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ORIGINAL ARTICLE

The climate change policy integration challenge in French Polynesia, Central Pacific Ocean

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Abstract

This paper discusses whether existing coastal risk reduction policies in French Polynesia—a French Overseas Territory with a high degree of political autonomy—(i) consider current and future coastal risks from climate variability and change, and (ii) are designed to evolve as new knowledge on climate change emerges. The analysis relies on the study of risk-relevant policy documents and considers *Coastal risk integration* (i.e. extent to which coastal hazards and associated impacts are considered) and *Adjustability* (i.e. potential for the policy documents to be adjusted over time) as proxy outcomes for climate change policy integration more broadly. The results show that there are still important gaps relating to an insufficient incorporation of climate-related coastal hazards into the existing policy documents, and to difficulties in both implementing these documents and making them more climate change-compatible. While recent examples on the ground provide encouraging early signs towards more adjustable local policies, they are to date too time- and/or space-bounded to represent any real shift at the territory level.

Keywords Coastal risks · Climate adaptation · Policy documents · Small islands

Introduction

This paper looks at whether existing public policy documents dealing with coastal risk reduction in French Polynesia in the Central Pacific Ocean (i) consider current and future coastal risks from climate variability and change, and (ii) are designed to evolve as new knowledge on climate change emerges. Such a framing refers to a broader challenge faced by climate adaptation policies worldwide in terms of being able to consider current and long-term risk reduction strategies together and, in turn, put in place the enabling conditions for current public policies to remain efficient over time. This challenge is widely recognized as a cornerstone of the governance of cross-cutting policy problems, and of climate adaptation in particular (Candel and Biesbroek 2016; Runhaar et al. 2018; Olazabal et al. 2019; Gussman and Hinkel 2021; Biesborek 2021).

This analysis focuses on risks related to coastal erosion and marine flooding. It does so referring to the case of French Polynesia, which is a French Overseas Territory with a high degree of political autonomy and that consists of a grouping of five archipelagos. This case illustrates the challenge of climate change policy integration in the context of small tropical islands. These territories are highly concerned with coastal risks and their reduction because of three main reasons. Firstly, coastal plains—which play a critical role for settlement and development (Kumar and Taylor 2015; Andrew et al. 2019)—and reef islands have low elevations (above sea-level) and small sizes. Secondly,

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the high climate sensitivity of their physical and ecological features (e.g. reef-dependent beach and reef island systems), and their societal conditions (e.g. marine-dependent small-scale economies and subsistence activities, and high population and built asset density in flood-prone areas) are driving increased exposure and vulnerability. Thirdly, small tropical islands are already experiencing extreme events including intense tropical cyclones and distant-source swells, and associated strong winds and waves leading to extensive marine flooding and coastal erosion (Hoeke et al. 2013; Smithers & Hoeke, 2014; Canavesio 2019; Duvat et al. 2019). Furthermore, climate change is expected to exacerbate marine flooding and coastal erosion, as a result of the combination of sea-level rise (Oppenheimer et al. 2019), increased storm wave heights from mid-latitude depressions (Vitousek et al. 2017; Mentaschi et al. 2017), increased frequency of tropical cyclones during El Niño events (Chand et al. 2017), and ocean warming and acidification (Gattuso et al. 2015)—which will decrease both storm wave attenuation by reefs and sediment supply to islands (Hughes et al. 2018; Perry et al. 2018).

This paper discusses whether local policies dealing with coastal risks in French Polynesia meet the climate change policy integration challenge through asking two questions: (i) Do policy documents integrate current coastal risks and their projected changes? And (ii) do they allow for continuous adjustment to align with new knowledge on observed impacts and projected risks? To address these questions, the paper refers to the two proxy concepts of '*Coastal risk integration*' and '*Adjustability*', which respectively refer to the extent to which coastal hazards and impacts are considered, and to the potential for the relevant policy documents to be adjusted over time. The term 'adjustment' is foundational to the definition of climate change adaptation, i.e. 'the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities' (Weyer et al. 2019, p. 678). Such adjustment is required as lessons are learnt from climate disasters, experience is gained over time in implementing responses that can reveal either adaptive or maladaptive outcomes (Juhola et al. 2016; Magnan et al. 2016; New et al. 2022), and scientific knowledge on climate projections and risks arises (Nicholls et al. 2021). It is acknowledged that institutions 'can manage shocks and perturbations by adjusting rules, boundaries, partners, and membership' (Cinner and Barnes 2019, p. 53), and that policy adjustment is critical to support reversibility processes (Hallegatte 2009). Whereas the word 'adjustability' is not systematically used in the literature, several terms have emerged over the last two decades that more or less refer to adjustability, including the following: 'flexibility', defined in relation to 'opportunities for switching between adaptation strategies and capture the diversity of potential adaptation options available' (Cinner et al. 2018, p. 118; see also Barnett and O'Neill 2010); 'adaptation pathways', defined as long-term strategies relying on decision cycles that sequence a set of possible actions based on alternative and uncertain developments (Haasnoot et al. 2013, 2021; Wise et al. 2014; Kelly 2015; Werners et al. 2020); and 'adaptive management', defined as the 'process of learning through readjustment processes that allows revision, redefinition or change to alternative pathways' (Olazabal et al. 2019, p. 5).

As a result of the framing above, and despite the focus on a specific case study, this paper has the potential to contribute to the literature on the broader context of low-lying coastal areas in the face of climate change, and on a range of topics including the following: the challenge of multi-level governance of environmental issues; the way public policies consider the complex nature of climate change (e.g. multiple hazards and uncertainty); the importance of the adjustability of adaptation responses to changing experience, information and risk perceptions; and the need to identify the early signs of potential progress towards more robust adaptation strategies. The literature on all these topics is extensive but remains limited on small islands, a gap that this paper also contributes to fill.

The paper first presents the French Polynesia geographical and policy context, as well as the methodological approach used in the study. It then develops the results for the *Coastal risk integration* and *Adjustability* pillars of analysis. Last, it moves a step further by discussing a proposal to renew risk reduction strategies in atoll island contexts as well as encouraging signs towards enhancing climate adaptation.

Study site, materials, and methods

The geographical and policy context

Geographical context

The 4,167-km^2 land area of French Polynesia (Fig. 1) is divided into mountainous, volcanic islands as well as low-lying atoll islands, distributed in five archipelagos (Society Islands, Tuamotu, Gambier, Marquesas, Austral Islands) stretching ~ 2,200 km North–South and ~ 2,300 km East–West. The total population doubled since the late 1970s, to reach 275,900 inhabitants in 2017 (ISPF 2018a) who mainly live in the Society Islands where the main island of Tahiti is located. Coastal areas have played a decisive role in human settlement history and continue to be the main places for settlement, economic activities, and infrastructure development. As a result, about 79% of the French Polynesia population is living less than 1 km from the sea (Andrew et al. 2019), and coastal densities are reaching ~ 2,960 hab/km^2 in the northwest districts

