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Conservation Objectives for Oligotrophic and Dystrophic Lake Types

Report to English Nature

Contract No. EIT 20/23/01

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Conservation Objectives for Oligotrophic and Dystrophic lake Types

Oligotrophic waters containing very few minerals of Atlantic sandy plains with amphibious vegetation: *Lobelia, Littorella* and *Isoetes*

Oligotrophic to mesotrophic standing waters of plains to subalpine levels of the Continental and Alpine Region and mountain areas of other regions with amphibious vegetation belonging to *Littorelletae uniflorae* and/or *Isoeto-Nanojuncetea*

Dystrophic lakes

A report to English Nature on
Contract No: EIT 20/23/01
October 1999

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Contract Objectives

- To summarise currently available information on conservation requirements of the following three freshwater habitats (from Annex 2 of the EC Habitats Directive):

1. Oligotrophic waters containing very few minerals of Atlantic sandy plains with amphibious vegetation: *Lobelia, Littorella* and *Isoetes*

2. Oligotrophic to mesotrophic standing waters of plains to subalpine levels of the Continental and Alpine Region and mountain areas of other regions with amphibious vegetation belonging to *Littorelletae uniflorae* and/or *Isoeto-Nanojuncetea*

3. Dystrophic lakes

- To define conservation objectives based on the requirements of the habitat, outlining:

1. Favourable conditions
2. Attributes (physical, chemical and biological parameters that define favourable condition)
3. Targets (Acceptable range for each attribute)

- To assess current monitoring of listed attributes and targets

- To identify modifications, or additions, to existing baseline monitoring

22.11 x 22.31 Oligotrophic waters containing very few minerals of Atlantic sandy plains with amphibious vegetation: *Lobelia, Littorella* and *Isoetes*

SAC Sites

Southern: Oak Mere, The New Forest (Hatchet Pond)
Northern: South Uist Machair

Notes to accompany summary table of conservation objectives (Table 1)

Community

This community is rare in the UK and has declined greatly in many parts of Europe (Arts *et al.*, 1990). The associate species, *Lobelia dortmanna* and *Isoetes* spp. (*I. lacustris* and *I. echinospora*), are currently only present in UK lowlands in the lochs on South Uist. These two species are thought to have been lost through eutrophication from the few southern lowland sites for which there are historical records, for example Bomere Pool in Shropshire (Sinker *et al.*, 1985). In other parts of Europe these species have been lost through acidification in combination with eutrophication (Roelofs, 1983).

The southern UK SAC sites have fairly exposed sandy substrates favouring the dominance of *L. uniflora* over *L. dortmanna* in shallow waters (Rodwell, 1995). Chris Newbold recorded *I. lacustris* at Oak Mere, whether it remains needs further investigation.

Water quality

Full detailed chemistry data of the lowland sites only exists for Oak Mere (Carvalho, 1993). Limited data is also available for the South Uist SAC sites (Spence 1967; Spence *et al.*, 1979). Because of this limited dataset no exact targets are provided in defining favourable conditions.

At any one site several variables combined may represent favourable conditions, whilst other parameters may be less important. For example, lowland sites in Outer Hebrides may not necessarily be acidic, but may represent favourable conditions because of the low nutrient concentrations and sandy substrate. Lowland sites in southern UK have higher total phosphorus concentrations (Oak Mere: 61 μg/l annual mean), but their low pH and sandy substrate restricts other macrophytic vegetation. A low pH (<7) and low total phosphorus concentration (<20 μg/l) combined would, therefore, hypothetically represent favourable conditions. Targets should be set for these two parameters to not increase and preferably to be reduced towards favourable conditions.

Current monitoring

The Environment Agency and landowners carry out monitoring of pH and water level informally at Oak Mere.

Hatchet Pond and South Uist sites require much more baseline chemistry data. No chemical data whatsoever are available for Hatchet Pond.

