indicators and the accessibility of data (Table 1).

We created four categories of resilience level between the extremes of 0 and 1 (Fig. 4).

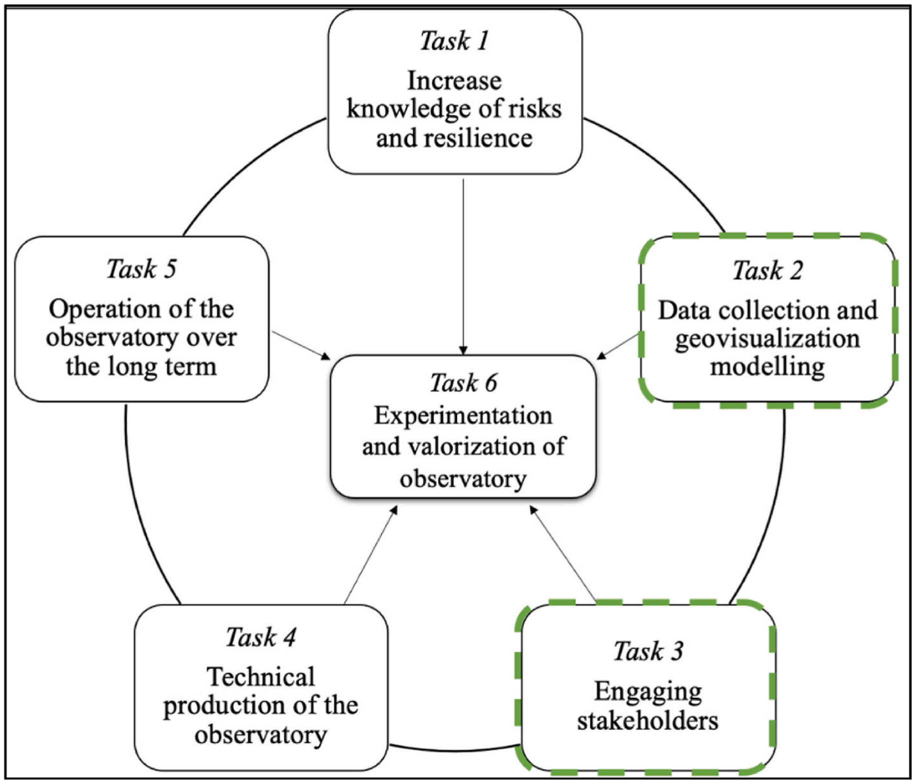

Fig. 3. Observatory tasks-investigation of task 2 and 3. Adapted from (Serre and Heinzlef, 2022).

Table 1
Adaptation of the indicators of (Serre and Heinzlef, 2018).

Indicators	Paper Sub-indicators	Sources	Reasons	References
Social Indicator	Risk knowledge/perception	Questionnaires and interviews	Here we analyze the degree of knowledge (tangible and factual) of the risks, but also their perception (vision of the event, related emotions).	(Doloisio and Vanderlinden, 2020; Jones and Tanner, 2017; Magee et al., 2016; Sansoulet et al., 2020; Vanderlinden et al., 2022; Vinet, 2017; Walker et al., 2014)
	Bonding and bridging social capital	Questionnaires and interviews	The notion of social capital is extremely important in the resilience process to create a community and collective mutual aid.	(Aldrich, 2012, 2017; Cutter et al., 2014; Fox-Lent et al., 2015; Lee, 2020; Tariq et al., 2021)
	Culture and memory of risk	Questionnaires and interviews	Risk culture and memory are key to learning	(Brulle and Norgaard, 2019; Crate, 2021; McEwen et al., 2017)
	Global and individual organization	Questionnaires and interviews	Collective and individual organization is essential to organize reactions, avoid panic and be effective before, during and after the event.	(Chen et al., 2019; Edgeley, 2022; Patriarca et al., 2018; Pratt et al., 2020)
	Informations elements given by authorities	Questionnaires and interviews	Transparent information from local authorities is a guarantee of understanding and acceptance of resilience strategies in the face of risk.	(Cutter et al., 2014; Kurwakumire et al., 2019; Turner et al., 2008)
	Adapted reactions	Questionnaires and interviews	Adapted, controlled and reasoned reactions are essential to avoid excess risks	(Cutter et al., 2008, 2010, 2014; Gifford et al., 2018)
	Fear/Apprehension	Questionnaires and interviews	Fear and apprehension are problematic before, during and after the event	(Castellnou et al., 2019; Marschütz et al., 2020; Schwarz et al., 2011)
	Limited human impacts	Questionnaires and interviews	Resilient risk management limits the impact of risk on individuals	(Abbas et al., 2018; Vu and Ranzi, 2017)
Urban Indicator	Buildings materials/ reconstruction	Field observations + interviews	Resilient risk management integrates the resistance and absorption of materials, and restores momentum by rebuilding in the event of material damage.	(Carter et al., 2015; Johansson et al., 2016; Mitigation Assessment Team Report, 2013; Nguyen and James, 2013)
	Urban planning	Interviews + field observations	Resilient risk management is also illustrated by urban planning choices that enable the area to resist, absorb and recover.	(Balsells et al., 2013, 2015; Barroca et al., 2006; Barroca and Serre, 2013; Serre et al., 2016)
	Location and condition of transport infrastructure	Interviews + field observations	The location and condition of the transport infrastructure are key to restoring service and getting activity back up and running.	(Lhomme et al., 2010, 2013; Serre, 2018; Serre et al., 2016)
Technical Indicator	Condition of the electrical and drinking water networks during and after Oli	Interviews + field observations	Urban networks are essential to a territory's resilience, and electricity and drinking water networks are key to avoiding territorial paralysis.	(Boin and McConnell, 2007; Lhomme et al., 2010, 2013; Pescaroli and Alexander, 2015; Pescaroli and Kelman, 2017; Serre et al., 2016)

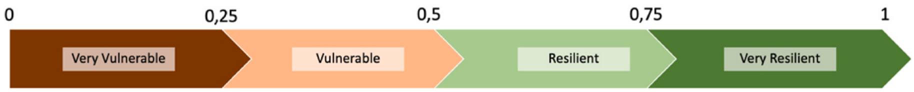

Fig. 4. Resilience categories.

