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A R T I C L E   I N F O

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Bottom up adaptation

A B S T R A C T

This chapter focuses on mainland coastal towns that have populations of between 10,000 and 50,000 inhabitants. Through six case studies, the chapter develops an understanding of the characteristics that shape each of the communities. By exploring the climate change hazards each of the case studies are experiencing now and forecast into the future, the physical and ecological profile and the human development condition, a view of the climate impacts for each is shaped. The six case study areas include towns that are large enough to be a regional centre, down to much less organised and resourced communities that are at a more subsistence level of development.

The case studies include communities that range from tropical storm areas to more temperate climatic areas. Adaptation strategies for each case study are observed, drawing out the similarities and the differences. Insights and lessons learnt show that the bottom-up inclusion of all communities in shaping the adaptation approach is crucial, together with alignment of policy between governments from national to local. Also crucial is the resourcing of local councils which sit on the front line of many adaptation initiatives. The role of universities and other research organisations to provide data, skills training and a toolbox of methodologies to those in the front line leadership roles. An important insight is the collaborative opportunity for universities, communities and agencies to draw out the innovative adaptation strategies that can inform other coastal communities from the smallest village to the largest city.

1. Introduction

The United Nations Sustainable Development Goals (SDGs) provide an opportunity for producing new approaches to adapt cities to the threats of climate change (Sanchez Rodriguez et al., 2018). However, urban research has generally been dominated by a focus on the larger cities with little attention paid to smaller settlements (Bell and Jayne, 2009). This is particularly true for the development and implementation of climate change adaptation strategies, with larger cities taking the lead. This is because they usually have easy access to climate, engineering, and management knowledge; access to accurate and reliable local scale climate data; access to financial resources; local stakeholders' participation; and political consensus (Major and Juhola, 2016). Conversely, smaller settlements struggle to access these resources to the same degree and therefore have difficulties when it comes to developing and implementing climate change adaptation (Bell and Jayne, 2009; Birchall and Bonnett, 2019; Birkmann et al., 2016; Hamin et al., 2014; Paterson et al., 2017; Pauleit et al., 2015).

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Coastal settlements will be greatly impacted by climate change due to the likely exacerbation of hazards such as sea level rise, storm surges, flooding, erosion, and salt-water intrusion (Masselink and Russell, 2013; Neumann et al., 2015; Vitousek et al., 2017; Werner et al., 2012). This means that adaptation of coastal settlements is greatly needed, however, given the problems smaller settlements have in developing and implementing adaptation, there are potentially a great number of coastal towns and cities that are not able to adequately adapt to climate change.

This article forms a part of a special issue on adaptation in coastal towns and small cities. This article focusses on coastal communities and cities of between 10,000 and 50,000 inhabitants. Six case studies are used within this article to assess the impacts of climate change at the local level, describe the adaptations that have already occurred, and finally an outline of the lessons that can be learnt from each case will be given. By conducting such an analysis, this article aims to begin to build a knowledge base that can assist coastal communities of a similar size to explore possible pathways to adaptation and increasing resilience.

2. Case studies

Six case studies of small coastal communities between 10,000 and 50,000 inhabitants are utilised within this article (Fig. 1 and Table 1). These cases differ in a number of ways such as the range of hazards they are exposed to, their economic, social, and cultural contexts, and the degree of management/adaptation planning and implementation. These six cases are part of a wider network of towns and small cities analysed within this special issue (Fig. 1), which offers a diversity of contexts and approaches, and key insights into climate change adaptation in small towns to be made.

For each of the case studies, researchers with experience of the settlement have taken the first steps to completing the developing typology (Lehmann et al., this issue) and a short narrative that summarises the current situation. Both the typology and the narratives were used to compare and contrast each of the cases and to generate the insights within this article. The reader can find further information about the cases from the narratives and typologies that included within the supplementary materials of this article.

The types of settlements at the six locations range from long established middle size urban settlements that are the centres of economic activity of the region with significant investment in infrastructure (Ballina, Ebro Delta, Middelfart and Costa da Caparica) to smaller communities with a more organic development history and characterized by lesser infrastructure investment (Rockport and Char Kukri Mukri Union).

Human Development Indices (HDI) a measure of human wellbeing in terms of income, education and life expectancy ranges from 0.608 for Char Kukri Mukri Union, below the global average to 0.939 for Ballina, Middelfart at 0.929, Rockport at 0.924 all in the very high range of wellbeing. Ebro Delta settlements are at 0.891 and Costa da Caparica at 0.847.

