

Climate-driven depopulation and adaptation realities in America's coastal ground zero

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With global temperatures poised to exceed the 1.5 °C Paris Agreement threshold—a level that triggered substantial ice-sheet collapse during the Last Interglacial—low-elevation coastal zones face sea-level commitments far beyond current planning horizons. With this geological frame of reference, we examine the impact of sea-level rise on what may be the most physically vulnerable coastal zone in the world using prehistoric and contemporary patterns of human mobility. We highlight the positive aspects of the recently commenced out-migration in this region and argue that the fate of communities landwards of this coastal zone will be decided in the next few decades.

Low-elevation coastal zones (LECZs), defined herein as regions subject to 1-in-a-100-year coastal floods, are among the most physically vulnerable environments on Earth due to climate change and other human-induced stressors. This exposure has been amplified by increased human migration towards the coast. The current global population number for areas below the high-tide line has been estimated at 110 million, but it may increase to 630 million by 2100 under a high-emissions climate scenario¹.

Coastal Louisiana has been referred to as a 'canary in the coal mine' with respect to climate impacts. As highlighted in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the central US Gulf Coast is the single most exposed LECZ in the world in terms of projected relative sea-level (RSL) rise throughout this century² (Fig. 1). Research in the Mississippi Delta (southeast Louisiana) has shown that the threshold rate of RSL rise for coastal wetland drowning in this area is about 3 mm yr⁻¹ (ref. 3), a rate that was surpassed (in terms of global mean sea-level rise) about 20 years ago⁴. Therefore, widespread conversion of this LECZ into open water is probably unavoidable, and the most recent assessment⁵ suggests that a loss of 75% of the remaining -15,000 km² of coastal wetlands by 2070 is a plausible outcome under Shared Socioeconomic Pathway 2-4.5 (SSP2-4.5), the current approximate climate trajectory. This unprecedented and increasingly RSL-driven wetland loss is placing >1 million inhabitants in harm's way³.

Given the inevitable transformation of coastal Louisiana from land to sea, this Perspective contextualizes the mechanisms that are

likely to shape the spatial transition of existing populations to high ground. The initial impetus consists of new evidence that RSL in this region is probably committed to 3–7 m of future rise, with a shoreline bound to migrate as much as 100 km inland. We argue that future RSL rise to this elevation—judging from field evidence rather than climate model output—is, in fact, a best-case scenario. Climate-driven human migration modelling is at an early stage of development that is unable to internalize such a drastic shift in coastal geography. Therefore, we take an inverse approach to utilize both archaeological evidence of the migration of Indigenous people and geological palaeo-shoreline reconstruction to examine the spatial dimension of the possible future of human settlement in this region. We argue that a carefully calibrated combination of planning and coastal restoration can define the difference between orderly managed relocation and disorderly market-driven movement of people and their assets. Our overarching message is that the depopulation that is already under way in this region may yield long-term first-mover advantages. Indeed, Louisiana has a unique opportunity to lead the way in pioneering policies, plans and engineering designs that advance a more sustainable footprint in migrant receiving zones that provide lessons for physically vulnerable LECZs worldwide.

Past sea level as a key to the future

Our sea-level analysis takes us back to the Last Interglacial (LIG, -125,000 years before present), a time when global average temperatures were 0.5–1.5 °C higher than pre-industrial values (medium confidence)⁶.

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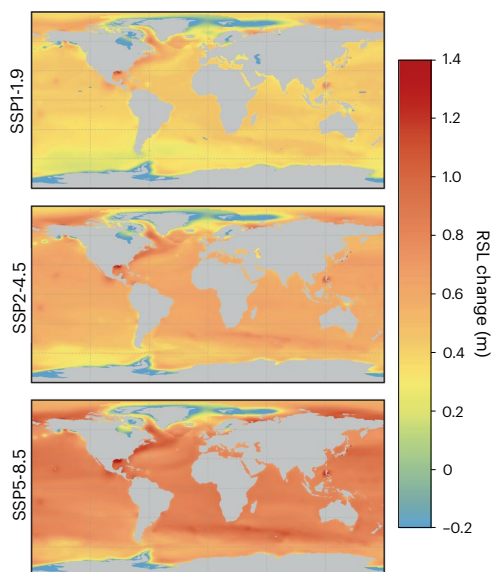


Fig. 1 | Sea-level projections for 2100. Magnitude of RSL change with reference to 1995–2014². Note the exceptionally high physical vulnerability of the central US Gulf Coast, regardless of the climate scenario. Data from refs. 2,77. Basemap and coastline data from Natural Earth (<https://www.naturalearthdata.com/>). Credit: Asif Hasan.

It has long been known that global mean sea level was considerably higher than present during the LIG, and the Sixth Assessment Report of the IPCC reports a likely range of +5 m to +10 m. As only -1 m of this rise can be attributed to sources other than the polar ice sheets, the IPCC concluded that “under past warming of the level achieved during the LIG (ca. 0.5 °C - 1.5 °C), it is *likely* that both the Greenland and Antarctic ice sheets responded dynamically over multiple millennia (*high confidence*)”². A previous special report by the IPCC⁷ pointed to a consensus that the contribution from Greenland was limited during the early stages of the LIG. Indeed, evidence from the Seychelles⁸ suggests an Antarctic contribution during the early LIG; the most likely source would be the West Antarctic sector⁹. This matters because West Antarctica would have a particularly large impact on sea-level rise in North America due to gravitational effects¹⁰.

The LIG is a critical benchmark for LECZs worldwide because it shows that levels of warming that are now being exceeded resulted in sea levels well above present-day conditions. The caveat is that LIG warming was driven by slow, millennial-scale orbital forcing rather than greenhouse gas emissions at unprecedented rates. With the planet now on the brink of surpassing 1.5 °C of warming, the possibility of much more rapid ice-sheet disintegration must therefore be considered. For example, it has recently been suggested that the ‘safe limit’ for ice sheets lies at or below 1 °C of warming¹¹.

A synthesis of LIG RSL data from the US Gulf Coast¹² shows numerous remnants of highstand shorelines stretching from Texas to Florida, but with a notable spatial gap in Louisiana that is attributed to erosion and subsidence. The sites closest to Louisiana exhibit inferred RSL elevations of +3.6 m to +7.2 m (central values, uncertainties up to -5 m)¹² (Fig. 2a). We assume that these features represent shorelines of maximum transgression during the LIG, and its remnants in Mississippi are located close to the modern shoreline (Fig. 2a). Here we present LIG RSL observations from southeast Louisiana that answer the critical question of where the LIG shoreline was positioned with respect to the most densely populated portion of the state.

