Managed retreat of settlements and infrastructures: ecological restoration as an opportunity to overcome maladaptive coastal development in France

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Running head

Restoration opportunities through managed retreat

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TF conceived, designed, and wrote the paper; MT, NF made additional contributions and edited the manuscript.

Abstract

The effects of climate change on coastal risk factors are increasing due to both rising sea levels and increasingly intense coastal floodings. However, these changes are only just beginning to be incorporated into planning strategies for coastal economies and land use in France. Recent coastal storms marked the turning point, and public authorities have now started to revise coastal management legislation, stating that the managed retreat of settlements and infrastructure is the preferred strategy to adapt to climate change. To date, this managed retreat has almost exclusively been discussed in relation to the current political, social, and economic obstacles that make it difficult to relocate equipment and houses inland. Here, we add to this discussion by depicting how the careful ecological restoration of dunes and salt marshes on land made available by managed retreat could overcome some of these obstacles. First, we describe three possible strategies to adapt to sea-level rise as well as the maladaptation of the current strategy. We then focus on the limitations and advantages of ecological restoration in terms of managed retreat and vice-versa. Finally, we depict how a new kind of land lease, introduced in draft legislation, can help tackle the multitemporal and multispatial issues that currently hinder managed retreat.

Key words

Adaptation, land use, marine submersion, restoration, sea level, social–ecological

Implications

- If restorationists do not neglect the social issues that accompany managed retreat, they have a major opportunity to create, restore, and conserve dune ridges, salt marshes, and their associated ecological communities on coastal land made available by managed retreat.
- Drawing from adaptive management, draft legislation introduces “zones of

authorization for resilient and temporary activities" that can help serve as an example of adaptation to sea-level rise for coastal land use acts in other countries.

Main text

INTRODUCTION

Sea-level rise (SLR) will have major consequences for populations in low-lying coastal areas (Wong et al. 2014). Despite the uncertainties surrounding the expected speed and magnitude of SLR (Carson et al. 2016; Cazenave & Llovel 2010), it is very likely to exacerbate long-term adverse impacts of storm surges and coastal floodings (Wong et al. 2014). Adaptation policies must therefore be developed to provide strategies for coping with the effects of global warming on coastal areas. Defined as "adjustments in ecological, social, or economic systems in response to observed or expected changes in climatic stimuli and their effects" (Adger et al. 2005), strategic adaptations can be considered to be either reactive (e.g., building dams or dikes after coastal flooding) or proactive. Proactive adaptations are measures taken to lessen the perceived negative impacts of future events (Engle 2011) such as prohibiting housing construction in future coastal flood-prone areas. In France, SLR and its consequences are an extremely important issue because the country's coastlines are of great ecological and economic value (Van Der Maarel 2003; Wong et al. 2014). Indeed, coastlines can be seen as four interconnected subsystems: sediment cells of beaches, coastal municipalities, management paradigms, and oceans, for which the spatial extent and temporal scales are shown in Table 1.

France was affected by an almost unprecedented winter storm (storm Xynthia) in 2010, which resulted in 47 fatalities and property damage estimated at €1.5 billion. More winter storms three years later exacerbated erosion and damaged man-made structures (Rocle & Salles 2017; Cour des Comptes 2010). Such winter storms diminish atmospheric pressure enough to raise the local sea level and trigger marine submersion (Wong et al. 2014). The fatalities and property damage caused by these storms and consequent flooding led to a national revision of coastal policies to take safety and environmental issues into consideration (Rocle & Salles 2017). Members of the French Parliament are currently debating updates to coastal land use laws in an attempt to introduce legislative levers that favor adaptations to SLR (Lurton et al. 2017).

In this paper, we focus on a coastal adaptation strategy known as managed retreat (MR), which is encouraged in the new draft of the coastal act. MR is sometimes called “planned retreat” or “managed realignment” and involves an inland relocation of infrastructures currently located on low-lying coastal land (e.g., coastal protection infrastructure, houses, industrial and commercial areas), which is at risk of coastal flooding (Heurtefeux et al. 2011). For example, a seafront road was relocated 40 meters inland between 2007 and 2012 in Sète, a coastal municipality in southern France (Heurtefeux et al. 2011). In France, MR is of particular interest, especially for 25% of the country’s coastlines with observable erosion (around 1,700 km, of which around 1,150 km are low-lying sand coasts) (Mineo-Kleiner 2017), as the retreating coastline draws nearer to infrastructure and jeopardizes it.

