Guidelines for the Selection of biological SSSIs

Part 2: Detailed guidelines for habitats and species groups

Chapter 1c Saline Lagoons

Authors

Brazier, D.P., Street, M. & Angus, S.

To view other chapters and Part 1 of the SSSI Selection Guidelines visit:
https://jncc.gov.uk/our-work/guidelines-for-selection-of-sssis/

Cite as: Brazier, D.P. (Lead Author), Street, M. & Angus, S. 2022. Guidelines for the selection of biological SSSIs. Part 2 Detailed guidelines for Habitats and Species. Chapter 1c saline lagoons.

Cover note

This chapter updates and replaces the previous Saline Lagoon SSSI Selection Guidelines (Joint Nature Conservation Committee 1996; Nature Conservancy Council 1989; Ratcliffe 1977). It contains guidelines for the selection of saline lagoons, including their associated biological communities and species, as Sites of Special Scientific Interest (SSSIs). This chapter (1c) of Part 2 of the Guidelines should be used in conjunction with Part 1 of the SSSI Selection Guidelines, as published in 2013 (Bainbridge *et al.* 2013), which detail the overarching rationale, operational approach and criteria for selection of SSSIs. This chapter, along with Coastal Habitats (1a) and Marine (Intertidal and subtidal) Habitats (1b) makes up the Coastlands chapter. This chapter has been prepared by Paul Brazier (NRW), Stewart Angus (SNH) and Margaret Street (NE) in association with Hugh Edwards (DAERA). Other relevant supplementary habitat and species chapters in Part 2 of the Guidelines may also be relevant to the selection of Saline Lagoons (https://jncc.gov.uk/our-work/guidelines-for-selection-of-sssis/) See Part 1 section 1.5 of Bainbridge *et al.* (2013) for an explanation of the relationship with ASSIs in Northern Ireland.

The main changes from the previous version are:

- Amendment of the selection criteria to reflect changes to Part 1, including the incorporation of ecological coherence, ecosystem services concepts and future climate change scenarios.
- Expansion of the species annex (see Appendix 1) to reflect changes to date.
- A more appropriate Areas of Search (AoS) framework that better reflects the nature of the distribution of saline lagoons in Great Britain.
- To ensure that the dynamics of coastal habitats, ongoing coastal change and the supporting coastal processes are clearly set out and that the boundary definition and feature selection, account for changes that may occur because of climate change and coastal management decisions.
- To ensure that saline lagoons, created as part of coastal habitat for the specific aim of countering losses to development or climate change, can be considered for site selection, and that their potential value is recognised as set out in Part 1, section 6.12.1 and 6.12.2.
- Revision of the use of selection units and consideration of the best means of describing those attributes that are considered important to conserve.
- The chapter stresses the limited extent of many lagoonal species and communities which supports the adoption of a minimum standards approach for the majority of saline lagoons.

This sub-chapter has been subjected to appropriate levels of evidence quality assurance. It is compliant with the JNCC Evidence Quality Assurance Policy 2014 and has been subjected to external peer review by Professor Roger Herbert.

1. Introduction

The purpose and overall rationale for Sites of Special Scientific Interest (SSSIs) designation are described in Part 1 of the 'Guidelines for Selection of Biological SSSIs' (Bainbridge *et al.* 2013). SSSIs are an important component, in the suite of conservation sites, for the protection of important and/or threatened habitats and species and as part of a wider landscape-scale ecosystem approach to the sustainable management of our environment (Bainbridge *et al*. 2013). These Guidelines are used to identify saline lagoons that have vascular plants, algae, invertebrates or communities of such species. The Guidelines do not cover birds, mammals or fish that may use the lagoon for all or part of their lifecycle (see other respective Guidelines).

Lagoons are defined in the UK interpretation manual (The Habitats Directive: selection of Special Areas of Conservation in the UK), as "Areas of shallow coastal water, wholly or partially separated from the sea by sandbanks, shingle or, less frequently, rocks" by Brown *et al*. (2013), but this has been amended to include an additional criterion of "sea exchange sufficiently restricted to impede exchange and/or impact functionality" (Angus 2017). Connection with the open sea is limited by sediment, shingle or rock and in many cases, sluiced lagoons have a limited connection via man-made structures such as culverts and valved sluices. Freshwater input is usually from direct drainage of surrounding land or groundwater seepage. The water in lagoons can vary in salinity from brackish (due to dilution of seawater by freshwater) to hypersaline (i.e. saltier than sea water, due to evaporation). Lagoons can contain a variety of substrata depending on their origins.

In summary, the procedure for identifying a saline lagoon SSSI is as follows:

- For each of the saline lagoon selections described in this section, available data on plant and animal communities and the species present are assembled. The communities or mixtures of communities present at different sites are identified;
- Data from each location are tested against the 'criteria for assessment and selection' and sites with habitat or community features fulfilling one or more of those criteria are considered further. Within each Area of Search (AoS), a minimum aim of SSSI selection is to include examples (and preferably the best) of the full range of habitats and associated communities **that satisfy the guidelines for selection**. For further information, see Part 1 Section 5 (Bainbridge *et al.* 2013; https://hub.jncc.gov.uk/assets/dc6466a6-1c27-46a0-96c5-b9022774f292);
- Particular care is taken to ensure those habitats and their associated communities and species which have a restricted national or international distribution are included in SSSIs. In general, the more important the habitat (according to degree of rarity or if listed in international Conventions), the greater the percentage of that habitat that should be selected; and
- Note that under the UK Marine and Coastal Access Act 2009 (Clause 123(4b)), The Marine (Scotland) Act 2010 (Clause 79(4c)) and the Marine Act (Northern Ireland) 2013 (Clause 20(c)), ASSSIs will legally form part of the Marine Protected Area (MPA) network where they are considered to protect marine features.

2. Saline Lagoon Characteristics

The plant and animal communities of lagoons vary according to the physical characteristics and salinity regime of the lagoon, and therefore there are significant differences between sites. Although a limited range of species may be present compared with other marine habitats, many of these species are specifically adapted to conditions of saline lagoons (varying salinity). Lagoons show uniquely high levels of environmental stress owing to the short-term and spatial variations in conditions prevalent in such lagoons. The currently accepted hypothesis for the restricted distribution of "specialist lagoon species" is that they are tolerant of these stress conditions and, while they can be outcompeted in adjacent saline habitats (estuaries, tidal rock- or marsh-pools, or the sea), they are better able to survive in lagoon habitats than are those more common taxa which outcompete them elsewhere (Bamber 2010). The species present in lagoon communities often have a restricted distribution and may be confined to sheltered brackish water. This means that low species diversity should not necessarily be regarded as a negative attribute (Joyce *et al*. 2005).

Due to saline lagoons being highly varied in their physical and biological characteristics, there has been great difficulty in defining biotopes as described by Connor *et al*. (2004) and JNCC (2015) – see Appendix 2. Where distinct vegetation types are found, these communities have been defined by the predominant vegetation and associated biological community. Sediment communities can be broadly subdivided by substratum (mixed stony substrata, sand or mud), with various influences of sediment stability and salinity. Rocky communities are also influenced by water flow, turbidity and salinity. Due to the limited connectivity between lagoons and with coastal waters, the stochastic nature of recruitment influences the biological communities that result. High levels of recruitment from within a lagoon system often result in dominance of the community by a limited number of species in high abundance. Recruitment from outside of the lagoon, from the marine environment, is likely to be limited. For these reasons, a discrete classification of lagoon biotopes is not possible, each lagoon demonstrating an element of uniqueness, in terms of the biological communities (Appendix 2). The vegetation may include beds of eelgrasses *Zostera* spp., tasselweeds *Ruppia* spp, the alga *Chaetomorpha linum*, pondweeds *Potamogeton* spp. or stoneworts such as foxtail stonewort *Lamprothamnium papulosum*. In more rocky lagoons, communities of fucoid wracks *Fucus* spp., sugar kelp *Saccharina latissima* and attached red and green algae are also found. The fauna are often characterised by mysid shrimps and other small crustaceans, worms which burrow into the sediment, prosobranch and gastropod molluscs and some fish species. Species that are particularly found in lagoons and consequently have restricted distributions in the UK include lagoon sandworm *Armandia cirrhosa*, lagoon cockle *Cerastoderma glaucum*, lagoon sand shrimp *Gammarus insensibilis* and foxtail stonewort *Lamprothamnium papulosum* (Appendix 1 for listed species). The intertidal zonation of saline lagoons is compressed when compared to the adjacent open coast, resulting in narrow zones, such as bands of fucoid algae that may extend into the subtidal zone in sites where the salinity is reduced. These fucoid algae may include hornwrack *Fucus ceranoides* which is only found in low salinity habitats, along with hybrids with *Fucus spiralis* and *Fucus vesiculosus*. Lagoons may also provide important habitat for waterfowl, marshland birds and seabirds (not covered in these Guidelines, see Birds SSSI Guidelines, Chapter 17).

There is no major riverine input, or in cases where rivers drain into saline lagoon systems, the lagoon basin is distinctly different from the physiographic features of an estuary (Pritchard 1967). On occasions, the status may be unclear, such as on the Howmore River, South Uist, where the lagoons are associated with the estuary (Angus 2018). Where the status of a lagoon (as opposed to an estuary, an arm of the sea or an enclosed bay) is unclear for the purposes of site designation, the physiography, salinity and associated biological communities should be considered in combination. Studies by Bamber *et al.* (2001b) have improved understanding of what constitutes a lagoon of high conservation importance, through comparison of the component species assemblages. Saline lagoons are important both as physiographic features and for their habitats, and for the species they support. Selection for SSSI is based on their relative importance according to the nature of the features (morphology, habitats and species) present. Some lagoon species, notably invertebrates and some plants, are specialists, matching the lagoonal environment and are therefore largely restricted to lagoons. In addition, saline lagoons are an integral part of coastal and wetland systems, contributing to both habitat and species diversity (Bamber *et al.* 1992; Angus 2018).

Saline lagoons exhibit great diversity of form, ranging from fully natural water bodies enclosed by gravel or sandy barriers, or lie within rock basins, to systems exhibiting varying degrees of human alteration, to artificial water bodies impounded by human structures (Conlan *et al.* 1992). There is a broad geographical variation in their form, with rock basins dominant in western Scotland, natural bar-built lagoons in England, Wales, Orkney and Shetland, and artificial impoundments dominant in Northern Ireland (NIHAP 2003). They are often categorised according to the mechanism of water exchange with the sea (Smith and Laffoley 1992; Bamber *et al.* 2001b). Coastal lagoons exhibit great diversity in substratum type (bedrock, sand, gravel, mud), salinity, depth and stratification, and marginal habitats and they range in size from over 800 ha, such as the Loch of Stenness in Orkney, to less than 1 ha.