Future Monitoring of listed attributes and targets

Mid-summer macrophyte surveys should be carried out at all SAC sites every two years (annual sampling may be too destructive and less frequent sampling would not pick up trends within the six-year reporting period of the Habitats Directive). Complete site surveys, using standard JNCC methodologies, should be carried out to obtain a full site species list with coarse estimates of relative abundance (DAFOR scale). These methods, however, provide scant information on declines or improvements in populations of interest. Additionally, surveys should be carried out along selected depth transects that span the populations of interest, to provide detailed data on declines/increases and improve understanding of regulating factors. Transect sampling should be based on the Environmental Change Network protocols (Sykes *et al.*, 1999): Record species abundance (% cover) in samples at 5m intervals from the shore along a minimum of three re-locatable transects (additional samples should be taken along transects where the depth gradient is irregular or steep). Shallow water samples should be measured visually using quadrats and a bathyscope to minimise disturbance.

Deeper water samples should combine two Eckman grab samples. Substrate type and organic content of sediment (LOI) should also be recorded along vegetation transects.

In addition to vegetation monitoring, the following environmental variables should be measured: water level against a fixed datum, pH, conductivity, total phosphorus (TP), dissolved inorganic nitrogen (DIN), dissolved organic carbon (DOC). Monitoring should be carried out bi-monthly, every year. This higher frequency of water chemistry monitoring is required to obtain accurate representation of annual mean values to compare with the proposed water quality targets.

Because of its role in the loss of this habitat from mainland Europe, local monitoring of atmospheric acid deposition, particularly forms of nitrogen, should be considered.

22.12 + (22.31 & 22.32): Oligotrophic to mesotrophic standing waters of plains to subalpine levels of the Continental and Alpine Region and mountain areas of other regions with amphibious vegetation belonging to *Littorelletae uniflorae* and/or *Isoeto-Nanojuncetea*

SAC Sites

Sites selected to include representatives from each of the main mountain areas in the UK:
Cairngorms
Snowdonia
Llyn Cwellyn
Lough Melvin
Wast Water
River Derwent and Bassenthwaite Lake

Notes to accompany summary table of conservation objectives (Table 2)

Community occurence

This type of water body is relatively abundant in the main mountain areas of the UK. Sites tend to be larger, deeper and have more rocky littorals than their lowland counterparts on Atlantic sandy plains. Bassenthwaite Lake constitutes a more enriched mesotrophic site. *L. dortmanna* and *J. bulbosus* are absent from the site whilst it has a richer assemblage of pondweeds and other elodeid species.

Water quality

Data are annual means based on quarterly samples of upland oligotrophic lakes in ECRC database that contain *L. uniflora*, *L. dortmanna* and *I. lacustris* (see Table 4). Data collected on behalf of the Acid Waters Monitoring Network (AWMN) and the Countryside Council for Wales (CCW) Lake Classification Contract (Allott & Monteith, 1999; Duigan *et al.* 1998). CCW data: single plant survey and quarterly chemistry for 1 year. Includes Llyn Cwellyn and Llyn Idwal.
AWMN data: quarterly chemistry and annual macrophytes since 1988. Includes *Littorella/Lobelia/Isoetes* association sites in Snowdonia (Llyn Llagi) and close to Cairngorms (Lochnagar in Grampians). Additional sites on database containing this association include Cumbrian Lake District (Scoat Tarn & Burnmoor Tarn), Llyn Cwm Mynach (N. Wales), Coire nan Arr (NW Scotland), Lochs Chon & Tinker (Trossachs), Round Loch of Glenhead & Loch Grannoch (Galloway) and Blue Lough, Northern Ireland.

Current monitoring

Quarterly chemistry (excluding total phosphorus) and annual macrophytes in Llyn Llagi Snowdonia as part of the Acid Waters Monitoring Network.
Palaeolimnological investigations show that several sites in the Cairngorms have been acidified since 1900 (Jones *et al.*, 1993).

