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Coastal adaptation to climate change through zonation: A review of coastal change management areas (CCMAs) in England

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ABSTRACT

Climate change and accelerated rates in sea-level rise are expected to increase flooding and erosion on the world's coastlines. Coastal managers and planners face the challenge of helping communities to adapt to the changing coast. Traditionally hard engineering has been used to defend communities on the coast, but as this option becomes unsustainable and financially unviable, coastal managers are increasingly employing planning policy to mitigate the risk posed by coastal change. Zonation of coastal change areas and delineation of erosion extents, such as set-back lines, are used globally to restrict development in the coastal zone. In England there is policy in place to allow planning authorities to restrict certain development in areas expected to be affected by coastal change. This study aims to examine how coastal planning authorities in England have implemented coastal change adaptation policies, specifically Coastal Change Management Areas (CCMA). These areas should include sections of coast that will experience significant change over the next 100 years through erosion, accretion or flooding. Through an analysis of planning documents, we have found that since the policy was introduced in 2012, only 15% of coastal planning authorities have designated a CCMA, with just 5.7% of the coast of England designated as a CCMA. We have found that inadequate and ambiguous guidance has reduced the effectiveness of the national policy with coastal planning authorities unsure of which datasets to apply for delineating areas of coastal change. This has led to vulnerable coastal areas being omitted from CCMAs. The datasets that are available for mapping the coastal change areas are found to vary in erosion extent and do not account for expected increases in the rate of sea-level rise. We suggest that for coastal zonation and climate change adaptation policy to be successful, a robust methodology, including a classification of coastal typologies and their response to sea level rise, is needed to delineate the extent of erosion or coastal change over the next 100 years. Understanding and mapping coastal response to sea level rise will aid planning authorities to build more resilient communities on the coast.

1. Introduction

The coastal zone is arguably the most important region for many coastal countries and communities due to the presence of critical infrastructure, significant economic activity and amenity (Vousdoukas et al., 2018). Additionally, it is estimated that 77% of the world global value is provided by coastal ecosystem services (Martínez et al., 2007). Approximately 40% (2.4 billion people) of the world's population live within 100 km of the coast (UN, 2017), with estimates ranging from 600 million to 1 billion living in areas less than 10 m above current sea level (Kirezci et al., 2020; Kulp and Strauss, 2019).

At the same time, the coastal zone is also one of the regions of the world that is most affected by climate change, in particular enhanced coastal erosion and flooding due to sea-level rise and potential increase in extreme weather conditions. Recent IPCC projections indicate that global mean sea-level rise (SLR) is accelerating and could rise between 0.29 and 1.10 m by 2100 (Oppenheimer et al., 2019). Rising sea level is expected to lead to an increase in coastal erosion and flooding (Brooks and Spencer, 2012; Climate Change Committee, 2018; Masselink et al., 2020; Vitousek et al., 2017), which poses complex challenges for coastal managers and communities globally (Hinkel et al., 2018). An increase in regional extreme sea levels (ESL), caused by tide, storm surge and wave action (Kirezci et al., 2020; Vousdoukas et al., 2018; Wahl et al., 2017) is also expected as these forcing components combine with rising sea

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levels. It is predicted that ESL events will increased in the English Channel throughout the twenty first century (Haigh et al., 2011) and that globally, an increase in ESL will cause 100-year flood events to occur annually by 2100 (Vousdoukas et al., 2018). This will push current sea defences to their limits and place coastal communities at increased risk. Currently, 630 million people live on land situated below the projected 2100 annual coastal flood levels (Kulp and Strauss, 2019).

Along naturally evolving and unconstrained coastlines, SLR and ESL events will drive onshore migration of beaches, barrier beaches, dunes and wetlands (mangroves and saltmarshes) (Borchert et al., 2018; Cooper et al., 2020; Mulder et al., 2020; Orford 2011; Schuerch et al., 2018). However, where this movement is restricted by coastal defences or cliffs, the coastal environments seaward of the structures, will narrow as sea level rises, in a process referred to as 'coastal squeeze' (Gracia et al., 2018; Luijendijk et al., 2018; Ranasinghe et al., 2012; Vitousek et al., 2017; Vousdoukas et al., 2020a). This 'squeeze' of the seaward coastal environment will ultimately lead to a reduction in amenity value, coastal habitats, ecosystem services and natural capital.

There are different adaptation strategies available to help mitigate against the adverse impacts of coastal erosion and flooding due to SLR. Defending the coast with hard structures has traditionally been the main management strategy, which allows infrastructure and communities to grow in the coastal zone as well as create societal benefit from the economic and amenity advantages that the coast offers. The disadvantage of this reliance on hard defences, is that it tends to attract increased investment in the infrastructure that is protected. This perpetuates the need to maintain and upgrade defences and locking coastal communities into a position of defend to survive (Lazarus et al., 2018). There has been a shift in some countries away from hard engineering coastal defences to softer engineering approaches as part of nature-based solutions, such as beach nourishment (Brown et al., 2016; de Schipper et al., 2021; Hanson et al., 2002; Morris et al., 2020). However, long-term coastal defences, based on either soft or hard engineering, are not always economically viable (Morris et al., 2020) and a more sustainable approach to coastal resilience is often required. As the pressure that climate change exerts on global coastal communities becomes more apparent (Kirezci et al., 2020; Masselink et al., 2020; Satta et al., 2017; Taherkhani et al., 2020; Vitousek et al., 2017; Vousdoukas et al., 2018), governments are utilizing coastal zonation and restrictive planning policy as an additional coastal management approach (Losada et al., 2019; Sanò et al., 2011; Storbjörk and Hjerpe, 2014; Young and Essex, 2020). The creation of these zones rely on robust predictions and estimations of future erosion and coastal change, with high levels of confidence, if they are to be successfully implemented with minimal opposition and appeals from coastal residents. Several countries have developed approaches to mapping buffer zones to inform coastal planning and management.

- In New Zealand, coastal erosion hazard zones (CEHZ) are used by planning authorities to manage development on the coast. CEHZ are set out in Regional Coastal Plans that are produced by individual regional authorities, but convey the national coastal policy. Generally, the Bruun rule (Bruun, 1952; Vousdoukas et al., 2020b) is used to determine shoreline response to SLR and the extent of the CEHZ, but the zone can be no less than 20 m in width (Ramsay et al., 2012; Rouse et al., 2017). As well as using Bruun or modified Bruun estimates, a number of other approaches and coastal modelling techniques for determining shoreline retreat have been deployed within New Zealand as described by Rouse et al. (2017). In New Zealand, coastal authorities are provided with a 'Good Practice' manual detailing a number of approaches for determining coastal change zones (Ramsay et al., 2012).
- New South Wales in Australia uses hazard lines to guide coastal development (Wainwright et al., 2014), which represent the future projection of the coastline by estimating retreat rates in response to storm events, sea level rise and local sediment budget. They are derived from historical aerial imagery and photogrammetry together with Bruun Rule estimations (Wainwright et al., 2014). The Hazard Lines usually comprise of an intermediate line, which represents short-term erosion due to storm events, and a line showing long-term erosional trends for the area.
- Romanian legislation states that no permanent buildings are allowed in the 'protected area' along the coast, which can be between 50 and 150 m in width (Sanò et al., 2011).
- The Mediterranean Integrated Coastal Zone Management (ICZM) protocol calls for a 100-m set back zone to be implemented by countries across the entire basin, within which development is restricted (Sanò et al., 2011).
- In Portugal, a coastal protection zone has been included in development policy since 1983. Initially, the zone was defined by drawing a line 200 m inland of the cliff top. Legislation was changed in 2012 to recommend that the zone should be defined by cliff retreat rates predicted over the next 100 years, derived from field studies (Pena et al., 2021).
- In the USA, the Coastal Zone Management Act (1972) provides individual states with more power to mitigate risk at the coast (Williams et al., 2018). Currently, 14 U.S states have set back zones where construction is controlled. These zones are typically based on long-term erosion trends and a setback distance that is equal to a set time span multiplied by theses calculated rates. Generally, they do not account for SLR or increased rates of SLR (Neal et al., 2018). Florida uses a Coastal Construction Control line together with an Erosion Protection Setback policy to limit unsuitable development at risk areas. The setback policy indicates that buildings should be located inland from the coast by 30 times the average annual coastal retreat rate (Williams et al., 2018).