We begin here by analyzing the persistent blockages of MR in certain areas. We then present several precautions in order to preserve mutual social and ecological benefits of MR and ecological restoration. Finally, we describe how the renewal of the coastal act presents an opportunity for MR and the ecological restoration of low-lying coastal areas.

We first base our assessment on a review of i) peer-reviewed articles from ecology, economics, geography, and political science journals, mostly published in French since storm Xynthia (2010). We complete these sources with ii) the minutes of meetings on coastal flooding management involving governmental agencies such as the “Conservatoire du Littoral” (body responsible for preservation of the French coastline) and the “Cour des Comptes” (French supervisor of public subsidies) from the same period, as well as iii) European reports on erosion and coastal adaptation to SLR strategies published since year 2000. The review results were supplemented with an exploratory field visit of Port-des-Barques in March 2017, a municipality affected by storm Xynthia in Charente-Maritime (Fig. S1), as well as personal communication with coastal land use planners.

1. FRENCH COASTLINE PLANNING IS MALADAPTED TO THE EFFECTS OF EXPECTED CLIMATE CHANGE

Three strategies to adapt to SLR and marine submersions

The effects of winter storms are expected to be exacerbated by climate change-related SLR, and although sea-level estimates for 2030 do not exceed 0.07m, they vary between 0.35m and 1m for 2100 (Lurton et al. 2017; Vinchon et al. 2011).

Allison and Hobbs (2004) suggest three broad options to adapt to such crises, with different intervention intensities. For municipalities that seek to prevent coastal disturbances, the most interventionist strategy is “command and control,” which involves a community actively fighting coastline erosion through the heavy use of technology. This strategy has been used in France in recent decades (Table 1), with the construction of coastal defences such as dikes, groins, seawalls, and geotextile tubes (Touili et al. 2014; Clément et al. 2015). Making “adjustments” through more gentle interventions (e.g., alert systems, insurance systems, flood-proof buildings) is the intermediate strategy (Cour des Comptes 2010). “MR” is the third and least interventionist strategy regarding erosive processes. Relocating sea-front housing, economic infrastructure (e.g., industrial areas, roads, factories), and strategic buildings (e.g., hospitals, fire stations) means that humans reduce their impact on the coastal ecosystem and adapt to the disturbance instead of repelling it; in this way, MR differs from the default position of doing nothing and corresponds to adaptive management principles (Engle 2011).

By relying on the expensive "command and control" strategy, French shorelines are on a maladaptive trajectory, as erosive processes and natural disasters are enhanced by climate change. To date, technological interventions have indeed disrupted beach accretion, and less sediment has been delivered to coasts because of the trapping of riverine sediment behind dams and the diversion of water for irrigation (Wong et al. 2014). Defensive structures dissipate wave energy by causing upwelling and decreasing the amount of sediment deposited at a particular location, thus resulting in down-drift erosion at other locations. Coastal defences therefore need to be constantly extended at a high cost to human lives and society.

French coastal municipalities persist in the "command and control" strategy

Here, we identify the economic, political, and social obstacles that compel local decision-makers to abide by their current maladaptive strategy of coastal armoring.

Economically, insurance companies supported the recovery of coastal inhabitants after storm Xynthia. In France, these companies reimburse policy holders for damage caused by natural disasters using money collected nationally from car and home insurance premiums (Clément et al. 2015). However, the demand for financial compensation is likely to increase unsustainably, because increasing numbers of people (due to the demographic pressure on coastlines) will be exposed to more frequent and intense coastal flooding (Lambert 2015). This economic connectedness of people through their insurance policies is accompanied by the connectedness of the state and affected municipalities, as the former partially funds the reconstruction of the latter. Coastal recovery was indeed strongly supported by public subsidies following storm Xynthia. For instance, one of the main areas affected by storm Xynthia, the Charente-Maritime department (Fig. S1), launched a €750,000 television advertising campaign to promote beach tourism, stating that the area would recover and be ready for the summer vacation period. Another €3 million was spent on restoring sea defences and sand replenishment (Anziani 2010). Such sea defences are contrary to the principles of MR because the authorities could simply wait for the land to become permanently submerged and then claim it as a public maritime domain, a procedure similar to the United States' "rolling easement system" (Siders 2013). Both the tourism-based economy and the financial connectedness between inland and coastal territories participate in maintaining this maladaptive "command and control" management, because the need for taking SLR into account is continually postponed.

