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Climatic and Environmental Changes Affecting Communities in Atlantic Canada

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Abstract: Small rural coastal communities located in Atlantic Canada are vulnerable to the effects of climate and environmental changes. Major storms have impounded the coastline, causing much physical damage and affecting the socioeconomics of these communities that are composed of an aging population. The current study relays findings based on interviews completed in 2011–2012, following the 2010 winter storms in Atlantic Canada. It portrays the physical and social–ecological impacts affecting 10 coastal communities located in the provinces of Québec, New Brunswick, and Prince Edward Island. Semi-structured interviews held in these provinces are the basis for the contributions of this research. The findings reveal physical changes related to coastal erosion from high-wave impacts and storm surge causing flooding of the coastal zone. Also considered are strategies preferred and actually implemented by residents, such as building of protection walls, although undesirable. Due to funding constraints, however, many of these large-scale flood protection projects are not possible without governmental support. Instead, it is suggested that development be controlled and some respondents in this study upheld that relocation be used to alleviate the situation. Finally, more work is required to improve emergency planning. Better concerted short- and long-term responses need to be coordinated by local authorities and higher up in the government in order to ensure the sustainability of these coastal communities.

Keywords: climate change; physical landscapes; impacts; responses; adaptation; sustainability

1. Introduction

Adaptation strategies are complex to define because of the types of impacts caused by climate change at the landscape level that can be exacerbated by cross-temporal and -spatial environmental changes. For this reason, a well-rounded adaptation effort is required, particularly where multiple impacts are observed or expected. Along Atlantic Canada shorelines, coastal communities can expect rising sea level, increasing wave movements from storm surges or hurricanes (depending on the season), and high winds, causing erosion, flooding, and saltwater intrusion [1]. Storms, as low-pressure systems, are known to frequently hit the eastern Canadian shoreline and cause damage to coastal communities.

This paper focuses on work performed in Atlantic Canada after a series of storms that occurred in December 2010 and January 2011 to better understand how damage affected communities and what coastline changes were observed and discussed in those communities. This was an opportunity for a multidisciplinary team that included physical geographers to engage in sustainability research and thereby contribute to the environmental sustainability of small rural communities in Canada.

The existing literature suggests that further work is required to understand how to adapt to the potential of accelerated changes, such as sea-level rise, increased storm intensity, diminished winter ice cover, and increasing future coastal erosion hazards [2]. One of the strategies that has been promoted by international organizations, such as the United Nations and its affiliates (e.g., the United Nations Environment Programme or UNEP and the United Nations Development Programme or UNDP) and the International Union for Conservation of Nature (IUCN), is ecosystem-based adaptation to climate change. This approach is based on using biodiversity and natural ecosystems to enhance adaptation at the landscape level [3]. There are natural barriers that can be integrated into physical landscapes to oppose environmental change, such as wetlands and mangroves that can serve as natural reservoirs for floodwaters and for their roles in wave attenuation, making it a critical part of coastline protection [4].

In Atlantic Canada, most of the coastline is susceptible to erosion, except the "granite shores of Nova Scotia [which] are highly resistant to erosion and coastal retreat" ([5], p. 35). Most regions where this study was completed encompassed sedimentary rocks, which are more susceptible to erosion than the granites shores of Nova Scotia. This is particularly true for regions of the province of Prince Edward Island that are mainly composed of brittle soft sandstone [5]. As stated by Atkinson et al. [5], "gravel and mixed sand-gravel beaches and barriers predominate in this region [Atlantic Canada], except in the southern Gulf of St. Lawrence, where sand-rich glacial deposits, derived from soft sedimentary rocks, support the development of extensive sandy barriers with large dunes" (p. 31). Wave action especially during storm surges on these systems can, therefore, greatly accelerate the rate of erosion [5]. The main challenge for these ecosystems have been the increasing frequency of less intense storms (mainly in the summer and fall) that do not give enough time for sediments to accumulate and for the rebuilding of small dunes, leading to cumulative destabilizing effects on the coast [6].

As the frequency of storms in the past two to three decades is becoming especially prevalent at higher latitudes, it is expected that sediment loss and widespread coastal erosion will continue occurring [7]. This sediment movement along beaches provides a mechanism of interaction between erosion processes and flood risk [8]. However, when human activities interfere with the natural dynamic movement of the coast, the ecosystem may be irreversibly altered through erosion [9]. Savard et al. [9] report that "shoreline hardening with various protection methods (walls, rip-rap, dikes, groins, pavements and landfill) and dredging have altered coastal circulation patterns and sediment transport, potentially exacerbating shoreline erosion and reducing the ability to attenuate flooding" (p. 115).