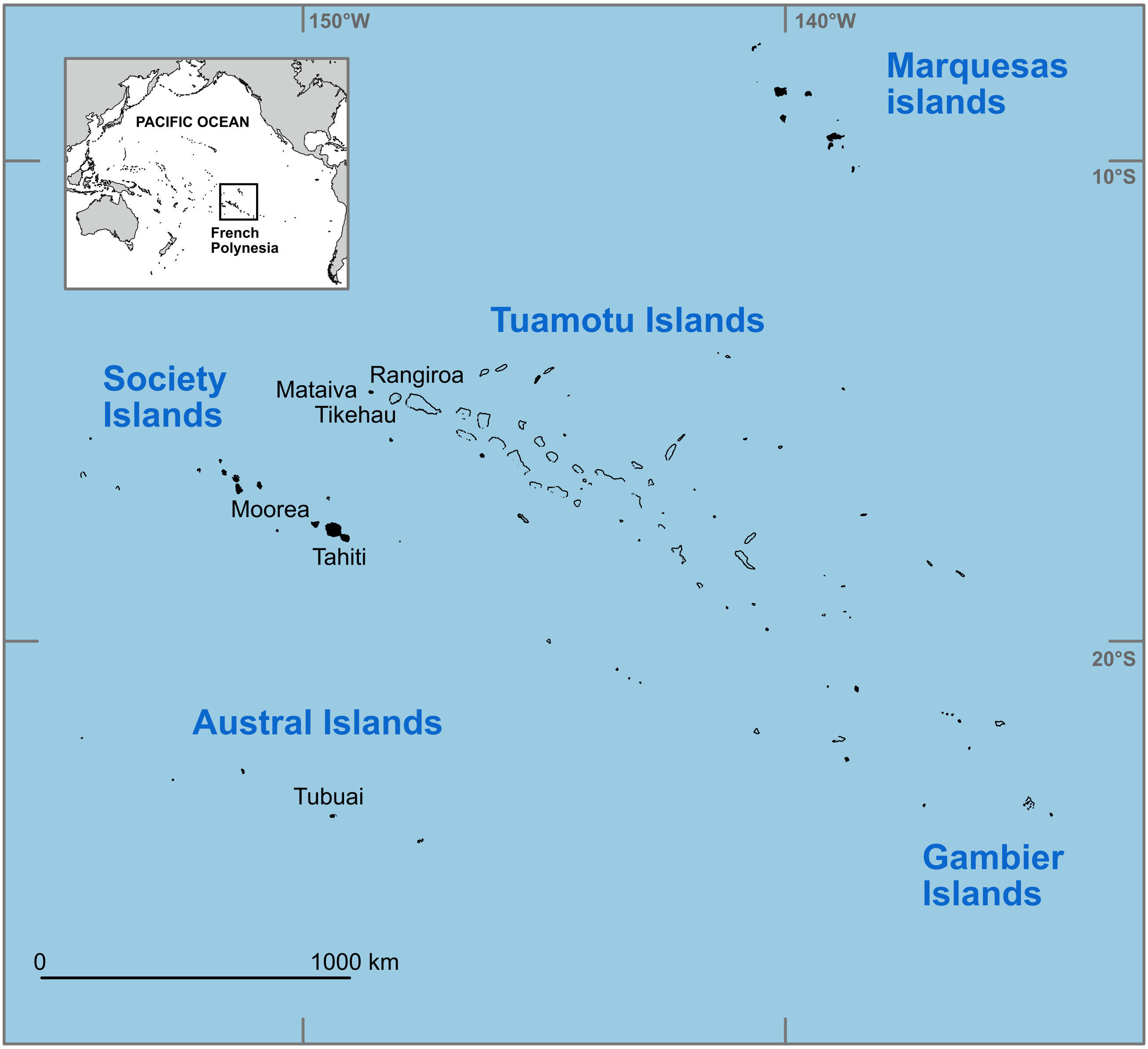

Fig. 1 Locations in the French Polynesia archipelagoes. Only the names of islands mentioned in the text are given

of Tahiti (Papeete, Faaa, Punaauia, and Pirae) and ~ 110 hab/km^2 in some populated atolls such as Rangiroa in the Tuamotu (ISPF 2018a). Coastal tourism (transportation, accommodation, catering, and related services) accounts for 27% of the GDP (ISPF 2018b), and pearl farming plays a critical and reputational role (IEOM 2020). Roads and infrastructure are also mainly coastal, e.g. Faaa international airport located 2 m above sea level (Bessat et al. 2006).

Coastal risks

Extreme events, including intense tropical cyclones and distant-source swells, are occurring in the region (Laurent and Varney 2014), causing widespread damage as a result of extensive marine flooding and coastal erosion (Duvat et al. 2017; Canavesio 2019). The January 2017 rainfall-driven flood event illustrates the vulnerability of French Polynesia to flood risks at the coast: in the two main inhabited islands of Tahiti and

Moorea, it caused the destruction of one hundred houses, the evacuation of about 300 households, and the closure of the Faaa international airport for a few days, with overall damages reaching around 27 million $US (Anonymous 2017).

Despite the lack of a systematic assessment of coastal erosion and marine flooding risks at the scale of French Polynesia, available studies report that intense tropical cyclones (e.g. Oli in 2010), moderate tropical depressions (e.g. in 2018 in Fakarava), and distant-source waves (e.g. in 1996) cause both marked shoreline retreat and overwash-driven sediment supply to coastal systems (Etienne 2012; Le Cozannet et al. 2013; Duvat and Pillet 2017; Duvat et al. 2017, 2020a; Salmon et al. 2019). During these events, marine flooding is widespread and affects inland areas, as waves cross over atoll islands from ocean to lagoon (Duvat et al. 2017, 2020a) and reach inland areas in mountainous islands (Etienne 2012; Salmon et al. 2019). In the future, it is estimated that locations, characterized by small variability in daily sea-level changes (especially caused by tides) such as the main urban area of Papeete in Tahiti, 'will experience large amplifications [of extreme sea levels (also caused by surges and waves)] even for a moderate rise in mean sea-level' (Oppenheimer et al. 2019, p. 359). Historical centennial events at Papeete tide gauge could therefore become at least annual before the mid-century or soon after 2050 (Lambert et al. 2020). In addition, and despite some uncertainty on local relative sea-level rise partly due to tide gauge measurement and ground motion issues at the Papeete site (Martinez-Asensio et al. 2019), sea-level projections are close to the global average and lead to conclude on more flooding events to be expected in the coming decades.

Governance landscape

French Polynesia is a French Overseas Territory with the status of a 'Collectivité d'Outre-Mer' (hereinafter referred to as 'the Collectivity'), meaning it has a high degree of political autonomy from the French state since its first legal status of autonomy in 1984, then reinforced in 1996 and 2004. The French state is locally represented by the High Intendance (locally called 'Haut-Commissariat'), which is in charge of organizing the activities conducted by the local services of the French state (e.g. army, police). French Polynesia Collectivity has its own locally elected Government and Assembly. It has the competence to regulate all the fields that are not expressly assigned to the French state or to the municipalities headed by a mayor, and is especially responsible for urban and rural planning, risk prevention, and environmental management.

The distribution of competences between the State, the Collectivity, and municipalities is however complex in practice. Most notably, in response to cyclone events, overlapping and sometimes conflicting interventions are carried out by both the representative of the French state—emergency coordination by the High Intendance and relying on national State services supported by local forces (municipal police and firemen)—, and French Polynesia authorities such as the Department of Construction that is in charge of assisting the affected populations and providing them with material, commodities, etc. along with municipalities (Terorotua et al. 2020).

Methodological approach

The study relies on the analysis of the most updated public policy documents dealing with planning coastal risk reduction, including those that deal with the coastal zone indirectly. In addition, semi-structured interviews have been undertaken in 2018–2019 among a set of key stakeholders.

Material

The policy documents have been selected based on our own experience of the French Polynesia context—most of us are conducting research[1] on this territory since 2013—, as well as on extended exchanges with other colleagues who recently mapped climate adaptation-related processes in French Polynesia. Inspired by the framing used in Terorotua et al. (2020) to identify key local public stakeholders a priori concerned with climate change, we considered a public policy document relevant when it addresses, even indirectly, coastal risks to people, infrastructures, and/or economic activities, possibly including risk from climate change beyond only sea-level rise. We paid particular attention to the treatment of two coastal hazards, i.e. coastal erosion and marine flooding, and distinguished between public policy documents that apply to the French Polynesia Collectivity as a whole and those that are designed for more local scale contexts (group of islands, island, municipality, etc.) (Fig. 2).

Two documents designed by the Collectivity and encompassing the whole French Polynesia territory are considered:

(i) The Climate and Energy Plan (*Plan Climat Énergie de la Polynésie française*; PCE 2015) is a policy plan established for the 2015–2020 period. It frames the general climate strategy of the country in terms of both mitigation and adaptation. It establishes a diagnosis at the French Polynesia level primarily of energy consumption and greenhouse gas emissions,

[1] RÉOMERS (2013–2016, French overseas territories' resilience to climate- and marine-related hazards in the context of climate change), STORISK https://lienss.univ-larochelle.fr/storisk (2016–2021, Small islands addressing climate change: towards storylines of risk and adaptation), and INSeaPTION http://www.inseaption.eu/ (2018 –2021, Integrating se-level Projections in climate services for coastal adaptation).

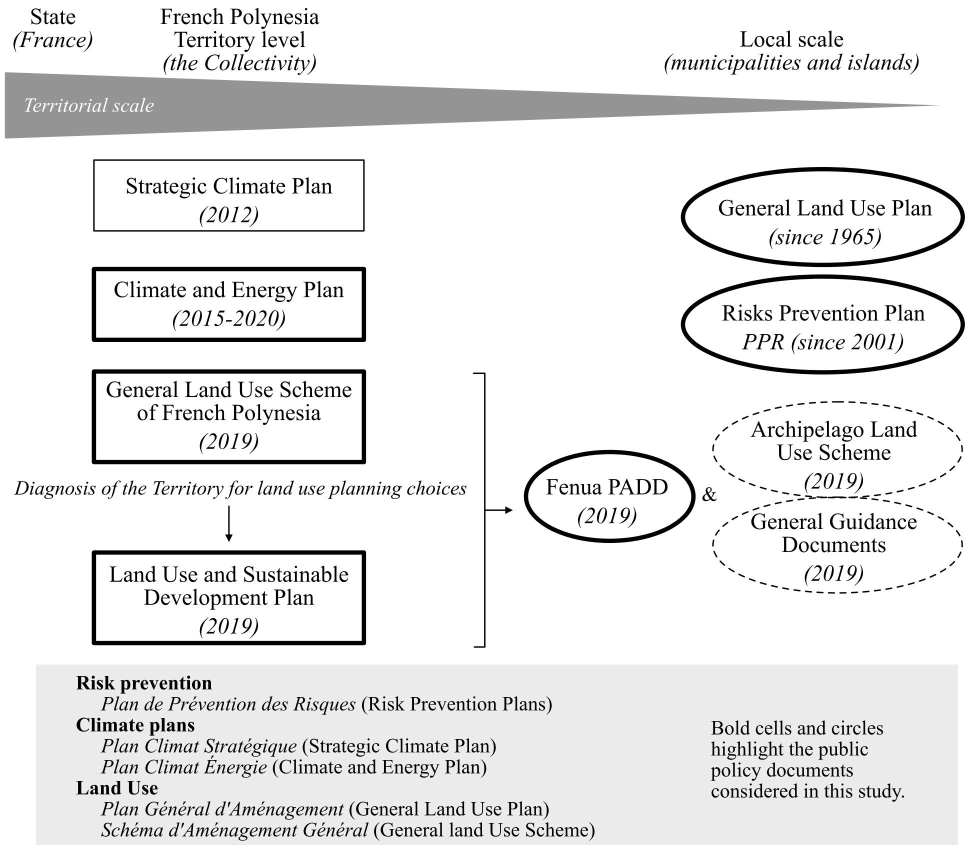

Fig. 2 Schematic policy landscape of (coastal) risk reduction policies in French Polynesia. Note that Risk Prevention Plans have implications on land use and prevail over other plans and regulatory documents