2.2. Data collection

The qualitative data is based on interviews (n = 10), questionnaires (n = 21) and also field observations and pictures. Interviews were conducted with local decision-makers (mayors and deputy mayors) and firemen, in December 2020 and questionnaires with residents (Table 2) in January 2021. The interviews lasted 1 h each and the questionnaires were elaborated and distributed with the Google Form tool.

The elements analyzed during the interviews were on two temporal scales; during the passage of cyclone Oli and their interpretation ten years later (Table 3).

The questionnaires were divided into four main sections.

- **Personal information**: age, gender, highest diploma, socio-professional category, place of residence, etc.,
- **Knowledge of risks**: according to them, what are the major risks for their commune, knowledge of their occurrence, experience of cyclonic risk, etc.,
- **Risk Knowledge**: have they been warned about the risks, according to them, is their house at risk, do they feel well warned by the commune, do they feel protected from the risk, do they know how to act when faced with the risk, etc.,
- **Resilience culture**: have they been warned about the risks, do they think their home is at risk, do they feel well warned by the commune, do they feel protected from the risk, do they know how to act in the face of a risk, etc.,
- **Experience of the cyclonic risk**: have they already lived through a cyclone, how many times, what was the most difficult moment, do they feel they have recovered from the event, etc.

2.3. Data analysis

The corpus of interviews was analyzed using the method of thematic analysis (Vanderlinden et al., 2022). Thematic analysis is a method of analysis that consists of identifying general recurring themes in verbal or textual expressions, i.e. "*systematically identifying, grouping and, subsidiarily, examining the discursive themes addressed in a corpus*" (Paillé and Mucchielli, 2016). The aim is to use words, verbs, expressions, adjectives and formulations to identify recurring and prominent themes in narratives, as well as implicit elements such as physical and emotional expressions. The identified sections are then reorganized regarding the resilience index defined previously.

The questionnaires were processed using the google form tool, which develops statistical analyses and graphs based on the number of responses to the various questions.

Finally, photos were used to contextualize the interviewees' statements and illustrate certain criteria.

The data acquired are used to develop databases stored in the Risk and Resilience Observatory.

Table 2
Qualitative data used.

Archipelago	Islands	People Interviewed	Number of residents answers to the questionnaires
Austral Archipelago	Rurutu	1 Mayor, 1 Deputy Mayor, 2 Firemen	6
	Tubuai	3 Inhabitants; 2 Firemen	1
Society Archipelago	Bora-Bora	1 Mayor	14

2.4. Case study

As mentioned in the introduction, we focused on three islands: Tubuai and Rurutu (Austral Archipelago) and Bora-Bora (Society Archipelago) (Fig. 5).

2.4.1. Tubuai

Tubuai is the capital of the Austral archipelago. The island is made up of two ancient volcanic complexes and has a land area of 45 km^2. The island is surrounded by an important lagoon which is the largest in the Austral Islands. The coral reef that surrounds it delimits a lagoon with a surface area of 85 km^2, i.e. twice the size of the island. It is sometimes 5 km wide, which constitutes a natural barrier against cyclonic risks, strong swells or the risk of tsunami. The eye of the cyclone Oli passed over Tubuai. The damage was mainly material, with more than a hundred houses destroyed, the drinking water and electricity networks unusable for several days, and the roads and the airport silted up. The death that was recorded is not a direct cause of the cyclone.

2.4.2. Rurutu

Rurutu is a volcanic island located 572 km south of Tahiti in the Austral Archipelago. Measuring about 10 km in length and 3 km in maximum width, it has a surface area of 32.3 km^2 surrounded by a fringing reef (but has no lagoon) and a highest point, Manureva, rising to 385 m. Rurutu had very little damage during Oli, the center of the cyclone being only about 100 km from the island.

2.4.3. Bora-Bora

Bora-Bora is located 252 km from Tahiti. This island of the Society archipelago has rather small dimensions: the main island measures only 8 km from north to south and 5 km from east to west; the total area of Bora-Bora, including islets, is less than 40 km^2. A coral necklace protects Bora-Bora like a dike. It is a barrier reef, which has only one opening to the ocean: the Teavanui pass, located west of the main island. The island was hit by the strong winds of Oli. Several houses and hotels were destroyed, electricity and drinking water networks were impacted and more than 700 tourists were evacuated.

3. Assessing resilience during oli event

3.1. Tubuai

As mentioned before, the island of Tubuai was the most directly impacted by the cyclone Oli, having been in the eye of the cyclone. Regarding the analysis of resilience during Oli, we based our methodology only on interviews and questionnaires.

3.1.1. Social resilience

The population of Tubuai has generally experienced the Oli cyclone well. The alert was given 2 days before the impact. The order to evacuate in the refuge areas, in the mountains, was given about 5–6 h before. This evacuation was well received:

> "*Everyone arrived with their belongings, their poker packs, their hammocks and their packs of beer*"(Inhabitant X, 2020).

3–4 days after Oli, a tsunami warning from Chile was issued. The population left in cars in the mountains but nothing happened. In the

Table 3
Analysis criteria and temporality.

Analysis Temporality	During	Examples	10 years later	Examples
Analysis criteria	Adequate information about the event	-"What informations did you have few hours before the event, during, and after?" -"Did you know the cyclone intensity and forecast winds?" -" Did you have any instructions from the high commission/ municipality?"	Memory of risk	-"Do you remember the event clearly?" -" Can you tell us about it?" " What did you do to keep the memory of the risk alive?" -" Was it a significant event for you?" " Did you learn anything as a result of this event?"
	Adapted reaction	- "What had you planned? Material or food stocks?" -"How did you communicate with your audience? By what means?" -"What were the guidelines? Were they followed?"	Adapted urban planning	-"What urban planning choices did you make after the event?" -"Have you rebuilt identically?" –"What developments have you carried out since Oli?"
	Limiting human and material damage	-" Have there been any injuries or deaths?"	Sensitization of the population	"Have you explained the events to the public? Have you developed training programs? Distributed information documents?" "Do you regularly organize information and training days?"
	Organization and social capital	-"Have you asked for volunteers?" -"Did residents help each other evacuate and/or rebuild?" -" What was the overall mood?" -" Were associations able to help?"	Learning about the disaster	"Have you carried out any feedback?" -" If so, is it public?" -" Can you identify the elements that worked/not worked during Oli?" -"If another cyclone happened today, how would you react?"

