Coastal lagoons at Keyhaven Marshes, Hampshire.

29. Saline Lagoons

Climate Change Sensitivity: **High**

Introduction

The trends and changes in coastal margin habitats including saline lagoons have been described most recently by the UK National Ecosystem Assessment (Jones *et al* 2011b). Like other coastal habitats, saline lagoons are highly sensitive to the impacts of climate change, especially to relative sea level rise and increased storminess.

The physical, chemical and ecological characteristics of coastal saline lagoons are highly variable and the impacts of climate change are also likely to vary between sites. Naturally formed lagoons could have potential to adapt to climate change by migrating landwards with rising sea levels, but the cumulative impact of climate change and anthropogenic stressors, including past and present interventions that restrict sediment processes needed for such adaptive mechanisms, make saline lagoons particularly vulnerable. Consequently, saline lagoons have been identified as one of the most vulnerable habitats in England and Wales, requiring urgent action in order to mitigate against the impacts of climate change (Brazier *et al* 2016; Jones *et al* 2011a; Mitchell *et al* 2007).

Habitat Description

Coastal saline lagoons are areas of typically (but not exclusively) shallow, coastal, saline water, wholly or partially separated from the sea by sandbanks, shingle, engineered structures such as sluices or, less frequently, rocks or other hard substrata. They retain a proportion of their water at low tide and may develop as brackish, fully saline or hyper-saline water bodies (Angus 2016).

Saline lagoons are complex and dynamic habitats that can form naturally through percolation of sea water through sand or shingle barriers, or artificially through engineered barriers that cut off a part of an estuary or the sea from direct tidal influences and/or restrict tidal movement. Freshwater input to saline lagoons usually occurs from direct drainage of surrounding land or through groundwater seepage. Although coastal lagoons can contain a variety of substrata, they most commonly include soft sediments.

Coastal lagoons are highly variable in size, form, and salinity regime. Even within sites, the physical characteristics and salinity often vary seasonally and can also change over a longer time scale due to their ephemeral nature (Duck and deSilva 2012). The plant and animal communities found within lagoons vary according to the physical characteristics and salinity regime of the lagoon and can be broadly divided into three groups; marine species that are tolerant of low salinity, freshwater species that are tolerant of high salinity, and lagoon specialists (Bamber 2010).

Although a relatively limited range of species may be present in saline lagoons compared with other marine habitats, many species are adapted to the highly changeable conditions that occur in saline lagoons and some are either mainly or entirely restricted in their distribution to this habitat. Such specialist species include the lagoon sand shrimp *Gammarus insensibilis*, tentacled lagoon worm *Alkmaria romijni*, lagoon sea slug *Tenellia adspersa*, starlet sea anemone *Nematostella vectensis*, tentacled lagoon worm *Alkmaria romijni*, trembling sea-mat *Victorella pavida*, foxtail stonewort *Lamprothamnium papulosum* and bearded stonewort *Chara canescens*, all of which protected under the Wildlife and Countryside Act (1981) as amended. Furthermore, despite their limited extent compared to many other coastal habitats, saline lagoons provide a highly important resource for large numbers of birds that use the habitat for feeding, nesting and roosting at high tide.

In England, there are currently 177 coastal saline lagoons, covering an area of approximately 1300 ha, with 450 ha being occupied by a single site (The Fleet in Dorset). The rarity of this habitat and the specialist flora and fauna it supports make saline lagoons especially valuable for nature conservation. For this reason, many coastal saline lagoons in England are protected by national and international designations.

Potential climate change impacts

Saline lagoons are increasingly threatened by climate change. Reviews of the potential impacts of climate change have identified a number of significant risks including relative sea level rise, increased storminess and changes in temperature and/or seasonal precipitation, which can alter the distribution, ecology and functioning of lagoon habitats (Mossman *et al* 2015).

These risks are listed in the table below. It should be noted that as each lagoon is unique, the impacts of climate change on lagoons are likely to vary between sites based on their physical characteristics and salinity regime. Furthermore, the impacts will not be the same everywhere around the coast of England; for example sea level rise is predicted to be the greatest along the southern coast of England whereas lagoons in the north and west of England may be more susceptible to freshwater inundation due to increased risk of flooding.