Although there are examples of coastal zonation, as a response to coastal change, from around the world, the practice is relatively uncommon, and all use varying methodologies to delineate the physical area where development is restricted. This paper evaluates the use of coastal zonation in planning policy in England. Firstly, we explore the current planning policy, specifically Coastal Change Management Areas (CCMAs), and describe where they have been implemented in England. Secondly, we detail the methodologies and datasets used by the Planning Authority to delineate the areas of coastal change for determining the CCMAs boundary. We then evaluate these methodologies and datasets to determine if they are fit for purpose, discuss their shortcomings and implications of this on the knowledge and skill set of coastal planners and managers. We argue that inconsistences and fragmented methods to determine CCMAs will lead to future management problems as longer-term climate change continues to accentuate impacts. Finally, we will provide recommendations on how to improve coastal change delineation to help increase the implementation of CCMAs in England and highlight the need to recognise that coastal adaptation policy and its implementation must be supported by robust estimates of coastal change.

2. Coastal zone management in England

2.1. Geography of coast of England

The English coast is geomorphologically highly diverse and includes hard and soft rock cliffs, sand and gravel barriers and beaches, dune systems, estuaries, tidal flats and salt marshes (Scott et al., 2011). This diversity is a product of the varying geology and its resistivity to denudation, sea-level history, glacial isostatic adjustment and differences in the external forcing, such as wave, tide and wind (Gehrels, 2010; Shennan and Horton, 2002). The east and south-east coasts, bounded by the North Sea and the English Channel, respectively, are characterised by soft unconsolidated cliffs (Fig. 1a) and long sandy beaches. Here, rapid erosion of the coastal cliffs occurs, with metres of land loss per year in places (Pye and Blott, 2015), but this coast also

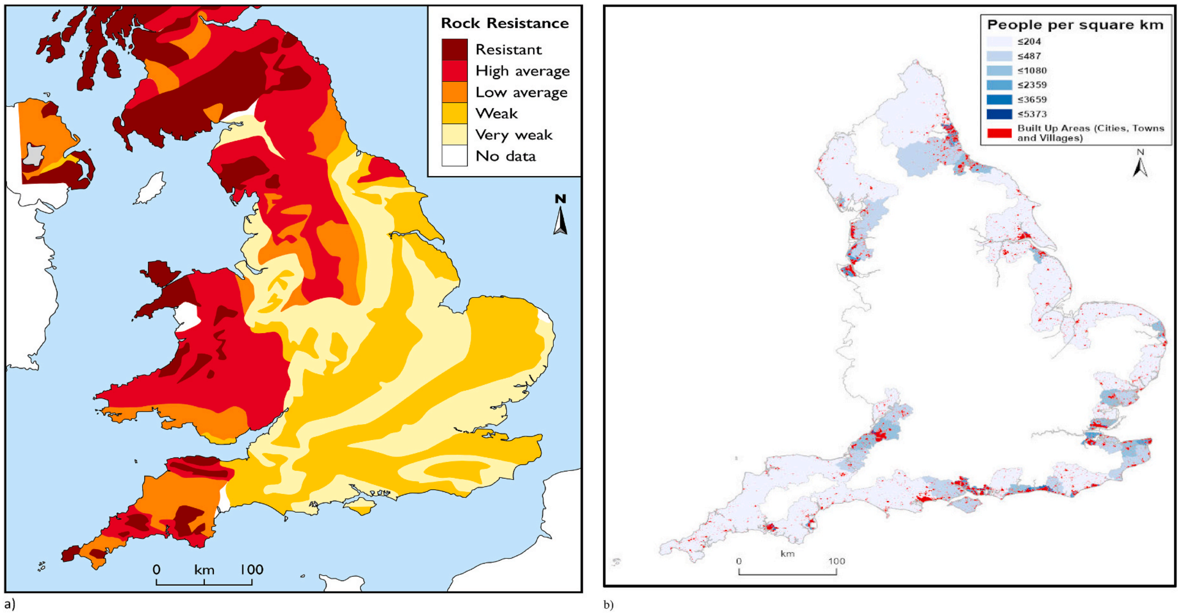

Fig. 1. a) Resistance of the geology of England to denudation (Clayton and Shamoon, 1998) b) Population density of Coastal Planning Authorities in 2019. Shown in people per km^2 and Built Up area of England as defined by ONS (2011).

features significantly prograding stretches of coast, fed by the erosion on the adjacent coast (Bristow et al., 2000; Montreuil and Bullard, 2012). Erosion is predominantly from wave and surge action acting from the sea, and structural and mass failures on the land. The east coast is also characterised by areas of low elevation and large-scale extreme coastal flood events have occurred in the recent past (Sibley et al., 2015; Steers, 1953; Wadey et al., 2015). The south-west coast, which stretches into the Atlantic Ocean, and similarly the north-west and north-east coasts, consists of mainly hard resistant rocky cliffs (Fig. 1a) and embayed beaches where erosion rates are slower, and dominated by sporadic failures triggered by rainfall or storm events (Clayton and Shamoon, 1998; Masselink et al., 2020). The south-west and the south coast experiences large-scale storm events and powerful wave energy from the Atlantic, with significant historical coastal damage and flood events (Masselink et al., 2016).

The coastline of England has 45.6% of its length protected with coastal defences (including sea walls and artificial beaches) (Masselink et al., 2020). These defences are in place to protect coastal residents who inhabit a number of larger coastal towns and cities, and smaller seaside villages. The English Environment Agency estimate that 5.2 million properties are at risk from flooding or coastal change (Environment Agency 2020). Fig. 1b shows the distribution of the population in England, with relatively high population density on the north-west and north-east coast, and along the south-east, around larger coastal cities and town. Coastal towns and built up areas of coastline can been seen in Fig. 1b, with smaller coastal communities spread around the entire coast of England.

2.2. Coastal management in England and the introduction of coastal change management areas

The UK government seeks to enhance community resilience to coastal change through coastal zonation using local government planning policy and the National Planning Policy Framework (NPPF, 2019). The NPPF, first published in 2012 and updated in 2019, mandates local planning authorities to include climate change adaptation policies within local planning strategies (NPPF 2019; para 148–169). The NPPF proposes coastal change adaptation in section 14, titled 'Meeting the challenges of Climate Change, Flooding and Coastal Erosion'. Here the concept of CCMAs was introduced as a vehicle to mitigate the effects of coastal change due to climate change and SLR. The NPPF states that coastal planning authorities (CPAs) should identify Coastal Change Management Areas (CCMAs), which cover parts of the coastline that are likely to experience significant change over the next 100 years (NPPF 2019; para 167–169). Coastal Planning Authorities (CPA) are encouraged to designate CCMAs within their Local Plans (LPs) (Fig. 2). Development within these CCMAs should be restricted and plans made to relocate existing infrastructure if needed. The full definition of a CCMA is given within the online document Planning Practice Guidance as 'an area identified in Local Plans as likely to be affected by coastal change (physical change to the shoreline through erosion, coastal landslip, permanent inundation or coastal accretion)' (Gov.uk, 2014a).

The policies set out in section 14 of the original NPPF (2012) were directly influenced by the Coastal Change Pathfinder (CCP) programme, which was run by the Department for Environment, Food and Rural Affairs (DEFRA) from 2009 to 2011 (DEFRA, 2012). The programme ran in 15 coastal communities trialling innovative and adaptive planning and coastal management techniques. The aim was to share positive outcomes with other coastal local authorities and subsequently included approaches within the NPPF. The Pathfinder showed, through a number of case study projects, how the use of planning policy could support coastal change adaptation (DEFRA, 2012). Another document that was instrumental in informing the NPPF was the 2011 Flood and Coastal Risk Management Strategy (DEFRA, 2011) produced by the Environment Agency, as a statutory duty under the Flood and Water Management Act 2010. This strategy highlighted the importance of, and government focus on, the need to adapt to coastal change.

