



Marine Monitoring Handbook

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Lagoons

Definition

Lagoons are expanses of shallow coastal salt water, of varying salinity and water volume, wholly or partially separated from the sea by sandbanks or shingle, or, less frequently, by rocks. Salinity may vary from brackish water to hypersalinity depending on rainfall and evaporation, or the addition of fresh seawater from storms, temporary flooding of the sea in winter or tidal exchange. With or without vegetation from *Ruppia maritima*, *Potamogeton*, *Zostera* or *Chara* (CORINE 91: 23.21 or 23.22).

Flads and gloes, considered a Baltic variety of lagoons, are small, usually shallow, more or less delimited water bodies still connected to the sea or have been cut off from the sea very recently by land upheaval. Characterised by well-developed reedbeds and luxuriant submerged vegetation and having several morphological and botanical development stages in the process whereby sea becomes land.

Introduction to the feature's interest

Lagoons have a restricted distribution on the Atlantic coast of Europe. The habitat type is complex, and a wide range of physical types and origins are included, with much geographical and ecological variation. Some of the types of lagoon found in the UK are rare elsewhere in Europe. This is a priority habitat type and is relatively uncommon in the UK. Therefore a high proportion of the sites identified as meeting the definition of the habitat type have been selected.

Although uncommon, lagoons may be clustered together on particular stretches of coast, where they are dependent on specific local physical processes. Such clusters have been considered particularly important for conservation of their structure and function. Some of the sub-types of lagoon have a very restricted distribution in the UK, with one type being found mainly in the Outer Hebrides and a high proportion of another type occurring on the east coast of England.

Lagoons are areas of shallow, coastal salt water, wholly or partially separated from the sea by sandbanks, shingle or, less frequently, rocks. Five main sub-types of lagoon have been identified in the UK, on the basis of their physiography, as meeting the definition of the habitat type.

Isolated lagoons are separated completely from the sea by a barrier of rock or sediment. Seawater enters by limited ground water seepage or by over-topping of the sea barrier. Salinity is variable but often low. Isolated lagoons are often transient features with a limited life-span due to natural processes of infilling and coastal erosion. Isolated lagoons may have less water exchange than percolation lagoons and consequently a more impoverished biota.

Percolation lagoons are normally separated from the sea by shingle banks. Seawater enters by percolating through the shingle or occasionally by over-topping the bank (e. g. in storms). The water level shows some variation with tidal changes, and salinity may vary. Since percolation lagoons are normally formed by natural processes of sediment transport, they are transient features, which may be eroded and swept away over a period of years or decades or may become infilled by movement of the shingle bank.

Silled lagoons occur where water is retained at all states of the tide by a barrier of rock (the 'sill'). There is usually a small tidal rise-and-fall, the extent depending on the height of the sill in relation to the tidal range. Seawater input is regular and frequent, and although salinity may be seasonally variable, it is usually high, except where the level of the sill is near to high tide level. These lagoons are restricted to the north and west of Scotland and may occur as sedimentary basins or in bedrock (where they are called 'obs'). Muddy areas are dominated by filamentous green algae, amongst which may be colonies of rare charophytes, such as foxtail stonewort *Lamprothamnium papulosum*. Beds of tassel-weeds *Ruppia* spp. and, in the deeper, most stable lagoons, eelgrass *Zostera marina* may be present.

1 These numbers are the habitat codes in the Palaearctic classification (originally the CORINE classification). For further information refer to *The Interpretation Manual of European Habitats – EUR 15* (version 2, October 1999) published by the European Commission (see: <http://europa.eu.int/comm/environment/nature/docum.htm>)

Sluiced lagoons occur where the natural movement of water between the lagoon and the sea is modified by human mechanical interference such as the construction of a culvert under a road or valved sluices. Communities present in sluiced lagoons vary according to the substrate type and salinity, and therefore may resemble all other silled lagoon types.

Lagoonal inlets are lagoons that have a permanent, but restricted, connection channel to the sea where seawater enters lagoonal inlets during each tidal cycle. Salinity is usually high, particularly at the seaward part of the inlet. Larger examples of this sub-type may have a number of different basins, separated by sills, and may demonstrate a complete gradient from full salinity through brackish to fresh water. This salinity gradient significantly increases the habitat and species diversity of the sites in which it occurs.

Only sites on natural substrata have been selected. Sites that are entirely artificial in origin, e. g. some docks, have been excluded from the selection, although in some cases the communities present may be similar to those of more natural sites.

