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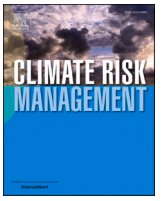

10 years and going strong? Coastal flood risk management in the wake of a major coastal event (the 2010 Xynthia storm, Charente Maritime, France)

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ABSTRACT

2020 marked the 10th anniversary of the Xynthia storm that hit Western Europe at the end of February 2010. In France it triggered an unprecedented coastal flooding event, with most human and material damage concentrated on the Atlantic coast in the Vendée and Charente Maritime region. A range of reforms and measures followed to manage the risk of coastal flooding at the local and national levels.

What conclusions can be drawn from these actions 10 years later? Did Xynthia mark a turning point in the doctrine of coastal flood risk management in France, in a similar way the 1953 storm and associated floods did for the Netherlands?

To answer these questions we carried out a two-step analysis. First we compiled, classified and analysed all the recommendations and other "lessons learned" that were made public following the Xynthia storm. Second we looked into local risk management plans and strategies and conducted a series of semi-structured interviews in Charente Maritime to identify current flood risk mitigation practices. We analysed these in light of the identified recommendations.

These analyses allow us both to take stock of the past ten years and to identify the acceleration effects attributable to storm Xynthia as well as the effects of lock-in and other elements hindering a more in-depth reform of coastal flood risk management in France.

More importantly these analyses allow us to reflect on the process of stocktaking itself, its potential pitfalls and the need for the development of an analytical corpus. Learning to take stock of events that are considered "extraordinary" today is a necessary step to manage climate risks on the coast that are likely to become "ordinary" in the future.

1. Introduction

The 10th anniversary of the Xynthia storm (26 February-1 March 2010) has recently passed. Many in the news and in government reflected on the disaster and the years that followed. France has been hit by coastal flooding events before, including those of 1953 and 1990 in the North of the country, 1982 and 1997 in the South and 1999 and 2008 in the West. Nonetheless, with its amplitude and

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damage caused, Xynthia is often considered as the first major coastal flooding event in the modern history of France and indeed still appears today as the landmark both in research and policy circles (Touili and Vanderlinden, 2017; Rocle et al., 2019; Ministère de la Transition Ecologique et Solidaire, 2020).

The results presented in this paper stemmed from the following question: "Did Xynthia generate a change of course in coastal flood risk mitigation practices, and if yes, how and to what extent?" Beyond the provision of results specific to the post-Xynthia situation, answering this question informs on the challenges of taking stock of extreme events in order to be better prepared for a changing climate.

Extreme events are often framed as turning points in risk management doctrines. Major catastrophes are seen as signposts for changes. Examples abound: the Titanic and the subsequent organisation of the 1914 International Convention for the Safety of Life at Sea (SOLAS) (Calvert, 1930); the Challenger (1986) and Columbia (2003) space shuttles disasters led to reviews of NASA's risk management practices (Guthrie and Shayo, 2005); the 9/11 attack changed the rules of the game for aviation security. Taking stock of past occurrences of rare, unexpected, events has developed into one of the key dimensions of risk governance.

Weather-related risks are no different. The 2003 heatwave and its consequences led to profound changes in heatwave related risk mitigation in France (Fouillet et al., 2008). The 1953 floods charted a course that defines today's landscape and associated risk mitigation strategies in the Netherlands (Correljé and Broekhans, 2015).

In this article we systematically reviewed the coastal flood risk management regime in France as it was before Xynthia (presented in section 2.1). We reviewed the knowledge base on the storm itself and its aftermath (section 2.2). We ascertained how other instances of rare events led to stocktaking and action (section 2.3).

We then identified and analysed (section 3.1) all textual material relating to the Xynthia storm and consequences in terms of "lessons learned" and "recommendations" from public inquiries and the literature. The product of this collection and analysis yielded a first set of results (section 4.1). In parallel we looked into local strategies and plans and conducted semi-structured interviews with coastal flood risk management stakeholders in the county of Charente Maritime, interviews that we analysed thematically (section 3.2). This yielded a second set of results (section 4.2 and 4.3). We discuss these results in light of other instances of major catastrophes which led to changes in flood risk management doctrines (section 5).

2. The Xynthia storm and its context

2.1. Coastal risk management in France before the Xynthia storm

In the early 2000s flood risk management in France was the product of an interplay between victim indemnification through compulsory insurance (and a state-guaranteed reinsurance scheme) and exposure reduction through land use planning, introduced by the 1995 Law Relating to the Strengthening of the Protection of the Environment (Barraqué, 2000; Carré, 2006; Deboudt, 2010; Ministère de l'Environnement, de l'Energie et de la Mer, 2016). Such a focus had become necessary, in the mid to late 1980s, as the failure of infrastructure at preventing major catastrophes did put the French State in an awkward position more than once (Gilbert and Gouy, 1998; Barraqué and Gressent, 2004). Yet the, new at the time, non-structural measures *de facto* added a layer on the existing structural measures creating a maze of risk mitigation measures, not all being implemented to their full extent. The shift to land use centred policies based on risk assessment and mapping did involve quite a steep learning curve (Bayet, 2000). In 2010, roughly 15 years after becoming compulsory, risk prevention plans were only approved in 37 % of the municipalities identified as at risk (Hissel et al., 2015).

Furthermore, in the mid-2000s, calls were heard to further shift coastal risk management to the governance end of risk mitigation options (Erdlenbruch et al., 2009; Deboudt, 2010). Collective action took centre stage and the inclusion of local and regional stakeholders became central. This added a new layer of complexity and represented a cultural shift for local authorities. Amongst other features, basin-wide integrated approaches were promoted and funded. These allowed, at great expense, for the sharing of risks across territories and scales (Erdlenbruch et al., 2009). This shift towards integration was itself accompanied by the development of local emergency planning (Lumbroso et al., 2011) and analyses of local risk perceptions (Anselme et al., 2008).

When the Xynthia storm hit the French Atlantic coast, coastal risk management in France thus consisted of layers of approaches, none fully implemented. It certainly did not qualify as a coherent and integrated system - flood risk management was, at the time, in the midstream and this for more than one dimension, at more than one scale. Reviews in other European countries show not a too dissimilar situation in terms of level of integration of different flood risk management strategies, and point to possible improvements for those with the most integrated approaches (Hegger et al., 2016).

2.2. Anatomy of the Xynthia storm

Xynthia was not an exceptional storm: winds were stronger during the storms of December 1999. Yet through a combination of factors, 47 people died in France as its result; 29 of these victims were in the municipality of La Faute-sur-Mer in Vendée and the other 12 spread across six municipalities of Charente-Maritime. Major property damage occurred in several other surrounding municipalities. The total cost of the storm was estimated at 1.5 billion Euros (Léonard, 2010).

2.2.1. Xynthia, the conjunction of a meteorological event and a spring tide

Storm Xynthia crossed France between 00:00 and 17:00 on Sunday, February 28, 2010. It followed a bow shaped trajectory; making landfall in Charente-Maritime. Its strength was considered as quite ordinary for a winter depression. It moved rather slowly (Anziani,

2010). Its exceptional character is rather due to the concomitance of a high level of the wave set-up, the relatively high astronomic tide coefficient and a very low pressure (Anziani, 2010; Leonard, 2010; Genovese and Przyluski, 2012). This led to paroxysmal conditions: well above water level within a 100-year return period (Pineau-Guillou et al., 2012).