and more secondarily of climate vulnerabilities. In June 2020, the Monitoring Committee estimated that over the last 5 years, only one third of the implementation of the Climate and Energy Plan as a whole has been achieved, compared to two third as initially planned, and with a strong focus on mitigation activities (Alter-echo & PTPU 2020). Preliminary works will start on July 2022 to design a new Climate Plan that will run until 2030.

(ii) The General Land Use Scheme (*Schéma d'Aménagement Général*; SAGE 2019) was approved on 24 August 2020 (Polynesian Law n° 2020–20) and defines the overall development strategy in terms of demography and economy at a 20-year timescale. It is also supposed to consider global warming issues (French Polynesia Planning Code, article LP 111–3). The General Land Use Scheme is composed of different parts, including the *Fenua* Sustainable Development Plan that establishes the settlement pattern of infrastructures in the fields of education, culture, information, transportation, energy and sports, as well as the preferential location of port facilities, urban, industrial, agricultural, handcraft, forest and tourism activities. It contains specific rules pertaining to natural areas and landscapes (e.g. protection). The General Land Use Scheme also identifies key development challenges and general roadmaps for each of the five French Polynesia archipelagos.

Two types of documents with a more local-scale focus are also considered:

(iii) The General Land Use Plans (*Plans Généraux d'Aménagement*) were initiated in the early 1960s by the French Polynesia Deliberation No. 61–44 (8 April 1961), but the first versions have only been adopted in the early 1980s (e.g. approved in 1981 in the municipality of Papara, Tahiti). To date, only a third of the 48 municipalities of French Polynesia has adopted one (Supplementary Material SM1). The General Land Use Plans are context-specific and apply at the municipality level. While the final General Land Use Plans are approved at the Collectivity level, the municipalities are involved in the design of their respective General Land Use Plan, and the local population is consulted. A given General Land Use Plan describes a 3- to10-year development strategy through the identification of specific functions for the different areas within the municipality, i.e. for settlement (residential buildings and public infrastructures), economic activities, or natural areas (e.g. protected areas and cultural sites). General Land

Use Plans can also highlight areas where constructions are not allowed in case natural risks have been identified. For example, the General Land Use Plan of the Fakarava Atoll (Tuamotu Archipelago) adopted by the Ministerial Order no. 1422, the 26th of September 2016, prohibits constructions in the coastal area exposed to strong swells and flooding (Stahl 2018), and requires buildings to be raised by 1.50 m above ground level (JOPF 2016).

(iv) The second set of local documents refers to the Risk Prevention Plans (*Plans de Prévention des Risques*, PPR), which are actually the most prominent documents, once adopted, to address risk prevention and reduction at the local scale. PPRs were transferred from the mainland France regulation into the Planning Code of French Polynesia since the Deliberation No. 2001–10 adopted on February 2001. PPRs aim at characterizing natural hazards at a sub-municipality scale in order to inform land use planning. PPRs identify areas where future constructions or activities are subject to specific rules or are prohibited, and where existing constructions must align with specific measures. Once approved by the French Polynesia Ministry Council, PPRs take precedence over General Land Use Plans to which they are annexed as a public utility easement. Despite their importance for risk prevention, only three PPRs—out of 48 drafted—have been adopted in the Punaauia municipality in Tahiti (JOPF 2010), Rurutu (JOPF 2018) and Rimatara (JOPF 2019) in the Austral Islands archipelago. Our analysis however also considers the PRR documents that have not yet been officially approved but exist as draft documents.

Policy document analysis framework

The documents listed above are accessible for free through Polynesian official websites. Desktop research essentially consisted in manually searching information related to the two climate change policy integration pillars (*Coastal risk integration* P1, and *Adjustability* P2). Given that we do not aim here at analyzing coastal risks and adaptation policies in a comprehensive way —i.e. by including multiple dimensions referring to detailed and cross-scale institutional mechanisms, related legal issues, human resources and financing—, our study considers P1 and P2 proxy outcomes for climate change policy integration more broadly. On this basis and to guide the desktop analysis, a set of variables informing P1 and P2 have been identified (Table 1), with the intention of defining proxies rather than seeking for comprehensiveness. These variables have been identified either through the published literature and/or by the authors' own experience on adaptation policies in small islands and French Overseas Territories in particular.

In this study, *Coastal risk integration* (P1) refers to the extent to which policy documents consider the natural and anthropogenic drivers of climate-related coastal risks, as this is here hypothesized to reflect whether the understanding of current hazards and impacts, including their drivers of change, is a core element or a secondary concern in decision-making and planning (Oppenheimer et al. 2019). The main assessment variable (see Table 1) relates to the level of consideration of coastal erosion and marine flooding, including non-hazard risk drivers relating to exposure and vulnerability. The sub-variables listed in the right column of Table 1 have in particular been inspired by recent works highlighting the need to integrate scientific knowledge of flood risk (Pasquier et al. 2020) and to refer to precise objectives in order to be in position of informing policy processes (Runhaar et al. 2018).

In this study, *Adjustability* (P2) refers to the capacity of the French State- and French Polynesia Collectivity-driven policy documents to consider local specificities (e.g. differences in coastal configurations and dynamics in mountainous and low-lying islands), and refine progressively coastal erosion and marine flooding control targets and strategies either after an extreme event (short-term perspective) or according to new scientific knowledge raised on future climate change-induced risks (anticipation for the longer-term; Nicholls et al. 2021). Some information on cross-institutional dynamics at work is also considered as enabling conditions for *Adusjatbility*. Finally, P2 includes the extent to which the public policy documents consider uncertainty of future changes in hazard patterns (trend, rate, geographical distribution), especially through the consideration of a range of coastal climate risk scenarios (Oppenheimer et al. 2019; Nicholls et al. 2021).

In practice, the desktop analysis consisted of adding a column to Table 1 to map, for each of the policy document considered, the extent to which the assessment variables were met. Two of the authors worked on this mapping, independently from each other, and used a three level framing (estimated low, medium, high match) associated with detailed justification based on their reading of the policy documents and feedbacks from the interviews (see below and Fig. 3 for a synthesis). A virtual discussion—one of the authors having resettled in French Polynesia—took place in Fall 2019 to allow to create a cross check between the two independent assessments, which actually aligned with each other on all the assessment variables.

Semi-structured interviews

Semi-structured interviews were carried out with the main French Polynesian institutions involved in the design and implementation of the above-described policy documents as well as key informants concerned with coastal risk management and/or land use and urban planning, and that were identified based on the authors' local experience and stakeholder network acquired since 2013 under several research projects (see footnote 1). All the informants identified through this process agreed to be interviewed, which allowed us to complete forty-two semi-structured interviews between mid-December 2018 and mid-February 2019. These semi-structured interviews relied on a series of open questions in order to allow interviewees to express personal views—though fed by their professional experience—on current and future coastal risk management and practices.

The open questions relating to *Coastal risk integration* (P1) reflected the assessment criteria in Table 1 and aimed at:

(i) Understanding the level of detail considered in the studied policy documents on coastal erosion and marine flooding. Related questions were as follows: *Are these hazards specifically mentioned? If so, are their major natural and anthropogenic drivers considered? Does the document(s) set clear objectives for erosion and/or flooding risk reduction; that is, are objectives formulated, and possibly quantified and time-bounded?* And *have indicators for monitoring results been established?*

(ii) Asking about the explicit consideration of extreme events generating erosion and flooding (especially tropical cyclones) as well as of sea-level rise projections (global or relative, scenarios considered).

On the *Adjustability* pillar (P2), questions also reflected the assessment criteria in Table 1 and referred to:

(iii) The consideration of uncertainty on local impacts. One central question was as follows: *Regarding marine flooding, does the policy document refer to a single scenario (e.g. low- or high-end) or to a range of scenarios (for example to account for the variability of potential sea-level rises or even flooding limits/areas)?*).