Future monitoring of listed attributes and targets

Mid-summer macrophyte surveys should be carried out at all SAC sites every two years (annual sampling may be too destructive and less frequent sampling would not pick up trends within the six-year reporting period of the Habitats Directive). Complete site surveys, using standard JNCC methodologies, should be carried out to obtain a full site species list with coarse estimates of relative abundance (DAFOR scale). These methods, however, provide scant information on declines or improvements in populations of interest. Additionally, surveys should be carried out along selected depth transects that span the populations of interest, to provide detailed data on declines/increases and improve understanding of regulating factors. Transect sampling should be based on the Environmental Change Network protocols (Sykes *et al.*, 1999): Record species abundance (% cover) in samples at 5m intervals from the shore along a minimum of three re-locatable transects (additional samples should be taken along transects where the depth gradient is irregular or steep). Shallow water samples should be measured visually using quadrats and a bathyscope to minimise disturbance.

Deeper water samples should combine two Eckman grab samples. Substrate type and organic content of sediment (LOI) should also be recorded along vegetation transects.

In addition to vegetation monitoring, the following environmental variables should be measured: water level against a fixed datum, pH, conductivity, total phosphorus (TP), dissolved inorganic nitrogen (DIN), dissolved organic carbon (DOC). Monitoring should be carried out bi-monthly, every year. This higher frequency of water chemistry monitoring is required to obtain accurate representation of annual mean values to compare with the proposed water quality targets.

Because of its role in the loss of this habitat from mainland Europe, local monitoring of atmospheric acid deposition, particularly forms of nitrogen, should be considered.

Additional Information on Isoetid Communities in Oligotrophic Lakes: Lowland sandy plains and upland mountain regions

Occurrence

Littorella uniflora, *Lobelia dortmanna* and species of *Isoetes* are characteristic of acid, oligotrophic lakes concentrated to the north and west of the UK. *L. uniflora* and *L.dortmanna* co-occur in the shallow waters, with *L.uniflora* more dominant in shallow, exposed waters with *L. dortmanna* replacing it in more sheltered, often slightly deeper water (Rodwell, 1995). In upland lakes, where stony substrates extend into deeper waters, the *Littorella-Lobelia* community is replaced by *Isoetes* (Spence, 1964). Detailed discussion of community changes along a number of environmental gradients (nutrients, dystrophy) are described further in Rodwell (1995).

Growth-form and physiology

All three are species of rosette growth form. Their ability to maintain growth in these conditions in spite of low concentrations of dissolved inorganic carbon in the water column is due to a number of factors (Madsen & Sand-Jensen, 1991):

- Their ability to exploit sediment sources of CO_2. These species all have extensive lacunae along longitudinal channels from the roots to the leaves, providing an effective transport route for sediment-derived CO_2.
- Their low relative growth rates.
- The larger proportion of root to shoot biomass enhances the absorptive surface for dissolved gases and nutrients.
- They all possess crassulacean acid metabolism (CAM) which allows them to efficiently concentrate CO_2 at night and utilise it during periods of carbon-limitation during the day (Keeley, 1998).
- Their rosette growth form ensures a short distance for gas and nutrient transport from roots to leaves.

Their inability to thrive in alkaline lakes is thought to be due to competition from faster growth rate plants (typically elodeid form) which are able to utilise bicarbonate. Isoetids can develop in alkaline lakes when heavy turbulence and coarse sediments exclude elodeids (Seddon, 1965). The occurrence of *L. uniflora* in Mere Mere, Cheshire illustrates this potential. Alkaline lakes generally have more enriched sediments and water column and isoetids decline through competition with elodeids and through epiphyte shading.

Substrate

Lobelia can grow on a wide range of substrates including organic silts and submerged peats, but is most typical of sand, gravel or rock low in organic matter (Spence, 1964). Pearsall (1921) described how in the Cumbrian Lake District it was more abundant in stony sites and was often replaced by *L. uniflora* in sites with higher organic contents. Some evidence suggests that *Lobelia* is intolerant of organic enrichment as reduced oxygen conditions in sediment create Fe/Mn plaques that bind the available phosphorus (Christensen & Sand-Jensen, 1998).

