Common Standards Monitoring Guidance

for

Freshwater Lakes

Version March 2015

(Updated from March 2005)

Joint Nature Conservation Committee

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Foreword

This updated common standards monitoring guidance for freshwater lakes replaces the original version, first published in 2005. It remains essentially similar in its general approach. However, we have made a number of refinements to the targets to reflect advances in understanding since 2005, and to make them more explicit. This is particularly the case for water chemistry where explicit targets have been added for nitrogen, chlorophyll and acidity.

A major change has been the development and widespread adoption of Water Framework Directive (WFD) monitoring and classification tools. Data and results from these are incorporated widely within the new guidance, in order to maximise efficiency. However, no simple read-across is possible between WFD status and Habitats Directive condition, reflecting the differing objectives and approaches of the two Directives.

Finally, we have substantially edited the guidance, dispensing with unnecessary text and appendices and changing the format so that individual targets appear next to the explanatory text. This has almost halved the length of the guidance, and we hope that the new format and reduced length will encourage readers to use the supporting text to provide context for target setting.

This document has been prepared by the Lakes Monitoring Subgroup of the Inter-agency Freshwater Group, comprising representatives of Natural England, Natural Resources Wales, the Northern Ireland Environment Agency and Scottish Natural Heritage.

This document has been externally peer reviewed by three independent expert referees according to JNCC procedures. The IAFG would like to thank them for their time and constructive comments.

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1 Introduction

This document contains guidance on monitoring lake habitats where these are notified or qualifying features on Sites of Special Scientific Interest (SSSIs)/Areas of Special Scientific Interest (ASSIs)[1], Ramsar sites and Special Areas of Conservation (SACs). Specific guidance is provided on monitoring species of aquatic vascular plants and stoneworts, as constituent parts of habitat features. Other attributes of lake habitats that should be considered in condition assessment are also documented.

This guidance is applicable to lakes and large ponds. Water bodies for which it may not be suitable are:

- Water bodies less than 1ha in size;
- water bodies that are less than 1m deep; or
- temporary water bodies.

These water bodies are unlikely to contain the submerged species expected in larger ponds or lakes, therefore the methods included in this document are unlikely to be suitable. If this is the case the national conservation agency freshwater specialist will be able to provide advice on an alternative method.

Where vascular plants represent notified features in their own right, rather than components of habitat features, the chapter of guidance for assessment of vascular plants should be considered, in addition to consulting this chapter. Lakes may also be notified for a wide range of faunal species, for which separate guidance should also be used – freshwater fauna, birds, mammals, reptiles, amphibians and invertebrates.

1.1 Standing water features

1.1.1 Standing water habitats

Standing water SACs in the UK may qualify for one or more of the following Annex I habitat types:

- H3160 Natural dystrophic lakes and ponds;
- H3110 Oligotrophic waters containing very few minerals of sandy plains: Littorelletalia uniflorae;
- H3130 Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea;
- H3150 Natural eutrophic lakes with Magnopotamion or Hydrocharition-type vegetation;
- H3140 Hard oligo-mesotrophic waters with benthic vegetation of Chara spp.;
- H3180 Turloughs;
- H3170 Mediterranean temporary ponds.

Detailed descriptions of these habitats are presented in McLeod *et al* (2002) (http://jncc.defra.gov.uk/SACselection). The habitat of Mediterranean temporary ponds is rare in the UK, so is not considered further in this guidance. The turloughs habitat is not considered further, as it refers to temporary water bodies.

[1] SSSIs apply to England, Wales and Scotland; ASSIs in Northern Ireland.

In the UK, selection of sites for designation involves the criteria of representativeness, rarity, species richness and naturalness. Lakes in SSSIs/ASSIs and Ramsar sites have been notified for a wide range of standing water feature types, as standing waters can be classified in a number of ways. *A Nature Conservation Review* (Ratcliffe 1977) identified six broad types, namely, dystrophic, oligotrophic, mesotrophic, eutrophic, marl and brackish standing waters. Selection of standing water SSSIs in Great Britain, as set out in the *Guidelines for Selection of Biological SSSIs* (Nature Conservancy Council 1989), was based primarily on a botanical classification system, recognising 10 lake types (Palmer 1989). Subsequently, a revision of this classification, using a larger dataset, has been published (Duigan *et al* 2006). In Northern Ireland, a parallel classification to that of Palmer (1989) was produced, and used for selection of ASSIs, in a similar way to selection of SSSIs (Wolfe-Murphy *et al* 1992). It is important, although often not straightforward, to determine why a particular site has been notified for its standing water interest. The citation, documents on criteria for notification, site management statement and Standing Waters Database should be consulted.

Approximate relationships between different types of lake classification are presented in Appendix 1. **However, links between SSSI/ASSI and SAC features are not always straightforward.** Although most SSSI/ASSI features can be 'matched' to Annex I types, there are categories of SSSI/ASSI lakes that are not adequately covered by the SAC habitat definitions. Descriptions of standing water features of SSSI/ASSI and Ramsar sites, which may not correspond exactly to SAC habitat types include those listed below, although this list is not exhaustive:

- meso-eutrophic lake
- base-rich lake
- machair lake
- brackish lake
- trophic range

Such difficulties arise in definition of lake types because of the different methods of classification, based on vegetation, pH/hardness/alkalinity and phosphorus/nitrogen/ chlorophyll *a*. For example, a lake with high concentrations of total phosphorus may have been termed eutrophic, but so may a lake with high values for alkalinity or hardness. This may be complicated by human influences changing the water quality of a lake, usually causing nutrient enrichment.

1.1.2 Plant species features of interest

The standing water interest may include rare and scarce vascular plants, or assemblages of notable vascular plants and charophytes. Alternatively, these plants may be notified separately as features of interest. The rare and scarce species involved include those listed below. *Najas flexilis* and *Luronium natans* are Annex II species of the Habitats Directive. *Luronium natans* is covered separately in the vascular plants CSM guidance.

- *Luronium natans* (SAC, SSSI/ASSI)
- *Najas flexilis* (SAC, SSSI/ASSI)
- Elatine hexandra (SSSI/ASSI)
- Elatine hydropiper (SSSI/ASSI)
- Eriocaulon aquaticum (SSSI/ASSI)
- Isoëtes echinospora (SSSI/ASSI)
- Limosella aquatica (SSSI/ASSI)
- Nuphar pumila (SSSI/ASSI)
- Pilularia globulifera (SSSI/ASSI)
- Potamogeton coloratus (SSSI/ASSI)
- Potamogeton filiformis (SSSI/ASSI)
- Potamogeton rutilus (SSSI/ASSI)

1.2 Explanation of terms

The following terms are used in this guidance:

ASSI – Area of Special Scientific Interest (applies in Northern Ireland only)

Baseline condition – the status of a site against which other data are compared. Often this is the status at designation, but if there is evidence that the site was impacted at that time, alternative targets may be set.

Characteristic species – a species that is typical of the habitat for which the site is designated and is indicative of the habitat still being present. Not all characteristic species are sensitive to pollution.

EPS – European protected species

GES – ‘good ecological status’ as used in WFD assessments

HES – ‘high ecological status’ as used in WFD assessments

LHS – Lake Habitat Survey

SAC – Special Area of Conservation

SSSI – Site of Special Scientific Interest

WFD – Water Framework Directive

‘Designated site’ – the whole of an SSSI/ASSI/SAC.

Conservation agencies – Natural England (NE), Natural Resources Wales (NRW), Northern Ireland Environment Agency (NIEA) and Scottish Natural Heritage (SNH).

Environment agencies – Environment Agency (EA), Natural Resources Wales (NRW), Northern Ireland Environment Agency (NIEA) and Scottish Environment Protection Agency (SEPA).

2 Skills requirements for monitoring

2.1 General

The field components of assessment require expertise in aquatic macrophyte survey and identification, boat handling and, where appropriate, experience in Lake Habitat Survey (LHS). All surveyors undertaking field work must have suitable training and accreditation where such a scheme exists. Water samplers need to be trained in the appropriate protocols for collection, storage and transport of water samples to the laboratory; where field measurements are taken, they must be trained in the calibration and use of meters and other equipment. Laboratory facilities used in water analysis must have accreditation in the relevant methods, and must be able to analyse samples to a suitable limit of detection.

2.2 Health and Safety

Safety issues are paramount when surveying lakes. Surveyors must comply with national Health and Safety legislation and the health and safety policies of the relevant conservation agency, must have received relevant training, and must follow any additional guidelines appropriate for working in or near lakes.

2.3 Biosecurity

Stringent biosecurity measures are crucial to minimise the spread of invasive and alien species between sites. In order to mitigate these risks, CLEANING and DISINFECTION of all field equipment between sites is essential. This should comprise (i) an initial visual check for biological material, followed by (ii) on-site washing and disinfection. Surveyors should refer to the 'Biosecurity and Prevention' section on the GB Non-native Species Secretariat website. All chemical disinfectants should be used and disposed of according to the manufacturers' guidelines and in accordance with environmental regulations. There should be a log of field equipment used at all sites in order to provide an auditable history of equipment usage and treatment for any site visited.

Additional care should be taken at sites where alien species are known to be. At these sites (including any commercial fishery), boats and survey equipment are washed and disinfected on-site, and then jet-washed and disinfected again prior to re-use. Since disinfection does not kill aquatic plants, physical removal of all plant fragments is essential to avoid spread through vegetative reproduction.

Particular vigilance is needed for the recently introduced 'killer shrimp' (*Dikerogammarus villosus*). The presence of this species requires all equipment to be quarantined (dried) for at least one week prior to reuse in accordance with the GB non-native species secretariat guidance given at: www.nonnativespecies.org

3 Attributes and targets

Assessment of the condition of standing water features requires consideration of the major characteristics, or attributes, that define lakes (Tables 1 and 2). All attributes are mandatory as part of the condition assessment. For different types of feature, targets have been set for attributes, in order to assess whether lakes are representative of their type of feature. Where results indicate that attributes are characteristic of the type of feature, and no significant negative change has been recorded, the feature is judged to be in favourable condition.

In addition to considering the macrophyte species, examining physical and chemical characteristics of lakes is necessary for a comprehensive assessment of habitat condition, as these factors determine the ecology of standing waters.

Information on attributes and setting appropriate targets for open water habitats is presented below. Targets for certain attributes are the same for all lake types. However, targets for macrophyte community composition and water quality are dependent on SAC lake habitat type. Every effort should be made to classify lakes according to SAC types, so as to use appropriate targets in condition assessment.

Table 1. Attributes used in CSM for assessment of habitat features.

Attribute

Surface area
Composition of macrophyte community
Macrophyte community structure
Water quality:
  Dissolved oxygen
  pH
  ANC
  Total phosphorus
  Total nitrogen
  Chlorophyll *a*
Hydrology
Lake substrate
Lake shoreline
Sediment load
Indicators of local distinctiveness
Alien/locally absent species

Table 2. Attributes used in CSM for assessment of aquatic vascular plant features.

Attribute

Surface area
Presence/absence
Population size/extent
Regeneration
Water quality:
  Dissolved oxygen
  pH
  ANC
  Total phosphorus
  Nitrogen
  Chlorophyll a
Hydrology
Lake substrate
Lake shoreline
Sediment load
Indicators of local distinctiveness
Alien/locally absent species

3.1 Surface area

The purpose of this attribute is to assess permanent changes caused by active management, such as infilling or channel diversion, or the permanent raising or lowering of the lake level. It does not refer to lake level fluctuation, which is covered under hydrology.

The surface area of a lake may be affected by a range of processes, such as groundwater abstraction, regulation, construction, excessive sediment deposition and natural succession. Where a site has been notified for the interest of the open water, it is important to maintain its extent. However, distinction between natural succession and anthropogenic factors may be necessary when setting targets and assessing data on this attribute. Evidence of increased sedimentation rates (see section 3.7.3) or knowledge of changes in catchment land-use, may be important in this respect. In cases where human influences have caused a reduction in surface area before a site was notified, at least the extent at time of notification should be maintained.

Table 3. Surface area target.

Target
No permanent change in lake surface area.

3.2 Macrophyte community composition

Lake flora are dependent not only on water quality, but also sediment quality and physical aspects of the system. Macrophytes are therefore good indicators of the condition of lakes. In addition, site designation has generally been based on lake types defined by their macrophyte community (Palmer 1989; Wolfe-Murphy *et al* 1992).

The aims for any standing water feature are to maintain the following:

- a representative flora (i.e. a macrophyte community characteristic for the lake type)
- populations of rare species supported by the lake
- species richness appropriate to the lake type
- a natural macrophyte assemblage.

Alteration in plant species composition may indicate changes to the habitat of the lake. Changes to the flora may indicate environmental changes, such as development of more acidic or eutrophic conditions, or alterations of other habitat attributes such as hydrology or extent.

A WFD macrophytes tool, LEAFPACS2 (WFD-UKTAG 2014a) is available and is used by the environment agencies for assessing eutrophication pressures. The definition of Good Ecological Status in LEAFPACS2 does not necessarily reflect the presence of a favourable macrophyte community or structure as defined in Habitats Directive or SSSI/ASSI feature community types. For this reason we do not recommend the use of LEAFPACS classification results in condition assessments. However, because LEAFPACS and CSM use a shared survey method, data collected during LEAFPACS surveys can be used for condition assessment, and CSM data can be used for WFD classification.

