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Paving the way to coastal adaptation pathways: An interdisciplinary approach based on territorial archetypes

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ABSTRACT

The attractiveness and urbanisation of coastal zones increase their vulnerability to climate change and sea-level rise, in particular to flooding and marine erosion. In the face of the projected increase in losses and damages, the anticipation and measures needed for adaptation involve physical, socioeconomic and political dimensions at different governance levels and timescales. A large literature addresses these various issues, generally in a targeted way. Drawing on adaptive policy pathways approaches and on research results of the past decade in mainland France, this article proposes an interdisciplinary characterisation of long-term adaptation pathways in coastal areas. Among the different variables and processes of change that characterise coastal zones and their future, particular emphasis is placed on social and institutional dynamics. This work contributes to the debate about adaptive governance in a highly uncertain context as well as to recent work to explore pathways and tipping points in support of climate adaptation policies.

1. Introduction

In the face of growing urbanisation and proven submersion and erosion risks, adaptation of coastal areas to climate change is now a major social challenge. According to Rao (2017), by 2100 some 300 American cities may lose at least half of their dwellings affecting some 1.9 million households. More generally, according to Tol and Dvarskas (2018), the loss in global Gross Domestic Product may range from 0.3%–9.3% depending on the scenario, with the building of dykes costing between 12 and 71 billion US dollars. Whilst these estimates remain hypothetical and need refining for the differences between States and areas, it is certain that global damages will increase in a future of rising sea level and sediment shortage.

Work on coastal adaptation to climate change has developed from a variety of disciplines and angles, often interwoven, which prevents the definition of a linear chronology (Birch and Reyes, 2018). Brown et al. (2014) analysed these developments using the IPCC reports published between 1990 and 2014. They note that, whilst attention initially focussed on impacts and "hazard-centred" approaches, the concern is now more specifically on adaptation strategies and drivers of change, with a "systemic" approach taken in the 4th and 5th IPCC reports. At the same time, coastal vulnerability has become better understood (Kelly and Adger, 2000; Meur-Ferec et al., 2008), with the integration of socio-economic issues supported by indicators and the spatialization of vulnerable areas to control urbanisation (Hurlimann et al., 2014; Santoso et al., 2018) and in some cases to develop crisis management plans. The literature review by Füssel and Klein (2006) shows a diversification of factors, in particular to address adaptation capacities at individual, local or national levels. More recent studies have promoted the integration of social aspects such as the reappraisal of social

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compromises, the consequences for inequalities (Ramm et al., 2018), the funding of adaptation measures, and the evolution of exposed property's insurance systems (Storey et al., 2017). Work in environmental psychology has also stressed the influence of place attachment and of risk memory (King et al., 2014) in social changes for adaptive capacities.

In parallel with this set of work, coastal risks management has moved from traditional protection strategies, in particular dykes which have often been preferred in the short and medium terms (Rulleau and Rey-Valette, 2017), towards a variety of approaches and more flexible and integrated management modalities (Bagstad et al., 2007; Lawrence et al., 2018). An example is the so-called "nature-based solutions" for improving the resilience of socio-ecological systems. Managed retreat, which has more recently been suggested as an adaptation approach, has seldom been tried (Biagini et al., 2014). Hino et al. (2017) showed that in practice the attempts that had been made were difficult to anticipate, often tending to follow a storm (Marino, 2018). Particular emphasis is placed on the difficulties encountered in social acceptability and funding (Henderson, 2018; Marino, 2018) and on the legal constraints concerning property rights and compensation (Bagstad et al., 2007; Byrne and Grannis, 2012; Henderson, 2018; Marino, 2018). Even when anticipated and planned, managed retreat can only be considered a few years ahead and commits stakeholders to an in-depth restructuring of the area. It must therefore be addressed via a systemic approach, taking into account other adaptation options and involving processes at various time-scales.

To do this, research on adaptive management has given way to exploratory and anticipatory approaches in highly uncertain situations (Armitage et al., 2008; Plummer, 2009), in particular dynamic pathways' approaches to assist decision-making in adaptation frameworks (Haasnoot et al., 2013, 2019). This article therefore seeks to explore coastal futures in a changing climate by characterising and identifying key variables and processes in long-term adaptation pathways for different types of coastal territories[1] . For this purpose, we developed a "place-based approach" by pooling empirical results of 13 research projects we conducted over the past decade on several coastal areas in mainland France (including an island on the French Atlantic coast), and performed an interdisciplinary analysis, combining a cross-reference of existing results with an expert-based forecasting, to encompass the key variables operating in adaptation pathways. A focus on governance mechanisms together with sociological variables (including individual and collective representations and behaviour) offers a scientific added-value on social and territorial dynamics that will play a key role in adaptation policies and that are generally poorly developed in existing pathways' approaches. We do so by the mean of territorial archetypes both to illustrate the diversity of pathways depending on coastal configurations and vulnerabilities (Haasnoot et al., 2019) and to identify the main obstacles to, and levers for, the conception and implementation of future adaptation policies and practices in coastal zones.

Underpinned by a literature review on dynamic pathways in adaptation policies, the second part of the article discusses the dimensions that must be taken into account to address coastal adaptation pathways. The third part presents the methodology used to construct the archetypes representative of coastal systems at the national level, to select the change variables in coastal dynamics and to develop adaptation pathways for each archetype. In the fourth part, the results are presented with examples of adaptation pathways and key processes function of the archetypes and some hypotheses about the rate of sea-level rise. The fifth and final part discusses how this approach contributes to supporting long-term adaptation policies depending on territorial resources and adaptive capacities.

[1] In this article, we use the term "area" or "zone" (e.g. "coastal areas") in a neutral and generic way. On the contrary, we use the term "territory" (and the adjective territorial), in a social sciences' sense in order to enlighten a systemic approach with social and cultural dimensions and to emphasise the role of stakeholders (e.g. to emphasize the unequal adaptive capacities of "coastal territories").

2. Opening up the "black box" of coastal adaptation pathways

Studies relating to climate change adaptation stress the need for a systemic approach to address the interactions between the values, rules and knowledge affecting the factors that determine adaptation capacities and hence the capacity for change (Urwin and Jordan, 2008; Gorddard et al., 2016). In this context, Termeer et al. (2016) propose an analytical framework emphasising reflexivity, resilience, reactivity and resizing that condition, regardless of scale, what the authors call governance capability, defined as "*governance actors' ability to act wisely when facing wicked problems, and the ability of the governance system to enable such acting*". Hence, management and planning policies must facilitate anticipation, take into account uncertainty, and incorporate more progressiveness (Storbjörk and Hedrén, 2011; Santoso et al., 2018; Lawrence et al., 2018) and creativity in line with an exploratory governance approach (March, 1991). By taking into account uncertainties and in accordance with studies on resilience (Holling, 1978), adaptive management and governance mechanisms can be defined according to natural ecosystem resilience conditions and based on the progressive improvement of information and social learning (Armitage et al., 2008; Plummer, 2009). Adaptive co-management is then proposed as a way to involve users and actors from various organisational levels in social learning in order to evaluate models and adapt or rebuild them depending on how the system evolves.