Lowland sites: Lake Kalgaard, Denmark LOI <5 % (Sand-Jensen & Søndergaard, 1979)

Temperature, altitude and latitude

Lobelia is recorded in the UK from sea level in the South Uists to 745 m at Llyn Bach. It has latitudinal limits of 68° 9′ N in Europe (Preston & Croft, 1997).

Littorella is more tolerant of colder climates, and is recorded at altitudes between 0-825 m a.s.l. (Preston & Croft 1997). It also appears to tolerate freezing conditions over winter if exposed (Oak Mere) so its shallow depth limit is unaffected.

Isoetes is frequent in Europe north of 53° N and also has high altitude records from the Spanish Pyrenees at 2120m a.s.l. (Vöge, 1997a; 1997b)

The current absence of *Lobelia* and *Isoetes* in southerly lowland UK sites appears to be due to their loss from the few potential acid, oligotrophic sites, following enrichment. Their much slower growth rates and lesser tolerance to organic soils, compared with *Littorella*, results in them being outcompeted or too stressed to survive. There is, however, a close correlation between the southern limit of *L. dortmanna* and the 17 °C July isotherm, but the reasons for this are unknown (Farmer, 1989).

Water level fluctuations and Depth

Littorella uniflora is very tolerant of changing water levels and exposure. It is particularly dominant in shallow, exposed waters (Rodwell, 1995)

Lobelia can tolerate short periods of emersion but is generally intolerant of desiccation (Farmer, 1989) which may limit its distribution in shallow waters at sites of fluctuating water levels. *L. dortmanna* is frequently more abundant than *Littorella* in more sheltered, deeper water (Rodwell, 1995).

Littorella and *Lobelia* have a higher photosynthetic capacity at high light levels than *Isoetes* so are more competitive in shallower depths. Their dark respiration rate is, however, higher than *Isoetes*, requiring certain levels of light to support respiratory demand. They are, therefore, limited by light in deeper waters (Sand-Jensen & Søndergaard, 1979). The two species co-exist between 0-2.5 m water depth.

Isoetes has a low dark respiration rate so can tolerate very low light climates (and hence deeper waters or waters with higher DOC concentrations). It has been recorded in Wast Water at depths of 7 m (Bennion *et al.*, 1997). It is, however, very sensitive to wave action, setting a shallow depth limit particularly in exposed sites.

Lowland sites: *L. uniflora* and *L. dortmanna* dominant in depths <1.5 m, *Isoetes* dominant >1.5 m (Spence, 1967). *L. uniflora* recorded 50 cm above water surface at Oak Mere (Carvalho, 1993); Lake Kalgaard, Denmark *Littorella* dominates 0-2.0m, *Isoetes* dominates from 2.0-4.5m (Sand-Jensen & Søndergaard, 1979).

DOC & light

Isoetes can tolerate lower light levels but the number of leaves and spores decline with increasing colour of the water leading to their absence in typical dystrophic lakes (Vöge, 1997a). *L. uniflora* and *L. dortmanna* are more likely limited by associated pH changes, rather than light levels, as DOC increases in dystrophic lakes. Their depth limits will certainly be narrower in higher DOC lakes.

Lowland sites: Lake Kalgaard, Denmark TOC 0.03-0.10 mM (Sand-Jensen & Søndergaard, 1979).

Upland sites: CCW lakes (includes Cwellyn and Llyn Idwal) DOC <5 mg/l (Allott & Monteith, 1999)

pH and Acidification

All three plants are typically found in acid waters, although summer pH values can exceed 7.0. They are adapted to acid, low free-CO_2 environments as they utilise sedimentary sources of CO_2 and are CAM plants so can store and recycle CO_2 produced at night. They lose their competitive advantage when pH is higher and CO_2 becomes less limiting.