3.2.1 Macrophyte community composition: characteristic species

For each lake, a list of characteristic species should be compiled. All macrophyte species, including vascular plants, aquatic ferns and stoneworts should be identified to the best taxonomic resolution possible based on available material[2]. Characteristic species should be identified using Tables 4 to 8, taking into account previous records and survey data for the lake. Useful data sources may include:

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[2] Macrophytes are normally identified to species level, but in some cases subspecies or hybrids may be appropriate. Occasionally material is too poor to identify accurately. Where this is thought likely to affect the outcome of the assessment, further efforts should be made to identify the taxon in question, for example by a repeat visit at a more favourable time of year for identification.

- site designation papers
- site management statement
- earlier survey data (e.g. from the Standing Waters Database, earlier cycles of CSM or environmental agencies' monitoring data)
- the BSBI distribution database
- historical records, including those derived from paleoecological studies.
- Aquatic Plants in Britain and Ireland (Preston & Croft 1997).
- local knowledge including conservation agency staff, county recorders, wardens etc.

In general, high diversity and frequency of characteristic species is a good indication that the site is in favourable condition. Conversely, if the most frequently occurring species is uncharacteristic or non-native, this indicates that the site is in unfavourable condition. Targets have been set so that a number of characteristic species must be present for the site to be in favourable condition. However, not every characteristic species would be expected at each site.

There is also a target for frequency of occurrence of characteristic species. This refers to the number of sampling points containing at least one characteristic species, compared with the total number of sampling points surveyed, and allows consideration of results relative to the area of substrate examined. In oligotrophic waters it is also necessary to consider the number of vegetated sampling points, as much of the littoral zone may constitute naturally unsuitable habitat such as boulders.

There should be no loss of any characteristic or nationally/regionally rare species that are part of the standing water feature. If a characteristic species previously recorded is not found, but another characteristic species which is a new record for the site is recorded, the conclusion remains that a characteristic species has been lost. Both species should be observed in later surveys, if the feature is in favourable condition. In deciding whether a species has genuinely been lost, consideration should be given to survey methods, previous abundance ratings and the life strategy of the species of interest.

Although important, the 'no loss' target should be applied with caution. Whole lake surveys have shown the CSM sampling method to be a robust means of generating a species list for a site, usually detecting 90% or more of species present. It is nevertheless a sample-based method rather than a comprehensive survey, and it is possible for a species that occurs only in a specific part of a lake to be overlooked. Where a previously recorded characteristic species is not found in a survey, a thorough search of the site is recommended. Further checks should be made to ensure that (i) there is no possibility of taxonomic error and (ii) that the missing species was previously well established at the site.

Non-characteristic species frequently occur with characteristic species, but often have broad ecological tolerances and are not good indicators of the habitat type.

Marginal swamp requires special consideration when setting targets. Sometimes it forms a dense belt around the edge, or even a floating margin. The assessment is affected by this, because part or all of the wader survey may then be occupied by swamp species such as *Phragmites* rather than characteristic species, thereby affecting the target. However, it may also be possible to maintain a community of characteristic species by techniques such as reed cutting, which creates a more open canopy and often provides good conditions for *Potamogeton*, *Chara* and *Utricularia* spp. Where management objectives aim to maintain a more open swamp, then the targets as proposed below should be used unchanged. However, where dense or floating swamp vegetation is the management aim, then sample points supporting this vegetation should be excluded from the cover targets (iii) and (iv) in Tables 5-7.

Table 4. Characteristic species target for natural dystrophic lakes and ponds.

Target	Characteristic species
i) No loss of characteristic species present at the site.	*Drepanocladus* spp. *Eleogiton fluitans* *Juncus bulbosus* *Menyanthes trifoliata* *Nymphaea alba* *Potamogeton polygonifolius* *Sparganium angustifolium* Aquatic *Sphagnum* spp. *Utricularia* spp.

Dystrophic lakes vary greatly in their macrophyte communities, with some having none at all. The target is highly site-specific. Dystrophic lakes are identified by their peaty catchments and high levels of organic matter within water. The vegetation targets for dystrophic lakes are unlikely to be appropriate where water quality data indicate that the lake would be classified as clear using WFD guidance (i.e. colour <30mgL^{-1} Pt units[3]).

Table 5. Characteristic species target for oligotrophic waters containing very few minerals of sandy plains *(Littorelletalia uniflorae).*

Targets	Characteristic species
i) Presence of at least three of the characteristic species listed opposite, of which at least one must be a *Littorelletea* species. ii) No loss of characteristic species recorded from the site. iii) Presence of at least one characteristic species in 60% of **vegetated** sampling points (boat and wader survey combined). iv) No significant decline[4] in total frequency of occurrence of characteristic species at **all** sampling points between surveys (boat and wader survey combined).	*Littorelletea* flora: *Isoëtes echinospora* *Isoëtes lacustris* *Littorella uniflora* *Lobelia dortmanna* Other flora: *Apium inundatum* *Elatine hexandra* *Eleogiton fluitans* *Luronium natans* *Myriophyllum alterniflorum* *Pilularia globulifera*

[3] May also be termed Hazen units.
[4] 'Significant decline' should be assessed at a site-specific level. However, as a guideline a decline of more than 20% could be considered as significant. Expert judgement is required.

Table 6. Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*

a. Characteristic species targets for oligotrophic type lakes.

Targets	**Characteristic species**
i) Presence of at least three of the characteristic *Littorelletea* species listed opposite ii) No loss of characteristic species recorded from the site. iii) Presence of characteristic species in at least 60% of **vegetated** sample points (boat and wader survey combined). iv) No significant decline[4] in total frequency of occurrence of characteristic species at **all** sampling points between surveys (boat and wader survey combined).	*Littorelletea* flora: *Eriocaulon aquaticum* *Isoëtes echinospora* *Isoëtes lacustris* *Littorella uniflora* *Lobelia dortmanna* *Subularia aquatica* Other flora: *Apium inundatum* *Baldellia ranunculoides* *Elatine hexandra* *Eleogiton fluitans* *Luronium natans* *Pilularia globulifera* *Sparganium angustifolium* *Utricularia* spp.

b. Characteristic species targets for mesotrophic type lakes (or lakes that exhibit transitional conditions between oligotrophic and mesotrophic).

Targets	**Characteristic species**
i) Presence of at least eight of the characteristic species listed opposite. ii) No loss of characteristic species recorded from the site. iii) Presence of characteristic species in at least 60% of **all** sampling points (boat and wader survey combined). iv) No significant decline[5] in total frequency of occurrence of characteristic species (see list opposite) in **all** sampling points between surveys (boat and wader surveys combined).	*Baldellia ranunculoides* *Elatine hexandra* *Isoëtes echinospora* *Isoëtes lacustris* *Littorella uniflora* *Lobelia dortmanna* *Luronium natans* *Najas flexilis* *Nitella* spp. (count each species individually) *Pilularia globulifera* *Potamogeton rutilus* *Potamogeton alpinus* *Potamogeton gramineus* *Potamogeton perfoliatus* *Potamogeton praelongus* *Potamogeton* x *nitens* (and any other established hybrid with one of these species as a parent) *Sparganium angustifolium* *Sparganium natans* *Subularia aquatica* *Utricularia* spp. (count each species individually)

[5] Significant decline' should be assessed at a site-specific level. However, as a guideline a decline of more than 20% could be considered as significant. Expert judgement is required.

Table 7. Characteristic species target for hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.

Targets	Characteristic species
i) One or more characteristic species should be present. ii) Presence of characteristic species in at least 60% of **<u>all</u>** sample points (boat and wader surveys combined). iii) No loss of characteristic species recorded from the site. iii) No significant decline in total frequency of occurrence of characteristic species at **<u>all</u>** sampling points between surveys (boat and wader surveys combined).	*Chara* spp. (excluding *Chara vulgaris)* e.g.: *Chara aspera* *Chara curta* *Chara fragifera* *Chara hispida* *Chara intermedia* *Chara pendunculata* *Chara rudis* *Chara virgata*

Chara will be the dominant feature of the vegetation, but a number of other species are associated with hard water lakes and populations of these species should be maintained. These should be considered under the local distinctiveness attribute.

Table 8. Characteristic species targets for natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation.

Targets	Characteristic species
i) Presence of at least six characteristic species. The list of characteristic species must include at least one broadleaved *Magnopotamion* species AND no more than three *Hydrocharition* species can count towards the total[6]. ii) No loss of characteristic species recorded from the site. iii) Presence of one or more characteristic species in at least 60% of **all** sampling points (wader and boat surveys combined). iv) No significant[4] decline in total frequency of occurrence of characteristic species at **all** sampling points (boat and wader surveys combined).	Broadleaved *Magnopotamion* species: *Potamogeton alpinus* *Potamogeton coloratus* *Potamogeton gramineus* *Potamogeton lucens* *Potamogeton perfoliatus* *Potamogeton praelongus* *Potamogeton* × *angustifolius* (or any other hybrid with one of the above species as a parent). Other characteristic species (positive indicators that may count towards the total): *Callitriche* spp. (except where confined to inflow / outflow areas) *Chara* spp. (each species contributes to the total) *Littorella uniflora* *Potamogeton crispus* *Potamogeton filiformis* *Potamogeton friesii* *Potamogeton obtusifolius* *Ranunculus circinatus* *Hydrocharition* species: *Hydrocharis morsus-ranae* *Riccia fluitans* *Spirodela polyrhiza* *Stratiotes aloides*[7] *Utricularia australis / vulgaris* agg.(each species counts individually) *Wolffia arrhiza*

3.2.2 Negative indicator species: invasive non-native species

Non-native species constitute a major threat to many standing waters. For example, species such as signal crayfish have been responsible for much of the decline of native crayfish through competition, habitat damage and the introduction of crayfish plague.

Some species native to Britain, especially fish, can be as damaging as alien species when they are introduced to parts of the country from which they were previously absent. These species are referred to as 'locally absent' (WFD-UKTAG 2014). As evidence becomes available on the impacts of particular locally absent species this will enable more accurate assessments to be made of the effect these species are having on favourable condition.

[6] It is common for even quite poor sites to retain a high diversity of *Hydrocharition* species. *Lemna* spp. have not been included as they are tolerant, very widespread and have little conservation value.

[7] Where this species is native – note that it is introduced in much of western and northern Britain and to Northern Ireland.

Once a site is recorded as unfavourable due to alien species a control or eradication plan should be put in place as quickly as possible. If possible, eradication is the first priority, followed by control to 'ecologically acceptable' levels of infestation. The subsequent round of monitoring should assess the success of management action and consider whether the site has improved to favourable condition.

Assessment of alien species is based on the principles used in assessing HES under the WFD, and applies to species on the banks and in the riparian zone as well as species of the open water and the margins.

Table 9. Alien/locally absent species targets.

Targets	Method of assessment
No high-impact alien species established (i.e. self-sustaining populations). Standard checklists of species are based on those used for WFD assessments For other species, a site will be assessed as unfavourable when there is good evidence that any non-native species or locally absent species is causing an impact on site integrity.	Where a macrophyte survey has been carried out, the presence of alien species in the UKTAG lists[8] should be noted. Where there are no macrophyte survey data, and for other organisms (e.g. invertebrates, fish), contact external organisations (e.g. EA, SEPA, fisheries trusts and boards) for local reports on alien or locally absent species.

3.2.3 Negative indicator species: filamentous algae

Filamentous algae absorb nutrients from the water column so may indicate high nutrient levels. 'Blanket weed' species (mainly *Cladophora* and *Spirogyra*), which produce dense floating rafts of algae or coat macrophytes, may be a particular cause for concern. Blanket weed may not develop high biomass in exposed waters due to wind action.

Interpreting filamentous algae results may be difficult. Dense growths of tufted algae may grow on hard substrates where other plants have difficulty establishing, such as on boulders or cobbles. On the whole this is not a cause for concern. However, unfavourable condition may be indicated by the formation of floating algal rafts or macrophytes being overgrown with filamentous algae.

Due to the natural variability associated with growth of filamentous algae, this target should be used in conjunction with other indicators of nutrient enrichment (e.g. elevated water column TP levels, phytoplankton blooms, limited depth of macrophyte colonisation) when reaching conclusions on condition.

Table 10. Filamentous algae target.

Target
Cover values of 3 for filamentous algae in no more than 20% of sampling points (boat and wader survey combined).

[8] http://www.wfduk.org/tagged/alien-species#. Note: This document includes a separate list of alien species for Ecoregion 17 (in which Northern Ireland lies); this list contains only high-impact species.

3.3 Macrophyte community structure

Healthy lakes support a range of distinctive vegetation zones, from deep water to fully terrestrial habitat. This structural diversity greatly increases habitat complexity and hence the biodiversity of the lake. Many species require a combination of habitats in order to complete their life cycles. Riparian vegetation also plays a role in regulating water quality and dissipating wave energy. Retaining the vegetation structure, including a well-developed riparian fringe, is important in providing a diversity of habitats within a lake.