face of anxiety and apprehension, the inhabitants are serene:

"*We are not worried; we know our territory. It has always worked like that. We live in the south of the island; we are protected by the lagoon. I've always lived here, I'm 40 years old and I've already lived through about thirty cyclones* " (Inhabitant X, 2020)

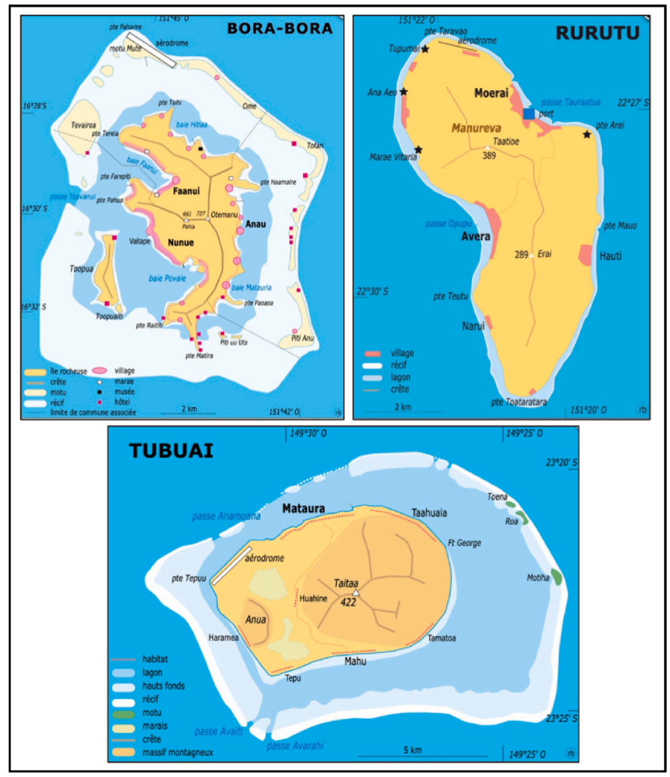

Fig. 5. *The 3 case studies: Bora-Bora, Rurutu and Tubuai. Source:* http://tresordesregions.mgm.fr/Mdir.php?p=cant.php&cl=Tubuai&region=987.

Knowledge of the risk therefore seemed sufficiently high:

"*The inhabitants know the risk. They had already stocked up on water and food for a 72-hour supply. They also had waterproof identity papers. They were ready to leave quickly*" (Fireman X, 2020)

On the other hand, this knowledge of risk is above all linked to a personal approach or experience:

"*There are indeed warning sirens that should sound on the first Thursday of every month, but they don't work. We follow individually on the site "windy.com". There are no guidelines to follow*" (Inhabitant Y, 2020).

One death was reported on the island, the only Oli-related death (La Dépêche, 2010; Le Parisien, 2010; Libération, 2010). However, the inhabitants and firemen confirm that this death is not related to the cyclone:

"*The dead man? he did not want to evacuate*" (Inhabitant X, 2020)

"*The deceased person slipped in a river because he was drunk. It was just before the cyclone*" (Fireman X, 2020)

Concerning solidarity, it was mixed. The role and presence of the churches was extremely strong, serving as refuge areas, distributing water and even food. The army was also extremely present and helpful with "*80 young soldiers at the disposal of the population*" (Inhabitant Y, 2020). On the other hand, among the inhabitants, it was rather "*every one for oneself, not too much between neighbors*" (Inhabitant X, 2020) or "*intra-family and not too much inter-family*" (Fireman X, 2020) help.

3.1.2. Urban resilience

It is essentially the north of the island that has been affected. It is in this place that the lagoon's flatness is the shortest. While it is about 2–3 m away, the length in the south is about 300 m. This is why the first facilities are located to the south. However, a few years ago, the main village was relocated to the North, including the airport. The airport was completely silted up. The main mission post Oli was to clear the runway to allow air links for food and human aid. The island's ring road, especially the northern part, "*required 4 days of work to clear it*"(Fireman X, 2020). The rest of the road system was not spared, "*other roads were full of holes and sometimes you had to drive through private property to get to your own house*" (Fireman X, 2020).

Regarding urban resilience and especially buildings, "*constructions are with bolted foundations so if it flies away, everything goes*"(Inhabitant Y, 2020). Oli affected more the North of the island (especially because of the low lagoon floor there), and "*destroyed all the wooden buildings*"(Fireman X, 2020). The buildings "*in hard were impacted at the level of the windows and openings*" (Fireman X, 2020). If the house was destroyed, "*we built a little hut quickly*" (Fireman X, 2020).

The waves were between 5 and 9 m high and mainly impacted infrastructure such as "*soccer stadiums*" (Inhabitant Y, 2020) or some bridges.

3.1.3. Technical resilience

The electrical and drinking water systems were extremely affected.

> "*All the power poles were down. We had to send people from Tahiti*"(Inhabitant X, 2020)

Water also came from Tahiti "*stocks came from Tahiti by plane*"(Fireman X, 2020).

> "*It took about 2 weeks to restore water and electricity. We needed power for water. It was first the administrations and then the inhabitants"* (Fireman X, 2020)

3.1.4. Conclusion

The level of resilience during Oli is extremely mixed (Fig. 6). While social resilience is quite good, both in terms of knowledge of the risk, reactions, level of anxiety and the degree of organization of the locals, urban and technical resilience are much more questionable.

The urban planning choices, in particular the location of critical infrastructure such as the airport in an extremely vulnerable area, the construction of a single ring road and the location of the main village in the north of the island, are inappropriate management choices. In addition, the time it took to restore basic services such as water and electricity took a fortnight, which is extremely long (Serre, 2018).