(iv) The potential to readjust existing erosion/flooding risk reduction strategies and include a longer-term perspective. The underlying questions (asked for both erosion and marine flooding) were as follows: *With respect to the short term, does the political/institutional framework allow for readjustment of erosion/flooding control strategies in case an extreme event occurs (e.g.*

Table 1 The framework used in this study to analyse coastal risk-related public policy documents

Pillar	Variable	Criteria	Question asked
P1 Coastal risk integration	V1 Level of consideration and information on coastal erosion and marine flooding (inspired by Pasquier et al. 2020)	*Extreme events* *(inspired by authors' experience)*	They refer to climate variability: (i) How accurate are information on cyclones (e.g. figures for the French Polynesia context? Very general level or some details on main characteristics? (ii) How accurate are information on distant swells?
		Coastal erosion *(inspired by authors' experience)*	Detailed consideration of the complexity of the subject, including: (i) Accuracy of information (extent, rates, main locations, etc.) (ii) Identification of the key drivers of coastal erosion, both environmental (lack of sediments, extreme sea levels, etc.) and anthropogenic (sand mining, poorly designed coastal protections, etc.)
		Erosion risk reduction targets *(inspired by* Runhaar et al. 2018*, and authors' experience)*	Are targets accurate, quantified and time-bounded? And include assessment criteria?
		Marine flooding *(inspired by authors' experience)*	Detailed consideration of the complexity of the subject, including: (i) Accuracy of information (spatial extent, main locations, etc.) (ii) Identification of the key drivers of marine flooding, both environmental (extreme sea levels, island topography, etc.) and anthropogenic (coastal vegetation clearing, coastal developments, etc.)
		Flooding risk reduction targets *(inspired by* Runhaar et al. 2018*, and authors' experience)*	Are targets accurate, quantified and time-bounded? And include assessment criteria?
		Sea-level rise *(inspired by* Oppenheimer et al. 2019 *and authors' experience)*	Does the document refer to sea-level rise? If yes: (i) Does it refer to global mean or local mean projection, or even projections per archipelago? (ii) Does it take into account a single mean or a range?

Table 1 (continued)

Pillar	Variable	Criteria	Question asked
P2 Adjustability	V2 Adjustability of policies contributing to risk reduction and adaptation to manage uncertainty	*Uncertainties on local impacts (inspired by* Oppenheimer et al. 2019; Nicholls et al. 2021*)*	Consideration of a wide range of coastal risk scenarios, e.g. through different ranges of sea level rise and/or different potential limits of marine flooding, and/or others?
		Policy flexibility to manage and/or anticipate coastal erosion risk (inspired by Haasnoot et al. 2021 *and authors' experience)*	Adjustability addressed through questioning the time-frames of management/anticipation: (i) in the short term: does the political/institutional framework allow for readjustment of erosion control strategies in the event of an extreme event (e.g. responding rapidly to an erosion peak), and according to local specificities? (ii) on a longer term: does the political/institutional framework allow the readjustment of erosion control strategies in the light of new knowledge (observed or projected for the future)?
		Policy flexibility to manage and/or anticipate marine flooding risk (inspired by Haasnoot et al. 2021; Nicholls et al. 2021*; and authors' experience)*	Same as above
	V3 Degree of stakeholder engagement in policy development	*Existence of a cross-institutions approach (inspired by* André et al. 2012*)*	That is, a cross-cutting approach involving at least key ministries in charge of coastal risk management-related issues (erosion and flooding in particular)
		Frequency of cross- institutions work (inspired by authors' experience)	Frequency of meetings (annual, semi-annual, quarterly, monthly, other, etc.)
		Quality of cross- institutions work (inspired by Few et al. 2007)	Quality of the cross-institutions work, measured through the degree of precision of the objectives of the meetings for the elaboration and/or implementation of the document: are the erosion/flooding/coastal risks topics specifically addressed?

responding rapidly to an erosion peak/flooding event), and according to local specificities? And *on a longer-term perspective, does the political/institutional framework allow for readjustment of erosion/flooding control strategies in light of new knowledge (e.g. observed or projected se-level extremes)?*

(v) Institutional capacities to have a cross-institution dialogue and ability to drive policy adjustments. This touches on multiple and complex dimensions, so here we only focused on proxy information through the following questions: *Is a cross-cutting approach involving at least key ministries in charge of coastal risk management related issues (erosion and flood risk in particular) in place? What about the frequency of such meetings?* And *are precise objectives settled for these meetings in terms of the elaboration or implementation or revision of the document, including specifically with respect to coastal erosion and marine flooding?*

No formal coding has been applied to the interviews. These latter have however been transcribed (in full), then summarized (main highlights) in order to support the assessment variables mapping exercise mentioned above and synthesized in Fig. 3, as well as more collective discussions at the moment of the writing of the paper. Hereafter, specific information raised in a given interview is referred as 'Act_XX_N' (SM2) where Act refers to a stakeholder interview; XX to the stakeholder's institution; and N to the number of the interview.

Results: coastal risk and climate change policy integration in practice

Figure 3 proposes an overview of the main gaps in climate change policy integration in French Polynesia.

Coastal risk integration (P1)

This section describes the way coastal risks are considered in risk reduction policy documents, and especially the PPRs. As a preamble, it is important to remind that some major

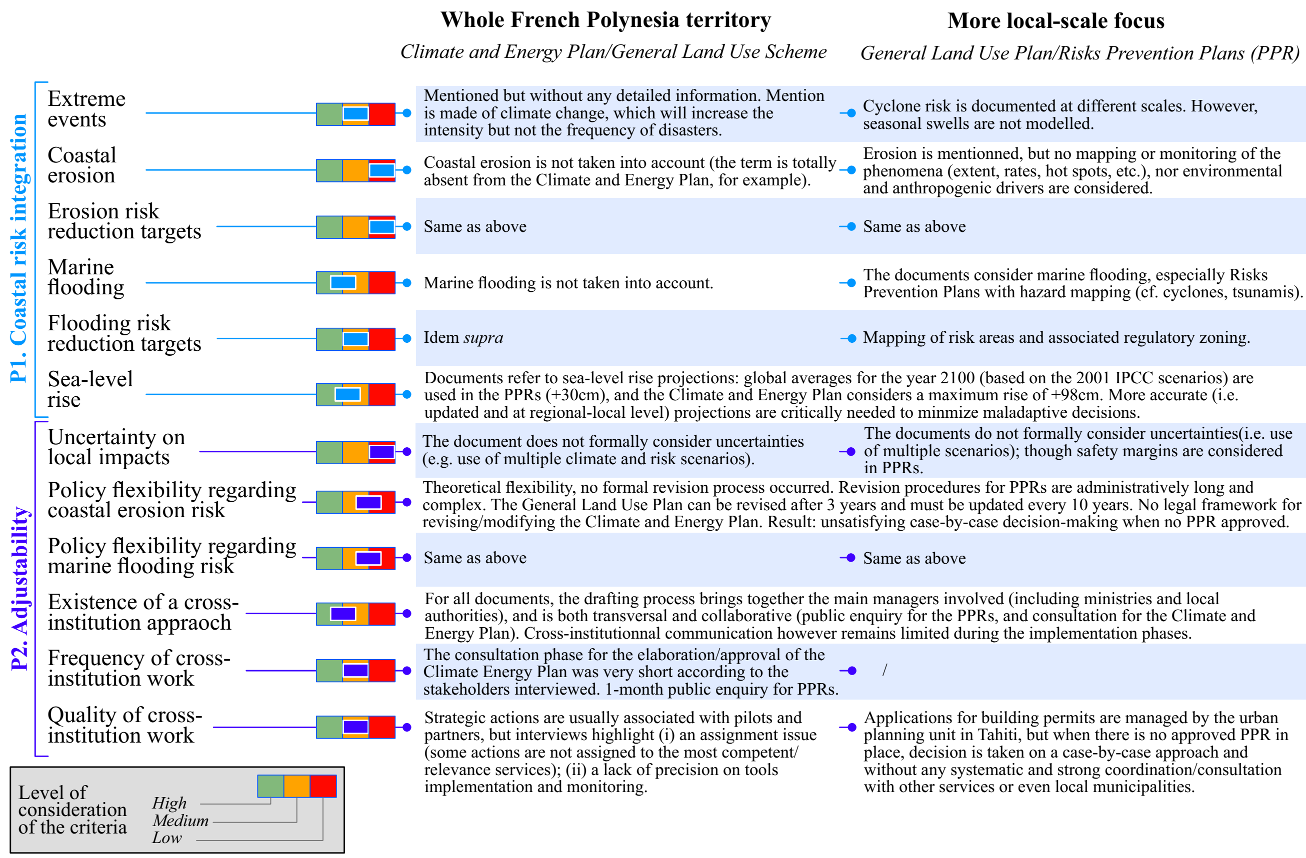

Fig. 3 A synthesis of the results of this study. The blue and purple colors are used only to highlight the conclusions for P1 and P2, respectively

advances in the French context (mainland and overseas territories) have been initiated in French Polynesia in the last few decades. A first one refers to the early adoption of sea-level rise scenarios in French Polynesia PPRs, even earlier than in mainland France, and despite various issues as described below. Second, PPRs have started to be considered in French Polynesia early after the national law instituting the PPRs (Law no. 95–101 of 2 February 1995), and following the cyclone Alan that caused 21 casualties in 1998, including 15 due to landslides (BRGM 2001), and motivated the development of studies ahead of the establishment of the PPRs. These studies have played a decisive role in improving knowledge locally on coastal flood modeling (Lecacheux et al. 2014; Pedreros et al. 2018) and the identification of local assets at risk.