In Atlantic Canada, milder winters are also affecting the rate of erosion due to changes in the timing of ice formation along the coasts and less ice cover with warmer sea surface temperature, leading to enhanced abrasion of the coast [10]. Because more variables than just sea-level rise and increased storminess are affecting coasts, research needs to examine other climatic parameters as well as combine marine-terrestrial erosion processes (see [10]). Subsidence (i.e., the post-glacial movement of the terrestrial crust) also affects Atlantic Canada leading to an amplified impact of sea-level rise [1].

Relatively stable surfaces are deposition-dominated, and areas where vegetation can establish, and act to further stabilize landforms. For instance, narrow beaches with low waves and low energy are less prone to erosion, which, allows for the establishment of upland vegetation (e.g., beachgrass, sea lyme-grass) [11]. Along active coastlines, coastal management plans need to be in-place and protection strategies are needed (e.g., vegetation protection, beach nourishment) to counteract coastal erosion and associated geohazards [12]. Human impacts, such as constructions, have affected sediment supply at the coast, leading to beach erosion and the landward retreat of sand barriers that protect the shoreline from storms [13] or could, alternatively, starve down-drift beaches of much needed beach protection [8].

Human impacts on coasts are among the multitude of factors that influence shoreline development. Activities such as vehicle use and foot traffic result in compaction as well as coarsening and steepening, as evident on Mobile Beach in eastern Newfoundland, Canada [14]. According to Catto [14], other stressors contribute to beach change and development, including natural local factors, such as the angle of wave attack and past event frequency. Several hurricanes [1] and strong (winter and autumn) storms (at least nine) impacted this coast between July 1989 and December 2005. Often, these physical landscapes are considered in isolation from socioeconomics and an integrated environmental approach is necessary, such as that of a social–ecological systems (SES) perspective [15]. Such an integrated approach is increasingly acknowledged as part of Anthropocene landscape evolution (e.g., [16]), during when humans have impacted landscapes around the world to such an extent that physical landscapes can no longer be considered independently of human inputs or alterations (cf. [17]).

Conversely, humans are affected by their landscapes and any changes that occur due to climate and environmental changes will impact these natural landscapes, especially in resource-dependent communities (e.g., fishing villages, etc.). For this reason, landscape change needs to be coupled with human dynamics, as for example is the case with affected property values along coastlines that have high rates of erosion and, hence, where stabilization costs are high [18]. The integration of social and ecological systems can contribute to an understanding of how to manage adaptation strategies for a greater sustainability of these coastal communities.

This paper examines the physical landscapes that are visible from small rural communities in the provinces of Québec (QC), New Brunswick (NB), and Prince Edward Island (PEI) located in Atlantic Canada. In particular, the focus is on any landscape change stemming from climatic impacts that are associated with the 2010 winter storms. Landforms, including cliffs, beaches, and marshes will be examined from the perspective of residents' perceptions of change. Specifically, based on interviews conducted in 2011–2012, perception- and experience-based views will be gauged in order to determine any environmental change derived from the winter storms and effects (e.g., storm surge, high waves, etc.) that are linked to climate change (sea-level rise, more intense storm activity, etc.) that impacted these communities through flood and coastal erosion hazards. Risks created by these include damage to people and property as well as infrastructure and affect the insurance industry and general socioeconomics as well as the physical environment locally to regionally within the study area.

2. Materials and Methods

This study was part of a larger project called Coastal Community Challenges-Community-University Research Alliance (CCC-CURA), which aimed to develop adaptation plans and attempted to improve the resilience of these communities (see [19]). Prior to any intervention, interviews were completed in 10 communities located in QC, NB, and PEI (Figure 1). These coastal communities were selected on the basis of their interest to be part of the project; having populations of less than 10,000 inhabitants, and many less than 3000, half of them having been affected by the series of storms in December 2010 and January 2011; and not received prior interventions from governments or institutions regarding climate change adaptation. All of them mainly relied on natural resource (i.e., fisheries, forestry, and agriculture) activities as income and all these communities had aging populations.