The extent and form of zonation depends on the morphology of the lake and its surrounding vegetation, as well as the substrate and underlying geology. Distinct zones should ideally include marsh and fen plants; swamp communities (often including reedbeds); floating-leaved species such as water lilies; submerged macrophyte beds and open water. In exposed or upland lakes, swamp communities and floating-leaved plants tend to be restricted to sheltered bays but there may be pronounced underwater zones consisting of *Littorella*, *Lobelia* and *Isoëtes* and stoneworts such as *Nitella* in deeper water. In lowland lakes, riparian woodland and the resulting dead wood may provide shelter for fish and a hard substrate for species such as sponges and bryozoans.

Changes to zonation often indicate negative impacts on the lake. Loss of shallow water species may indicate alteration of the shoreline, or changes in hydrology, extent or substrate. Grazing, shading and wave action all have the potential to reduce the emergent vegetation present.

Vegetation zonation should initially be assessed using data from the macrophyte survey, field notes and LHS. Subsequent analysis will depend on initial observations of any deterioration and the weight of evidence required. Digitising zones using aerial photographs with a GIS to evaluate change may be appropriate where deterioration is suspected. Zones observed may include wet grassland; marsh, fen and bog; swamp (including reedbed); riparian woodland; floating-leaved plants; short amphibious vegetation and submerged macrophytes. Submerged macrophytes cannot be assessed using aerial photography, instead macrophyte survey data should be used.

Table 11. Macrophyte community structure targets.

Target	Method of assessment
Presence of characteristic zones of vegetation. No deterioration in extent from baseline situation. Where possible, restoration targets should be sought.	Aerial photography LHS data Macrophyte survey

An important indicator of condition of community structure is the maximum depth of plant colonisation (Z_v). Whereas Secchi depth and chlorophyll *a* concentrations are specific to the time of survey, Z_v is related to the conditions that have been present in the lake over several months or more. Z_v is calculated as the mean of the maximum colonisation depths of the four boat transects (Spears *et al* 2009). Atypical transects that lack vegetation should be excluded. Alternatively, a hydroacoustic survey may be used to map the depths to which the macrophyte beds extend. The following points are important when assessing condition:

- targets for Z_v do not apply to dystrophic lakes, as water clarity is naturally poor
- fluctuations in lake level should be considered when examining this variable

- for shallow lakes it may be appropriate for the target to specify macrophyte cover throughout the submerged habitat.

Suggested type-specific targets for Z_v are presented in Table 12. However, targets for Z_v should be site-specific, because no satisfactory method has been established for predicting Z_v based on environmental variables. A reduction in Z_v of 0.5 m or more would be defined as significant, but consideration should also be given to the loss in area of colonisation to which this corresponds.

Table 12. Maximum depth of colonisation targets.

Lake Category	**Target**
Oligotrophic and mesotrophic lakes	$Z_{v\,=}$ the larger of 3.5 m or baseline Z_v unless water depth is <3.5 m, habitat is shaded or water colour is influenced by humic substances, in which cases baseline should be used as target. Note that some lakes in this category may naturally have very clear waters with Z_v of 6 m or more.
Hard oligotrophic to mesotrophic *Chara* lakes	$Z_v \geq 5.0$ m unless water depth is <5.0 m, habitat is shaded or water colour is influenced by humic substances, in which cases baseline should be used as target.
Eutrophic lakes	$Z_{v\,=}$ The larger of 2.5 m or baseline Z_v

3.4 Water Framework Directive: additional biological tools

The environment agencies use various methods (termed classification tools) in their WFD lake monitoring programmes. These include the lake phytobenthos method (DARLEQ2) (WFD-UKTAG 2014b), the chironomid pupal exuviae technique (CPET) (WFD-UKTAG 2008a) and the Lakes Acidification Macroinvertebrate Metric (LAMM) (WFD-UKTAG 2008b; McFarland *et al* 2009). The first two respond primarily to eutrophication and either or both tools may be used on some lakes. Where data are available for any of these methods, the targets in Table 13 should be met.

Where relevant data are not available and there are ecological risks that can be most effectively monitored using any of these tools, they may be used if appropriate. To ensure consistency, it is recommended that environment agency staff are consulted.

Table 13. Targets for additional WFD biological tools used in WFD lake monitoring.

WFD Tool	**Target**
DARLEQ / CPET	At least Good Ecological Status (with high confidence) OR If High Status, no deterioration.
LAMM	High ecological status

3.5 Water quality

Ecosystem structure and functioning in lakes is partly determined by climatic factors and the physical properties of the catchment area. Geology, soils and land use in the drainage basins of lakes determine the chemistry of the water and sediments in these water bodies. Key water quality parameters affecting ecosystem functioning of lakes are pH, alkalinity, phosphorus (P) and nitrogen (N).

Determination of alkalinity allows confirmation of lake type, links to the WFD typology for lakes, and enables calculation of acid neutralising capacity (ANC). Assigning lakes to the WFD typology is desirable, to facilitate setting of appropriate water quality targets. The UK Lakes inventory includes lake type for most water bodies but local validation of type is recommended using measured alkalinity values. Chemical data are sometimes available from the environment agencies.

3.5.1 Dissolved oxygen

Human activities leading to phytoplankton blooms and increased loadings of organic matter to lakes can cause decreases in the concentration of dissolved oxygen available to support the species present. The WFD standards have been adopted. The standard divides lakes into salmonid and cyprinid waters, reflecting the different environmental tolerances of these fish groups. The values for GES were developed for July and August, i.e. the time of year when DO levels are likely to be lowest. If the lake already meets the standard for HES then this target should be adopted in order to prevent deterioration.

In monitoring for WFD-related purposes, DO values are measured at 0.5 m depth intervals in July or August. When a lake stratifies, i.e. there is a significant temperature gradient between the top and bottom of the water column, the target refers to the mean DO concentration below the thermocline only. Where the lake does not stratify, the target is the mean of all dissolved oxygen readings throughout the water column. Table 14 indicates the appropriate target for lake types irrespective of their fish community.

Very shallow lakes are at low risk of deoxygenation because they are usually well mixed by the wind. Deoxygenation is rare in these sites unless they are very small and / or sheltered. In very shallow lakes, dissolved oxygen monitoring should be carried out on a risk basis.

Table 14. Dissolved oxygen targets.

Lake type	GES	HES
Dystrophic, oligotrophic, mesotrophic, hard (salmonid waters)	>7.0 mg L^{-1}	>9.0 mg L^{-1}
Eutrophic (cyprinid waters)	>6.0 mg L^{-1}	>8.0 mg L^{-1}

3.5.2 pH

pH is an important variable, as it influences all chemical and biological processes in lakes, e.g. P binding in sediments, sources of carbon for photosynthesis, chemical speciation and the development of toxic effects of pollutants. Changes in pH, either through eutrophication or acidification can, therefore, have considerable effects on lake ecology. The optimum pH range for fish health is pH 5.5–9.0, although pH values of between 5.0 and 5.5 are not generally directly toxic to fish. However, many dystrophic lakes may not support fish, due to naturally acidic conditions.

Table 15. Guideline pH values associated with different lake types.

Lake type	Guideline pH (annual mean)
Dystrophic	<5.0
Oligotrophic (sandy plains)	5.5 to 7.0
Oligotrophic	5.5 to 7.0
Mesotrophic	6.5 to 8.0
Hard	7.0 to 8.5
Eutrophic	>7.0 to <9.0

No type-specific targets are presented in this chapter, as there are difficulties with setting targets for pH in lakes. pH values vary within lakes daily and seasonally for a number of reasons, some of which may cause significant changes, such as snowmelt leading to acid pulses, and photosynthesis causing high pH during the day. These factors make target setting and interpretation of pH problematic. Other effects of pressures that cause extreme pH values may be assessed using ANC (section 3.5.3) or chlorophyll *a* (section 3.5.6).

Although there are difficulties in developing type-specific standards, it is possible to set site-specific targets. In many lakes of low nutrient status, variability in pH is generally limited and values are low, so where pH ranges are highly variable and exhibit high values this is an indication that the feature is in unfavourable condition. Conversely, mesotrophic, hard and eutrophic lakes may be in unfavourable condition if low pH values are present in the water column. Values for pH in hard water systems would be expected to be stable, so an increase in variability would suggest problems at the site. In general, high variability in pH may be associated with unfavourable condition. With the exception of dystrophic lakes, pH would not be expected to be at values that would result in toxicity to biota. Toxicity may occur at both low and high pH. There are reasons, therefore, why an individual feature may be judged to be in unfavourable condition with regard to pH, in the context of having a reliable set of monitoring data, rather than an individual measurement.

3.5.3 Acid neutralising capacity (ANC)

Some lakes have low concentrations of dissolved ions and are acid sensitive. Where this is not the case, this assessment need not be carried out. Acid sensitive lakes occur predominantly in northern and western Britain over hard geologies or base-poor sand – they are almost always oligotrophic, dystrophic or more rarely, mesotrophic. Acidification occurs when airborne pollutants (principally sulphur dioxide, and to a lesser extent nitrogen oxides) are deposited in lakes or their catchments, reducing their buffering capacity.

As a result, pH values may fall rapidly particularly at certain times of year, and especially during heavy rainfall or following snowmelt. The resulting low water column pH may kill sensitive organisms including fish, plants and invertebrates. In general, lake survey programmes involve a limited number of visits to the water bodies of interest, so pH data are limited. It is possible to use data-loggers to provide a continuous record of values, but this is beyond the scope of CSM and WFD monitoring. However, the buffering capacity, i.e. the ANC of the lake, provides a good measure of its vulnerability to decreasing pH.

ANC is calculated from alkalinity (measured using Gran titration) and dissolved organic carbon (DOC) concentration, to take into account additional buffering capacity provided by humic substances. This variable was used in classification schemes of lake condition, such as the lake quality classification scheme of SEPA (Fozzard *et al* 1997) and subsequently developed lake classification tools for the WFD (McFarland *et al* 2009). The ANC target in Table 16 is based on the HES standard for lakes.

To assess the target, at least four samples, collected quarterly over a period of one year, must be used. Monthly data over a one year period is considered best practice.

Table 16. Acid neutralising capacity target.

Lake Types	Target
All lakes	>40 μeq L^{-1} (annual mean)

3.5.4 Total phosphorus (TP)

a) Background

Changes in the ecology of a lake, due to anthropogenic nutrient inputs, are often first apparent in the phytoplankton population within the water column. The relationship between increased water column TP concentrations and increased phytoplankton biomass is well-established. Increased loadings of P to a lake are likely to lead to higher algal biomass in the water column, which in turn can have significant impacts on the lake ecosystem through, for example, competition with vascular plants for nutrients and light, changes in pH, oxygen depletion and production of toxins. Decreasing dissolved oxygen and increasing ammonia levels are associated with death and decay of algal blooms, as is a release of toxins from toxin-producing species. It is therefore important to include TP levels in condition assessment.

Increases in nutrient levels increase the risk of a switch from a macrophyte dominated state, to an algal dominated one. This may occur, for example, as a result of increases in biomass of phytoplankton or filamentous algae, changes in algal community structure or in the fish community. Hence, while increases in nutrient concentrations alone do not constitute eutrophication, any increase beyond the targets outlined below represents an unacceptable risk to site integrity.

b) Data availability

For a number of lakes TP data are available from the routine monitoring programmes of the UK's environment agencies. Elsewhere, site-specific investigations or research projects may have collected TP data, although caution should be exercised in using old data or TP concentrations determined from a single sample. Further advice on considering confidence in data is provided in section 7.2. Where there are no TP data there are three options: a) to arrange for water sampling and analysis as part of CSM monitoring, b) to arrange for water sampling and analysis through liaison with the environment agency, or c) to estimate present TP concentrations through use of loss coefficients and models. The last of these is useful in determining the magnitude of likely P loads, based on catchment population and land use, but due to the errors associated with modelling and in loss coefficients the results should be interpreted with caution, and reference made to the assumptions of the models. If these options are not feasible, it will be necessary to assess the nutrient enrichment pressure through surrogate attributes (e.g. presence of excessive algal growths, water transparency). Where these surrogates or the use of loss coefficients and models suggest a problem, investigative work should be undertaken, involving measurement of TP concentrations and estimation of P loadings within the catchment.

Where water sampling is used, at least four samples, collected quarterly over a period of one year, must be used. Monthly data over at least a one year period is recommended.

c) Setting targets

Type-specific targets have been developed (Table 17) but site-specific targets should be set for each lake where possible. This approach is necessary because type-specific targets are relatively broad. When setting targets for a WFD water body an additional test of stringency needs to be applied (see 'Use of WFD Standard' below).

The WFD typology is defined by alkalinity and mean lake depth (Table 17). TP levels have been considered with respect to depth, as the bathymetric properties of lake basins influence the resident ecological communities. The link between alkalinity and types of lake is long established. Low alkalinity lakes are often nutrient and species poor, while high alkalinity lakes tend to be richer in nutrients, flora and fauna. However, since high alkalinity lakes are usually in lowland areas, they are also subject to a higher level of impact.

d) Type-specific targets

Generally, the capacity of a lake to immobilise P increases with increasing alkalinity, as the concentrations of cations that may bind with P increase. In lakes with higher alkalinity, the capacity for immobilisation of P, combined with the presence of a stable macrophyte community, discourages augmentation of algal biomass. Hence targets for low, medium and high alkalinity lakes are different.