Of the six case studies submitted for inclusion, three are settlements associated with estuaries that have important environmental (in terms of ecosystem services) and socio-economic attachments for the settlements. While Ballina, Ebro Delta and Char Kukri Mukri Union each share the ecosystem value of an estuary, Ebro Delta has a dependent tourism industry associated with bird watching (estuaries typically provide habitat for both resident and migrating bird species of interest). Tourism is an important part of the economy for all three towns in the Ebro Delta and includes water activities, ecotourism and bird watching in the Punta de la Banya nature reserve. Ballina, Ebro Delta's Sant Carles de la Rapita and Rockport each have important fisheries contributing to the local economy.

Each of these six case study areas are waterfront and under the influence of sea-level changes. However, Ballina, Rockport and Char Kukri Mukri Union are particularly in areas that could be subject to either direct impact of cyclones (typhoons or hurricanes) or the rain events of degenerated cyclones (typhoons or hurricanes). These three case studies, together with the Ebro Delta towns are also the most vulnerable to tidal, storm surge and river flooding, given their close proximity to the rivers and delta waterways and low elevations, typically less than 10 m.

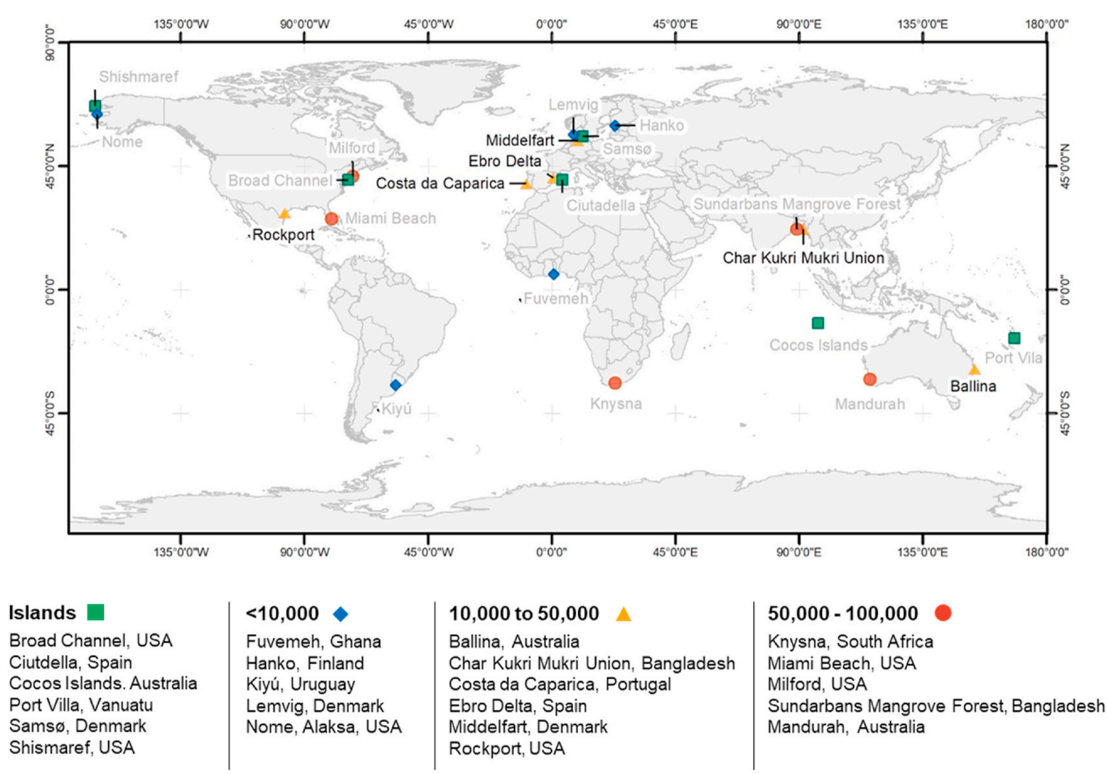

Fig. 1. Map showing the location of case study towns pertinent to this article and within the wider special issue.

Table 1
Impacts associated with climate change in small coastal communities and cities of between 10,000 and 50,000 inhabitants. This data in this table is derived from the case study typologies, therefore for the original sources of these data see the supplementary material.

