# Coastal Erosion Risk: Population Adaptation to Climate Change A Case Study of the Pays de la Loire Coastline.

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# Coastal Erosion Risk: Population Adaptation to Climate Change—A Case Study of the Pays de la Loire Coastline

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ABSTRACT: Studying the population's perception of coastal erosion is essential and is increasingly used by coastal administrators, especially because it strongly influences the acceptance of coastal adaptation strategies. This article explores the population's perception of coastal risk on the Atlantic coast of France (Pays de la Loire region) that is an at-risk territory historically affected by erosion and is particularly sensitive to coastal flooding. The major goal of the paper is to collect data in terms of risk perception by carrying out a field survey on three territorial collectivities, with the aim to enhance the feasibility of the managed retreat operations that will be implemented on this coast in the next years. A total of 700 surveys were collected and several original results can be drawn: the population has a good knowledge of erosion in the area where they live, and this knowledge is key because the territory is vulnerable. Similarly, the respondents have a good knowledge of protection measures, but some are more important than others: for example, the reinforcement of coastal defenses is the most commonly cited strategy to deal with coastal hazards whereas relocation is the second-most-known but least-popular scenario. Several factors influence people's perception of risk: for example, time spent in the residence and age of residents are two elements contributing to place attachment that must be taken into account before starting to implement any climate adaptation policies.

KEYWORDS: Coastlines; Risk assessment; Vulnerability

## 1. Introduction

Coastal erosion depends on processes with different temporalities, which are established in the short term for few hours-long tempestuous events, in the medium term as the historical outcome of a series of tempestuous events and geomorphological resiliency phases lasting from a few months to several years, and in the long term when considering sea level rise. An increasing number of studies highlight the recognized and alleged effects of climate change on these various terms that consequently lead to the probable acceleration of the shoreline's erosion by 2100 (Bruun 1962; Durand and Heurtefeux 2006; McDonald 2011; Masselink et al. 2016; Cazenave et al. 2014; Ranasinghe 2016; Luijendijk et al. 2018; Oppenheimer et al. 2019). Therefore, the increased vulnerability of densely populated coastlines to erosion is becoming a topical issue and this phenomenon is now extensively taken into consideration by the scientific and public authorities (Callaghan et al. 2009).

In France, 19% of shorelines are currently in erosion (Depresle et al. 2019). According to the same source, which relies on studies from the Centre d'Études et d'Expertise sur les Risques, l'Environnement, la Mobilité et l'Aménagement (CEREMA) (Centre for Studies on Risks, the Environment, Mobility and Urban Planning), 5000–50 000 housing units would be in danger by 2100 (CEREMA 2019). This would represent 37 coastal towns and, in the worst-case scenario, 10% of their population. Under these circumstances, many areas would have to consider relocation policies sooner or later. Relocating shoreline issues is given various names in scientific publications whether it mentions coastal erosion or marine submersion. Managed retreat, which has frequently been put forward by international organizations, is also taken into account by government agencies to implement coastal management strategies (Department for Environment, Food and Rural Affairs/Environmental Agency 2002; Department for Environment, Food and Rural Affairs 2005; Kousky 2014; O'Riordan et al. 2014; Ministère de l'Écologie du Développement Durable et de l'Énergie 2012; Depresle et al. 2019; Rocle et al. 2021). In France, it is more generally considered within the scope of territorial restructuring proceedings. Managed retreat might be seen as a one-time event (moving a house, at best a housing project), which takes part in a larger project of territorial restructuring. For example, the second action plan (2017–19) of the national strategy of coastlines' integrated management [stratégie nationale de gestion intégrée du trait de côte (SNGITC)], through its axis C, encourages thinking about territorial restructuring in terms of experimental approaches.

In this context, the Pays de la Loire regional observatory of coastal risks (OR2C) launched a study. It is part of the SNGITC action plan, which the OR2C is charged to implement in the Pays de la Loire coastlines (Kerguillec et al. 2019). It aims to lead a multidisciplinary reflection on managed retreat strategies, while simultaneously providing tools for the areas that might want to commit to the process sooner or later. This study intends to upgrade the tools: if French authorities have considerably increased

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the means to implement in case of sea floods since the 2010 Cyclone Xynthia (legal tools, action plans and flood prevention plans, etc.), it is rare to see the specificities of coastal erosion to be taken into consideration. While some rocky coast areas are locally concerned by the clear retreat threatening the infrastructure, it is mostly problematic on sandy coasts, which register a strong historical movement of the shoreline (from $5.1 \pm 0.35$ to $-1.5 \pm 0.35$ m yr$^{-1}$ from 1950 to 2011) (Robin et al. 2019). The corresponding stakes can affect up to hundreds of housing units (Juigner et al. 2017).