The Ponchatoula Ridge consists of multiple east–west trending, shore-parallel, smoothly curving ridges with relief of -1 m (Fig. 2b) abutting the Pleistocene upland -50 km north of New Orleans (Fig. 2a). A cross-section perpendicular to this landform shows that it is underlain by 4–5 m of sandy deposits that transition sharply into mud (Fig. 2c). We

interpret the Ponchatoula Ridge as a palaeo-shoreline shaped by wave action; the sand body largely encased in mud exhibits a striking similarity to the late Holocene chenier ridges in southwest Louisiana. We dated the formation of this landform and obtained an LIG age (Fig. 2c). Using the Louisiana Chenier Plain as an analogue¹³, we estimate that LIG RSL in this region peaked at $+3.1 \pm 0.9$ m (Supplementary Information).

The reason that the inferred LIG RSL is lower than in adjacent regions is readily explained by deep-seated subsidence driven by the enormous sediment load of the Mississippi Delta. This includes faulting; the Baton Rouge Fault Zone is near the Ponchatoula Ridge (Fig. 2b). Investigations on multiple segments of this fault zone¹⁴ found a time-averaged rate of fault motion of 0.02–0.07 mm yr⁻¹. The implication is that the original RSL elevation was considerably higher, estimated here at $+7.5 \pm 1.2$ m.

Studies that provide a longer perspective on future sea-level change show that even under favourable emissions scenarios, global sea level may continue to rise for millennia¹⁵. In summary, and with the caveat that a timeline cannot yet be provided, it is expected that sea level in this region will continue to rise and at a minimum reach the level last seen during the LIG. Absent major action to curb emissions, the current warming is on track for 2.6 °C (1.9–3.7 °C) by 2100¹⁶. Thus, there is a serious threat that RSL will continue to rise above the LIG level, with a shoreline migrating even farther inland.

The geological reality that long-term static defence is physically impossible necessitates a shift towards relocation planning, with large impacts on people as the shoreline migrates well beyond the confines of today’s urban centres. A relevant enquiry is therefore to explore how humans have adapted to this rapidly evolving delta region in the past and how modern societies can employ this Indigenous knowledge. Thus, we examine how Native American populations were able to thrive in a landscape that even without accelerated sea-level rise would rank among the most dynamic environments on Earth.

Ancient patterns and modern parallels

Native American communities of the Mississippi Delta were hunter–fisher–gatherers who foraged from this exceptionally productive coastal plain¹⁷. Archaeological research suggests they innovated unique lifeways despite acute and chronic environmental hazards. Extraordinary amounts of *Rangia cuneata* clams were harvested, to eat and to elevate landforms, to build mounded platforms and monuments, and to create villages that were occupied for multiple generations. These were long-lived communities where select individuals placed their domestic and/or ritual structures that shaped long-term ecological histories, as demonstrated in similar portions of the American Southeast¹⁸. Mounded platforms and monuments made of earth and/or shell were typically situated on natural levees or crevasse splays, landforms that already exceeded the average elevation¹⁹. This created a coupled cultural–natural system that possessed some resilience to environmental threats, notably flooding^{20,21}.

The Mississippi Delta consists of a number of lobes (also known as subdeltas) that grew seawards sequentially over centennial to millennial timescales²². Previous investigations have shown that Native American settlement patterns shifted in close association with successive subdeltas²³. We build on this work and confirm that archaeological sites become progressively younger along the growth axis of subdeltas (Fig. 3). While Native communities continued to inhabit land even after delta growth had shifted elsewhere, the rapid occupation of the Lafourche subdelta after abandonment of the St. Bernard subdelta is striking—new settlements closely track the seaward-migrating shoreline (Fig. 3).

In summary, the spatiotemporal evolution of delta occupation shows that migration was an adaptive response by Native American cultures. We illustrate a few potential migration routes in Fig. 3 but stress that these are not based on explicit evidence that ties sites together and should not be seen as future migration routes. While