2.2.2. *Xynthia, the conjunction of increased human presence and a poorly managed protection system*

In the mid to late 2000s France in general, and Charente Maritime in particular, was well into a major demographic transition on its coastline. The population of French coastal territories (coastal municipalities and hinterland) had increased considerably (+26 % between 1986 and 2006, population density 45 % above the national average) (Deboudt, 2010).

This rise in exposure was accompanied by real estate development in historically marginal areas, some of these being flood prone. The 1986 Law "Loi Littoral" was introduced to prohibit any new construction and installation less than 100 m from the shore outside urbanised areas, however stocktakes showed that the law could only slow down urbanisation on the coastline but not stop it completely (Délégation interministérielle à l'Aménagement et à la Compétitivité des Territoires, 2007; Ministère de l'Ecologie, du Développement Durable et de l'Energie, 2014). The law was also weakened by delays in implementation and exclusion of some estuaries and areas already urbanised (Prieur and Leost, 2015). In high impact municipalities such as those in Charente-Maritime or in Vendée, authorities were actively opposing land-use regulation that would limit constructability (see Chauveau et al., 2011 for Vendée). Most of the affected territories lay either in or close to areas reclaimed from the sea. These were historically protected by dikes, levees, breakwaters, some of these structures dating back to the 18th century, while others were built in the mid to late 20th century. These structures were neither intended nor designed to protect urban areas; they were originally designed to protect agricultural land. (Kolen et al., 2013; Vinet et al., 2012; Genovese and Przyluski, 2013)

These characteristics, combined with the nature of the Xynthia storm and its timing tide wise, led to loss of lives and major damage.

2.3. *On disasters as turning points*

The analysis of past events to either prevent their future occurrence or to reduce their impact is a vibrant field of risk studies. Historical analyses are now identified as central instruments to better assess potential impacts of future storms. As Cœur and Lang (2008) quite clearly demonstrate: "The knowledge of past catastrophic events can improve flood risk mitigation policy" (p. 1) both as a source of data on floods and as a source of information on human behaviour whenever floods occur.

The major policy shift from the lessons learned following the 1953 floods in the Netherlands are now well documented, including the setting of very high safety standards for flood defence in the 1960s (Kolen et al., 2013; Gerritsen, 2005). In the United Kingdom, the major legacies of what is known as the 1953 "Big Flood" are a coastal flood forecasting system, a more scientific approach to sea defences and the building of the Thames barrier (Baxter, 2005). In the analysis of a more recent flood in the UK, that of the Somerset Levels and Moors (2013–14), Smith et al. (2017) show how the policy response did put dredging back in favour as a flood management option.

High-impact and rare flood events thus act as a pointer of risk situations that need to be addressed. As such they may, as in the Netherlands and UK cases, contribute to recharting the course of coastal flood risk management.

Stocktaking is part of the policy-making culture in France. As Vinet (2007) writes at the time:

> "Stocktaking is a method of ex-post evaluation that is most used in France. It is almost systematic after floods, […] However, it should be noted that these stocktaking show shortcomings in terms of medium and long-term monitoring of the post-crisis and reconstruction phases.[1]" (p.201)

Indeed, evaluating on the longer-term policies that aim to mitigate risks and subsequent disasters to occur tends to lack in practice, the focus being instead on measuring by the implementers whether a project or a policy has implemented what was initially intended, through the devising of indicators, as opposed to monitoring the effective results (Marteau and Vermeersch, 2020). A parallel with the challenges of evaluating climate adaptation policies can be drawn here. Few studies (Owen, 2020) have attempted to assess outcome measures and what makes good adaptation. This is despite an increasing number of indicators, resilience scorecards or normative principles being proposed (Berrang-Ford et al, 2021).

Furthermore, drawing lessons from these events may open a window on what the future has in store under a changing climate. Indeed, the IPCC Special Report on the Ocean and the Cryosphere stresses the significance of sea-level rise and the increase in frequency of extreme events (Oppenheimer et al., 2019; Collins et al., 2019). In the Xynthia case, even if the storm has not been attributable to climate change, one could argue that it holds some of the key to future extreme events. As Galliot (2012) and Jouzel (2012) point out, Xynthia prefigures what could happen at the end of the century, with events considered extreme and rare today becoming more common and frequent tomorrow.

Taking stock of the Xynthia storm is thus not about preventing the past from repeating itself. It is about avoiding a more sinister course for the future while also building a coastline that can fully grasp socio-economic, environmental and climate challenges and

[1] Our translation from : « Le retour d'expérience est un mode d'évaluation ex post de plus en plus pratiqué en France. Il est quasi systématique après des inondations, diligenté par le ministère en charge de la prévention des risques. Ces retours d'expérience, pluridisciplinaires et multi-sectoriels, sont menés par des inspecteurs des différents ministères ou corps de l'Etat. Ils sont également pratiqués en interne par d'autres ministères (Intérieur, Défense) ou des acteurs de la gestion de crise et de la prévention dans leur secteur de compétence. Cependant, il faut constater que les retours d'expérience présentent des insuffisances dans le suivi à moyen et long terme des phases de postcrise et de reconstruction. »

opportunities, thus contributing to effective climate adaptation of the coastline.

Yet an event is not necessarily enough to align policy-making, public values and politics in a way that allows for changes in a risk management doctrine. Making sense of the situation after Xynthia is precisely the purpose of this paper.

3. Methods

This research applied in-depth qualitative methods to understand how coastal flood management in France has evolved over time and the extent to which Storm Xynthia has had an impact. The county of Charente Maritime is used here as a case study. Together with Vendée, Charente Maritime was the area of the country most impacted by Xynthia and it is one of the most exposed counties to coastal flooding (Ministère de l'Ecologie, du Développement Durable et de L'Energie, 2012). It received considerable attention following the disaster and is today a major recipient of the State Fund on Risk Prevention, used in particular to finance protection works and acquire at-risk properties (Ministère de la Transition Ecologique et Solidaire, 2020). It is also a very dynamic county from a socio-economic and touristic point of view (INSEE, 2016). While significant at the national level for coastal flooding, it also illustrates how risk mitigation measures are implemented at the local level.

3.1. Understanding the disaster and learning lessons

The first part focused on a systematic, iterative and thematic analysis of the special inquiry reports from the French Parliament, Government and Cour des Comptes, as well as the Xynthia-related literature published in the immediate aftermath of the storm or in the subsequent years. The aim was twofold: extract from these secondary sources and synthesise what was identified as factors to the disaster; extract the main recommendations to address these factors and thus reform how coastal flood risks are managed in the country.

The analysis relied on themes emerging from the special inquiry reports (see column 1 of Table 3). These themes were then used to code the literature and the reports. A second coding iteration was conducted in order to distinguish within a theme what would qualify

Table 1
List of strategies and plans analysed in detail.