Socially, the reluctance to change can explain how maladaptive individual and collective behaviors hinder adaptations to SLR. As a coastal community grows and becomes richer, it will apply increasing pressure on local decision-makers to choose sea defences as opposed to MR. For instance, following storm Xynthia, the inhabitants of Charente-Maritime demanded for dikes to be built instead of demolishing vulnerable houses (Mineo-Kleiner & Meur-Ferec 2016). Sea defences support a false sense of security, causing counteradaptive misperceptions of risks (Mineo-Kleiner & Meur-Ferec 2016). For instance, fatalities could have been avoided if inhabitants trapped in flooded houses had felt vulnerable enough to participate in prevention programs and learn to keep their shutters open, thus allowing for an emergency exit (J. Laugraud, ex-mayor, personal communication). Ultimately, the pressure to build sea defences was applied to mayors, some of whom see coastal land use as an electoral lever through employment and population growth. Local political mandates last for 6 years in

France, which is short relative to the time required for a return on investment in MR. Maladaptive policies therefore fail to reward investment in MR, because benefits are only perceived in the future (Abel et al. 2011).

The self-reinforcing first strategy of “command and control” calls for a renewal of recent French coastal policies. So how can MR be an opportunity to implement coastal ecological restoration?

2. CAN MR BENEFIT ECOLOGICAL RESTORATION AND VICE-VERSA?

By releasing land, MR can be a chance to create, restore, or preserve coastal ecosystems, as long as care is taken to respect the balance between socio-economic issues and ecological considerations.

Benefits and precautionary measures of MR for ecological restoration

Above all, MR favors ecological restoration by providing habitats for coastal species: the creation, restoration, and conservation of dune ridges and salt marshes benefit coastal plant communities by preventing beaches from steepening and foreshortening (Feagin et al. 2005). MR also improves species resilience to climatic fluctuations by providing habitats for species to recolonize neighboring areas that have become eroded or destroyed (Adger et al. 2005).

It is also essential to avoid potentially counterproductive measures of MR in terms of ecological restoration. If the target site has been recently damaged, land released through MR will initially require work to bring it back to the desired environmental trajectory. For soil that has been brought into an artificial state before MR or mechanically disrupted during the demolition of infrastructure during MR, doing nothing favors common species at the expense of species of ecological interest (Affre et al. 2015). Anthropogenic interventions try to accelerate ecological recovery at a target site, as illustrated at the Sète lido, where 300,000 marram grass (*Ammophila arenaria*) seedlings were planted (Vinchon et al. 2011). To improve respect for the site, newsletters and liaison groups were used to explain to visitors why MR is important (Dixon et al. 2008).

On coastlands affected by MR, there may also be species that are protected or of ecological interest. Cases have been reported in which translocation and rescue programs for plants and animals were considered necessary for MR to be successful (Dixon et al. 2008).

Above all, MR involves relocating infrastructure inland, which means that natural or agricultural land away from the coast is at risk of being artificialized. Indeed, the land shortage in France impedes the relocation of houses and equipment to unaffected land (Mineo-Kleiner 2017). There are legal safeguards to avoid displacing urbanization pressure and destroying natural soils such as the prohibition to build on preserved land and injunctions to relocate within urbanized areas. Yet political arbitration between the various sources of local pressure on land makes the task complex, especially since electoral mandates are relatively short (Table 1).

Ecological restoration assets favoring MR

Inversely, ecological restoration presents beneficial side effects for MR. For instance, the revegetation of newly cleared land restores sediment cycling. Dune ridges and salt marshes are ecosystem-based reducers of destructive wave energy, which protect the land (Temmerman et al. 2013). Coupled with wave-breaking plants such as sea grass (*Posidonia oceanica*) and eelgrass (*Zostera marina*), ecological restoration as part of MR permits the effective adaptation to coastal erosion and flooding (Temmerman et al. 2013).

Instead of emphasizing restoration constraints, publicizing the benefits of natural processes for MR encourages stakeholders with potentially contrasting interests in environmental issues to work together. For example, the restoration of coastal marshes simultaneously increases biodiversity, stores carbon, and limits seawater intrusion (Temmerman et al. 2013; Mossman et al. 2012). Consequently, a relevant integration of the beneficial side effects of MR fosters the transition from a static perspective of biodiversity to a "monitor and adapt" management system (Table 1).

Limitations of MR due to ecological restoration

Dedicating released land to ecological restoration alone endangers the social acceptability of MR. This can be counteracted by fostering tourism-based employment that relies on the use of light infrastructure (e.g., moveable buildings on stilts) (Mineo-Kleiner & Meur-Ferec 2016). From this perspective, most MR scenarios include an economic appraisal of the released land by coupling the project with low-impact economic activities. Based on experience, the touristic valuation of restored coastlines is compatible with environmental processes. In terms of cleaning up beaches, it is possible to retrieve non-organic waste alone or leave foreshore tide marks untouched until tourists start frequenting the area. This favors nucleation and the accumulation of sand on dune ridges, because it maintains the supply of organic material to feed dune vegetation and allows sand sequestration (Temmerman et al. 2013; Lambert 2015; Wong et al. 2014). Touristic valuation also sometimes relies on shuttle buses linking beaches to parking lots that no longer stand close to the seaside because of MR.