Although the concept of CCMAs was first introduced in 2012, specific guidance into how to delineate the risk areas for physical coastal change was not published until 2015 (Halcrow, 2015). Previous to the guidance publication local authorities could refer to erosion and flooding data provided within their local SMP (if the SMP had been completed). The Coastal Change Adaptation Planning Guidance (CCAPG) published in 2015 provided specific guidance to coastal managers and planners on how to implement and identify CCMAs. The CCAPG stated that identification of CCMAs could be achieved in a four-stage strategy: (1) reviewing Shoreline Management Plan (SMP) policy; (2) identifying risk; (3) mapping areas of risk; and (4) delivering adaptation through planning. Noticeably, the main NPPF document does not mention SMP policy as a tool for designation of CCMAs. It is not until the CCAPG was

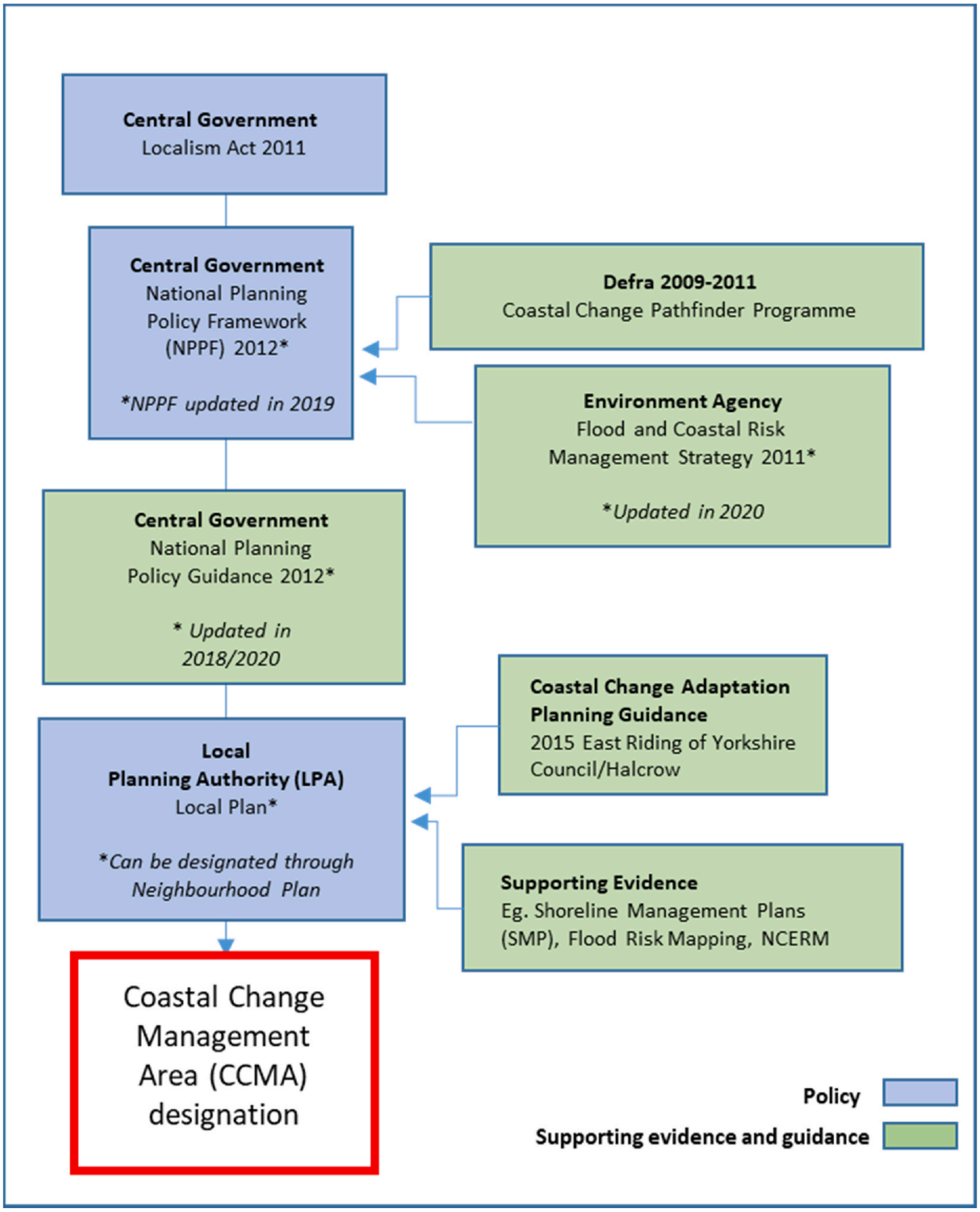

Fig. 2. Hierarchy of policy associated with Coastal Change Management Areas in England. Showing initial evidence used to inform government policy and guidance documents associated with CCMAs.

published that use of the SMP to designate a CCMA was recommended. The guidance suggested various approaches to define CCMAs, but did not give a definitive methodology for determining coastal change. The main data sets indicated in the 2015 guidance are the Shoreline Management Plans for England (SMPs), the National Coastal Erosion Risk Mapping (NCERM), and the National Flood Zone Mapping (NFZM) for Planners, which are discussed in more detail below.

2.2.1. Shoreline Management Plans (SMPs)

SMPs are regional assessments of coastal processes and include the long-term non-statutory policy framework that should be applied to manage coastal risk for specific regions. The first SMP was published in the 1990s, underwent a comprehensive review (SMP2) in 2006, with publication in 2010. The main aim of the SMPs was to provide a consistent nationwide approach to coastal management. The SMP2 covers the entire English and Welsh coast but is divided into 22 plan areas. Each of these areas is then subdivided into ‘coastal cells’, each with their own recommended coastal management policies. Management policies cover three epochs: short (0–20 yrs), medium (20–50 yrs) and long term (50–100 yrs). The policy assigned to a unit can change through the epochs. There are four management policies that can be assigned to a coastal cell: (1) ‘Hold the Line’ (HTL), which maintains or upgrades the existing coastal defence or coastline; (2) ‘Managed Realignment’ (MR), which involves the managed realignment of the coastline, backwards or forwards, to create a sustainable shoreline, by reducing erosion or building defences landward of original defences; (3) ‘Advance the Line’ (ATL), which allows coastal defence seaward of existing defences or land reclamation; and, (4) ‘No Active Intervention’ (NAI), which means that no further investment will be provided to maintain defences or that the coast will be allowed to evolve naturally.

The policy approaches from SMP2 are currently in use nationwide; however, a SMP-Refresh was commissioned in 2019, which is expected to be published in 2021.

The initial guidance for CCMA implementation (Halcrow, 2015) stated that CCMAs did not need to be defined in areas covered by a HTL or ATL SMP policy that extended to the end of the long-term epoch. This statement was updated in 2019 to include the wording 'subject to evidence of how this may be secured', which indicated that SMP policy may not be maintained due to financial constraints. However, no further guidance was issued to indicate if CCMAs should now be designated in places where there is a HTL policy or how the evidence of funding could be obtained.

The SMP also includes erosion risk mapping in some areas, with erosion extent indicated over the three policy epochs. The erosion extents are estimated for two scenarios: (1) With SMP management policy is in place (2) No management policy in place (some SMPs only provide erosion mapping with SMP policy in place). The SMP guidance recommends that the Futurecoast Behaviour Systems Approach (DEFRA, 2002) is used to determine erosion for both unconstrained and managed coastlines. This approach involves the identification of local coastal structures and understanding how they interact both temporal and spatially, and importantly how they react to changes in management. The main datasets used to delineate erosion extents in the SMPs are Futurecoast, historical shoreline change data and bespoke studies of coastal erosion (where available) (Halcrow, 2012). The indicative erosion extents are given for the short- (present– 2025), medium- (2026–2055) and long-term (2056–2105) epochs. The Futurecoast dataset used historical and current coastal data, such as historical and present day Ordnance Survey mapping, to derive historical cliff recession. Shoreline position was then categorised into either retreat, advance, oscillation or no change. The magnitude of change was also classified over a 100-year period, ranging from Negligible <10 m change to Extreme >200 m (DEFRA, 2002).

The erosion extents from the SMP mapping have been included in some, but not all, of the SMPs. This inconsistency is explained because, contemporaneously to publication of the SMP2s, another erosion risk mapping dataset, was developed by the UK Environment Agency, known as National Coastal Erosion Risk Mapping (NCERM) dataset. The choice of datasets meant that some SMP2s included their own erosion mapping, while some of the later plans included NCERM.