For mesotrophic, hard water and eutrophic lake types, different targets are presented for <u>deeper</u> (WFD 'shallow' and 'deep' types) and <u>very shallow</u> water bodies. The upper limit for very shallow waters of these lake types is higher than that for deeper waters. This is because very shallow lakes usually have a higher carrying capacity for nutrient enrichment. For peaty and low alkalinity lakes in particular, this is not necessarily the case, so the targets do not vary with depth. Small changes in TP levels of lakes with naturally low TP concentrations can have significant effects, particularly on phytoplankton ecology, and in very shallow lakes a high proportion of the water column receives sufficient light to support photosynthesis, so is a potential habitat for algae.

Targets for deeper medium and high alkalinity lakes are more stringent than those for shallow waters, recognising that:

- in deeper lakes, a smaller proportion of the water volume is occupied by macrophytes, and hence there may be greater potential for algal blooms to develop;
- retention times in deeper lakes are generally longer;
- in deeper lakes there is greater potential for P to be lost to the sediment or hypolimnion; thus, for a given P load the expression of P concentration in the water column may be lower in a deeper lake, while masking a potential problem of accumulation of P in the sediment or hypolimnion.

Lakes with hard water have a high capacity for P immobilisation due to co-precipitation of P with calcium and / or magnesium. Thus, P concentrations are typically low in these lakes, even when they are receiving relatively high external P loads. Targets for marl lakes are, therefore, lower than for equivalent high alkalinity lake types.

In peat dominated catchments, TP may exist in humic–iron–P complexes. This may result in an apparent failure of the TP target. Additional P from anthropogenic sources does not bind well with sediments of low pH and high organic content, such as may be found in these water bodies. Although there is reduced light penetration, increases in algal biomass remain possible, as certain algal types (e.g. species of blue-green algae), are suited to harvesting light under such conditions and / or may have P uptake strategies that are more suited to utilisation of the additional P source. Therefore, in dystrophic lakes, slightly elevated TP (up to 25 µg L^{-1}) should not be used on its own to place a site in unfavourable condition, especially where there are no catchment nutrient sources that could explain such a failure.

In Table 17, upper limits for TP levels are presented for each lake type. The type-specific ranges are the values between the maxima for the different types. For example, the upper limit for deeper oligotrophic lakes is 10 µg L^{-1}, while the upper limit for deeper mesotrophic lakes is 15 µg L^{-1}. TP values for deeper mesotrophic lakes would therefore be expected to fall between 10 and 15 µg L^{-1}.

Table 17. Generic total phosphorus targets.

Depth categories correspond to the WFD lake depth categories and are based on mean depth. The relevant types are: 3 m or less = very shallow; >3 m = deeper (this is a combination of the WFD 'shallow' (>3-15 m) and 'deep' (>15 m) types).

Lake habitat feature type	Depth Category	Maximum Annual Mean TP (µg P L^{-1})	Approximate match to WFD typology
Dystrophic	All	10	Peat
Oligotrophic	All	10	Low Alkalinity
Mesotrophic	Deeper Very Shallow	15 20	Moderate Alkalinity
Hard water	Deeper Very Shallow	10 15	Marl
Eutrophic	Deeper Very Shallow	35 50	High Alkalinity
Brackish	All	35	Brackish

e) Site-specific targets

Site-specific targets should be set within the type-specific ranges. However, where there are good water quality and/or biological data, or evidence from palaeolimnology, that a target outside the type-specific range is more appropriate, a site-specific target may be used to reflect this. Palaeolimnology uses present-day relationships between diatom species and chemical variables to estimate historical values for chemical variables. For example, analysis of diatom remains in the sediment may indicate that historically, a deep, mesotrophic lake has always had P concentrations in excess of 15 µg P L^{-1} or less than 10 µg P L^{-1}. Modelling methods may be used to set P targets such as the Morpho-Edaphic Index (MEI) (Vighi & Chiaudani 1985) and Phosphorus Landuse Slope (PLUS) (MLURI 1995). Site-specific targets generally require the collection of a certain amount of additional data (for example MEI requires mean depth and alkalinity). Modelled targets should be compared with measured data and the type-specific target to ensure that it is suitable for the long-term maintenance of the ecosystem in favourable condition. In many cases, the site-specific targets would be expected to be lower than the upper limits of the type-specific targets (e.g. Wiik 2012).

For lakes recovering from historical nutrient enrichment, it may be necessary to set interim targets that are different from those in Table 17. These are likely to be site-specific and will require further investigative work, such as estimation of nutrient budgets and sediment sampling. Setting these targets is outside the scope of this document, but specialist advice should be sought.

f) Use of WFD standard

If standards for GES under the WFD are more stringent than CSM targets then those GES standards should be used as targets for favourable condition. If HES has already been achieved (and is more stringent than the CSM target) then those standards should be used as favourable condition targets. It is important to note that WFD standards use a geometric mean. This needs to be taken into account when comparing stringency. Geometric means are always lower than the equivalent arithmetic mean so WFD targets for the same dataset may appear to be more stringent. It is recommended that the dataset is compared against Table 17 as a check for stringency.

It should be noted that the majority of WFD standards are based on site-specific calculations from the MEI model (see above).

3.5.5 Nitrogen

It has previously been recommended that nitrogen targets are only required for lakes that are nitrogen limited, but this neglects the impact of nitrogen on macrophytes. There is evidence that high nitrogen concentrations are detrimental to macrophyte diversity and abundance, charophyte growth and the persistence of *Phragmites australis*. Although these studies suggest that it is nitrate which causes this effect, nitrate can fall below levels of detection due to denitrification and uptake, particularly in the summer months. Consequently, the mean annual total nitrogen concentration is used as a surrogate to assess nitrate loading (Table 18). Therefore, regardless of which nutrient is limiting, mean annual total nitrogen concentrations above 1.5 mg L^{-1} should lead to an assessment of unfavourable condition, as suggested by Barker *et al* (2008).

More stringent nitrogen targets may be required to limit algal growth to concentrations typical of the lake type, particularly in naturally unproductive lakes. This will need to be considered for lakes currently limited by nitrogen and lakes that are currently not limited by phosphorus or nitrogen, but where reduction in nitrogen concentration can contribute to the control of algal growth. The potential for nitrogen and phosphorus to limit productivity at different times in the year should also be considered. These targets should be set in consultation with technical specialists.

To assess the target, at least four samples, collected quarterly over a period of one year, must be used. Monthly data over a one year period is considered best practice.

Table 18. Nitrogen targets.

Lake type	Target
All lakes	Annual mean TN concentration should not exceed 1.5 mg L^{-1}. No deterioration from baseline.
Nitrogen-limited lakes and lakes where reduction in nitrogen concentration can contribute to the control of algal growth.	Targets should be set in consultation with technical specialists.

3.5.6 Chlorophyll *a*

Chlorophyll *a* is a pigment used for photosynthesis by plants, so the concentration of chlorophyll *a* in the water column during the growing season provides a good indicator of the abundance of phytoplankton. Phytoplankton is an important driver of structure and functioning in lake ecosystems, and high phytoplankton biomass (algal blooms) is usually associated with nutrient enrichment and sedimentation of organic matter in lakes.

Phytoplankton growth in lakes is variable. Variability is high in enriched water bodies. However, in naturally nutrient-poor lakes, phytoplankton abundance is more stable. Due to variability in plant growth, a single monitoring visit will not provide evidence of change. Even in enriched waters, a clear water period is to be expected and, conversely, blooms sometimes occur under natural conditions, for example following long periods of dry weather.

Chlorophyll *a* concentrations are measured routinely by the environment agencies as part of their lake monitoring work for the WFD. However, the number of lakes covered is limited. Where such data are not available, measurement of chlorophyll *a* concentrations in the water column is strongly recommended, to assist in assessment of condition.

The UK Administrations have set type-specific standards for chlorophyll *a* concentrations. However, as with TP targets, site-specific chlorophyll *a* targets are preferable to lake type targets, as they take into consideration the individual characteristics of a lake. The environment agencies have produced a WFD assessment method for phytoplankton in lakes that includes chlorophyll *a* (WFD-UKTAG 2014c). This involves determining the annual geometric mean of chlorophyll *a* concentrations measured monthly (January to December). The mean values are then compared with site-specific targets calculated using an equation involving alkalinity and depth. <u>Where possible, site-specific WFD standards for HES should be used in condition assessment.</u> If no WFD standards are available, site-specific data can be used to calculate an appropriate target in consultation with the conservation agency technical specialist. If a site is in favourable condition, current chlorophyll *a* data can be used to set a target for no deterioration. If a site is in unfavourable condition, historical data may be used to inform target setting.

To assess the target, monthly data over at least a one year period is recommended.

Where possible, chlorophyll *a* data should be interpreted in combination with macrophyte depth distribution, nutrient concentrations, palaeolimnology and Secchi depth to give a powerful impression of the extent of nutrient impacts on the lake.

3.5.7 Other pollutants

Data on the chemical status of individual water bodies may be available from the environment agencies. Good chemical status is the target for any pollutant listed on Annex VIII of the WFD and not specifically considered above. Whilst these standards may have limited ecological meaning, failure to meet them is likely to reflect a problem that may not be picked up by other monitoring.

3.6 Hydrology

Hydrology influences lake ecosystem functioning in two ways: determining flushing rate and water level fluctuations. Flushing of lakes is important for dilution and removal of nutrients and phytoplankton, and for reduction in sedimentation. Both annual and within-year flushing patterns should remain unchanged. The timing of different flushing rates within the year influences the biology of the lake. For example, reduced flushing in summer would encourage bloom conditions. In practice, adverse impacts on flushing should be evident through assessments of water quality and the biology of the system, although effects may be delayed.

Water level fluctuations can have effects on habitat diversity and trophic structure that are both positive (e.g. providing opportunities for germination or seed dispersal) and negative (e.g. flooding marginal and riparian plant habitats or exposing plants to desiccation). In particular, water level fluctuations play a critical role in the succession and development of littoral and emergent vegetation. Reduced water levels, occurring as a result of lake drawdown, have the potential to cause adverse impacts on littoral floral and faunal communities and may result in the loss of marginal plant populations. Furthermore, water level fluctuations may affect lake morphology through the influence of wave action on shoreline stability, particularly if rooted plants are no longer present.

The WFD standard for lake hydrology uses the lake bathymetry and inflows to calculate changes in lake area relative to the natural lake area, taking into account seasonal drawdown. These data may be available from the relevant environment agency and should be used in assessment.

Determining whether there is an appropriate hydrological regime from a single site visit is difficult, although there may be evidence of major impacts, for example stranded marginal vegetation, exposed lake sediments, or signs of former shorelines. Emergent plants may exhibit morphological differences under different hydrological regimes, but this varies between species; for example, *Phragmites australis* seedlings may form longer leaves under exposed conditions, but *Schoenoplectus lacustris* seedlings may display the same morphological change when submerged as when emergent. In practice, evidence from site visits requires interpretation with reference to information on known changes to the hydrology of the catchment.

Loss of *Lobelia dortmanna* from a lake is indicative of excessive fluctuations in water level, as this species has a narrow depth tolerance. Extensive areas of colonisation of the shore by the terrestrial form of *Littorella uniflora* are indicative of drawdown.

Hydrological regime should initially be assessed using field notes from the macrophyte survey and LHS data (if available). Subsequent analysis will depend on initial observations of any deterioration and the weight of evidence required. The entire catchment area of the lake should be examined when considering possible changes to the natural hydrological regime. Management of upstream waters, e.g. through regulation of reservoirs, may have considerable impacts on downstream lakes and artificial drainage may alter seasonal dynamics.

Some lakes rely heavily on groundwater. There is always much more uncertainty about the extent of the groundwater catchment feeding them, its importance relative to any surface water inputs, the nature of the aquifer and the effects of any groundwater abstraction on hydrology. Changes to groundwater supply may also have significant effects on water quality. Assessment of changes to groundwater supply on lake condition should be supported by specialist hydrological advice.

Table 19. Hydrology target.

Target	Comment
No deterioration in hydrological regime compared with baseline.	Baseline may be defined by the situation at time of designation, or may refer to natural conditions, depending on the objectives for the individual lake.

3.7 Habitat structure

Lakes with a high degree of naturalness will be governed by dynamic processes that result in a variety of physical habitat features, including a range of substrate types, natural variations in the shoreline and variations in sediment load. This section aims to assess each of these in turn.

3.7.1 Lake substrate

Lake sediments consist of mineral material (e.g. clays, silicates), decomposing organic matter, and inorganic components of biological origin (e.g. skeletal material, siliceous shells). Particulate material is transported from the catchment area, but is also generated within lakes, e.g. plant debris. On reaching a lake, heavier particles are expected to settle out first, finer material taking longer. Lake sediments are therefore sorted along particle size gradients. Once deposited, sediments are subject to a number of processes such as degradation or slumping. The distribution of sediment particle size and organic content influences the biology of the lake and will affect the suitability of within-lake habitats for invertebrates and macrophytes, and fish spawning grounds. Increases in sediment loading from activities in the catchment area, including those on the lake shore, may result in the smothering of coarse sediments. Increased inputs of leaf litter, as a result of scrub encroachment, may also be cause for concern, as organic-rich sediments may be a poor rooting medium for macrophytes.

Inclusion of hard engineering solutions to lake management may have detrimental effects on lake ecology, replacing natural substrates with imported or man-made materials.