Whilst five types of physiographic type of saline lagoon have previously been identified (Table 1, JNCC 1996), the nature of the habitats and species in a saline lagoon is more dependent on other factors, including rates of exchange of water, salinity regime, depth and substratum. The physiographic types are not exclusive, and a particular lagoon may be described as a number of different types. Although the categories listed in Table 1 below have been widely applied, the validity of using physiographic criteria to classify a habitat has been questioned (e.g. Oliver 2005) and more recent approaches involve the biota or biodiversity, both of which depend on the amount rather than the nature of saline exchange.

Table 1. Physiographic types of saline lagoon (JNCC 1996).

Saline Lagoon Type	Salinity Regime	Depth and Substratum
Isolated	Little marine input (ground water or over-topping), likely trending towards freshwater over time	Typically, shallow with sediment bottom due to low energy levels present
Percolation	Small, but consistent marine input through a permeable barrier.	Typically, shallow with sediment bottom due to low energy levels present
Sluiced	Variable	Highly varied, according to the geology and coastal processes local to the saline lagoon
Silled	Variable	Highly varied, according to the geology, although typically rocky in nature. Sediment in deeper basins is likely.
Inlet	Frequent and consistent marine input, ranging from reduced salinity to fully marine	Highly varied, according to the geology, although typically rocky in nature. Sediment in deeper basins is likely.

The influence of exchange of sea water is determined partly by the height of any sill or other isolating barrier(e.g. a sluice, above spring low water, its breadth, the volume of the lagoon, and the amount of freshwater flowing into the lagoon). Independent of the levels of freshwater entering the system, the amount of exchange of sea water also influences the recruitment opportunities and biodiversity within the system. The conditions change as the influence of the sea declines with increasing distance from the sea exchange. Some lagoons are brackish throughout, while in others there is a distinct salinity gradient, along which there is a transition from virtually freshwater communities through to fully marine communities of animals and plants. Other factors that affect the habitats present are the surface area and depth of the lagoon. All of these factors influence the stability of the waterbody, which in turn influences the formation of thermoclines and haloclines, and deposition of sediments. Larger and deeper lagoons often have less fluctuating environmental conditions and may therefore harbour the richest communities. Some of the larger lagoons also have a more complex basin structure, each of which may have its own environmental characteristics, conferring increased complexity and resilience on such lagoons.

Where conditions of limited exchange with the open sea, with significant freshwater input, as can be the case for isolated, percolation, sluiced and silled saline lagoons, consistently low salinity across the lagoon will result. The terrigenous input and low energy levels in the lagoon results in a sediment bottom of muddy habitats. Where water turbidity is low, muddy and sandy areas are dominated by filamentous green algae amongst which may be colonies of rare charophytes such as foxtail stonewort *Lamprothamnium papulosum* and in some examples beds of the tasselweeds *Ruppia* spp. can grow. Recruitment of marine species is limited by the constrained input from the sea and the low salinity levels. Where freshwater input is also limited, the salinity is maintained at a higher level, allowing better establishment of marine and lagoonal species and may include species of eelgrass *Zostera noltei* and *Zostera marina*. Where the substratum is rocky, such as in sluiced and silled lagoons of limited marine exchange, green algae can dominate the subtidal areas, with sheltered rocky communities on the edges of the lagoon, characterised by fucoid algae.

Sluiced saline lagoons are modified such that a mechanical device controls the ingress and egress of water to and from the lagoon. This may take the form of a simple pipeline to culvert the water, a sluice, a sill or a system of valves that restrict water flow as necessary to prevent tidal flooding. The status of the water management regime will be key to the conservation value of a sluiced saline lagoon and must be considered when evaluating the quality and future value. There are likely to be conflicting interests in maintaining water levels at a particular height, such as fishery interest, breeding birds (terns) and flood defences.

Where sites have a sluice or sill close to mean high water of spring tides, salinity is often medium (around 15 PSU (Practical Salinity Units)). The basin of the lagoon is usually sediment-filled, though generally fringed with rock. The sediment is usually dominated by ephemeral filamentous green algae, occasionally with beds of tasselweed *Ruppia* spp. or, in very shallow depths, *Z. noltei*. The fringing rock is colonised by further filamentous green algae and colonial diatoms. Amongst the weed in these lagoons may be a number of amphipod and gastropod species and the three-spined stickleback *Gasterosteus aculeatus*. Habitat diversity is low in these sites and, the stress of low salinity usually leads to low species richness. The hydrographic regime of silled saline lagoons with a high sill creates conditions, and therefore communities, which may be similar to some percolation or isolated lagoons.

Most lagoons are shallow, with a depth of less than 5 m, although Loch Obisary in the Outer Hebrides reaches a depth of 45 m in its northern (seaward) basin (Angus 2018). In all but the shallowest lagoons, seasonal thermoclines with associated haloclines may develop. In shallower examples, wind-generated water-mixing prevents deoxygenation in all but the calmest, sunny weather, and communities below the halocline may be characterised by a number of marine species which are tolerant of slightly reduced salinity, such as the ascidian *Ciona intestinalis*. Exceptionally, haloclines can develop in much shallower lagoons and may happen frequently even in winter when there has been rainfall and little wind. This has been confirmed from Loch an t-Sruith Mhoir in North Uist over winter – the maximum depth of this loch is 4 m.

Where the sluice or sill is around mid-tide level, water exchange is generally high and salinity may reach around 30 PSU (Practical Salinity Units), close to that of full seawater. In the subtidal areas of lagoons, the cape form of sugar kelp *Saccharina latissima* may form dense forests, often loose-lying over soft muddy sediment, along with other species typical of this environment such as green fingers *Codium fragile*, cord weed *Chorda filum* and *Phyllophora pseudoceranoides*. Beds of eelgrass *Zostera* spp. may also be present. The infauna of lagoon sediments may be rich, including dense populations of bivalves such as the sand gaper clam *Mya arenaria* (considered a non-native species) and a range of polychaetes including the lugworm *Arenicola marina*. Particularly outstanding examples may have populations of sea cucumbers (including *Labidoplax media*) living either on the sediment surface or attached to the fronds of kelps. The intertidal community around the entrance of lagoons is often of high interest since the increased flow of water and permanent wetness encourage the growth of many species, such as sponges and ascidians, which do not normally occur in the intertidal zone (Howson *et al.* 2014). These species are often attached to fucoid algae such as *Fucus serratus* and *Fucus vesiculosus*.

Where the sluice or sill is close to the level of mean low water of spring tide, water exchange with the open sea is usually high. Such lagoons may therefore have a salinity approaching that of full seawater (34 PSU). However, in calm conditions, the depth of the sluice or sill often means that water flowing in from the sea runs under a less dense surface layer of freshwater, allowing the development of a halocline. In this case, communities in the intertidal and shallow subtidal may be subjected to reduced or variable salinity, whilst those of deeper water are fully saline. Communities present will be like those of sites with a mid-tide level sluice or sill, with forests of *Saccharina latissima*, meadows of seagrasses and a rich associated fauna. Intertidal communities at the entrance may be of high interest due to the rich assemblage of species thriving in the increased water movement.

Tidal rapids are associated with some lagoons, such as Loch an Dùin (Uists) and The Fleet (Dorset – Dyrynda and Farnham 1985), and are caused by accelerated tidal movement of water through the restricted entrance channel in response to tidal rise and fall in the sea outside the lagoon. The communities of these rapids are often extremely species-rich, dominated by colonies of filter-feeding sponges and ascidians which thrive in the fast-moving water. The rocky bed of these channels can be dominated by pink encrusting coralline algae which may include rhodoliths attached to pebbles and/or free-living maerl. Larger boulders and bedrock can be colonised by species of kelp *Laminaria* and support columns of the pod weed or sea oak *Halidrys siliquosa* which in turn may be extensively colonised by sponges and ascidians. The biological communities of tidal rapids are identified in Chapter 1b (Intertidal and Marine) as important features of Low Energy Rock and Mixed Substrata shore types. Intertidal tide-swept algal biotopes are also considered nationally or internationally important and should be designated.

3. National and International Importance

Coastal saline lagoons are localised in Europe and have a restricted distribution on the Atlantic seaboard of Europe (Joint Nature Conservation Committee 2016). Saline lagoons formed by sediment impoundments are ephemeral in geological time as shingle barriers migrate landwards and obliterate them, and thus there are fewer such lagoons today than after the last Ice Age 11,500 years ago.

Around the UK, a large proportion of the national resource occurs in England and Scotland. Although uncommon, lagoons may be clustered together on specific stretches of coast, where they are dependent on specific local geomorphological processes, such as in Suffolk, Norfolk, the Solent and Isle of Wight, Orkney, Shetland and the Outer Hebrides, whilst a few stretches are lacking in lagoons, including much of Devon and Cornwall and some parts of the east coast of Scotland. Some of the different types have a restricted distribution in the UK; rock basin lagoons are found mainly in the Outer Hebrides, reflecting the complex terrain, and a high proportion of sediment-impoundment lagoons occur in Wales, south and east England (Bamber *et al*. 2001b; MCCIP 2018), reflecting the influences of coastal sediments and longshore drift.

The large tidal range (compared with most other areas of Europe with extensive lagoons), in Britain is important and results in the development of the rock-bound lagoon habitats in parts of Scotland where isolation and subsequent development of brackish conditions occurs due to the limited access of seawater. The saline lagoons in rock basins of western Scotland (and western Ireland) are not represented elsewhere in Europe, since Scotland is unusual in having fjardic inlets coinciding with a large tidal range. Since ‘coastal lagoons’ are a priority Annex I habitat, the United Kingdom has an international obligation to conserve saline lagoon sites of European importance (Bamber *et al.* 2001b).

4. Assessment Criteria

The same principles and criteria are used for the selection of marine features as are identified in Part 1 of the Guidelines (Bainbridge *et al.* 2013).

4.1. Typicalness

Typicality of saline lagoons can be described broadly, in terms of the physiography, salinity regime and hydrodynamics, but as a comparative criterion, this is difficult to apply. As described in the introduction, a key aspect of saline lagoons is the high diversity of characteristics across different lagoons. See Section 2 for a full description of the variety of saline lagoons.

4.2. Fragility

Whilst the interior of saline lagoons is sheltered from extreme wave and tidal action, they are very sensitive to changes in hydrodynamic regime and physical disruption to the fluxes of saline and freshwater input and water quality changes in coastal geomorphology. They are vulnerable to activities from terrestrial sources such as dumping of waste, infilling, intensive agriculture and livestock in the proximity of the lagoon. The high residence time can result in nutrient build up, and in depositional systems, can lock away pollutants within the sediments. The risk from the effects of climate change have been covered in Section 6.9.