The plants decline in abundance in very acid waters (below 4.5) due to competitive effects of epiphytes (Lazarek, 1986), *J. bulbosus* and/or *Sphagnum* species (Roelofs 1983), or through a decline in sedimentary CO_2. *J. bulbosus* is very tolerant of acid environments and is present in acid mine-drainage lakes at pH <3. Because of its faster growth rate, *J. bulbosus* is particularly competitive in shallow waters when acidification associated with ammonium ions occurs, as has occurred in many sites in the Netherlands (Arts *et al.*, 1990; Roelofs 1983; Roelofs *et al.*, 1984). Liming of acidified lakes has also led to the development of dense stands of *J. bulbosus* and suppression of *L. uniflora* and *L. dortmanna* (Roelofs *et al.*, 1994).

Lowland sites: Oak Mere 4.6-6.9 (Carvalho, 1993); Lake Kalgaard, Denmark 6.5-8.2 (Sand-Jensen & Søndergaard, 1979)

Upland sites: CCW (includes Cwellyn and Idwal) pH <6.7 (Allott & Monteith, 1999)

Eutrophication

All three plants prefer oligotrophic waters. Eutrophication is thought to be responsible for their loss from sites in the UK (Sinker *et al.*, 1985) and mainland Europe (Arts *et al.*, 1990). They can tolerate both lower nutrient concentrations in sediments and water column because of their slow growth rates and nutrient acquisition mechanisms (Oxygen-rich root environment aids phosphorus availability). If enrichment of the sediment occurs, more competitive, faster growing, elodeid forms are able to dominate (e.g. *Myriophyllum alterniflorum*) (Roelofs, 1983). If further enrichment of the water column occurs, plankton blooms and epiphyte-shading cause declines.

I. lacustris and *L. dortmanna* have been lost from several lowland UK sites (and many lowland Dutch sites) Bomere Pool in Shropshire is one such site where eutrophication is highlighted as the primary cause of this loss (Sinker *et al.*, 1985).

L. uniflora is more tolerant of enrichment than *L. dortmanna* (Farmer & Spence, 1987). Its faster rate of spread by vegetative stolons allows it to maintain dominance in shallow, exposed environments (e.g. Mere Mere population)

Lowland sites: Oak Mere: annual mean TP 61 µg/l, annual mean DIN 0.33 mg/l, annual mean chl. a 7 µg/l (Carvalho, 1993)

Upland sites: CCW lakes (includes Cwellyn and Idwal): TP <20 µg/l, chl. a <3 µg/l (Allott & Monteith, 1999); Wast Water TP <10 µg/l and Bassenthwaite TP 25 µg/l (Bennion *et al.*, 1997).

Restoration

Restoration of lowland sites from the effects of eutrophication may prove difficult. Restoration would require strict control of nutrient loading from the catchment, including diffuse sources of pollution. Additionally a low pH (6-7) and littoral sediments of sand and gravel are required for successful establishment.

Feature: **22.14 Dystrophic lakes**
Scope: Dystrophic water bodies on blanket or raised bog systems

SAC Sites

Caithness and Sutherland peatlands, Rannoch Moor, West Midlands Mosses (Abbotts Moss & Clarepool Moss)

Notes to accompany summary table of conservation objectives (Table 3)

Occurrence of community

The lake type is characterised by heavily stained "brown-water" lakes and pools on blanket or raised bog systems. Widespread in northwest regions on blanket bog systems, scarce in lowland regions on raised bog systems.

SAC sites have been selected to include representatives from both upland and lowland regions containing relatively large examples of the habitat type

Water quality

Water quality data is virtually non-existent for the SAC sites and very limited for other sites in the wider literature. An abundance of dissolved humic compounds and a low pH are characteristic as they restrict bacterial metabolism, maintaining the dystrophic state. Clarepool Moss (West Midlands Mosses SAC) is unusual as a dystrophic water body in that it has a relatively base-rich water quality and higher pH (5.4 recorded by Gorham in 1955) due to greater water and nutrient inputs from groundwater sources.

Monitoring of listed attributes and targets

No regular vegetation or chemistry monitoring is carried out. All sites require much more baseline data.