The water in lagoons can vary in salinity from brackish (following dilution with fresh water) to hypersaline (i. e. saltier than seawater because of evaporation). A significant factor determining the biology of a lagoon is whether the salinity fluctuates markedly (tending to lead to low species richness), or is more stable (tending to lead to higher species richness). Thus 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, these species are especially adapted to the varying salinity and some are unique to lagoon habitats. The vegetation may include beds of eelgrasses *Zostera* spp., tasselweeds *Ruppia* spp., pondweeds *Potamogeton* spp., and stoneworts such as foxtail stonewort *Lamprothamnium papulosum*. In more rocky lagoons, communities of furoid algae *Fucus* spp., sugar kelp *Laminaria saccharina*, red algae and green algae are also found. The fauna is often characterised by mysid shrimps and other small crustaceans, worms which burrow into the sediment, prosobranch and gastropod molluscs and some fish species such as stickleback. Species that are particularly found in lagoons and consequently have restricted distributions in the UK include the starlet sea anemone *Nematostella vectensis*, lagoon sandworm *Armandia cirrhosa*, lagoon sand shrimp *Gammarus insensibilis* and foxtail stonewort *Lamprothamnium papulosum*.

Typical attributes to define the feature's condition

Generic attributes

The attached generic guidance does not preclude the inclusion of other attributes that may be required in relation to particular threats to a site, but any such additions would need to be clearly justified. For example the characteristic species *Lamprothamnium papulosum* could be used as an indicator of phosphate levels where nutrient enrichment is considered a threat to the lagoon feature.

Table 3.8-1 lists the generic attributes for lagoons and presents examples of the measures proposed for some of the candidate SACs in the UK. This table is based on guidance developed for the lagoons in England and may change when equivalent guidance is available for lagoons in the remainder of the UK. For example, biotopes have not been referred to within the attributes as many lagoons in England comprise variations on only one biotope (ENLag.IMS.Ann) and the presence of another (ENLag.Veg). However, where other biotopes are present which are of note, e.g. *Zostera* beds, there would be justification for their inclusion in the overall monitoring programme.

Table 3.8-1 A summary of attributes that may define favourable condition of lagoons

<i>Attribute</i>	<i>Measure</i>	<i>Comments</i>
<i>Extent</i>		
Extent of lagoon	Area of the lagoon basin	Extent of the feature is an attribute on which reporting is required by the Habitats Directive. Extent influences both sensitivity of the habitat and (together with shape, i.e. length to breadth ratio) the diversity of the biological community present.
	Area of water occupying the basin measured at the same time of year (preferably in late winter/early spring and late summer)	Critical to both the definition and maintenance of a lagoon, and the community of species it supports, is the retention of most or all of the water mass within the system at low water in the adjacent estuary or sea. Concomitant with this is maintenance of a relevant depth of water. Extent of water in late winter/spring may be taken as the likely extent of the lagoon basin. Extent of water in late summer in lagoons with a shallow basin is likely to be less than the extent of the basin. Monitoring the extent of water within the lagoon basin, in conjunction with the presence and nature of the isolating barrier, will provide a surrogate for the attribute <i>water depth</i> once the relationship between these attributes has been established, based on the profile of the lagoon bed, from survey to characterise the site.
<i>Physical properties</i>		
Topography	Average water depth within the lagoon basin (metres) at low tide, measured at same time of year (preferably in late winter/early spring and late summer).	Many (the majority in England) saline lagoons are shallow. The influence of depth is a balance between sufficiently shallow to enable light penetration, and therefore photosynthesis, and sufficiently deep to submerge vegetation (and thereby affect oxygenation, food resource, habitat diversity and colonization by lagoonal fauna), determining temporal duration of stratification, and buffering against environmental change, particularly dehydration. <i>Empirical analysis of English lagoons suggests the majority of the bed should be less than 1m deep, particularly in smaller lagoons, but with a small proportion of deeper habitat. Actual values will depend on the site. Where it is more appropriate to a site, e.g. those with steep banks, water depth should be monitored.</i>
Isolating barrier – presence and nature	Most appropriate measure of integrity and nature of the barrier – <i>Percolation:</i> length, width and height (relative to basin and to tidal levels) <i>Isolated:</i> length, width and height (relative to basin and to tidal levels) <i>Inlet:</i> width, depth of inlet channel (or, as a surrogate, an indicator of hydrological conditions around the mouth of the inlet). <i>Sluiced:</i> Height of base of sluice(s) (relative to basin and to tidal levels), integrity (leaking or not) and frequency of opening/closure.	The presence of an isolating barrier is fundamental to the structure and function of a saline lagoon (indeed the nature of the barrier and degree of separation from the sea defines the type of lagoon in the UK). Except in the case of over-topping (isolated and some percolation lagoons) the key factor determining input and output of seawater is the height of the bottom of the inlet bed (channel, sluice, weir or impermeable base of a percolation route) relative to ambient low water levels to allow retention of the majority of the lagoonal water at low tide. Generally speaking, experience suggests the horizontal level should be a little below high water neaps.
Salinity regime	Seasonal averages (‰) to be measured at least once during the reporting cycle (preferably in late winter/early spring and later summer to indicate seasonal low and high) <i>Depending on the size and shape of the lagoon, it may be necessary to measure along a salinity gradient.</i>	Salinity is critical to both the structure and function of a lagoon, e.g. in defining the habitat, contributing to diversity within a site, and determining what species are present. The evolution of a specialist lagoonal community appears to be related to intrinsic variation in salinity both in time (short-term tidal, seasonal) and space. It is essential that salinity is measured at a similar time of the year and state of tide on a site. Salinity of the adjacent open coastal waters should be measured at the same time. <i>Empirical analysis of lagoons and specialist lagoonal species in the UK suggests a salinity range predominantly between 15‰ and 40‰. Variation outside this range is tolerable in the short term (days rather than weeks) but <10‰ and >50‰ should trigger remedial action.</i> <i>N.B. Percolation lagoons: the long-term natural trend at some sites is to become freshwater as silting within the lagoon prevents percolation of sea water and shingle builds up preventing overtopping.</i>