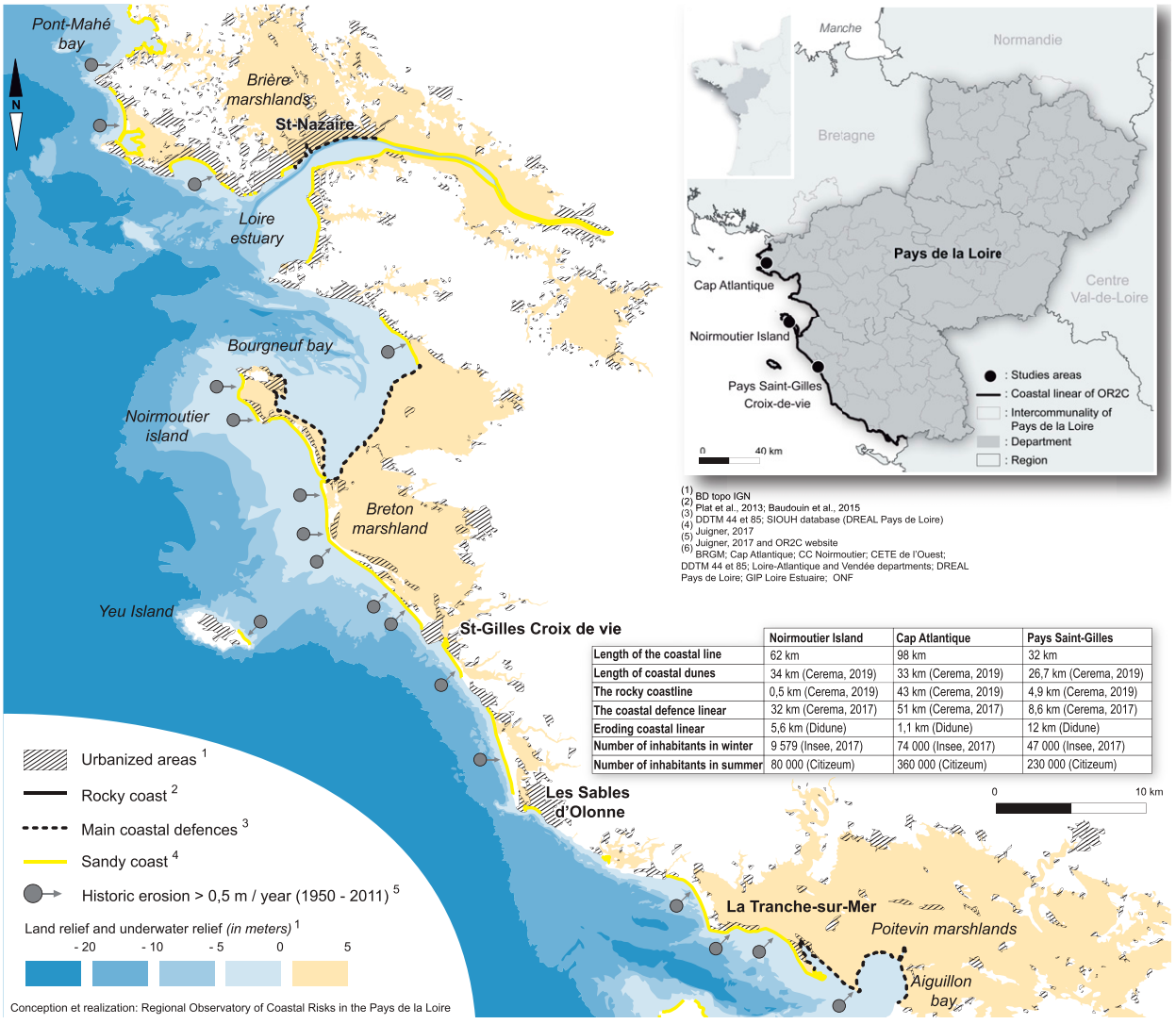
Because climate change is noticeable through its impact, it is pertinent to take an interest in how individuals assess the associated risks. It thus seems essential to study how nonexperts evaluate risks, as they do not do so in the same way as experts (Slovic 1987, 2000). Risk perception is all the more interesting to consider as it could explain how individuals face up to risk (Aitken et al. 2011; Lin et al. 2008; Slovic 2000). According to the psychometric paradigm, risk perception is composed of two factors: knowledge of the risk and perceived fear (Fischhoff and Morgan 2009; Slovic 1987, 2000). While the misconception of a risk is related to unobserved, unknown and/or new events, fear designates lack of control and the catastrophic aspect of the situation (Slovic 2000). This brings us to legitimate the question of coastal populations' perceptions of the risk combined with coastal erosion in Pays de la Loire region. The notion of perception is related to sensitivity, as it is a kind of knowledge that defines a phenomenological relationship with reality, to what the subject experiences thanks to his senses (Doise 1987). Reality, which is activated by the subject's experiences, is also determined by socially constructed representations, since experiencing reality is the product of a person's social and sensitive activities (Navarro 2017). Population's erosion risk perception, that is to say how they assess the hazardous nature of the event and possible aftereffects on their well-being, cannot be limited to the objective conditions of their exposure. These perceptions are fundamentally influenced by social knowledge coming from social interactions through media and interpersonal communications (Fischhoff et al. 1993; Sjöberg 2002; Joffe 2003). It is, however, important to take into account that risks, as they are defined by experts based on theoretical knowledge, are differently perceived or understood by the nonexpert population, who relies on social knowledge (Fischhoff et al. 1978; Slovic et al. 1980). The experts shape the decisions and adaptation plans chosen. This sociocultural framework defines how people judge the situation, the level of danger, the importance of the threat, the population's ability to individually or collectively respond to the risk as well as the measures offered by the authorities and their efficacy. Risk perception must be clarified, since it allows us to understand the behaviors and life plans of the population of a given area: the memory, the awareness, and the knowledge (sociocognitive dimension of risk perception) that the inhabitants have of the risk are key to understanding individual adaptive processes (Navarro and Michel-Guillou 2014). In addition, the affective dimension (like place attachment), which is particularly correlated by the time spent in the residence and the way the respondent talks about the place, contributes to assessing how well coastal adaptation strategies are accepted by the inhabitants.

Indeed, place attachment is likewise a significant factor in coastal risk perception (Navarro et al. 2020, 2021) and more broadly in environmental risk perception (Bonaiuto et al. 2016). Place attachment contributes to a strong emotional awareness of belonging both to a place and to a localized group. The concept of place attachment refers to the subjective relation that individuals sustain with an environment (Moser 2009) and may convey a positive emotional link with a place (Low and Altman 1992), thus leading the individual to remain spatially and temporally close to this place (Hidalgo and Hernández 2001).

Several works on other areas and at different scales demonstrate that the population's risk perception can significantly influence the acceptance of adaptation strategies (Hurlimann et al. 2014; André et al. 2015; Huteau 2015; Lambert 2016a; Rey-Valette et Rulleau 2016; Guéguen and Renard 2017; Michel-Guillou et al. 2016; Mineo-Kleiner and Meur-Ferec 2016; Rey-Valette et al. 2018, 2019). Thus, a population's perception is a main issue to be considered in managed retreat operations. Mineo-Kleiner and Meur-Ferec (2016) confirm that the opinion of residents on managed retreat is essential because it is generally a poorly accepted solution. Some authors underline that the acceptance of a managed retreat operation requires to reinforce communication, awareness, and consultation of populations (André et al. 2015; Lambert 2016a; Navarro et al. 2020; Bazart et al. 2020; Philippenko et al. 2021). For these reasons, the French SNGITC recommends developing actions of communication in order to raise awareness of coastal risks among populations (Ministère de l'Écologie du Développement Durable et de l'Énergie 2012, 2015). Several publications also underline the need for change in governance to raise awareness of residents and managers (Lambert 2016a; Rey-Valette and Rulleau 2016; Chotard et al. 2021). They promote a shared governance to reach socially acceptable solutions and develop a shared coastal risk culture. Some authors highlight the importance of cognitive biases in populations affected by coastal risk (Rey-Valette and Rulleau 2016; Rey-Valette et al. 2018). For example, Rey-Valette et al. (2018) demonstrate that despite a significant vulnerability, some habitants are willing to face the risk. Moreover, some authors show that the knowledge is sometimes fairly limited, on a general level (sea level rise, exposed coastlines, etc.) but also close to their home (Rey-Valette et al. 2019). This lack of information raises the question of the capacity for judgment of the habitants and could influence the acceptance of managed retreat strategies.

Because population's perception and opinion on the matter of erosion and the notion of managed retreat is still poorly known on the Pays de la Loire coasts, the major goal of this study is to improve this knowledge in order to enhance the acceptance of the managed retreat operations that could be implemented on this coast in the next years.