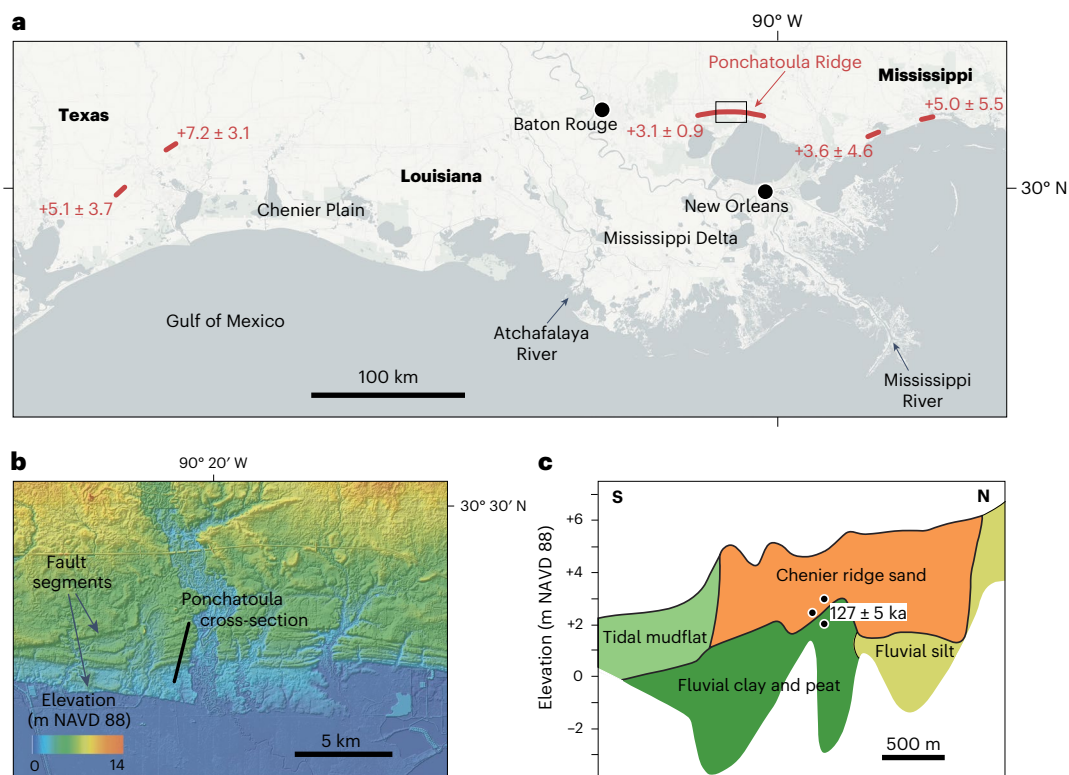


Fig. 2 | LIG highstand shoreline along the central US Gulf Coast. a, Previously reported palaeo-shoreline reconstructions and inferred RSL from Texas and Mississippi¹², plus the recently identified Ponchatoula Ridge in southeast Louisiana (all shown in red). **b**, Digital elevation model showing the Ponchatoula Ridge, which separates the low-lying Holocene delta plain to the south and the Pleistocene upland to the north (for location, see **a**). **c**, Cross-section over the Ponchatoula Ridge (location in **b**) with the age of chenier ridge sands and

associated deposits obtained by optical dating, in thousand years before present (ka). Elevations are referenced to the North American Vertical Datum of 1988 (NAVD 88). Further details about the stratigraphic analysis can be found in Supplementary Information. Basemap in **a** from Esri, TomTom, FAO, NOAA, USGS. Map data in **b** from the National Oceanic and Atmospheric Administration (NOAA)⁷⁸.

Native American populations were highly capable of responding to this rapidly changing landscape, this adaptive capacity reversed with the influx of Europeans, Old World models of land tenure, and the transition to static, place-attached rural and urban communities. Place attachment and rigid approaches to modern coastal settlement planning leads to socioecological ‘traps’ that are inconsistent with long-term sustainability perspectives²⁴, as our model for pre-contact Native American settlement patterns illustrates.

Figure 3 highlights the complex incremental steps within the broader arc of the adaptation of settlements to changing environmental conditions. In contemporary terms, managed relocation is not merely a function of moving populations from place A to B. Rather, it is a near limitless range of planned, incremental steps that speak to the sociocultural, economic and institutional complexities that shape our capacity for adaptive resettlement. Native American populations probably also faced complex sociocultural, economic and place-based attachments, but they had hundreds of years to negotiate the settlement and resettlement of the region. At present, we probably have hundreds of months to plan for and invest in the transition of the subject region.

Present-day coastal out-migration

Coastal Louisiana offers a compelling case study of climate-driven population loss, although this demographic transformation must be understood within a complex web of environmental, socioeconomic and cultural factors shaping human mobility²⁵. Substantial population declines have occurred across most of this region since 2000 (Fig. 4). Since 2005, for example, Orleans Parish (that is, the city of New Orleans) lost about 25% of its inhabitants, and rural Cameron Parish declined

more than half. A temporal analysis (inset in Fig. 4) reveals relatively stable or slowly declining populations punctuated by sharp losses following major hurricane seasons. Although population loss reflects Louisiana’s statewide trends, coastal areas exhibit greater losses and a distinct pulse–retreat pattern of net migration. We use ‘pulse–retreat’ to describe multidirectional population loss and recovery within the context of a statewide loss trend since 1960²⁶. As with all climate-driven migration, out-migration in coastal Louisiana is multi-causal, and climate drivers intensify pre-existing drivers such as poverty, suburbanization and economic development.

These findings align with established models of disaster-driven displacement, although recovery patterns reflect complex interactions associated with pre-existing social vulnerabilities²⁷. Particularly instructive is the post-Katrina recovery trajectory in New Orleans, where the population rebounded but plateaued at approximately 80% of pre-storm levels after a decade—matching what has been referred to as the ‘functional reconstruction timescale’²⁸. Like many disasters, Hurricane Katrina exacerbated pre-existing social inequalities, with return rates strongly influenced by housing damage, socioeconomic status and race²⁹.

Human mobility extends beyond socioeconomic calculations to include affective decision-making and collaborative processes involving family and social networks³⁰. For LECZ residents, climate risk perceptions operate within broader migration feasibility considerations, including labour opportunities, skill transferability, geographic affordability, family obligations and material resources³¹. Beyond episodic shocks and chronic environmental stressors³², economic pressures increasingly shape climate-related displacement. Rising housing, insurance and utility costs create potentially divergent effects: constraining