	Ballina, New South Wales, Australia	Char Kukri Mukri Union, Bangladesh	Costa da Caparica, Portugal	Ebro Delta, Spain	Middelfart, Denmark	City of Rockport, Texas, USA
Population	41,790	11,214	13,400	Amposta (20,606) Deltebre (11,505) Sant Carles de la Ràpita (14,611)	37,981	10,490
Human Development Index	0.939	0.608	0.847	0.891	0.929	0.924
Sea Level Rise	0.4 m by 2050 and 0.9 m rise by 2100 (based on 1990 levels)	SLRs of 14, 32 and 88 cm for the years 2030, 2050 and 2100, respectively	13–68 cm rise by the 2050s.	Mean sea level increased by 3.1 cm per decade in the period 1990–2017 (Estartit station)	Relative sea level rise of 0.3 m and 0.6 m within this century	6 cm per year by 2020
Increasing storm intensity	High intensity rainfall exceeding capacity of storm water systems with average summer and autumn rainfall increasing by 5–20% and winter rainfall decreasing 5–10%	Located in cyclone and storm zone, with sever cyclones in 1970, 2007, 2009, and storm surges in 1991 and 2010	Located in Atlantic storm zone with last major storm surge in 2014	The number of intense cyclones is expected to reduce in the future, however they are predicted to become more severe when they do occur	Increasing intensity of heavy rain fall exceeding capacity of runoff infrastructure	The probability of a hurricane or tropical storm occurring in this area any given year is 23%. With potential to experience a Category 5 storm in the future.
Coastal erosion	Erosion of the dune system and/or failure of seawalls with future erosion, with estimates of 10 m lost by 2050 and 25 m by 2100	Extensive and rapid with a large loss of land	Significant loss of sand in storms with ocean swells	Yes, exacerbated by decreased sediment import from the Ebro River	Not significant	Areas affected by coastal erosion include but are not limited to Copano Bay, Aransas Bay, Cedar Bayou, Cove Harbor, and Little Bay.
Decreasing river flow	Not available at this time	Not available at this time	Not applicable	Reduction of 14 m^3/decade resulting in deficits in sediment import affecting coastal habitats	Not significant	Not significant
Increasing river flow	Changes in the annual distribution of rainfall and storm frequency, including ex-cyclones, are creating high intensity rainfall vents that increase flood peaks in rivers	Monsoon flows would increase by the 2050s with peak flows increasing +24%	Not applicable	Not Significant	Not applicable	The probability of storm surge damage occurring is approximately 7.2% per year
Increasing air temperature	Mean average number of days >35 °C increase by 5–10 days by 2070	Not available at this time	Not available at this time	Mean air temperature increased by 0.42 °C per decade, and maximum air temperature increased by 0.6 °C per decade in the period 1990–2017	Not available at this time	34 heat advisories were issued between 2005 and 2015
Increasing sea temperature	Average 26 °C or above January to March each year peak 28 °C	26 °C or above March to November peak 30 °C	+0.1 °C per decade	Mean sea temperature increased by 0.26 °C per decade at surface level, and 0.16 °C per decade at depth of 80 m in the period 1990–2017	Not available at this time	Average 26 °C or above June to October each year peak 31 °C

The Costa da Caparica zone is predominantly at risk of storm surge and sea level rise, particularly at times of high tide. Middelfart however shares a common risk with many of the other case studies of coping with a high rate of rainfall in “cloudbursts”, a phenomenon that has impacted many Scandinavian communities in recent years.

2.1. Ballina

Ballina is situated within an estuary, close to the river mouth of the Richmond River. Ballina began as a river/sea port and has become a regional service centre for the surrounding areas. The Ballina region surrounding Ballina is 484 km^2. The economy includes a significant fishing cooperative and is home to many agricultural producers and manufacturing/warehousing, with good access to major roads to capital cities. Ballina and its surrounding area receive significant infrastructure investment. Close to the entrance to the mouth of the Richmond River and alongside the river for the full length of the town, Ballina is built on what is effectively an island, and its landscape is very flat and close to sea level in the town centre. During high tide, storm surge and heavy rainfall, the city centre can be periodically flooded to a small depth. Ballina experiences mild winters and hot summers with annual rainfall averaging over 1600 mm as it is in a humid subtropical climatic zone (See Ballina supplemental material).