2.2.2. National Coastal Erosion Risk Mapping (NCERM)

NCERM was released in the UK in 2011, as the culmination of a project started in 2006, with the aim to provide erosion risk mapping for the whole of the English and Welsh coastline. The methodology used to produce the NCERM dataset is based on the Risk Assessment of Coastal Erosion (RACE) research and development project run by the Environment Agency (Rogers et al., 2014). RACE produced a probabilistic method for assessing the risk of coastal erosion using historic retreat rates. The erosion risk is presented in a series of erosion risk bands, covering the short- (0–20 years), medium- (20–50 years) and long-term (50–100 years). Each epoch is presented in three percentiles (5th %ile, 50th %ile and 95th %ile) that represent the confidence in the erosion risk. The 50th %ile is the mean erosion likely to occur over that time period, the 95th %ile is the minimum erosion that might occur, and the 5th %ile is the maximum erosion that might occur. The RACE methodology uses different analytical techniques to determine coastal erosion risk depending on the coastal geomorphology and which data are available for the area (see Table 1).

NCERM focuses on cliff and slope erosion, and incorporates it with the probability of the failure of defences. There are some coastal types that NCERM does not cover, such as complex cliffs which are defined as geologically complex large-scale coastal landslides (Moore and Woodget, 2010) and are simply marked as areas of instability, while dune systems are omitted because of their dynamic nature.

Table 1
Analytical approaches used by RACE and NCERM to determine erosion rates. Adapted from (DEFRA, 2007)

Expert Judgment	Uses expert knowledge of the area to determine erosion rates
Futurecoast Assessment	Uses Futurecoast erosion rates
Site Specific Assessment	Uses real site data, which supersedes Futurecoast
Single rate recession method	Uses real data to calculate cliff (or slopes/gently rising ground) recession using The soft Rock Cliff Manual (Lee and Clark, 2002)
Probabilistic recession Method	Uses a behaviour model based on the site, historical event frequency, probabilistic stability analysis and process simulation models – all set out in Lee and Clark (2002)

2.2.3. National Flood Zone Mapping (NFZM) for planning

NFZM for Planning is also cited as a dataset available to CPA for determining the boundaries of their CCMAs. These data are provided by DEFRA and the UK Environment Agency and covers both coastal and fluvial flooding. The dataset is based on still water projections of flooding and indicates the probability of flooding in certain areas based on four zones of flood risk (Table 2). This flood mapping is widely used in the UK. For example, flood zones are indicated on the deeds of properties and development in flood risk zones is subject to certain restrictions. The dataset does not take account of the possible impacts of climate change and the changes in the future probability of flooding. Therefore, when development is planned in a medium or high flood risk area, the local planning authority must complete a more in-depth strategic flood risk assessment (SFRA), which should include the most recent climate change and SLR projections, as well predicted changes to wave and wind climate (Gov.uk, 2014b). The availability of flood risk maps has 'disciplined' planners into considering this natural hazard as a standard material consideration in the determination of planning applications (Porter and Demeritt, 2021).

3. Methodology

A comprehensive review of Local Planning Authorities (LPAs) was conducted to investigate where and how CCMAs have been designated in England. A visual inspection of LPA boundary data (UK ONS 2020) identified 100 LPAs that have jurisdiction over an area of coastline, which can be regarded as Coastal Planning Authorities (CPAs). Some planning authorities were considered where tidal influence was noted (e.g., some upper estuarine authorities); however, only LPAs with their coastline mapped within the SMP and within 10 km of the low water mark (excluding Greater London) were included (Fig. 3). SMP documents were referred to in the study so that CCMA designation could be related to SMP policy.

The 100 CPAs formed the sampling population of a desk-based investigation using a staged and analytical approach to determine if and how CCMAs are included in the CPAs' Local Plan (LP). Using publicly available Local Plan documents (available on the CPA websites), each CPA was categorised in terms of its CCMA status. The research was undertaken between October 2019 and October 2020. A workflow was

Table 2
Flood zone definitions from the UK Flood Risk Mapping for Planners. Adapted from Flood risk and coastal change Guidance (Gov.uk, 2014b).

Zone 1 Low Probability	Land having a less than 1 in 1000 annual probability sea flooding.
Zone 2 Medium Probability	Land having between a 1 in 200 and 1 in 1000 annual probability of sea flooding
Zone 3a High Probability	Land having a 1 in 200 or greater annual probability of sea flooding.
Zone 3b The Functional Floodplain	This zone comprises land where water has to flow or be stored in times of flood

1	Cornwall and Isles of Scilly LPA	26	Barrow-in-Furness LPA	51	The Broads Authority LPA	76	South Downs National Park LPA
2	Torridge LPA	27	Copeland LPA	52	East Suffolk LPA	77	Lewes LPA
3	North Devon LPA	28	Lake District National Park LPA	53	Ipswich LPA	78	Brighton and Hove LPA
4	Exmoor National Park LPA	29	Allerdale LPA	54	Babergh LPA	79	Adur LPA
5	Somerset West and Taunton LPA	30	Carlisle LPA	55	Tendring LPA	80	Worthing LPA
6	Sedgemoor LPA	31	Northumberland LPA	56	Colchester LPA	81	Arun LPA
7	North Somerset LPA	32	North Tyneside LPA	57	Maldon LPA	82	Chichester LPA
8	Bristol, City of LPA	33	South Tyneside LPA	58	Rochford LPA	83	Havant LPA
9	South Gloucestershire LPA	34	Sunderland LPA	59	Southend-on-Sea LPA	84	Portsmouth LPA
10	Stroud LPA	35	County Durham LPA	60	Castle Point LPA	85	Gosport LPA
11	Forest of Dean LPA	36	Hartlepool LPA	61	Basildon LPA	86	Fareham LPA
12	Cheshire West and Chester LPA	37	Stockton-on-Tees LPA	62	Thurrock LPA	87	Eastleigh LPA
13	Wirral LPA	38	Redcar and Cleveland LPA	63	Ebbsfleet Development Corporation LPA	88	Southampton LPA
14	Warrington LPA	39	North York Moors National Park LPA	64	Dartford LPA	89	New Forest LPA
15	Halton LPA	40	East Riding of Yorkshire LPA	65	Gravesham LPA	90	Isle of Wight LPA
16	Liverpool LPA	41	Scarborough LPA	66	Medway LPA	91	New Forest National Park LPA
17	Sefton LPA	42	Kingston upon Hull, City of LPA	67	Swale LPA	92	Bournemouth, Christchurch and Poole LPA
18	West Lancashire LPA	43	North Lincolnshire LPA	68	Canterbury LPA	93	Dorset LPA
19	South Ribble LPA	44	North East Lincolnshire LPA	69	Thanet LPA	94	East Devon LPA
20	Preston LPA	45	East Lindsey LPA	70	Dover LPA	95	Exeter LPA
21	Fylde LPA	46	Boston LPA	71	Folkestone and Hythe LPA	96	Teignbridge LPA
22	Blackpool LPA	47	South Holland LPA	72	Rother LPA	97	Torbay LPA
23	Wyre LPA	48	King's Lynn and West Norfolk LPA	73	Hastings LPA	98	South Hams LPA
24	Lancaster LPA	49	North Norfolk LPA	74	Wealden LPA	99	West Devon LPA
25	South Lakeland LPA	50	Great Yarmouth LPA	75	Eastbourne LPA	100	Plymouth LPA

Fig. 3. Coastal Local Planning Authorities in England, boundaries are taken from ONS data set of local planning authorities 2020. Coastal denotes planning jurisdiction over an area of coastline.

produced to investigate each CPA and its LP (Table 3).

Each CPA was investigated using online resources to determine whether a Local Plan was present, either adopted or in draft. If the Local Plan was adopted, it was interrogated for reference to CCMAs, using text searches including CCMA, Coastal Change, flooding and erosion. If reference was made to a CCMA, the LP was then investigated for evidence of implementation, such as designation maps and methodologies. Correspondence were sent to several local authorities to request further details where online resources were limited. CCMAs that were mapped and within the adopted plan were categorised as 'Implemented'. If the adopted plan referenced a CCMA, but did not actually include one, it was categorised as 'Mentioned'. If the LP did not reference CCMAs, it was categorised as 'No Mention', but was further investigated for the inclusion of other coastal management policies and references to climate change adaptation.