3.2. Rurutu

3.2.1. Social resilience

Rurutu was barely affected by Cyclone Oli. The inhabitants did not feel any fear in front of the event "*today we are not afraid, but before we were apprehensive. The means help. Now with the weather services we know the strength and the trajectory of the cyclone*"(Stakeholder X, 2020). The

Indicators	Paper Sub-indicators	Sources	Level of resilience
Social Indicator	Risk knowledge/ perception	Questionnaires and interviews	Very Resilient
	Bonding and bridging social capital	Questionnaires and interviews	Resilient
	Culture and memory of risk	Questionnaires and interviews	Resilient
	Global and individual organization	Questionnaires and interviews	Resilient
	Informations elements given by authorities	Questionnaires and interviews	Resilient
	Adapted reactions	Questionnaires and interviews	Resilient
	Fear/ Apprehension	Questionnaires and interviews	Very Resilient
	Limited human impacts	Questionnaires and interviews	Resilient
Urban Indicator	Buildings materials/ reconstruction	Field observations + interviews	Very Resilient
	Urban planning	Interviews + field observations	Vulnerable
Technical indicator	Location and condition of transport infrastructure	Interviews + field observations	Very vulnerable
	Condition of the electrical and drinking water networks during and after Oli	Interviews + field observations	Very vulnerable

Fig. 6. Level of resilience-Tubuai-During Oli.

cyclone passed near Rurutu during the night, people stayed in the shelter, "*if it had been the day, they would probably have been more curious and would have gone out*" (Stakeholder X, 2020). Polynesians have a special relationship with nature. "*Many people don't want to evacuate. There is a Christian belief of the power of nature, 'God willing'*. If the cyclone shifts, prayer has succeeded." (Stakeholder Y, 2020).

From an organizational point of view, the island works with relay persons to alert people on the list of vulnerable individuals (Fireman Y, 2020).

3.2.2. *Urban resilience*

No impacts directly related to Hurricane Oli were mentioned in the various interviews and questionnaires.

3.2.3. *Technical resilience*

No impacts directly related to Hurricane Oli were mentioned in the various interviews and questionnaires.

3.2.4. *Conclusion*

Oli did not directly impact the island of Rurutu. The urban and technical resilience can therefore not be directly analyzed (Fig. 7). Regarding social resilience, the acceptance of risk is extremely strong, as in Tubuai. The local collective organization is also very present and underlines the autonomy of the Polynesian islands, geographically distant from the decision-making center of Tahiti.

3.3. *Bora-Bora*

3.3.1. *Social resilience*

There were no casualties in Bora-Bora. People stayed at home because there were no cyclone shelters. It is essentially the hotels located on the motu which are strongly impacted. Tahitian officials had asked to evacuate the hotels on stilts, but for the mayor, these were the safest areas: "*Tourists were confined to the hotels. There were about 700 immobilized*" (Stakeholder Z, 2020).

3.3.2. *Urban resilience*

The damage recorded was due to the cyclonic swell and not to the winds, mainly at the level of the only beach of the island, the point Matira with a significant erosion. The "hard buildings were not affected by Oli" (Stakeholder Z, 2020). "*There was no total closure of hotels after the cyclone*" (Stakeholder Z, 2020), it is mainly the roofs of the bungalows that have been impacted as well as some pontoons. The mayor has encouraged all hotels located on motu to be built with bungalows on stilts. The first reason is to keep the cultural dimension of Polynesian architecture alive. On the other hand, "*in my memory, none of these constructions has ever been washed away*" (Stakeholder Z, 2020). It is therefore also a resilient urbanistic choice, by adapting the building to the presence of cyclonic risks on Bora-bora.

Indicators	Paper Sub-indicators	Sources	Level of resilience
Social Indicator	Risk knowledge/ perception	Questionnaires and interviews	Resilient
	Bonding and bridging social capital	Questionnaires and interviews	Resilient
	Culture and memory of risk	Questionnaires and interviews	Very Resilient
	Global and individual organization	Questionnaires and interviews	Very Resilient
	Informations elements given by authorities	Questionnaires and interviews	Resilient
	Adapted reactions	Questionnaires and interviews	Resilient
	Fear/ Apprehension	Questionnaires and interviews	Very Resilient
	Limited human impacts	Questionnaires and interviews	Very Resilient
Urban Indicator	Buildings materials/ reconstruction	Field observations + interviews	Very Resilient
	Urban planning	Interviews + field observations	Very Resilient
Technical indicator	Location and condition of transport infrastructure	Interviews + field observations	Very Resilient
	Condition of the electrical and drinking water networks during and after Oli	Interviews + field observations	Very Resilient

Fig. 7. Level of resilience-Rurutu-During Oli.

3.3.3. Technical resilience

Regarding technical resilience, "*the electrical system was mostly overhead at the time of Oli, the trees fell and we had weeks with nothing*" (Stakeholder Z, 2020). There are "*some emergency generators located in the town hall, in the police stations and in some hotels*" (Stakeholder Z, 2020).

3.3.4. Conclusion

It was mainly the tourists who had a "bad experience" with Oli in Bora-Bora. The economic recovery system was very quick, with some hotels not even closing for a few days (Fig. 8). The choice of building on stilts has favored this rapid economic and social recovery.

4. Assessing resilience 10 years after oli event

4.1. Tubuai

4.1.1. Social resilience

10 years later, the serenity and confidence are still there: "*We know our territory*" (Inhabitant X, 2020), "*We are not afraid of it happening again*" (Fireman X, 2020). On the other hand, forgetfulness is pointed out "*a tent is built in the northern zone for the Heiva. But a tent flies away. Yet it is the same mayor as during Oli*" (Inhabitant Y, 2020). Concerning the memory and culture of risk "*for two years, after Oli, we were given a brochure to raise awareness. After that, nothing*"(Inhabitant X, 2020). Concerning the emergency services, "*there is no training in relation to the cyclonic risk*" (Fireman X, 2020). The insurances related to natural disasters "*we don't have any if it's above* 250 km/h. *But it is always above*"(Inhabitant Y, 2020).

4.1.2. Urban resilience

6 months after Oli, a sign is installed to announce 12 km of new road "*but it was never done*" (Inhabitant Y, 2020). Several riprap systems have been consolidated and updated (Fig. 9).

However, some infrastructure, especially roads, are still weakened (Fig. 10).

Hundreds of Fare OPH (Polynesian Housing Office) were built after Hurricane Oli. These Fare are slightly elevated, economically accessible constructions (Fig. 11).

After Oli, a new regulation to build at least 60 m (Fig. 12) from the sea was decreed, "*except when the reef is far enough*" (Inhabitant X, 2020).

Concerning the regulations, there is no PPR (risk prevention plan), but zones of different colors according to their degree of constructability. However, even in the red zones "*you can build if it is tourist, because it is not year-round*" (Inhabitant X, 2020).

4.1.3. Technical resilience

No information on the technical system has been collected.