The article presents the results of a 2019 survey that aimed, by relying on an exploratory and descriptive approach, to assess the inhabitants' perception of coastal erosion and question them about the solutions they would believe in. Relocating was included in the scenarios proposed in the survey. Therefore, the




| | Noirmoutier Island | Cap Atlantique | Pays Saint-Gilles |
|---|---|---|---|
| Length of the coastal line | 62 km | 98 km | 32 km |
| Length of coastal dunes | 34 km (Cerema, 2019) | 33 km (Cerema, 2019) | 26,7 km (Cerema, 2019) |
| The rocky coastline | 0,5 km (Cerema, 2019) | 43 km (Cerema, 2019) | 4,9 km (Cerema, 2019) |
| The coastal defence linear | 32 km (Cerema, 2017) | 51 km (Cerema, 2017) | 8,6 km (Cerema, 2017) |
| Eroding coastal linear | 5,6 km (Didune) | 1,1 km (Didune) | 12 km (Didune) |
| Number of inhabitants in winter | 9 579 (Insee, 2017) | 74 000 (Insee, 2017) | 47 000 (Insee, 2017) |
| Number of inhabitants in summer | 80 000 (Citizeum) | 360 000 (Citizeum) | 230 000 (Citizeum) |

FIG. 1. Geographic context of the study.

objective of this article is to check whether the level of knowledge of the inhabitants in this area contributes to their adherence to adaptation strategies, among which managed retreat is a solution increasingly considered.

## 2. Method

### *a. Study area*

Three studies areas in the Pays de la Loire were chosen to conduct this survey: Noirmoutier Island and the local council communities of Pays de Saint-Gilles-Croix-de-Vie and Cap Atlantique (Fig. 1). Even if the three areas have different dynamics, they are all clusters of touristic activities at the regional level. The demographic pressure, added to the potential coastal risks on all three areas, increases the fragility of the shoreline and exposes them to relocate some of their infrastructure sooner or later. These particular areas, on a 400-km-long shoreline, were chosen for several reasons. These reasons are related to the coastal erosion taking place in parts of their territories, to their demographic pressure (that is to say the number of permanent inhabitants) and to the geopolitical context there. Considering the context of coastal risk exposure, the dialogue between the stakeholders (inhabitants, associations, elected officials and state administrations, etc.) can be tense, which is why the survey was easier to perform in some areas than in others. It is a prominent element when choosing the studied areas. Also, it is interesting to select an island among the areas chosen to assess and compare its inhabitants' perception with the mainland and consequently to study the incidence of places on answers: if one goes past the hypothesis that the knowledge of the risks is higher among the coastal respondents, does the island become a variable or is it its vulnerability that might influence the respondents' answers? This is also one of the elements that will be tested in this analysis.

Noirmoutier Island Etablissement Public de Coopération Intercommunale (EPCI) (a French public institution focusing on local communities' cooperation on urban, economic, and social policies) includes four towns and is located in the Vendée department. It is limited by the Bourgneuf Bay in the north and the Atlantic Ocean in the east. The island is connected to the land by the Gois passage at low tide and the Noirmoutier bridge. At the French Atlantic coast scale, Noirmoutier Island represents a prominent and attractive touristic center since one can find 18 000 commercial accommodations there and 65.5% of housing are secondary residences. This island's distinctive feature is its low topography (the maximum altitude is 22 m) and the presence of numerous low areas with polders and swamps. They are protected to the west by successive dune ridges that are subject to storms and erosion, even if some coastal protection structures have sometimes been locally built to limit their impacts. Two-thirds of its surface is located below high tide sea level during spring tides (Fattal et al. 2010) and numerous areas are then subjected to possible marine submersions. From 1770, the island's inhabitants have taken measures to protect themselves from the sea. Yet, while these measures have been reinforced, they are not enough to prevent erosion. For instance, Eloux Beach, which is located at the southwest of the island, has retreated of 0.7 m $yr^{-1}$ between 1832 and 2006 and it reached 1.9 m $yr^{-1}$ between 1999 and 2006 (Fattal et al. 2010). During storm Ciara (February 2020), the Gueriniere dune eroded up to 10 m in some places, which led to the reappearance of a nineteenth-century work on the beach surface.

Pays de Saint-Gilles-Croix-de-Vie local council community is located along the Vendée coast, between Pays de Mont and Sables d'Olonne. It includes 14 towns; only 3 of those are located along the Atlantic coast. The remaining 11 are located in the backshore. The EPCI counts 50 000 inhabitants on a surface area of 293.90 $km^2$. The coast is strongly urbanized, especially in Saint Gilles Croix de Vie. This can be explained by the territory's appeal during the summer period. This EPCI's coastline is vulnerable to erosion: during the 2013/14 winter storms, Maidens' Beach (Saint-Hilaire-de-Riez) moved back 4–5 m, which bared the bottom of the protection work; as for Les Becs beach (Saint-Hilaire-de-Riez), it moved back 6–8 m This retreat was followed by a landslide from the top of the riprap that was provoked by the drainage of big waves (Pays de Saint Gilles Croix de Vie in 2015). Numerous measures aiming to fight erosion are implemented in this area: sand buildup, reconstituting of the dune ridge, reconditioning protection works after each storm. These erosion stages are nonetheless recurrent. Therefore, it is interesting to question the EPCI's inhabitants to understand their perception of erosion risks and to record their opinion on the implementation of a long-term relocating strategy related to vulnerable housing.

This paper's third study area is Cap Atlantique local council community. It counts 15 towns spread over two departments and regions, the Morbihan (Brittany) and the Loire-Atlantique (Pays de la Loire). It is located between two estuaries: the Loire and the Vilaine rivers. Eleven of the 15 towns in this EPCI are along the coast. This EPCI's particularity is the important number of wetlands, especially within Brière Regional Natural Park, but also with Guérande salt marshes. This area's coastline is alternatively sandy and rocky. There are several major low areas, like Guérande and Mès salt marshes as well as the Brière. Cap Atlantique has major tourist attractions that are very appealing during the summer period.

### b. *The survey and the survey protocol*

The survey is organized in four parts to analyze four parameters that may play a part in the population's perception of coastal risks. The first one covers the presentation of the respondents' sociological parameters (age, gender, professions, and socioprofessional categories, whether they are owners or tenants, etc.) as well as place attachment. The second part deals with coastal erosion knowledge, and the consequences it can have on the territory. This part is completed by questions around existing risk management and control strategies aiming to prevent erosion. The third part is dedicated to knowing who the coastal managers are and the last part enables to specify the respondent's ability to foresee risk by providing him/her with a cartographic simulation of the area in 2100 by way of an introduction (IPCC 2014; RCP2.6). The survey was built from previous work done on coastal risk perception, including by the research team (Rey-Valette et al. 2018, 2019; Ruz et al. 2020; Navarro et al. 2021) with a particular focus on coastal erosion risk that previous work did not specifically address. The survey includes questions requiring short answers (yes/no) to facilitate postsurvey processing but also to avoid encroaching on a more qualitative scheme that was subsequently implemented and will be the subject of a future publication. Several questions also included scales to more accurately assess the opinion of the surveyed population. To ensure the representativeness of the surveyed population and to be able to make comparisons between territories, quotas were set up. They are based on the age and gender distribution of the population present in these territories, using statistical data provided by the French Statistics Institute (Insee).