Mid-summer macrophyte surveys should be carried out at all SAC sites every two years (annual sampling may be too destructive and less frequent sampling would not pick up trends within the six-year reporting period of the Habitats Directive). Complete site surveys, using standard JNCC methodologies, should be carried out to obtain a full site species list with coarse estimates of relative abundance (DAFOR scale). These methods, however, provide scant information on declines or improvements in populations of interest. Additionally, surveys should be carried out along selected depth transects that span the populations of interest, to provide detailed data on declines/increases and improve understanding of regulating factors. Transect sampling should be based on the Environmental Change Network protocols (Sykes *et al.*, 1999): Record species abundance (% cover) in samples at 5m intervals from the shore along a minimum of three re-locatable transects (additional samples should be taken along transects where the depth gradient is irregular or steep). Shallow water samples should be measured visually using quadrats and a bathyscope to minimise disturbance. Deeper water samples should combine two Eckman grab samples. Substrate type and organic content of sediment (LOI) should also be recorded along vegetation transects.

In addition to vegetation monitoring, the following environmental variables should be measured: water level against a fixed datum, pH, conductivity, total phosphorus (TP), dissolved inorganic nitrogen (DIN), dissolved organic carbon (DOC). Monitoring should be carried out bi-monthly, every year. This higher frequency of water chemistry monitoring is required to obtain accurate representation of annual mean values to compare with the proposed water quality targets.

Because of its role in the loss of this habitat from mainland Europe, local monitoring of atmospheric acid deposition, particularly forms of nitrogen, should be considered.

A detailed understanding of site hydrology is also strongly recommended.

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Table 1: Summary table of conservation objectives: oligotrophic waters containing very few minerals of Atlantic sandy plains with amphibious vegetation: *Lobelia, Littorella* and *Isoetes*

Feature	Community
22.11 x 22.31 Oligotrophic waters containing very few minerals of Atlantic sandy plains with amphibious vegetation: *Lobelia, Littorella* and *Isoetes*	Lowland oligotrophic lakes on Atlantic sandy plains: Lowland lakes with sandy littoral substrates dominated by shoreweed, *Littorella uniflora*. This is the only constant species. Common associates are water lobelia, *Lobelia dortmanna*, also in shallow water and the quillworts (*Isoetes lacustris* and *I. echinospora*) in deeper water.

Conservation objective: maintain favourable conditions to support the characteristic species of interest. Favourable condition is achieved when the following criteria are met:

Attribute	Target	Measure	Comment
Extent of cover	Selected areas of shoreline with >30 % cover *L. uniflora* or *L. dortmanna* and low % cover of *Juncus bulbosus* Selected areas in deep water with >75 % cover of *Isoetes* spp. (Spence, 1967)	Survey selected transects in summer as outlined in notes	Baseline survey required to identify transects in most favourable condition (highest % cover) to be monitored for deterioration and transects of low % cover to check for improvements.
Water quality	Acid, oligotrophic conditions (see notes): pH: <7 Total Phosphorus: low	Monitor as outlined in notes	Minimise diffuse and point sources of pollution from catchment. Support reductions in atmospheric acid deposition, particularly forms of nitrogen. High % cover of *Juncus bulbosus* and/or *Sphagnum* species in acid waters indicates less than favourable conditions as does a high % cover of elodeid vegetation (e.g. *Myriophyllum*) in eutrophic waters
Littoral Substrate	Typically sand, gravel or stones. Low organic content, <5 % loss on ignition (Sand-Jensen & Søndergaard, 1979)	Monitor as outlined in notes	Protect against catchment erosion and sediment accumulation.
Water depth	*L. uniflora* and *L. dortmanna* dominant in depths <1.5 m; *Isoetes* dominant >1.5 m (Spence, 1967) *L. uniflora* recorded up to 50 cm above water surface during periods of low water level (Carvalho, 1993) *L. uniflora* can tolerate extreme inter-annual fluctuations in water level and long periods of exposure. *L. dortmanna* is tolerant of short periods of exposure but intolerant of desiccation	Record depth range along selected transects Monitor water level	Ensure fluctuations in water level associated with natural climatic variability and not enhanced by impoundment or abstraction within the catchment.