Building on work on the dynamic, multi-dimensional and systemic characteristics of vulnerability (Blaikie et al., 1994), new methodologies and tools to assist decision-making have been developed to promote anticipatory adaptation approaches. Among this work, an exploratory modelling framework described as Dynamic Adaptive Policy Pathways (DAPP) (Haasnoot et al., 2013) enables various adaptation options to be identified using a dynamic and flexible approach. This requires defining transitional scenarios and evaluating the robustness of these options over time, as a function of the paths followed, the timing and duration of interventions and the associated socio-ecological processes. It involves, in particular, developing adaptation pathway scenarios (Wize et al., 2014) integrating bifurcation trees to anticipate some major changes and tipping points (Haasnoot *et al.,* 2013; Lawrence et al., 2018; Ramm et al., 2018). Adaptation is then a function of climate change rhythm and intensity and of the reactivity of the implemented measures. This type of approach aims to limit path dependency (Lawrence et al., 2018) by identifying (pathways towards) possible or desirable futures despite the high level of uncertainty.

Although intellectually challenging and relevant as they take into account a number of adaptation options, these pathway approaches have limits given the range of factors that must be integrated. They struggle to identify and anticipate the emergence of bifurcation points (Bosomworth et al., 2017) that may result from crossing thresholds or interacting multiple factors. The latter may relate to changing hazard levels with the varying frequency of extreme events, social transformations facilitating the acceptability of some solutions, or new conditions of economic profitability affecting collective preferences and public choices. Hence, Buurman and Babovic (2016) propose an analytical framework integrating *Adaptation Pathways* and *Real Option Analysis* in order to connect the bifurcation points to results of economic evaluations. Similarly, Kwakkel et al. (2016) stress the value of the complementarity between DAPP and Robust-Decision-Making (RDM). In order to combine these approaches, traditional public economics calculation methods must be adapted by integrating sequential analysis.

Furthermore, structural factors that determine the range of "possible futures" for a given territory or system have to be taken into account. Such factors include the morpho-dynamic context and the socio-historical and socio-technical backgrounds as hazard history, urban

planning and risk management strategies. Fincher et al. (2014) for example emphasise the representations and memory of inundations to build scenarios anchored in history. This historical foothold may explain some resistance to change through path dependency such as the existence of acquired rights (Wize et al., 2014) or the role of defensive routines (Argyris, 1995) whilst recognizing that some bifurcations may relate to social change, whether incremental or rapid. Constructing adaptation pathways must therefore integrate the weight of interactions between past, present and future social and ecological vulnerabilities (Duvat et al., 2017), in line with the dependence on the initial conditions of systemic approaches (Bertalanffy, 1968) under which adaptation policies should be implemented.

More generally, it seems that institutional and political dimensions are poorly developed in this type of approach. Hence, Bosomworth et al. (2017) highlight the need to integrate the evolution of goals and values through potentially conflicting dynamics in problem framing and structuring, as well as the role of networks and political alliances. This leads to a discussion, depending on the scale, of the division of the relevant set of variables into endogenous and exogenous ones. It is therefore important to examine the evolution of institutional conditions and governance mechanisms and to assess their impact on maintaining some trends or, on the contrary, on creating transformational change. Along these lines, another limit is the difficulty in anticipating the evolution of values, compromises and trade-offs that will occur as a function of climate change impacts and the level of acceptability of associated risks (Tschakert and Dietrich, 2010; Bosomworth et al., 2017). Addressing climate change along with the societal changes that go hand-in-hand with the evolution of values, institutions and behaviour still remains a scientific challenge in adaptation pathways (Wize et al., 2014; van der Brugge and Roosjen, 2015; Abel et al., 2016). The evaluation of an adaptation pathways approach in Australia by Lin et al. (2017) showed that "'*adaptation pathways was generally framed narrowly and conservatively toemphasizeextant economic, administrative and legal considerations over community, participatory, or exploratory ones.*" Anticipating and developing scenarios for ethical values, social representations and practices requires being able to rely on sociological and anthropological analyses (Brugger and Crimmins, 2013) and paying attention to "weak signals" of change. At the individual level, for example, the role of sense of place (Lewicka, 2011) is under increasing scrutiny as a determining factor in the choice of mobility and adaptation through relocation.

Building territorial archetypes is therefore a relevant way in order to account for the variety of physical dimensions within common coastal adaptation methods (Haasnoot et al., 2019) but also to encompass: the diversity of socioeconomic variables at stake and local situations, the magnitude of socio-historical pathways and the processes that are convergent or perhaps even common to these situations. Furthermore, it may help to address interdependencies and trade-offs between pathways (in the same or between several archetypes), for example between "soft" and "hard" paths (Sovacool, 2011). This methodology, applied to coasts in mainland France, is presented in the section below.

3. Data and methods: building territorial archetypes and dynamic pathways' narratives

This work has been conducted by pooling data and results from a dozen research programs (a list of which is available in Appendix A) undertaken on the three French mainland coastlines and the island of Oléron on the Atlantic coast. These programmes include in particular 10 quantitative surveys of more than 20 000 people undertaken between 2006 and 2017[2] : these surveys were mainly focused on social perceptions and representations about coastal risks and adaptation measures for coastal residents and users. Not all questionnaires had the same questions, but a lot were quite similar and were performed in different coastal areas enabling to assess differences and similarities between different coastal areas and to discuss the conditions under which results could be compared or generalized. For the study, these surveys have made it possible to feed the items on risk perceptions, questions of solidarity for adaptation, or the socio-demographic dynamics that will play a role in the recomposition of coastal territories. A qualitative analysis was also performed on ten mechanisms for adaptation governance and support: they consisted in pilot studies and local experiments for supporting adaptation to sea-level rise in different coastal areas, for example within a call for proposals launched by the French Ministry for Environment to improve the feasibility of coastal planned retreat in a few pilot sites (Rocle and Salles, 2018). This genuinely interdisciplinary approach has thus involved geographers, economists, sociologists who conducted the surveys, but also geologists, oceanographers and political scientists to bring inputs on physical phenomena according the coastal archetypes as well as analyses about social learning and governance mechanisms.

The systematic comparison of data on contrasting field-cases and on each of these themes enabled the identification of recurrent variables playing a structuring role in adaptation drivers and processes. The key variables identified were split among seven components: spatial configuration, territorial economy, socio-demographic characteristics, governance, innovation pathways, psycho-social characteristics and exogenous variables. It is noteworthy that some variables are more constitutive of the main characteristics of a territory at instant t, and condition or constrain the types of risk incurred as well as the possible evolution pathways, especially the "spatial configuration" (type of coast/hazard/urbanization, demographic profile, land reserves) and the "territorial economy" components (financial resources, type of economy, attractiveness). Other variables contribute more to the direction taken by a territory pathway, either individually or cumulatively with other variables: Table 1 below presents the all set of variables grouped in these seven components as well as the different attributes that the variables can take on according to foresight hypotheses. The dynamic aspect is for example illustrated in the sense that public authorities' resources (ET3 variable) affect the adaptation capacities of a territory but may also evolve along the adaptation pathway and trigger a change in the course for the territory (as highlighted in Section 4).