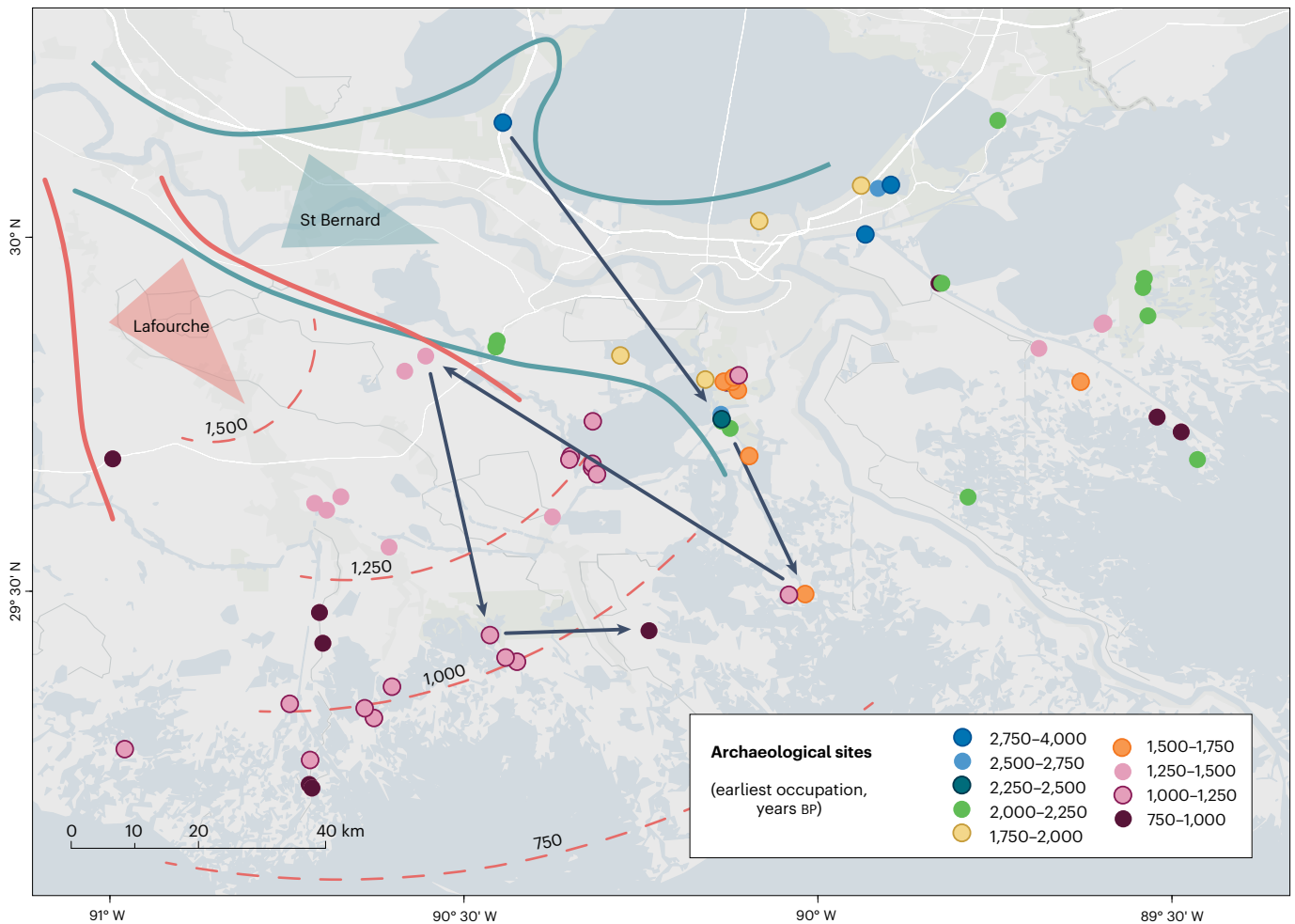


Fig. 3 | Prehistoric occupation and migration across a portion of the Mississippi Delta. The dots indicate the earliest known ages for archaeological sites between 4,000 and 750 years BP. Further details about the underlying data, including an animation, are provided in Supplementary Information. The map highlights the proximal portion of two subdeltas (St Bernard and

Lafourche; active 4,000–1,700 and 1,700–500 years BP, respectively)¹³; coloured arrowheads indicate direction of subdelta growth. Past shorelines are marked by dashed timelines (with ages in years BP) that reflect the growth history of the Lafourche subdelta⁴². Black arrows indicate examples of potential migration routes. Basemap from Esri, TomTom, FAO, NOAA, USGS.

financial resources for relocation while simultaneously eroding the benefits of staying in place^{33,34}. Moody’s Investor Service warned in 2024 that Louisiana faces “severe loss of working-age residents due to long-term demographic trends and the state’s susceptibility to natural disasters,” and they cited insurance costs as a potential driver. Escalating insurance premiums are one factor potentially transforming manageable risks into a threshold consideration for shaping out-migration.

In stark contrast to Louisiana, Florida’s coastal counties have experienced remarkable economic and population growth during this same period (Fig. 4) despite numerous major hurricane strikes. The demographic trajectories of these states reflect their fundamentally different economic structures, development policies, place-based social norms and state-level governance approaches. Florida’s continued growth reflects aggressive development promotion, comparatively strong fiscal capacity, and amenity-driven preferences and values. Louisiana’s population changes, conversely, occur within a context of economic stress defined by dependence on declining extractive industries, strained fiscal resources for adaptation and post-disaster recovery, and cultural place attachment that influence mobility decisions. In fact, the especially deep place-based cultural values in Louisiana undoubtedly have prevented higher population loss than has been observed³⁵. The demographic divergence between these states also reflects what might be termed ‘socioeconomic amplification’ of

environmental pressures, where underlying socioeconomic vulnerabilities interact with environmental stresses to produce population loss that environmental factors alone cannot explain.

While the chronic wetland loss explored in the next section creates conditions conducive to out-migration, catastrophic storms function as primary displacement triggers that drive the pulse–retreat pattern. Research over the past few decades has led to increasing consensus regarding the link between climate change and tropical cyclones. Most notably, an increase in storm intensity and precipitation as predicted by models³⁶ has been confirmed by observations, such as rainfall rates³⁷. While these factors collectively increase the threat of storm surge and compound flooding (that is, due to storm surge as well as extreme precipitation), it is important to note that even if the storm dynamics remain unchanged, these impacts would still increase in severity due to accelerating RSL rise. A ‘deep uncertainty’ assessment of the future risk in New Orleans has highlighted Antarctica, and particularly storm surge, as the most important factors³⁸. The impact of storm surge is expected to worsen considerably due to the ongoing conversion of tidal marsh into open water.

A fragmenting coast

The Mississippi Delta, like most major world deltas³⁹, has enjoyed substantial net growth since the slowdown of global sea-level rise about