The greatest threats to the existence of saline lagoons are from coastal development and the effects of climate change such as sea-level rise and changes in hydrology. These affect the geomorphology and dynamics of tidal and freshwater flow, whilst the threat to the condition of saline lagoons stems from changes in land management and upstream water flow and quality. In this respect, saline lagoons are very fragile and require management of the wider countryside to ensure their continued condition. Historical losses demonstrate the continued decline due to these threats (Section 6).

4.3. Size (extent)

Size or extent is considered important as larger sites tend to contain greater diversity and support more viable populations. Larger saline lagoons are usually more stable in character and this is likely to encourage species richness, but shape and complexity of the lagoon are also important (Bamber *et al*. 1992), whilst small simple lagoons are more susceptible to adverse environmental fluctuations.

Larger lagoons, which have a complex shape, tend to have salinity gradients and more localised variation in habitat and host a higher number of specialist lagoonal species (Bamber *et al.* 1992). For example, Loch Bee (Loch Bi) is one of the most species-rich saline lagoons in Scotland (see Section 4.4). Loch Bee has sea exchanges on two different coasts, resulting in two salinity gradients.

These guidelines include the entire range of saline lagoon types, from small sediment-filled isolated saline lagoons, covering an extent of less than 0.5 ha, to larger brackish water systems. The largest saline lagoons in Scotland are the Loch of Stenness in Orkney and Loch Bee in South Uist; both are around 800 ha; in Wales; Cemlyn lagoon at 12 ha; and in England The Fleet (Dorset) which is 480 ha.

4.4. Diversity

Diversity, in terms of the variety of habitats in a particular lagoon, is broadly dependent on the diversity of the physical and chemical substratum and habitats present and the presence of physical gradients across the site. Species diversity, in terms of species richness, directly relates to the number of habitats present and also to the stability (or not) within some of those habitats. The presence of additional specialist habitats such as bedrock exposures (in sediment dominated saline lagoons), tidal rapids and seagrass beds will add to the diversity (Thorpe *et al*. 1998; Bunker *et al*. 2003). Rock-fringed lagoons will contain communities like those enclosed by shingle or sediment but will additionally contain fringing rocky communities which, particularly in the Scottish types, will increase the habitat diversity (Thorpe 1998). Algae can support large numbers of invertebrates, but algal abundance is highly variable seasonally and from year to year within some sites.

Some saline lagoon systems have a very wide range of associated communities and species because of the salinity gradient which occurs along them or between different interconnected basins in a lagoon system. Diversity of habitats and species can also be increased if conditions of oxygenation and summer warming of surface layers along a gradient or between interconnected basins creates different communities.

Larger, more complex saline lagoons tend to have a higher species richness than small simple lagoons. This is, however, a broad generalisation with diversity depending on other factors such as water depth and exchange, age of the lagoon and proximity to other lagoons.

Saline lagoons often have a low diversity of habitats and associated communities, with many lagoons characterised by single communities. However, the species present in lagoon communities often have a restricted distribution and may be confined to sheltered brackish water. This means that low species diversity should not necessarily be regarded as a negative attribute (Joyce *et al*. 2005).

By far the most widespread habitat type is sediment, particularly mud and some fine sand. The communities associated with this sediment will vary according to prevailing conditions but is generally one of loose-lying algae with an infauna of polychaete worms and bivalve molluscs living in the sediment and amongst the algae. Particularly noteworthy sediment communities occur at sites with beds of tasselweed *Ruppia* spp. or eelgrass *Zostera* spp. *Ruppia* communities are often present in stable low salinity lagoons, whilst *Zostera* communities may be present in higher salinity lagoons which have a large water volume and stable conditions. Where present, these communities may cover large areas, but *Zostera* spp. in particular are not a common constituent of saline lagoons. Also associated with the sediment habitat may be stoneworts such as *Chara aspera* and *Lamprothamnium papulosum* (JNCC 1996).

4.5. Naturalness

Whilst natural habitats that are unmodified by humans are valued highly, some saline lagoons have been created by human activities such as gravel extraction and quarrying or have been modified by installation of sluices (Pembroke mill pond) or are entirely artificial structures. The biological communities of non-natural systems may be equal to that of many natural systems, provided the appropriate management is in place. By example, Freiston lagoon is a 15 ha lagoon that was created in 2002, as part of a flood defence scheme on the east coast of England. Whilst studies of invertebrates have not been carried out here, surveys in 2006 of over-wintering waterbirds identified 38 species, at least 10 of which bred (Badley and Allcorn 2006), many of which will be dependent on the macro-invertebrates as a food source. As further example, extensive saline lagoons within the Hurst Castle and Lymington River SSSI, that were dug out of old saltworking ponds (salterns) and re-engineered as part of a large flood defence scheme in the 1980s and where water levels are controlled by sluices, contain many protected species (Bamber *et al*. 2001b).

Selection for notification of managed saline lagoons, must come with a clear understanding of the management policy for the artificial barrier and of the long-term sustainability of the saline lagoon features. In general, only sites that are composed of natural substrata are considered here, although rarely, man-made saline lagoons such as those created by docks will have suitable lagoon habitats and species and, in the absence of other sites nearby, can be considered using these criteria. The factors which have created the lagoonal conditions need to be taken account of when deciding management issues. Any potentially damaging operations (referred to as Operations Requiring Natural England's Consent(ORNEC, England), Operations Likely to Damage the Special Interest (OLDSI, Wales) and Operations Requiring Consent (ORC, Scotland)) must be clearly defined to complement the management.

Saline lagoons maintained by sediment barriers are potentially temporary features on eroding or depositional coastlines, and as such, their continued existence may well depend on active intervention to maintain them, thus affecting their naturalness. The required management to maintain the features of the site must be established, considering other factors such as bird and fringing freshwater and terrestrial vegetation interests. In some cases, the saline lagoon will be allowed to evolve, to the detriment of some features, but with the potential for the formation of different habitats. Coastal defences or managed breaches of over-riding public interest may result in the destruction of a saline lagoon. However, the creation of saline lagoons may be part of management realignment schemes, which themselves may be part of wider coastal defence schemes or habitat creation for nature conservation.

Although marine habitats have generally been modified to some extent by human activity (e.g. structures, disturbance, pollution, introduction of non-native species), the impact on many marine habitats, communities and species is not generally as severe as for terrestrial habitats. SSSIs will not normally extend into areas that are substantially modified by coastal or marine structures, aquaculture, recreational use, pollution, or similar pressures. Where there is justification for notification in substantially modified locations, then any impacting activities must then be managed (e.g. sluice or weir maintenance, water quality controls). The naturalness of the supporting physical processes should also be considered, these are an essential element of the special interest of a marine feature. The dynamic successional and transitional nature of communities and strong influence of natural processes on the intertidal and shallow marine environment requires the approach to site selection to take this into account.

The presence of non-native species in a saline lagoon is an indication of invasion through human activity (primary introduction) or spread from another location (secondary introduction). Secondary introduction may be from further human activity or natural spread from transfer of spores or larvae by natural means. Most non-native species in saline lagoons are good indicators of suitable lagoonal environment and habitats, and are therefore not automatically dismissed as an unacceptable component of the biological community. *Nematostella vectensis* is considered a non-native species in Great Britain (Reitzel *et al.* 2008). *Alkmaria romijni* is considered as *cryptogenic*. (Cryptogenic, in this context meaning ‘a species with no definite evidence of their native or introduced status (Carlton 1996) and species whose probable introduction occurred in ‘early times’ and has not been witnessed’). Cinar (2013), considers *A. romijni* as an alien species, and it is on the Denmark Register of Introduced and Invasive Species, but is only considered as cryptogenic and not non-native by the European Network on Invasive Alien Species (NOBANIS 2022). The sand gaper clam *Mya arenaria* is considered a non-native species by the GB Non-Native Species Secretariat (NNSS), and introduced 400–700 years ago, although the path of introduction is unclear(Jensen 2010).

4.6. Rarity

Saline lagoons are a rare feature, with a limited distribution in Europe at least. This is due to the unusual conditions required for their formation (barrier beach formation on depositional coasts with suitable Quaternary deposits offshore, or in the case of rocky basins in Scotland, glacial action and subsequent inundation by sea-level rise). Their total extent in Scotland, England and Wales is 3,900 ha, 1,205 ha and 37 ha respectively.

Species that inhabit lagoons are those which can survive the rigours of fluctuating or permanently lowered salinity, extremes of temperature variation and, in some saline lagoons, temporary deoxygenation. Since they are predominantly marine species, assessment of rarity uses the criteria developed for marine species (Sanderson 1996) (Appendix 1).

The Sanderson (1996) list was revised by Sanderson in 2000 (Wyn *et al*. 2006), although it remains provisional and requires review in the light of more data since 2000. (Nationally rare = recorded in eight or fewer 10 km x 10 km squares of the Ordnance Survey National Grid (OSNG); Nationally scarce = recorded in 9–55 10 km x 10 km squares of the OSNG). Their rarity is linked to their low capacity to compete with other marine and freshwater species, whilst having the advantage of tolerating saline lagoon conditions. Bamber *et al*. (1992) identified specialist lagoon biota from their study mainly of English and Welsh lagoons as predominantly "stenohaline marine lagoonal specialists", and "euryhaline lagoonal specialists" but with an additional category of "under-recorded lagoonal species". Other species that occurred in saline lagoons they studied were predominantly "freshwater species", "estuarine species pre-adapted to lagoons" and "estuarine species incidental in lagoons". They hypothesised that lagoonal specialist species, the main contributors to rare species in lagoons, are adapted to the stresses of a variable environment (in terms of its salinity, temperature and pH) of reduced tidal exchange, though being evolved from marine ancestors which prefer a salinity of 35 PSU. They survive in saline lagoons because here they are not outcompeted by their less tolerant marine or estuarine counterparts. Species predominantly or only found in saline lagoon habitats are shown in Appendix 1. It is also possible that freshwater or marine species that are rare might, by chance or favourable conditions, be recorded from a lagoon. Gilliland and Sanderson (2000) further reviewed the lagoon specialist nature of *Alkmaria romijni* and concluded that the species could not be considered as confined to lagoons.

Many specialist lagoon species are protected by the Wildlife and Countryside Act 1981 (as amended) or other legislation (Appendix 1) and the presence of a viable population of any of these protected species would warrant the selection of a saline lagoon as an SSSI. The presence of other, unprotected, specialist lagoon species would raise the value of the site when compared to similar locations lacking specialist lagoon species.