Climate and ocean hazards

Extreme events Extreme events are briefly mentioned in the Climate and Energy Plan, but without any detailed information. The Climate and Energy Plan establishes a link between tropical cyclones and climate change, recognizing that despite 'no indicator foresees a significant increase in cyclones with regard to the current climate models in the Polynesian basin' (PCE 2015, p. 17), changes in cyclonic hazard cannot be excluded. Accordingly, and also referring to the increase in vulnerability and exposure due to urbanization (p. 96), the document suggests a potential exacerbation of coastal risk. Cyclonic risk is usually, but not systematically, better documented in PPRs, e.g. through the characterization of the phenomenon over the last 130 years. In order to identify areas where to ban the development of new buildings or set up specific regulations for existing buildings, PPRs consider several hazards at the same time (especially tsunamis, cyclones and landslides, among others) and focus on the maximum hazard level among all those affecting a given area. In most of the PPRs, tsunamis are considered the most important threat to buildings, and cyclone-driven threats tend to be disregarded also due to the lower height of cyclone waves in local history (PPR Punaauia 2016; PPR Rurutu 2018; PPR Rimatara 2019). The same applies to regular swells not generated by storms or cyclones and that are disregarded as well in PPRs ([Act_SAU_1, Act_SAU_2]). Non-storm-induced swells are also briefly mentioned in the General Land Use Scheme (SAGE 2019, volume 2) as a driver of coastal erosion, together with storms and possibly tsunamis. It should be noted here that despite a study in 2013 updating knowledge and providing further insight into non-storm-induced swells and cyclonic hazards (Lecacheux et al. 2014), no approved PPR uses these results yet.

Sea-level rise PPRs refer back to global mean sea-level rise projection under a high global emission scenario of the IPCC Fourth Assessment Report (AR4), i.e. + 30 cm in 2050 relative to 1980–1999 (Meehl et al. 2007; BRGM 2010, 2013). The Climate and Energy Plan uses another estimate highlighted in the IPCC Fifth Assessment Report (AR5), i.e. the upper bound of the likely range of RCP8.5, i.e. + 98 cm in 2100 relative to 1986–2005 (Church et al. 2013). Some recent technical reports supporting future potential PPR studies use regional projections of Slangen et al. (2012; see BRGM 2013), but have not been integrated into existing PPRs yet.

The fact that French Polynesia tends to consider mean sea-level rise associated with high emission scenarios and that the Climate and Energy Plan uses more recent mean estimates than the PPRs are positive outcomes. Such integration however raises two major concerns. First, the sea-level rise scenarios considered in these documents do not align with the latest results of scientific research, which systematically concludes on higher projections (Garner et al. 2018). In the case of PPRs, that is of major concern for now as the recent sea-level projections from the IPCC SROCC report (Oppenheimer et al. 2019) show that the 30-cm scenario by 2050 still holds as a cautious scenario (Fig. 4). This indicates a lag between scientific knowledge development and its integration into local regulations, which could become problematic in the near future. Indeed, the 50-cm scenario (or 60-cm scenario as in the mainland France PPR regulation) lies within the middle of the likely range of an intermediate emission scenario (called RCP4.5). Even for low emission scenarios, these 50 cm could be exceeded earlier than 2100 because of uncertainties in ice-sheets melting (high-end scenario, dark line in Fig. 4). In addition, sea-level rise is projected to continue rising after 2100 (Oppenheimer et al. 2019), so that any of the sea-level scenarios currently considered for adaptation planning in the twenty-first century will be exceeded sooner or later. As a consequence, if sea-level rise follows high-end projections, the safety margin that could apply to the coming decades may erode quickly over the second half of the twenty-first century. Such a rationale aligns with the selection of the 'uncertainty' and 'anticipation' sub-criteria of our second assessment variable (V2 in Table 1). Issues that would deserve clarifications for sea-level rise consideration in PPRs include (Le Cozannet et al. 2017): (i) the time evolution of the process, to plan adaptation measures over time; (ii) the consideration of subsidence, which is suspected to play a role at least in Tahiti (Martinez-Asensio et al. 2019); and (iii) the consideration of uncertainty, whether in the form of safety margin (high-ends) or most likely values. By comparison, the UK and the Netherlands for instance update their climate scenarios periodically (Lowe et al. 2009; van den Hurk et al. 2014; Lowe et al. 2019).

A second concern is that no regulatory document in French Polynesia specifically builds on more regional or local sea-level rise projections [Act_SAU_3] (sub-criteria 'sea-level rise' in Table 1). This is not specific to French Polynesia and is also observed in mainland France (MEDDTL 2011) where the regulation established in 2011 and prescribing to consider a 60 cm sea-level rise scenario by 2100 in coastal PPRs is based on the global upper likely range of scenario A1F1 used in the IPCC Fourth Assessment Report (Meehl et al. 2007). Re-analyses of sea-level trends over the recent decades however highlight that local situations can substantially deviate from the global mean (e.g. in terms of rates of sea-level rise; Becker et al. 2012), so that not relying on local projections could potentially reveal maladaptive—for example because this could inspire action designed to address regional-level trends but overlooking potentially diverging local context-specificities.

Impacts at the coast

Marine flooding Marine flooding is not explicitly taken into account in the Climate and Energy Plan, but is included in some General Land Use Plans and is definitely foundational to PPRs. These latter include maps describing exposure levels and laying the foundations for related mandatory or recommended measures [Act_SAU_1, Act_SAU_2], taking into account sea-level rise. Noteworthy, while the flood hazard maps are developed by a scientific institution (the *Bureau de Recherches Géologiques et Minières*, State level), the interviews indicate that associated exposure and risk maps are co-established by the *Bureau de Recherches Géologiques et Minières* and the Urban Planning Service (Collectivity level), with municipalities playing a consultative role. The risk maps therefore include some considerations not related to the hazard, e.g. the local policy-sensitivity of assigning residential building areas with high risk levels.

PPRs especially highlight three marine flooding hazard-prone zones, each associated with specific regulations (Fig. 5). While the 'green zone' characterizes a low hazard level, the 'blue zone' corresponds to a medium hazard level. In the blue zone, the majority of constructions and modifications to existing buildings are authorized, provided that the ground floor of residential buildings is at least 1 m above the mean island elevation [Act_SAU_1, Act_SAU_2, Act_ SAU_8]. The third zone refers to a high hazard level and is commonly called the 'un-constructible fringe' or 'red zone' [Act_SAU_1, Act_SAU_2, Act_SAU_4, Act_SAU_6, Act_SAU_7, Act_SDE_1, Act_ SAU_8, Act_COMm_2]. In high islands, starting at the shoreline, the red zone varies

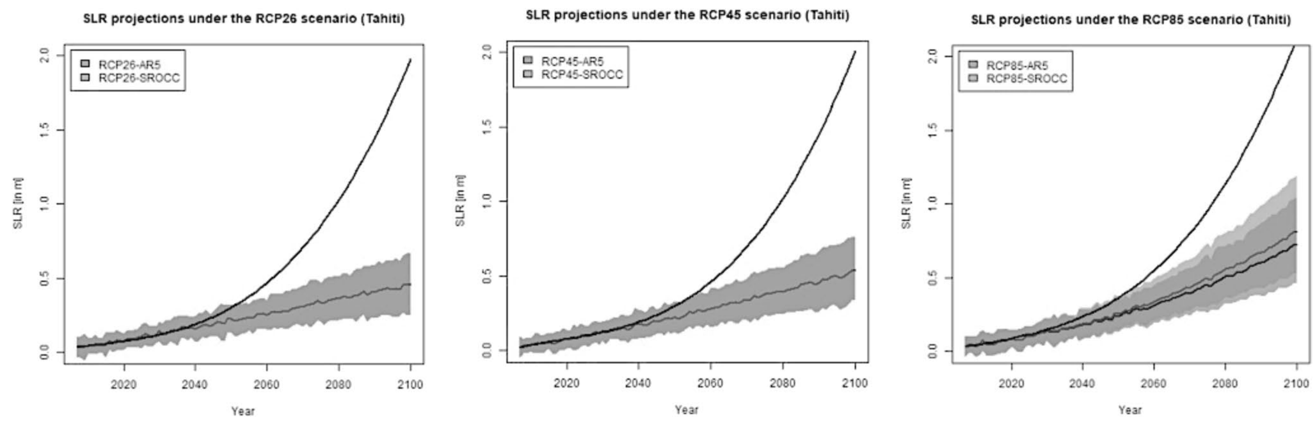

Fig. 4 Sea-level projections from the Church et al. (2013) and Oppenheimer et al. (2019) downscaled to Tahiti for 3 scenarios (RCP2.6, 4.5 and 8.5, roughly corresponding to 2 °C, 2.5 °C, and 3 °C of global warming). The dark lines illustrate a low-probability/high-impact high-end sea-level scenario involving large ice melting. Methods: see Slangen et al. (2012). High-end scenario assumption: See Thiéblemont et al. (2019)