Indicators	Paper Sub-indicators	Sources	Level of resilience
Social Indicator	Risk knowledge/ perception	Questionnaires and interviews	Very Resilient
	Bonding and bridging social capital	Questionnaires and interviews	Resilient
	Culture and memory of risk	Questionnaires and interviews	Very Resilient
	Global and individual organization	Questionnaires and interviews	Resilient
	Informations elements given by authorities	Questionnaires and interviews	Resilient
	Adapted reactions	Questionnaires and interviews	Resilient
	Fear/ Apprehension	Questionnaires and interviews	Resilient
	Limited human impacts	Questionnaires and interviews	Very Resilient
Urban Indicator	Buildings materials/ reconstruction	Field observations + interviews	Very Resilient
	Urban planning	Interviews + field observations	Very Resilient
Technical indicator	Location and condition of transport infrastructure	Interviews + field observations	Vulnerable
	Condition of the electrical and drinking water networks during and after Oli	Interviews + field observations	Vulnerable

Fig. 8. Level of resilience-Bora-Bora-During Oli.

Fig. 9. Riprap systems, Tubuai. Personal photo (12/2020).

Fig. 10. Road system, Tubuai. Personal Photo (12/2020).

4.1.4. Conclusion

The degree of social resilience at the population level is the same as at the time of the hurricane. On the other hand, the notion of memory and culture of risk is strongly questioned. No official approach has been launched or maintained over the long term, either in terms of information or training.

Regarding urban resilience, new construction guidelines have been launched, but the maintenance of infrastructure is not always maintained. Finally, concerning the drinking water and electricity networks, no change has been mentioned, and the system is still aerial concerning the electrical system (Fig. 13).

4.2. Rurutu

4.2.1. Social resilience

As for Tubuai, the notion of fear or apprehension is non-existent in Rurutu. However, there is no "*work of memory or transmission*" (Stakeholder X, 2020) that is set up by the actors for the inhabitants, whether it is for Oli or for other hurricanes. However, "*simulation exercises are set up for the actors and firemen twice a year, concerning cyclones, tsunamis and fires*"(Fireman Y, 2020). There are no "*evacuation signs yet, so the information is done through meetings with the inhabitants to know the escape points*" (Fireman Y, 2020; Stakeholder Y, 2020).

4.2.2. Urban resilience

As for Tubuai, Fare OPH constructions have multiplied. "*Individuals are inspired by these homes. It wasn't done before*" (Stakeholder Z, 2020).

A PPR is "*validated for two years. But it is a political document*" (Stakeholder X, 2020).

Fig. 11. Fare OPH in Tubuai, personal photo (12/2020).

4.2.3. Technical resilience

Today "*generators are available*" for the inhabitants (Stakeholder Y, 2020).

4.2.4. Conclusion

The resilience of Rurutu is generally good. Despite the lack of training given to the inhabitants, simulation exercises are organized for the local actors. New forms of housing are developed, more adapted to the situation (Fig. 14).

Fig. 12. 60 m of distance from the sea, Tubuai. Personal photo (12/2020).

4.3. Bora-Bora

4.3.1. Social resilience

On the societal level, the dimension of “risk culture and memory” is very much invested in creating a link between “*the teachings of the ancestors and the constructions on stilts. It is important to continue to maintain the culture, the traditions. Don't be afraid to do good for your people.*” (Stakeholder Z, 2020) and crisis management. In spite of this “*there are few archives at the town hall*” (Stakeholder Z, 2020). Economically, given that there was no “*total closure of hotels after the cyclone*” (Stakeholder Z, 2020), the economic impact was not felt too much.

4.3.2. Urban resilience

Since it was mainly the water that impacted the constructions, it was decided to “*raise the existing bungalows*” (Stakeholder Z, 2020). The construction techniques have also evolved by developing “*roofs with 4 points. It is better for cyclones, it is more resistant*” (Stakeholder Z, 2020). The “*construction standards have been strengthened for public buildings. We follow the metropolitan code. To fight against a wind of* 150 km/h" (Stakeholder Z, 2020). Regarding development choices (Fig. 15), “*hotels on stilts have become marine protected areas, to have a systemic dimension of the environment and its protection*” (Stakeholder Z, 2020).

4.3.3. Technical resilience

The choice was made to bury the electrical system. “*Today 80% of the system is underground*” (Stakeholder Z, 2020) in order to protect it in case of a cyclone and trees that could fall on the power lines. The objective is to be able to “*quickly restore electricity*” (Stakeholder Z, 2020).

From a security point of view, the goal is for Bora-Bora to be “*energy*

Indicators	Paper Sub-indicators	Sources	Level of resilience
Social Indicator	Risk knowledge/ perception	Questionnaires and interviews	Very Resilient
	Bonding and bridging social capital	Questionnaires and interviews	Vulnerable
	Culture and memory of risk	Questionnaires and interviews	Vulnerable
	Global and individual organization	Questionnaires and interviews	Vulnerable
	Informations elements given by authorities	Questionnaires and interviews	Vulnerable
	Adapted reactions	Questionnaires and interviews	Resilient
	Fear/ Apprehension	Questionnaires and interviews	Very Resilient
	Limited human impacts	Questionnaires and interviews	Resilient
Urban Indicator	Buildings materials/ reconstruction	Field observations + interviews	Resilient
	Urban planning	Interviews + field observations	Resilient
Technical indicator	Location and condition of transport infrastructure	Interviews + field observations	Vulnerable
	Condition of the electrical and drinking water networks during and after Oli	Interviews + field observations	Very Vulnerable

Fig. 13. Level of resilience, Tubuai. After Oli.

Indicators	Paper Sub-indicators	Sources	Level of resilience
Social Indicator	Risk knowledge/ perception	Questionnaires and interviews	Resilient
	Bonding and bridging social capital	Questionnaires and interviews	Resilient
	Culture and memory of risk	Questionnaires and interviews	Vulnerable
	Global and individual organization	Questionnaires and interviews	Resilient
	Informations elements given by authorities	Questionnaires and interviews	Resilient
	Adapted reactions	Questionnaires and interviews	Resilient
	Fear/ Apprehension	Questionnaires and interviews	Very Resilient
	Limited human impacts	Questionnaires and interviews	Very Resilient
Urban Indicator	Buildings materials/ reconstruction	Field observations + interviews	Very Resilient
	Urban planning	Interviews + field observations	Very Resilient
Technical indicator	Location and condition of transport infrastructure	Interviews + field observations	Resilient
	Condition of the electrical and drinking water networks during and after Oli	Interviews + field observations	Resilient

Fig. 14. Level of resilience-Rurutu-After Oli.