The survey lasted 6 days in December 2019 and each questionnaire took on average of 15 min to complete. This was the most opportune time of year to focus on permanent inhabitants, but the meteorological conditions were often constraining, which sometimes made it difficult to give the survey. All study areas were prospected, and the inhabitants were interviewed in the street. After cleaning the database, a total of 743 surveys were collected (250 for the local council communities of Pays de Saint Gilles Croix de Vie, 246 for Noirmoutier Island, and 247 for Cap Atlantique).

The database built from this survey's results was processed using the Sphinx software. The statistical treatments carried out are based on three main factors: the $\chi^2$, the $p$ value, and the degree of freedom (df). These indicators are recalled in each of the proposed figures. Some analyses (such as scale and correlational reliability) were processed using the SPSS software. To verify how significant the correlation of some variables was, an analysis of variance (ANOVA) was calculated.

TABLE 1. Characteristics of population surveyed. Here, $N = 743$.

| Characteristic | Percent |
|---|---|
| Gender | |
| Woman | 52.8 |
| Man | 47.1 |
| Age (years old) | |
| 15–29 | 11.8 |
| 30–44 | 16.2 |
| 45–59 | 23.4 |
| 60–74 | 29.7 |
| ≥75 | 18.8 |
| Housing Status | |
| Owner | 68.5 |
| Tenant | 24.5 |
| Freeloading | 6.6 |

Since this was positive, a Bonferroni post hoc test was used to determine the basis for the differences between the three territories studied. The survey's results make it possible to get an idea of the population' perception of coastal erosion risk and how informed they currently are about relocating strategies from a general standpoint. The results are presented per area, but, when it proves useful, they were compared to identify particularities in some groups such as between islanders (Noirmoutier Island) and mainlanders (Cap Atlantique and Pays St-Gilles-Croix-de-Vie).

### c. *Participants*

Several criteria were chosen to test the correlation of variables such as age, time spent in the residence, whether one owns his/her accommodation, and the inhabitants' outspoken place attachment (Table 1). These elements could possibly influence the way people answer questions on risks and managed retreat. Cap Atlantique respondents live in the two main towns of the area, 43.7% live in la Baule-Escoublac and 26.7% in Guérande; the rest come from some other towns in the EPCI: Pouliguen, Le Croisic, and Batz-sur-mer. For Noirmoutier Island, the majority of the respondents live in Noirmoutier-en-l'Ile and Guerinière, as both towns correspond to 68% of the surveys. For the Pays de St-Gilles-Croix-de-Vie, the questionnaires predominantly come from St-Gilles-Croix-de-Vie, St-Hilaire-de-Riez and Brétignolles-sur-Mer.

The respondents who were born between 1945 and 1960 (between 60 and 74 years old) represent the majority of the sample since they are 29.7% of all the respondents and the 45–59-year-olds count as 23.4% of the respondents. Retired people compose 43.3% of the sample, knowing that they usually represent 45% of Pays de Loire towns' population, even though the average is 26.9% in France, proving how attractive this coast is for this age group; 68.5% of the respondents are landowners, and for 92.9% of them it is their main home. These data are consistent with regional indicators and ensure that the sample of the surveyed population is representative of the population in the territories where the survey was conducted.

## 3. Results

### a. *Coastal risks and sea level rise: A general approach*

When asked what coastal erosion means to them, 90.7% of the respondents declared "seashore destruction," followed closely by "cliff collapse" (79.8%) and "animals/plants disappearance" (Fig. 2). On the other hand, for 38.1% of the respondents, coastal erosion does not suggest "displacement of populations"; 3% of the respondents suggested other answers; among those appears "coastline retreat" and "marine submersion."

By 2100, the sea level rise in metropolitan France will be a phenomenon that 61.5% of the respondents estimate to be between 25 cm and 1.10 m, while the majority of them estimate it to be between 25 and 77 cm. For 23.4% of them, sea level rise would be higher than 1.10 m. According to 92.4% of the inhabitants, sea level rise is linked to climate change (Fig. 3). $CO_2$ emissions, pollution, and urbanization are also important causes of the rising level of the sea (around 80%). On the other hand, only 53.8% agree or do not totally agree with the idea that it is a natural phenomenon. The main consequences of this rise are the coast's erosion (93.1%) and putting people's lives at risk (88.5%). The increasing frequency and intensity of natural disasters total around 85% of "agree" and "completely agree." Nevertheless, the managed retreat of housing units (85.2%) and infrastructure and equipment (82.3%) constitute a consequence not to be ignored.

Facing coastal erosion risk, the majority of the respondents say they are worried (64.4%), whereas 43.8% of them do not feel particularly exposed. The islanders (Noirmoutier Island) are more worried than the mainlanders (Cap Atlantique and Pays de St-Gilles-Croix-de-Vie) ($F = 19.43$; $p < 0.001$). Feeling anxious and personally exposed to the risk of erosion is more present for people under 60 (born before 1960). Correlate risk perception and the duration of residence has also been done: the results demonstrate that the respondents who have lived for less than 20 years in their accommodation are more worried than the people who have lived there longer. The $\chi^2$ test, however, shows that this relationship is not significant on a statistical level ($\chi^2 = 38.45$). The hypothesis considering that the time spent in the residence influences risk perception is therefore not confirmed. It is also an element that is related to the fact of being an owner or a tenant for a longer or shorter period. Indeed, the majority of the surveyed people have lived in their current accommodation for less than 10 years (48.3%) and 33.2% for less than 5 years. Overall, Noirmoutier's inhabitants have lived in their homes for longer than the respondents of other areas.