Category	Document title	Salient content
Programmes of action on flood prevention ("Programme d'Action de Prévention des Inondations" - PAPI)	PAPI La Rochelle (2013), Oléron Island (2017 extension), Charente Estuary (2016 extension), Gironde Estuary (2015), Seudre (2017)	Actions, and methods to define actions, in the fields of: protection, prevention, forecasting, warning, crisis management, risk culture and vulnerabilities; involvement of populations; coherence and integration
	2011 national guidelines ("Programmes d'action de prévention des inondations (PAPI), de la stratégie aux programmes d'action - cahier des charges")	Guidelines for the involvement of populations; methods to be used to define measures; how people's vulnerability is taken into account; balance between components
	2017 national guidelines ("Cahiers des charges Papi 3″)	Differences between the 2011 and the 2017 guidelines
Fast Submersion Plan ("Plan Submersions Rapides" - PSR)	2011 PSR	Actions in the fields of: protection, urbanisation, forecasting, early warning, crisis management and risk culture
	2014 mid-term evaluation ("Evaluation a mi-parcours du Plan Submersions Rapides")	What has been achieved and what is left to be done
	2017 Assessment ("Bilan du Plan Submersions Rapides 2011-2016″)	What has been achieved and what is left to be done
Coastal Risk Prevention Plans ("Plan de Prévention des Risques Littoraux" - PPRL)	PPRL Aytré (2014 anticipated version), Châtelaillon-Plage (2019), Yves (2019)	Dictates and levels of restriction according to the zones; adequacy with flooded areas.
	2014 national guidelines ("Guide méthodologique: Plan de prévention des risques littoraux")	Guidelines for the involvement of the population; hazard and zoning maps
Territorial Coherence Scheme ("Schéma de Cohérence Territoriale" - SCoT)	SCoT La Rochelle (2011), Rochefort (2007), Marennes Oléron (2005 + ongoing revision documents), Ré Island (2012 - cancelled)	How coastal risks are taken into account
Intermunicipal Urban Plan ("Plan Local d'Urbanisme Intercommunal" - PLUi)	PLUi Ré Island (2019), La Rochelle (2019)	How coastal risks are taken into account
Local Strategies on Flood Risk Management ("Stratégie Locale de Gestion du Risque Inondation" - SLGRI)	SLGRI Ré Island (2018), La Rochelle (2018), Littoral Charentais-Maritime (covering Charente Estuary, Gironde Estuary, Seudre and Oléron Island) (2017)	Differences with the PAPIs; involvement of populations
Crisis Management Plan ("Plan Communal de Sauvegarde" - PCS)	National guidelines ("Plan Communal de Sauvegarde - Guide pratique d'élaboration")	How people's vulnerability is addressed
Regional Scheme for land management, sustainable development and territories equality ("Schéma Régional d'Aménagement, de Développement Durable et d'Egalité des Territoires" - SRADDET)	SRADDET for Nouvelle-Aquitaine region (2019)	How coastal risks are taken into account

as "observation" (i.e. non normative statements) and what would qualify as "signposts" or recommendations (i.e. normative statements identified by verbs such as "must", "should" and "need"). These results are presented in section 4.1 (Table 3).

3.2. 10 years on, achievements and Xynthia legacy

The second part focused on the post-Xynthia years up until today to understand what actions have been taken in Charente Maritime to manage the risk of coastal flooding and what influence Xynthia has had. We first proceeded with the systematic analysis of risk management plans and strategies at the local level. We analysed documents that are directly addressing coastal flooding as well as those focused on land management and sustainable development as they also affect how the risk of coastal flooding is managed and they provide possible responses (see Table 1).

Other important policy documents and laws at the national level had a significant impact on risk management at the local level, including the MAPTAM law (*Loi n° 2014–58 du 27 janvier 2014 de modernisation de l'action publique territoriale et d'affirmation des métropoles*) which reorganises responsibilities for flood management at the local level (GEMAPI) and the Law Relating to the Strengthening of the Protection of the Environment (*Loi n° 95–101 du 2 février 1995 relative au renforcement de la protection de l'environnement*) setting up in particular the Risk Prevention Plans and the Barnier Funds financing prevention and protection measures against natural risks. References are made to these in the analysis.

A series of 15 semi-structured interviews with individuals in relevant local and national authorities and public bodies (see Table 2) complemented the document analysis by providing additional information on the measures effectively in place to manage risks and insights into current challenges, priorities and beliefs. The choice was made to target state level entities and territorial/local level ones as well as other public bodies involved in flood and land management. The respondents' sector of expertise varied and included protection, town planning, land management and coastal land management or it was cross-cutting. A snowball sampling procedure was used to determine the persons to interview until saturation was reached. Regarding the local authorities, different location set-ups were represented: towns (La Rochelle and suburb Aytré), islands (Ré and Oléron), touristic locations (Châtelaillon-Plage) and rural places (Yves).

Interviews were held either in person (n = 11) or over the telephone (n = 4) between July 2019 and June 2020. They were audio recorded (n = 13) and transcribed or captured through handwritten notes (n = 2). Interviewees were asked about their perception of the risks and issues at stake, the actions undertaken to manage coastal flooding, their assessment of progress since Xynthia on flood risk management, challenges they face, their current and future priorities, finally their perception of climate change and climate impacts on the coast.

4. Results

4.1. Stocktaking and associated signposting for the future

In the aftermath of the event, four special inquiries – one from each chamber of the French Parliament, one cross-ministries and one from the supreme body in charge of auditing the use of public funds in France – were launched to analyse the causes and consequences of the disaster and to suggest recommendations to manage the risk of coastal flooding going forward. In parallel, the international research community examined in detail what happened, adding to the overall investigation effort. Ten recurrent themes emerged from this. Table 3 first presents for each of these themes a synthesis of what was observed as a factor leading to the disaster and second the recommendations made for better flood management practices.

Table 3 points towards several overarching results. First, the pre-Xynthia storm diagnostics, synthesised in section 2.1, were correct and heavy with consequences. Flood risk management at the time was particularly deficient. Hard structures were in disrepair while alternative, more governance based approaches, were far from being implemented, or even, in some cases, accepted by those

Table 2
List of interview respondents by type of organisation and sector of expertise.

Organisation	Type
Conseil Départemental de Charente Maritime	Local authority (County)
Communauté d'Agglomération de La Rochelle	Local authority (Intermunicipal)
Communauté de Communes de l'Ile de Ré	
Communauté de Communes de l'Ile d'Oléron	
Aytré	Local authority (Municipality)
Aytré	
Châtelaillon-Plage	
Yves	
Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement	Service-orientated public body
Pays Marennes Oléron	
Établissement Public Territorial de Bassin Charente	
Conservatoire du Littoral	
GIP Littoral	
Direction Départementale des Territoires et de la Mer de Charente Maritime	National authority
Ministère de la Transition Ecologique et Solidaire	

responsible for their implementation. Second, these results indicate that observations and recommendations were not so much centred on integrated risk approaches. Each and every structural and non-structural dimension is scrutinised; yet the dynamic interaction between the various approaches and how they can form a coherent whole is not so much discussed. This points to a possible shortcoming: depending on where one's (non-flood-related) interests lie, one will shop for solutions that do not threaten these interests (protecting urban development, investing in engineering solutions, favouring top-down approaches etc). Finally while all policy-centred reports did involve exhaustive consultations and auditions of the scientific community, the focus of these two fields is not quite the same, the latter emphasising further the need to adopt a response that takes into account social differences in vulnerability and that is based on wider collaboration and consultation.