4.7. Occurrence and geographic distribution of specialist lagoon species

The geographic distribution around the UK of lagoon species within lagoons is incomplete, and includes occurrences of some of these species in estuaries. Some recent losses from some lagoons means that there are often insufficient current distribution data. Few species are widespread, but notably the lagoon cockle *Cerastoderma glaucum* has been recorded from all coasts of the UK. The foxtail stonewort, *Lamprothamnium papulosum*, has a restricted distribution from the central southern coast of the English Channel, north Wales (BSBI 2017) and to the Outer Hebrides. *Ecrobia* (*Ventrosa*) *ventrosa* and *Nematostella vectensis* (now believed to be a non-native species (Reitzel *et al.* 2008)) are mostly limited to saline lagoons, although have also been recorded from estuarine conditions and can be locally abundant. Some lagoon species are restricted to the south and east of England, including *Armandia cirrhosa*, *Caecum armoricum*, *Gammarus insensibilis*, *Gammarus chevreuxi, Idotea chelipes* and *Nematostella vectensis*. Some of these species, for example *Gammarus insensibilis* and *Hydrobia acuta neglecta* are found elsewhere on the coasts of Atlantic Europe and into the Mediterranean. At the more local level, the species found in lagoons is much less predictable, and recruitment of specialist lagoon species appears to be entirely stochastic. The process by which specialist lagoon species recruit to new or adjacent lagoons remains unknown, although avian propagule dispersal may be important (Herbert *et al*. 2018). Almost all of the species in Appendix 1 have no dispersive larval stage. The stochastic nature of such recruitment is exemplified by the few new lagoon habitats which have been studied. Cams Hall Golf Course lagoon, Hampshire, was created in the 1990s as a "water-feature" adjacent to the fourth hole. Within the first year the lagoon cockle, *C. glaucum*, had colonised the lagoon, and by year four the alga *Chaetomorpha linum* and rare opisthobranch mollusc *Haminoea navicula* were also present, but no other lagoonal specialists were present (Bamber 2010). In saline lagoons, *Chara baltica* is also associated with other brackish water stoneworts, including *L. papulosum*, *C. canescens* (Oliver 2007) and *Tolypella nidifica*. It has a very limited distribution, and can be found in lower salinities, along with *C. canescens* (UK Biodiversity Group 1999).

4.8. Ecological Coherence

This is a concept that is difficult to apply, due to individual saline lagoons often being geographically and functionally isolated from each other. Section 7 discusses the setting of boundaries. Where numerous saline lagoons form a chain or inter-linked features, then the boundary should encompass the full extent of the feature and the adjacent processes that act upon them. The extensive systems of the Outer Hebrides are good examples of these. Clusters of sites, such as within the Solent, may provide ecological resilience, particularly in proximity to areas of higher risk of damage and environmental change.

Some of the specialist lagoon species are known from outside of saline lagoons, such as in estuaries and are potential sources of new populations. In terms of species connectivity, saline lagoons should be seen as part of the wider system, which fits with the broader guidance on ecological coherence (Bainbridge *et al*. 2013) (Section 2 for further details on our understanding of connectivity of lagoons). Bainbridge *et al.* (2013) states that “At the wider, landscape scale, ecological coherence should be considered in terms of representing the full range of variation in relevant species and habitats; protecting threatened species and habitats; and supporting dispersal, gene flow and migration between sites”.

4.9. Potential Value

Saline lagoons have been identified as being highly vulnerable to future climate change (see Section 6.1), due to their proximity to the coast and dependence on precise hydrodynamics. This also offers an opportunity for new saline lagoons to develop because of future sea level rise and coastal realignment, where previously coastal freshwater or lowland topographic features become inundated by seawater. The modelling of future scenarios provides an opportunity to anticipate future changes and identify those lowland (terrestrial) areas that are not sustainable through coastal defence. Management strategies can then be developed to allow evolution of these systems into potential saline lagoons (though this may not always be the ultimate outcome) (Angus 2016).

In some cases, physiographic features that are not considered suitable currently, have the potential to become saline lagoons in the future, through appropriate management to improve the value. This may be at the loss of existing designated freshwater or lowland SSSI features and the case for notification will need to consider the long-term resilience of the present SSSI features, in the presence of continued rising sea levels.

Angus (2017) suggests that, in Scotland, the extent of the habitat could be maintained due to the capture of inland water bodies to form new lagoons, replacing those converted to marine habitats by rising sea level. New lagoons are also likely to form and original lagoons may alter in shape and size on England’s low-lying coasts, because of increasing storminess and rising sea levels. Natural lagoons with rock sills are likely to experience increased saline influence with rising sea levels and a landward shift in the marginal habitats. Geomorphological evolution of natural lagoons is often inhibited by infrastructure and human activities. Many are likely to experience coastal squeeze because of defences on their landward margins; the barrier migrates landward, but the inland lagoon margins are fixed. Conversely, artificial lagoon habitats are likely to be maintained and may even increase in area if they are actively managed. In Poole Harbour, saline lagoon habitat is being maintained by creating new lagoon habitats as part of managed coastal realignment projects, restoring undesignated, degraded and polluted lagoons and identifying previously unknown coastal lagoon habitats (Herbert *et al*. 2019).

Lagoons with man-made isolating barriers, such as sluices, are also dependent on ongoing intervention. These opportunities may result in saline lagoons that are of sufficient quality, according to these guidelines, to be selected for notification as a SSSI for lagoon features. Factors such as increased nutrients from air or water pollution, management of habitats and delivering more sustainable coastal risk management all need to be taken account of in the development and management of the protected sites network. Each case will be different but the predicted changes and measures to address these should form part of the consideration for site selection, with site boundaries large enough to allow these processes to occur naturally. Adaptive management of the coast is required to respond to changes (Natural England and RSPB 2014). Consideration should be made of the effect on other SSSI features other than lagoon habitats and species, including Birds (see Chapter 17, Birds), for example nesting terns in the lagoons and nesting waders on adjacent lowlands and habitats such as saltmarsh (see Chapter 1a – Coastlands). For artificially maintained lagoons (i.e. through weir, sluice or culvert management), adjustment of the weir is possible, to limit saline intrusion, should the salinity creep up because of higher tides or greater wave action causing overtopping (Pye & Blott 2010).

4.10. Recorded History

Many saline lagoons have been studied for some time, where they are accessible. This provides the advantage of a better understanding of the hydrodynamic requirements of the system. Features that have historical data associated with them can be considered valuable for their inherent, historic baseline data. Whilst the distribution of species is reasonably understood, there are many species that are rare, and hence there are not enough data to understand what influences the distribution and populations of these species. Often, where the species presence at a site is well understood, the underlying water flow, water quality, temperature and mixing are little understood. This in turn makes developing a management program for saline lagoons difficult, therefore, sites with adequate physical and biological data are valued. Species can be difficult to locate and in some cases techniques such as environmental DNA (eDNA) might be required to confirm the continued presence of an elusive species (Angus 2016). This methodology has been trialled in lagoons in the Isle of Wight, working with *Gammarus insensibilis* and *Nematostella vectensis*, but is currently problematic and further work is needed (Tang e*t al.* 2018).

5. Selection Requirements

The same principles and criteria are used for the selection of saline lagoons as are identified in Part 1 of the Guidelines for other SSSI designation (Bainbridge *et al.* 2013). A notable difference is that, in the marine environment, animals as well as vegetation characterise the biological communities and are therefore important in the assessment of these habitats.

The approach for saline lagoons is based on the selection of whole saline lagoons. Each lagoon typically consists of a body of water of varying salinity, including its connection with the adjacent open coast if it is directly connected by a channel. This approach corresponds with that taken for whole shores in the intertidal section (Brazier *et al*. 2019).

5.1. Site Selection Principles

The selection of SSSIs for saline lagoon habitats, biological communities and species is based on the approach outlined in the introduction to this chapter. The term 'good', here, reflects those examples, that, relative to other examples are considered to have more interest, according to the following principles.

General principles for selection of saline lagoon sites include the following:

i. The sites are the best examples in terms of the variety of habitat types and their associated biological communities within the AoS.
ii. The site additionally contains good quality examples of specialised habitats such as bedrock exposures, tidal rapids or other unusual features (see Appendix 1).
iii. The site contains habitat or community features of a restricted nature on a national or international (north-east Atlantic) basis.

iv. The site contains one or more of the protected species or specialist lagoon species listed in Appendix 2, including nationally rare and scarce, those listed in Schedules 5 and 8 of the Wildlife and Countryside Act 1981 (as amended) and other initiatives, and also those listed as Species of Conservation Importance (SOCI) under the Marine and Coastal Access Act (2009), Marine (Scotland) Act 2010 and Marine Act (Northern Ireland) 2013. Species that are listed as SOCI under the Marine and Coastal Access Act (2009) are only protected when they occur within a Marine Conservation Zone (MCZ).

v. The site may exhibit a wide range of salinity and may exhibit a salinity gradient within it (from fully marine seawater to low salinity brackish water).

vi. The site is of sufficient extent to maintain the features as a single unit or as several units joined together by natural or man-made connections.

vii. The site exhibits particularly high biodiversity in relation to similar sites. The naturally low diversity nature of lagoons means that this principle should be used with caution.

One or more examples of saline lagoons that meet one or more of the above criteria could be designated within each country (AoS). It is expected that, due to the highly variable geomorphology and physical conditions exhibited by saline lagoons, that several sites will be necessary to adequately represent the full range of communities present. A saline lagoon should not be selected for notification based on its size alone (vi above), but it is likely that extensive saline lagoons will have other interests as a consequence of their size.

A specialised habitat is described as a sub-feature of the lagoon that is considered to enhance the habitat diversity or biodiversity of the site. This may be through increasing the variety of substrata, additional niches or perennial stands of plants. This list suggests some examples, but is not exhaustive (see Chapter 1b Marine (intertidal and subtidal) Guidelines for other relevant examples):

- Pockets of sediment with an infaunal population, in an otherwise rocky environment;
- Rocky knolls, providing attachment for algae and associated epifauna, in an otherwise sediment dominated system;
- Overhanging or steep sided rock where the biological community is different from surrounding upward facing rock;
- Moderately extensive stands of seagrasses with a rich epibiota; and
- Tidal rapids within, at the entrance or exit flows of the lagoon, that has a distinct tide-swept community.

The distribution of saline lagoons is not uniform around Great Britain. Saline lagoons are often concentrated in a specific AoS, for example in Scotland almost all the saline lagoons are in the Northern Isles (Orkney and Shetland) and the Outer Hebrides, with only a few examples in the Inner Hebrides and even fewer on the mainland. Shingle structures (other than shingle backing hard substratum shores) are predominantly a feature of the eastern and southern coasts of Great Britain, and this affects the distribution of percolation pools which rely on a permeable barrier for their development (Rees *et al.* 2019). The process of selecting sites for notification needs to consider this uneven distribution of saline lagoons, which will lead to varying proportions of designated sites across the AoS. Certain AoS will be expected to hold considerably more lagoon SSSIs than other AoS across Great Britain. The converse of this is that a different AoS may not hold any lagoons of sufficient quality for selection on the basis of the lagoon features (although it may have other interest features that meet the guidelines for other habitats or species).