2.2. Char Kukri Mukri Union

Char Kukri Mukri Union of Bhola District is located on the edge of an outer Island on the Meghna River in a delta area, facing the open sea of the Bay of Bengal. The total land area of Char Kukri Mukri Union is 36.79 km^2 with a climate largely humid and tropical. Most of the people in Char Kukri Mukri Union are involved in fishing and agriculture for their livelihood. Others are involved in day labour and forest-based livelihoods. Most of the livelihood resources have been affected either directly or indirectly by extreme climate hazards. Much of the areas is impacted by tidal surge, river erosion, water logging, and salt-water intrusion (See Char Kukri Mukri Union supplemental material).

2.3. Costa da caparica

The Costa da Caparica is part of the Almada municipality located on the ocean facing beachfront adjacent the mouth of the Tajo River in Lisboa. Costa da Caparica is the beach side municipal zone along Almada’s Atlantic coast. Situated on the ocean side of the delta, it is bordered to the east with a high-density area, making up the remaining Almada municipality. The Costa da Caparica is a zone 1.5 km long and an area of 2 km^2. The zone with its attractive beaches is a tourist magnet, particularly in summer, when the tourist population swells dramatically (Rosenzweig et al., 2018).

2.4. Ebro Delta

The Ebro Delta is one of the most valuable coastal systems in the Western Mediterranean with more than 65% of its area used for rice cultivation (Genua-Olmedo et al., 2016). The delta was formed by the Ebro River, which has the highest discharge in Spain (Fatorić and Chelleri et al., 2012). The settlements within the Ebro Delta are in the estuarine area upstream of the delta mouth. Ebro Delta has a Mediterranean climate with hot dry summers. The Ebro Delta case study includes three towns, Amposta, Sant Carles de la Rapita, and Deltebre. Amposta, located approximately 12 km upstream from the river mouth has a long history of more than a thousand years, as does Sant Carles de la Rapita, which is located on the Mediterranean foreshore adjoining the southern edge of the Ebro Delta, partly hemmed in from the Mediterranean Sea by an island and spit. Amposta and Deltebre have populations of approximately 21,000 and 11,500, with land areas of 138 km^2 and 103 km^2 respectively. Sant Carles de la Rapita with a population of 14,600 and a land area of 53 km^2 and is a key fishing port within Catalonia (See Ebro Delta supplemental material).

2.5. Middelfart

Middelfart is located on the Funen Island on the edge of one of Denmark’s inner straits between the Baltic Sea and the North Sea. Middelfart region occupies an area of 298 km^2 with Middelfart as the regional centre. The climate of the city is cold, with a warm summer and devoid of a dry season. The topology of the city and the surrounding landscape is flat with hills. The economy is a mixture of agriculture, regional services, transport and warehousing (See Middelfart supplemental material).

2.6. Rockport

Rockport is situated in a coastal lake/bay system created by offshore islands. Rockport is steeped in history, and has a similar beginning as a shipping/river port as Ballina in the 1800s. The settlement of Rockport has a total area of 28 km^2 of land and has a humid, subtropical climate with mild winters and warm summers. Rockport has become a hub for fishing, boat-building, and tourism. The economy of Rockport thrives on activities related to its wetlands; such as commercial fishing, shrimping, birdwatching, sport fishing, kayaking, and boating (See Rockport supplemental material).

3. Hazards and impacts

Climate change impacts (Table 1) on the six case studies includes sea level rise, storm surges, and increased rainfall intensity associated with increasing severity of coastal storm systems (or cyclones/typhoons/hurricanes). Sea level rise in the case study areas is consistently increasing. An increase in storm intensity was observed in all case studies except Ebro Delta. In particular Ballina, Rockport and Char Kukri Mukri Union are all subject to cyclonic or ex-cyclone activity bringing heavy rain and strong winds, whilst Middelfart is subject to other storm activity and high intensity rainfall “cloudburst” phenomena. This combination of hazards creates increased risk of flooding from one or a combination of sources (fluvial, pluvial, or coastal).

With a collective population of just over 48,000 inhabitants, Ebro Delta’s three towns are vulnerable to sea level rise, changing sea and air temperatures and decreased river flows that exacerbate coastal erosion, flooding from sea level inundation, saltwater intrusion, sediment supply deficits, and impacts upon natural habitats and livelihoods. For example, the normalized rice production index could reduce from 61.2% in 2010 to 33.8% by 2100 in the worst considered scenario, resulting in an estimated decrease of profit of up to 300 € per hectare (Genua-Olmedo et al., 2016).