Interviews were held singly and in couples with 74 residents of these communities in their native language (French or English). Participants were originally identified by personal and public invitations; and a snowballing sampling strategy was subsequently deployed in order to increase the sample size that was based on interviewee referral. The number of interviews was limited by the concern of saturation of interviews, as these were small communities and there was currently a diversity of projects (not only on climate change) in those communities. Prior to doing the interviews, human research ethics was sought at universities and pretests were completed in one of the communities.

Questions were based on six research themes: (1) experience with storms; (2) financial capital; (3) social capital; (4) vision for the future; (5) information sources; and (6) understanding of what is resilience. In this study, the authors targeted the themes and information that attested to the state of the physical environment and how landscapes were affected by the 2010 winter storms. The most relevant research themes addressed in this paper tended to be themes (1) and (4) because of their focus on experiences (and any perceptions that can be derived from these) as well as future vision based on their experiences, as for instance views of coastal protection. Perception can also be gleaned from any lessons that were learned based on experiences.

The demographic characteristics of the study sample were tracked for each person or couple; and the influence of gender, for example, has already been published by the authors [20]. Semi-structured interviews held in people's homes lasted 40–75 min. They were completed by two research assistants, who kept the same order of questions, and were audio-recorded. They were then transcribed by a research assistant and verified by one of the researchers. Finally, the data were coded using NVivo v.10 software (QSR International) by one researcher and rechecked by a second one. As some of the interviews were in French, they were later translated into English.

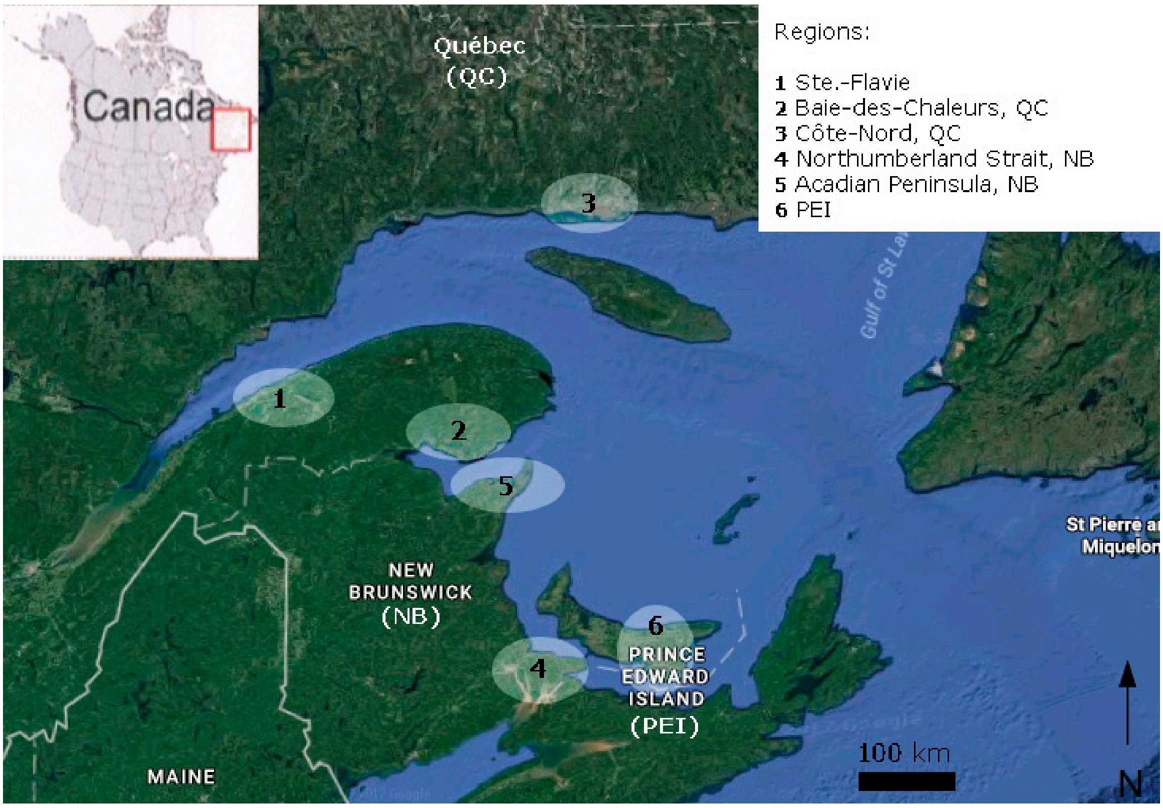

Figure 1. Map of the study communities in the study area.