by default from 10 to 20 m in width, depending on whether there is a reef facing the ocean or not. In atoll islands, it basically extends until 30 m and 10 m inland on the ocean and lagoon sides, respectively. In red zones, the majority of constructions are not allowed (e.g. new residential buildings), and the modifications to existing buildings are very constrained so that they do not aggravate existing vulnerabilities, do not create new risks nor significantly increase the number of people exposed. While the reconstruction of buildings destroyed by natural phenomena is prohibited in red zones, repairing damages is allowed but 'subject to reduced vulnerability' (PPR Punaauia 2016, p. 15). Finally, the inhabitants are encouraged to leave individual housings located in red zones over 5 years after the approval of a PPR, 'unless protection and safety works against […] the effects of the sea are carried out, which are general in scope and not specifically aimed at a given building or plot of land' (PPR Punaauia 2016, p. 17). The implementation of those particular works has however never been monitored in Punaauia since the approval of its PPR in 2010 [Act_SAU_1, Act_SAU_2]. What is worthy of note is that, while the approved PPRs of Punaauia, Rurutu, and Rimatara are mandatory, the rules defined in non-approved PPRs—status of 45 out of 48 PPRs in French Polynesia—concerning the blue zone are only recommended [Act_SAU_1, Act_SAU_2, Act_ SAU_8]. Nevertheless, risk areas identified in the PPR drafts and the associated 'un-constructible fringe' are supposed to be taken into account while delivering building authorisations in accordance with jurisprudence (Stahl 2018) [Act_SAU_1, Act_SAU_2].

Another point to be made on marine flooding policy integration refers to the way uncertainty is considered. Although some interviewees state that the studied documents poorly take into account uncertainty in climate-related hazards and impacts [Act_SAU_1, Act_SAU_2, Act_SAU_5, Act_SAU_6, Act_SDE_1], safety margins are actually considered in documents such as the PPRs, in line with conclusions from scientific works (Green and Weatherhead 2014; IPCC 2019; Stephens et al. 2017) acknowledging that uncertainty is critical to decision-making. Safety margins are however used only for computing extreme water levels due to cyclones, and not for sea-level rise. There is therefore no consideration of high-end scenarios in French Polynesia, nor in mainland France. On the policy side, some interviews made it explicit that revising upwards sea-level rise projections would imply expanding the red zone un-constructible fringes [Act_SAU_1], while these latter are already highly unpopular locally especially because they affect public and private development projects [Act_SAU_1, Act_SAU_2, Act_SAU_4, Act_SAU_6, Act_SAU_7, Act_CESC_1, Act_COMm_1, Act_COMm_2] (Stahl 2018; Magnan et al. 2019).

Coastal erosion Despite tropical cyclones and distant-source swells cause extensive erosion along French Polynesian island shorelines (Etienne 2012; Le Cozannet et al. 2013; Duvat et al. 2017; Duvat and Pillet 2017; Salmon et al. 2019) and the fact that French Polynesia stakeholders identify coastal erosion as an important impact of climate change (Terorotua et al. 2020), the studied documents do not systematically touch on coastal erosion. This phenomenon is mentioned in the General Land Use Scheme as a consequence of swells, storms and possibly tsunamis, and is not mentioned in the Climate and Energy Plan [Act_SDE_1]. At the local level, while the General Land Use Plans usually but not systematically integrate

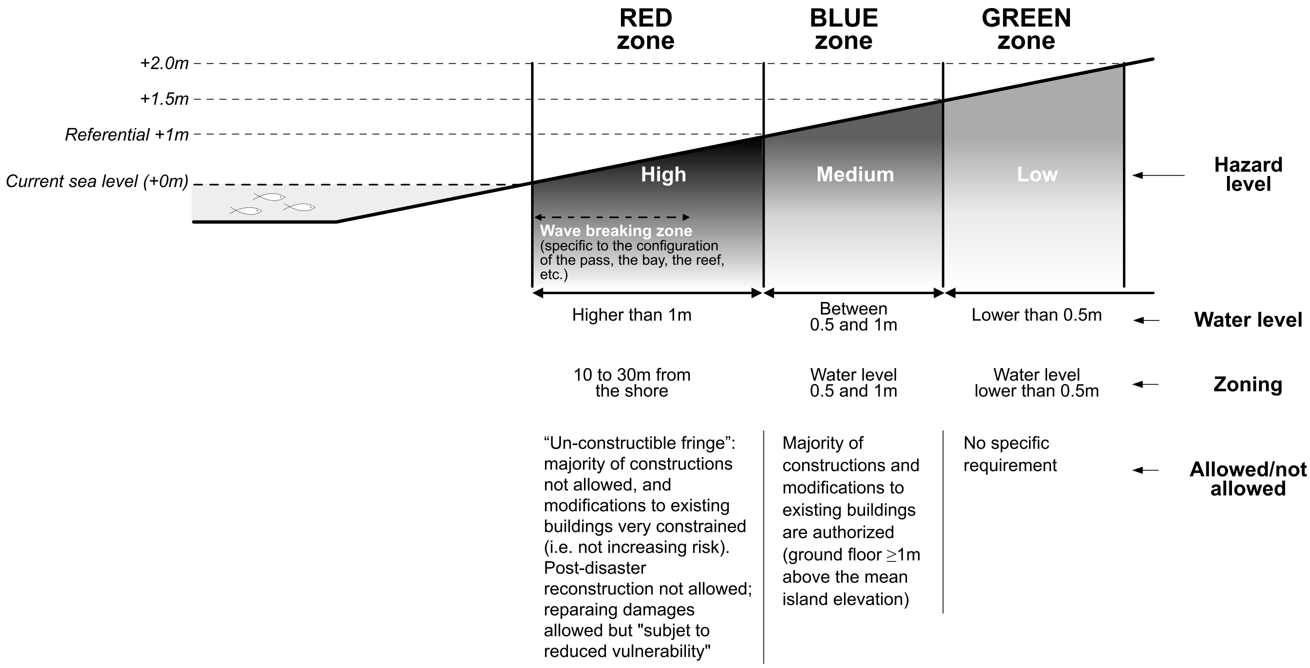

Fig. 5 The marine flooding hazard-prone areas framing used in the Risk Prevention Plans (PPR). Based on underlying reports by the Bureau de Recherches Géologiques et Minières released in 2003 and 2013

coastal erosion, they do not provide any figure or map, neither do they identify affected areas where, for example constructions could be limited or forbidden [Act_SAU_3, Act_SAU_4, Act_PA_1]. Knowledge on coastal erosion risk is neither directly addressed in PPRs [Act_SAU_1, Act_SAU_2, Act_COMm_1].

As a logical consequence, the anthropogenic drivers which worsen natural coastal erosion such as sand mining or human constructions that interfere with natural processes (including reclaimed plots, jetties, quays, and groynes), are mostly overlooked, even if they play a prominent role in explaining past-to-current erosional trends on highly developed French Polynesian islands (Duvat et al. 2017, 2020a; Salmon et al. 2019). While the General Land Use Scheme (Collectivity-level) refers to reclamation works, seawalls and riprap as aggravating factors of coastal erosion caused by swells and cyclones (SAGE 2019, Volume 1, p. 91) as well as marine and river aggregate exploitation (p. 182), nothing is said about these disturbances in PPRs (PPR Punaauia 2016; PPR Rurutu 2018; PPR Rimatara 2019). Anthropogenic drivers therefore rather fall under the regulations that deal with the use of the Public Maritime Domain (owned by the Collectivity) or specific regulations (e.g. sand mining Deliberation No. 68–136 of 12 December 1968), but not specifically in relation to coastal erosion and risks. These drivers are regulated on a case-by-case basis, but regulations are not risk management-oriented (Duvat et al. 2020b).

Adjustability (P2)

The revision of the General Land Use Plans cannot be carried out prior to a 3-year period of enforcement [Act_SAU_3, Act_SAU_4], but the documents must be assessed after a 10-year period to evaluate the need for revision (French Polynesia Planning Code, article LP.113–5). Also, as stated in Article D113-2 of the French Polynesia Planning Code, current and future General Land Use Plans should be made compatible with the General Land Use Scheme 2 years after this latter's adoption, i.e. in 2020. The Climate and Energy Plan is not subject to any legal obligation to be regularly revised [Act_SDE_1]. Such a process remains on a voluntary basis [Act_SDE_1], which especially raises the issue of how urgent climate change is perceived by French Polynesia-level decision-makers, as further discussed below. The case of PPRs deserves some more analysis as it raises various issues constraining the officially stated revision process.