Fig. 15. Sofitel Hotel – Bora-Bora. Personal photo (01/2021).

self-sufficient. One of the strategies would be to combine hydrogen and thermal energy linked to the cold marine currents" (Stakeholder Z, 2020). Since 1989 *"many things have been done because there was no running water on the main island*" (Stakeholder Z, 2020).

4.3.4. Conclusion

Efforts to increase Bora-Bora's resilience are extremely extensive (Fig. 16). They are primarily focused on urban planning and technical measures, both in terms of the choice of materials and regulations and in terms of development techniques. The vision of crisis management is also a long-term one in Bora-Bora.

4.4. Resilience of the austral and Society Archipelago population

The questionnaires that were distributed to the population of the 3 islands confirmed the message held by the actors of the territory. Knowledge of risk is high as well as past events (Fig. 17). In addition, the memory of the risk seems strong for the inhabitants (Fig. 18). This directly echoes the strong bond that seems to link Polynesians and their territory.

In addition, their ability to rebound is particularly marked, integrated individually and collectively (Fig. 19).

The populations consider themselves alerted by the authorities and more particularly by the city hall (Fig. 20).

On the other hand, an effort on training, simulations, communication systems is desired (Fig. 21). This same reality was observed during the interviews.

Indicators	Paper Sub-indicators	Sources	Level of resilience
Social Indicator	Risk knowledge/ perception	Questionnaires and interviews	Very Resilient
	Bonding and bridging social capital	Questionnaires and interviews	Resilient
	Culture and memory of risk	Questionnaires and interviews	Very Resilient
	Global and individual organization	Questionnaires and interviews	Very Resilient
	Informations elements given by authorities	Questionnaires and interviews	Resilient
	Adapted reactions	Questionnaires and interviews	Resilient
	Fear/ Apprehension	Questionnaires and interviews	Very Resilient
	Limited human impacts	Questionnaires and interviews	Very Resilient
Urban Indicator	Buildings materials/ reconstruction	Field observations + interviews	Very Resilient
	Urban planning	Interviews + field observations	Very Resilient
Technical indicator	Location and condition of transport infrastructure	Interviews + field observations	Resilient
	Condition of the electrical and drinking water networks during and after Oli	Interviews + field observations	Very Resilient

Fig. 16. Level of resilience- Bora-Bora. After Oli.

5. Discussion

Cyclone Oli is a perfect illustration of the complex resilience management of coastal risks. In a context of climate change, these coastal and island territories are increasingly vulnerable (IPCC, 2023). Whether in terms of the intensity and recurrence of events, the complex geomorphology of the islands, or their geographical, economic and political remoteness from major development axes, these territories concentrate multiple vulnerabilities. French Polynesia, by its geographical distance from mainland France and its diversity of archipelagos and communities, illustrates this complexity. Cyclone Oli underlines this in-between situation: distance between the archipelagos, geographical diversity of the islands and their lagoons, local communities and activities marked by their specific environment, strong links with the "natural" environment, vulnerability of the built environment, etc.

The degree of resilience to Cyclone Oli is therefore heterogeneous. The degree of social resilience, knowledge of the risk, attachment to the territory, risk culture, confidence in the territory, is very high. This social resilience is very strong on the three islands, specifically during the cyclone. There was a high level of mutual aid, both from the government, which provided temporary housing for disadvantaged families who had lost their homes (Canavesio et al., 2014), and from individuals, who helped each other rebuild their homes and clear the main roads. This dimension is part of an individual culture but also and above all in a local collective culture. Furthermore, Polynesian culture is extremely marked by the importance of nature and respect for the "natural" functioning of ecosystems. A risk is therefore perceived as something "normal", "natural", and not as a threat that could lead to disengagement from the territory. This dimension is fully illustrated by the interviews and questionnaires. However, a variation can be seen 10 years later, with Bora-Bora the most resilient, having invested more in social capital, culture and the memory of risk. Rurutu, which was the island least directly impacted, hardly invested at all in culture and the memory of risk. As a result, the experience was neither valued nor given a long-term perspective. Learning from the event is therefore open to question.

Urban and technical resilience are more questionable. Concerning buildings, great efforts have been made by the three islands to develop and adopt more adapted constructions, especially on stilts. These constructions are mainly recent and have increased in number after Oli. Several urban planning choices have been initiated, notably to move buildings away from the shoreline, to develop PPRs or to develop stricter building standards. However, there is no relocation of certain infrastructure, nor of secondary infrastructure, especially roads. Concerning the networks, only Bora-Bora has initiated major protection work by choosing to bury its networks. Tubuai, which was hard hit, is still highly vulnerable in terms of critical electricity and drinking water infrastructures. In addition, the state of the transport networks is still very vulnerable 10 years on.