Table 2: Summary table of conservation objectives: Oligotrophic to mesotrophic standing waters of plains to sub-alpine levels of the Continental and Alpine Region and mountain areas of other regions with amphibious vegetation belonging to *Littorelletae uniflorae* and/or *Isoeto-Nanojuncetea*

Feature	**Community**
22.12 + (22.31 & 22.32) Oligotrophic to mesotrophic standing waters of plains to sub-alpine levels of the Continental and Alpine Region and mountain areas of other regions with amphibious vegetation belonging to *Littorelletae uniflorae* and/or *Isoeto-Nanojuncetea*	Oligotrophic to mesotrophic lakes in mountain areas of the UK with *Littorella* and *Isoetes*: Characterised by isoetid vegetation. Shoreweed, *Littorella uniflora* in shallow waters and the quillworts (*Isoetes lacustris* and *I. echinospora*) in deeper waters are constant species. Water lobelia *Lobelia dortmanna*, bulbous rush *Juncus bulbosus*, bog pondweed *Potamogeton polygonifolius*, needle spike-rush *Eleocharis acicularis*, alternate water-milfoil *Myriophyllum alterniflorum* and floating bur-reed *Sparganium angustifolium* are common associates. Floating water-plantain *Luronium natans* and pillwort *Pilularia globulifera*, two nationally scarce plants also occur in this community.

Conservation objective: maintain favourable conditions to support the characteristic species of interest. Favourable condition is achieved when the following criteria are met:

Attribute	**Target**	**Measure**	**Comment**
Extent of cover	Selected areas of shoreline with >30 % cover *L. uniflora* or *L. dortmanna* and low % cover of *J. bulbosus*. Selected areas in deep water with >75 % cover of *Isoetes* spp.	Survey transects in summer as outlined in notes	Baseline survey required to identify transects in most favourable condition (highest % cover) to be monitored for deterioration and transects of low % cover to check for improvements.
Water quality	Acid, oligotrophic conditions: pH <7 Total Phosphorus <20 µg/l Dissolved Organic Carbon <6 mg/l	Monitor as outlined in notes	Support reductions in atmospheric acid deposition, particularly forms of nitrogen. Minimise diffuse pollution from catchment. High % cover of *Juncus bulbosus* and/or *Sphagnum* species in acid waters indicates less than favourable conditions as does a high % cover of elodeid vegetation (e.g. *Myriophyllum*) in eutrophic waters
Littoral Substrate	Typically sand, gravel, stones and boulders Low organic content, sometimes locally high peat content.	Monitor as outlined in notes	Protect against catchment erosion and sediment accumulation.
Water depth	*L. uniflora* and *L. dortmanna* dominant in depths <1.5 m; *Isoetes* dominant >1.5 m. *L. uniflora* can tolerate extreme inter-annual fluctuations in water level and long periods of exposure. *L. dortmanna* is tolerant of short periods of exposure but intolerant of desiccation	Record depth range along transects Monitor water level	Minimise water level changes from abstraction or impoundment.

Table 3: Summary table of conservation objectives: dystrophic lakes

Feature	**Community**
22.14 Dystrophic lakes	Dystrophic water bodies on blanket or raised bog systems: Heavily stained "brown-water" lakes and pools on blanket or raised bog systems. These water bodies are all characterised by a high loading of humic organic matter. Floating-leaved lilies (*Nymphaea alba* and *Nuphar lutea*), bogbean (*Menyanthes trifoliata*) and marsh St John's-wort (*Hypericum elodes*) may be abundant around the margins. A notable type of dystrophic lake is the transition mire, or quaking bog, which is characterised by an advancing floating raft of *Sphagnum* around the margin, often containing *Eriophorum angustifolium*. Submerged vegetation is absent in extreme dystrophic systems. *Juncus bulbosus* and *Sphagnum auriculatum* can dominate sites with lower DOC values. *Potamogeton polygonifolius* may also be fairly common, particularly in very shallow waters. *Utricularia* spp. and *Myriophyllum alterniflorum* are occasionals in more enriched sites with pH values generally >5.