CPAs with their Local Plan under review, or in draft, were interrogated in the same way as adopted plans, but were categorised differently. Draft plans may change in the consultation phases, so mention of CCMAs within draft plans were split into two categories. If the CCMA was mapped in the draft plan, it was categorised as 'Planned' (not implemented like in the adopted plan). If a CCMA was mentioned, but no mapping had been supplied, it was categorised as 'Mentioned' (as in the adopted plans). The inclusion of the 'Planned' category is important because, although the Local Plan may not be adopted, the proposed CCMA and evidence base may still be considered by planning officers when considering planning applications.

Some Local Plans did not include CCMAs or mention them and these were categorised as 'No Mention'. It must be noted that some CPAs were in the process of updating their LP during the period of this research but had not yet submitted a draft for consultation. In these cases, the existing LP was investigated. Development plans, known as Local Development Frameworks, were first introduced in 2004 as part of the Planning and Compulsory Purchase Act (2004) and these were replaced by Local Plans in the planning reforms of 2010. Therefore, only Local Plans that were produced after 2012 (after the NPPF first made reference to CCMAs) were investigated. All CPAs with plans produced before 2012 were categorised as 'No Mention'.

CPAs were also investigated for evidence of other Development Plan Documents (DPDs) that might include or reference CCMAs. These were then categorised in the same way as the LPs. The inclusion of the Newquay Neighbourhood Plan is due to the fact that it is referenced in Cornwall Council's DPD. Cornwall is the first and only CPA to designate a CCMA through a Neighbourhood Plan. Designation through the Neighbourhood Plan occurred because the Cornwall Council Local Plan failed to include CCMAs and the CPA needed a statutory vehicle for designation (Dr D. Watkins, Cornwall Council, Personal communication 2020).

If a CCMA had been implemented or planned, a further investigation was conducted into the methodology used to determine its boundaries. The method was recorded and supporting evidence was reviewed. Using the policy maps provided by the CPA, it was also possible to estimate the total coastal frontage that had been designated as a CCMA in each CPA.

Corresponding SMP policies within each implemented CCMA were examined to investigate how CPAs have interpreted the NPPF guidance to only consider a CCMA in areas where the policy is not HTL. Relocation policy within the designated CMMA(s) was also recorded if it had been included or mentioned within the coastal adaptation section of the LP. Based on the assessment of all the CPAs' Local Plans and Development Plan Documents, the complete geographical distribution of CCMAs in England has been achieved, including an analysis of the methodologies used to determine the areas. The results from this survey are outlined in the next section.

4. Results

4.1. CCMA implementation

The uptake of CCMAs in England has, to date, been limited. Of the 100 CPAs that were investigated, only 15 of them had fully implemented CCMAs (15%), defined as being mapped and included within an adopted Local Plan or Neighbourhood Plan (Fig. 4). A further 14 CPAs had planned CCMAs, but the Local Plan had not yet been adopted (14%). Seven CPAs mentioned CCMAs, but did not include them in their Local Plan (7%). The remaining 64 CPAs did not mention or include reference to CCMAs within their adopted or draft local plan documents (64%). Where CCMAs have been designated, the proportion of coastline included is highly variable. For example, Torbay has designated its entire coastal frontage as a CCMA, while in Cornwall has designated just 1.5% of its coast. In total just 5.7% of the entire coast of England has been designated as a CCMA. Geographically, the majority of CCMAs, 9 in total) have been implemented by CPAs situated in areas of geologically

Table 3
Example of examining questions to investigate CPAs Local Plans and the inclusions of CCMAs and Coastal change policies.

Coastal Local Planning Authority	Adur	Allerdale
Local Plan	Yes	Yes
Adopted Local Plan	Yes	Yes
Year adopted	2017	2014
Mentions CCMA	No	Yes
Includes CCMA	No	Yes
CCMA mapped and implemented	No	No
CCMA designation method	N/A	N/A
Mentions Climate adaptation	Yes	Yes
Notes		Plan is adopted but no information on CCMA method or where the designated areas are yet as the maps have not been drawn (Jan 2020)
Relocation Policy	No	Yes

less resistant coastlines such as the South East, East and North West (Sefton, Fylde and Wyre) coast (Fig. 1a).

4.2. CCMA methodology: SMP policy use and policy justification

The 15 CPAs that have implemented CCMAs have used differing methodologies to determine their designation. All have used the SMP policy as guidance and that almost half of these (7) have omitted areas of coastline with a HTL policy stretching over the three SMP epochs. However, this approach is not consistent throughout all CPAs (Table 4). Torbay has disregarded NPPF guidance and designated CCMAs where the SMP policy is a mix of HTL, MR and NAI over the three epochs. Areas where SMP policy is HTL for all epochs have been included within the CCMA. In contrast, Cornwall have omitted areas from the CCMA if the SMP policy is HTL over the three SMP policy epochs, but included areas that are HTL in the first and second epoch, but move to MR or NAI in the long term.

Justification for designation of the CCMAs also varies throughout England. Only 5 of the 15 CPAs suggest that the designation of the CCMA is to aid coastal community adaptation to coastal change. 4 CPAs suggest that the CCMA is to protect important environmental assets such as sand dunes. 2 CPAs have used the CCMA designation to limit development of new drainage systems or mineral extraction sites.

4.3. CCMA methodology: delineation of coastal change extent

This section details the methodology for each CCMA as defined by each CPA within the evidence base and technical reports included as part of the LP documents. The methodology and databases used for CCMA designation varies with no two CPAs using the exact same method to determine the physical areas affected by coastal change. The most common erosion projection used by CPAs is the SMP 2105 indicative coastal erosion extent which represents predicted erosion in ~100 years with SMP policies in place. Cornwall, Wyre and Dover have opted to use the 5th %ile long term (50–100 year) NCERM prediction. Table 5 details the methodologies used by each CPA to delineate the coastal change area and shows the two main data sets used: SMP and NCERM. Exmoor National Park, Swale, East Suffolk and Somerset West and Taunton have also used the NFZM for Planning dataset in combination with both the SMP and NCERM.

4.4. CCMA methodology: planned CCMAs

Investigation of draft local plans showed that 14 CPAs have included mapped CCMAs within their drafts. Most of the planned CCMAs have been delineated using the diversity of methods noted in Section 4.3 (SMP erosion predictions, NCERM database and NFZM for Planning). Havant District Council, who have a planned CCMA, are already consulting the draft plan in planning decisions, and have started restricting development within the planned CCMA area (M. Stratton, Personal Communication 2020). Havant have two CCMAs designated: one covers the only area on Hayling Island that is NAI and the other one is at Hayling beach, which is HTL in all epochs. Northumberland have used the 2105 indicative coastal erosion epoch extent together with a 30-m buffer to designate their entire coastline. Dorset Council have several CCMAs planned, including one at Purbeck. Here a CCMA zone is mapped using the SMP erosion horizons. Dorset Council have in-house coastal expertise and CCMAs have been recommended for areas in Dorset since 2015. A delay in the adoption of Local Plans and, more recently, the formation of a Joint Local Plan (two planning authorities joining together to form a LP) has meant that planned CCMAs have not been formally adopted. Finally, Castle Point Council have three CCMAs in planning for Canvey Island, Hadleigh Marshes and South Benfleet. All of these have been delineated mainly using flood zone mapping due to the low-lying nature of the areas.

4.5. Other approaches

Some CPAs have designated CCMAs in all but name. For example, Kings Lynn and North Norfolk Borough Council (KLNNBC) have mapped a coastal hazard zone (CHZ) along their coast using data from the SMP and EA flood risk 3 mapping. This CHZ acts as a CCMA in restricting development and was adopted in the 2016 LP. KLNNBC initiated a review of their LP in 2019 and have renamed the CHZ to CCMA (R. Goodliffe, Personal Communication 2020). Great Yarmouth Borough Council have used the SMP 2105 indicative coastal erosion epoch extent to define their planned CCMA on their coastline. In some areas, this designation has been modified due to local strategies that are in place, such as dune management. Canterbury District have planning restrictions in a delineated ‘Coastal Overtopping Zone’ and ‘Coastal Protection Zones’. The Coastal Protection Zones are areas that are at risk from coastal erosion as identified in the SMP. Canterbury have proposed a CCMA within their LP, which is currently in consultation. Chichester District use an Integrated Coastal Zone Management Strategy to set out restrictions to development. The strategy does not show a coastal erosion line on any policy maps, but they do state that development within 25 m of coastal defences will be refused and coastal zone development will be restricted. Colchester has designated a ‘Coastal Protection Belt’, which includes some reference to managed realignment projects and restricted development in these areas.