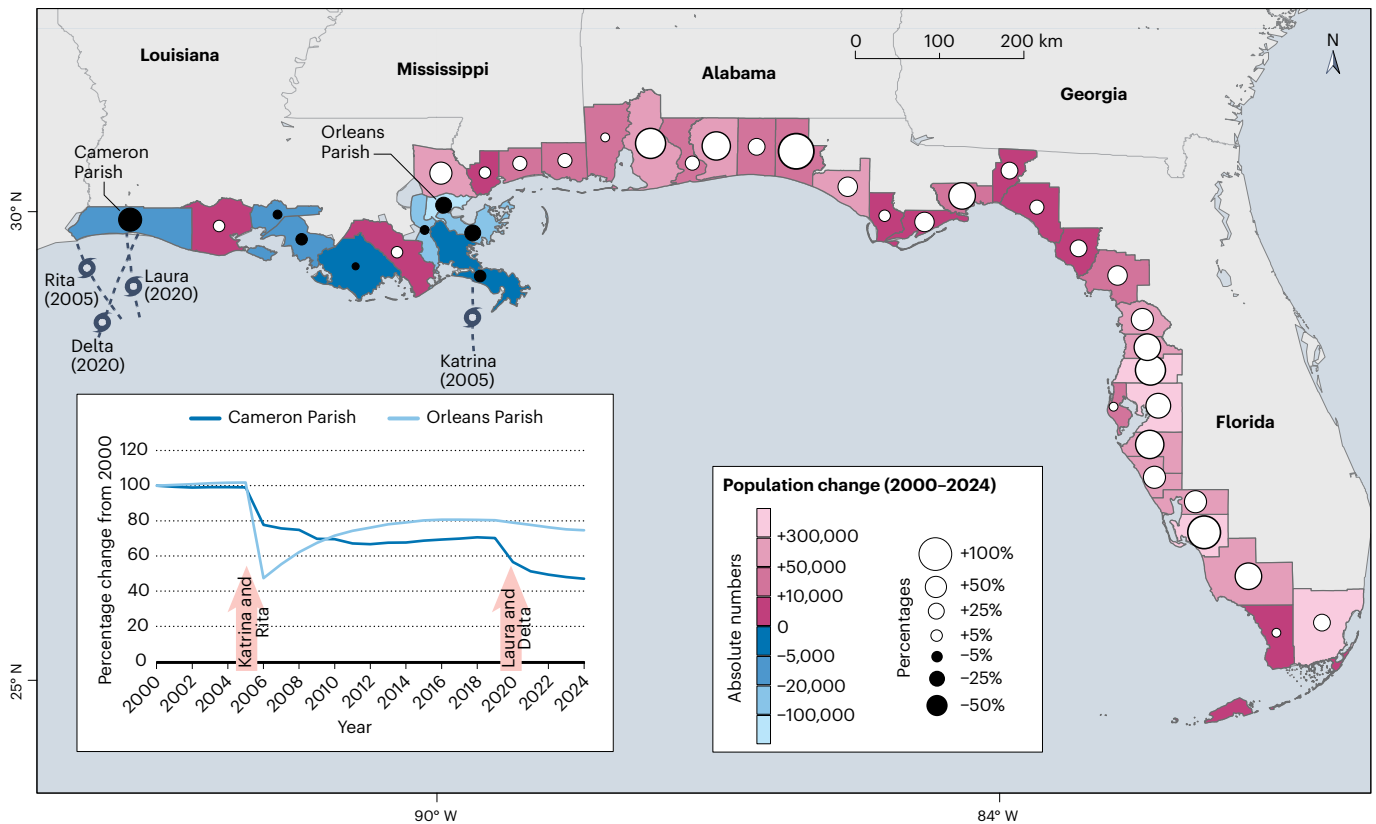


Fig. 4 | Population change along the US Gulf Coast, Louisiana to Florida (2000–2024). The map shows changes at the county level (parishes in Louisiana) in terms of absolute numbers and percentages. The underlying data are provided in Supplementary Information. The inset shows the changes graphically in the most urban (Orleans Parish) and rural (Cameron Parish) portions of coastal Louisiana.

Both have been affected by major hurricanes during this time frame (landfall locations are shown on the map). Basemap from Esri, TomTom, FAO, NOAA, USGS, Garmin, OpenStreetMap contributors, and the GIS User Community. Credit: Asif Hasan.

7,000 years ago. As shown earlier (Fig. 3), an alternation of subdelta growth, abandonment and transgression characterized this delta—subjects with a long history of research^{40,41}. Prehistoric growth rates of the Lafourche subdelta amounted to 6–8 km² yr⁻¹ (ref. 42). Nevertheless, only 30–70% of the incoming sediment was trapped on the delta plain⁴³. The remainder was transferred offshore, partly feeding the adjacent Chenier Plain (southwest Louisiana), a muddy coastal zone that grew seaward by >10 km over the past 3,000 years¹³.

This net land gain was reversed approximately one century ago, and coastal wetland loss has become the defining environmental challenge for this region. Wetland loss appeared on the agenda during the 1970s⁴⁴, a period with rapidly increasing environmental awareness, and many subsequent studies have addressed the wetland loss crisis^{45,46}. The total area lost since the 1930s exceeds 5,000 km² (ref. 47) but with considerable spatial differences. For example, areas in the vicinity of the mouth of the Atchafalaya River have fared relatively well compared with central portions of the Mississippi Delta⁴⁸. A detailed analysis of a portion of this central region has shown that the main culprits—in order of importance—are a reduction of sediment input from the Mississippi River due to embankments, accelerated subsidence due to fluid (notably oil and gas) extraction, and damming of the Missouri River, the main sediment source⁴⁹. In addition, a vast network of canals excavated mostly for the oil and gas industry has accelerated saltwater intrusion and wave erosion, further exacerbating the problem⁵⁰.

Beyond these well-documented drivers of wetland loss, a more fundamental reason why rapid environmental degradation is happening earlier in Louisiana than in other LECZs is the limited elevation capital. The Gulf of Mexico is characterized by a microtidal regime, with a tidal range in Louisiana <0.5 m. This has major implications because the

elevation of marshes is dictated by the high-tide level. With elevations of only a few decimetres above mean sea level, it takes only a short time of accelerated RSL rise to drown these wetlands⁵. Many other LECZs are less exposed as they possess more elevation capital due to a larger tidal range. For example, model predictions of the future of Indo-Pacific mangroves suggest that settings with a tidal range >1 m, even with low sediment availability, will not be submerged by 2100 even with 1 m of sea-level rise⁵¹.

The demise of coastal wetlands leads to a variety of negative outcomes, including the rapid loss of key habitat for many juvenile marine species that threatens to decimate fisheries⁵², and a reduction of storm-surge protection⁵³. As a result, there is a strong incentive to protect and/or restore coastal wetlands since they host some of the most economically valuable ecosystems on the planet. It is important to note that over the past century, RSL rise has not yet been a major driver of wetland loss, but this is presently changing⁵, and going forwards, climate-driven sea-level rise will increasingly become a dominant factor. Climate change is also intensifying tropical cyclones. As a result, coastal Louisiana will face compound challenges surpassing what has been seen in the past century.