The different coastal configurations were constructed and represented by territorial archetypes, i.e. simplified representations of the main characteristics of existing territories. These archetypes constitute a typology of the various spatial, urban and economic configurations that can be found on French mainland coastal and insular systems. Six territorial archetypes were identified and characterised, as presented in Fig. 1. A factsheet for each archetype can be found on the online Supplementary material, but their main characteristics are summarized below.

To construct the adaptation pathways, a generic framework was framed combining three elements: the configuration and specificities of the archetype, the possible evolution of change variables for each archetype, based on available empirical results and forward-looking assumptions, as well as assumptions about sea-level rise according to two hypotheses: 1) a "slow" progression (a 1 m rise by 2100) against a background of extreme weather events (Oppenheimer et al., 2019), 2) a

[2] Institutional changes have taken place during this period, one important factor being the storm Xynthia in 2010 following which the issue of flooding was increasingly integrated and put on the political agenda. However, these

(*footnote continued*)
developments have made it possible to integrate a dynamic vision of these political and institutional changes, and constitute as many signals to identify prospective hypotheses and evolutionary trends in order to explore a diversity of local adaptation pathways taking into account these policy instruments and governance rules at higher levels.

Table 1
Characterisation of a (generic) coastal system: components, change variables and their attributes.

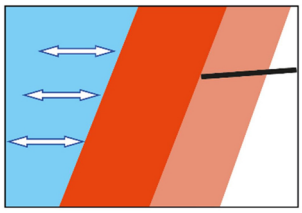
Local spatial configuration	Type of coastline (CL1)	(1) Rocky coast or cliff with slow erosion; (2) rocky coast or cliff with rapid erosion; (3) form of accumulation in dynamic equilibrium; (4) blocked (defence structures and/or dense urban development) form of accumulation; (5) form of accumulation being eroded
	Type of urbanisation (CL2)	(1) Urban sprawl (rural, urban, peri-urban), (2) urban area, (3) proximity to the coast, (4) date of urbanisation, (5) horizontal or vertical (e.g. bungalows or buildings)
	Demographic weight/struc. (CL3)	Individual characteristics of population income, age, family structure, education level, proportion of active people, proportion of property owners…
	Existing land reserves (CL4)	Existence or absence of land reserves for the purpose of managed retreat
	Hazard types (CL5)	(1) Coastal erosion, (2) marine inundation, (3) coastal hinterland flooding
Territorial economy	Local financial resources (ET1)	Local authority investment capacity and/or local indebtment according to the population size, the nature of the tax base (rich or poor) and the financial capacity
	Local economy structure (ET2)	(1) productive (fishing, shellfish culture, marine transport…), (2) tourism-based (in-place economy based on seasonal tourism), (3) residential (permanent residents)
	Attractiveness (ET3)	Degree of attractiveness (+/-) resulting in population flows (permanent or seasonally) and impacting on land and property prices
Demography	Worsening inequalities (SD1)	Multi-dimensional inequalities (socio-economic, risk exposure…) with consequences on migratory flows, risk awareness and social cohesion
	Socio-cultural population profile (SD2)	Changing socio-cultural population profile (related to CL3) related to transformation of urban districts (e.g. gentrification) or the arrival of neo-rural people ; (1) the well-off (2) the working class (3) neo-rurals
Governance	Relationships between central and local authorities (G1)	Nature of organisation and cooperation (+ synergy ; - opposition) between central and local governments, relating to i) the sharing of competencies and responsibilities and ii) the combination/interaction of legal and regulatory tools (*e.g.* within a prevention plan)
	Institutional arrangements/Trust (G2)	Vertical and horizontal relationships and solidarity between local authorities (+/-) related to the existence and the functioning of co-operative and mutualising structures for planning, developing and managing the coastline and the quality of the relationship
	Level of Science-Politics-Society co-operative (G3)	Functioning of the science/politics/society interface: joint development of knowledge (monitoring systems, working groups…), transmission and consultation; citizens involvement in public procedures according to form of social participation
	Institutions' political capacities (G4)	Capacities (+/-) to mobilise resources and move the political project forward (related to knowledge of how institutions work, networks, leadership, communication, project preparation (policy entrepreneurship)
	Social commitment, lobbying (G5)	Mobilisation and lobbying aimed to defence private and public interests (professional lobbying, unplanned participation, active citizen initiatives)
	Pilot sites and experimentation for adaptation (G6)	Creation of ambitious and operational institutional mechanisms to drive regional adaptation and potentially contribute to adaptive governance through policy experiments, policy learning…
	Urban policy (G7)	Ability of local authorities to anticipate pressures (1) Control of property prices by adapting supply (2) Reorganise urban planning (3) Pre-emption policy to anticipate needs for managed retreat (4) Incentives to adapt existing buildings (subsidies, information…)
	Institutional strategy towards coastal risk management (G8)	Implementation by local authorities of coastal risk management tools: (1) Strengthened coastal defences (2) Renaturation of the shoreline (3) Managed retreat (4) Abandon defence structures with no managed retreat policy
Innovation	Technological / major works (TI1) or Urban model (TI2)	Innovation (+) whether technical TI1 (e.g. floating dams, certified fishery, alternative maritime transport), or an urban model TI2 (e.g. houses on stilts, decentralised ecodistricts) according to high quality urban models attract the wealthy ;
	Path dependency (TI3)	*or no innovation (-) if maintains its old strategy whatever the context (dependency on historical choices) TI3*
Psychosocial variables	Sense of place (PS1)	Evolution (Strengthened or weakened +/-) of people's sense of place (combining place attachment, place identity, place dependence and place meaning)
	Adaptation acceptability (PS2)	Residents' acceptance of adaptation policies *vs* opposition to them (gradual acceptability by some social groups)
Exogenous variables	Insurance system and buy-out programs (EX1)	Changes in the "natural disaster" insurance system (+: working in favour of adaptation; -: worsening inequalities) which does not currently take into of risk exposure, does not promotes adaptation and exacerbates inequalities.
	(Supra)National institutions (EX2)	Intervention of a new institution, guideline, rules or regulation outside the area changing the local government action framework
	Natural hazard (EX3)	Nature and frequency of natural hazard: (1) A major storm (2) A series of storms (3) Erosion (4) Rising temperatures

Variables' attributes may be of two kinds depending on whether they convey a strengthening (+) or a weakening (-) of some variables or whether they involve various processes that are then numbered (example for the SD2 variable: (1) the well-off; (2) the working class; (3) neo-rurals).
Note 1: CL1 to CL5 variables have rather been considered as 'structural variables' to construct the coastal archetypes that are presented below.
Note 2: In-place economy (a name suggested by the statistician Christophe Terrier (2006) for "économie présentielle") is a recent French concept designating the economy generated by the population present in an area at a given time.
Note 3: A "form of accumulation" refers to sandy and/or muddy sediments; Hydro-morphological forms such as "estuaries" belong to one of the 5 listed types; A low-lying area behind the shoreline may further define the 5 types listed (e.g. form of accumulation being eroded with low-lying area behind).

"reasonable" hypothesis (see in particular Bamber et al., 2019; DeConto and Pollard, 2016) of "fast" progression (a 1 m rise by 2060) with extreme weather events of greater impact.