North Devon and Torridge District Council and East Devon District Council have both been involved in a research project run by the University of Plymouth, which aimed to delineate CCMAs in both regions. This project has developed a methodology that uses cliff face volume to calculate recession rates and includes the UKCP18 data to account for future climate change. This novel, more localised approach has found that the SMP and NCERM can over-as well as under-predict coastal change in some places (Fig. 5). This variability is because of the fine

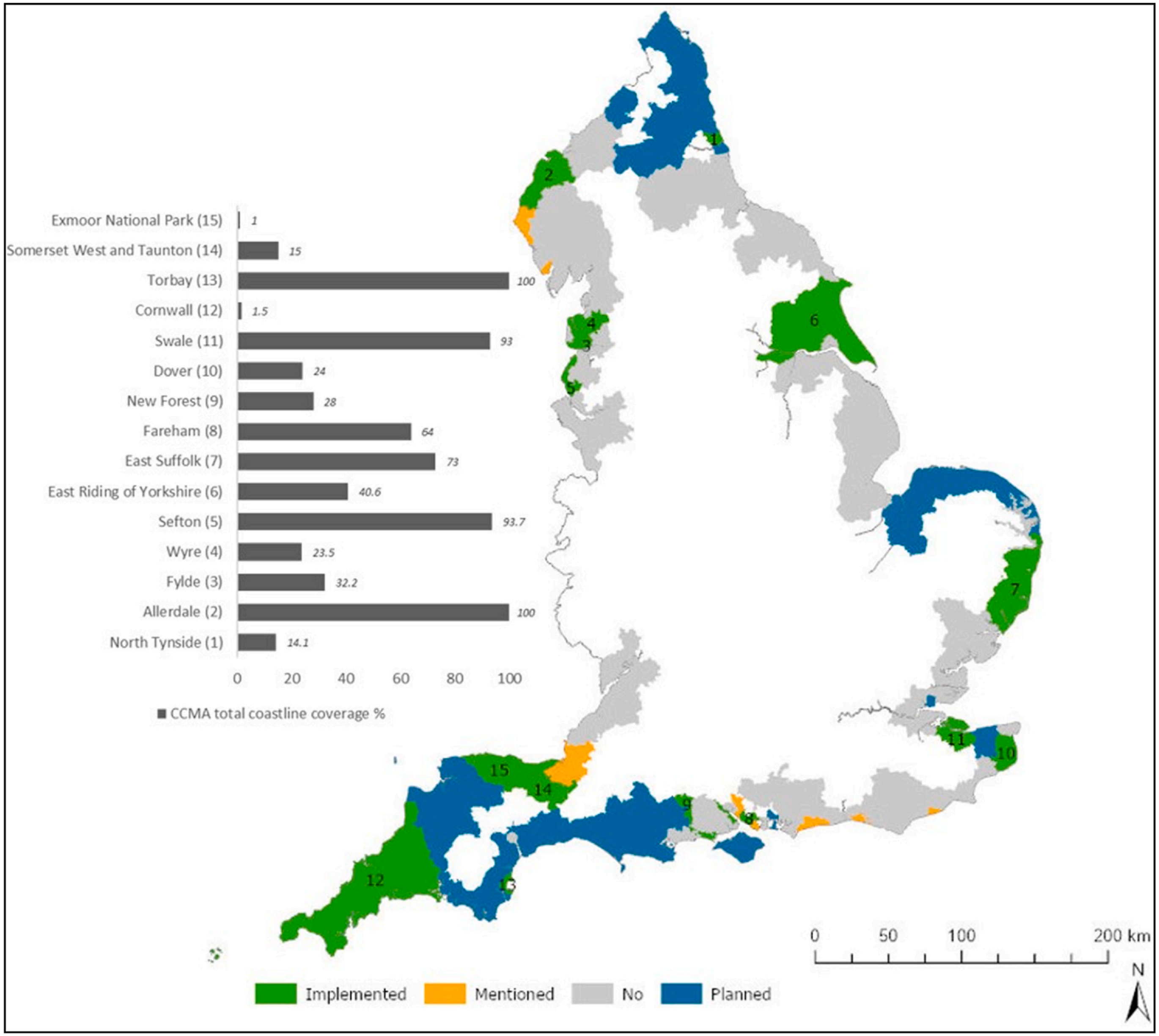

Fig. 4. Status of CCMAs in England (October 2020) showing CPAs that have CCMAs Implemented, Mentioned, No (not mentioned), or Planned. Locations are numbered to indicate CPA. Insert bar chart shows percentage of the CPA's (implemented only) coastline covered by a CCMA.

Table 4
Coastal Planning Authority approach to designating CCMA regarding the SMP policy in place, justification for CCMA designation and indication if CCMA has been designated to aid community adaptation to climate change as proposed by the National Planning Policy Framework. Orange indicates Coastal Planning Authority has designated CCMA for community adaptation, as evidences in states within their Local Plan.

CPA	SMP policy within CCMA	HTL areas included in CCMA	Measures and Justification for CCMA policy	CCMA designated to help community adaptation to coastal change
North Tynside	Covers MR and NAI (only a small area covered. Is not consistent over whole area as there are other areas of MR in the long term but HTL in the short/medium in the CPA area that are not covered by CCMA. There are also areas of NAI which are not covered.	No	To limit development in areas suspectable to coastal change to temporary structures only and to define areas where no further remedial work will happen allowing coast to erode. CCMA designated to allow beach and dunes natural evolution.	No
Allerdale	The whole coastline has been designated a coastal zone management area. However, in areas that have a HTL policy the boundary extends only to the current defences, indicating that the SMP erosion estimates have been used therefore omitting HTL areas.	No	To limit residential development in areas of coastal change and preserve environmental assets.	No
Fylde	CCMA covers areas of HTL through all epochs, and some areas that are MR in the short term but move to HTL in the medium/long term. They also cover areas that are currently HTL but moving to MR in the long term, and also some areas of NAI are not covered by the CCMA. Not consistent with the SMP policies or NPPF guidance.	Yes	Protection of important coastal habitats and preservation of open coastal character.	No
Wyre	Covered an area up stream of tidal estuary that is HTL in the short term but moves to MR in the medium and long term. Also covers an area, which is HTL in the short term but MR in the medium and returns to HTL in the long term. CCMAs in all areas of MR in the long term.	Yes	To allow potential roll back, natural evolution of shoreline and saltmarsh creation with CCMA which will enhance natural flood defence and protect against coastal squeeze. Also, to protect against development with in an area encouraged to be a BAP habitat.	No
Sefton	CCMA cover entire coastal frontage regardless of SMP policy with the exception of the Port areas in Bootle. Defined as a line rather than a zone.	Yes	CCMA to maintain current extent of the sand dune complex and to enhance funding chances to protect rail line if areas are designated to be at risk from coastal change.	No
East Riding of Yorkshire	Covers NAI (and one area or MR) but also omits some settlements that are NAI in the SMP.	No	Proactive management of development in CCMAs including lifetime limits and temporary contraction and ensure that any development can be removed fully at the end of its lifetime, thus limiting underground infrastructure.	Yes
East Suffolk	All policy units are included in the CCMA. Including HTL areas. The Council have designated the entire coastline with the exception of the Port area at Felixstowe.	Yes	To restrict development within the coastal change area and allow residents within the CCMA to benefit from relocation and Roll back policy. Proactive coastal change adaptation.	Yes
Fareham	Covers only NAI areas.	No	To restrict development within a nature reserve and on a flood plain. Restrict or stop mineral extraction and excavation activities that could destabilize the cliff.	No
New Forest	The CCMA covers both MR and NAI areas. There is also a note in the LP evidence that states other areas of coastline regardless of policy were considered but significant change was not predicted.	No	To stop residential development and restrictions on new soakaway drainage systems that are known to affect cliff stability in the region.	No
Dover	Covers only NAI and one area that is HTL until the 100-year epoch when it may change to NAI.	No	CCMA not intended to be used to define areas at risk from coastal change – the role is to identify areas where only appropriate sustainable development is allowed.	No
Swale	Covers some HTL (all epochs) areas up the estuary towards Sittingbourne. Omits area of HTL at Sheerness. All other coastal frontage is covered including HTL in short term moving to MR and NAI in medium and long term. (Based on flood risk mapping)	Yes	To aid sustainable development on the coast with lifetime limits on development that is allowed.	No
Cornwall	Omits HTL in 100-year epoch, covers MR and NAI. Covers areas where it is HTL in 20 and 50 but NAI in 100. Only area under Newquay Neighbourhood plan is included. No other CCMA designation in Cornwall.	No	To stop development on the unstable coast and maintain natural evolution of coastline as much as possible. To stop ad hoc protection of cliffs in discrete areas. Community driven stop inappropriate development while management strategies are formulated.	Yes
Torbay	Covers both HTL in all epochs and NAI (full CCMA coverage regardless of SMP policy).	Yes	HTL areas will continue to be maintained but defences will not be extended to areas currently undefended. Permanent residential properties unlikely to be granted planning. Routes and critical infrastructure maintained but communities maybe be told to relocate or roll back. Development behind coastal defences expect to contribute to maintenance of defences.	Yes
Somerset West and Taunton	CCMA covers a stretch of HTL in all epochs coast at Wall common to Stolford and at Minehead to Blue Anchor.	Yes	Sustainable tourism on the understanding it may not be tenable long term. Supports SMP policy of MR. CCMA formed from the second line of defences mapped out in SMP.	No
Exmoor National Park	NAI through all epochs. Only small area designated at Porlock Weir.	No	Proactive mitigation to coastal change in communities where accepted evidence has been provided. Residents helped to relocate with favourable planning. NAI in CCMA so need for plan for infrastructure relocation. No new dwelling with in CCMA. Measure to adapt and be prepared form SLR and coastal change	Yes