Finally, with regard to the systemic and long-term vision of risk

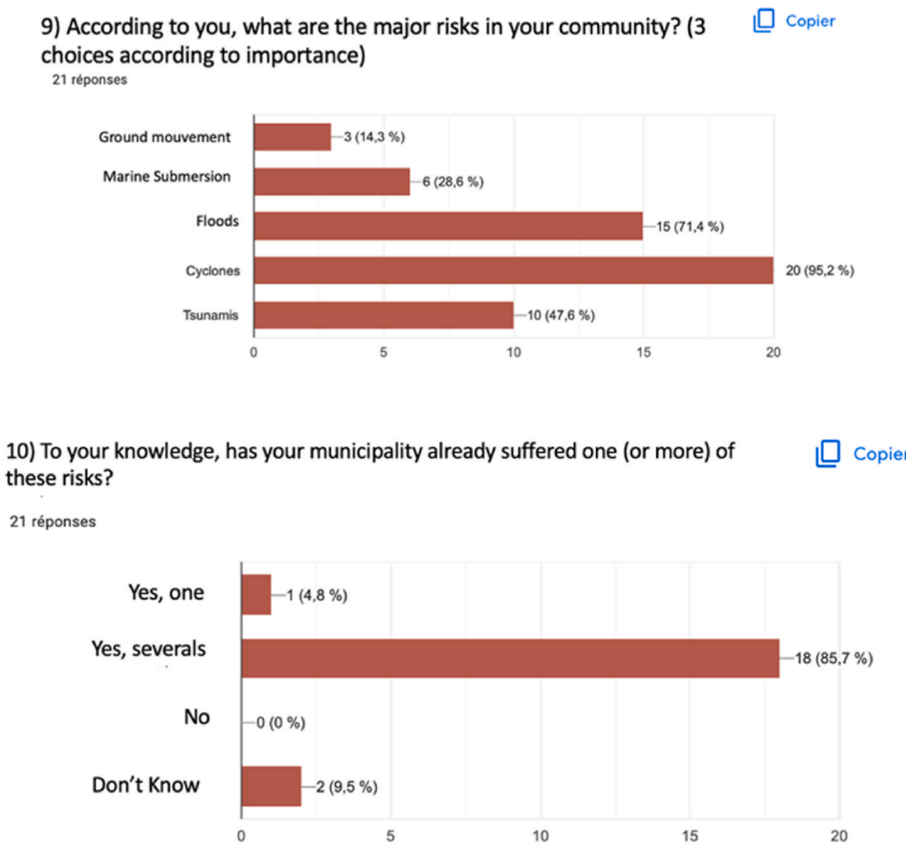

Fig. 17. Knowledge of risk – Tubuai, Rurutu, Bora-Bora.

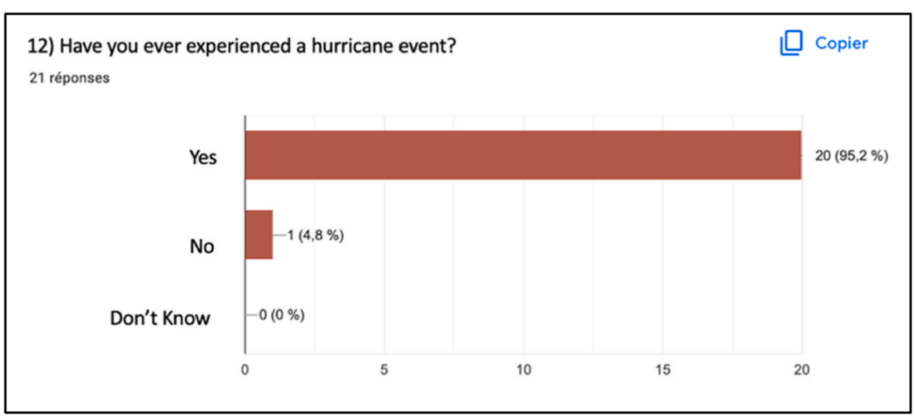

Fig. 18. Risk experiences– Tubuai, Rurutu, Bora-Bora.

management, only Bora-Bora is involved in this dimension. This result is fully reflected in the urban planning choices made. The mayor has invested in the management of drinking water and wastewater treatment, in getting hotels to adhere to a policy of lagoon preservation by encouraging the creation of artificial coral reefs under bungalows and near hotels, and finally in fisheries management by re-establishing an ancestral fishing fallow custom, the "rahui". In 2021, the island launched Objective 5.0 for the French Overseas Territories: zero carbon, zero waste, zero agricultural pollutants, zero exclusion, zero vulnerability. This strong dynamic is mainly explained by local values, but is also undoubtedly influenced by Bora-Bora's strong tourism component. Bora-Bora's international image, aura and appeal are much stronger than those of Tubuai or Rurutu, which are more remote and little-known. Tubuai and Rurutu are therefore "only" local issues, while Bora-Bora is both local and international.

This methodology was designed as part of the development of a risk and resilience observatory. The objectives were to produce data on resilience in the face of cyclonic risk and to develop participatory approaches with local stakeholders and populations.

Several limitations can be noted.

- The choice was made to pre-define resilience assessment criteria. These criteria were defined with the help of international literature on the evaluation of the concept of resilience. However, another approach could have been taken, namely to collect data without having pre-identified these criteria. Interpretation bias to be questioned

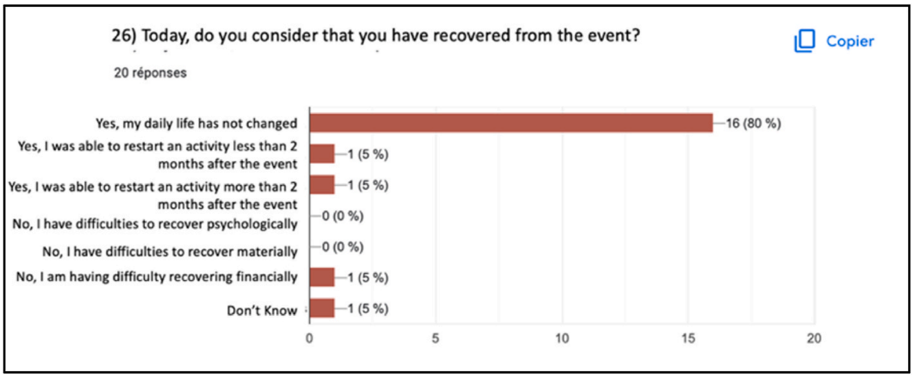

Fig. 19. Rebound capacity- Tubuai, Rurutu, Bora-Bora.