4.2. How the regulatory framework has evolved since Xynthia

Some of the results presented in section 4.1 call for policy reform, others for better policy implementation. In the 10 years after Xynthia, the following legal reforms have been observed.

The European "Flood Directive" of October 2007 (Directive 2007/60/EC on the assessment and management of flood risks) has been incorporated into French law with the law on national commitment to the environment (*Loi n° 2010–788 du 12 juillet 2010 portant engagement national pour l' environnement - loi ENE*) of July 2010 and the decree of March 2, 2011 (*Décret n° 2011–227 du 2 mars 2011 relatif à l'évaluation et à la gestion des risques d'inondation*). This generated a whole new regulatory framework involving an assessment of risks per hydrographic district, leading to flood maps and flood management strategies at the national, district and local levels. In parallel, through a series of decrees, circulars, new guidelines and laws, existing plans and strategies were revised, in particular to include the risk of coastal flooding and to factor in climate change, and their implementation accelerated.

Our analysis of these evolutions shows that there has been a major effort over the last 10 years to make progress on all three layers of France's approach to managing flooding risks, as summarised in section 2.1. Results also show that Xynthia was the trigger for this progress and led to the revision and acceleration of all the tools in place at the time.

> "Xynthia is a catastrophic event that in the end triggered a lot of things, it allowed us to make a lot of progress in the field of risk prevention." (National authority see Table 2)

Major investments have been made into the refurbishment and building of new protection infrastructures along the coastline. A nation-wide reform of the governance system – the GEMAPI reform following the MAPTAM Law – towards more decentralisation to manage those infrastructures over time has also been completed. This reform also led to the creation of the GEMAPI tax to be used by local authorities to finance flood management, in particular flood defences.

> "There is a before and an after Xynthia […] the series of events has generated a political awareness which resulted into a regulatory evolution until the GEMAPI reform today" (Local authority, county)

Similarly on urbanisation in flood-prone areas, a reform of the methodology to draw risk prevention plans and an acceleration of the procedure were adopted.

The programmes of action on flood prevention, in place before Xynthia, got extended in 2011 to include the risk of coastal flooding. This opened the door towards a more integrated approach, covering and overseeing protection, urban planning, forecasting, warning, crisis management and risk awareness. The local strategies implemented in the late 2010s follow the same logic. There has also been an acceleration of the adoption of local crisis management plans. The display of Xynthia flood marks along the coastline of Charente Maritime and Vendée is seen as a key measure to increase public awareness.

Nonetheless many actions are still a work-in-progress today and respondents were very well aware of this.

> "10 years later, when we see the delays to undertake the works or else, we are not prepared to face a Xynthia-type event today. Overall in Charente Maritime, there are no areas entirely ready" (Local authority, intermunicipal)

Indeed in Charente Maritime, 32 "urgent" risk prevention plans are yet to be adopted (Ministère de la Transition Ecologique et Solidaire, 2020), more than half of the protection works is yet to be completed, evacuation exercises are yet to be organised and all interviewees recognise that the culture of risk, while it has increased amongst local councillors, is still very low amongst populations.

Not everything is completed today but we find the situation to be quite different from the not-fully-implemented-layer approach before Xynthia. While measures were not fully implemented then, whether for a lack of clarity, control or regulation, today we face a much more structured system. Both programmes of action and local strategies introduce an element of monitoring and add weight in terms of accountability, as much for local residents who want to see some results. In addition, the series of subsequent floods that has occurred in France since is a reminder of the necessity to act.

> "The winter 2013–14 with the series of small storms which eroded the coastlines was a reminder of the risks and of our fragility" (National authority)

Adaptation to present risks, including addressing exposure and vulnerability to climate variability, as much as adaptation to future risks in a changing climate, is in the end a process that is constantly evolving and iterative. Policies and measures can change or transform in light of new information, trends or predispositions but the now more structured approach should ensure decisions are well thought out and actions implemented. Table 4 presents these regulatory tools, their nature in light of section 4.1, and their post-Xynthia evolution in Charente Maritime.

Table 3
Results of a systematic review of the ex-post analysis of the Xynthia storm. Observations on the one hand and signposts and recommendations on the other hand are thematically organised. We identify sources produced both by public and policy-making bodies and by scientific research. Numbers in brackets refer to the last line of the table where sources are identified.

Theme	Observation made	Associated signpost for recommendation
Forecasting	Forecasting system poorly adapted to coastal events -> Inability to assess the risk of coastal flooding (Public and policy-making bodies: (1); (2); (4); scientific literature: (5); (6); (7); (8)) Limited tidal information, both for forecast and real time analysis -> Advised to stay home and few campsites evacuated (Public and policy-making bodies: (1); (2); (3); scientific literature: (5); (6); (7))	Improve the modelling system on coastal risks and flooding/ Strengthen the scientific collaboration towards forecasting/ Formalise coordination of forecast (Public and policy-making bodies: (1); (2); (3); (4); scientific literature: (7); (8))
Early warning	Warning messages didn't cover coastal risks in a useful way, if at all -> Inappropriate instructions, warning limited to the wind (Public and policy-making bodies: (1); (2); (4); scientific literature: (5); (9); (10)) Complexity and misunderstanding of warning messages by local authorities, rudimentary chain of communication -> Wrong messages were given to populations and no evacuations organised -> Limited capacities for smaller towns to warn their populations (Public and policy-making bodies: (2); (4); scientific literature: (9); (7))	Review the content and readability of the warning messages/ Factor in the timing of the hazards in communication/Review the communication chain and responsibilities to issue warnings/Develop contingency planning for failure of equipment and communication links/Set up an operational warning system/Ensure coherence of warning measures across towns (Public and policy-making bodies: (1); (2); (3); (4); scientific literature: (7); (8); (9); (11))
Crisis management	Crisis management satisfactory, yet areas of improvement exist (air interventions, coordination air/land, phone lines, rescue centres location, lack of local crisis management plans or plans not operational enough, outdated risk maps, equipment deficit, difficult transition from emergency management to reconstruction, ORSEC plans organising emergency services at departmental level not up-to-date, no flooding drills). (Public and policy-making bodies: (1); (2); (4); scientific literature: (5); (8))	Improve and extend the emergency digital communication network/Mandatory adoption of a crisis management plan when appropriate/Consider inter-municipal crisis management plans/Plan flooding drills/Public service buildings, rescue centres and assembly points away from flood-prone areas/Specific procedures for event uncertainty and multiple breaches/Scenario-based training for managers and for technicians/Integrate responses to flood and wind events/Need focus on awareness and perception/Improve coordination/Include coastal flooding in the departmental scheme on risk analysis and coverage of risks (SDACR)/ National planning of air resources (Public and policy-making bodies: (1); (2); (3); (4); scientific literature: (12); (13); (10); (6); (7); (11); (14); (10))
Culture of risk	Deficit in culture of risk (population, public authorities). -> Negative impact on warning efforts and evacuation possibilities (Public and policy-making bodies: (1); (2); (3); (4); scientific literature: (5); (6); (8); (12); (15); (16)) Information documents on risks too generic, not up-to-date, not operational or inexistent (Public and policy-making bodies: (4))	Include risk communication and dialogue, based on values and perceptions/Better inform populations about emergency procedures/Conduct flooding drills/Involve populations and civil society at all steps of coastal risk governance/Develop information documents on risks (DDRM, DICRIM, information for property buyers and tenants)/Update and disseminate risk maps (Public and policy making bodies: (1); (2); (3); (4); scientific literature: (5); (7); (8); (11); (12); (17); (18); (19); (20))
Urban development, land use and planning	Outdated urban plans, poor respect of land-use regulations, especially associated to known coastal flooding risk -> Urbanisation in flood-prone areas since the 1960s (Public and policy-making bodies: (1); (2); (3); (4); scientific literature: (5); (6); (7); (8); (12); (13); (15); (16); (21); (22); (23); (32)) Many risk prevention plans were not finalised at the time of Xynthia or prescribed in areas exposed to risk, delays caused by opposition from some mayors Poorly implemented risk prevention plans (underestimation of reference events, no taking into account of the micro-topography, lack of a consistent methodology, watering down of the urban constraints) (Public and policy-making bodies: (1); (2); (3); (4); scientific literature: (8); (12); (13); (15); (16); (21); (24))	Revise and reinforce land-use regulations in flood-prone areas/Prohibit urbanisation behind dikes/Update hazard maps on a regular basis/Resist local development pressures/ Stronger assertiveness from the State and local representatives/More human resources in charge of controlling urban decisions/Address uncertainties/Integrate flood risk into all land-use documents/Think of alternative uses for flood-prone areas (Public and policy-making bodies: (1); (2); (3); (4); scientific literature: (5); (6); (9); (11); (12); (13); (14); (15); (21); (23); (24))
Flood protection	Flood protection structures failed or were overtopped. The presence of dikes may have been a mortality factor as creating a false sense of safety. (Public and policy-making bodies: (1); (2); (3); scientific literature: (5); (6); (7); (12); (13); (22); (23); (25); (26))	Repair damaged dikes and build new ones/Clarify and reform the ownership, management and funding regime/Reiterate that protection shouldn't result in more urbanisation/Balance costs and benefits/Engage a reflexion on technical norms (Public and policy-making bodies: (1); (2); (3); (4); scientific literature: (7); (9); (12))