<i>Attribute</i>	<i>Measure</i>	<i>Comments</i>
<i>Biotic composition</i>		
Species composition	Presence and abundance of composite species, measured at least once during the reporting cycle, measured at same time of year.	<p>Composite species are important contributors to the structure of the saline lagoon habitat, The community will reflect to varying degrees the structure and function of the habitat as a whole.</p> <p>The species will include one or all of the flora, infauna, epifauna, plankton/nekton and phyton. The community is likely to (and indeed should) include species characteristic of lagoons. It may include specialist and rare/scarce species of interest in their own right. Reference should be made to such species but only if there is a clear case for a species as an indicator of the community as a whole (there are almost no known examples) or an attribute that is of specific relevance at the individual site level, e.g. <i>Lamprothamnium papulosum</i> as an indicator of phosphate levels on sites where such levels are a concern to condition of the feature.</p> <p>Where infauna are monitored, associated monitoring of the sediment, e.g. particle size analysis, would be sensible, but not essential unless it is critical to the species composition of the biotope concerned.</p>

Suggested techniques for monitoring attributes of lagoons

For each of the attributes likely to be selected to monitor the condition of a feature, there are many techniques available to measure its value. To help implement the UK's Common Standards for Monitoring programme, it is necessary to recommend a small number of techniques that are likely to provide comparable measures (Table 3.8-2). The UK Marine SACs project evaluated the inter-comparability of some of these techniques (recording biotope richness, species counts), but further work is required on other techniques (such as measuring extent with remote sensing techniques). The advice presented below will be updated when new information becomes available.

Table 3.8-2 Suggested techniques for measuring lagoon attributes. The terms under *Technique* appear under the heading *Summary title* in the procedural guidelines provided in Section 6. Guidance will be developed for the techniques in italics.

<i>Generic attribute</i>	<i>Feature attribute</i>	<i>Technique</i>
Extent	Extent of lagoon (basin; area of water)	<i>Air photo interpretation; Remote imaging; Intertidal resource mapping; Direct measurement (small lagoons only)</i>
	Biotope extent	<i>Air photo interpretation; Remote imaging; Intertidal resource mapping; Intertidal biotope ID; Point sample mapping; transect survey (by snorkelling or diving) AGDS; Side scan sonar (large lagoons only)</i>
Physical properties	Substratum: sediment character	Particle size analysis; <i>Sediment chemical analysis</i>
	Salinity regime	Measuring water quality; <i>Water chemistry data loggers</i>
	Water depth	<i>LIDAR; Bathymetry survey; On-site measurement (stick/gauge)</i>
	Presence and nature of isolating barrier	<i>Air photo interpretation; Direct measurement (small lagoons only)</i>
	Nutrient status	Measuring water quality; <i>Water chemistry data loggers; Algal mats: see Species composition/ richness below for abundance measures; see Biotope Extent for the extent of algal mats</i>
Biotic composition	Species composition, Species richness Characteristic species	Intertidal ACE; Intertidal quadrat photography; Intertidal quadrat sampling (see Subtidal quadrat sampling); Intertidal core sampling; Subtidal quadrat sampling; Subtidal biotope ID; Subtidal core sampling; Grab sampling; Suction sampling; Fish on sediments; <i>Plankton sampling</i>
Biological structure	Spatial pattern of biotopes	Intertidal resource mapping; Intertidal biotope ID; <i>Air photo interpretation; Remote imaging; Point sample mapping; Transect survey (by snorkelling or diving) AGDS; Side scan sonar (large lagoons only)</i>