3. Results

Communities experienced different levels of storm damage following the 2010 winter storms. Those located in Rivière-au-Tonnerre and Bonaventure (QC), Shippagan and Dundas (NB), and Stratford (PEI) experienced none to very little storm damage. The damage mainly affected the communities of Ste.-Flavie and Maria (QC), Ste.-Marie-St.-Raphael and Cocagne-Grande Digue (NB), and Morell (PEI), where there were various impacts from storm surge causing flooding and erosion. It appeared that the most impacted communities were located in Ste.-Flavie and Maria (QC), where there was the greatest amount of damage, including houses on the coast being swept by the storms.

When asked about any observed changes, participants reported that the most notable observed changes had occurred in the last 5–10 years. Participants believed that there is an increasing intensity of storms in this region and a cause to become more nervous than before, particularly following the 2010 storms: *"And it is the intensity of the experience that makes this a moment. The intensity and then the repetition of the experience"* (R.C., Baie-des-Chaleurs, Bonaventure). Although this participant was not impacted by the 2010 storms, the sentiment remains the same as affected people because members of his family were seriously affected. These impacts were, therefore, evident not only at the local (community) level but also at the regional scale (R.C.'s family was in other communities of the region). Commonalities related to stronger (more intense) storms that were shorter in duration, but produced heavier rainfall and increased erosion. In the Acadian Peninsula, there was less sea ice reported in the winter. This change in sea ice was quite important, as it increased damage during storms in the winter, when wave action was stronger at the coast.

Table 1 provides a summary of the regional weather patterns that could be contributing to landscape patterns. It is clear (from Table 1) that most interviewees observed and experienced a greater number of storms and that this had an impact on the landscape. Erosion, for example, was a major factor. Moreover, human activities appeared to have exacerbated the situation. More runoff was evident and attributable to deforestation and agriculture, indicating that human impacts are having an effect on the physical landscape. Owners of properties on the shore in Ste.-Flavie were faced with a new reality during the December 2010 storms when some houses were destroyed by coastline erosion. The interviewees of this community were aware of the power of the ocean and its effects on the shoreline.

Table 1. Physical changes that participants observed along their coastal communities.

Region	Weather	Landscape
Ste.-Flavie	more storms unpredictable weather	erosion loss of land
Baie-des-Chaleurs, QC	longer autumn, winter more intense storms [1] water rises high	erosion river rising in autumn (not spring) more runoff [2]
Côte-Nord, QC	less winter snow unpredictable weather [3]	erosion more sand on beaches [4]
Northumberland Strait, NB	higher tides stronger waves stronger winds increase temperature increased rain intensity extreme summer weather increased storm frequency increased storm severity	changed river flow reduced streamflow increased water temperature floodwater indundation higher water level
Acadian Peninsula, NB	reduced sea ice [5] stronger winds bigger storms higher, stronger tides more summer drought milder winters autumn, winter start later less snow	more erosion/loss of land [6] higher seawater levels [7] overflowing rivers/creeks
PEI	more intense storms shorter storms changed wind direction more rain less snow shifting seasons less ice	more erosion increased river siltation

[1] More heavy rain in a shorter period of time. [2] Attributed to deforestation. [3] Especially temperature. [4] E.g., Ste.-Flavie. [5] Most common observation in this region. [6] Second most mentioned observation in this region. [7] E.g., Shippagan.

In Table 2, social and ecological patterns for each region of the study area are summarized. It shows that on the ecological side, as most of these communities are fishing villages, natural resources were a significant concern and the interviewees have seen changes related to fishing. The social changes varied among communities and reflected their main concerns in their region. For example, in Ste.-Flavie the damage caused by the storms of 2010–2011 led to more conflicts and social stress. In the Acadian Peninsula, however, the perspectives were ambivalent, spurred by more cottages and positive issues to greater stress in the fisheries sector with larger boats.

Table 2. Social–ecological changes based on participant observations.