Storm intensity in combination with sea level rise is forecast to intensify coastal erosion and saltwater intrusion in Char Kukri Mukri Union, Ballina and Costa da Caparica, with groundwater contamination by saline intrusion a potential impact. However, in the Char Kukri Mukri Union, the combination with large river flood events is already causing extensive and rapid loss of land (Fig. 2) from erosion, which is already disrupting communities and forcing many thousands of people to migrate into the cities of Dhaka and Chittagong, often into slum conditions (Luetz et al., 2018). The large scale erosion that is taking place on the islands is also being redeposited by the same flooding and climate events in different locations in the delta. However, it is likely that the possibility of resettlement onto those newly formed areas will take many years of stabilisation.

Costa da Caparica has also already experienced erosion, with the loss of beach during storm surge events. Events over the past century have eroded significant volumes of sand from the beaches. The most recent event occurred in 2014 during a storm surge in combination with a high tide. Erosion of the beachfront and abnormally high levels of water were

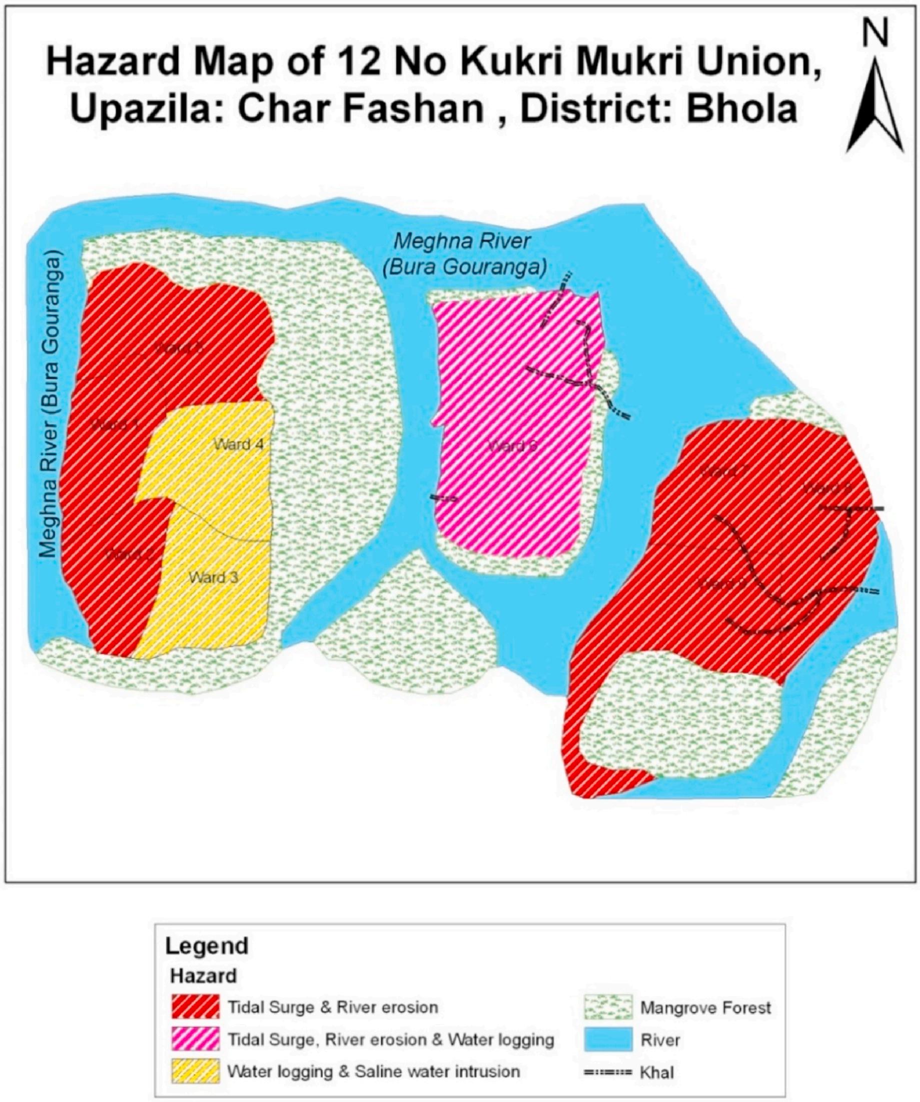

Fig. 2. Hazard map of char kukri mukri union. (Source: CRA Final Report, 2010).

experienced from the event, creating a risk to adjacent buildings.