This generic framework was applied in a similar way to formalise plausible storylines and develop adaptation pathways for each territorial archetype by combining empirical results from past research programs, analysis of "weak signals" of change, and a sequenced combination of different adaptation options regarding both climate impacts (due to sea-level rise in particular) and socioeconomic and political dimensions (through the different modalities for each type of variables, see Table 1). Presenting the pathways through qualitative narratives, as it is the case for global projections within Shared Socio-economic Pathways (SSP, e.g. O'Neill et al., 2017), makes it possible to go beyond highly-abstract conventional approaches and to ensure a

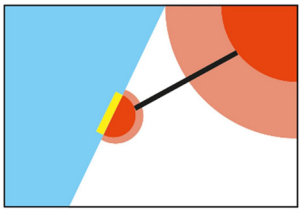
N° 1: Large coastal metropolis (Aix-Marseille, Nice Côte-d'Azur, Toulon)



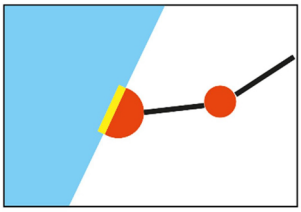
- Heavily-and diversified populated coastal urban centres
- Rocky shoreline with moderate erosion but few land reserves and insufficiency of existing defensive structures
- Attractive metropolis with diversified economy but social and spatial inequalities
- Significant capacity of local administrative bodies (subsidies and support from higher levels of power)

N°2: Peri-urban and tourist resort in the coastal hinterland (Palavas les flots, La Grande Motte, Fouras, Ouistreham)

- Peri-urban areas of moderate size based on in-place economy with local identity linked to the sea and to recreational activities
- Sandy coast exposed to inundation and erosion with few land reserves and regular beach nourishments
- Tensions between population due to spatial and social inequalities
- Little adaptation capacity (low knowledge of risk) and adaptation strategy and fund depending of the hinterland central urban pole



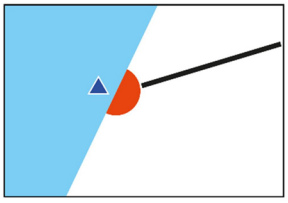
N° 3: Small seaside resort with its town centre in the coastal hinterland (Lacanau-Ocean, Le Crotoy, Vendres)



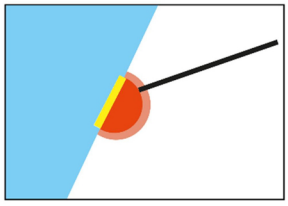
- Small beach resorts in a rural area with a market town in the hinterland
- Coast exposed to erosion and inundation with strong coastal risk recognition, but hard coastal protection structures deteriorated
- In-place economy with moderate property prices and majority second-home owners and some hinterland city workers
- Political and financial capacity depends on the potential association with other neighbouring towns
- Strong place attachment due to the quality of life and marine identity

N°4: Predominantly productive small- or medium-sized town (La Cotinière, Concarneau, Marennes, Roscoff)

- Small sized port towns specialised in sea products, low attractiveness
- Port and part of the residential area exposed to erosion and inundation with strong coastal risk recognition
- Economy relies on traditional fishery, shellfish, or salt production which are already declining
- Ageing population consisting mainly of permanent residents and limited political and financial capacities



N°5: Famous seaside resort (La Baule, Arcachon, Quiberon, Dinard, Deauville, Porto-Vecchio, Saint Tropez)



- Coastal resorts structured around a beach with a high heritage value and architectural quality depending on rich residents (ultra-gentrified seafront)
- Hard coastal defence structure and regular beach nourishment, maintaining the commune reputation and its attractiveness
- Strong political capacity but high local taxes increase
- Low risk perception and strong attachment to the place and lobby to preserve a private social club

N° 6: Insular system (Ile de Ré, îles du Ponant, Corse)

- Low islands with sandy or rocky coastlines and/or small cliffs protected by old and not maintained sea-walls but reluctant to change their defence strategy
- In-place and tourist-based economy leading to an increase of the land prices
- Ageing population little concerned by risk but with strong insular identity
- Great ability (lobbying) to obtain subsidies to preserve these emblematic islands
- High quality of life and strong attachment to the place

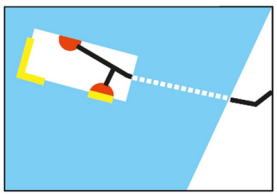


Fig. 1. Description of coastal territorial archetypes.

grounded theory[3] . It is for this reason that the pathways proposed for each archetype were developed from pooled studies undertaken in various French coastal areas, taking into account possible changes in legal, financial and institutional dynamics at the national scale (and to a lesser extent at the European level).

4. Main results

An overview of the coastal adaptation pathways is given in Table 2 below: for space reasons, one pathway per archetype is described in a synthetized manner in the table; it could be a "fast" or "slow" one (depending on the sea-level rise hypothesis) according to the archetype in order to highlight a range of possible coastal futures depending on territorial configuration. A summary presentation of the other adaptation pathways developed in this work is available in Appendix B, while a complete and detailed description of the pathways for each archetype is given online in the Supplementary material.

This summarized version of one adaptation pathway per archetype first helps to highlight that different variables may be mobilized depending on the archetypes and that their number could vary according the different pathways (see below). Furthermore, for a same variable the attributes may differ from one archetype to another. In addition, Appendix C summarises the occurrences of (coded) variables as a function of the archetypes and the risk management strategies implemented according to the two chosen timings for seal-level rises (3 pathways were performed for archetype 3 in order to take into account anticipation capacities for the same hypothesis of "fast" sea-level rise). It provides a comprehensive overview of the variables used to describe the pathways of each archetype.

The first noteworthy result is that some variables occur more often than others, the "slow" pathways involving a slightly greater number of variables. These variables are ET1 (Local authorities' financial resources), ET3 (Attractiveness), G8 (Institutional strategy towards coastal risk management) and EX3 (natural hazard) which are found in over 3/4 of the pathways. Other important, but less frequent, variables are SD2 (New socio-cultural population profile), G1 (Relationships between State and local authorities), and PS1 (Sense of place). The pathways that are developed show that not all variables apply to each archetype: there are 6–12 variables depending on the archetypes and their pathways. Furthermore, some variables may change over the course of the adaptation pathway and their order may matter (G8 and EX3 variables). Apart from 4 pathways, it is worth noting the key role of a natural event resulting in a bifurcation in the pathway and correlatively, the significant role of institutional strategy towards coastal risk management, except for archetypes 1 and 2.

For a given archetype, some variables may work in the opposite direction depending on whether they intervene in slow or fast pathways. This is the case, for example, of public authorities' financial resources (archetype 1, 2 and 6) or attractiveness (archetypes 1, 2, 5 and 6). On the other hand, some variables always operate in the same direction regardless of the pathway: G2 (Institutional arrangements) in archetype 3, ET2 (Preference given to the productive economy over the *in-place* economy) and G5 (Social commitment and lobbying) in archetype 4, ET1 (Evolution of local authorities' financial resources) in archetype 5 and TI1 (Technological innovation) in archetype 6.

5. Discussion: advantages and limits of a place-based approach to address adaptation pathways

5.1. A place-based approach and the dominant role of key variables

If the very nature of the approach is simplifying, it is worth recalling

[3] Grounded theory advocates moving backwards and forwards between the field and data analysis. It sets out a research process for the development of theories, through trial and error and iterations and, in so doing, it highlights the importance of reflexivity (Denzin and Lincoln, 2000; Glaser and Strauss, 1967).