Region	Ecological	Social
Ste.-Flavie	loss of lands coastal restoration	more nervousness social conflicts desire to reduce environmental damage out-migration
Baie-des-Chaleurs, QC	none noted	greater awareness more nervousness
Côte-Nord, QC	none noted	more tourism investments more development [1] desire to reduce environmental damages [2] out-migration [3]
Northumberland Strait, NB	planting new species [4]	thinking more about storms
Acadian Peninsula, NB	new aquatic species [6] habitat change variation in lobsters harder to collect shellfish	more environmental perspectives [5] fish-processing plants more aware of coastal erosion changed perspective of coastal living but still more cottages on coast larger fishing boats
PEI	shrinking Atlantic salmon [7] strawberries grow earlier more birds overwintering different bird species die back of white spruce more cord grass growing	community closer due to landing built [8] rise in consumerism

[1] More chalets since 1978. [2] At community level. [3] Noted in the past 1–2 years. [4] Those that were not planted 10–15 years ago, e.g., peaches, cherries. [5] Especially among young people; over 50 years. [6] E.g., sharks. [7] Fewer on southern range. [8] In St. Peter's.

4. Discussion

The regional analysis presented in this study reveals interesting patterns affecting physical landscapes (environment) and socioeconomics that are important from a sustainability standpoint. Most respondents observed that storms are occurring more frequently in Atlantic Canada and several also stated that they were more intense, although current data do not completely support their perceptions in terms of intensity [2]. These storms have led to coastal inundation and enhanced erosion, causing flooding and property damage as well as reduced landmass at the coast that is available for occupation and development. For small communities with limited tax-based financial support, the loss of land and having houses that need to be relocated due to erosion can become a major financial burden and a strong political issue [21]. Vasseur and Catto [1] report that in Atlantic Canada, rural communities do not have the financial capacity to relocate houses or build protection walls and differ greatly from larger urban centers (e.g., Halifax) in the effect. It is important to note that most of these communities have an aging population, with more than 15% being over 64 years old and increasing, due to youth out-migration (compared to 13% in the rest of Canada) [1]. In addition, as stated by [1] and [19], people affected by these storms have suffered not only financial losses (due to infrastructure damage and unemployment), but also in many cases mental health issues, including depression. Ste.-Flavie represents a good example of these challenges, where the aftermath of the 2010 storms included significant out-migration of youth and families, one divorce, and increased social conflicts [19]. Its population decreased by 3.4% and 225 out of 884 inhabitants are over 65 years old (25.4% versus 18% for the rest of the province). Similar trends are found in Bonaventure with 26.5% versus 18%, Shippagan with 24.6%, and Cocagne with 25% being over 65 years old, while the rest of NB is 19.9% [22].

A combination of natural and human effects should be considered when interpreting the damage, as both have cumulative effects when storms hit the coasts. For instance, the shape of the shoreline may affect the recovery of the shoreline. Communities built very close to a low coastline, like in Cocagne, Ste.-Flavie, and Maria, can have a greater potential for flood damage and could expect buildup effects of floodwaters due to shoreline shape and sea level rise. More research is needed to address the effects of shoreline shape in order to inform territorial or landscape planning and any future relocation policy.

Communities located in NB also observed more intense rainfall, with rain falling heavily over a shorter period of time. In a previous study, [23] reported that people in NB have noted climatic extremes in the summertime, such as too much wetness or drought. They explained that such seasonal changes have affected river flow, such as that of the Bouctouche River and the Little Bouctouche River, in particular, the water level of which has been reduced. This is possibly attributable to dry spells when river temperatures increase to 30 °C, leading to shallower rivers and infilling with debris and siltation. In the Acadian Peninsula, fishing seasons have been affected; for example, fishing herring is now possible in August (rather than July). The location of shrimp has changed farther offshore due to warmer near-shore waters. This is also affecting lobsters, that are now bigger due to milder winters and because they are eating more. However, it is more difficult to collect shellfish because of the lack of low-water areas in places that are undergoing sea-level rise and/or subsidence. Places are affected differently, for example, L'ile-aux-Puces is being inundated by water. Reduced winter sea ice is prohibiting people from walking on beaches in January; for example, they can no longer walk out 4.8 km (3 mi) since 1998. Also frequently mentioned were higher seawater levels (e.g., [19]), with sunken places evident in Shippagan, Lameque, etc., and with cottage waterlines affected as water creeps up the shore. Consequently, people are more aware of erosion and coastal change, causing reduced demand for real estate (after 2008) in affected areas. Greater affluence is also influencing people living by the coast who want to be right by the sea and have their own private beaches [23].