Built infrastructure in most of the case studies in estuaries are subject to flooding of storm water, roads and sewerage systems. Each of these towns are located in the floodplain, with past infrastructure decisions leaving some critical assets such as pumping stations at Rockport at risk of inundation and evacuation routes at risk of disruption due to flooding.

Acidification of the ocean in combination with storm surge can adversely affect certain built infrastructure with loss in durability of the exposed building materials. This is particularly a risk in low-lying settlements of Ballina, Char Kukri Mukri Union, Ebro Delta and Costa da Caparica where elevations in much of the settlements are less than 10 m above mean sea level (MSL).

Increasing sea temperature and acidification is expected to trigger marine species movement or loss with flow on effects to ecosystems and commercial industries and tourism. In the less urbanised communities of Char Kukri Mukri Union, fishing and agriculture is a mainstay of their livelihood and most of the livelihood resources will be affected either directly or indirectly by extreme climate hazards.

3.1. Compounding factors

Ballina, Rockport and Char Kukri Mukri Union are all in zones where the confluence of storm surge and high intensity rain fall leading to river flood levels can compound to increase the risk of inundation, erosion and contamination of water and sanitary systems. This can be further compounded in countries such as Bangladesh where while there is a climate change strategy and action plan, it is a top down only approach and lacks proper implementation of the action plan programs. Another compounding factor is the influence of heat waves that encourage people to live closer to the sea for cooler conditions, while at the same time placing extra strain on infrastructure and exposing greater populations to the former hazards. Costa da Caparica is a zone where the confluence of storm surge with high tides and sea level rise, compounds with summer expansion of tourist population in the most exposed areas.

4. Adaptations

Due to the hazards and impacts described above there have been a number of adaptational responses within the case studies, and given their local contexts, there are different approaches used. In Middelfart, the key focus is on reducing the rate of runoff in “cloudburst events”. Besides past and ongoing investments to increase the capacity of the sewer system, the city of Middelfart is changing its adaptation strategy to solutions in synergy with the development of urban space to retain rainwater locally and increase urban liveability. This involves changing the current roles of citizens from passive service receivers to active participators. The project was realised in collaboration with the Municipality of Middelfart, Middelfart Wastewater utility and citizens (garden owners). The process has strengthened the already good neighbourhood and made it possible to combine some SuDS elements across garden boundaries.

Adaptation approaches in Ballina are being formulated both locally by Council and also through State Government Office of Environment & Heritage supported workshops that have engaged local government staff and other agencies in the Northern Rivers. These have made visible the forecast trajectory on climate change impacts and to collectively identify with these frontline councils and agencies on how to transition into adaptive strategies that can have practical effect in regions such as Ballina. Some of these strategies include establishing knowledge-sharing initiatives, between disciplines and inclusive of indigenous knowledge, to understand holistic adaptation approaches throughout the catchment.

In Rockport, the need for locating essential infrastructure outside vulnerable areas such as floodplains is identified. Whilst many of these are located in less vulnerable locations, some essential wastewater lift stations remain within the 100-year floodplain. In an initiative to build collaboration between higher level governmental and NGO groups and agencies, the Aransas County Multi-Jurisdictional Floodplain Management Plan (Aransas County, 2017) aims to minimize the associated risks from flooding in the county and bring relevant results and meaningful roadmaps to adaptation for its jurisdictions. This is the first floodplain management plan in this area and sets the groundwork for how floodplain management will be addressed in Aransas County in future years. This document gives essential guidance for the near future, providing the base from which these communities can make informed decisions about how best to direct their time and resources.

Historically, the adaptation approaches to coastal erosion of the beaches in Costa da Caparica has been to install hard infrastructure in the form of groins and seawalls. The measures were effective for the years following the installations. However, since 2000 the beaches have shown signs of instability causing significant depletion of sand in the beach. In response, the Almada municipality has introduced softer approaches to artificially nourish the beaches with 2.5 million cubic metres of sand, but beaches were still significantly eroded and flooded in a 2014 storm surge. More recently the local government introduced adaptation requirements in the form of flooding quotas to restrict development in inundation zones and has integrated climate change studies into the development of other plans, creating synergies between the various plans. The national Portuguese government has since increased its focus on coastal vulnerability, funding vulnerability assessment, development of risk maps, artificial beach nourishment and coastal monitoring. Collaboration and alignment is not only occurring between local and national government agencies, but also with university based research organisations, including a local information-sharing network in ClimAdaPT and in the development of an alarm system to warn of coastal flooding.