Table 2
Overview of coastal adaptation pathways (one for each territorial archetype: the "fast" ones are on grey background).

Pathway Narrative
N° 1 - Large coastal metropolis: "Intelligent and resilient metropolis"
Where extreme events have a low recurrence rate, the metropolis' public actors make use of their capacity to become part of the wider international effort (G4), participating actively and increasingly in city networks sharing innovative experiments (TI1). This participation promotes awareness among elected officials, who recognise such measures as powerful tools for economic development and funding (ET1). These strengthened political and financial capacities offer the possibility for technical innovations towards resilience (TI1) leading to high-tech engineering projects. The focus is on adapting existing buildings and undertaking large-scale developments (G7) in line with adaptation measures taken by some large cities worldwide, promoting for example vertical urban development (TI2). Their economic importance in a context of global competition enables local authorities to benefit from increasingly good relations with the State or the European Union (G1). Large-scale projects are made possible through public action mechanisms promoting "the right to experiment" (G6). Having become a reference the coastal metropolis attracts highly-qualified people (ET3) including top-level researchers and start-up companies (G3). Place attachment is increasing (PS1); education and awareness strengthen the involvement of residents whereas increasing socio-spatial inequalities (SD2, SD1).
N° 2 - Peri-urban and tourist resort in the coastal hinterland: "Decline and de-skilling due to a lack of local reactivity and solidarity"
Alliances with the central town lead to the managed retreat of the most exposed property but the increasing number of exceptional storms (3 in 12 years) (EX3) has so indebted the commune that it can no longer afford the transition. The price of exposed property has dropped significantly, attracting people with lower income (SD2), whilst prices have raised in non-exposed areas (SD1) benefitting peri-urban residents. The peri-urban area is growing in the hinterland and a low-cost tourism is growing with receipts gradually falling over the years and therefore lower tax income (ET1). Image of the commune (ET3) is affected and then becomes incompatible with the symbolic sense of place (PS1). Better-off people gradually leave (SD2). The general decline in quality of life, infrastructure and services (ET3, TI1) and the departure of the most politically-aware people (G4) are not conducive to ecotourism. The central town welcomes residents who leave the coastal commune but chooses to densify existing districts and to reduce to a minimum any solidarity with the coastal commune (G2). As it controls urban planning, it restricts coastal constructions in order to reduce future damages and costs and choose to invest only in some of communes, leaving the others to decline. Coastal communes (G2) may compete for financial and engineering support (for example from an hypothetical "French Agency for Climate Adaptation" or some new European funds targeting adaptation).
N°3 - Small seaside resort with its town centre set back in the coastal hinterland: "Managed retreat and area reconfiguration"
A new European guideline concerning climate change adaptation implemented by a newly created national agency (EX2) and a succession of storms (EX3) in 2022 are enough for agree on a managed retreat strategy (G8, PS3). The political will and the necessary resources (G4) emerge as part of a partnership strategy with a 2060 deadline. The institutional responsibility for this strategy lies with a newly-created joint association (G6) in close collaboration with a public land institution (G2) and the various urban-sector operators. The necessary legal instruments (G6) have been experimented in other sectors in France and the resort benefits from this experience from technical, economic and legal viewpoints (G3). The area reconfiguration resulting from this strategy is based on the strong attachment (PS1) to the resort, in terms of its identity and its local importance. Tourist activities continue to dominate but have diversified through partnerships with the main neighbouring towns and metropolises. Solidarity within the area (G2) results from significant political involvement at different levels to achieve an area reconfiguration that would respect the diversity and plurality of coastal activities.
N°4 - Predominantly productive small -or medium- sized town: "Renewal of maritime jobs"
The slow progression of climate conditions allows for the technical adjustment of activities and the transformation of maritime jobs. This transformation is eased by political involvement at all levels (G1) and through subsidies prioritizing sustainable maritime activities (ET2). Producer organisations and regional fisheries committees, ports and the chamber of commerce prepare, with the *intercommunality*, a new adaptation program: maritime jobs change; they become multifunctional, heavily-focussed on environmental protection (PS1) as well as on fishery-tourism, Marine Renewable Energy, etc. They also benefit from the development of high quality, high value-added value chains (G5, TI1). The relationship with scientists strengthens (G3): a small marine technology park with an experimentation centre develops (EX2). The maritime productive identity (TI1) is consolidated. Priority is given to the protection of productive

(*continued on next page*)

Table 2 (*continued*)

Pathway Narrative
equipment and the beaches are gradually disappearing. De facto, homes are no longer a priority (ET2) for sea defence investments. Thanks to subsidies, the residential area which has suffered much damage migrates. Thanks to renaturation policies, the coast retains a "wild" and natural character which adds to the cultural identity of the area. Attachment to the place is strong (PS1). Hence, living by the sea is no longer an end in itself (PS2).
N° 5 - Famous seaside resort: "Too much status quo leads to a breaking point"
Following a long phase of status quo supported by very significant financial resources (ET1), the increased storm frequency (EX3) and the new insurance requirements (EX1) due in particular to new European regulations (EX2) gradually lead to changes in viewpoints and strategies (PS2), residents hesitate to repair recurrent damage… particularly as property prices begin to fall (ET3). A major triggering event (EX3) raises awareness of the danger and shows that storm impacts are impossible to control. Significant works, causing much disturbance, are carried out together with managed retreat (G8) that change the landscape and the relationship with the place (PS1), reducing place meaning and heritage attractiveness. The resort image suffers and a proportion of the wealthier population leaves (SD2). The newcomers seek to manage and protect their property as they see fit, using their social capital to obtain exceptions to the rules by intense lobby (G5). The communes gradually lose development control (G4). The relationship with the place becomes more and more utilitarian (place dependence) and symbolic (PS1). The notion of "living together in harmony" breaks down (G3) with growing individualism which calls into question the acceptability of tax contributions by owners, regardless of their income level. The new actors, as rich foreign investors, aim to transform the town into a museum that serves as a billionaires' shop window. However, the latter develop private club strategies that, in the long run, undermine social cohesion and internal political choices, exacerbating social divisions and inequalities with other areas (SD1).
N°6 - Insular System: "Fortress island"
Policies are focussed solely on maintaining defences against marine hazards (G8). The protection of people and property is guaranteed by a significant seawall system on the island. This project is underpinned by enduring social cohesion and insular identity. Quality of life is maintained and property prices remain high with an in-place economy. However, very quickly the strong local political power runs up against national and European guidelines (G1). Indebtedness (ET1) soon becomes unbearable and the limits of the model, based on a defence strategy with solid structures, are quickly reached. Initially, only the better-off can adapt rapidly to these radical changes (TI1); the less well-off have to leave the island (SD1). The result is to strengthen the close-knit nature of the community and its social cohesion. Subsequently, the defence structures increase the erosion process (EX3) in some areas and land is lost as a consequence. Adaptation capacities are limited: there is no room to manoeuvre and vulnerability increases. Faced with these problems, properties are put up for sale, areas are abandoned and wastelands appear. The number of properties put on the market drives prices down (ET3). Owners are more affected than tenants, which increases social inequalities. The population is not renewed as the risk is such that the island is no longer attractive. The tourist and in-place economy eventually collapses with no economic alternative to replace it.

that the archetypes are based on genuinely-existing coastal territories. The approach enables a general overview to be given of various forms of adaptation according to the local context and realities, targeting some key variables relevant to a territory. The diversity of pathways depending on the territorial archetype confirms first of all that it is relevant to put the adaptation strategies into context according to social and territorial constraints and capacities (Adger et al., 2009; Ford et al., 2010; Dupuis and Biesbroek, 2013). The importance of this contextualisation is shown by the weight attached to three variables: territory's attractiveness which is often decisive in socio-economic dynamics, financial resources and funding capacities (Henderson, 2018; Marino, 2018), as well as sense of place which relates to cultural and ethical values attached to a given area (Adger et al., 2009).