It is worth noting that an important portion of the inhabitants does not know the origin of this phenomenon (40.1%). 75% of the respondents know which French coastal sectors have already been subject to coastal erosion. Among their answers, the Landes (8.6%), Noirmoutier Island (8.6%), the Normandy coast (8.1%), the Vendée Coast (5.9%), Soulac-sur-Mer (4.5%), Brittany (4.1%), or even Saint-Gilles-Croix-de-Vie (3.8%) are often mentioned. Among the seven most mentioned coastal sectors, three are located on the Loire–Atlantique coasts. From the $\chi^2$ test, it was worth noting whether the respondents knew well the places that were indeed subject to erosion. The relationship is very

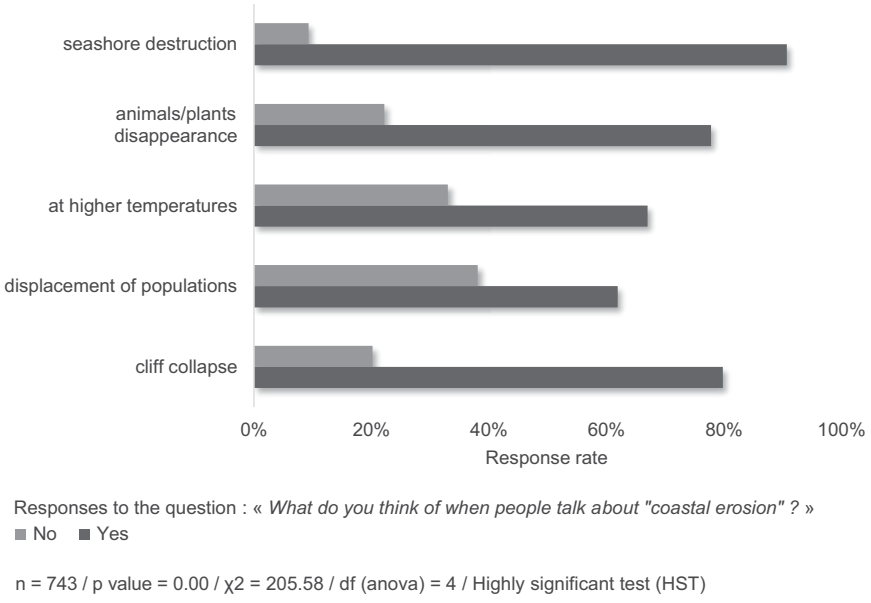



FIG. 2. Vocabulary associated with coastal erosion among the inhabitants of the territories studied.

significant: Noirmoutier Island is mentioned at 93.6% by its inhabitants, the large beaches of Saint-Gilles-Croix-de-Vie at 100% by the town's and the local council communities' inhabitants just like Penestin (the gold mine cliff) and La Baule, two sectors that have only been mentioned by Cap Atlantique inhabitants. To be more precise, the places mentioned on every territory are indeed areas subject to erosion: the entire west coast of the island and more precisely the coasts of Guérinière and Luzéronde for Noirmoutier, La Baule Bay and the wild coast from Pouliguen to Croisic for Cap Atlantique and St-Gilles-Croix-de-Vie's large beach for the third area. Note that Noirmoutier's inhabitants mention the sectors that are potentially subject to erosion on their island more than the inhabitants of other study areas.

Overall, 47.1% of the respondents consider that their town is exposed to coastal retreat linked to cliff/dune erosion "as of today." The objective here was to evaluate the temporality with which the population could feel threatened. Differences, however, can be noted between the three study areas: according to 65% of Noirmoutier's inhabitants, their island is exposed to this risk "as of today," while it is the case for 33% of Cap Atlantique inhabitants and about 42.8% for the inhabitants of Pays de Saint-Gilles-Croix-de-Vie. In this area in particular, the majority of the respondents think the area will not be exposed to coastal erosion before 100 years and even "never" for 5.6% of them (Fig. 4). Nevertheless, would they be ready to move?—46.2% are, in all three study areas, and they would do so even if the does not offer any compensation.

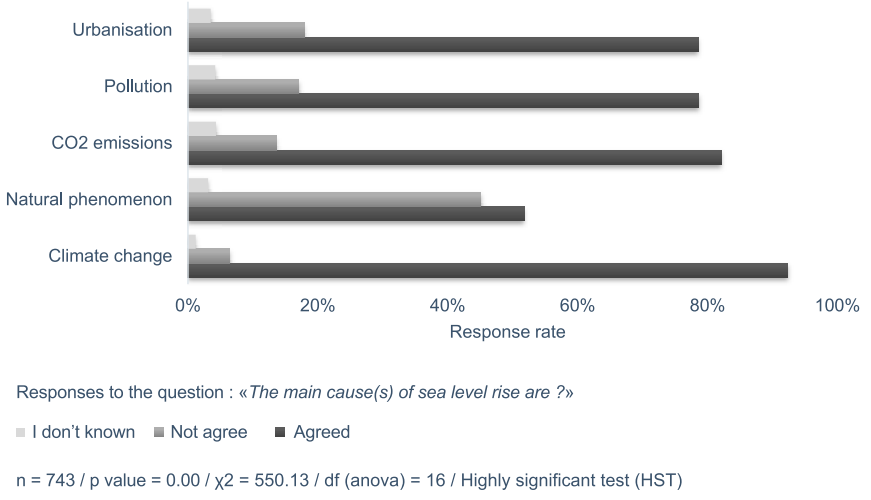



FIG. 3. The main causes of sea level rise according to the inhabitants.

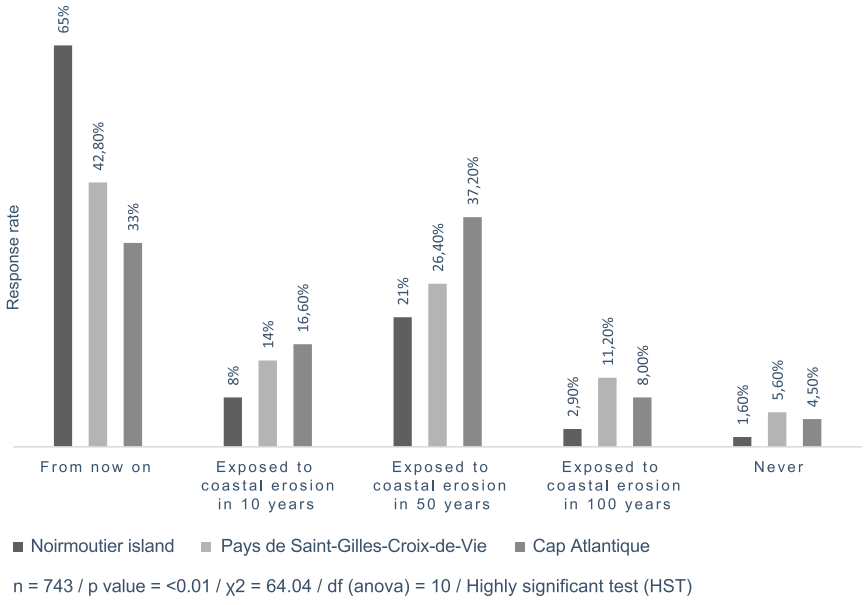



FIG. 4. The commune's exposure to coastline recession according to the inhabitants.