(*continued on next page*)

Table 3 (*continued*)

Theme	Observation made	Associated signpost for recommendation
	Dyke ownership and governance stemming from an outdated law (of 1807) unknown to those responsible for maintenance (riparian owners) -> Orphan dikes and lack of maintenance (Public and policy-making bodies: (1); (2); (3); (4); scientific literature: (6); (7); (12); (13)) Lack of finance or willingness to invest according to stakeholders' interest -> Lack of maintenance (Public and policy-making bodies: (1); (2); (3); (4); scientific literature: (6); (12))	Concept of nature-based and more flexible solutions, including managed retreat and depolderisation/Requires concertation with populations (Public and policy-making bodies: none; scientific literature: (11); (13); (18); (23); (26); (27); (28); (29))
Insurance	Every French resident contributes to the insurance regime equally and insurance cover is at an affordable price -> doesn't encourage prevention measures and exposure mitigation behaviour -> Unfair system between insured people who are at risk and those who are not -> Those exposed are often wealthy second home residents (Public and policy-making bodies: (2); (3); scientific literature: (6); (23); (30))	Better define risks and intensity of a catastrophe included in the insurance regime/Encourage prevention behaviours through measures linking risks to excess and premium/Make insurance companies contribute to the protection works refurbishment/Create a prevention observatory gathering all risk evaluation tools from the State and insurance bodies/ Engage discussion on insurance for local authorities properties/Engage discussion on impact of climate change and equity considerations/Exclude from the State-guaranteed reinsurance scheme properties built with no regulatory basis (Public and policy-making bodies: (2); (3); (4); scientific literature: (6); (23))
Governance and coherence	No coordination between prevention, protection and forecast approaches Multiplicity and fragmentation of tools, plans and regulations and stakeholders involved -> Deficit of local authorities involved in flood risk management. (Public and policy-making bodies: (1); scientific literature: (6); (32))	Consider collaboration between municipalities for land and urban planning/Reconcile administrative scale and risk management scale/Have a holistic and integrated risk management approach/Adapt the notion of catchment to homogenous coastal areas/Formulate and pass a national strategy for flood risk management and implement the EU Flood Directive (Public and policy-making bodies: (1); (4); scientific literature: (5); (10); (12); (14); (30))
Social vulnerability and inequalities	The typology of the victims (age, ill health, second-home residents) made them more vulnerable and prevented some from taking refuge in the higher floors -> Old people were overrepresented within the deceased (75% of the victims were over 60 years old). (Public and policy-making bodies: none; scientific literature: (5); (7); (11); (22))	Implement tailored measures on risk awareness and crisis management/Undertake a nation-wide stocktaking of high human vulnerability areas (Public and policy-making bodies: none; scientific literature: (5); (11))
Vulnerable/low quality buildings as source of exposure	Many houses were single storey buildings with no escape through the roof and with electric shutters or iron bars at their windows -> People could not find refuge in higher grounds and were trapped inside their house. (Public and policy-making bodies: none; scientific literature: (11); (22); (31); (5); (6); (7); (8); (15))	Undertake studies on vulnerability of private properties and on building methods against flood risk/Undertake structural measures to reduce it/Modify building standards/State or cities to buy exposed houses (Public and policy-making bodies: (1); (4); scientific literature: (6); (11); (12); (14))

(1) Anziani, 2010; (2) Leonard, 2010; (3) Bersani et al., 2010; (4) Cours des Comptes, 2012; (5) Genovese and Przyluski, 2013; (6) Cunge and Erlich, 2014; (7) Kolen et al., 2013; (8) Chauveau et al., 2011; (9) Kolen et al., 2010; (10) Lagadec, 2012; (11) Vinet, et al., 2011 ; (12) Przyluski and Hallegatte, 2012 ; (13) Rode, 2012 ; (14) Camphuis and Bidault, 2012 ; (15) Vinet et al, 2012 ; (16) Magnan et al., 2012 ; (17) Idier et al., 2013; (18) Rocle et al., 2019; (19) Quenault, 2015 ; (20) Marchand and Colbeau-Justin, 2012 ; (21) Prieur and Leost, 2015; (22) Genovese et al., 2012; (23) Mulot, 2015; (24) Chadenas et al., 2013; (25) Verger 2010; (26) Verger, 2011; (27) Hallegatte and Dumas, 2012; (28) Valadier and Richer, 2015 ; (29) Huguet et al., 2018 ; (30) Mineo-Kleiner and Meur-Ferec, 2016; (31) Mercier et Chadenas, 2012; (32) Douvinet et al., 2011

4.3. Key implementation challenges identified through the interviews

The analysis of the interviews led to a more precise identification of the challenges associated with the implementation of the post-Xynthia recommendations.

4.3.1. Factors of delay

A first reason explaining the delay in implementation as mentioned in section 4.2 relates to administrative processes and reforms.

> "There's always instability. Instability in terms of institutional organisation, on legislation, on competences… There are always things that make the deadlines slip." (Service-orientated public body)

A second reason for delay is connected to the electoral cycle. Interviews revealed local elections can be a factor of delay when documents such as the crisis management plans need to be updated or when newly elected local councillors need to be briefed on risks and procedures; On the other hand it can also lead to an acceleration when local councillors are eager to finalise their work before the next election.

Table 4
Flood-related regulatory tools and their post-Xynthia storm evolution in Charente Maritime.