resolution data used in the study and the incorporation of more recent climate change projections. In addition to the novel erosion mapping, they have also used Strategic Flood Risk Assessment mapping data to delineate the CCMA around the Torridge estuary.

5. Discussion

This study has revealed that coastal management zonation in England is extremely inconsistent and fragmented, and we would argue that this potentially burdens future generations with avoidable costs associated with the adverse impact of climate change, notably coastal flooding and erosion, on inappropriate development in the coastal zone. England has had planning policy in place for a decade that allows local authorities to restrict development on the coast and built resilient coastal communities; yet, only 15% of CPAs have fully implemented a CCMA. Even when including CPAs that have CCMAs in the draft phase, this figure only rises to 29%. It has become evident through this review of CCMA implementation that a number of factors are affecting the use of this planning policy, including interpretation of the guidance provided, but also inconsistencies and shortcomings in the datasets recommended for use.

5.1. Interpretation of the NPPF guidance

The original 2012 NPPF guidance stated that CCMAs did not need to be considered where SMP policy is HTL. However, in the revised guidance issued in 2019, this statement was caveated with the need for CPAs to be able to demonstrate that the SMP policy was financially sustainable over the next 100 years. As very few (if any) coastal defense schemes will be able to demonstrate funding for this length of time, CPAs need to decide if a CCMA should now be considered in areas that fall under HTL policy. This study has shown most CPAs do omit HTL units from CCMAs, and it has become evident from this study that the NPPF guidance, relating to the non-inclusion of HTL policy units, can be, and has been, interpreted in many different ways.

Sefton covers HTL units within its CCMA and has made this decision because they acknowledge that funding to maintain SMP policy may not be available in the future. It is estimated that fulfilling all SMP policy in England and Wales through to the long-term epoch (100 years) would cost £18–30 billion (CCC, 2018). Torbay, on the south coast, has decided to designate its whole coastal frontage within its CCMA. Torbay has a proactive in-house team of coastal engineers and has been a part of the EU-Circle coastal flooding project (EU Circle, 2019), which has produced detailed flood risk modelling for the area. A combination of historical flooding and the availability of localised flood risk modelling from academic research has raised the scientific understanding of coastal change within the CPA, and helped facilitate political support for the designation of a CCMA in the district (D. Stewart Personal Communication 2019). Broads National Park and Blackpool CPA state in their LP that they have deliberately not implemented a CCMA because the entire coastal frontage of the area is HTL. The difference in interpretation of the guidance, and the recent (2019) inclusion of the caveat of proving funding for maintaining SMP policy, has led to inconsistences and confusion over where CPAs should be using CCMAs.

The fact that CCMA guidance suggests not to include HTL areas is in itself problematic. The SMPs are not statutory and therefore there is no guarantee that the management strategy will be maintained. HTL areas are often the most vulnerable, and hence defended, and have the most economic importance. There is a real concern that excluding HTL areas from CCMAs leads to unsuitable development behind defences that may not be funded and maintained in the future. Often the perception is that a government-funded flood defense will always be maintained in perpetuity, and this perception is perpetuated by CPAs permitting development and capital growth within the defended area (Filatova, 2014). In the USA, despite flood risk management, zoning and regulatory efforts, Lazarus et al. (2018) found that residents were re-building bigger and more expensive properties after hurricane events, thereby reducing resilience to future flooding. Incorporating CCMAs into HTL areas would be beneficial to increase resilience and allow the defended community to adapt to future scenarios. The inclusion of a community within a CCMA may help educate them how the coastal risk will change with time and how defences maybe affected by funding capacity (Hinkle at al., 2018).

Another important reason to include HTL areas in CCMAs is the gap in knowledge of what happens to the coastline when a sea defense is removed. Although this area of understanding is currently poor and complex to forecast, Payo and Walkden (2018) have demonstrated that, when a defence is removed, accelerated erosion can occur in a process termed 'coastal catch up'. Other examples of accelerated coastal change are given by Dornbusch and Mylroie (2018), who found in one location on the south-east coast of England, that roll back of a barrier beach was up to 20 times faster than historic rates, when the constraining sea defence was removed. The potential for increased rates of erosion following removal of coastal defences highlights the need for CPAs to have an understanding of what will happen to areas behind coastal

Table 5
CPA CCMA designation methodology.

CCMA Designation Methodology					
CPA	*Method of designation clearly defined within separate planning documents*	*NCERM 5th %ile 50–100 year extent*	*SMP Erosion mapping*	*SMP as guidance*	*NFZM for planning*
Exmoor National Park			X	x	x
Dover	x	X	X	x	
Swale	x		X	x	x
Cornwall		X	X	x	
Wyre		X		x	
Fareham		X* *No reference of which NCERM banding used*		x	
North Tyneside			x	x	
Sefton			x	x	
Torbay			x	x	
New Forest			x	x	
Fylde			x	x	
East Riding of Yorkshire			x	x	
Allerdale			x	x	
East Suffolk			x	x	x
Somerset west and Taunton			x	x	x

Fig. 5. Variations between erosion mapping. Blue line indicates SMP 2105 indicative erosion extent, green banding indicates NCERM 5th %ile 50–100 year erosion banding and red line shows Plymouth University/East Devon DC collaboration 100 year erosion extent using cliff face volume analysis and UKCP18 SLR/Acceleration in SLR projections. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

defenses if they are not maintained into the future. There is a need for adaptation strategies, like CCMAs, to be in place before defences either fail or cease to be maintained, to allow for human adjustment or relocation and to avoid apparent sudden changes in flood protection, which might have severe financial implications for property owners.

Of the 15 CPAs who have designated CCMAs, five are pro-actively implemented to put policy in place that will help the coastal community to adapt to future coastal change and SLR. East Riding of Yorkshire, East Suffolk, Cornwall, Torbay, Somerset West and Taunton and Exmoor National Park all include reference to adaptation and community resilience through planning by utilizing the CCMA to restrict development and help communities to adapt or relocate. The remaining ten LPAs have used the CCMA designation in a variety of ways, including to protect dune systems, to restrict development of new drainage systems and to limit excavations that might destabilize the cliffs. The ambiguity in the NPPF guidance, and the lack of complete understanding within the CPAs planning departments, of how and what a CCMA should be used for, has led to CCMAs being designated in areas where their full potential as a coastal community adaptation policy is not realised.

CCMAs used correctly should enhance coastal community resilience, whilst informing them of the risks posed by SLR and coastal erosion. The political pressure on SMPs was in many places quite large, but these are non-statutory documents; CCMAs in the planning system are 'law' and resistance therefore is and will be immensely larger. North Norfolk Council, who have a planned CCMA, have worked with local communities to communicate their adaptation policy. Here they found that local communities did not have a good understanding of SMP policy. Once the SMP had been 'bedded' into the community, the proposal of a CCMA was more acceptable, because they were able to understand the coastal processes and risks that were expected. There were concerns about coastal 'blight', but these have been eased by showing the flexibility within CCMAs for some appropriate development in places where the previous policy had allowed none (Pers. Comm. Rob Goodliffe NNDC 2020). This example highlights the negative connotations associated with zonation and provides another barrier for CCMA implementation. It also provides another justification for the need for transparent and robust scientific methodologies for determining the extent of future coastal change. If the CPA can provide reliable evidence to the coastal communities of future coastal change, they are more likely to be successful in gaining support of CCMA policies.