3. A DRAFT LAW TO OVERCOME MULTISCALE OBSTACLES TO MR

MR has been described as a cost-efficient long-term means of coping with the effects of SLR (Abel et al. 2011), and the obstacles for its adoption are well documented. So how can the draft legislation help French coastal municipalities implement MR?

The rise of MR in research programs

After storm Xynthia in 2010, the stakeholders who clamored for changes in coastal policies were mostly insurance companies and the Cour des Comptes, or in other words, those paying for the restoration. Public agencies and insurance companies try to refine their decision-making by investing in efforts to decrease uncertainty (e.g., SLR celerity, recovery costs after marine submersion). Consequently, scientific projects were launched in France to learn lessons from storm Xynthia (Vinchon et al. 2011). The Sète lido was involved in a call for proposals and partly changed from a "command and control" strategy to MR. This 12 km long and 2 km wide strip of sand, which is very popular with tourists, separates the sea from a lagoon on the south coast of France (Fig. S1). The lido also hosts an economic asset: the renowned Listel vineyard, which has been subjected to severe coastal erosion (Heurtefeux et al. 2011). A seafront road was relocated between 2007 and 2012 to allow the sand dunes to recover. The dunes were made more stable using bundles of brushwood, and they now protect the lido (Heurtefeux et al. 2011). MR was partly made possible, because the demand for income from tourism and the support for the well-being of inhabitants, linked to the stability of the beach, were strong, and because no houses had to be relocated (Mineo-Kleiner & Meur-Ferec 2016). This rare case of MR is distinguished on account of its foresight and long-term investment (MR cost of €54 million). Interestingly, the French state, which previously granted maladaptive public subsidies for the reconstruction of sea defences, now funds experimental MR. This small change points out to a transformation in the representation of human interventions on ecosystems, from a static perception of coastlines to adaptive management practices (Table 1), which are now echoed in the draft legislation.

What can a new law do for MR?

The law entitled "Adapting coastal territories to climate change" is currently being passed by the French Parliament (Lurton et al. 2017). Drawing from research outputs such as Sète's results, draft legislation was developed. It is also based on experimental findings from other countries, thanks to exchanges with the UK Environment Agency (Pontee 2007; Creed et al. 2014; Rocle & Salles 2017). The law will introduce "zones of authorization for resilient and temporary activities," a new type of land lease designed for vulnerable coastal strips. These leases will last between 5 and 99 years, and tenants will be required to leave when the risks exceed a threshold indicated in a prevention plan (Lurton et al. 2017) – hence the legislative interpretation of "resilience" for labile and removable activities (e.g., windsurf schools). Ultimately, the law will also define a "coastline mobility zone" in which natural barriers (e.g., salt marshes and dune ridges) are preferred over manmade sea defences. Governance mechanisms have been designed for a smooth transition to MR, drawing on an economic study of MR cost sharing (see, for example, the insights from a willingness-to-pay analysis in Rey-Valette et al. [2016]).

The originality of this draft law is its acknowledgement of the complex social and ecological interdependancies of coastal subsystems with their different spatial and temporal scales (Table 1). With the new type of lease, the draft legislation offers an innovative tool to implement MR as a multiscale "no-regret" solution to SLR. Focusing on the level of coastal municipalities as the main constraint to MR, the decision to end new leases is not motivated by a temporal deadline but instead by a risk threshold that functions as lever against the temporal uncertainties of SLR.

Moreover, the draft does not set aside the financial crux of MR. The inclusiveness of ecological restoration as a solution to problems of different spatial scales makes it possible to attract various funding, especially when public spending is restricted. Obtaining money from more sustainable sources than public subsidy alone could also help overcome the reluctance of the private sector to become involved. As a land restoration approach, MR has a legitimate place in land use policies when compensating for flood defence and port projects, as investigated (with mixed success) in England (Dixon et al. 2008). Salt marshes formed through MR comply with the criteria from the European Fisheries Fund, because they act as nurseries for fisheries (Dixon et al. 2008). Funding also exists from schemes to protect the connectivity of an area, provided that MR meets the requirement of achieving a good ecological status. The integration of greenhouse gas removal into the European 2030 climate and energy framework is currently underway, setting the stage for possible financial retribution of carbon stocking by MR.