The response in Char Kukri Mukri Union is twofold. The first and most important one is to work with the local residents to inform and empower them to decide their own adaptive approaches, a bottom-up approach. The main effort was to enable villagers (including the poorest) to focus on what are the approaches they can most influence. For them, it is essentially enhancing livelihoods (which use the natural capital of the forest and fishing) which in turn builds capacity to deal with future climate change.

The second response is to help the national government of Bangladesh to apply a top down effort to put policies in place on climate change, such as indirectly addressing the impacts of climate change through programmes that reduce vulnerability. For example, through poverty alleviation, employment generation, crop diversification and specifically targeting climate change by mainstreaming climate change into sectoral plans and national policies (Huq and Jessica 2008).

In the Ebro Delta, the focus was on a participatory approach combining local and scientific knowledge to increase community ownership in adaptation solutions. Respondents in Ebro Delta favoured nature-based solutions such as restoring sand dunes or beach replenishment (where costs permitted), or a combination of soft and hard infrastructure approaches, using the ecosystem approach to better understand interactions between anthropogenic impacts, estuarine functioning and society (Fatorić and Chelleri et al., 2012).

5. Lessons from case studies

This work is a first attempt at populating the typology. This has revealed to some degree, the lack of visibility and in some cases availability of information in various communities. Gaps in available data are evident in Table 1, together with a need to standardise the reporting of quantitative information such as rate of sea level rise. The typology questions and parameters will also need fine tuning as more case studies are added and initiatives are put in place to source the required information.

5.1. Ballina

Even in a society with a high degree of governance, barriers to adaption can be found. Policy vacuums in state and federal governments have made it difficult for local councils to be effective in leading the front-line adaptation action. However, efforts by the more highly resourced state government is helping the local councils and agencies to be supported with the data and skills they need to adequately provide adaptation pathways.

Provided appropriate funding, data and skills support is provided to councils, local community and industry champions, well suited bottom-up adaptation initiatives have the opportunity to take shape. It was observed through the Ballina Case study that collaboration with communities is generally easier in towns and small cities. When coupled with lesser complexity in mobilising initiatives, this opens up the opportunity for towns and small cities to likely be the engine room for adaptation innovation.

5.2. Char Kukri Mukri Union

The case study of Char Kukri Mukri Union has provided a demonstration on the process to engage with local villages to help them build bottom-up approaches that they can work with. A key observation was to include everyone in the process, including the poorest. The decision to concentrate on enhancing their livelihoods brought into focus the following guiding points:

In summary, they include:

- Increasing awareness and knowledge about climate change (to encourage people to start adapting)
- Developing skills, providing training and education (to facilitate adaptation)
- Providing advanced technology to manage disaster at a local level, e.g. radio transmission, signals, etc. (to minimize loss from extreme weather events exacerbated by sea level rise)
- Advocating good governance with leaders (integrating local issues into decision-making)
- Empowering women (to reduce the vulnerability of one of the most vulnerable groups)
- Ensuring equity for all people residing in the coastal communities.
- Do not presume the specific variables that represent exposures, sensitivities, or aspects of adaptive capacity, but rather seek to identify these empirically from the community.

However, for communities of this type, the practical, achievable points above are not sufficient in the long term if they focus only on immediate circumstances. Longer-term future changes in environmental conditions may not be appreciated by villagers, yet may have implications for the sustainability of their adaptive strategies and livelihoods. These risks need also be considered in adaptation programs.

5.3. Costa da caparica

The experience and current strategies in this zone of Almada reinforce the importance of bottom-up approaches to adaptation, and the important role of local government. The importance of collaboration with other stakeholders and alignment of strategy is drawn out in the case study. The role of university and allied research organisations in providing adaptation methodologies, evidence based data and toolbox tools, such as an alarm system, for the practitioners to apply, is reinforced in this case study. The type of physical adaptation approaches to apply in coastal erosion situations is questioned. The experience from this case study suggesting that softer adaptation measures or a combination with them, is more effective than purely hard engineering approaches.