Alterations to lake substrate character need not be monitored routinely. However, pressures resulting in deleterious changes to lake substrate should be noted. Where certain activities or structures are consented or where impact from an existing structure is suspected it may be appropriate to use the Lake Habitat Survey (LHS) method (Rowan *et al* 2006a, 2006b, 2008).

Table 20. Lake substrate target.

Target
Maintenance of natural and characteristic substrate for the lake type

3.7.2 Lake shoreline

Lakes in favourable condition should have largely unmodified shorelines. Specific targets are presented in Table 21 below.

Table 21. Lake shoreline target.

Targets for lake shorelines	Method of assessment
Near-natural planform in ≥95% of shoreline length	Historical maps, aerial photographs and other methods of remote sensing
Near-natural slope profile in ≥95% of the length of the shore zone	Hydromorphological surveys (e.g. LHS)
The structure and material of the banks should be near-natural with no more than 0-5% affected by hard engineering or 0-10% by soft engineering	Hydromorphological surveys (e.g. LHS); databases; aerial photos If using LHS, key hab-plot data include Section 2.2 Bank Face: 'predominant bank material' and 'bank face modifications'; Beach: 'predominant shore forming material'

3.7.3 Sediment load

The sediment loading from the catchment area to a lake occurs due to soil disturbance and precipitation. Natural variation occurs in the sediment loading to different lakes, depending on local conditions. The magnitude of loss of soil to watercourses is related to catchment size and soil type, but is increased through factors such as lack of vegetation cover, trampling by cattle, inappropriate field drainage and ploughing regimes, type of crop, etc. The organic matter loading may increase because of inadequate storage facilities for biological waste. Increased sediment loadings may result in clogging of the lake bed, increased siltation in the basin and deoxygenation of sediments. Blockage of coarser substrates with finer sediment restricts water flow-through, while increases in organic matter increase biochemical oxygen demand.

Sediment loading need not be monitored routinely. However, pressures resulting in increases in sediment loading to the lake should be noted. Where certain activities or pressures are suspected to cause excessive sedimentation, more detailed investigation using techniques such as palaeolimnology to estimate sedimentation rates (e.g. Bennion *et al* 2010), the LHS method or catchment based GIS studies may be required.

Table 22. Sediment load target.

Lake Type	Target
All lakes	Maintenance of the natural sediment load

3.8 Connectivity

Maintaining connectivity within a lake, and between the lake and the surrounding areas, is critically important for the functioning of natural processes and for achieving favourable condition. Aspects of connectivity that are important include:

- exchange between groundwater and surface water within the lake;
- connection with groundwater in the riparian zone;
- sediment transport;
- connectivity of the lake with adjacent riparian wetlands;
- connectivity of migratory movement between littoral and riparian zone; and
- connectivity of migratory movement into and out of the lake, upstream and downstream.

Many of these features are assessed using other parts of the guidance. The baseline for assessment may be defined by the situation at the time of designation, or may refer to natural conditions, depending on the objectives for the individual lake. No specific condition targets are proposed as assessing this feature is only possible qualitatively using expert judgement and local knowledge. However, an indication that connectivity is disrupted may be given by:

- extensive sections of the shoreline affected by hard engineering (e.g. impermeable concrete structures impeding groundwater exchange);
- conspicuous evidence of bank erosion;
- non-natural grain size distribution in the substrate;
- a significant area of lake bottom sealed by construction;
- changes to sediment permeability; or
- presence of barriers (e.g. causeways, weirs, dams).

3.9 Indicators of local distinctiveness

This attribute is intended to cover any site-specific aspects of the habitat feature (forming part of the reason for notification) that are not covered adequately by the previous attributes, or by separate guidance (e.g. for notified species features). This is a discretionary attribute, in that it may not be applicable to every site, but where local distinctiveness has contributed to the selection of a site for standing waters it should be mandatory. Local distinctiveness may refer, for example, to rare plant or invertebrate species, high diversity of *Potamogeton* or charophyte species, or notable habitat features.

For ‘notable’ species (e.g. Red List and Nationally scarce plants or species rare in lakes) it is not intended to set a target for detailed species monitoring, rather to provide a rapid indication of presence/absence and/or approximate extent, allowing for natural fluctuations in population size. The same approach applies for ‘notable’ features. Where a European protected species (EPS) is contributing to the local distinctiveness, increased survey effort is advised, and survey effort for Schedule 8 and Red List species should be above the minimum.

Table 23. Target for local distinctiveness.

Targets for local distinctiveness
Maintain distinctive elements (e.g. rare species, habitat features) at current extent/levels and/or in current locations

4 Vascular plant notified features of interest

Where rare vascular plants are notified features of interest in the lake, assessment of the population status is required. In addition to this chapter, the guidance on monitoring vascular plants (available from the JNCC website) should be also consulted. Note that *Luronium natans* is considered in that guidance and is not covered further here.

4.1 Presence/absence

Presence / absence of the species is a mandatory attribute. The notified feature should be described as being in unfavourable condition when there has been a loss of a species which (a) constitutes the vascular plant feature or (b) contributes to a vascular plant feature. If all other targets are met but the species cannot be found, the results should be referred to the country agency specialists.

Table 24. Presence/absence target.

Target
Species should be present

4.2 Population size/extent

Population size/extent and regeneration are discretionary attributes. However, population size/extent and regeneration data are useful in assessing sustainability, which is an integral part of Favourable Conservation Status (FCS). Monitoring these attributes is therefore recommended, particularly where a site or series of sites support a significant proportion of the UK population of that species. In the case of *Najas flexilis* in particular, it is ***strongly recommended*** that the other species attributes are examined, as this is an EPS. Schedule 8 and Red List species should also receive particular survey effort.

The feature should be classed as unfavourable when there is a decrease in the number or size of populations present, but consideration should also be given to occurrence of metapopulations. Size of population may be examined in terms of number of plants or in the area over which the population is growing; it is also advisable to consider cover. As in the vascular plants guidance, when examining the number of plants present, a scale is used to take account of natural fluctuation (0-100, 101-300, etc.). However, the life-history strategy of the species of interest should be considered. Species that exhibit high variability in numbers (e.g. annuals) should preferably be monitored on more than one occasion during each 6-year cycle.

To be defined as discrete, populations of plants must be greater than 50 m apart. In lakes that are too small to contain two populations (e.g. small peatland or floodplain pools), it is more appropriate to consider whether there are other small populations in other lakes in the vicinity within the site. Hydrological connectivity should be maintained between populations.

Table 25. Population size / extent targets.

All of the targets should be met except where site-specific factors indicate that a given target is inappropriate.

Target
Presence of two or more discrete populations, OR single large population of species stretching >100 m
Presence of species of interest in at least 20% of sample points within each population surveyed
Loss of ≤50% frequency of occurrence of species of interest in sample points within each population surveyed (with reference to baseline)
Maximum decline of 1 category of scale of population size (0-100, 101-300 etc.)

4.3 Successful regeneration

It is recommended that features are classified as being in unfavourable condition when the plants of the species of interest do not exhibit evidence of their reproductive strategy.

Table 26. Successful regeneration target.

Target
Plants of differing sizes present OR plants producing flowers, fruits or vegetative propagules.

5 Pressures

In addition to examining the attributes above, pressures likely to affect the lake such as land management (e.g. forestry, agriculture, human habitation) fish introductions, exploitation, vegetation management and boating should be noted by surveyors as an accompaniment to, although not part of, assessing condition. Noting these activities is intended to help set the context for condition assessment and to collect information necessary for site management.

6 Monitoring

6.1 Approach to monitoring biological attributes

Condition assessments are carried out with respect to targets, but it is also necessary to assess whether feature condition is declining, recovering or unchanging. Accurate macrophyte distribution maps, and plant counts from entire lake basins, are generally not achievable, due to difficulties associated with working under water, isolating individual plants, incomplete coverage by plants within areas of colonisation, and limitations to resources for carrying out surveys. In addition, in many cases, there are no existing data.

The most practical approach to lake habitat CSM is to gather semi-quantitative data, in representative parts of lakes, i.e. to conduct partial surveys. The monitoring method recommended is based on recording presence/absence data in a large number of point samples. This is a more statistically robust approach than assessing counts, or cover, in small numbers of large samples (Gunn *et al* 2004), and reduces the time required for survey at each lake. Point frequency sampling produces objective, repeatable and quantifiable data.

The results of the partial surveys of lake macrophytes are then used in combination with information on other attributes, and site management, to assess condition and identify changes with time.

6.2 Preparation for monitoring of biological attributes

6.2.1 Timing of surveys

Monitoring work should take place at least once during each reporting cycle. Aquatic macrophytes are most easily located and identified from June to September. Surveys undertaken outside this growing season are likely to be problematical, due to presence of lower biomass, smaller individual plants, and the absence of distinguishing characteristics, such as flowering parts or seeds. The biology of individual species should also be taken into account, as plants of different species develop throughout the summer. Conducting surveys in June or July may be too early to make representative records of certain species. For example, it is better to search for *Najas flexilis* in August and September. Geographical differences should also be considered when scheduling surveys. The growing season is likely to start later and be of shorter duration in the north of Scotland than in the south of England.

6.2.2 Selection of water bodies to be examined

In sites where the feature is represented by many water bodies, such as occurs in Caithness and Sutherland Peatlands SAC, if resources are limited it will be possible to monitor only a small number of representative lakes. Lakes that should be considered for monitoring are those which:

- are named in the site account or the citation of the SSSI;
- have been surveyed previously;
- are in a near-natural state;
- support species of particular interest;
- contain a rich assemblage of characteristic species;
- are highly representative of their type;
- are at greater risk of harm; and
- are accessible.

When determining survey priorities for water bodies, factors such as the results of previous surveys, inclusion in sampling programmes by the environment agency, and the risk assessments under the WFD, may also be considered. It is strongly recommended that where other factors allow (e.g. ease of access), the lake at greatest risk is surveyed, since if one lake is in unfavourable condition the site is in unfavourable condition.

Where practical or financial difficulties dictate that monitoring is limited to a minimum, the coincidence of qualifying features should also be taken into account, e.g. if there are three features in one site, and all are found in one lake, monitoring that lake only would be appropriate to reduce survey effort.

6.2.3 Choice of locations within lakes to be surveyed

If adequate baseline information is not available, an initial survey should be carried out to locate species or communities of interest in the lakes to be monitored. In each lake, work should focus in areas that support the macrophyte species or communities characteristic of the feature, as monitoring in areas of naturally unsuitable habitat would lead to recording false negative results. Before survey, plant records, Ordnance Survey and bathymetric maps should be examined, along with information on the ecology of different plant species or groups, to identify areas that are likely to support the macrophytes of interest.

See Appendix 2 for details on choice of survey sector location.

6.3 Methods for monitoring

6.3.1 Skill requirements for macrophyte work

Taxonomic expertise is required for monitoring lake macrophytes. Plants should be recorded to species level using Stace (2010) and Stewart and Church (1992). Voucher specimens should be taken where it is not possible to confirm the identification of a species in the field. For difficult genera such as *Potamogeton*, *Callitriche*, *Utricularia*, *Chara* and *Nitella*, samples should be collected for verification by independent experts.

6.3.2 Methodology

The methodology for monitoring biological and non-biological attributes of features of standing water habitats and vascular plants is presented in Appendix 2.

6.3.3 Outputs from field work

Field data recording forms and a reporting form should be submitted for each feature examined. The reporting form should include site name, feature, methods used, summary of results, interpretation of results and recommended condition category. In addition, the activity assessment form, which summarises the positive and negative activities in the catchment, should be completed.

6.3.4 Use of data from other monitoring programmes

The environment agencies have an extensive programme of lake monitoring, especially in larger water bodies, to determine whether they are meeting GES as required by the WFD. In order to minimise overlap between monitoring programmes and maximise data usage, the CSM methods use WFD monitoring information at various levels. Many of the variables in the CSM methods are measured during WFD monitoring, so it is recommended that before designing a monitoring programme local representatives of the environment agency are contacted to establish what data are already available. In general, environment agency lake monitoring data are only likely to be available from larger lakes, or from lakes within SACs.

7 Condition assessment

7.1 Targets referring to natural and/or baseline conditions

Targets for non-biological attributes may refer to ‘natural’ or ‘baseline’ conditions, e.g. those for hydrological regime and shoreline of the lake, as the intention is to safeguard habitats that remain in their natural state. For example, in cases where hydrology was natural at the time of designation, it is likely that the target would be ‘no change from natural conditions’. However, where the attribute has been altered before designation and the alterations do not constitute a threat to the other attributes of the feature, a standing water feature may be judged to be in favourable condition. Judgements as to when this applies must be made site by site.

7.2 Data confidence

7.2.1 Results from macrophyte surveys

Expert judgement is necessary when considering apparent loss or extreme decrease in the presence of a species, as different species exhibit a range of natural variability in numbers and distribution within individual water bodies. In general, perennial plants exhibit much less variability than annuals, while deep water plants are less variable than shallow water species.

The probability that an observed change in abundance is significant depends on the intensity and timing of sampling, weather conditions during survey, and the variability of the species in question; detection of change will be more easily accomplished for species that remain relatively stable in their numbers and distribution. Further consideration will be required when a species of highly variable abundance has become scarce, or has not been recorded within the lake during CSM. The reliability of the viewing method should also be considered (e.g. if boat and bathyscope are used in the examination of deep water species, instead of snorkelling or SCUBA techniques, there is a higher risk of false negatives). A further survey of the same lake may be necessary, to confirm the condition assessment. When signs of reproduction have not been observed, consideration should be given to whether inappropriate timing of the survey could have resulted in a false negative.