The approach also helps to show the unequal and inevitably different adaptation capacities of coastal systems, and moderates the idea that local adaptation capacities are proportional to the degree of urbanisation, i.e. based on the intensity of the density/diversity ratio (of population, functions, resources…), as Sterzel et al. (2020) recently highlighted by providing a typology of coastal urban vulnerability under rapid urbanization. Indeed, even for a High Income Country like France, we see that the "large coastal metropolis" (archetype 1) presents two very contrasted pathway types ("Intelligent and resilient metropolis" versus "Urban collapse") whereas the evolution of the archetype "Predominantly productive small- or medium-sized rural towns" presents two adaptation pathways that avoid the collapse pathway ("Renewal of maritime jobs"/"Renatured coastline"). However, the archetype approach should not encourage a compartmentalized vision of coastal areas. There will necessarily be interactions between archetypes, for example between regional-scale coastal metropolises (archetype 1) and much more local-scale territories such as beach resorts (archetype 5) or predominantly productive ports (archetype 4). Moreover, bifurcations and tipping points may be multifaceted, multiplying pathway changes arising from numerous, and partially interdependent, dynamics. The pathways discussed here present only one bifurcation point; a more detailed analysis might reveal additional pathways and bifurcations.

The greater diversity of variables involved in "slow" pathways attests to the interest of planning over time in order to link factors and build a more sustainable equilibrium. Variables involving a cumulative and co-constructive process such as the appropriation and acceptability of adaptation policies (PS2), pilot projects for adaptation (G6) or establishing Science-Politics-Society co-operative arrangements (G3) are less readily available in fast pathways as they require time and anticipation. All the same, they remain central and particular attention should be paid to them in order to avoid top-down approaches, the only justification for which would be the lack of time for concerted approaches. In this regard, it is noteworthy that the key, or triggering, role of meteorological events in some pathways, whether as a major storm or a series of storms, is often identified as a factor of change in representations (King et al., 2014; Hino et al., 2017; Marino, 2018). Similarly, psycho-social variables convey the importance of sense of place that stems from interactions over time between heritage resources, lifestyle development and the life histories of residents.

5.2. The need for a systemic approach to address variables' interdependency and adaptation processes

The narrative approach to construct adaptation pathway also enables the interactions between a wide variety of factors to be shown, as the variables are linked together within plausible storylines, and improves understanding of the determining processes in governance arrangements. It shows the impact of individual and collective strategies and the significance of multi-stakeholder partnerships, going beyond the generally-mentioned role of purely legal and financial constraints. Multi-stakeholder partnerships are part of multi-level governance, defined as alliances: (i) between territories, (ii) with the State, which has a very significant role in France in coastal planning and risk management, and (iii) with research organisations and/or local associations… These institutional arrangements may facilitate experimentation and pilot schemes, applying a learning approach towards adaptive and contextualised solutions (Biagini et al., 2014; Termeer et al., 2016; Storey et al., 2017; Pinto et al., 2018), as illustrated in the pathway presented for archetype 3, which benefits from managed retreat experiments elsewhere in France before being implemented in this coastal resort. Our approach thus emphasizes the importance of learning devices, notably a stronger collaboration between research labs and policy actors through experiments and pilot projects, but also on the positioning as innovative territory to catalyse (at least for a while) synergies between different stakeholders and to mobilise grants more easily.

The fact that some variables are more frequently used in pathways' development (see the occurrence of the different variables in Appendix C) should not overshadow the diversity of factors and the significance of interdependence between political, institutional, economic, historical, social and psychological variables (Ramm et al., 2018). This confirms the need for a dynamic and multi-dimensional approach. The long-term view entails significant physical and societal changes that

could have been given more weight in some pathways. Here the emphasis was placed on the evolution of some institutional factors (Storey et al., 2017), probably more at short to mid-term, as well as social values and representations. For example, while it is not considered in much of the pathways' approaches, "socio-cultural population profile" appears to be of great importance in most of the adaptation pathways presented here, implying or resulting of social and environmental inequalities and having major influence on social cohesion and place identity as drivers of adaptation strategies. But the system of values and standards that underlies the socio-demographic and political processes is likely to be substantially modified beyond 2050, with for example new and difficult-to-predict transformations in coastal attractiveness and visitor numbers (residents, tourism).

Over and above their dynamic nature, the variables used in these pathways may be analysed considering the conditions for change and for intentionality (Dupuis and Biesbroek, 2013), i.e. the local governments' capacities to intervene, and their relationship with more exogenous variables, in order to anticipate favourable or unfavourable conditions for adaptation (van der Brugge and Roosjen, 2015). As such, one of the France's specificities currently resides in its "national insurance solidarity scheme for natural disasters" ("CAT NAT system") and in the predominant role played by the State in the prevention and management of coastal risks. The French insurance mechanism has "status quo effects" on post-disaster resilience: in a perspective of more frequent or severe coastal risks, this mechanism presents some limits regarding the so-called "build-back better" because it allows through subsidies to reconstruct in the same place and in the same way after a natural hazard. However, this mechanism tends to be challenged not only for financial reasons but also to increase the accountability of relevant local governments and individuals. This trend towards increasing accountability and changing the scale of solidarity requires improved preventive information for both residents and local representatives, and the strengthening of risk management at the local level and of inter-area coordination mechanisms. Transferring responsibilities to local authorities may well increase stakeholders' accountability but it may also worsen inequalities, with the risk of creating dependency as a function of resource types and historical choices.

6. Conclusion

Based on research results from different fields of study, this interdisciplinary approach aimed to examine adaptation pathways to sea-level rise through six archetypes that are representative of the variety of French coastal territories. It offers an alternative to broad-based hazard-centred approaches and shows a variety of possible pathways according to technical, social, historical, economic and political systems. The emphasis placed on the multifactorial nature of variables and key processes of adaptation helps to go beyond the path dependency process (Lawrence e*t al.,* 2018), while recognising the role of historical decisions and past management, by strengthening reflexivity and reactivity (Termeer *and al.,* 2016), collective learning (Lawrence and Haasnoot, 2017), and capacities for change (Urwin and Jordan, 2008; Goddard et al., 2016). This calls for moving beyond an expert-based approach and going further with participative approaches, from which outputs have yet to be translated into real policy tools for transformative and adaptive governance at different scales (Rocle and Salles, 2018).