Previous research⁴⁸ has examined the link between wetland and population losses and argued that the two are connected. However, an analysis of shoreline change and human migration since 1940 showed that only two of ten coastal parishes exhibited significant landward population movement⁵⁴. This reflects the broader economic and cultural factors that influence residential choice beyond environmental considerations, such as the historically abundant employment opportunities in the oil and gas industry. Nevertheless, the extant coastal wetlands that are foreseen to be largely lost surround 1.2 million inhabitants³,

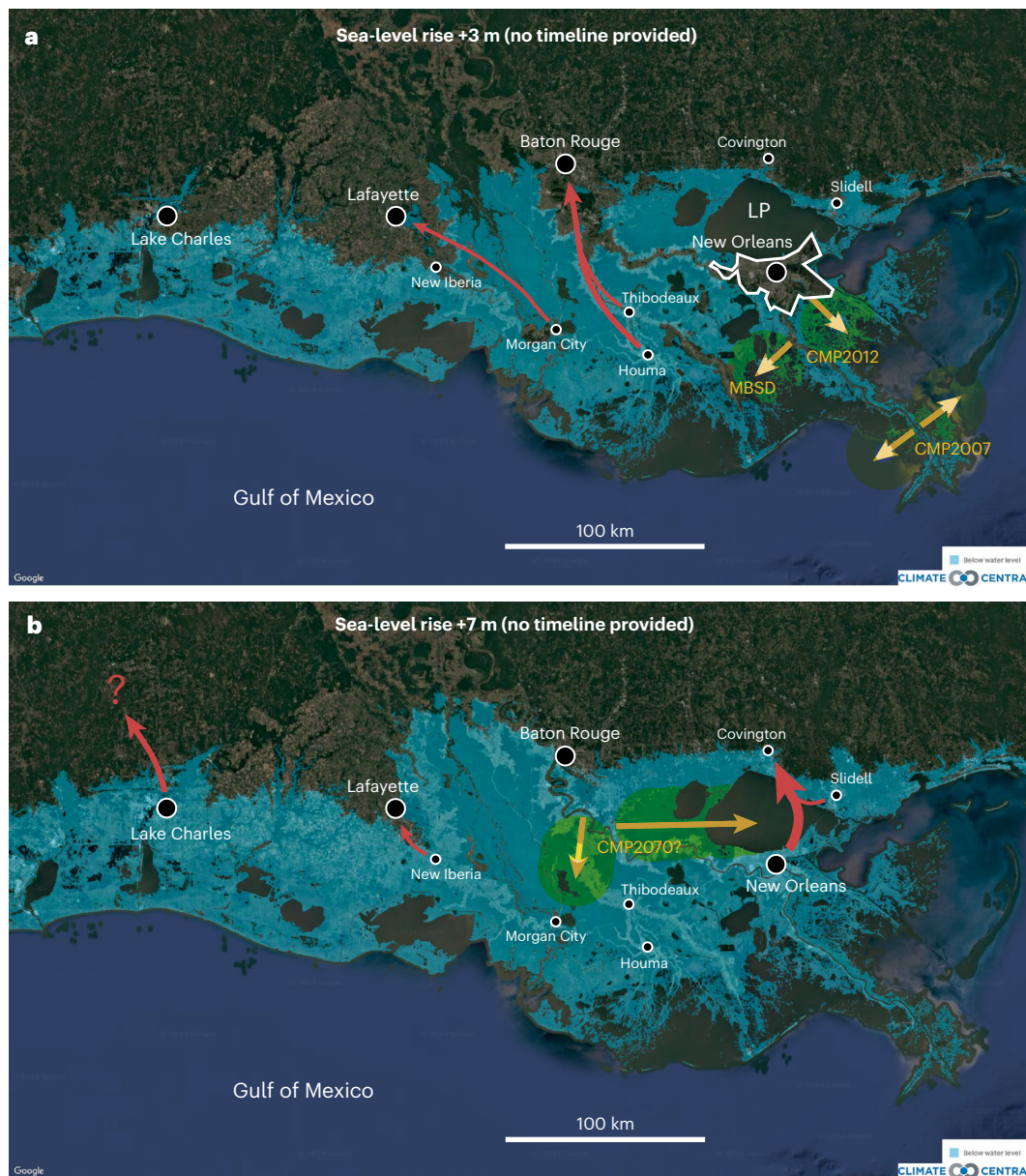


Fig. 5 | Minimum future RSL highstand conditions in Louisiana. a, Shoreline position based on the present elevation of the LIG shoreline. **b**, Shoreline position after correction for fault motion. In **a**, the New Orleans metropolitan area is protected by a coastal-defence system; with +3 m of RSL rise it will at best become a highly exposed island in the Gulf of Mexico. No coastal-defence system is expected to be effective when RSL rises to +7 m (**b**). Red arrows show potential migration paths when population centres have to be abandoned. LP, Lake Pontchartrain; CMP2012 in **a** shows the location of recently cancelled river

diversions. CMP2070? in **b** shows envisioned sediment diversions that may become operational later during this century. MBSD, Mid-Barataria Sediment Diversion. Note that these are passive inundation maps that do not include changes due to sediment deposition or erosion. This is justifiable because the RSL elevations are based on observed LIG shoreline fragments, that is, conditions that included morphologic change. Credit: Ben Strauss/Climate Central. Map data from Google.

and an even larger population currently resides on the ‘wrong’ side of the LIG shoreline in southeast Louisiana. Consequently, we have seen only the beginning of the landward migration in this region. The chaotic pulse–retreat demonstrates the high social cost of unmanaged migration, highlighting the urgent need for policy interventions.

From shoreline retreat to managed relocation

Our analysis indicates that coastal Louisiana is probably locked in for a shoreline retreat that will reach >100 km in its southeastern sector. Figure 5 shows where the shoreline might stabilize if RSL rise reaches LIG levels. Here we consider two scenarios: the first (Fig. 5a) based on the +3 m elevation as derived directly from field observations and a second (Fig. 5b) that includes a correction for fault motion, resulting

in an elevation of +7 m. We reiterate that the strength of this approach lies primarily in the spatial rather than the temporal component as it is currently unknown when this future shoreline position will be reached. This high likelihood about spatial outcomes, combined with uncertainty about timing, creates a unique strategic advantage: Louisiana can develop managed relocation frameworks while still having choices, rather than implementing them under crisis conditions.

Despite the population losses in recent decades, it is crucial to recognize that most of coastal Louisiana’s residents are not immediately contemplating or otherwise engaged in relocation in response to environmental challenges. Instead, many choose to adapt in place through a combination of strategies, including home elevation, flood-proofing, insurance and lifestyle modifications to live in a wet environment.