When results indicate a reduction in the frequency of occurrence, cover or extent of a species, the species is of low variability, and the survey has been thorough and well-timed, the site should be classed as being in unfavourable condition. In contrast, if a species is highly variable in its frequency, cover or extent, or it is difficult to detect, or the survey has not been thorough, or was badly-timed, further monitoring should be carried out. Information on habitat attributes may be helpful in clarifying the decision on whether the site is in favourable condition.

7.2.2 Water quality data

If water quality results do not fall within the target range for a lake, and confidence in the data is high, then it should be concluded that the site is not in favourable condition. If confidence in the data is low, further investigative monitoring should be undertaken.

Confidence relates to the representativeness and accuracy of the data. Consideration should be given to the quality assurance of the analytical results, and the location, timing and frequency of sampling.

Confidence in water quality data decreases from those obtained from multiple, in-lake samples, to single outflow samples, to edge samples. However, the majority of data is likely to be from lake edge with a throw bottle or outflow samples as this often represents the most cost-effective sampling approach.

7.2.3 Hydrology, substrate and sedimentation

Information on hydrology, substrate and sediment loading should be subject to site-specific, expert judgement. In the majority of cases, only observational information from the day of survey will be available for consideration. Interpretation of results is dependent on the quality and quantity of data available; as with water quality, confidence in the results should be considered when assigning condition category.

7.3 Relationships between condition assessment and WFD status

Although the conservation objectives and the WFD requirements of GES may seem similar, there are some important differences. Conservation objectives are generally relatively specific about desirable habitats, whereas WFD requirements summarise habitat quality as an Environmental Quality Ratio, which does not necessarily reflect the feature for which the site was designated, or the Annex I habitat type. For example, in marl lakes there is no requirement under WFD for *Chara* to dominate, whereas favourable condition would normally be determined by high *Chara* cover.

Wherever possible, the WFD standards and methods have been adopted. However, some aspects of favourable condition such as nitrogen, zonation and connectivity are not covered by WFD assessments. Moreover, due to the rules for combining ‘quality elements’ in WFD, GES can cover a wide range of environmental conditions, not all of which are suitable to support favourable condition. Different tools also have different environmental sensitivities, such that the Good/Moderate boundary may be more stringent for some tools than others. It is therefore necessary to look at quality elements individually. For many quality elements, high status is the target, as detailed under the individual sections of the guidance.

In summary, although it is recommended that data collected during WFD monitoring are used in condition assessment, it should not be assumed that favourable condition corresponds with any particular ecological status under WFD.

7.4 Overall assessment

Lakes respond in a wide variety of ways to environmental pressures, and different attributes inherently need different interpretation. Different attributes are detectable at different levels of confidence, and reflect pressures over different timescales. No one attribute is necessarily a reliable measure of pressure.

A site may be classed as unfavourable if any individual attribute fails to meet its target. However, classing a site as unfavourable based on failure to meet a single attribute runs the risk of drawing the wrong conclusion due to sampling error, site-specific factors, unusual weather conditions or misidentification. Where a single attribute is used to fail a site, careful consideration must be given to the confidence in the data collected for that attribute, the magnitude of any failure and the appropriateness of the target in the context of the setting.

Moreover, lakes tend to respond as a system to pressures and therefore a lake suffering ecological pressures will usually manifest this in more than one attribute. For example, a lake suffering from nutrient enrichment is likely not only to have elevated nutrient levels, but also algal blooms, deoxygenation of deep water areas, and a decline in cover of characteristic macrophyte species. During the early stages of impact, these symptoms may not be very pronounced and failures of targets may be small. However, whereas a small failure of a single target may be attributed to measurement error, failure of several related targets – even by quite small margins – should be a trigger for action. In this way a more robust assessment is achieved by using a weight of evidence approach. Whichever approach is used, an understanding of the inherent variability of different methods and the pressures that they detect is required.

If condition assessment is required for a site with many lakes then all monitored lakes should be in favourable condition to report the whole site as favourable. However, expert judgement can be used to decide whether the failure of individual lakes is sufficiently serious to warrant the whole site being classed as unfavourable.

8 References

BARKER, T., HATTON, K., O'CONNOR, M., CONNOR, L. & MOSS, B., 2008. Effects of nitrate load on submerged plant biomass and species richness: results of a mesocosm experiment. *Fundamental and Applied Limnology,* **173**, 89-100.

BENNION, H., BURGESS, A., ROSE, K., YANG, H. & THOMAS, R., 2010. *Palaeoecological Study of Llyn Padarn*. CCW Contract Science Report No. 918. Countryside Council for Wales, Bangor.

DUIGAN, C., KOVACH, W. & PALMER, M., 2006. *A Revised Classification of British Lakes.* Joint Nature Conservation Committee, Peterborough.
Online at: http://jncc.defra.gov.uk/page-4260

GUNN, I.D.M., CARVALHO, L., DARWELL, A.M., ROY, D.B., ROTHERAY, P., WADE, P.M., STEWART, N., DENT, M.M., KIRIKA, A., JAMES, J.B., HODGSON, P.M. & ABEL, D.V., 2004. *Site Condition Monitoring of Standing Waters Phase 1, Report 1: Aquatic Macrophyte Method Development.* Scottish Natural Heritage and English Nature Commissioned Report.

MCFARLAND, B., CARSE, F. & SANDIN, L., 2009. Littoral macroinvertebrates as indicators of lake acidification within the UK. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **20**, S105-S116.

MCLEOD, C.R., YEO, M., BROWN, A.E., BURN, A.J., HOPKINS, J.J. & WAY, S.F. (eds), 2002. *The Habitats Directive: Selection of Special Areas of Conservation in the UK.* 2nd edn. Joint Nature Conservation Committee, Peterborough.
Online at: http://jncc.defra.gov.uk/SACselection

MACAULEY LAND USE RESEARCH INSTITUTE (MLURI), 1995. *PLUS: The development of a GIS based tool for calculating the total phosphorus load from a catchment.* A collaborative project between Macaulay Land Use Research Institute and Forth River Purification Board.

NATURE CONSERVANCY COUNCIL (NCC), 1989. *Guidelines for Selection of Biological SSSIs*. Nature Conservancy Council, Peterborough.
Updated version online at: http://jncc.defra.gov.uk/page-2303

PALMER, M., 1989. *A botanical classification of standing waters in Great Britain*. JNCC Research & Survey in Nature Conservation, No 19. Joint Nature Conservation Committee, Peterborough.

PRESTON, C.D. & CROFT, J.M., 1997. *Aquatic Plants in Britain and Ireland*. Harley Books, Colchester.

RATCLIFFE, D.A., 1977. *A Nature Conservation Review.* Cambridge University Press, Cambridge.

ROWAN, J.S., SOUTAR, I., BRAGG, O.M., CARWARDINE, J. & CUTLER, M.E.J., 2006b. Lake Habitat Survey in the United Kingdom: field survey guidance manual, version 3.1, May 2006. SNIFFER project WFD42. Scotland and Northern Ireland Forum for Environmental Research, Edinburgh.
Online at: http://www.epa.gov/nheerl/arm/documents/WFD42_fieldguide.pdf

ROWAN, J.S., SOUTAR, I., BRAGG, O.M., CARWARDINE, J. & CUTLER, M.E.J., 2008. Lake Habitat Survey Field Survey Form, version 4, December 2008. Scotland and Northern Ireland Forum for Environmental Research, Edinburgh.
Online at: http://www.sniffer.org.uk/files/8213/4183/7998/LHS_Field_Form_v4_2008_web.pdf

STACE, C., 2010. *New Flora of the British Isles*. 3rd edition. Cambridge University Press, Cambridge.

STEWART, N.F. & CHURCH, J.M., 1992. *Red Data Books of Britain & Ireland: stoneworts*. Joint Nature Conservation Committee, Peterborough.

SPEARS, B.M., GUNN, I.D.M., CARVALHO, L., WINFIELD, I.J., DUDLEY, B., MURPHY, K. & MAY, L., 2009. An evaluation of methods for sampling macrophyte maximum colonisation depth in Loch Leven, Scotland. *Aquatic Botany*, **91**, 75-81.

VIGHI, M. & CHIAUDANI, G.,1985. A simple method to estimate lake phosphorus concentrations resulting from natural background loading. *Water Research*, **10**, 987-991.

WATER FRAMEWORK DIRECTIVE UK TECHNICAL ADVISORY GROUP (WFD-UKTAG), 2004. Aquatic Alien Species and the WFD: Proposed List of 'Locally Absent' Species and Guidance on its Interpretation.
http://www.wfduk.org/sites/default/files/Media/Environmental%20standards/Locally%20absent%20species%20paper_final_200412_0.pdf

WFD-UKTAG, 2008a. *UKTAG Lake Assessment Methods - Benthic Invertebrate Fauna: Chironomid pupal exuviae technique (CPET).*
Online at: http://www.wfduk.org/resources%20/lake-cpet

WFD-UKTAG, 2008b. *UKTAG Lake Assessment Methods - Benthic Invertebrate Fauna: Lake Acidification Macroinvertebrate Metric (LAMM).*
http://www.wfduk.org/resources%20/lake-invertebrate-acidification

WFD-UKTAG, 2014a. *UKTAG Lake Assessment Methods - Macrophytes and Phytobenthos: Macrophytes (Lake LEAFPACS2).*
Online at: http://www.wfduk.org/resources/lakes-macrophytes

WFD-UKTAG, 2014b. *UKTAG Lake Assessment Methods - Macrophytes and Phytobenthos: Phytobenthos - Diatom assessment of lake ecological quality (DARLEQ)*.
Online at: http://www.wfduk.org/resources/lakes-phytobenthos

WFD-UKTAG, 2014c. *UKTAG Guide to Phytoplankton in Lakes - Phytoplankton classification with uncertainty tool (PLUTO).*
Online at:
http://www.wfduk.org/sites/default/files/Media/Characterisation%20of%20the%20water%20environment/Biological%20Method%20Statements/Lake%20Phytoplankton%20UKTAG%20Method%20Statement.pdf

WIIK, E., 2012. *Understanding the ecological response of marl lakes to enrichment: a combined limnological and palaeolimnological approach.* PhD thesis, University College London.
Online at: http://discovery.ucl.ac.uk/1379025/

WOLFE-MURPHY, S.A., LAWRIE, E.A., SMITH, S.J. & GIBSON, C.E.,1992. *The Northern Ireland Lake Survey: Part 3. Lake Classification Based on Aquatic Macrophytes.* Department of the Environment and Queen's University Belfast.

9 Further reading

DEFRA, 2009. *The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2009.*
Online at:
http://archive.defra.gov.uk/environment/quality/water/wfd/documents/river-basin-typology-standards.pdf

FOZZARD, I.R., DOUGHTY, C.R. & LEATHERLAND, T.M.,1997. Chapter 11. Defining THE QUALITY OF Scottish freshwater lochs. Pages 134-143. In: Boon P. & Howell D.L. (editors). *Freshwater Quality: Defining the Indefinable?* The Stationery Office, Edinburgh.

MAY, L., SPEARS, B.M., DUDLEY, B.J., HATTON-ELLIS, T.W., 2010. The importance of nitrogen limitation in the restoration of Llangorse Lake, Wales, UK. *Journal of Environmental Monitoring*, **12**, 338-346.

PALMER, M.A., BELL, S.L. & BUTTERFIELD, I., 1992. A botanical classification of standing waters in Great Britain: applications for conservation and monitoring. *Aquatic Conservation: Marine and Freshwater Ecosystems,* **2**, 125-143.

ROWAN, J.S., CARWARDINE, J., DUCK, R.W., BRAGG, O.M., BLACK, A.R., CUTLER, M.E.J., SOUTAR, I. & BOON, P.J., 2006a. Development of a technique for Lake Habitat Survey (LHS) with applications for the European Union Water Framework Directive. *Aquatic Conservation: Marine and Freshwater Ecosystems,* **16**, 637-657.

SCOTTISH GOVERNMENT, 2009a. *The Scotland River Basin District (surface water typology, environmental standards, condition limits and groundwater threshold values) Directions 2009.*
Online at: http://www.scotland.gov.uk/Publications/2010/01/06141049/1

SCOTTISH GOVERNMENT, 2009b. *The Solway Tweed River Basin District (surface water typology, environmental standards, condition limits and groundwater threshold values) (Scotland) Directions 2009.*
Online at: http://www.scotland.gov.uk/Publications/2009/12/14130958/0

WILLBY, N., 2005. *Macrophyte inferred reference conditions and supporting chemistry for marl lakes.* Environment Agency Paper, WFD-UKTAG/Lakes Task Team, paper 91.

Appendix 1 Broad correspondence between UK standing water classifications

This includes associated NVC communities, Habitats Directive Annex I types and BAP Priority habitats. NB In most cases there are no exact equivalents under each heading for the standing water categories. The NVC types are indicative only, with much overlap.