Specific issues affecting the monitoring of lagoons

Lagoons are listed as a priority habitat in the Habitats Directive and under the UK Biodiversity Action Plan.^a The Habitat Action Plan for saline lagoons^b includes some basic advice on monitoring. Comprehensive guidance on the management of saline lagoons in England, Scotland and Wales, including monitoring their condition, is being prepared by the Saline Lagoon Working Group.^c The information presented below is a brief summary of the main points to consider, and the more comprehensive guidance mentioned above must be fully consulted when planning a monitoring study of a saline lagoon.

It is important to consider the whole ecosystem of a lagoon when planning a condition monitoring programme. It may be necessary to consider attributes of the sediment infaunal, epifaunal, phytoplankton and vegetative components of the lagoon system to comprehensively evaluate the condition of the lagoon itself.

Lagoons are a rare and vulnerable habitat in their own right, and support a variety of scarce and rare species. In Great Britain, 12 species of invertebrates and plants associated with lagoons are protected under the Wildlife and Countryside Act 1981.² A licence is required from the relevant statutory conservation agency³ to collect any scheduled species but many, with training, can be identified *in situ*.

The minimum frequency of monitoring is at least once per reporting cycle (six years). Whilst it is important not to generate an unnecessarily burdensome monitoring programme, it may be necessary to have more frequent monitoring because of the conservation importance of lagoons, and their sensitivity to damage. Any decision on whether to monitor more than once during a reporting period will need to take account of other factors, i.e. degree of threat, management action, or research needs; this obviously cannot be indicated at a generic level. It is likely that some monitoring of at least part of each SAC will be required more than once every six years.

Seasonal effects

Most lagoonal submerged plant species show marked seasonal cycles of growth and/or die back. For example, populations of the important charophyte *Lamprothamnium papulosum* die back in the winter and should thus be monitored in the summer. Seagrasses (*Zostera* spp. and *Ruppia* spp.) have similar seasonal patterns in their population density. Seasonal changes in vegetation must be considered when undertaking any remote sensing investigation because a change in 'colour' of the land surface will significantly affect any temporal comparison between images^d. Most invertebrate species are present throughout the year although some species have an annual life cycle and will show seasonal patterns in abundance. Bamber *et al.* (in prep.)^e concluded that '... unsynchronised annual monitoring, i.e. not at the same time each year, is likely to give results of little value where seasonal patterns do exist.' In general, monitoring studies should be undertaken in late summer and late winter/early spring to identify, and coincide with, seasonal low and high salinity/water levels.

Seasonal changes in rainfall may affect the salinity regime, water depth and extent of a lagoon. Such changes will be directly related to the dimensions of the lagoon. Lagoons with a large water volume are more able to buffer seasonal variations. Seasonal changes in the rate of inundation may affect the rate of sediment deposition or re-suspension, with a consequent change in turbidity that may influence the lagoon vegetation.

Meteorological changes

Salinity is a key factor determining the biological composition and its associated spatial organisation. A lagoon, by definition, has a limited exchange with the open sea where the restriction is often linked to tidal cycles. Tidal inundation may vary with ambient conditions (air pressure has an inverse effect on tidal height), storm action and the stage of the monthly or annual tidal cycle. Rainfall will also influence the salinity in a lagoon, particularly those lagoons with very restricted links to the open sea.

Weather cycles can result in changes in the biotic assemblages. Wind may push algal communities or floating vegetation over sediment, particularly after a seasonal die-back. A large bank of detached vegetation had been blown onto the shore of the Fleet lagoon by recent strong winds during November 1999.^d This vegetation obscured the underlying habitat and affected the classification of remote sensing images.

Access

Land surrounding a lagoon will often be under private ownership and therefore it will be necessary to seek the landowner's permission to gain access to the water. Where boat access is required, it may be necessary to seek permission to use a private pier or jetty.