A dynamic adaptive pathways' approach helps to explore some adaptation processes and to identify strategic variables in the sense that they play a triggering role in their evolution (for example a marine weather event, a change in compensation rules, or political change). As such, the qualitative and narrative approach we adopted puts in light the key role of governance arrangements in adaptive capacities: such capacities depend not only on territorial characteristics (such as physical settings and associated tipping points, Haasnoot et al., 2019) but also on more generic national variables, for example legal instruments (the so-called "Littoral law", property rights…) and insurance mechanisms, that determine the range of pathways at more local scales. This supports the argument of Ford et al. (2010) that "*meta-analyses are needed to integrate and synthesize the findings of place-based studies to identify opportunities for adaptation policy at regional to national levels, complementing the continued importance of local-level studies.*" The combination, or the interdependence, of several variables may thus have cumulative effects and lead to (favourable or unfavourable) feedback loops that are difficult to address, even in this type of approach.

Finally, the significantly less resilient nature of pathways construed in terms of "fast" scenarios of sea-level rise should be stressed. They induce an inability to anticipate structural changes that may lead to breaking or tipping points. This relate to the fact that without ambitious mitigation strategies, most of the adaptation efforts could lead to worst-case scenarios and pathways, be they on physical and economic aspects or on social cohesion and environmental inequalities in the face of climate change. Hence, the climate change clock is a crucial feature in the progress of adaptation pathways, reminding us that urgent mitigation policies are a key condition to conceive equitable and robust adaptation pathways.

CRediT authorship contribution statement

Nicolas Rocle: Conceptualization, Methodology, Visualization, Writing - review & editing. **Hélène Rey-Valette:** Conceptualization, Methodology, Visualization, Writing - review & editing. **François Bertrand:** Conceptualization, Methodology, Writing - original draft. **Nicolas Becu:** Conceptualization, Methodology, Writing - review & editing, Visualization, Project administration. **Nathalie Long:** Conceptualization, Methodology, Visualization, Writing - review & editing. **Cécile Bazart:** Methodology, Writing - original draft. **Didier Vye:** Conceptualization, Methodology, Writing - original draft. **Catherine Meur-Ferec:** Methodology, Writing - original draft. **Elise Beck:** Methodology, Writing - original draft. **Marion Amalric:** Conceptualization, Methodology, Writing - original draft. **Nicole Lautrédou-Audouy:** Methodology, Writing - original draft.

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.

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Appendix A. Listing of the research programs used for the construction of the research work

Project title (Period of time)	Funding	Coordinating laboratory	Research area and results addressed in the research project
ADAPTEAU (2011 – 2015)	National Research Agency	IRSTEA Bordeaux	Participatory foresight and governance of adaptation to variations in hydrological regimes in the estuarine environment of Garonne-Gironde (South Atlantic coast)
ALTERNALIVE (2012 – 2015)	Fondation de France	LIEU Aix-en-Provence	Resistance to relocation, cost-benefit analysis of relocation compared to protection by dikes. Innovative land purchase methods.
COCORISCO (2011 – 2014)	National Research Agency	UMR LETG Brest	Evaluation of the stakes, practices and representations for the definition of coastal risk prevention and management strategies.
INEVI (2012 – 2016)	Fondation de France	UMR LIENSs La Rochelle	Analysis of environmental inequalities in coastal cities
INEGALITTO(2016 – 2020)	Fondation de France	UMR LIENSs La Rochelle	Analysis of environmental inequalities in the management of coastal amenities and coastal risks
LITTOSIM (2015 – 2017)	National Centre for Scientific Research (CNRS)	UMR LIENSs La Rochelle	Barriers to changing prevention strategies at the local level and study of social learning from participatory simulation
MAGIC (2013 – 2017)	Belmont Forum – National Research Agency	IRSTEA Montpellier	Vulnerability transfers in the context of climate change adaptation in coastal areas; specific study of inhabitants' place attachment
MISEEVA (2009 – 2012)	National Research Agency	BRGM Orleans	Perceptions of risks and adaptation measures. Assessment of vulnerabilities and damages of municipalities by 2100
PERMALA (2013 – 2016)	Nouvelle-Aquitaine Region	IRSTEA Bordeaux	Analysis of institutional and political dynamics relating to climate change adaptation on the Aquitaine coast
PSYCOM RELOC (2015 – 2016)	National Centre for Scientific Research (CNRS)	CEE-M Montpellier	Psychological dimensions and the role of emotion in the acceptability of relocation. Impact of different forms of communication on relocation
R^2QUALIEN(2013/2016)	State-Region Contract Plan	UMR LIENSs La Rochelle	Analysis of social practices and representations of the environment of second home owners in the coastal area of Charente-Maritime
REPLI (2013-2014)	Ministry for Environment – Public Interest Group of Aquitaine Coastline	IRSTEA Bordeaux	Analysis of social representations and local knowledge on marine erosion and its stakes in the commune of Lacanau in Gironde
SOLTER (2012 – 2015)	Ministry for Environment	CEE-M Montpellier	Conditions for the implementation and social acceptability of relocation. Study of "solidarity areas" for the financing of adaptation

Appendix B. Complementary adaptation pathways for each coastal archetype (the "fast" ones are presented on grey background)