An ambiguous alternative case-by-case approach

In French Polynesia, while the above-described gap in the accuracy of climate and hazard data used to develop regulatory tools appears to be problematic from a scientific perspective (see P1), on the policy side it seems to allow for some room for manœuvre in terms of interpretation and decision, therefore supporting consensus building locally.

Some interviews indicate for example that, where draft PPRs are not officially approved, the Urban Planning Service (Collectivity level) 'can better adapt the PPR zoning, recommendations and prescriptions to the real-world local situation and the specific project' [Act_SAU_1, Act_SAU_2, Act_SDE_1], a point officially restated in May 2019 by the Minister of Housing and Land Use (Anonymous 2019). Said differently, where no approved PPR exists locally, French Polynesia-level authorities decide for permits and authorisations on a risk-informed basis—mostly documented by initial draft maps of PPRs elaborated by the *Bureau de Recherches Géologiques et Minières* and the Urban Planning Service in the 2000s with the contribution of consultants– rather than on regulatory maps and fixed regulation (PPR content) that can only evolve after a long review process (French Polynesia Planning Code, articles D. 182–2 to D. 182–5). Even if such a case-by-case approach could contribute to *Adjustability* as a whole, and therefore to the climate change policy integration challenge, it also raises serious concerns. First, in a context of data gaps on local risks, a lack of effective training on coastal risks of the Urban Planning Service's staff [Act_SDE_1, Act_CCISM_1, Act_SPCPF_1, Act_SAU_1, Act_SAU_2, Act_SAU_3], and a general pressure on land availability, this case-by-case approach carries the risk of granting building permits in highly risk-prone areas, a well-known practice shown in many other cases elsewhere, e.g. in mainland France (Genovese and Przyluski 2013; Chadenas et al. 2014) or the USA (Kates et al. 2006). Such a process is exacerbated by the lack of clear regulations. Yet, building in dangerous areas and the implications in terms of potential losses, damages, and casualties is exactly what the PPRs aim to prevent, hence highlighting the role of enhanced regulatory mainstreaming as framed by Runhaar et al. (2018). Second, the relevance of such an approach to address the longer-term adaptation challenge critically depends on both the availability of local risk assessments and the extent to which such risk assessments consider long-term projections, which remains challenging not only in French Polynesia but worldwide.

A cumbersome risk prevention plan revision process

In theory, PPRs can be revised (normal procedure with a public inquiry) or updated (simplified procedure with a public consultation) at any moment and for multiple reasons. The updating of PPRs includes consideration of modifications related to changes reported on the ground (due to natural or human factors) or in scientific knowledge (French Polynesia Planning Code, article LP.182–7 of the Loi pays; Ah-Scha 2015), but can only intervene at the scale of a plot or group of plots. Concretely, when a new risk or exposed area is identified, or conversely when exposure to a risk is reduced (e.g. as a result of the implementation of protection measures), French Polynesia authorities can revise or update PPRs. The revision procedures are administratively and politically cumbersome, which in practice limits the number of effective modifications. This conclusion aligns with the ones from various studies discussing adaptation barriers and limits, for example in terms of institutional path-dependencies (Barnett et al. 2015; Olazabal et al. 2019; Biesbroek 2021). The revision of a PPR is mandated by order of the Council of Ministers and follows the same procedure as for its establishment: opinion of the PPR Commission, then of the relevant municipal council, then public consultation and approval by the Council of Ministers (Ah-Scha 2015). The updating of a General Land Use Plans follows the same procedure except that the public enquiry is replaced by a public consultation. The purpose of those procedures is to ensure information and participation of the public as well as the consideration of third parties' interests.

In practice, only one revision has been undertaken to date, in Punaauia in 2016, but was cancelled by the Administrative Tribunal in 2017 because it aimed at modifying the hazards zoning in order to enable new projects of buildings but without any new field data concerning a reduction of hazards extent and intensity (TA 2017; Stahl 2018). Yet, according to the Administrative Tribunal, changing the hazard zoning of a PPR can only rely on a new knowledge or an observed change. This judgement was confirmed by the Paris Administrative Court of Appeal (CAA Paris 2019). This is an established case law in the risk field but it goes even further because where authorities are competent in the risk prevention domain, as French Polynesia is, they have to consider the most updated and scientifically established knowledge when delivering building authorizations, even if this knowledge is contradictory to an existing PPR risk delimitation. If they do not so, they can be liable for the damages caused to people or constructions by a hazard that could have been anticipated because they were deemed 'predictable' at the date of issue of the authorization.

According to some interviews, the revision and updating procedures finally appear to be 'too constraining' from a policy perspective [Act_SAU_1, Act_SAU_2, Act_SAU_3] as, together with calling for long public consultation processes, which requires staff mobilization, it is seen to challenge the existing *status quo* among multiple stakeholders.

Accurate risk perception as a background condition for adjustability

Given the role of local consultation in the adoption, implementation, and revision of policy documents such as the PPRs, the way the local authorities and populations perceive these documents (rules and content) as well as current and future risks, can play as an additional barrier to policy adjustability, or a powerful driver depending on the direction of these perceptions (Barnett et al. 2015; Olazabal et al. 2019; Biesbroek 2021). As far as PPRs under preparation are concerned, they meet difficulties to be adopted. As suggested above, if the legal approval of PPRs relies on the Council of Ministers of French Polynesia, a PPR project is not adopted if local stakeholders (municipality level) and populations do not consent [Act_SAU_1, Act_SAU_2]. Yet, it has been shown that the engagement of central governments and local authorities in enhancing climate change policy integration critically depends on the extent to which policy-makers consider climate change a real concern, which is highly variable from one context to another, e.g. estimated low in New Zealand (Archie et al. 2018) and rather high in Kiribati (Mallin 2018). In French Polynesia, recent perception studies indicate that climate change is considered by both State/Collectivity-level decision-makers and island populations as a danger in the long-term (Walker et al. 2014; InSeaPTION 2018; Goeldner-Gianella et al. 2019; Terorotua et al. 2020), making it a distant psychological risk (Spence et al. 2012; Mortreux and Barnett 2017) and therefore most often not a priority area for public and private action. Other critical problems such as pollution reduction, waste management or land use issues (e.g. land tenure conflicts and urban planning) are seen of more immediate concern (Terorotua et al. 2020). As an additional factor, the fact that French Polynesia has experienced 'only' 8 deadly cyclones in the last 133 years contributes to the weakening of climate risk awareness and, through socio-cognitive processes (Cinner and Barnes 2019), to hampering the in-depth revision of policies towards more climate-compatible framing documents.

Climate change is definitely not completely ignored and French Polynesia Collectivity-level decision-makers interviewed on this topic recognize sea-level rise as the most important climate change-related concern (Terorotua et al. 2020). Despite this, however, the general feeling is summarized by a representative of the General Department of Education and Teaching: 'before tackling climate change, we should tackle practical problems [such as waste and pollution]' (Terorotua et al. 2020, p. 8).

Discussion: ways forward to enhance coastal adaptation in French Polynesia

By identifying gaps in climate change policy integration in French Polynesia, this study highlights the need to move beyond current decision-making barriers. In this view, this section advances some clues to improve *Coastal risk integration* (P1; Sect. 4.1) and highlights encouraging signs towards enhanced policy *Adjustability* (P2; Sect. 4.2).

Land scarcity and susceptibility to flooding push for renewing the local and long-term coastal risk reduction strategy

Despite their initiation at the end of the 1990s, the implementation of coastal PPRs is now in a deadlock according to our interviews [Act_SAU_1, Act_SAU_2]. Only three coastal PPRs have been approved so far in French Polynesia and to date there is no plan to further develop new ones. Even in the case of approved PPRs, some attempts to circumvent the rules and build in areas highly exposed to coastal hazards have been reported. Our interviews suggest that one of the main underlying reasons for this deadlocked situation relates to the lack of available physical space for coastal development, either due to the already intense coastal urbanization such as in Tahiti and Moorea (e.g. Aubanel et al. 1999), or to the very nature of the islands (e.g. small and low-lying in atolls). In French Polynesia, land scarcity usually combines with land tenure constraints—i.e. 'undivided land'-related issues rooted in 'complex land tenure system causing numerous and long-lasting conflicts among families and their relatives' (Duvat et al. 2020b, p. 581)—and a lack of supporting financial mechanisms, for example to enable the resettlement of most-at-risk populations (Stahl 2018). This can explain why local inhabitants advocate for freely developing their owned plots, strongly oppose to the coercive nature of the risk-related regulations (e.g. non-constructible coastal fringe), and build houses without any building permits [Act_SAU_1, Act_SAU_2, Act_SAU_3, Act_SAU_4]. Another factor adding to the difficulty to limit coastal development is that, to date, potentially damaging events such as tropical cyclones have occurred at a quite low frequency in French Polynesia. Only few cyclones per decade affected the Society islands, and even fewer in the case of the Tuamotu atoll islands where the last sequence of catastrophic events occurred during the 1982–1983 season, and then in 1998 (in Mataiva Atoll especially). The fact that these events have been rare in local history limits personal experience of risk and therefore tends to lessen the inter- and intra-generational risk awareness (Mortreux and Barnett 2017).