In PEI, seasons are also shifting in such a way that freezing does not occur until December. Moreover, wind is coming from a different direction (more southerly and from the southwest rather than from the west) and wave action is changing due to ice severity decline in winter [24]. In PEI, people are questioning whether human-made coastal defenses (hard engineering) are actually beneficial or whether this has worsened problems associated with coastal erosion. However, built infrastructure, such as a landing built in St. Peter's, aids movement and thereby reduces isolation. The latter point is important when considering evacuation routes and procedures.

Future challenges for resource-dependent communities involve changing climatic influences of seasonality affecting fish and seashell species, such as Atlantic lobster [25]. In addition to these biological challenges, there are also physical ones, such as damages to buildings and infrastructure [1]. Community infrastructure, including storm wastewater systems, groundwater sources, roads, bridges, the power grid, etc., need to be repaired and maintained, and government inputs are required for this. Options to address the physical challenges include some expensive solutions, as for instance protection measures in order to deal with erosion, flooding, wind, etc.; however, many require government inputs to be able to afford expensive hard defenses, even though some people already incur some economic costs of their own for this at the individual-to-household level [21]. These aged communities are financially dependent and cannot resolve these issues on their own. On the other hand, retirees are available to volunteer in their communities and can work toward improving the situation where they live.

Governance has become an issue in small rural communities that are not incorporated in municipalities. In the Northumberland Strait of NB, Cocagne, and Grand-Digue are local service districts, and there are conflicting views as to whether community members or the government should take more responsibility [26]. Developing regional emergency management plans can be tricky, as it requires the provincial government to give its approbation. This can frustrate communities that do not have the financial means to contribute to a community generator, for example, in case of emergency [19]. In most coastal communities, in order to develop sustainable plans that consider social, ecological, and physical features of their landscape, there is a need for accompaniment by experts and organizations to enhance governance and improve resilience [27].

Alternative solutions to coastal physical impacts were provided, including relocation/retreat (moving out of the risk zone in the community or out of the region). Coastal retreat was an option that was considered by some respondents: "*The long-term challenge is to withdraw quietly from the sides and really adapt our way of life in function of this*" (Acadian male, Petite Lameque, affected by 2010 storms, 2012). However, not everyone favored relocation as a solution. In QC, people from Ste.-Flavie felt that hard decisions were needed, but that personal choices were involved rather than a concerted community effort. In most coastal communities, protection (retaining) walls and other hard structures have been deemed important to bring a sense of safety to people [28]. However, as stated by Savard et al. [9], "hardening of the coastline by rigid, linear, coastal protection structures can also lead to rapid loss of biodiversity and contribute to coastal squeeze by trapping coastal habitats and ecosystems between the rising sea and landward [human]-made barriers. Another disadvantage of hard-protection measures is that they are generally irreversible" (p. 136). In general, people were aware that these structures might not be efficient in the long term and, in fact, could become a maladaptation to erosion; however, they were often seen as a quick fix by some of the participants in this study. For example, in the Baie de Kamouraska, QC, the construction of dykes to increase agricultural land along the coast has led to coastal squeeze and loss of beaches and intertidal zone [9]. How to pay for these structures remains a challenge and, as stated by [19] and [28] in regards to these communities, most people do not want to pay and are instead expecting that the government cover the costs. Participants in this study are part of aging communities that mainly rely on natural-resource extraction as economic activities, and they cannot afford coastal defenses.

5. Conclusions

There are many physical changes along the coast of Atlantic Canada that have been identified with communities in the course of this research. These landscape alterations stem from extreme events, such as heavy rainfall, storm surge, and high waves that have increased under climate change, leading to coastal erosion and affecting the natural and built environments. They have also been reported in several assessments (e.g., [1,2]). It is, therefore, clear that alternative solutions are necessary to adapt to climate change and ensure the sustainability of theses coastal communities. Relocation does not suit everyone, however, and people encourage increasing awareness and education so that community members can make informed hard decisions regarding which actions to take. Some respondents called for government action to make important decisions and for concerted efforts in response to climate-evoked landscape change. The expense of hard defenses at a time when governments are strapped for funds may be unrealistic, however, and local efforts, including soft-engineered responses, are preferred. Solutions need to accommodate short- and long-term trends as well as respond to physical and social problems.

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