WATER CATEGORY	GRAN ALKALINITY (μeq L^{-1})	COLOUR (mg Pt L^{-1})	PHASE 1	JNCC TYPES (1989)[1]	NI LOUGH GROUPS[2]	2006 JNCC TYPES[3]	NVC COMMUNITIES (Aquatic, Swamp, Mire)	HABITATS DIRECTIVE ANNEX I TYPE
Very high alkalinity (marl)	>1000	≤30	Standing water: marl G1.5	4, 5, 7, 10b	(VI), VIII, (XII), XV, XVI	I	Various, but especially **A** 8, 11 **S** 2, 3, 4	Hard oligo-mesotrophic with *Chara* spp. H3140
High alkalinity	>1000	≤30	Standing water: eutrophic G1.1	7, 8, 9, 10a, 10b	V, VI, VII, X, XI, XII, XIII, (XVI)	F, G, H, I	**A** 1, 2, 3, 5, 6, 8, 9a & b, 10, 11, 12, 15, 16, 19, 20 **S** 1-8, 10, 12-19, 22-24	Natural eutrophic lakes H3150
Moderate alkalinity	200 - 1000	≤30	Standing water: mesotrophic G1.2	4, 5	(V), (VII), VIII, IX, XIV, XVI	D, E	**A** 2, 3, 4, 7, 8, 9a, 9c, 10, 13, 15, 16, 19, 20 **S** 1-4, 6-12, 14, 17, 19, 22, 23	Oligotrophic to mesotrophic standing waters H3130 (part)
Low alkalinity	<200	≤30	Standing water: oligotrophic G1.3	2, 3	II, III, IV, VIII, IX	B, C1, C2, D, E	**A** 7, 9c, 14, 22, 23, 24 **S** 4, 9, 10, 19	Oligotrophic to mesotrophic standing waters H3130 (part); Oligotrophic waters of sandy plains H3110
Highly acidic (peat)	Not applicable	>30	Standing water: dystrophic G1.4	1	I, (IX)	A	**A** 24 **M** 1-3	Natural dystrophic lakes and ponds H3160

[1] Palmer (1989).
[2] Wolfe-Murphy *et al* (1992).
[3] Duigan *et al* (2006).

Appendix 2 Method for assessing standing water habitat features and vascular plant species features of interest

11.1 Biological monitoring of standing water habitats

The following standardised approach to biological monitoring of standing water habitats is recommended, based on literature review and the results of field trials in 2003/04 (Gunn *et al* 2004) and subsequent use of the method over the last decade. It is focused on a number of sectors of shoreline, rather than complete lake surveys.

11.2 Sampling strategy

11.2.1 Sectors

Each sector is 100 m in length. In most lakes four 100 m sectors are expected to give a representative sample. In large, complex water bodies (typically >100 ha in area), where many aquatic plant species are present, consideration should be given to increasing the number of sectors to (e.g.) six or eight, whereas in smaller water bodies <5 ha, two or three 100 m sectors may be sufficient to characterise the water body. Work at each sector involves a strandline and perimeter survey search, and a number of short transects, from shallow to deep water (a wader survey), and a single boat transect, from deeper water to shallow water (a boat survey).

11.2.2 Location of the sectors

i. Sectors should be located in areas where characteristic macrophyte communities, or species of interest, are likely to occur, i.e. selection of locations of sectors is not random.

ii. Where possible, the selection should be based on previous surveys. If macrophyte data are not available, locations should be chosen to represent the potential range of habitats or species at the site based on an initial reconnaissance.

iii. One habitat sector should normally be in the sheltered part of the shore, where plant fragments are likely to accumulate.

11.3 Water level

Lakes may fluctuate markedly in water level, especially if they are used as water supply reservoirs. As water level can significantly affect the results of the macrophyte survey (for example, the spatial location of wader transects), it is important that water level be recorded wherever possible. This may be accomplished by measuring against an existing gauging board, or by reference to a fixed structure or natural feature using a graded ranging pole or tape measure. A photograph showing the water level should be taken for future reference. If on the day of survey, water levels are obviously raised or lowered, survey should be postponed as results are unlikely to be comparable.

11.4 Survey method

A strandline survey, a wader survey and a boat survey should be carried out in each lake to be examined. Work should be undertaken in deeper water, using a boat, in order to assess deep water macrophyte communities/species, zonation and maximum depth of colonisation. Wader surveys are necessary to assess shallow water communities/species. **Except in a few cases, both a wader and a boat survey are necessary components of the CSM survey.**

GPS and NGR coordinates should be used to map sampling positions. These data should be supplemented with photos.

11.5 Strandline (perimeter) survey

Along the strandline of each 100m sector, presence / absence data should be recorded. The sector should be divided into five equal sections, and presence of species noted in each section as ‘S’ if washed up, and ‘G’ if growing at the water’s edge. The results of the strandline survey are not normally part of assessments of frequency of occurrence of species, or groups of species. However, they should be used when examining targets for presence of characteristic species. They may also be used if practical problems are encountered in undertaking wader or boat surveys.

11.5.1 Surveys in the lake

a) Survey using waders

The wader survey, for each 100 m sector, should include 20 quadrats (or sampling points), each covering an area of 1 m^2. Five transects from the shore to deeper water should be spaced at 20 m intervals, along the 100 m sector, and a sampling point surveyed at 0.25 m, 0.5 m, 0.75 m and >0.75 m depth on each transect. Quadrats should be used at 0.25 m, 0.5 m and 0.75 m depth. A bathyscope, and if necessary, a grapnel, should be used to examine the species present at each sampling point. In addition, a grapnel haul of 4 m length should be undertaken parallel to the shore, at 0.25 m, 0.5 m and 0.75 m depth. At >0.75 m depth, a 4 m grapnel haul should be taken at a direction perpendicular to the sector. A 4 m haul of a 25 cm wide grapnel covers 1 m^2. The positions of transects and sampling points, for each 100 m sector, are illustrated in Figure A2.1.

The following data should be recorded from the 1 m^2 sampling point and from the grapnel:

i. all species present
ii. an estimate of total vegetation abundance (scoring 0-3)
iii. an estimate of (non-charophyte) algal abundance (i.e. filamentous algae / blanket weed) (scoring 0-3).

The scoring for vegetation abundance should be assigned as follows:

0 absent (bare substrate)
1 <25% cover
2 25 - 75% cover
3 >75% cover.

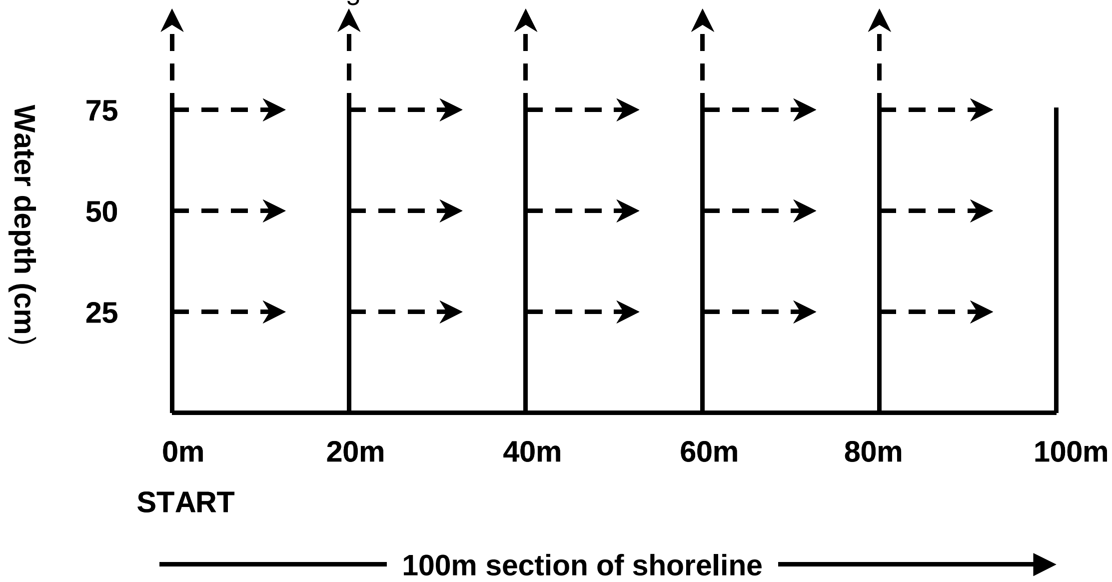

Figure 11.1 The location of transects and sampling points on each 100m sector (Gunn *et al* 2004).

b) Boat survey

Each boat transect should be located at the 50 m point on the 100 m sector. The transect should begin at the maximum depth of macrophyte colonisation. At each of 20 regularly spaced sampling points an area of lake bed of 1 m^2 should be examined, or if visibility is poor, a 4 m grapnel haul should be carried out. Sampling points should be evenly distributed across the range of depths covered by the boat transect. Where the lake bed slopes off very steeply, fewer points may be sampled, but at least 10 points must be sampled on all transects. Where the colonisation depth exceeds the maximum depth of the lake, transects should stop half way to the opposite shore.

At each sampling point, records should be made of the following:

- water depth
- all species present
- an estimate of total vegetation abundance (scoring 0-3)
- an estimate of (non-*Chara*) algal abundance (scoring 0-3).

The maximum depth of macrophyte colonisation should also be noted.

Adaptation of boat transect methods may be necessary to suit the characteristics of each lake. The chosen method should be recorded, so it is repeatable in future surveys.

11.6 General points

- The combination of 100m shore sectors with short, wader transects, plus 100m shore sectors with individual boat transects, should, in total, be no fewer than four, unless the lake is small and species-poor. Where necessary (e.g. large, rich sites), the number of wader transects per shore sector may be reduced in order to increase the number of sectors examined. However, there should be no fewer than three short transects per sector.

- Where a transition from freshwater to wetland interests has been documented on the citation, its presence at the time of survey should be checked.

- Records from the boat and shore-based wader survey should be pooled when looking at targets.

- Every effort should be made to ensure that characteristic species are included in the wader and boat transects. However, in cases where all characteristic species previously recorded in a lake have not been recorded in the sectors, it is **strongly recommended** that a further general 'sweep' of areas of the lake containing suitable habitat is carried out, to find the species or to increase the confidence in the assessment that the species have been lost.

11.7 Findings of field application

The above method (Gunn *et al* 2004), was designed to be cost-effective, practical and flexible, in response to different macrophyte communities, substrate types and accessibility, and was tested in a number of designated sites in England and Scotland. Following the first CSM field survey of Scottish lakes in 2004, the surveyors reported the following to be a practical strategy for characterising a site (Gunn *pers. comm*. 2005):

- Use of a combination of the three habitat survey methods, i.e. perimeter, boat transect and wader transects, to assess macrophyte attributes.
- Assessment of non-biological attributes, e.g. cut-down version of LHS, TP levels.
- Surveys generally comprised 2 - 3 perimeter and wader surveys.
- Limitation of surveys to 2 perimeter surveys for dystrophic pools.

In cases where it was not possible to carry out a wader or boat survey, e.g. dystrophic pools, the surveyors found it useful to use a 5-point scoring system for the perimeter survey, *i.e*. presence/absence data for growing species would be collected in each of the 20 m sections of the sector, to give frequency of occurrence scores up to a maximum score of 5 per perimeter survey. Stranded species contributed to the species list.

In practice, each site took an average of 2.5 days (surveying 3 sectors -1 day; data entry and sample sorting - 0.5 days; reporting 1 day).

However, the above observations were made in the context of the original target for macrophyte community composition, i.e. that characteristic species should be present at a higher frequency of occurrence than uncharacteristic species, and of limited resources. On analysis of results collected in the first cycle of CSM, this target was found to be insufficiently sensitive to indicate all sites that were in unfavourable condition. In response to this difficulty, there is now more emphasis on particular characteristic species in the targets. Although two well-placed sectors may be adequate to find all species in a species-poor system, at least four sectors are required to record the species present in richer lakes (Gunn *et al* 2004). It should be borne in mind also that it is not only recording the presence of certain species that is important, but the frequency of occurrence of those species. For meaningful comparisons of frequency of occurrence between sampling visits, it is important to maximise the number of presence/absence data points and therefore the number of sectors. In addition, as there is now more emphasis on particular species, some effort may be required in searching in areas not covered by the sectors, should individual characteristic species not be recorded within the sectors.

11.8 Vascular plant features and rare species as notified elements of the standing water feature of interest

The following standardised approach to monitoring of rare aquatic plants is recommended, based on literature review and results from field trials (Gunn *et al* 2004). The CSM guidance on vascular plants should also be consulted (see http://jncc.defra.gov.uk/page-2230).

Areas of lake bed that have been colonised by the species of interest should be located from earlier records, knowledge of each species' habitat requirements and use of appropriate viewing techniques, i.e. by wading, using a boat and bathyscope, snorkelling or SCUBA techniques. Depending on the size of the lake and the distances between areas of plant colonisation, clusters of plants may be regarded either as discrete populations, or as metapopulations of the complete population. In large sites, discrete populations may be defined as areas of plant colonisation that are at least 50 m apart. In lakes supporting more than one population of the species of interest, at least two populations should be examined.

Minimum and maximum depth of each population should be recorded. If a population extends to water deeper than the depth that can be sampled when using the wader method, this should be noted and, if possible, a boat should be used to cover the remainder of the population. Where a population extends beyond 100m in any direction, this should be recorded. In small water bodies, where there may be one large population, adjacent water bodies should be investigated for the presence of the species.