The above actually calls[2] for challenging the way the mainland-dominated coastal risk prevention approach is applied to the local French Polynesia context. While in mainland France the PPRs aim at protecting both lives and buildings, and so at acting on both vulnerability and exposure to risk, the context of atoll islands where cyclones are

[2] The reflection that is developed here is not based on neither the interviews nor the scientific literature, but on our own experience of coastal risk research in atoll island contexts over the last 20 years (in the Seychelles, Maldives, Kiribati, and French Polynesia essentially), including what we have learnt from atoll communities over the years.

still rare and land is very scarce and entirely low-lying, raises a sensitive question: is it possible to save both people and buildings in the face of an extreme event? That is, is targeting a reduction in both vulnerability and exposure (of existing assets) a necessarily relevant or realistic strategy in such constrained territorial contexts? Would an approach differentiating between lives and built assets priorities make more sense in terms of enhancing the enforceability of current risk reduction policy documents such as the PPRs? The rationale behind this is the following: in case of a cyclone, accept damages to individual buildings, while providing the populations with solutions to prioritize saving human lives (e.g. cyclone-proof shelters). This view does not oppose to the imperative of avoiding the increase of people and building exposure in the future, e.g. through regulations limiting the development of new built assets in high risk-prone areas, nor to the imperative of limiting existing exposure as much as possible, e.g. through accommodation options such as inland embankments, drainage systems or subsides for the construction of cyclone-proof houses (DIRMOM 2021). However, one must acknowledge the potential in atoll islands for relatively high residual exposure—i.e. that remains despite adaptation efforts—, and therefore the need to have an open discussion on the trade-offs and benefits of a risk reduction policy prioritizing social vulnerability over existing asset exposure to the hazard. Such a way of approaching risk reduction, despite its potential to raise multiple controversies, could help allocate limited capacities (financial, but not only) as efficiently as possible, for example when a decision needs to be made between expanding a dyke or upgrading a cyclone shelter.

The potential effectiveness of such an approach over time will of course depend on the future trends in the frequency and intensity of tropical cyclones in the region. Duvat et al. (2021) note, first, that in the southern Pacific Ocean, no significant changes in the intensity of tropical cyclones have been observed over the past 39 years. Second, 'in non-equatorial atoll regions, the proportion of high-intensity tropical cyclones is projected to increase whereas the total number of cyclones is expected to remain the same or decrease slightly' (Duvat et al. 2021, p. 9), which aligns with recent conclusions by the IPCC (Ranasinghe et al. 2021). There are however also more immediate basic enabling conditions. First, in addition to the cyclone shelters that have already been built in some Tuamotu islands, an excellent alert system is needed to support accurate local early warning while minimizing false alarm (i.e. when an event reveals not as threatening as initially expected). Besides the data collection and survey issues, effective early warning systems require the local stakeholders to be in capacity to rapidly analyse the risk-related information and decide for raising the alert, which in turn calls for a better training of both technical staff and elective representatives. It also calls for islanders to agree and be able to evacuate in due time, which refers to multiple aspects ranging from transportation systems to social acceptability. Yet, we lack scientifically based information on these latter aspects. Second, some financial compensation mechanisms for the post-event reconstruction phase are needed, especially through significant public investment and given that damages will certainly not be covered by insurances (for which our risk reduction approach will be unprofitable).

The question raised here more broadly touches on the one of defining what is 'acceptable risk', and hence on the local collective perception of what level of risk can be considered tolerable or intolerable. For example, the loss of structures and property may result in cascading effects on mental health and wellbeing, for example making our proposal much more complex than dealing with built assets only, and with potential collateral effects on social vulnerability. 'Intolerable risk' is usually defined in relation with exceeding adaptation limits (Handmer and Nalau 2019), these latter being by nature context-specific. In the atoll islands of French Polynesia especially, the issues of land scarcity and high susceptibility to flooding imply some physically-driven societal adaptation limits. Addressing the 'acceptable risk' issue looks critical in the French Polynesia context in order to be able to then ask about the level of climate change policy integration (*Coastal risk integration + Adjustability*) that should be targeted, and identify more precise targets for the various criteria we used in this study.

Early signs towards some enhanced policy adjustability

Recent real-world examples demonstrate that radical modifications to risk-related policy framings can occur in French Polynesia—although to date they have been time- and space-bounded—, and therefore provide encouraging signs in terms of the potential for local policy to move adjustability forward. One example refers to the relaxation of land tenure-related rules by the French Polynesia Land Tenure Service in Tubuai Island, Austral Islands, in the aftermath of tropical cyclone Oli in 2010. Right after the event, the need for quickly rebuilding destroyed houses either in situ—of course when not located in the 'un-constructible fringe' of the PPR draft—or in a safer family land rapidly exacerbated the above-mentioned 'undivided land'-related issues and land tenure conflicts, especially due to the opposition by non-affected family members. To by-pass this problem, the authorities accelerated the agreement procedures on license to (re)build in less risk-prone areas, in particular through the limitation of family authorization to only five signatures, when 'undivided land' often involve several generations of a same family, meaning in general more than ten owners. Another post-disaster decision referred to the simplification of administrative steps, as done in France in general in the post-catastrophe phase (Moatty 2017).

Such experiences could lay foundations for more long-lasting changes in procedures,[3] e.g. in relation with implementing revised building location regulations according to new sea-level rise projections, and in that way, enhance *Adjustability*. A similar point is made by recent studies on adaptive management (Olazabal et al. 2019) and adjustment processes (IPCC 2019). It is however important to note that flexible policy frameworks allowing for some degree of *Adjustability* do not automatically contribute to risk reduction and climate adaptation. The case of the revision of the PPR of Punaauia (see above) provides an example of a change that, if implemented, would have had increase coastal risk. This illustrates the fact that, as advocated in this paper, while *Adjustability* is a necessary condition for policies and systems to gradually adapt, it needs to be associated with a robust decision-making process to decide whether a given change moves risk reduction policies a step forward or rather introduces a risk of maladaptation. The robustness of such a decision-making process is hard to define because, first, it depends on multiple local conditions (e.g. decision-makers' knowledge and skills on climate changes and the societal context specificities, independency vis-à-vis the local stakeholders, etc.) and, second, it raises institutional and ethical questions (e.g. who decides for whom?) (New et al. 2022).

Conclusion

This paper discusses whether existing policy framing in French Polynesia (i) takes into account current and future coastal risks, especially related to marine flooding and coastal erosion, and (ii) is able to evolve as new knowledge on climate change emerges. Focusing on the analysis of coastal risk-relevant policy documents, our framing includes two pillars as proxies to climate change policy integration more broadly, i.e. the consideration of coastal hazards and associated impacts (i.e. *Coastal risk integration*, Pillar P1), and the potential for the policy documents to be adjusted over time (*Adjustability*, P2). There are still important gaps in terms of climate change policy integration in French Polynesia, mainly relating to difficulties in both implementing the existing relevant policy documents and making these latter more climate-compatible (i.e. adjustable over time). These difficulties are fueled by various underlying factors including, among others, local policy processes (e.g. reluctances to implement State- and Collectivity-level top-down policies); contextual factors such as land tenure issues; and the still weak appropriation by stakeholders and populations of climate adaptation challenges—especially the need to stop considering climate change as a distant psychological risk and, more practically, the need to already deal with changing environmental conditions at the coast (e.g. sea-level changes). Recent examples on the ground however provide encouraging early signs towards more adjustable local policies, though to date they are too time- and/or space-bounded to represent any real shift at the Collectivity level.

Overall, it is hard to blame French Polynesia as climate change policy integration remains difficult in most coastal areas around the world, including other French Overseas Territories and small islands more broadly. Our analysis however highlights promising ways forward, including drawing lessons from the above-mentioned examples of policy adjustment in favor of risk reduction, as well as the rethinking of the underlying strategy of coastal risk reduction in areas that are highly and/or growingly exposed to sea-level changes.

[3] Of note, at the French Polynesia level, progress have been made since 2015 in terms of lowering the level of "undivided land"-related constrains for construction and development. A co-owner of an undivided land can now submit an application for a building permit without the signed agreement of one or more of the other co-owners. He/she should present, in addition to the formal documents inherent to such a request, "an attestation certifying on his honor that he/she has the necessary rights to apply for this building permit" which has to be, in theory, "not fraudulent" (Ewart 2021, p. 25).

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