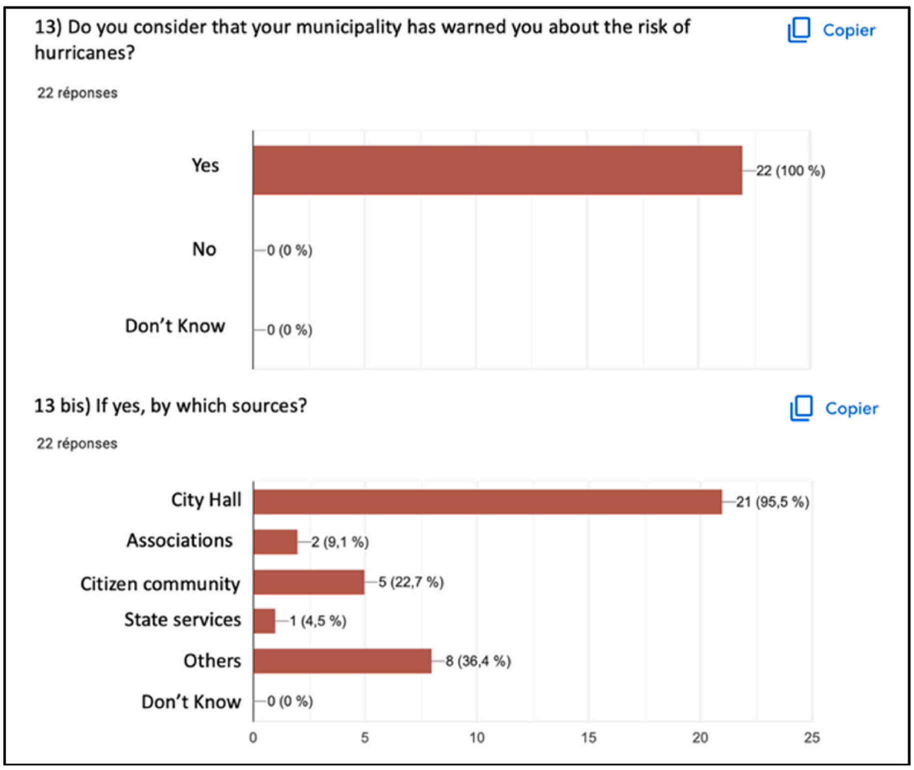

Fig. 20. Feeling of Beeing alerted-Tubuai, Rurutu, Bora-Bora.

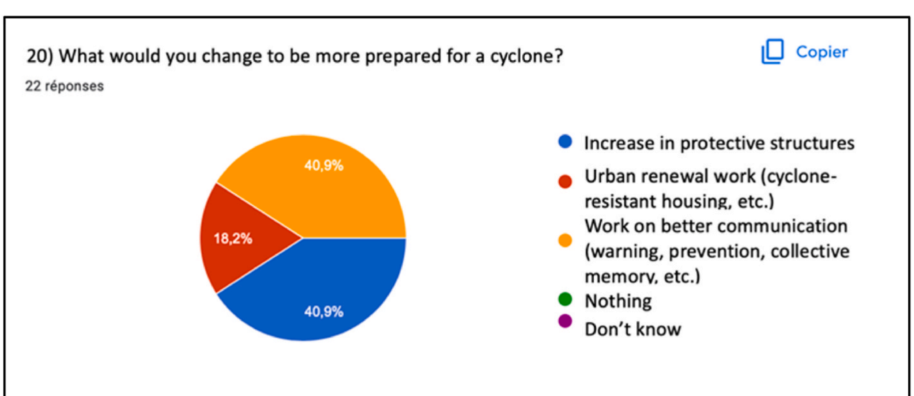

Fig. 21. Preparation elements - Tubuai, Rurutu, Bora-Bora.

- The number of people interviewed (n = 10) and questioned (n = 21) may also represent a limitation. Despite numerous reminders for the questionnaires and via numerous distribution media (e-mail, Facebook, via town halls), only 21 people responded. This raises questions about the interest, investment and sense of belonging of other individuals.
- Finally, the results illustrate strong disparities between the islands. Even so, they were not all affected in the same way by the cyclone. This suggests that the degree of resilience during the cyclone is questionable.

Despite these limitations, this approach allowed to address several issues.

- Analysis and assessment of resilience to cyclonic risk over the long term. This notion is extremely crucial in order to identify trends, evolutions and learning in the face of a climatic event. This kind of analysis in the face of cyclone Oli had never been done before, only a crisis management analysis was produced (Canavesio et al., 2014);
- Developing a multi-methodological approach (interviews and questionnaires) is extremely enriching in order to have the most exhaustive possible assessment of resilience in the face of cyclones;
- Involving local stakeholders and inhabitants in the process of narrating, defining and analyzing events a posteriori is a guarantee of involvement, of the sustainability of the results, and of their understanding and adoption. This participatory approach is imperative for long-term success;
- Finally, developing this methodology as part of the construction of a spatial decision support system, in the form of a risk and resilience observatory, means that the qualitative results can be perpetuated in the form of a database. These data are stored, transformed and, in the next stages, made accessible to other stakeholders and users. It's a form of perpetuation, of long-term registration, which is vital for the resilience of the Polynesian islands.

While current risk management in Polynesia focuses primarily on crisis management (Heinzlef et al., 2024), this approach highlights the need to integrate the concept of resilience into strategies. This integration is crucial if we are to adopt a long-term approach, integrating the multitude of institutional, local, community and individual stakeholders, and address the complexity of systemic management of current and future coastal, island and lagoon risks.

6. Conclusion

This approach allowed the development of a long-term analysis of territorial and social resilience to cyclonic risk. It identified vulnerability and resilience factors, both in 2010 and 2020. This methodology has highlighted the processes of memory and risk culture. The post-disaster analysis also allowed us to demonstrate the post-disaster learning processes, the individual and collective reconstruction and the improvements initiated both at the citizen and local actor levels. Despite the non-exhaustiveness of the method, it has reconnected different actors involved in a disaster, the inhabitants, the mayors, the firemen. In order to go beyond quantitative analyses, this methodology fully integrates qualitative data, based on local experiences, feelings, memories, but also the dynamics of adaptation, rebound, and learning that have been taking place since 2010. Integrating these data into a decision support tool favors a comprehensive, multi-temporal, multi-scalar and systemic analysis of resilience to climate risks. In addition, local actors feel fully active, integrated in the process of resilience to climate risks. This is a guarantee that strategies and concepts will be adopted and that risk management strategies will be implemented over the long term. This method, based on a qualitative, multi-temporal and systemic analysis of resilience, can therefore be applied to other catastrophic events and other risks. This approach feeds directly into the two components of the observatory aimed at producing data and involving local stakeholders in the co-construction of resilience strategies in the face of climate risks. In addition to these two aspects, this methodology promotes the adoption and use of the observatory as a decision-making tool, implemented in the practices, needs and cultures of local populations.

Unlisted references

Fireman, 2020, Inhabitant, 2020, Stakeholder, 2020; Stakeholder, 2020.

CRediT authorship contribution statement

Charlotte Heinzlef: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing. **Damien Serre:** Funding acquisition, Investigation, Project administration, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors are unable or have chosen not to specify which data has been used.

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