The percentage increases if the state does, to 66.9% (as has been also noted by André et al. 2015). There is a strong difference, however, between what islanders and mainlanders think. In both cases, islanders remain more reluctant to move. The time spent in the residence in their current housing plays a role in the answer, since the longer it is, the more reluctant the respondent is to change accommodation: 73.7% of the respondents who have been living in their current accommodation for less than 5 years are ready to move if they are compensated, as compared with 31.2% for people who have lived in their current accommodation for more than 40 years. Yet, the islanders are the population with the longest time spent in their residences.

When the respondents are questioned on the level of efficacy of the protective measures against coastal erosion, dikes are the most mentioned, outshining all the other measures with 43.9% of the answers ("completely agree") (Fig. 5). Even if the dune is not in strict terms a protective measure, islanders are particularly convinced of its efficacy with 56.5% of "completely agree," whereas only 18.9% of mainlanders think so. Among the suggested solutions, displacing the inhabitants and the roads ranks third with 38.6% of the respondents saying they "completely agree" with their efficacy. The islanders, however, think using riprap at the bottom of cliffs and groynes beach remain the most efficient protective means against

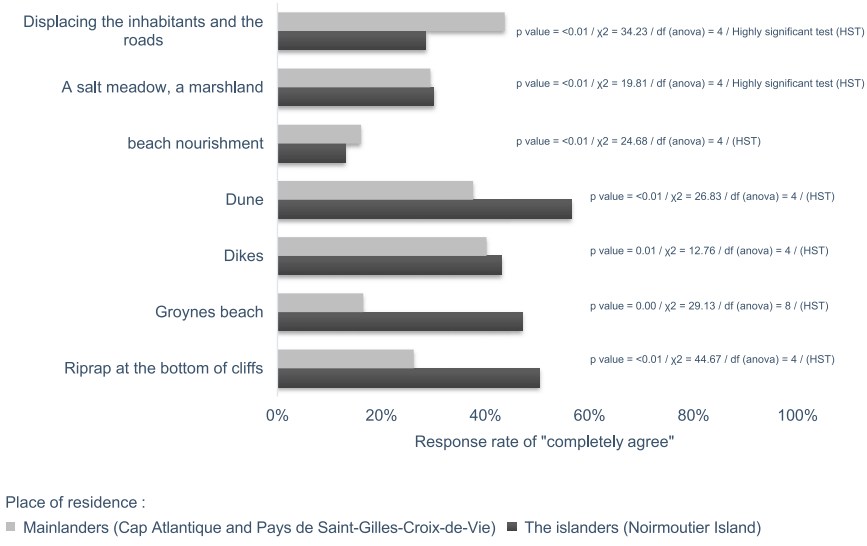



FIG. 5. Relationship between place of residence and choice of coastal erosion protection.

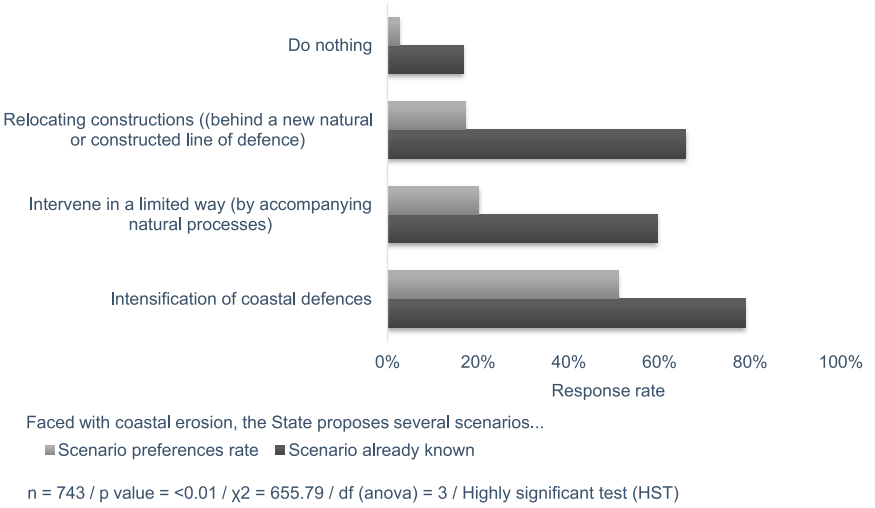



FIG. 6. Knowledge of the inhabitants on the scenarios proposed by the state to deal with coastal erosion.

coastal erosion with respectively 50.4% and 47.2% of "completely agree."

The majority of respondents (53%) consider that their opinion about coastal management is not taken into account as citizens: this opinion is, however, mostly shared by mainlanders and only 29.3% of islanders. Furthermore, 81.2% of the respondents think it is up to their town or even their local council communities to manage the coastline, thus illustrating the proximity with which they consider the solutions must be found.

Since 2017, SNGITC emphasizes people's and properties' vulnerability to marine submersion and coastal erosion along with spatial restructuring. Through SNGITC, the state offers several scenarios to face coastal erosion. During this study, the respondents were questioned on the knowledge they had of these scenarios (Fig. 6). The intensification of coastal defenses is the scenario the respondents know best (79%) and the best one for their town for 51% of them. Relocating constructions is the second most well-known scenario (65.8%) but it is also the least popular (17.2%). Only 16.7% of the inhabitants have already heard about the "do nothing" scenario. The answers are about the same in all study areas.

### b. *The scale of the living place: Place attachment and vulnerability of coastal erosion*

#### 1) THE INHABITANTS AND THEIR PLACE ATTACHMENT

The territorial anchoring of the population was measured through the place attachment scale (Hidalgo and Hernández 2001), as well as questions about the reasons for this attachment, including the attachment to one's neighborhood (Fig. 7). 77.7% of the respondents like living in their neighborhood "enormously" and 59% say they are "enormously" attached to it. Whether it is the time spent in the current accommodation or the place attachment, the $\chi^2$ test is highly significant and the ANOVA calculation testifies to significant differences between the three study areas, which enables us to isolate Noirmoutier Island from the other two on these same variables; 53.8% of the respondents declare they would regret moving out of their neighborhood. Four reasons can be noted to explain the respondents' choice of residence: the closeness to the sea (74.2%), the quick access to the sea (69.3%), the landscape (74.4%), and the weather (75.8%).