11.9 Survey method

11.9.1 Choice of survey method

The choice of survey method will depend on factors discussed above for habitat, but also on the rare species to be monitored. Species such as *Limosella aquatica*, *Pilularia globulifera*, *Potamogeton coloratus*, *Potamogeton filiformis*, *Elatine hydropiper* can typically be surveyed using the wader method. Examples of species usually growing in deeper waters and typically requiring a boat and/or snorkelling survey are: *Nuphar pumila*, *Potamogeton rutilus*, *Najas flexilis*, *Isoëtes echinospora*, *Elatine hexandra*. This list is a guide only, as some species, e.g. *Elatine hexandra*, have been found in deep or shallow water.

a) Survey using waders

For shallow water species, surveys can be undertaken using waders and bathyscopes, as described for boat/snorkelling surveys.

b) Boat/snorkelling survey

Where species distribution is too deep for wader survey, the minimum requirement should be that macrophytes are examined using a boat and bathyscope. Where resources allow, snorkelling should be considered as the favoured method of viewing submerged plants. In particular, snorkelling should be considered for SAC sites, at which slender naiad (*Najas flexilis*) is the feature. In highly turbid waters or sites where the plant of interest is in deeper water than can be adequately surveyed by snorkelling, SCUBA techniques should be considered.

Within each population, 20 x 1m^2 quadrats should be placed at random. Within each quadrat, the following should be recorded:

i. all species present
ii. abundance of each species recorded (scoring 1-3)
iii. proportion of quadrat with bare substrate (scoring 1-3)
iv. depth of sampling point
v. evidence of reproductive strategy (e.g. rhizomes, flowers).

The number of individual plants in each population should be estimated as 0-100, 101-300, 301-1000, 1001-3000, 3001-10000, >10000.

- Grid references for species records may be inaccurate, or imprecise.
- The source of species records for sites may be unclear.
- The target population may be very small and easily missed.
- It may be difficult to determine the extent of the target population.
- The timing of the survey is important in assessing species features.
- The habitat conditions at the time of survey must be taken into account.
- Additional sampling may be necessary if conditions are suboptimal for the species.

11.9.2 Notes

Use of a grapnel should be avoided in areas of colonisation of rare or protected species unless the water is turbid and the population of rare species is large. A licence must be obtained from the relevant conservation agency for work in lakes for which there are records of slender naiad (*Najas flexilis*) or floating water plantain (*Luronium natans*).

GPS and NGR coordinates should be used to map sampling positions. These data should be supplemented with photos if necessary.

11.10 Collection of information on non-biological attributes

11.10.1 Lake Habitat Survey (LHS)

Collection of data for non-biological attributes should be undertaken with reference to Lake Habitat Survey (LHS) methods (Rowan *et al* 2006b, 2008). The purpose of the LHS technique is to describe the hydromorphology of and pressures on lakes, in a consistent, systematic way. All records are made on the standard LHS form, so data may be used to calculate either a lake habitat modification score, or a lake habitat quality assessment.

LHS form:
http://www.sniffer.org.uk/files/8213/4183/7998/LHS_Field_Form_v4_2008_web.pdf
LHS field survey guidance manual:
http://www.epa.gov/nheerl/arm/documents/WFD42_fieldguide.pdf

The three elements to a full LHS survey are as follows:

i. the habplot
ii. the shoreline survey
iii. the reference site.

The habplot is 15 m wide, with length defined by the littoral, shore and riparian zones. For the purposes of LHS, the littoral zone section is the area between maximum wader depth (up to 10 m from the waterline) and the start of the shore zone. The shore zone is situated between the littoral and riparian zones. The riparian zone occupies the area from the top of the bank of the shore zone to 15m inland.

The shoreline survey is conducted between habplots, from a boat, or from an opposite shoreline. Observations are made, for example, on bank construction, land cover, landforms and pressures. In this way, information on habitats and pressures is recorded for the entire lake.

The reference site is situated at the deepest part of a lake. At this location, the following determinations are made: temperature and dissolved oxygen profiles, Secchi depth, pH and alkalinity. Observational information is also recorded on water quality, e.g. the presence of an algal bloom is noted.

While developing LHS, it was found that 8-10 habplots are required to characterise a lake (Rowan *et al* 2006a, b, 2008). Given the time requirements of the botanical survey methods, this survey effort is beyond the scope of CSM. For CSM, surveyors should undertake habplots at the locations of the sectors for the botanical surveys only. Whole lake shoreline observations should also be undertaken while carrying out the botanical surveys. Typically, it would not be expected that the reference site is visited during CSM, unless only a small number of sites are to be visited, and surveyors have access to a boat and equipment for measurement of physico-chemical variables.

Although this approach does not constitute an LHS survey, and will not normally result in collection of sufficient data to characterise an entire lake, it ensures consistency in recording and provides detailed information on the physical environment associated with each sector. In addition to allowing records to be taken with reference to the attributes in CSM, the LHS form also facilitates collection of useful background information on pressures. Examples of sections of the LHS form that are applicable to each CSM attribute are given in the relevant sections below.

11.10.2 Surface area

The surface area of a lake may be compared to a baseline map; aerial photographs may also be useful in this regard. However, allowances may be made for natural succession. It is intended that examination of this attribute will indicate changes in available freshwater habitat, so evidence of activities such as sediment extraction and in-lake construction should be sought.

The LHS form will facilitate recording of data relevant to this attribute (e.g. section 4, Hydrology).

11.10.3 Water quality

As with botanical surveys, specialists are required for reliable water sampling and analyses. Sampling vessels should be of appropriate materials and should have undergone an adequate treatment, cleaning and rinsing regime, with reference to the determinants to be measured. For example, containers for samples for TP analysis should be of glass, or polyethylene treated with iodine. The importance of these factors should not be underestimated. In low level nutrient analysis, the accuracy, precision and limit of detection are compromised easily by inadequate cleaning or inappropriate containment.

The timing and location of sampling points are extremely important in collecting representative samples. In order to obtain useful water quality results, monthly, or at least quarterly, water sampling is recommended. If only one sampling visit is possible, this should take place early in spring. Nutrient concentrations determined at this time of year represent the total available for algal growth, before increased biological activity, and after the previous year's inputs have been assimilated, at a time when the water column is fully mixed. The results from spring samples may be compared from year to year. In low nutrient waters, little change would be expected in nutrient levels throughout the year. However, in richer systems, in summer, TP and N levels may be influenced by sediment processes and uptake by algal cells. Consequently, it may be difficult to compare the results of summer sampling between years, unless several samples have been taken throughout the summer. At the time of a single summer sampling visit, algal biomass may be at its peak, but conversely the sampling may coincide with the clear-water period. Timing of water sampling should be considered further, e.g. the sample may not be representative of the lake during high winds, as there may be considerable resuspension of sediment in shallow basins.

With regard to sampling location, sampling from the water's edge is likely to generate unrepresentative results. Sampling from the outflow may generate spurious results, due to incomplete mixing of the lake, localised increased sedimentation, or resuspension, proximity of the sampling location to lake sediment, and localised build-up of algal biomass. Water samples should be taken from several locations and depths, from surface to deep water, and sampling points should include the deepest part of the lake. During full surveys of lakes, temperature and dissolved oxygen profiles should be recorded, from surface to deep water, at each sampling site. However, despite the advantages of sampling within lakes, restriction of resources, or access, may necessitate outflow sampling.

Samples should be kept cold (4°C) and dark until processing is carried out. Processing should be undertaken as soon as possible after sampling, on the same day as collection. Water samples should not be stored with other samples of high nutrient content (e.g. sediments). With regard to analytical quality assurance, the laboratory should use techniques that are consistent with HMSO Blue Book methods (The Standing Committee of Analysts) and should have high standards of accuracy and precision, good sensitivity, and in the case of TP, preferably a limit of detection of 1.0 μg P L^{-1}. Measurement of pH should be undertaken in the laboratory, with a calibrated, robust and accurate bench-top meter and probe. Alkalinity should be measured by titration of the sample with 0.01M hydrochloric acid, to a pH 4.5 end point, using an indicator solution. Results should be expressed in meq L^{-1}. Material for chlorophyll *a* analysis should be obtained by filtration of water samples, using GF/C filter papers. Chlorophyll *a* should then be measured following implementation of a methanol extraction method. The filtrate can be used for analysis of dissolved P and N fractions.

Collection and analysis of water samples to obtain meaningful results may be beyond the scope of CSM. However, it is mandatory to consider water quality in condition assessment. It may be possible to obtain data on a number of sites from the statutory environment agency. Where no sampling regime exists, it is recommended that the possibility of future sampling is discussed with the appropriate environment agency. When data are not available, observations should be noted on whether there is an algal bloom in the lake. If possible, the dominant species in the bloom should be identified. Blooms of blue-green algae may suggest that TP levels have increased, while blooms of green algae may indicate a higher TP concentration than those of blue-green algae.

Where access to open water is possible, temperature and dissolved oxygen profiles, and Secchi depth should be measured in the deepest part of the lake. However, interpretation of Secchi data, in terms of water quality, should be undertaken with caution, as water transparency is influenced by factors other than increased algal biomass, e.g. water colour. For measurement of temperature and dissolved oxygen, a combined temperature/oxygen probe must be attached to the meter, by sufficient cable to allow measurements from surface to deep water. Before use, the instrument must be calibrated using appropriate temperature/dissolved oxygen tables. When taking measurements with the Mackereth type of probe, either a mixer device should be used, or the probe should be continually agitated. DO and temperature readings may be plotted against depth, to illustrate the degree of mixing or stratification within the water column. Secchi depth is determined using the black and white Secchi disc on a measured rope. On lowering the disc into the water, Secchi depth is that at which the disc can no longer be seen.

Information on water quality may be recorded using the LHS form, e.g. LHS form section 2.4 (Littoral Zone) and section 5 (Reference site).

11.10.4 Hydrology

Owing to natural variability in lake water levels and inflow/outflow rates, ideally long-term monitoring data should be used when considering this attribute. However, such data are often unavailable. It is, therefore, likely that it will be necessary to base the assessment of this attribute on observational data. Information should be collected in accordance with LHS methods (e.g. LHS form, section 4, Hydrology). When visiting the site, it should be borne in mind that the following hydrological variables all constitute elements of the extent and quality of habitat: surface area, mean and maximum depth, volume, residence time/flushing rate. Evidence to suggest that there has been a change in hydrology includes lack of marginal vegetation, ‘stranded’ littoral vegetation, exposed littoral sediments, a clear distinction between the physical lip of the basin and the extent of the water in the lake. In interpreting this evidence, it is important to consider both the timing of the site visit and natural fluctuations in water levels. If possible, observations should be noted several times within the year.

11.10.5 Substrate and sedimentation

Sedimentation rates may be examined through collection of cores, or use of sediment traps. Sampling of sediment would allow work on the particle size distribution (e.g. through use of sieving techniques, coulter counter analysis), organic content (e.g. through loss on ignition) and nutrient concentrations (e.g. through use of acid digestion, followed by colorimetric techniques, or use of C/H/N analyser). Collection of data on suspended solids concentrations and flow rates of lake inflows allows calculation of sediment loadings.

Detailed examination of substrate and sedimentation is unlikely to be possible within the constraints of CSM. Projects running at other institutions may involve collection of such data, in individual drainage basins, or sub-catchment areas. It is recommended that the relevant institutions are requested for information.

If it is not possible to follow a detailed monitoring programme for these aspects of the lake environment, observations should be made, ideally several times within the year. Information should be collected in a manner consistent with LHS methods (e.g. LHS form sections 2.2 shore zone, 2.4 littoral zone, 3.2 whole lake pressures, and 3.3 landform features). Obvious erosional features proximate to inflow waters and the lake itself should be recorded. Notes should be taken on evident contraventions of appropriate pollution prevention codes, which may be causing increased soil losses within the catchment. Evidence should be gathered from visual assessment of the lake's substrate, e.g. smothering of course substrate with fine material, build-up of leaf litter on mineral sediments.

11.11 Equipment

Equipment required for shore-based monitoring of macrophytes includes the following:

- lifejackets
- waders
- latex gloves
- bathyscope with rope and belt clip
- wading pole marked at 25 cm intervals
- grapnel and 10 m rope
- quadrat
- 1 m rule
- sample containers
- polaroid sunglasses
- GPS
- site map
- recording forms
- strong resealable plastic bags for macrophyte samples
- sterilin tubes for charophyte samples, with IMS preservative
- blotting paper and folder for pressing specimens
- identification floras
- waterproof pen
- pen-knife
- camera

If survey in deeper water is intended, the following will also be required:

- boat
- marker buoys
- weight
- anchor
- rope
- survey pole
- Eckman grab
- Secchi disc
- handheld echo sounder
- spare batteries
- handheld compass
- dissolved oxygen / temperature meter and probe with 20 m cable
- SCUBA or snorkelling equipment, as needed.

The following biosecurity equipment will be required:

- disinfectant e.g. 1:100 solution of Virkon Aquatic
- buckets for disinfection
- scrubbing brushes
- access to jet wash for thorough physical removal of plant fragments

Surveyors should ensure that all equipment required under health and safety regulations is included.

For biosecurity purposes, all equipment must be thoroughly cleaned and disinfected or dried before moving to the next site. It may be necessary to have more than one set of equipment if one set is quarantined.