Theme	Tool acronym (see Table 1 for details)	Evolution in Charente Maritime since the Xynthia storm
Land use and planning	*PPRL* Since 1995. Tool for taking risk into account in urban planning policies. Includes hazard and zoning maps, bans or restricts constructability in at-risk areas. Since 2011, 20 cm and 60 cm sea-level rise has been added to short and long term hazards. Responsible authority: national.	- 82 municipalities designated as priority areas after Xynthia. - 36 PPRLs approved as of end of 2019. - Others have "anticipated" versions, adopted under an accelerated procedure after Xynthia, currently being revised. - Tension between the State and local authorities and difficult cooperation was raised. - Public consultation on documents before final approval.
	PLU/PLUi Since 2000 for the PLU and 2010 for the PLUi. Land planning, urban prescriptions. Duration: 10–15 years. PPRLs form an annex to the PLU(i). Responsible authority: local.	- Two PLUi approved in 2019 – Ré Island and La Rochelle urban area. - PLUi idea rejected in other towns. Standard PLU in place. - Public consultation on documents before final vote.
	SCoT Since 2000. Land and sustainable development planning document at the intermunicipal level (usually larger than a PLUi). Duration: 20 years. PLU(i) follow the SCoT orientations. Responsible authority: local.	- All SCoTs dating back to 2005–07 or 2011–12 (La Rochelle and Aunis). - Little reference to coastal risks. - All currently being revised.
Crisis management	*PCS* Since 2004. Sets out responsibilities, measures and chain of actions in the event of a crisis. Mandatory for PPRL cities. Responsible authority: local.	- Plans in place in all cities. Need for update. Lack of conviction in some cities was raised. - Two drills organised (in La Rochelle in 2018 and in 15 towns in 2019). Tested the installation of removable protections and the warning chain. Little implication of populations. Issue of coordination raised.
Intersectoral action, flood-centred	*PAPI* Since 2003 but didn't cover coastal flooding until 2011. Main tool for flood risk management at local level. Cross-cutting actions on prevision, prevention and protection. Duration: six years. Funding from the State, region, county and cities involved. Risk-basin approach. Responsible authority: local.	- Eight PAPIs in place since 2012–13, one more currently being drafted. - Public meetings to present actions and progress. - Four protection options assessed: relocation, protection on properties, collective protection close to the stakes (thus promoting the use of wetlands) and protection at the coast. - Most of the funding go to protection works. 30–40% completed today. - Height of protections follow a (up to) Xynthia + 20 cm level, mirroring sea-level rise indicator chosen for the zoning maps.
	SLGRI Introduced by the EU Floods Directive implemented by the ENE 2010 Law. Duration: six years. Risk-basin approach. Responsible authority: local.	- Three SLGRI in place since 2018–19. - Doesn't always follow the same perimeter as that of the PAPIs. - Issue of timing with the PAPIs. - Their relevance is called into question in light of the existing PAPIs.
	PSR Direct response to Xynthia for actions at national level. Duration: 2011–2016. Covers forecasting and warning, urbanisation, protection and resilience of populations. Responsible authority: national.	- Led to: reform and acceleration of PPRLs - new forecasting system and increased capacity of Météo France – interviewees overall content but use of rudimentary data at local level and ongoing collective effort to improve modelling - revision of warning tools - GEMAPI reform - provision of additional funding for coastal defences

> "The local elections are putting pressure on the PLUi to be voted on first. Otherwise, the new teams are going to jeopardise all that work." (Municipality).

A third reason mentioned concerns political will, or lack thereof, amongst local councillors which can make it more difficult to implement the regulation or can reduce the effectiveness of an action.

> "It is certain that some municipalities do their crisis management plans just as a formality and others not" (Intermunicipal)

4.3.2. Integrating changes in environmental conditions

Delays are overarchingly threatening the implementation of reforms, yet reforms also have to take into account boundary conditions. The revision of plans and strategies following Xynthia was the opportunity for the State to integrate climate change into planning and it did so as early as 2011. The integration of sea-level rise in risk mapping, impacting directly local urban planning

policies and indirectly the heights of coastal protections, became part of the new instructions from the State.

Interviewees made the connection between climate change and their day-to-day work. They recognise climate change as a key challenge for the coastline. Yet confusion exists and climate change is not systematically addressed. Drivers that lead to keeping policies on the present timescale include: the multiple reports on climate change that are regularly published and publicised in the media which can have different messages; the urgency for local decision-makers to deal with present risks; the uncertainty regarding sea-level rise and its temporality; and finally a lock-in effect when strategies and calculations to mitigate risks have already been made. These factors make it more difficult to fully integrate climate change into planning, in particular how to manage uncertainty.

> "We don't have the skills at the local level to interpret all the scientific data that comes in all directions, there are many reports in this field so it is very complicated" (National authority)
> "For now things have been decided based on Xynthia + 20 cm [of sea-level rise] to 2050, it's complicated to go back […] if we had to take up the studies and calculations again in relation to the IPCC's evolving expertise, it would be complicated. Maybe Xynthia + 20 cm will be reached in 2040, in 2060… This is more what will change, the lifespan, the time scale that will not be the same." (Service-orientated public body)

4.3.3. *Instigating a risk culture*

How to nurture a risk culture is another key challenge as risk awareness amongst local populations remains low despite a series of measures undertaken by local authorities. The need to focus further on this emerged unanimously from the interviews. Overall respondents were positive, although somewhat concerned about the risk of memory loss and cases of denial they have faced.

> "With the solidarity zones, people fought to keep their property, and recognising the risk is somehow proving those who wanted to expropriate them right. It's not that they don't have awareness, but they don't want to show it too much because it would go against their fight to stay in the houses." (Intermunicipal)

The involvement of residents in the design and planning of policies remain limited:

> "With the new version of the PAPI guidelines, the State is asking for consultation with the population, to collect their observations before the PAPI file is submitted before works are carried out, and to take these considerations into account. This was not the case in 2012. Today, we are just going to provide information. " (Intermunicipal)

The new guidelines at the national level to involve further the populations (Ministère de l'Environnement, de l'Energie et de la Mer, 2017a) followed by a similar requirement at the regional level (Conseil Régional de Nouvelle Aquitaine, 2019) should result with time in a change of practice at the local level. Recent experiments on participatory democracy in France could have the potential to encourage such a move[2]. However support and more thoughts into the best format will have to be made:

> "It is complicated to involve people when you are at the strategic stage and you don't have anything concrete […] Involving them when we are really working on the project, for example, what will be the exact layout, the exact height, the materials, etc., but earlier it is complicated." (Service orientated public body)

Greater participation could contribute to resolving the existing confusion local populations face with the diversity and significant number of urban planning and flood management documents. Interviewees stressed that some documents were perceived by residents as well as some councillors as contradicting each other.

> "By putting security in place, people feel safe behind the dikes, and as a result, policies are less well understood […] That's what people don't understand, they tell us "but wait, I don't understand, we're building dikes so we're protected, we don't have water anymore, and you come in and put me in a red zone so we can't build any more". Yes, it's true that it's difficult to make people understand and to explain." (National authority)

Local authorities all have difficulty making it clear that there is no such thing as zero risk. Staff in local councils handling urban planning noted that house sales continued despite the information on risks, and that sale prices were even increasing. This confusion can thus create new risks. It also does not facilitate the assimilation and ultimately the approval of what is undertaken by local authorities to manage risks.