Pearson's correlation tests led us to identify relationships between variables so as to better understand the overall dynamics. First, as the scientific literature shows (Kyle et al. 2004; Scannell and Gifford 2010; Low and Altman 1992; Devine-Wright 2013; Bonaiuto et al. 2016) place attachment increases positively and significantly with age ($r = 0.28$; $p < 0.01$), as well as the time spent in the residence ($r = 0.24$; $p < 0.01$) and the town ($r = 0.25$; $p < 0.01$). Place attachment would be boosted or reinforced by the length of time spent in the town. In the same way, risk perception correlates significantly, even if weakly, with place attachment (Table 2), and it also correlates positively and significantly with the negative emotions presented above. The more attached to a place people are, the more sensitive to erosion risk they become. However, this relationship is complex since the correlation between erosion risk perception and the time spent in the town (age, time spent in the residence and town) is negative, that is to say the younger people are and the less they have lived in the town, the more they feel vulnerable to erosion risk.

#### 2) THE EVOLUTION OF EROSION RISK PERCEPTION AND CARTOGRAPHIC SIMULATION

A map was added at the end of the survey (area simulation in 2100—IPCC RCP2.6), which allowed us to question the respondents on choosing managed retreat as a possible coastal management strategy. It aimed to question risk perception again after learning new information thanks to the map (erosion scenario in 2100) in order to assess if people could change their mind. To complete this assessment, an emotion scale was given. Four emotions were then felt, which correspond to reflex behaviors: concern (42.8%), sadness (36.6%),

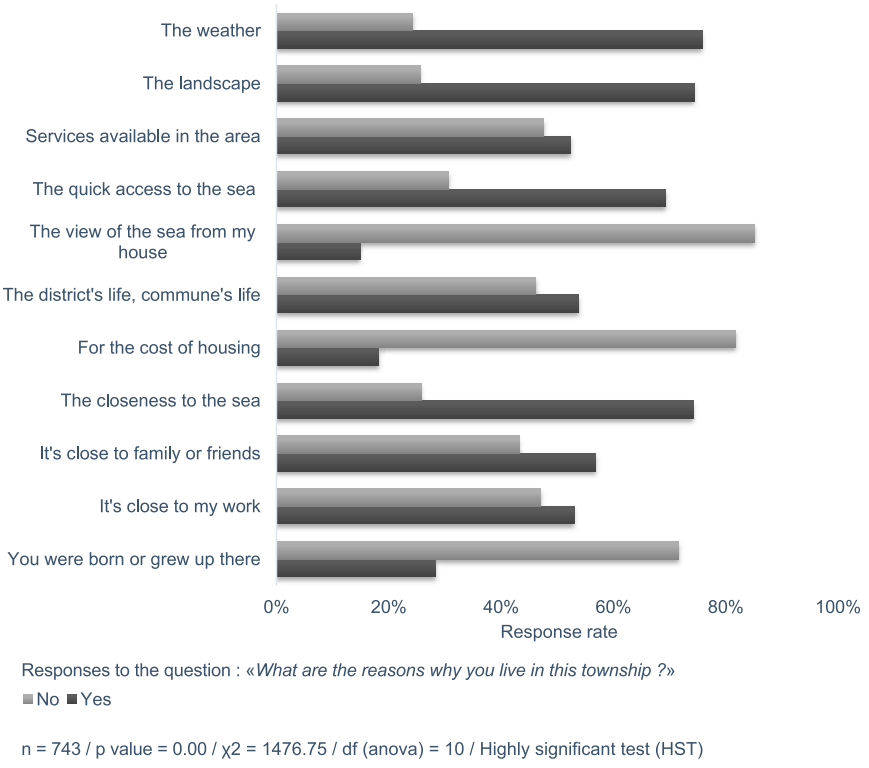



FIG. 7. The reasons to explain the respondents' choice of residence.

fear (26.5%), and anger (25.1%). On the other hand, emotions related to one's capacity to think an opinion, which are linked to decision-making, were rejected. Indeed, for 87.3% of the respondents, this map does not make them want to change where they live, and 74.7% of them are not skeptical about the shown scenario. However, the feeling of being personally exposed to coastal erosion or vulnerable because of risk perception increases after seeing the map. A Student's *t* test permitted us to compare the before and after (seeing the map) scores because of the following question: "Am I feeling personally exposed to coastal erosion?" The difference is significant: $M_{\text{before}} = 2.19$, $M_{\text{after}} = 2.34$, and $t = 48.153$, with $p < 0.001$; 47.2% of islanders feel more exposed, that is to say, an increase of 13.1% and 23.9% of mainlanders, which is 6% more than at the beginning of the survey.

## 4. Discussion

This survey's results show that the closer the respondent lives to the coastline, the greater his knowledge and perception of the risk, as noted by Ruz et al. (2020) and by Navarro et al. (2021). For confidentiality reasons, the respondents did not indicate their precise place of residence, but only the commune they live in. Thus, it is possible, on the scale of the sample, to know if the inhabitants of the most exposed communes have a better knowledge of coastal risks than an inhabitant of a commune farther from the sea. Contrary to other studies (Ruz et al. 2020; Navarro et al. 2021), this one also shows that the dissemination of general information on coastal risks, climate change and its consequences on the coast, more important in coastal territories, contributes to a more detailed knowledge of coastal risks among residents. At the national scale, the question is more and more topical and debated publicly and this may explain the differences in results between studies with 10-yr gaps in publication dates. Even if the knowledge is imprecise, it is present: in France, the implementation of the National Strategy of Coastlines' Integrated Management in 2012, which followed the Grenelle de la Mer project (2009) and Cyclone Xynthia (2010), participated in raising awareness about coastal risks in a

TABLE 2. Correlations between risk perception and emotions. Here, one and two asterisks indicate a significance level *p* of less than 0.05 and 0.01, respectively.

| | Negative emotions | Attachment to place | Age | Residence time in the municipality | Residence time in the housing |
|---|---|---|---|---|---|
| Perception of erosion risk | 0.380** | 0.089* | −0.138** | −0.131** | −0.115** |

much more efficient way in the last 10 years. Local strategies of risk management implemented on territories posing an important risk [territoires à risque l'important (TRI)] become operational thanks to one or more action plans. They define the list of precise actions related to several spheres of flooding risk prevention policies including proactive information, education and risk awareness. These various strategies, studies, and public debates lead to a better understanding or at the very least to a population more involved in preventing these phenomena, especially when the question is comprehended on coastal territories. This precise analysis is more important when dealing with marine submersion risk than coastal erosion. This is confirmed by another study, which was realized as part of an interdisciplinary project founded by the University of Nantes, called Evaluation of the Vulnerability and Adaptability to Coastal Risks (EVADRISk), a psychology/geography comprehensive approach; Lemée et al. 2019). This qualitative approach was based on location, since each respondent was chosen because of their accommodation's exposure to one of these risks. Marine submersion probably represents a known risk for the respondents because of their previous experience with Cyclone Xynthia in 2010. Several studies have indeed shown that previous experience can contribute to enhancing risk perception (Keller et al. 2006) or at least to modify population's representation (Giordano et al. 2010). Yet, these last few years, several portions of the coastline retreated because of coastal erosion on Noirmoutier Island. This may be an element highlighting how specific this territory's results are in comparison with the gother two areas chosen for this study. Other reasons may explain the differences between the island and the two other territories: the proximity to the sea and therefore to the risk of coastal erosion is more important for the inhabitants of the island of Noirmoutier than for others. In the other two territories, some of the inhabitants interviewed lived farther from the sea and therefore had a lower level of risk apprehension. Another interesting element is that on the island of Noirmoutier, an environmental protection association has existed for a long time. It organizes conferences and publishes articles in the press to make the population aware of the risks. This communication contributes to increasing the knowledge of the population's perception of risk and may explain the differences between the territories. The results of this survey confirm the need to organize adequate communication at the local community level, as several authors have already pointed out (Fischhoff et al. 1993; Sjöberg 2002; Weichselgartner et al. 2016).