This pattern of in situ adaptation, while demonstrating community resilience, may paradoxically increase long-term socioecological vulnerability. Migration research demonstrates that each decision to adapt in place rather than relocate creates additional barriers to future mobility—through increased financial investment in property improvements, deepened social networks and place attachment, and psychological commitment to community continuity⁵⁵.

Here the divergence between our three lines of evidence comes into sharp focus. While the geological record (Fig. 2) confirms that the land supporting static communities is impermanent, and the demographic record (Fig. 4) warns that delayed migration results in chaotic pulse–retreats driven by tropical cyclones, the archaeological record (Fig. 3) offers a counter-narrative: successful adaptation in this LECZ has historically required mobility, not stasis. To avoid the disorderly displacement currently under way, policy must break the modern cycle of lock-in and operationalize the incremental and strategic mobility that once defined this region.

While bold visions have been proposed to elevate large swaths of New Orleans⁵⁶, there are physical and socioeconomic limits to in situ adaptation. As Fig. 5 highlights, physical limits are increasingly apparent. Before reaching a triggering decision to move, intervening climate impacts (for example, storms, disease, declining labour market) present a complex array of push and pull factors that shape both human mobility and immobility⁵⁷. These complex social behaviours, together with a shifting environmental landscape for the underlying habitability of LECZs, suggest an inherently uneven process of spatial relocation⁵⁸. Those with capabilities and aspirations will migrate, while those with limited means risk being left behind in a disorderly range of processes that further socioeconomic amplification and marginalization⁵⁹.

Considering the uncertainties about the timeline of RSL rise, an argument could be made that managed relocation would at present be too disruptive. However, this is a long process that cannot be put off. For example, the currently ongoing managed relocation of one-third (~6,000 inhabitants) of the population of Kiruna, Sweden (due to expanding iron ore mining that puts a large portion of the city at risk), is a 30-year project to be completed in 2035. What is in store for Louisiana will require considerably more time that can be expected to play out over multiple generations. Decision-making will require a dynamic adaptation-policy pathway approach⁶⁰ that allows for flexible adjustments and avoids lock-in. In short, while nobody alive today will see the end result, this cannot be an excuse for delay.

The concept of ‘managed relocation’ represents concerted efforts to engage various pathways for the movement of human, financial and environmental capital⁶⁰. Louisiana’s early experience with climate-driven population movements positions it to become a model for developing these approaches—creating exportable expertise that will become increasingly valuable as other LECZs confront similar challenges. Managed relocation in the context of LECZs not only is seeking to mitigate the risk of leaving people behind, but also is centred on the opportunity to plan for a more sustainable built environment in receiving zones, for example, north of Lake Pontchartrain (Fig. 5b). As people move to high-elevation land, the challenge will be to align regional planning for infrastructure and housing development with local social services policies that can help manage the relocation of people and businesses⁶¹. A failure to plan is likely to lead to a market-driven disorderly movement of human and financial capital that not only imposes disproportionate burdens on local receiving zone populations through crowding-out and climate gentrification⁶² but also runs the risk of recreating carbon-intensive and physically vulnerable forms of settlement that further undermine human and environmental welfare.

Managed relocation in coastal Louisiana can only be successful if simultaneous efforts are made to slow wetland loss. This will buy time to manage a multi-generational spatial transition of the population. By extension, adaptation policies are needed to facilitate the orderly

movement away from future inundated areas. If rapid environmental and economic changes ensue, a pulse–retreat pattern may break down into an absolute retreat pattern defined by household displacement, rapid devaluation and trapped assets. Given the necessity to buy time, we therefore proceed to examine coastal restoration in more depth.

Public sector maladaptation

While climate mitigation should remain the first step to prevent the worst outcomes, coastal Louisiana has evidently already crossed the point of no return. A possible silver lining herein is the fact that the timing of multi-metre RSL rise is uncertain. Therefore, slowing coastal degradation by means of targeted coastal restoration remains a viable adaptation strategy. This could expand the time window to enable managed relocation, rather than inviting chaos.

As noted, the projected potential future shorelines (Fig. 5) do not explicitly consider changes in the landscape due to sediment deposition or erosion. This brings back one of the fundamental causes of wetland loss: the decline of sediments making it to the coast⁴³ and, most importantly, the inability of this sediment to be dispersed across the delta plain⁴⁹, with accelerated future land loss as a likely outcome^{3,5}. While today’s sediment accumulation is still substantial, it consists to a large extent of organic matter⁶³ and is thus prone to sediment compaction and less suited for long-term land building⁶⁴.

Large river diversions that feature controlled openings in embankments to allow water and sediment to disperse across the degraded wetlands during peak discharge^{65,66} would change this. This restoration strategy was first proposed in the 1970s⁶⁷ and has subsequently found strong support from the scientific community^{45,46}. It gained considerable momentum in the post-Katrina years, when Louisiana’s Coastal Protection and Restoration Authority (CPRA) was established. One of the main tasks of CPRA is to produce the Coastal Master Plan (CMP) for the state (Box 1), which has resulted in advanced plans for two major river diversions (Fig. 5a).

The CMPs offer insight into the rapid change in thinking about coastal restoration. A striking example is the contrast between the plans from 2007 and 2012; in the former, the main focus area for sediment diversions was near the mouth of the Mississippi River (Fig. 5a) whereas only a few years later this had shifted well upstream. This reflected a shift to a more defensive strategy due to the recognition that some portions of the coast cannot be sustained. It may not be coincidental that this revision occurred after the publication of the landmark paper by Blum and Roberts⁴³ that drew attention to the sediment deficit that will prevent the Mississippi Delta from keeping up with future RSL rise. As a result, it is now well understood^{42,68} that future rates of land building will fall short of wetland loss rates.

Groundbreaking for the first large sediment diversion (the Mid-Barataria Sediment Diversion; Fig. 5a) occurred in August 2023, but this US\$3 billion project was cancelled in July 2025 by a new gubernatorial administration in Louisiana, mainly citing high costs. The second planned major diversion was cancelled in October 2025. It is hard to overstate the implications of these decisions: large sediment diversions are arguably the last chance to extend the lifetime of select portions of this LECZ, given that other restoration methods are not only unsustainable but also much more expensive (Box 1). Therefore, abandoning large sediment diversions effectively means giving up on extensive portions of coastal Louisiana, including the New Orleans area. With a threshold rate of RSL rise for marsh survival that has already been crossed³ and an (imminent) loss of 75% of remaining wetlands that may be a reality by 2070⁵, the embanked New Orleans area may well be surrounded by the Gulf of Mexico before the end of this century.