Pathway Narrative
N° 1 - Large coastal metropolis: "Urban collapse"
Although starting from the same point as in pathway 1, the increased frequency of extreme events (EX2) greatly destabilised the existing economic model. Technological innovation is no longer sufficient (TI1) to ensure adequate resilience. Any re-building is quickly overcome by a new event causing economic reconstruction costs to soar. This vulnerability of the system affects not only the town itself but also its sphere of influence which can be very large (as many metropolitan area services are affected: energy networks/ports/health services etc.). In order to avoid being dragged into the crisis (ET1), hinterland municipalities withdraw from the greater metropolitan area. The governance system based on the solidarity principle falls apart (G2) and area self-interest takes over. Regular infrastructure destruction discourages investors and curbs the arrival of creative classes and other high-tech companies (ET3, SD2). The speculative bubble bursts and the property market crashes which further weakens public finances already plagued by the breakdown of the governance system. The system is then bankrupt (ET1), the smart city (intelligent and creative city) becomes the "shrinking city". Could this collapse be an opportunity for the emergence of an alternative model ("city in decline") promoting restoration to the natural state?
N° 2 - Peri-urban and tourist resort in the coastal hinterland: "A solidarity-based transition led by the peri-urban residents"
The central town pushes for managed retreat as it wishes to preserve the neighbouring recreational sites. A massive storm (EX3) led the *commune* not to rebuild like-with-like in order to benefit from *intercommunality* solidarity (G2), institutional support (EX2) and European funds (G1). This strategy is backed by peri-urban residents who have gained locally in recognition and political responsibility (EX7). A Private Public Partnership (G5) (PPP) enables the creation of a consortium with developers favouring new eco-constructions (Tl2) (wooded area with a view of the lagoon and outskirts of the central town). The coastal *commune* has lost low- and average-income residents but its residential and well-off character has been maintained (SD2) whilst tourism has evolved towards eco-tourism. This restructuring spread over 20 years. Governance is totally dependent on the *intercommunality* (G2). The new image remains residential but the recreational aspect is strengthened by ecotourism. Residents' place attachment (PS1) is stronger and property prices remain high (SD2) which secures property owners' capital and maintains symbolic ties with the place. Taxes remain high (ET1) and even though the *commune* has lost some of its residents and is further indebted, it can deal with the transition.
N°3 - Small seaside resort with its town centre set back in the coastal hinterland: "Stand firm then abandon the seafront under constraint"
The defence strategy is continued (G8, TI3) without anticipating climatic change and without major changes in the local development strategy, but the high cost of protection rapidly increases the local authority's indebtedness to the point of insolvency (ET1). Indeed, with increasing decentralisation, the State has progressively withdrawn (G1) and a change in the "natural disaster system" (CatNat system) (EX1) means that insurance and compensation conditions are increasingly restrictive and unequal. Despite support at Regional and Departmental levels (G2), this withdrawal weighs very heavily on communal and intercommunal budgets. As erosion worsens (EX3) more weaknesses gradually appear in the protection system leading local decision-makers to a laisser-faire attitude as they are constrained by a lack of technical and financial resources (ET1). Local politicians decide to adjust local urban planning and related documents (G7) in return for peri-urbanisation where it is still possible in order to re-house residents who, willingly or not, stay in the commune (because of attachment or dependency). The productive economy develops (forest-wood value chain, new forms of agriculture…) in the rest of the commune and new jobs in services appear around the resort. Efforts are made towards restoring and rehabilitating the seafront (G8), which has lost much of its attractiveness and economic momentum, through recreational activities.
N°4 - Predominantly productive small -or medium- sized town: "Renatured coastline"
The close succession of storms and crises (EX3) hinders the adaptation of the productive economy. Political mobilisation at State and European levels is not swift enough (G1). The productive and maritime identity of the commune is diluted in addition, by the constitution of an *intercommunality* (G1). The damage suffered by protective structures exceeds *intercommunality* resource. Only some of them are maintained occasionally to protect productive activities but seawall defences of the residential areas are abandoned (G8) which causes a clear disaffection and a fall in house prices (ET3). People living by the seaside tend to leave of their own accord, without a clear managed-retreat policy. This situation alters local power relationships with a strengthening of actors engaged in protection of the natural environment (G5) such as the Conservatoire du Littoral, a coastal protection agency. They encourage alternatives (G8) and managed retreat policies, and represent a means to finance such measures. On the other hand, conflicts between endogenous and exogenous actors (G5) cannot be ruled out, one of them militating against adaptation options. In depolderised areas, some recreational activities burgeon. Their renaturation (G8) and cheap property (ET3) are an opportunity for individuals who are attracted by the proximity of the sea and nature. A new generation of "neo-rural" farmers (SD2, ET2), young and aware of environmental issues, prone the use of soft adaptation methods. These new arrivals contribute to keep the average natural net migration rate in balance.
N° 5 - Famous seaside resort: "A dynamic of innovation and gentrification that favours the status quo"

Pathway	Narrative
	Following extreme weather events (EX3), the elected representatives continue to protect the shoreline through solid defence structures and increasing nourishment (G8, TI3) to preserve the resort's beaches, seaside heritage and symbolic capital. The strong attachment to the place (PS1) and the financial and political capacities (ET1, G4) enable the status quo to be maintained. Managed retreat (G8) is restricted due to the unavailability of land reserves (CS4). However, some very prestigious landmarks, located along the seafront, are relocated in order to preserve the reputation of the place. Rebuilding some of the heritage sites like-for-like also contributes to increasing taxes (ET1) which is considered legitimate and is socially accepted. The ultra-gentrification (SD2) favours financial investments in technological innovations (TI1) that support the status quo. Priority is given to maintaining attractiveness and reputation (ET3) (revegetation of threatened areas, hummocks, buildings on stilts and underwater hotels…). These developments, coupled with relatively rare storm events, strengthen the lack of concern about risk and legitimise the political choices (PS2). For a while, these unusual choices make the resort more attractive (ET3) for the rich and for up-market tourism with a growing concentration of wealth.
N°6 - Insular System: "Floating Island"	
	With the support of the State and Europe (G1), local politics strongly aims to preserve these emblematic islands. Residents receive subsidies (ET1) to adapt their homes. Land prices (G7) are controlled to prevent substantial increases. At the same time, a robust policy is implemented by the local authorities to make the island attractive (ET3) and to maintain young people on the spot. Adaptation techniques (TI1) are developed to confront hazards (houses on stilts, taller dwellings…). Only a few very vulnerable areas with significant value are protected by sea walls (G8) whilst others are abandoned to the sea (G8). This strategy contributes to remain people on the island but it leads to some inequalities and unfairness as the less valuable assets are usually the ones that are relocated. Local authorities put the conditions in place to revive entrepreneurship and promote a productive economy (ET2). The increase of newcomers (SD2) goes hand in hand with a reduction in social cohesion (main-homeowners and primary sector workers attached to insular identity and newcomers). The sense of place is undermined (PS1) and well-off people end up leaving the island. Tax incomes and property prices also decline. Gradually, the island returns to an insular productive system, focussing on green tourism.

Appendix C. Listing of the variables used in the adaptation pathways

Components	Variable abbreviation	Archetype 1		Archetype 2		Archetype 3			Archetype 4		Archetype 5		Archetype 6	
		Slow	Fast	Slow	Fast	Slow	Fast (no anticipation)	Fast (with anticipation)	Slow	Fast	Slow	Fast	Slow	Fast
Area economy	ET1	+	–	+	–		–	+			+	+	+	–
	ET2						+		+	+			+	
	ET3	+	–	+	–			+		–	+	–	+	–
Socio-demography	SD1	+			+			+				+		+
	SD2*	1	2	1	2					3	1	2	3	
Governance	G1	+		+			–	–	+	–			+	–
	G2		–	+	–	+	+					–		
	G3	+				+			+					
	G4	+			–	+			+	–	+	–		
	G5			+				+	+	+		+		
	G6	+				+			+					
	G7	4				3	2						1	
	G8*					3	1 then 2	1	1 then 3	4 then 2	1 and 3	3	1 and 2	1
Innovation pathways	TI1	+	–						+		+		+	+
	TI2	+		+	–									
	TI3						+	+	+		+			
Psycho-social variables	PS1	+		+	–	+		+	+		+	–	–	
	PS2					+			+		+			
Exogenous variables	EX1						–				+	+		
	EX2			+		+						+		
	EX3*		2	1	2 and 4	2	3			2	2	2 and 1		3

*Variables' attributes may be of two kinds depending on whether they convey a strengthening (+) or a weakening (-) of some variables, or whether they involve various processes that are then numbered as follow:

SD2: (1) the well-off; (2) the working class; (3) neo-rurals.

G7: (1) Control of property prices by adapting supply (2) Reorganise urban planning (3) Pre-emption policy to anticipate needs for managed retreat (4) Incentives to adapt existing buildings (subsidies, information…).

G8: (1) Strengthened coastal defences (2) Renaturation of the shoreline (3) Managed retreat (4) Abandon defence structures with no managed retreat policy.

EX3: (1) A major storm (2) A series of storms (3) Erosion (4) Rising temperatures.

Note: Reading the table by columns makes it easier to address the number of variables used according to the archetype pathway, whilst the rows show clearly how frequently a variable is used to describe all the pathways.

Appendix D. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.envsci.2020.05.003.

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