DISCUSSION AND CONCLUSIONS

In our view, the success of MR relies on the inclusion of socio-economic issues in ecological restoration. Coastal municipalities make use of technology (dams, dikes, etc.), anticipate recurring events (marine submersion, storms), and display continual interactions between human and non-human agents on various spatial-temporal scales. Thus, they can be qualified as social-ecological systems, because these processes lead to their establishment, maintenance and reorganization in a form that would otherwise not exist, influencing their capacity to adapt to the effects of SLR (Gunderson & Holling 2002; Sanderson et al. 2016). From this perspective, and because MR is first intended for human groups and initially depends on external economic inputs, it can be considered to be a social-ecological restoration (Fernández-Manjarrés et al. 2018). Importantly, this should not be regarded as the intrusion of social issues into ecological restoration, but on the contrary, as an opportunity for ecological restoration to integrate a utilitarian adaptation to climate change.

To support the draft law, a relevant holistic narrative could reveal how interlocking economic, political, and social impediments to local change can be addressed using an imperfect, but promising solution: MR. Panarchy, for instance, combines results on various spatio-temporal scales and from various disciplines (economics, ecology, and others) in a single framework. Unlike hierarchical descriptions of top-down systems, panarchy describes the dynamics of nested natural and social systems that interact in creative, destructive, and evolutionary ways. Each system experience growth and a subsequent stabilization, followed by a collapse phase triggered by an external disturbance (in the case of MR, the interacting subsystems could be those decribed in Table 1); the system can then reorganize and start the cycle again (Gunderson & Holling 2002). Albeit its essentially descriptive approach of social-ecological systems, panarchy is of great help if used in combination with explanatory theories, and has been applied in various research fields including forestry and archeology and other coastal social-ecological systems (Kharrazi et al. 2016; Sanderson et al. 2016).

Incentives to switch to MR (i.e., protecting lifes, saving money, restoring ecosystems) are still too weak before the conservative wait-and-see strategy, because of the strong recovery processes and cognitive biases, and because organizations tend to wait for technological developments (Clément et al. 2015; Rey-Valette et al. 2012). Improving the acceptability of MR and ecological restoration as no-regret opportunities is a way to trigger change.

Anticipation is the key to transforming the system, and active territorial planning in the French context is a step in this direction (Lurton et al. 2017; Adger et al. 2005; Abel et al. 2011). Unlike in the United States, which has market-driven coastal land-planning policies, the cultural preference in France is for territorial projects with a holistic approach, designed with and by the public authorities. This benefits the implementation of MR (Siders 2013; Mineo-Kleiner & Meur-Ferec 2016), supported by the positive outcomes of ecological restoration.

These particularities of the current context indicate that ecological restoration offers multiple advantages for MR and that the path to adapting the effects of climate change on coastlines is steep but straight.

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Tables

Table 1

Current social-ecological environments of French coastal municipalities with their spatial and temporal scales. Characteristics and scales inspired by Wong et al. (2014), Feagin et al. (2005), Carson et al. (2016), and Mineo-Kleiner (2017).

	Beach sediment cells	Coastal municipalities	Management practice	Ocean systems
Nature of the system	Biophysical transport of sediments	Social and economic development strategies in municipalities with seafront access	Mental representations of human interventions regarding ecosystems	Climatic cycles of oceans
Spatial scale	1–10 km	5–20 km	France	Planetary
Temporal extent under current functioning	Years	Municipal mandate (6 years)	10–50 years	Geological times, 10^4–10^6 years
Indicator of change	Accumulation of sediments	Population growth and seasonal affluence of visitors	Prevalence of knowledge and representations of management practices	Sea level
Indicator of resilience	Seasonal return of beach vegetation	Return rate of population and visitors after disturbance	Ability of the current values to keep leading coastal policies	Latence time needed to return to pre-industrial periodic oscillations of geological climate
Former state of the system	Balance between erosion and sediment accumulation	Plans for tourism development, population growth, gradual institutionalization of conflict resolution through property rights or coastal laws	Command and control	Pre-industrial sea level
Current state of the system	Coastline retreat	Coastal armoring, tourist and transportation saturation, with degradation of tourist resorts by winter storms	Static perception of coastline land use (no influence of environmental changes) with conflicting rules and consolidated institutions	Sea-level rise
State of the system under managed retreat	Dune and salt marsh revegetation	Managed retreat economy: beach tourism, outdoor recreative coastal usage	Adaptive management of climate change, “monitor and adapt” approach	Uncertainties, but projected higher sea levels and disrupted marine streams