The disconnect between public perception and measures to manage risks is also exemplified by the concept of flexible management of the coastline which has gained traction in recent years at the national level (Ministère de l'Environnement, de l'Energie et de la Mer, 2017b; Depresle et al., 2019) and through small-scale experimentations.

> "In Charente Maritime, we are on areas of marshland that have been reclaimed from the sea historically, so culturally at once we say it's no longer tenable, we have to work with nature and perhaps accept to retreat, we are not at all in the same beliefs, some people can be strongly opposed. This discourse is not at all understood." (Service-orientated public body)

The solidarity zones, formerly called black zones, where entire areas in Charente Maritime and Vendée were expropriated and properties bought by the State just after Xynthia, were felt as a "trauma":

> "Today the only managed retreat that has been put in place is the black zones, it is the deconstruction of houses, and it has been experienced as a trauma both for the population and local councillors." (Intermunicipal)

Local populations and councillors of Charente Maritime will have to get over this in order to envisage managed retreat as a serious

[2] See: https://www.conventioncitoyennepourleclimat.fr/en/

option.

> "We need to move away from the caricature: I would like to put dikes everywhere on my territory or on the contrary managed retreat is a good thing and so let's do it everywhere. Because we see both positions and in the end the goal is to reach a compromise as pragmatic as possible." (Service-orientated public body)

Xynthia has also showed that the cultural and historical belief that people can in all situations reclaim land from the sea for their own use is not without any consequences today, especially as the use of the land has changed from agricultural practices to urban development.

> "We cannot stop everything and no longer live on the coast either, it's not in line with the way of the world" (National authority)

But today it is rather seen as a long-term option.

> "The philosophy is that people are there, they stay there, we have made protections, they are for that, so it's difficult to tell these people to leave. Maybe in the future, yes. We know that these protections have a limit […] Local councillors will have to have the courage to say we have to leave. But for the moment we are not there. We are limiting new construction." (Municipality)

Beyond the cultural and social aspects, financial, regulatory and planning obstacles will have to be addressed and tools provided to facilitate their implementation.

> "The conclusion is that today with the tools we have we cannot do much concretely. It is difficult for a local authority to take the decision alone to do something because it depends on the subsidies it is going to be able to obtain, the regulatory authorisations it is going to be able to obtain and therefore on the benevolence and organisation of all the public partners, which is going to be very complex and ambitious." (Service-orientated public body)

4.3.4. Operationalising integrated approaches

Reinforcing the integration of the various approaches taken has also proved to be complex. Both programmes of action on flood prevention (PAPI) and local strategies (SLGRI) follow an integrated and "basin of risk" approach.

However, while providing a single home for all flood management components, they don't necessarily contribute to having a better integration. Initially most of the focus and finance was indeed on coastal protections which was determined through a cost-benefit analysis. This evolved to reflect the need to strike a balance between different components and the multi-criteria analysis was introduced as a methodological tool (Ministère de l'Environnement, de l'Energie et de la Mer, 2017a).

PAPIs and SLGRIs don't lead either to a stronger integration of the various coastal risks faced by one area. For example coastal flooding and erosion could be combined in all risk management plans and could be placed under one authority both at the local level and the national level, as it is currently not the case.

Land-use planning documents, on the other hand, don't follow a basin of risk approach. Interviews revealed the underlying tensions between stakeholders from the coastline and those from the hinterland who are involved in one plan, showing difficulties in collaboration.

> "Local councillors on the coast have no power over the SCoT" (Municipality)
> "Local councillors say that the best perimeter is the one on which the elected representatives are able to get along to carry out a project." (Service-orientated public body)

Interviewees are aware of the lack of coherence and there have been talks to adapt the scale to the coastline but there is currently no strong support for it. Plans are set and a lock-in effect may play its part in this.

The issue of coherence also appears in terms of timescale. The first programmes of action started in 2012 in Charente Maritime while the local strategies deriving from the Flood Directive were adopted in 2018–19.

> "The action programme was done before the strategy, it was completely in the wrong order." (Local authority, county)

The cycle of both documents currently doesn't align therefore there is a risk of permanent mismatch.

Action programmes, local strategies, urban planning documents, land-use planning documents: they are all on a short timescale, on average 5–6 years, with the longest being 20 years, although these 20-year documents are all from before Xynthia or right after and they are all currently being revised. This makes it more difficult to integrate long-term risks and therefore long-term solutions, as well as fully appreciating the consequences of long-lived decisions taken today.

> "It's not the same objectives in 10, 20, 30 years' time. And the goal is to work on all facets of management, not to occupy the short term and the emergency when there is one, and to be able to get out of these emergencies but without leaving aside more long-term and forward-looking reflections and to advance both at the same time." (Service-orientated public body)

Certainly having a cross-cutting coordination mechanism at the territorial/regional level could help in monitoring, advising and assessing the extent of coherence and integration between the various plans and strategies, not only focusing on flooding but also on land management.

4.3.5. Reviewing the governance system

Finally, one more category of challenges relates to the governance system. The sharing of responsibilities from the national through to the local level to manage flood risks has been increasing (see Table 4). However it doesn't necessarily bring a change in how strategic directions are made and by whom, the State keeping the upper hand on actions at the local level, in particular through guidelines to follow and through approval power and financing.

> "Today, to have 40% of the State Fund on Risk Prevention, it is necessary to integrate the PAPI and the Rapid Submersion Plan into this system. In practice, without the 40%, it is complicated to complete the financing plans." (Local authority, county)

Furthermore it leads to several issues: the alignment of priorities between the national and the local level is not always smooth and local authorities do not all feel their opinion is heard; new structures are created to manage coastal protections making the governance system more complex; and the increasing role given to intermunicipal authorities doesn't necessarily come with the financial means to implement their new responsibilities which can lead to issues of inequality:

> "The difference with the Netherlands, England and Australia is that the protection works are centralised by the state. In France, it is decentralised. The perverse effect is that it can generate inequalities in terms of means because local authorities are more or less rich." (Local authority, county)

5. Discussion

5.1. Single events as sources of changes: Xynthia compared to others

The results that are presented above show that Xynthia did have an accelerator effect on the implementation of coastal flood risk mitigation measures. Yet, reforming a complex coastal flood management system takes time. Our observations are not unique in that dimension. In the UK, following the 1953 Big Flood, it took 15 years to reach a decision on a London flood barrier and 10 more years to render it operational (Baxter, 2005). In the Netherlands both the sheer size of the engineering work and its profound impact on water management and landscape led to delays associated with engineering work and public opposition (Correljé and Broeckhans, 2015; Gerritsen, 2005). Risk management regime shifts do not occur in a policy vacuum. They involve negotiations regarding land and water use, standards, and about what should be considered as an acceptable risk.

Also, when regime shifts bring about generational changes, priorities may shift. Correljé and Broekhans (2015) analyse how public values may be factored in in such situations, using 1953 and the Netherlands as a case study. They show that in the 1953 flood aftermath flood risk control was given the top priority. Yet, as time went by other values associated with water and its control took importance as well (e.g., nature and landscape preservation or economic activities).