Cause	Consequence	Potential impacts
Relative sea level rise (RSLR) and increased storminess	Altered coastal dynamics and changes to the amount of sediment supplied	■ Increases in the rate of sea level rise will substantially alter the sediment balance. Coastal systems are dynamic and have the potential to adapt to rising sea levels, but only if there is an adequate supply of sediment to allow accretion, and if there is landward space for the coast to roll-back into. Sea defences and other coastal management interrupt the movement of sediment between systems and prevent natural coastal realignment. ■ The behaviour of any coastal sediment will change with increasing rates of RSLR, but sites will differ according to topography and sediment supply. There will be a tendency for shingle impoundments to migrate landwards as RSLR progresses but once RSLR exceeds a 'tipping point' around an annual rate of 3-4 mm, widespread reorganisation of coastal landforms, including lagoons, may occur (Rennie and Hansom 2011).
	Coastal Squeeze	■ Saline lagoons with natural barriers may be able to migrate with rising sea levels by barrier 'over-washing' and the transfer of sediment from the front to the rear of the barrier (Jones *et al* 2011b). ■ Policies that allow natural coastal rollback will cause losses of lagoon area unless the lagoons are able to migrate landward. In many cases, this is unlikely due to engineered barriers. This 'coastal squeeze' will diminish the extent of saline lagoons (Spencer and Brooks 2012). ■ Artificial lagoons will be entirely dependent on continued human intervention (Brazier *et al* 2016).

Cause	Consequence	Potential impacts
	Increased seawater inundation	■ Many lagoons are protected from tidal inundation by sand or shingle barriers. RSLR and increased storminess may result in increased frequency of breaching and overtopping of lagoon barriers. Seaward enclosing barriers may become increasingly susceptible to breaching or more extensive morphological collapse as sea-level rises and storminess potential increases (Lowe *et al* 2009). Even if barriers remain in place, changes in wave height and/or force may result in increased frequency of barrier over-washing. ■ Increased seawater inundation may lead to increased and/or less variable salinity levels in lagoons. While most lagoon organisms have optimal salinity regimes, they also tend to have wide salinity tolerance, especially as adults. The problem of increasing salinity for lagoon invertebrates is that most, if not all, have close marine counterparts, which are likely to out-compete them at salinities close to that of pure seawater (Angus 2016). As a result, the lagoon community composition and diversity may be drastically altered as a result of increased seawater inundation. ■ Increased seawater inundation may lead to changes in water quality, which may have a negative impact on the diversity and composition of lagoon species.
Drier summers and increased annual average temperatures	Changes in seasonal water availability	■ During drier and/or warmer periods, (most likely in southern Britain), an increase in hypersaline conditions is likely as water evaporates from lagoons (Mitchell *et al* 2007). A different suite of species tolerant of these conditions may become evident. ■ Increased summer temperatures may lead to increased drying out and an increased level of desiccation in the intertidal area, restricting the distribution of intertidal species (NIHAP 2003), depending on precipitation amounts.
Wetter winters	Increased seasonal precipitation	■ Climate change models suggest that most regions in northern Europe will experience wetter winters in the future, with increased frequency of flooding events in coastal areas (McClatchey *et al* 2014). Changes in the volume and timing of freshwater discharge into lagoons due to higher precipitation has the potential to alter the salinity regime of the lagoon, which combined with potentially more frequent overtopping during storms will lead to changes in water chemistry. A reduction of salinity may occur where the balance shifts towards higher input of freshwater, and will result in a shift in species composition according to their tolerances. ■ Reduction in water quality may also have an impact on the diversity and composition of lagoon species. Lagoon water quality may be reduced as a result of increased nutrient runoff from the surrounding land caused by increased precipitation and more frequent flooding (Anthony *et al* 2009).
Changes in seawater temperature	Changes in lagoon water temperature	■ Warmer water could hasten the spread of invasive non-native species. For example, *Ficopomatus enigmaticus* is an annelid tubeworm which is thought to be at, or close to, its temperature minimum for maintaining populations and successful reproduction along the southern coast of Britain (Zibrowius & Thorp 1989; Thorp 1994). It was previously thought only to survive in artificially heated northern waters, but is now colonising lagoons along the south coast, such as Cockle Pond near Portsmouth Harbour.