5.4. Ebro Delta

Application of a participatory framework utilising different knowledge constructs within the local context of adaptation has provided valuable insights. Past adaptation has occurred mainly through unsustainable measures (hard infrastructure), whereas over half of the participants in the stakeholder process favoured natural adaptation measures like restoring dune systems and raising ground level, and a quarter were in favour of mixed hard and soft approaches. A key lesson to be drawn from this case study is the importance of integrating local understanding, perception and knowledge with science to empower local decision-making.

5.5. Middelfart

This case study is a reminder that investments in infrastructure may be made less effective due to the changing climate situation. However, what may be considered a loss in value may on the flip side provide opportunity for a change that not only adapts, but adds value in a different way, achieving other benefits. For example, Middelfart Municipality changed its strategy to not add additional sewer system capacity to cope with "Cloudbursts" but to instead create solutions in synergy with the development of urban space to retain rainwater locally and increase urban liveability. This also fits with the growing view on green and blue urban structures, as desirable to create a liveable city.

The collaboration has taught professionals as well as citizens to think of rainwater as a resource. Furthermore, the process has inspired citizens in the area to redesign gardens for both recreational and functional purposes.

5.6. Rockport

An aspect that is important to remember from this case study is the "what to do" and "what not to do" in design. Keeping essential systems, such as waste water lift stations, clear of the most vulnerable locations such as the floodplain is a case in point. At the time the infrastructure was designed and built the location may have been suitable. However, the design parameters of the past may be shifting with the climate situation and flexibility to adapt needs to be included in designs from this point forward, particularly for long life assets.

6. Conclusions

These collective case studies have brought out a wide breadth of approach and lessons to take away for many different contextual situations. It is however, pertinent to draw out of the section a number of specific insights.

Each of the case studies are of towns exposed to climate hazards that are compounded by the degree of climate hazard overlaps and the geographical context of the town. The challenges facing each of the towns and their surroundings, are similarly shaped by the communities, their government, their collective resourcefulness, and their means to respond and adapt.

Middlelfart, Ballina, Rockport and the Ebro Delta case studies all show a means and a willingness for collaboration and bottom up driven adaptation initiatives. However, some of the case study communities are in countries that do not have the means to respond.

The Char Kukri Mukri Union situation is somewhat concerning. The hazards in that settlement are already seriously impacting the communities and there are suggestions that adaptive capacity may be significantly bolstered by mainstreaming disaster risk education (Luetz and Sultana 2019). The case study has shown communities with a similar willingness to be engaged in bottom up adaption, but unlike the other case study communities, have little means to respond in the face of the loss in land that is taking place. The Bangladesh experts have also identified from studies that the land loss is balanced by land accretion in other areas that could be used for relocation, but there is uncertainty in whether those areas can be stabilised from future climate events (Luetz et al., 2018).

The Ebro Delta case study showed a preference to adapt to the progressive impact of sea level rise by utilising natural adaptation measures such as creation of new sand dunes instead of groins and sea walls. Building with nature initiatives like this and perhaps the "sand engine" near Ter Heijde in the Netherlands, could help provide adaptation solutions for situations such as at the Char Kukri Mukri Union. The Costa da Caparica experience in controlling sand depletion in storm surge events across 60 years serves to reinforce the approach of building with nature. Connecting the lessons and insights like this, between settlements by sharing case studies, adds weight to the proposition that small cities and towns can be the engine room for adaptation innovation through collaborative knowledge sharing.

The lack of visibility, uniformity and in some cases availability of source information in various communities, points to the need for an effort to improve the situation. The typology questions and parameters will also need fine tuning as more case studies are added and initiatives are put in place to source the required information.

As adaptation is an unchartered territory, local government and organisations at the front line of climate change adaptation need to be adequately resourced, not only financially but with staff, skills and toolboxes of methodology to enable them to deal responsively as situations change. The role of universities in developing these skills and toolboxes is an important initiative to be explored. Each of the case studies have discussed innovative methods for engaging local communities into the process of creating adaptation pathways that appear to have been successful. These methods are an opportunity to add to the toolbox for sharing amongst other towns. The observation that towns and small cities, with the appropriate resources, are likely to become engine rooms for adaptation innovation, is a key insight. This opens up the potential for good practice adaptation pathways and pitfalls, to be shared with other towns, small cities and even inform pathways for larger cities.

The process of collating more case studies and cross connecting the experiences of each can only serve to enlighten all in the potential pathways for transitions into adaptation and provide opportunity to draw out the innovative adaptation strategies that can inform other coastal communities from the smallest village to the largest city.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2021.105790.

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