Smith et al. (2017) analyse such a regime shift after the Somerset Levels and Moors flood of 2013–14. They demonstrate how "dredging as a solution became highlighted and eventually adopted during the period in which the problem, policy and politics converge" (p.17). The flood management doctrine was under pressure, yet it took a major event to put it on new tracks. The acceleration may thus be associated with a triggering effect.

Similarly, analysing the situation after Katrina, Carr-Chellman et al. (2008) show how inertia ("familiar ways," "old problems," the "larger culture" that bear on the system) and changes (values, leadership) interact dynamically to chart the course for the future with an outcome loaded with indeterminacy.

A triggering effect followed by a slowing down (stalling at times) of the process has been observed in the years following the Xynthia storm in terms of managed retreat. In the flood's direct aftermath one-sided, heavy-handed, decisions to remove some of the houses and neighbourhood were enacted by the State. These generated quite a strong response from those being displaced (Lagadec, 2012; Marchand and Colbeau-Justin, 2012). This led to the cancellation of some of the decisions and the adoption of a slower paced approach to coastal retreat. The interplay of shock and urgency triggered a policy shift. Yet the need to take account of local values and culture is central to the success of such an endeavour. Hino et al (2017) document 27 cases of managed retreat from around the world and one conclusion is that residents' perspectives and values matter to define success. This is where a central concept of the post-Xynthia coastal risk discourse comes in: that of "risk culture".

5.2. Single events as opportunities to operationalise emerging concepts: Xynthia and the concept of risk culture

Developing a risk culture amongst the populations at risk came out as a major challenge that risk managers in Charente Maritime recognise they haven't quite mastered yet. A population is not uniform and indeed in Charente Maritime there are different segments – lifelong residents, second-home residents, tourists, new pensioners, transiting residents – that are themselves regularly evolving, reflecting the dynamism of the region. Working on public perception involves adapting awareness measures and communication to each segment through a more tailored and direct approach.

Furthermore, providing information is not enough (Vanderlinden et al., 2017). How information is processed depends on many factors and scholars have showed the complexity of what a risk and a risk culture really mean. Blesius (2013) brings a more detailed definition of risk culture as the fact of "living with" the risk, being aware of situations of risks by keeping a memory of past events and adopting safety behaviours when facing a risk. Calvez (2007) argues that a given context will determine what is considered as a risk and that the task of defining what is an acceptable risk should take into account this diversity and variability that is influenced by social and cultural dynamics.

This involves being aware of the complex system of beliefs and values which can impact on risk perception despite having the information (Kahan et al., 2012; Vanderlinden et al., 2017). Coquet et al. (2019) studied the mechanism of spatial and temporal bias in relation to risk perception and show that individuals tend to underestimate exposure to risk of their own home and they tend to consider that risk will be greater in the future. Chionne (2018) found through a study with the population of the Oléron Island in Charente Maritime a decoupling between a place and its inhabitants and a lack of interest for the issue of risk. Working on risk awareness involves a two-way approach that sees populations not just as recipients of information but also as actors who help define

what is an acceptable level of risk, for themselves and for their town or city.

Stepping back from Xynthia and its aftermath, these results point to the challenges of operationalising concepts emerging, or re-emerging, in a post-crisis situation. Understanding and influencing risk perception, and associated behaviours, has been the subject of a rich literature (see for instance Renn, 2008; Vanderlinden et al., 2017). Yet the operationalisation of this literature in policy and practice calls for another cultural shift that would bring public participation into risk governance (Kahan et al., 2012; Lee, 2019). For this to work, support will have to be provided so the populations can have the capacity to make informed decisions. The Citizen's Convention on Climate, held at the national level in 2019–2020, is an example of how knowledge can be instrumental in the acceptance of radical measures.

5.3. Singles events as prequels to climate change: Xynthia as a window into the future?

Our results show that Xynthia has been framed as a window into the future, a future influenced by climate change (Oppenheimer et al., 2019). Indeed, a new element in France's coastal risk management strategy occurred with the inclusion of sea-level rise which marked a first anticipation by the State of climate impacts.

Yet, in the face of climate change the concept of risk itself has evolved, with a greater emphasis given to representations of risk such as that proposed by Kron (2002): risk = hazard × exposure × vulnerability. This model is now widely used after its adoption as a reference representation by the IPCC (e.g., Collins et al., 2019, p. 594).

What our results show is that the discourse on risk in the post-Xynthia context remains within the conceptualisation that doesn't take fully into account variations in vulnerability. This seems counter-intuitive as Xynthia affected the elderly significantly more. Reducing vulnerabilities and targeting vulnerable groups seem, in hindsight, a major miss.

The post-Xynthia policy-making literature did put an emphasis on the nature of the event, and, more importantly, on over-exposure, and on its corollary, risk culture. Xynthia's aftermath had a somehow hybrid feel. The future had been seen and policies were changed accordingly. Yet the conceptual tools already developed to face a changing climate were not fully mobilised. The conditions for their adoption or else the defining of new, climate change relevant, conceptualisations of risk seem to be an area deserving further enquiry.

6. Conclusion

Ten years after the Xynthia storm and the associated flood disaster, we enquired into its impact on coastal flood management in France. Our results indicate that it did generate an acceleration in the implementation of risk management measures; it did not lead to a clear regime shift. The initial acceleration has been followed by more questioning such as greater spatial and sectoral integration, and their corollaries, the broader governance system and the role of public participation within it. Xynthia is still considered today as a reference against which, at least informally, one assesses risk mitigation options.

Flood risk management in France has improved following the Xynthia storm. Nonetheless we highlight challenges that need to be addressed. Extending the analysis to the other areas impacted by the storm, including the Vendée, Gironde and Loire Atlantique counties, would allow to grasp cultural, political and socio-economic differences which can all play a part in how the risk is managed.

The extent to which progress will allow for the mitigation of the consequences of future events is not easy to qualify nor quantify. Devising a monitoring, evaluation and learning system would avoid relying on other less robust approaches, including the risky position of using the next storm event as a test for what has been implemented.

Our results also point to important stocktaking dimensions regarding high-impact events. First, the aftermath of catastrophes do constitute critical hinge points. New practices may emerge; new concepts may be adopted within the realm of policy-making. Yet, we find that such changes are often delayed and are contingent upon many factors. Local and non-local culture influences the adoption of new risk management practices; policy-making traditions and constraints do not disappear after a storm. Their practical application may not be within immediate reach.

Figuring out the causes of a disaster implies looking at the multiple dimensions of what leads to a catastrophe: as much those factors that are in full sight as those that are underlying, located in the socio-economic, cultural, political and institutional sphere. Understanding the causes is also not sufficient, one has to have the means to act on such causes while handling other policy priorities and keeping in mind the longer-term sustainable development of the affected area.

Finally, taking stock of past floods is critical to addressing coastal risks in a changing climate. Learning from the lessons learned may very well be as important as the lessons themselves to improve how we manage risks that seem exceptional today but likely ordinary tomorrow. This pushes further the concept of monitoring and evaluation to make space for learning. Such monitoring and evaluation would then recognise that risk management can only be effective and sustainable through time by adopting a dynamic real-time learning approach. Such an approach would not only look at what happened in the past. It would embrace the challenges of the evolving climate and socio-economic context, this in a radically, and much needed, forward looking manner.

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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