Adaptation responses

Although coastal lagoons are highly sensitive to the impacts of climate change, naturally formed lagoons are ephemeral habitats that at least, in theory, have considerable ability to adapt provided there is space for adaptation with minimal human interference. However, saline lagoons do not exist in isolation but are part of the wider coastal system, which consists of a series of interconnected habitats including saltmarsh, coastal grazing marsh and estuaries, as well as smaller features such as shingle bars. In England, these dynamic habitat complexes have rarely escaped human influences, and coastal processes seldom operate in their fully natural state. The complex and dynamic processes between different coastal habitats also remain poorly understood (Mossman *et al* 2015).

Although there is a need for greater understanding about how coasts in England function in their entirety and the degree of naturalness that still remains within them (Beer and Joyce 2013), it is clear that adaptation responses for interconnected coastal habitats should consider the coast as a whole. It needs to be recognised that gains for some coastal habitats may mean the loss of others, but that there is also potential for the creation of new habitats to offset habitats that have been lost.

Three potential courses of action have been suggested as adaptation responses to climate change for coastal lagoons (Angus 2016):

1. Non-intervention, i.e. allowing processes to operate naturally. This option may mean that individual lagoons are formed, lost or relocated, or new and different coastal habitats are formed.
2. Manage the impacts of sea level rise by raising the height of the isolating barrier (if feasible and appropriate).
3. Translocation of vulnerable species to analogue sites. The success of this method is yet to be proven.

While option 1 is generally favoured, there is a risk that this could result in the local extinction of vulnerable lagoon species. Further research and monitoring is required for options 2 and 3 (Angus 2016).

Some of the potential adaptation options for this habitat are outlined below.

- Act to eliminate or reduce non-climate change associated pressures on coastal lagoons, including erosion caused by altered drainage flows or removal of sediment, eutrophication, heavy metal and synthetic contaminant exposure, marine litter and recreational pressures.
- Restore or maintain habitat so that it is in the best possible condition and better able to withstand external pressures caused by climate change.
- Anticipate future changes and develop approaches to managing the land adjacent to the lagoon, including identifying and protecting landward habitat for the lagoon to retreat to naturally as sea level rises.
- Adjust the boundaries and interest features of protected sites as coasts evolve, and aim to enlarge functional units.

Ringed plovers feed in the shallows and margins of saline lagoons. © Natural England/Allan Drewitt

- Sediment recharge may be considered on vulnerable areas, for example where the isolating barrier of a lagoon is a shingle ridge. However, the impact of sediment recharge on other coastal habitats needs to be carefully considered before proceeding with this option.
- Develop and implement management plans that respond to predicted changes along the whole coast and not in individual sites in isolation. As a part of a wider coastal management scheme, a lagoon may need to be allowed to move naturally or even to be lost entirely and recreated elsewhere if appropriate.

Relevant Stewardship options

CT3 Management of coastal saltmarsh

This option can include small lagoons if they are part of the saltmarsh area. The precise management agreed will depend on the particular conditions on a site. It could include maintaining an appropriate grazing regime around the lagoon, restrictions on the use of fertilisers on adjacent land, appropriate land drainage and controlling damaging activities associated with public access. This option will contribute to climate change adaptation and help to conserve and strengthen the distinctive local character of estuarine and coastal landscapes.

CT4 Creation of inter-tidal and saline habitat on arable land

CT5 Creation of inter-tidal and saline habitat by non-intervention

CT7 Creation of inter-tidal and saline habitat on intensive grassland

These options run for 20 years instead of the standard 5 years, in recognition of the level of management change involved and their largely irreversible nature.

These options create inter-tidal and saline habitats, including transitional areas (transitions between saltmarsh and nearby habitats), on arable land, improved grassland or following the unmanaged breach of sea walls or the overtopping of sea walls. As a result of tides bringing in sediment and seeds, a range of inter-tidal habitats will form such as mudflats and coastal saltmarsh, together with saline lagoons and transitions between these and other habitats. These habitats will benefit many specialised plants and animals adapted to the differing degrees of tidal inundation and saline influence. These factors result in variations in vegetation cover from bare mud to dense saltmarsh, and succession between them over time.

The creation of small-scale saline lagoons, which require an input of seawater, can be promoted by these options. They will also contribute to more sustainable flood management, adaptation to climate change and enhancement of the coastal landscape.

Further information and advice

Countryside Stewardship scheme details and management options.