This study has found that 14 of the 15 implemented CCMAs are included within the CPAs Local Plan. The remaining CCMA is designated through a Neighbourhood Plan. Limiting the legislative vehicle by which CCMAs can be designated has become a barrier to implementation, as one example, Cornwall Council, who failed to include CCMAs in their LP (adopted in 2016) has found. They state '*The designation of CCMAs is currently deferred to Neighbourhood Plans in line with the recommendation of the Local Plan Inspector. This has yet to happen in the majority of cases and strategic action is required to clarify the situation*' (CC, 2021). Neighbourhood Plans are not a legal requirement so some communities, that are at risk from SLR and coastal change, may choose not to complete one.

5.2. Erosion mapping

To ensure that the CCMA is the most accurate representation of coastal erosion over the next 100 years, climate change and SLR must be incorporated into coastal change mapping and so coastal adaptation policy (CCC, 2018; Ranasinghe, 2020). Both NCERM and the SMP erosion mapping do incorporate some future SLR, but neither accounts for current UKCP18 projections in SLR nor the acceleration in the rate of SLR in the next 100 years.

Moore et al. (2010) validated erosion rates produced by NCERM against UK09 SLR projections and found that the NCERM recession rates are comparable under the UK09 SLR scenario in the short-term epochs, but are not applicable to the medium- and long-term epochs Consequently, the NCERM data underestimates erosion extent (as the rate of SLR is expected to increase). If the datasets used to determine the physical long-term coastal change do not account for the future changes in the rate of SLR, then how can CPAs confidently delineate a CCMA? There is a possibility that a CCMA boundary could become obsolete as erosion over takes the landward boundary, this scenario has occurred in some US states with the construction set back lines, that now sit offshore, as the rate of erosion has overtaken earlier predictions. Another concern is that local regulation within the CCMA is challenged by developers and property owners because of a lack of confidence in the methods used to determine the erosion extents (Neal et al., 2018). There is a need for a methodology to determine retreat rates that can be updated to reflect future climate change projections and that also account for the accelerated rate of SLR, so that the CCMA boundary lines do not become out of date before they are implemented.

The two coastal datasets used by CPAs in defining areas at risk from coastal change are the SMP erosion mapping (SMP 2105 indicative erosion extent) and NCERM (5th %ile long-term 50–100 year extent).

Both of these datasets rely on historical retreat rates to predict future shoreline positon. They both are informed by the Futurecoast study (DEFRA, 2002) and rely on historical mapping to derive the historical shoreline position and so determine historical retreat rates. Yet, they produce different erosion extents for the same areas of coastline (Fig. 5). This inconsistency in datasets and variance between erosion extents is not only confusing to CPAs, but it exposes them to challenges against the implementation of a CCMA.

There have been considerable advances in cliff retreat predictions and shoreline change mapping (Earlie et al., 2015; Young, 2018). Earlie et al. (2014) show that analysis of cliff top change can underestimate retreat rates compared with cliff face volume change derived retreat rates. Limber et al. (2018) explore the variability in cliff retreat models to suggest that a combination of models is needed to reduce uncertainty in retreat rates. The CCMAs proposed by the collaboration between East Devon and North Devon and Torridge Councils and the University of Plymouth have been delineated using cliff retreat rates derived from LiDAR derived volumetric changes in the cliff face and the most recent SLR projections. The erosion extents that they have produced vary from both the NCERM and SMP extents, sometimes showing greater or smaller rates of erosion, as illustrated previously in Fig. 5.

Both SMP and NCERM focus mainly on cliff retreat and use methodology that describes cliff recession, which does not account for how other coastal types (dunes, barriers etc.) will respond to SLR or accelerated rates of SLR in the future. In the guidance for defining coastal hazard zones in New Zealand, Ramsay et al. (2012) highlight the importance of defining each coastal type and assigning specific retreat and evolution models to give the most accurate estimate of the future shoreline. This exemplary guidance document and recent research (McCarroll et al., 2021) shows that 'one size does not fit all' in coastal erosion zonation and that various approaches are needed depending on the coastline or coastal types.

A recent study which used the Bruun rule to evaluate the effect of SLR on sandy beaches suggested that all sandy beaches will disappear over the next 100 years (Vousdoukas et al., 2020b). However, further analysis with additional model components, such as accounting for backshore morphology and accommodation space behind beaches (Cooper et al., 2020; Dean and Houston, 2016), shows that sandy beaches can respond to SLR in a number of ways, and not simply disappear. CPAs need to identify coastal types in more detail, by including other parameters, such as back-beach morphology and dune height, so that the most suitable evolution model can be applied, and the accurate mapping of coastal risk can be achieved.

Another shortcoming of the NCERM and SMP datasets is that they fail to include estimates of erosion in complex cliffs (defined by Moore et al. (2010) as geologically complex large-scale coastal landslides), and instead mark them simply as areas of instability. The absence of these areas of complex cliff has meant that no areas of complex cliffs have been included within a CCMA. One example is in Dover, where the supporting evidence for their CCMA states that the designation has gaps where complex cliffs occur, as there are no data available to map the CCMA extent. Failure in complex cliffs tends to be episodic, but can be sudden and extensive. It is therefore important that complex cliffs are included in CCMAs. This problem of predicting cliff recession in complex cliffs has propagated throughout the SMP and NCERM databases and there appears to be few studies that address it (Hapke and Plant, 2010). However, regardless of the complexity in deriving future erosion rates of complex cliffs, the simple fact that they are unstable should mean that they are included with a CCMA.

6. Conclusions

The implementation and adoption of CCMAs as effective coastal management policies remains highly fragmented and inconsistent within England. The National Planning Policy Framework (NPPF) is in place to allow CPAs to designate coastal change management areas, where development is restricted because of the long-term coastal change in that area. However, since 2012, only 15 of the 100 CPAs have implemented CCMAs, with only another 14 planned in the immediate future. Where CCMAs have been implemented, there are inconsistences in how they correspond to the Shoreline Management Plan policies in the same area, because of the ambiguity of the guidance provided. This issue has led to vulnerable areas being omitted from CCMAs and often coastal areas that have little critical infrastructure being included. The ambiguity in the guidance has also meant that only 5 of the implemented CCMAs have been designated to directly aid the coastal community to adapt to further SLR and coastal change, with the remaining 10 CCMAs, designated for various reasons such as ecological habitat protection or restricting the development of new drainage systems. Our results also show that in at least one coastal planning authority, CCMA implementation has been restricted because they failed to include them in their current Local Plan and are having to defer them to Neighbourhood Plans. This raises the case for an additional vehicle by which CCMAs can be designated separately to the Local Plan, which may not be updated for several years.

The two main datasets used by CPAs to determine coastal retreat rates – NCERM and SMP erosion mapping – both fail to incorporate current climate projections of SLR and acceleration in the rate of SLR over the next 100 years and are therefore not suitable for delineating the boundary of a CCMA. The two datasets both rely on historical rates of change determined from coarse resolution historical mapping. Recent advances in LiDAR derived volumetric cliff face analysis can give more accurate rates of historical cliff recession. Advances in coastline retreat quantification coupled with the inclusion of the most recent future SLR scenarios, can give a much better idea of coastal change extent over the next 100 years.

For coastal zonation adaptation policy to be successful there is a need for CPAs to identify the coastal types and recognise the response of each coastal type to SLR. This evidence would allow CPAs to confidently determine recession rates and delineate CCMAs, which could also be updated to reflect new climate change projections. It would also allow CPAs to include the coastal morphologies that the NCERM and SMP fail to cover at a resolution more appropriate to the coastal areas that the CCMA will cover. CPAs are responsible for delivering coastal change adaptation policy but often do not have the resources or internal skill sets to implement them confidently. There is a need for clearer guidance and collaboration between planners and coastal scientists if these policies are to be successful.

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.

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