Assessment of importance will take account of whether the site has transitions inland to coastal terrestrial vegetation types, geological or geomorphological features or seawards, to intertidal or subtidal marine community types which are of high interest. Sites that have such features will be more highly rated than otherwise identically rated locations.

Notification of a saline lagoon will be independent of any designation as an MCZ and will be based on the criteria for SSSI designation and the appropriate list of species.

5.2. Supporting Information

Summaries of the resource and its distribution have been gathered for England (Smith & Laffoley 1992; Bamber 1997), Scotland (Howson *et al.* 2014; Covey *et al.*1998; Thorpe 1998; Thorpe *et al*. 1998) and Wales (Sheader & Sheader 1989; Bamber *et al*. 2001a). It should be noted that country agencies are likely to have more up to date opinions on the merits of the various saline lagoons or lagoon-like waterbodies in each country. The biology of saline lagoons is best described by Bamber *et al*. (1992).

Phase 1 mapping is useful in listing the habitats/substratum present and describing their distribution within the saline lagoon as a contribution to formulating the citation and subsequent management of the site. The biotope classification (Connor *et al.* 2004) for saline lagoons is poorly developed due to the difficulties in clearly defining biotopes in such a highly varied environment. In recent iterations of the habitat classification, only three broad level biotopes were identified for saline lagoons (JNCC 2015) – see Appendix 2. In many cases, the availability of comprehensive species data is still limited. In order to make some comparison between lagoons, some measure of habitat type and diversity is required, but this may not be at the biotope level in all cases. The difficulty of acquiring and of identification of specimens means that voucher specimens are an important resource.

It is important to consider the temporally variable nature of saline lagoons. There are patterns in the timing of freshwater input as well as with saline input. Rainwater input tends to be greater in winter and spring, and least in summer or early autumn. River or stream flows, or groundwater supplies of freshwater, follow a similar pattern, driven by the intensity of rainfall (Bamber 2010). Where lagoons have a flowing freshwater input, this will often lead to vertical or horizontal stratification of water in the lagoon, generating a spatial variation in salinity. While the extent or degree of this variation will vary seasonally, and can to a degree be broken down by wind-driven turbulence, permanent vertical stratification can exist in some lagoons (Bamber 2010). This makes the confident characterisation of the water column, benthic habitats and species particularly challenging, requiring repeat visits and, ideally continuous logging of the physical parameters to fully understand the nature of the site.

5.3. Areas of Search

Areas of Search (AoS) are explained in Bainbridge *et al*. (2013; Section 4.13). These provide a conceptual framework that should reflect natural variation in climate, topography, geology, soils and land use and help spread the distribution of the SSSI network. At the coast, other factors such as degree of maritime exposure, aspect and coastal processes also provide a strong influence. The process of identifying sites for selection for saline lagoons may, in some cases, require a degree of flexibility between countries as to how the AoS framework is applied. The following factors will influence the way in which AoS are used:

- Coastal processes operate at different scales to most administrative boundaries;
- Terrestrial biogeographical areas (such as National Character Areas in England) may not coincide with coastal sediment cell boundaries at the coast;
- Areas of Search for marine site selection (Chapter 1b) are based on coastal sediment cells (Wallingford 1997), but these are unlikely to be appropriate for saline lagoons;
- Saline lagoons are not evenly distributed across AoS, with some areas important for one particular type of lagoon; and
- Selection of sites where one AoS may have a high proportion of the country or GB extent.

Saline lagoons, as described previously are clustered in parts of Great Britain, which makes the use of small AoS impractical, for this reason, the most appropriate framework for selecting saline lagoons is to use whole countries of Great Britain as the AoS. This avoids the likelihood of having to identify adequately qualifying lagoons in an AoS where there are few saline lagoon habitats or none at all. Due to the large scale of these AoS, it will be necessary to ensure multiple examples of saline lagoons, to ensure that the variety of lagoon types, habitats and species are well represented.

Within an AoS it is possible that SSSIs with marine or coastal features may have been designated for a number of different reasons (species, habitats or geological features), which may include or be complementary to saline lagoon features. The addition of further sites that have similar habitats, associated communities and species of existing sites within that AoS, should only be undertaken if the quality is clearly and significantly higher in the new site. Comparisons with existing SSSIs would be recorded as part of the process. A review of SSSIs within each AoS will identify shortfalls in representation of certain lagoon features. Under these circumstances, it may be necessary to extend existing SSSIs or notify additional SSSIs using these Guidelines. Consideration should be given to include new lagoons created because of managed retreat and set-back schemes.

6. Past and Potential Future Changes in Saline Lagoons

The trends and changes in coastal margin habitats have been described most recently by the UK National Ecosystem Assessment (Jones *et al.* 2011a). The natural dynamism of coastal environments means that adjustments to morphology and extent occur constantly from pressures such as isostatic land changes, fluctuations in sediment deposited or erosion by waves, wind and storms and changes in sea level. There has also been direct or indirect change resulting from human activities often leading to longer term changes as the system attempts to adjust to a new form of 'equilibrium'. The changes since 1945 are outlined in Jones *et al.* (2011a). Such actions will have longer term and wider impacts on the function of coastal processes, which are ongoing and will potentially increase in the face of sea level rise (Orford and Pethick 2006). Changes in land use and agricultural practices also affect the quality and extent of lagoon habitats.

Lagoons were indicated in a 2005 UK Biodiversity Action Plan (BAP) report to be stable in all UK regions. However, earlier work by Bamber *et al.* (2001b) estimated that some 30–40 lagoons were lost in England alone during the 1980s. In 1992, it was estimated that about 120 ha of coastal saline lagoons in England (10% of the existing English resource) would be lost over the subsequent 20 years, mainly due to sea-level rise (Smith & Laffoley 1992). A study of the vulnerability of marine habitats to climate change in Wales identified Annex I Coastal Lagoons as being highly vulnerable, due to their restricted capacity to adapt to sea-level rise, changes in wave energy and changes in seasonal precipitation (Natural Resources Wales 2015).

A serious issue facing coastal habitats in the future may be the reduction in sediment availability which could have implications for the long-term sustainability of certain features. Increases in the rate of sea-level rise will alter the sediment balance. Mossman *et al*. (2015) concludes that there will be a requirement to manage the coast in a more adaptive way in the future. Both sea-level rise and changes in rainfall patterns and temperature will need to be addressed. In addition to direct impacts on natural barriers, the interruption of sediment supply through coastal engineering works can cause changes in barrier morphology and sedimentology, altering porosity, persistence and dimensions. Associated with this, the landward margins of the lagoon will be flooded, and the marginal habitats will migrate over terrestrial environments. The patterns of barrier evolution are highly site-specific and dependent on the rate of sea-level rise, sediment supply, transport modes (along-shore/cross-shore) and the surrounding topography. The various scenarios for barrier evolution are outlined by Carter *et al.* (1987). Barriers may breach, accrete, break down, or migrate, according to local circumstances. There are obvious differences in the responses of the back-barrier lagoon to each of these changes.

Coastal defences or infilling associated with waterfront development have altered many lagoons, and this threat will continue (Jones *et al*. 2011a). Lagoons are also created artificially and extensive human interference in their geomorphology is often advocated to maintain habitat (Symes and Robertson 2004). Managed realignment policies in Shoreline Management Plans (SMPs) (Defra 2011) and subsequent strategies should ensure consideration of creating new artificial lagoons, which would increase the extent of saline lagoon habitat. To maintain the SMP policy of 'Hold The Line' the barrier will require to be raised artificially, while allowing the barrier to migrate naturally through a 'No Active Intervention' policy could lead to changes in flood risk to landward. In some cases, this may mean a reduction in lagoon area. Holding the line in an adjacent coastal area can reduce the sediment supply to a lagoon barrier (Carter & Orford 1993). Those saline lagoons fronted by shingle or sand barriers are subject to the implications of SMP policies that affect the barrier. There is an increasing move towards working with coastal change, as holding the barrier in place artificially is known not to be sustainable as barriers lose sediment.

The salinity regimes of lagoons are subject to natural change as succession leads to freshening of the water and eventually to vegetation such as fen carr. Thus, some formerly saline sites are now freshwater lagoons. In contrast, the regime of Porlock lagoon in Somerset is shifting in the opposite direction since artificial maintenance of the gravel barrier halted. A breach of the barrier in 1998, transformed this into a more saline system (Orford *et al.* 2001). Regulation of freshwater inputs and artificial manipulation of seawater input through inlet/outlet control can impact on salinity, residence time and water quality.

The Water Framework Directive (WFD) is another policy driver for saline lagoons, although the WFD was formulated without consideration for the particular conditions of coastal saline lagoons (i.e. their inherent variability over ranges of scale and duration, both in space and in time). The establishment of "type-specific reference conditions" (under Annex II 1.3 of the Water Framework Directive) is therefore challenging for lagoons. There are two typologies of coastal lagoons in WFD (depending on whether they are associated with transitional or coastal waters). The inevitable conclusion is that, as a starting position, "good condition" must be defined on a site-specific basis for each lagoon, and this condition must include the range of variation experienced naturally (Bamber 2010).

Invasive non-native species represent an increasing threat to benthic assemblages in a wide variety of coastal habitats, and lagoons are no exception. Although some important and protected lagoonal species are known to be non-native (e.g. *Nematostella vectensis*) they are not currently thought to be ecologically problematic. The stochastic nature of lagoonal recruitment that can cause major fluctuations in population size and species dominance, may enable the co-existence of a wide range of native and non-native inhabitants. Yet some species have the potential to cause significant change to species assemblages. For example the northwards progression of the invasive brown alga *Sargassum muticum* could be particularly detrimental to lagoons in the Western Isles of Scotland (Davison 2009). Rising temperatures, combined with various pathways of introduction (sea-borne traffic, aquaculture, coastal developments) makes it increasingly likely that other non-native invasive species will arrive and colonise lagoons, particularly in close proximity to major ports, as indicated by the recent occurrence of the red alga *Agarophyton vermiculophylla* in Brownsea Island lagoon in Poole Harbour (Krueger-Hadfield *et al*. 2017).