Tens of square kilometres of new wetlands seawards of the main population centre could enhance the storm buffer⁵³, allowing for more time to enable successful managed relocation⁶⁰. In addition, the new knowledge gained by developing this nature-based solution will be invaluable. For example, as shown in Fig. 5b, we envision that similar diversions

BOX 1**Louisiana's CMP**

The 2005 Atlantic hurricane season had a devastating impact on Louisiana. Hurricane Katrina caused >1,500 deaths and >US\$150 billion in damage, making it the costliest environmental disaster in US history. In December 2005, the CPRA of the State of Louisiana was “established as the single state entity with authority to articulate a clear statement of priorities and to focus development and implementation efforts to achieve comprehensive coastal protection for Louisiana.” One of the primary responsibilities of CPRA is to produce the CMP, the first of which appeared in 2007 (with successors in 2012, 2017 and 2023). The primary goals of the CMP include “Land Loss Reduction” and “Storm Surge Risk Reduction,” with a planning timeline of 50 years and a projected budget of US\$50 billion. Supporting this investment, US\$8.7 billion became available in 2016 through settlements following the 2010 Deepwater Horizon oil spill. Planned investments outlined in the CMP are about evenly split between risk reduction and restoration. By far the largest component of restoration consists of marsh creation projects (>60% of the restoration budget in CMP2023), a method that relies on pumping sediment from a source (for example, the Mississippi River) to a targeted area that has experienced wetland loss. While this creates rapid results, it is energy intensive and unsustainable in the long term. By comparison, nature-based solutions such as sediment diversions are cheaper (~10% of the restoration budget in CMP2023) and much more likely to enable long-term, sustainable land building. Over the past two decades, CPRA has established itself as a national leader in coastal management.

will be needed in the future to build a storm buffer for the rapidly growing receiving zones, such as communities north of Lake Pontchartrain that may accommodate large numbers of migrants from the New Orleans area.

Global lessons from Louisiana

Global sea-level projections between now and mid-century exhibit only minor differences between climate scenarios². However, given the slow response of the ocean, the pathway of greenhouse gas emissions within the next few decades will be critical; by mid-century, the sea-level trajectory for the remainder of the century may be broadly known⁶⁹. The implication is that policy decisions within the next ~30 years are key⁷⁰ and will determine whether the future RSL rise in Louisiana can be limited to an LIG scenario. Within this context, we highlight the sobering observation that LIG conditions were roughly on par with the most favourable emissions scenario (SSP1-1.9; Fig. 1), which is projected to peak at just over 1.5 °C of warming within the next few decades. In other words, major emissions reductions will be necessary to optimize the prospect of the highstand shoreline eventually stabilizing at a position comparable to what is shown in Fig. 5, and a formidable task awaits to prevent the future shoreline from migrating even farther inland. While the window of opportunity to save the New Orleans area in the long run has probably closed, the next few decades will be decisive as to whether other population centres that are presently well landwards of the coast will be among the next to face their seawards fate.

The population moving out of coastal Louisiana bucks the trend of ongoing human migrations into coastal zones that are seen elsewhere in the US and worldwide. For example, demographic modelling suggests that in Bangladesh—home to the largest LECZ population in the world—migration towards the coastline may continue throughout this century under all climate scenarios⁷¹. The exceptional vulnerability of

the central US Gulf Coast can open a window to what may be expected in LECZs around the globe later during this century. Even though the population loss in coastal Louisiana has to date been largely unmanaged, it is arguably less painful than what is in store for LECZs that are still seeing rapid population growth, such as in Florida.

Contrary to conventional discourse where population loss is seen as a negative, we propose that it may offer a first-mover advantage to learn what policies and plans are effective at advancing social welfare and environmental quality in the managed shift from sending to receiving zones. Time is of the essence: the longer this is put off, the more challenging it will become. While pre-contact Native American communities have shown a remarkable ability to adapt, they often had centuries to do so. Now the timeline probably shrinks into a matter of decades. Nevertheless, this still offers a critical temporal advantage: developing relocation expertise during relatively stable conditions allows for deliberate policy design that crisis displacement does not.

The past few decades have seen a surge of interest in nature-based solutions for climate mitigation and adaptation interventions⁷², including the recognition that static deltas are bound to be unsustainable⁷³. Within this context, river diversions represent particularly important sedimentation-enhancing strategies⁷⁴, and they are not limited to natural deltas but also increasingly thought of for densely populated deltas^{75,76}. Notwithstanding the expectation that coastal restoration will pay dividends, it will have to occur in tandem with relocation plans. Restoration efforts can buy valuable time that could make the difference between orderly managed growth in receiving zones and disorderly dislocation in sending zones. Building on the leadership role of the CPRA (Box 1), the Louisiana experience could lead to a surge in new knowledge about coastal management that would be highly beneficial for other LECZs in the future, as coastal restoration expertise will be in increasing demand globally. This region has the opportunity to build an exportable knowledge base and economy that pioneers managed relocation as an opportunity, not merely as a threat or burden.

For any jurisdiction, we argue that managing the relocation of a population requires strategic vision and tactical flexibility that cut across sectors and political cycles. It requires institutions whose continuity is validated to be in the public interest in a manner that guards against speculation and displacement. They must simultaneously preserve cultures and the dignity of socioecologically vulnerable households, while at the same time plan for the rapid urbanization of once vast rural regions. To manage relocation is to ride a wave that—judging from Louisiana's coastal depopulation already in motion—is building in strength. If policymakers rise to the challenge, how Louisiana manages this transition will establish the template that other global LECZs will need as sea-level rise accelerates. Seeing the shoreline ahead provides a landmark for getting the next generation to shore.

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Author contributions

T.E.T. initiated the work and wrote the first draft. Z.S. carried out field and laboratory work that led to the sea-level reconstruction, J.M.M. synthesized the archaeological data, B.C. performed the demographic analysis, and J.M.K. focused on the policy, planning and economic implications; each author wrote most of the respective sections. All authors contributed to editing the paper.

Competing interests

The authors declare no competing interests.

Additional information

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