At the same time, the island's vulnerability sometimes results in important and regular damage, whether it is linked to marine submersion or erosion, and in particular dune crests behind which urbanization developed. Some sectors have equally been struck by these phenomena on Cap Atlantique and Pays de Saint-Gilles-Croix-de-Vie local council communities but in a more limited way. It is also worth noting that this survey focused on permanent residents, which explains that, for numerous variables, the answers are relatively homogeneous, as opposed to what has been shown by other studies who did not necessarily distinguish between permanent and secondary residents [like Rey-Valette et al. (2012) or even Claeys et al. (2017)].

Another interesting result is that respondents do not feel personally worried. It is difficult to talk about risk denial since no precision about the place of residence was required except for the obligation to live in the area surveyed. Consequently, it is impossible to know the proportion of inhabitants living near the seashore or a potential erosion risk. Such surveys exist (Ruz et al. 2020), but the approach is different, more qualitative, with the sought-after result focusing on housing, its vulnerability, and the participants' representations. In the present study, this survey aimed at grasping coastal risk perception on a bigger sample, at the scale of a coastal local collectivity that is the scale of land management in France, in order to understand the way people consider coastline management scenarios without a precise place of residence interfering in the answers. To this end, the answers given are enlightening and the survey organization itself contributes to bringing more knowledge on how respondents perceive coastal risks. Another originality of this work lies in the presentation of a map of the territory at the end of the survey. This device induces representations and emotions related to this reality. The map forces the respondents to focus on their territory and leads to a notable change in the representations of the inhabitants concerning the vulnerability of their area and the strategies necessary to limit it. The answers to the questions asked after the presentation of the map make it possible to verify the information given at the beginning of the survey about knowledge of the risks. This is important in particular because "the risk and climate change management and adaptation policies introduce a concerted management at local scales which require information about the expectations and representations of the population" (Rey-Valette et al. 2012). This contributes to more largely diffuse information about the risks an area is confronted with and the consequences for its population.

However, the manifestation of one insular peculiarity is not the only result to be taken from this survey. Several other elements are worth noting since they contribute to placing the area with regard to long-term strategies to implement. For example, the respondents are relatively interested in "hard" solutions, like a riprap at the bottom of cliffs, a groyne, or a dike. On the other hand, beach restoration, dunes, or the presence of marsh are slightly less popular ways to protect the coastline. However, relocation is the strategy cited immediately after the intensification of coastal defenses (Fig. 6). There is, therefore, knowledge of this type of strategy among respondents, which shows the need for adequate communication and a relative urgency for the population to be informed of these devices.

If the respondents are aware of this type of strategy, the blockages remain important and the recourse to "hard" solutions persists in their mentalities. This phenomenon is perhaps due to the fact that "in the past, and to a very large extent still today, priority has been given to resistance to the sea. It is therefore the engineering techniques that have been decisive in what can be called a policy of marine erosion control" (Miossec 1998). In the Netherlands, "for more

than a millennium, Dutch diking and drainage techniques aim to dominate meteorological hazards by pushing back the sea" (Gueben-Venière 2015). The current context of climate change, the awareness of the costs generated by the maintenance of dikes and therefore the need to prioritize actions on certain sectors more than others, certainly contribute to changing attitudes. In addition, "softer" solutions, less disturbing for the natural environment, are increasingly used. However, the evolution of mentalities requires time and the use of an adequate sensitization of the inhabitants of the coastal zones.

## 5. Conclusions

The results of this study can help implement measures to boost the acceptance of coastline management strategies in the years to come. However, even if the survey shows that the population has a good knowledge of coastal risks, it would be useful to implement more qualitative surveys (e.g., Ruz et al. 2020; Navarro et al. 2021) to specify the place the inhabitants' housing location in order to understand to what extent the distance to the coastline can explain a more refined perception of coastal risks among these respondents. This result could help territorial managers to set up more effective communication and contribute to a better acceptance of the adaptation strategies envisaged in these territories. This is essential because the questionnaire shows that "hard" solutions, such as dikes, groynes, or breakwaters, are still very popular. Local authorities must get residents to understand that the temporalities of coastal dynamics are different from those of elected officials and that we must go beyond the idea of using methods that seems to reinforce the security of property, but only in the short term (Veyret 2016).

This knowledge could influence the acceptance of coastal adaptation strategies that will be carried out on the Pays de la Loire coast by 2030. In September 2021, the OR2C has conduct studies to strengthen territorial diagnostics (i.e., prospective studies of coastal hazards and vulnerability by 2050). Three territories were selected within the project led by Association Nationale des Elus du Littoral (ANEL)/CEREMA, the goal of which is to provide help to organize an anticipated management of coastal risks (https://www.cerema.fr/fr/appel-partenaires-gestion-integree-du-littoral). Other territories intend to experiment managed retreat or nature-based solutions as part of the European Green Deal project (https://www.bdi.fr/fr/lappel-horizon-2020-green-deal-est-publie/). These solutions based on nature may imply relocating equipment or even restructuring coastal areas greatly (Observatoire National sur les Effets du Réchauffement Climatique 2019). Thus, this type of survey plays an essential part since it enables the experts and stakeholders to understand the nonexperts' perception so as to adapt to the best of their abilities speeches and actions to implement in the years to come (Moser et Dilling 2011). This article underlines the interest in combining a quantitative approach such as this survey with a more qualitative approach to complement this work. As suggested by Weichselgartner et al. (2016), highlighting cultural aspects specific to each territory and, in particular, to work on the attachment of place (Bonaiuto et al. 2016; Scannell and Gifford 2010) would make it possible to explain the postures of individuals but also of the community as a whole with regard to the choices of adaptation strategies that the community wishes to make.

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*Data availability statement.* The dataset on which this paper is based is too large to be retained or publicly archived with available resources. Documentation and methods used to support this study are available from author Marc Robin (marc.robin@univ-nantes.fr) at the University of Nantes.

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