Pollution, especially nutrient enrichment, leading to eutrophication, can have major detrimental effects on lagoons, including species loss, although studies in the Fleet lagoon in Dorset demonstrate that a distinctive ecosystem can be maintained under such conditions (Weber *et al.* 2006). Johnston and Gilliland (2000) list the following impacts on water quality of saline lagoons (in relation to the Fleet, south England):

- Nutrient enrichment: including direct metabolic effects on species (for example foxtail stonewort *Lamprothamnium papulosum*), which most frequently occurs at sites where soluble reactive phosphate is below 10 µg/l; an increase in growth of epiphytic, floating, ephemeral, benthic and phytoplanktonic algae and associated competition with lagoon vegetation of conservation interest; and indirect effects on lagoon fauna;
- Turbidity: including an increase in light attenuation and smothering, or inhibition of feeding of lagoon invertebrates;
- Toxic contamination: suggested contaminants of concern from studies outside lagoons include heavy metals, herbicides/pesticides and chronic oil pollution. These potentially impact on the suitability of lagoons as habitats, and the exploitation of their living resources; and
- Organic enrichment: likely to be of limited concern given that lagoon sediments are naturally high in organic material.

6.1. Effects of Climate Change

Reviews of the potential impacts of climate change have identified a number of risks (Mossman *et al.* 2015; MCCIP 2018). Saline lagoons were identified as the most vulnerable of habitats in England and Wales (Jones *et al.* 2011b; Mitchell *et al.* 2007) and requiring the most urgent action.

Future climate scenarios suggest that all current saline lagoons are likely to be adversely affected by sea level rise, increased summer and winter temperatures and changes in seasonal precipitation patterns. Modelling of future storm conditions has not demonstrated a clear shift in storm track location or of storm strength (Jenkins *et al*. 2009). Differences in the degree of climate change expected in different geographic areas means that saline lagoons in Scotland will experience a different set of changing parameters to those in the south of England. For example, in England, increased summer temperatures and winter precipitation were identified as important factors that will affect species distribution in saline lagoons (Mitchell *et al.* 2007), whilst in Wales, increased run off and water turbidity, stemming from increased precipitation are seen as important factors (Jones *et al.* 2011b).

Increased summer temperatures because of climate change may lead to an increased level of desiccation in the intertidal area, restricting the distribution of intertidal species (NIHAP 2003). Increased water temperatures may affect lagoon specialists at their temperature limits that have limited dispersal ability. Under the medium emissions scenario, changes in summer mean temperatures are greatest in parts of southern England (up to 4.2ºC (range 2.2 to 6.8ºC)) and least in the Scottish islands (just over 2.5ºC (range 1.2 to 4.1ºC)). The biggest changes in precipitation in winter are seen along the western side of the UK, with increases up to +33% (+9 to +70%). Decreases of a few percent are seen over parts of the Scottish Highlands (–11 to +7%) (UKCP09 – Jenkins *et al.* 2009). Sea-level rise will be greatest in southern Britain. An indirect effect of temperature increase is the likely formation of algal blooms (macroalgae or phytoplankton), where there is possible oxygen reduction, eutrophication and/or pollution.

Changes in the volume and timing of freshwater discharge due to climate change have the potential to alter lagoon salinity regimes. In Scotland, water level in lagoons tends to be significantly lower in summer due to reduced rainfall, but rainfall regimes are likely to alter with climate change. The main implications of the effects of sea-level rise on saline lagoons will be increased inundation (of lagoons and low-lying coastal areas), saline intrusion (both surface and sub-surface) and potential landward movement of sediment barriers (in percolation lagoons). Where natural landward transition is not possible, coastal squeeze will diminish the extent of the saline lagoon, for example where the landward transition is too steep. Saline lagoons with natural barriers can migrate landwards with rising sea levels by barrier 'over-washing' and the transfer of sediment from the front to the rear of the barrier, where the slope permits (Jones *et al.* 2011a). In order for successful roll back of the saline lagoon feature, a suitable land management arrangement must be in place to allow change of natural character of the landward fringe. Jones *et al*. (2011b) points out that this also provides opportunities for new saline lagoons.

A reduction of salinity where the balance shifts towards higher input of freshwater will result in a shift of species depending on their tolerance. This may result in loss of some species, if the salinity remains too low or too variable. During drier and/or warmer periods (likely in the south of Britain), an increase of hypersaline conditions is likely (Mitchell *et al.* 2007). A different suite of species will be evident, that are likely to tolerate these conditions, which are only experienced elsewhere in rockpools on the open coast.

Angus (2017) states that the most serious threat was to lagoon species that could not transfer from a lagoon threatened by sea level rise to a new site due to poor dispersal powers, and suggested a three-tier approach to management of the risk: abandonment, management of level of sea exchange to match Relative Sea Level Rise (RSLR) rates, and translocation, but each of these options has associated problems. Although the second option is most applicable to rock basin lagoons; sediment-impounded lagoons in Scotland tend to have fewer specialist lagoon species than the rock basins.

7. Boundary Definition

The approach for saline lagoons should be based on the selection of complete systems as a geomorphological feature. This is compatible with the terrestrial use of broad habitats rather than separate communities for selection; it is also pragmatic and creates readily defined areas for selection and management.

Overarching boundary principles are detailed in Bainbridge *et al*. (2013).

- The boundary should encompass all the features that are the ‘reasons for notification’;
- The boundary should include critical physical or ecological processes which support notified features (e.g. immediate sediment supply for marine habitats, tidal channels that are essential components of the structure and function of the feature); and
- The boundary should include the area necessary to provide space for change. For saline lagoon sites, the boundary should be sufficiently large to encompass the likely extent and locations of the notified features for between 20 and 50 years. This will depend on existing datasets to understand the trajectory of the lagoon, as well as judgement as to the likely future trajectory. Detailed modelled future prediction is unlikely to be available, so a precautionary approach is advised in setting buffers on saline lagoon boundaries.

This guidance should be read in conjunction with that for Coastlands (Rees *et al*. 2019), where features form a continuous transition within a system with common physical drivers. A review of the local rates of erosion or accretion over a relevant period will provide a useful understanding of the degree of geophysical change over time. Certain saline lagoons are particularly vulnerable to increased erosion from climate change driven sea-level rise hence their future extent and location should be considered when setting boundaries.

Boundaries should be established to include all the features which contribute to selection of the site as a SSSI. Additional areas should be included within the boundary, where they occur within a mosaic of qualifying features and where, to exclude them would result in fragmentation and reduced viability of the site.

Boundaries must also be clearly identifiable in practice; this may mean that boundaries are drawn between conspicuous features or that they are a continuous extension of the boundaries of landward habitat features that are also being included as part of the site (e.g. fence line). In all cases, convenience must not compromise the setting of boundaries that relate to the extent of the special interest. The ‘special interest’ of biodiversity features is not necessarily fixed in time.

Saline lagoons rely on continuation of the established water exchange with the sea and freshwater input. With this in mind, the selected area should include the connection to the sea. In the case of lagoonal inlets and silled lagoons, this will be the bed of the connecting channel. With sluiced lagoons it will include the pipeline or connection channel, and in the case of percolation or isolated lagoons it will include the shingle necessary to maintain seawater percolation or other barrier between the lagoon and the sea. The designated area should include the bed of the lagoon, extending to a landward limit at the height of maximum tidal influence as a minimum. This will therefore include fringing communities such as *Fucus cottonii* in saltmarsh turf and lichen zone. Small scattered lagoons, which are linked within a coherent unit (such as a shingle structure or fjardic inlet) may best be considered as a single site. In addition, careful consideration should be made of including terrestrial and freshwater habitats adjacent to or as part of the catchment of the saline lagoon, where key management will be important to maintain the condition of the features of the site. Often, there will be important features described in other chapters of the SSSI Selection Guidelines (Bainbridge *et al.* 2013) that should be notified alongside the saline lagoon (e.g. other Coastal, Intertidal and Marine, Lowland Grassland and Wetland habitats and Birds).

In most cases, SSSI will not overlap with MCZs in England and Wales, designated under the Marine and Coastal Access Act (2009). However Pagham Harbour MCZ, which includes Ferry Pool lagoon, demonstrates several overlapping and supporting designated habitats and species features Here there are two SOCI listed for the MCZ; these are *Gammarus insensibilis* and *Caecum armoricum.* Seagrass beds are also listed as a Habitat of Conservation Interest (HOCI). All of Pagham Harbour MCZ lies within Pagham Harbour SSSI; the protection for MCZ SOCI and HOCI only extends to the area that is within the MCZ. The Wildlife and Countryside Act (1981) (as amended) applies to the entire SSSI; there is effectively extra protection for SOCI and HOCI within the MCZ. Many MCZs above Mean Low Water are underpinned by SSSIs but it would theoretically be possible to designate a SSSI in an area that is already fully or partially within a MCZ.

8. References

Angus, S. 2016. Monitoring and surveillance of a highly variable habitat: The challenge posed by Scottish saline lagoons. *Regional Studies in Marine Science*, **8**, 20–26.

Angus, S. 2017. Scottish saline lagoons: Impacts and challenges of climate change. *Estuarine, Coastal and Shelf Science*,**198**, 626–635.

Angus, S. 2018. Beyond the meta-ecosystem? The need for a multi-faceted approach to climate change planning on coastal wetlands: An example from South Uist, Scotland. Ocean and *Coastal Management*,**165**, 334–345. DOI: 10.1016/j.ocecoaman.2018.08.013

Bainbridge, I., Brown, A., Burnett, N., Corbett, P., Cork, C., Ferris, R., Howe, M., Maddock, A., Mountford, E. & Pritchard, S. (eds) 2013. Guidelines for the Selection of Biological SSSIs. Part 1: Rationale, Operational Approach and Criteria for Site Selection. JNCC, Peterborough, ISBN 978-1-86107-625-0. https://hub.jncc.gov.uk/assets/dc6466a6-1c27-46a0-96c5-b9022774f292.

Bamber, R.N. 1997. Assessment of saline lagoons within Special Areas of Conservation. English Nature Research Report No. 235.

Bamber, R.N. 2010. Coastal saline lagoons and the Water Framework Directive. Natural England Commissioned Reports, Number 039.

Bamber, R.N., Batten, S.D., Sheader, M. & Bridgwater, N.D. 1992. On the ecology of brackish water lagoons in Great Britain. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **2**, 65–94.

Bamber, R.N., Evans, N.J., Sanderson, W. & Whittall, A. 2001a. Coastal saline lagoons and pools in Wales: review and proposals. Bangor: Countryside Council for Wales Contract Science Report No. 464; 69 pp.

Bamber, R.N., Gilliland, P.M. & Shardlow, M.E.A. 2001b. Saline lagoons: a guide to their management and creation (interim version). Peterborough, English Nature.

Badley J. & Allcorn, R.I. 2006. The creation of a new saline lagoon as part of a flood defence scheme at Freiston Shore RSPB Reserve, Lincolnshire, England. *Conservation Evidence*, **3**, 99–101.

Botanical Society of the British Isles (BSBI). 2017. Welsh Annual Reports Anglesey (VC52): Ian Bonner & Nigel Brown, BSBI, UK. https://bsbi.org/wp-content/uploads/dlm_uploads/Vice-County-Recorder-Reports-2017-Wales.pdf.