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Relevant Case Studies

The Wallasea Island Wild Coast Project

The RSPB's Wallasea Island Wild Coast Project in Essex aims to combat the threats from climate change and coastal flooding by creating a large area of inter-tidal habitats, including mudflats and saltmarsh, lagoons and pasture. It will also help to compensate for the loss of such tidal habitats elsewhere in England. A range of features have been incorporated into the design to benefit wintering and passage SPA water birds. Islands have been created to provide high-tide roosts for waders, and nest sites for terns and spoonbills. Areas of saline lagoon and lowland wet grassland are being created to provide additional feeding areas for birds when the intertidal mud is covered at high tide.

For further information see **The Nature of Climate Change**, page 39 – 41.

Medmerry managed realignment scheme

The realignment scheme at Medmerry in Sussex is one of the largest managed realignment projects in the UK and the first of any notable size to be undertaken on an open coast. It is unique because it is the first scheme in the UK to be created by excavating a breach through a mobile shingle barrier.

The scheme was designed to provide the local community with sustainable flood and coastal protection (to a 1 in 100 year standard), as well as creating new intertidal habitat (mudflats, saltmarsh and lagoons) that was needed to compensate for losses of these habitats across the Solent. It was also designed to provide recreation space for visitors and local people.

It was completed in September 2013 and proved to be successful in achieving its goals. In particular it withstood the severe sequence of storms that hit the UK coastline during 2013/14. Around 185 ha of intertidal habitats were formed (along with transitional grassland and farmland) inside 4 miles of new flood protection embankments.

Steart Marshes

Steart Marshes in Somerset is a habitat creation project managed jointly by the Environment Agency and the Wildfowl and Wetlands Trust. Here, the issues of flood risk management, coastal squeeze and sea-level rise are being addressed by the creation of new areas of habitat, including saltmarsh, coastal grazing marsh, lagoons and mudflats.

Mapping coastal change at Cley/Salthouse and North Norfolk Lagoons

The lagoons at Cley are percolation lagoons, and depend on a shingle ridge which acts as the isolating barrier to regulate seawater intake. Prior to 2006, this shingle ridge was artificially profiled and prevented from migrating landwards, but in 2006, as a flood risk management measure, the Environment Agency and Natural England agreed to restore it to a more natural beach profile. The impact of this management decision has been monitored, using archive and newly commissioned LIDAR data.

In December 2013, parts of the UK experienced the biggest storm surge in 60 years, which was followed by another storm surge in January 2017. The coast of East Anglia was one of the hardest hit areas and has offered an opportunity to investigate how a coastline evolves naturally in response to change.

© Natural England/Andy Millar

The use of novel remote sensing techniques has enabled mapping of the storm surge breaches and sediment transport on engineered and gravel barriers that separate the saline lagoons from the sea. Researchers from the Centre for Environment, Fisheries & Aquaculture Science (Cefas) and the University of East Anglia have studied newly obtained aerial images of the area that were affected by the surge on December 2013. The impacted coastline encompasses the Wash and North Norfolk Coast European Marine Site (EMS) with its several designated saline lagoons, including the lagoons at Cley marshes that comprise 36% of the lagoon area within the EMS. The research has revealed widespread, long-term changes to parts of England's eastern coastline caused by the surge, including damage to the engineered and natural defenses and saltwater flooding in the lagoons. Sediment was transported for over 100 meters inland, in places infilling protected saline lagoon habitats.

The above photograph shows the landward side of the shingle ridge at Cley following the 2017 storm surge. A large, new outwash fan and proto-lagoon in its lee can be clearly seen. Some existing SAC lagoons were completely rolled over and have disappeared.

For further information see **Natural England (2011)** pp. 14 -23.

Increasing the Resilience of the UK's Special Protection Areas to Climate Change
Saline lagoons are important feeding, breeding and roosting habitat for many bird species, and many form part of European designated Special Protection Areas (SPAs). A **report** commissioned by Natural England in 2016 considered the ecological consequences of climate change for Special Protection Areas (SPAs). A series of case studies was developed to highlight how current management might be adapted at site level to address future climate change impacts, including at **Minsmere - Walberswick** in Suffolk and the North Norfolk Coast.

At Minsmere-Walberswick, proposed management responses include increasing control over water levels and salinity through adjusting inputs of freshwater and sea water (where possible); and on the Norfolk coast, the creation of shallow saline water bodies as part of management realignment schemes, and allowing saline lagoons to develop naturally where the local topography allows it (Franks *et al* 2016,a,b).

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