Access for monitoring a lagoon will depend on the size and depth of the lagoon and its substrata. Small, shallow lagoons may be sampled from the edge or by wading carefully. Large, shallow lagoons may be snorkelled while large, deeper lagoons may require boat access. Nevertheless, the substrata will have an overriding influence on the mode of access. In Loch Maddy cSAC, the mud in the lagoons was so soft and flocculent that even snorkelling would cause undesirable disturbance to the habitat, and direct sampling was not feasible.^e In the extensive Fleet lagoon, Dorset, a prohibition order on motorised vessels made biological sampling difficult and arduous, and restricted the options available when planning a survey strategy.

In all cases, field staff must take account of the need for minimal disturbance to this fragile habitat.

2 Or the Wildlife (Northern Ireland) Order 1985. At the time of writing there are no lagoon species listed in Northern Ireland.

3 Countryside Council for Wales, English Nature, Scottish Natural Heritage.

Sampling issues

The following three points are mentioned above but merit re-emphasising when planning a sampling exercise in a saline lagoon:

- Lagoons are a fragile habitat and disturbance must be kept to a minimum. It may be appropriate to use sampling devices that take a smaller volume of sediment (e.g. *Ekman* grab rather than a Day grab; smaller diameter cores⁴), or reduce the number of samples recorded.⁵
- One possible development that could compromise disturbance and improve data on the key attribute of salinity is the use of data loggers. However, the technology for measuring salinity (usually conductivity) is such that sufficiently small and cheap loggers, such as for temperature, may not be available for some time.
- Lagoons can support species scheduled under the Wildlife and Countryside Act 1981 and a licence is required for their collection. If collection is required, the quantity of specimens should be kept to the minimum necessary, and if possible, returned to their habitat alive if a permanent record is not required.

A monitoring programme must collect sufficient information to assess the condition of the whole lagoon, or suite of lagoons within the SAC. The complexity of such monitoring will depend on the physical dimensions and the ease of access to a lagoon. It must consider both the physical, water quality (e.g. salinity) and biological aspects of a lagoon to assess the integrity of the entire lagoonal ecosystem. Bamber *et al.* (2000)^e provide detailed guidance on sampling issues for lagoon monitoring studies, including the main attributes to measure. They note:

‘The scale of larger lagoons, such as many sites in Scotland and the Fleet, Dorset, poses particular challenges for monitoring. Many lagoons can be treated as a collection of sub-habitats which may therefore be studied separately, whereas extensive areas of uniform habitat will need to be "sub-sampled" by transects or by stratified random sampling. The greatest difficulty is posed by mosaic habitats, where site-specific protocols will need to be devised. In larger lagoons remote sensing techniques may enable monitoring of the extent and other attributes of certain biotopes.’

Site marking and relocation

It is unlikely that a lagoon site will require marking or pose any problems for relocation. Marking sampling stations within a lagoon is more difficult and must take full account of the fragile nature of the habitat. For hard substrata, the site marking and relocation issues discussed under Reefs earlier will equally apply to lagoons. Similarly, the section on subtidal sandbanks will apply to sand habitats including eelgrass beds. For small sites, permanent marking of stations in sediment is unlikely to be necessary; larger sites should be considered case-by-case. Pooley and Bamber (2000)^d concluded that dGPS was satisfactory for recording position within the Fleet lagoon, Dorset; this conclusion should apply to most extensive lagoons in the UK. For smaller lagoons, the location and relocation of sampling stations could use transits/bearings from landscape features (Figure 3-5) and drawings/sketches of specific local features (Figure 3-4).

Health and safety

All field staff must follow approved safety procedures published by their host institution, or that of the contracting agency, whichever are the more stringent. Risks specific to working in lagoons are:

- *Wading in soft sediment.* There is a risk of getting stuck or, worse, drowning after falling when the feet are immobilised.
- *Illness and disease from contaminated sediment.* Sediments are known to bind contaminants such as heavy metals (& radioactive isotopes) at high concentrations, which are subsequently released upon disturbance. It is possible to contract serious diseases such as hepatitis from sewage effluent in sediment.

4 It is important to consider the body size of the characteristic infaunal organisms to ensure that a smaller sampling device will collect adequate samples.

5 A pilot investigation may be necessary to fully evaluate the minimum number of samples necessary to record any change.

If there is any history of such discharges into the lagoon under investigation, protective gloves should be used to avoid skin contact with the sediment.

Subtidal sampling in lagoons may involve snorkelling and SCUBA diving techniques. All diving operations are subject to the procedures described in the Diving at Work Regulations 1997⁶ (see: <http://www.hse.gov.uk/spd/spddivex.htm>) and must follow the Scientific and Archaeological Approved Code of Practice⁷ (<http://www.hse.gov.uk/spd/spdacop.htm> - a).

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