Bratton, J.H. (ed.) 1991. British Red Data Books: Invertebrates other than insects, published by the Joint Nature Conservation Committee, Peterborough.

Brazier, D.P., Hiorns, N., Kirkham, E., Singfield, C., Street, M., Steel, L. & Kent, F. 2019. Guidelines for the selection of biological SSSIs. Part 2 Detailed guidelines for Habitats and Species. Chapter 1b Marine Intertidal and Shallow Subtidal Habitats, JNCC, Peterborough. https://hub.jncc.gov.uk/assets/3e8b58d8-ff6b-4bc6-ba4f-aeed92710e14.

Brown, A.E., Burn, A.J., Hopkins, J.J. & Way, S.F. 2013. The Habitats Directive: selection of Special Areas of Conservation in the UK. JNCC Report No. 270. [1997 report regularly updated online at https://hub.jncc.gov.uk/assets/5d20b480-9cc1-490f-9599-da6003928434].

Bunker, F.St.P.D., Mercer, T.M. & Howson, C.M. 2003. *Chesil and the Fleet cSAC Sublittoral Monitoring 2002.* A report to English Nature from Aquatic Survey and Monitoring Ltd.

Carter, R.W.G. & Orford, J.D. 1993. The Morphodynamics of Coarse Clastic Beaches and Barriers: A Short- and Long-term Perspective *Journal of Coastal Research SPECIAL ISSUE NO. 15. Beach and Surf Zone Morphodynamics*, pp. 158-179. https://www.jstor.org/stable/25735728.

Carter, R.W.G., Orford, J.D., Forbes, D.L. & Taylor, R.P. 1987. Gravel barriers, headlands and lagoons: an evolutionary model. Proceedings Coastal Sediment 1987, New Orleans, LA, USA, May 12–14, 1987. American Society of Civil Engineers, 1776–1792.

Carlton, J.T. 1996. Biological invasions and cryptogenic species. *Ecology*, **77**(6), 1653–1655.

Cheffings, C.M. & Farrell, L (Eds). 2005. The Vascular Plant Red Data List for Great Britain - Species Status No 7. 120pp, Joint Nature Conservation Committee, Peterborough. ISBN 1473-0154.

Conlan, K., White, K.N. & Hawkins, S.J. 1992. The hydrography and ecology of a redeveloped brackish water dock. *Estuarine Coastal and Shelf Science*, **35**, 435–452.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. 2004. The Marine Habitat Classification for Britain and Ireland. Version 04.05. [Online] Peterborough: Joint Nature Conservation Committee. https://hub.jncc.gov.uk/assets/d216bdbd-503b-4fc4-a9d8-69ea8266e03d.

Covey, R., Fortune, F., Nichols, D. & Thorpe, K. 1998. Marine Nature Conservation Review Sectors 3, 4, 12, 13 & 15. Lagoons in mainland Scotland and the Inner Hebrides: Area summaries. Joint Nature Conservation Committee, Peterborough (Coasts and Seas of the United Kingdom. MNCR Series).

Davison, D.M. 2009. *Sargassum muticum* in Scotland 2008: a review of information, issues and implications. Scottish Natural Heritage Commissioned Report No.324 (ROAME No. R07AC707) (See section 11.3.4 Lagoons, page 158)

Defra. 2011. Guidance on the preparation of second generation Shoreline Management Plans (SMP). https://www.gov.uk/government/publications/shoreline-management-plans-guidance.

Dyrynda, P. & Farnham, W.F. 1985. Benthic communities of a rapids system within the Fleet lagoon, Dorset. *Progress in Underwater Science*, **10**, 65–82.

Gilliland, P. & Sanderson, W.G. 2000. Re-evaluation of marine benthic species of nature conservation importance: a new perspective on certain 'lagoonal specialists' with particular emphasis on *Alkmaria romijni* Horst (Polychaeta: Ampharetidae). *Aquatic Conservation*. **10**, 1–12.

Gobler, C.J. 2020. Climate Change and Harmful Algal Blooms: Insights and perspective Harmful Algae Volume 91

Herbert, R.J.H., Broderick, L.G., Ross, K., Moody, C., Clarke, L. & Stillman, R.A. 2018. Artificial coastal lagoons at solar salt-working sites: A network of habitats for specialised, protected and alien biodiversity. *Estuarine, Coastal and Shelf Science*, **203**,1–16.

Herbert, R.J.H., Ross, K., Whetter, T. & Bone, J. 2019. *Maintaining ecological resilience on a regional scale: coastal saline lagoons in a northern European marine protected area*. In: Humphreys, J. & Clark, R. 2019. Marine Protected Areas: Science, policy and management. P631-647. Elsevier.

Howson, C.M., Chambers, S.J., Pye, S.E. & Ware, F.J. 2014. Uist Lagoons Survey. Scottish Natural Heritage Commissioned Report No. 787.

H R Wallingford. 1997. Coastal cells in Scotland. Scottish Natural Heritage Research, Survey and Monitoring Report No 56.

Jenkins, G.J., Murphy, J.M., Sexton, D.M.H., Lowe, J.A., Jones, P. & Kilsby, C.G. 2009. UK Climate Projections: Briefing report. Met Office Hadley Centre, Exeter, UK.

Jensen, K.R. 2010. NOBANIS – Invasive Alien Species Fact Sheet – *Mya arenaria* – From: Identification key to marine invasive species in Nordic waters – NOBANIS www.nobanis.org.

Johnston, C.M. & Gilliland, P.M. 2000. Investigating and managing water quality in saline lagoons based on a case study of nutrients in the Chesil and the Fleet European marine site. English Nature. (UK Marine SACs Project).

Joint Nature Conservation Committee. 1996. Guidelines for the Selection of Biological SSSIs: Intertidal Marine Habitats and Saline Lagoons, JNCC, Peterborough. https://webarchive.nationalarchives.gov.uk/ukgwa/20220301120016/https://hub.jncc.gov.uk/assets/b0c3d93f-5c1d-4101-9973-0830742ca9d6.

Joint Nature Conservation Committee. 2016. 1150 Coastal lagoons. Online: https://sac.jncc.gov.uk/habitat/H1150/.

Joint Nature Conservation Committee. 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03. Online: https://mhc.jncc.gov.uk/.

Jones, L., Angus, S., Cooper, A., Doody, P., Everard, M., Garbutt, A., Gilchrist, P., Hansom, J., Nicholls, R., Pye, K., Ravenscroft, N., Rees, S., Rhind, P. & Whitehouse, A. 2011a. National Ecosystem Assessment. Chapter 11 Coastal Margin Habitats.

Jones, D., Bain, V., Dawson, S. & Watt, T. 2011b. Assessing the vulnerability of marine habitats in Wales to the impacts of climate change. CCW Contract Science Report. Report No. 969, 192 pp, CCW, Bangor.

Joyce, C.B., Vina-Herbon, C. & Metcalfe, D.J. 2005. Biotic variation in coastal water bodies in Sussex, England: Implications for saline lagoons. *Estuarine, Coastal and Shelf Science*, **65**, 633–644.

Krueger-Hadfield, S.A., Magill, C.L., Bunker, F.St.P.D., Mieszkowska, N., Sotka, E.E. & Maggs, C.A. 2017. When invaders go unnoticed: the case of *Gracilaria vermiculophylla* in the British Isles. *Cryptogamie Algologie*, **38**, 379–400.

Mann, H. & Nambudiri, E.M.V. 2005. Charophytes of Insular Newfoundland II: *Chara evoluta* and *Chara canescens*. *Canadian Field-Naturalist*, **119**(1), 26–37.

MCCIP 2018. Climate change and marine conservation: Saline Lagoons (Eds Marsh, M. and Street, M.) MCCIP, Lowestoft, 8 pp. doi: 10.14465.2018.ccmco.004-slg.

Mitchell, R.J., Morecroft, M.D., Acreman, M., Crick, H.Q.P., Frost, M., Harley, M., Maclean, I.M.D., Mountford, O., Piper, J., Pontier, H., Rehfisch, M.M., Ross, L.C., Smithers, R.J., Stott, A., Walmsley, C., Watts, O. & Wilson, E. 2007. England Biodiversity Strategy – Towards adaptation to climate change. Final Report to Defra for contract CR0327.

Mossman, H.L., Grant, A, Lawrence, P.J. & Davy, A.J. 2015. Implications of climate change for coastal and inter-tidal habitats in the UK. Biodiversity climate change impacts report card technical paper 10. http://www.nerc.ac.uk/research/partnerships/lwec/products/report-cards/biodiversity/papers/.

Natural England and RSPB. 2014. Climate Change Adaptation Manual.

Natural Resources Wales. 2015. Climate Change Vulnerability of Marine Natura 2000 Features. LIFE Natura 2000 Programme for Wales.

Nature Conservancy Council. 1989. Guidelines for selection of biological SSSIs. Peterborough.

NIHAP (Northern Ireland Habitat Action Plan). 2003. Saline lagoons. Final Draft April 2003. Online: https://www.daera-ni.gov.uk/sites/default/files/publications/doe/natural-plan-habitat-action-saline-lagoon.pdf.

NOBANIS. 2022. Available from http://www.NOBANIS.org.

Oliver, G.A. 2005. Seasonal changes and biological classification of Irish coastal lagoons. PhD Thesis, University College Dublin.

Oliver, G. 2007. Inventory of Irish coastal lagoons (version 2). Unpublished report to the National Parks and Wildlife Service.

Orford, J.D. & Pethick, J. 2006. Challenging assumption of future coastal habitat development around the UK. *Earth Surface Processes and Landforms*, **31**, 1625–1642.

Orford, J.D., Jennings, S.C. & Forbes, D.L. 2001. Origin, development, reworking, and breakdown of gravel dominated coastal barriers in Atlantic Canada: future scenarios for the northwest European coast. Ecology & Geomorphology of Coastal Shingle, (eds J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal) pp. 23–55. Westbury Academic and Scientific Publishing, Otley, West Yorkshire.

Pritchard, D.W. 1967. What is an estuary: physical viewpoint. In: Estuaries, ed: by G.H. Lauff, 3-5. Washington, American Association for the Advancement of Science. (AAAS Publication, No. 83.)

Pye, K & Blott, S.J. 2010. Cemlyn Bay and adjoining areas, Anglesey: Geomorphological Assessment. External Investigation Report No. EX1208. Report for the National Trust.

Ratcliffe, D.A., ed. 1977. A nature conservation review. The selection of biological sites of national importance to nature conservation in Britain. Cambridge, Cambridge University Press, for Nature Conservancy Council/Natural Environment Research Council.

Rees, S., Angus, S., Creer, J., Lewis, H. & Mills, R. 2019. Guidelines for the selection of biological SSSIs. Part 2 Detailed guidelines for Habitats and Species. Chapter 1a Coastlands (coastal saltmarsh, sand dune, machair, shingle, and maritime cliff and slopes, habitats). https://hub.jncc.gov.uk/assets/36b59d93-8487-471d-9428-bc3d7dff0423.

Reitzel, A.M., Darling, J.A., Sullivan, J.C. & Finnerty, J.R., 2008. Global population genetic structure of the starlet anemone Nematostella vectensis: multiple introductions and implications for conservation policy. *Biological Invasions*, **10**(8), 1197–1213.

Sanderson, W.G. 1996. Rarity of marine benthic species in Great Britain: development and application of assessment criteria. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **6**, 245–256.

Sheader, M. & Sheader, A. 1989. Coastal saline ponds of England and Wales: an overview. Peterborough, Nature Conservancy Council. (CSD Report, No. 1009.)

Sheader, M., Suwailem, A.M. & Rowe, G.A. 1997. The anemone, *Nematostella vectensis*, in Britain: considerations for conservation management. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **7**, 13–25.

Smith, B.P. & Laffoley, D. 1992. A directory of saline lagoons and lagoon-like habitats in England. Peterborough, English Nature.

Symes, N.C. & Robertson, P.A. (eds). 2004. A Practical Guide to the Management of Saline Lagoons. The RSPB, Sandy.

Tang, C.Q., Crampton-Platt, A., Townend, S., Bruce, K., Bista, I. & Creer, S. 2018. Development of DNA applications in Natural England 2016/2017. Natural England Commissioned Reports, Number 252. http://publications.naturalengland.org.uk/publication/5777898271408128.

Thorpe, K. 1998. Marine Nature Conservation Review Sectors 1 & 2. Lagoons in Shetland and Orkney: area summaries. Joint Nature Conservation Committee, Peterborough. (Coasts and Seas of the United Kingdom. MNCR Series.).

Thorpe, K., Dalkin, M., Fortune, F. & Nichols, D. 1998. Marine Nature Conservation Review Sector 14. Lagoons in the Outer Hebrides: area summaries. Joint Nature Conservation Committee, Peterborough. (Coasts and Seas of the United Kingdom. MNCR Series.).

Tyler-Walters, H., Marshall, C.E. & Jackson, A. 2017. *Nematostella vectensis* Starlet sea anemone. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [online]. Plymouth: Marine Biological Association of the United Kingdom. [cited 13-06-2019]. Available from: https://www.marlin.ac.uk/species/detail/1136.

UK Biodiversity Group. 1999. Tranche 2 Action Plans – Volume V – maritime species and habitats. ISBN 1 85716 467 9

Weber, G.J., O'Sullivan, P.E. & Brassley, P. 2006. Hindcasting of nutrient loadings from its catchment on a highly valuable coastal lagoon: the example of the Fleet, Dorset, UK, 1866–2004. *Saline Systems*, **2**, 15.

Wilson, I.F., Gosling, E.M., & Tapper, W. 1999. The systematic status of the lagoon periwinkle, Littorina tenebrosa. *Journal of the Marine Biological Association of the UK*, **79**, 653–660.

WoRMS Editorial Board 2015. World Register of Marine Species. Online: http://www.marinespecies.org at VLIZ.

Wyn, G., Brazier, D.P., Birch, K., Bunker, A., Cooke, A., Jones, M., Lough, N. McMath, A. & Roberts S. 2006. Handbook for Marine Intertidal Phase 1 Biotope Mapping Survey, Countryside Council for Wales, ISBN: 1861691440.

Appendix 1. Species relevant to current legislation and policy within the scope of the saline lagoon SSSI Selection Guidance

- This Appendix includes those species that have formerly been identified as rare or scarce (Sanderson 1996) and should include, in the future, any species that meet the criteria in Sanderson (1996). Species that are newly identified as qualifying and including species new to science and new records (range extensions of NE Atlantic species) to Britain should be included as potential SSSI features. Nationally rare or scarce plants are from vascular plant red data list (Cheffings *et al*. 2005). In addition, species identified in subsequent legislation as important are included. Species names are from World Register of Marine Species (WoRMS 2015) at the time of publication.

- Intertidal and subtidal species are included that may occur in a lagoon. All saltmarsh species, including *Salicornia* sp. and *Spartina* sp., are covered in the Coastal chapter and not repeated here. **N** = not listed.

- The 'Listed Species' is an aggregated list of species from various initiatives or legislation (environment Acts and Directives), including the Priority Marine Features (PMF) of Scotland, and lists from the NERC Act (Species of Principal Importance in England and Section 42 in Wales). The PMF list in Scotland is a prioritised list of species and habitats of conservation importance that supports a wider seas approach to conservation, for example, through Scotland's National Marine Plan. The OSPAR list is the list of threatened and/or declining species. A maintained, up to date list is available on the JNCC website. The Species of Conservation Importance (SOCI) list for the review of features of conservation importance (Marine and Coastal Access Act) to inform Marine Conservation Zone designation, is based on the same original lists, and is therefore comparable to this list (SOCI).

- IUCN codes: DD – Data Deficient; LC – Least Concern; NT – Near Threatened; VU – Vulnerable; EN – Endangered.

Listed Species	Common Name	Wildlife and Countryside Act 1981 – Schedule 5 or 8	Lagoon Specialist species	Listed species E = England, W = Wales, S = Scotland	IUCN Red List (Based on 2001 guidelines, unless otherwise stated)	Nationally Rare Marine Species *	Nationally Scarce Marine Species *	Nationally Rare (Ra) or Scarce (Sc) Plants
Pachycordyle navis	A hydroid	Y	Y	E	-	**N**	**N**	**N**
Edwardsia ivelli +	Ivell's sea anemone	Y	Y	E	EN - Pre 1994	Y	**N**	**N**
Nematostella vectensis ++	Starlet sea anemone	Y	Y	E	VU - Post 1994	**N**	Y	**N**
Alkmaria romijni ++	Tentacled lagoon worm	Y	Y	W	-	**N**	Y	**N**
Armandia cirrhosa	Lagoon sand worm	Y	Y	E, W	-	Y	**N**	**N**
Gammarus chevreuxi	A sand shrimp	**N**	**N**	**N**	-	**N**	Y	**N**
Gammarus insensibilis	Lagoon sand shrimp	Y	Y	E	R - Pre 1994	**N**	Y	**N**
Idotea chelipes	An amphipod	**N**	Y	S		**N**	Y	**N**
Lekanesphaera hookeri	An isopod	**N**	Y	S		**N**	**N**	**N**
Monocorophium insidiosum	A mud shrimp	**N**	Y	S		**N**	**N**	**N**
Caecum armoricum	De Folin’s lagoon snail	Y	Y	**N**		Y	**N**	**N**
Cerastoderma glaucum	Lagoon cockle	**N**	Y	S	-	**N**	**N**	**N**
Ecrobia ventrosa	Spire snail	**N**	Y	S	-	**N**	**N**	**N**
Hydrobia acuta neglecta	Mud snail	**N**	Y	S	LC	**N**	**N**	**N**
Onoba aculeus	Pointed cingula	**N**	**N**	S	-	**N**	**N**	**N**
Tenellia adspersa	Lagoon sea-slug	Y	Y	E,S,W	NT	Y	**N**	**N**

Listed Species	Common Name	Wildlife and Countryside Act 1981 – Schedule 5 or 8	Lagoon Specialist species	Listed species E = England, W = Wales, S = Scotland	IUCN Red List (Based on 2001 guidelines, unless otherwise stated)	Nationally Rare Marine Species *	Nationally Scarce Marine Species *	Nationally Rare (Ra) or Scarce (Sc) Plants
Conopeum seurati	bryozoan	**N**	**N**	**N**	-	**N**	Y	**N**
Victorella pavida ++	Trembling sea-mat	Y	Y	E	-	Y	**N**	**N**
Tolypella nidifica	Bird's nest stonewort	**N**	Y	S	EN	Y	**N**	Ra
Lamprothamnium papulosum	Foxtail stonewort	Y***	Y	E, S	NT	**N**	**N**	**N**
Chara canescens +++	Bearded stonewort	Y***	Y	**N**	-	**N**	**N**	Ra
Chara baltica	Baltic stonewort	**N**	Y	W	-	Y	**N**	Ra
Chara connivens	Convergent stonewort	**N**	Y	Y	LC	**N**	**N**	**N**
Ruppia maritima	Beaked tasselweed	**N**	**N**	S	LC	**N**	**N**	**N**
Ruppia cirrhosa	Spiral tasselweed	**N**	**N**	S	NT	**N**	**N**	Sc
Zostera marina **	Eelgrass	**N**	**N**	W**	LC	**N**	**N**	**N**
Zostera noltei **	Dwarf eelgrass	**N**	**N**	W**	VU	**N**	**N**	Sc

+ *Edwardsia ivelli* may be extinct in Great Britain.
++ listed on Schedule 5, but since being listed, they are considered to be non-native or cryptogenic species, (Sheader *et al.* 1997). They have been left in this list, since they are useful indicators of lagoonal conditions (Tyler-Walters 2017).
+++ *Chara canescens* found in Ireland lagoons (Oliver 2007), as well as lagoons of Newfoundland (Mann & Nambudiri 2005).
NB *Littorina tenebrosa* (*Littorina saxatilis* var *lagunae*) is not currently considered to be phylogenetically different from *Littorina saxatilis*, although Wilson *et al.* (1999) did identify a *restricted* gene flow.
* Improved data on species distribution is likely to adjust the rarity. Includes from Bratton 1991.
** If the *Zostera* species are to be designated as species (rather than priority marine habitat), then they must meet the criteria laid out in Chapter 11 Vascular Plants.
*** Schedule 8 of the Wildlife and Countryside Act 1981.

Appendix 2. Saline Lagoon habitats

The highly varied nature of saline lagoons in Great Britain makes the identification of biotopes impractical. The UK/Eire classification system (JNCC 2015) identifies three high-level biotopes according to the sediment types (within the sublittoral sediment classification (level 3)). This does not fully reflect the habitats that can be found in saline lagoons and as such, should not be used for SSSI selection.

SS.SSa.SSaLS - Sublittoral sand in low or reduced salinity (lagoons)
Shallow sand and muddy sand in areas of low or reduced, although relatively stable salinity (may vary annually), with largely ephemeral faunal communities.

SS.SMu.SMuLS - Sublittoral mud in low or reduced salinity (lagoons)
Shallow, typically anoxic, muddy and sandy mud sediments in areas of low or reduced, although stable, salinity (may vary annually) with largely ephemeral faunal communities.

SS.SMx.SMxLS - Sublittoral mixed sediment in low or reduced salinity (lagoons)
Shallow, muddy mixed sediments in areas of low or reduced, although stable, salinity (may vary annually) with largely ephemeral faunal communities.