Conservation objective: maintain favourable conditions to support the characteristic species of interest. Favourable condition is achieved when the following criteria are met:

Attribute	**Target**	**Measure**	**Comment**
Extent of cover	Floating-leaved lilies (*Nymphaea alba* and *Nuphar lutea*), bogbean (*Menyanthes trifoliata*) and marsh St John's-wort (*Hypericum elodes*) may be abundant around the margins or floating rafts of *Sphagnum* that can completely cover the pool (transition mire type) Submerged vegetation is typically poor	Survey as outlined in notes	Baseline survey required to identify transects/pools in most favourable condition (highest % cover of listed plants). Selected sites to be monitored annually.
Water quality	Heavily stained, acid conditions, usually nutrient poor: Dissolved Organic Carbon >6 mg/l pH generally <4.5	Monitor as outlined in notes	High % cover of filamentous green algae indicates less than favourable conditions (acidification by nitrogen compounds). Support reductions in atmospheric acid deposition, particularly forms of nitrogen.
Water quantity	Water table at, or near, surface of the ground. Water originating mainly from atmospheric precipitation	Monitor water level	Minimise hydrological changes from over-abstraction or peat-cutting in surrounding landscape.

Table 4: Water Chemistry data from ECRC lake database

		All sites	Littorella uniflora	Lobelia dortmanna	Isoetes lacustris	Littorella/Lobelia/Isoetes Association	Juncus bulbosus
No. of Sites		41	26	32	22	21	23
Conductivity (µS/cm)	Min	22	25	25	22	25	22
	Max	585	345	63	66	57	78
Calcium (µeq/l)	Min	29	33	33	29	33	29
	Max	5800	2279	187	191	187	183
Alkalinity (µeq/l)	Min	-28	-28	-28	-28	-28	-28
	Max	3997	2079	108	108	108	99
pH	Min	4.6	4.6	4.6	4.6	4.6	4.6
	Max	8.3	8.3	6.7	6.7	6.7	6.7
DOC (mg/l)	Min.	0.8	0.8	0.9	0.8	0.9	0.8
	Max	14.6	13.3	6.1	6.1	6.1	8.5
Nitrate-N (µg/l)	Max	1940	700	400	453	400	400
Soluble Reactive Phosphorus (µg/l)	Max	1580	74	5	5	5	10
Total Phosphorus (µg/l)*	Max	1800	48	20	20	20	48

Figures are annual means based on quarterly samples of oligotrophic waters in ECRC database that contain *L. uniflora*, *L. dortmanna* and *I. lacustris*. Data collected on behalf of the Acid Waters Monitoring Network (AWMN) (DETR Contract) and the Countryside Council for Wales (CCW) Lake Classification Contract (Allott & Monteith, 1999; Duigan *et al.*, 1998).

CCW data: single summer macrophyte survey and quarterly chemistry for 1 year. Includes Llyn Cwellyn and Llyn Idwal.

AWMN data: quarterly chemistry and annual summer macrophyte surveys since 1988. Includes *Littorella/Lobelia/Isoetes* association sites in Snowdonia (Llyn Llagi) and close to Cairngorms (Lochnagar in Grampians). Additional sites on database containing this association include Cumbrian Lake District (Scoat Tarn & Burnmoor Tarn), Llyn Cwm Mynach (N. Wales), Coire nan Arr (NW Scotland), Lochs Chon & Tinker (Trossachs), Round Loch of Glenhead & Loch Grannoch (Galloway) and Blue Lough, Northern Ireland.

*Total phosphorus data only available for 31 Welsh sites, 24 of which have at least one of the 3 plant species recorded in recent surveys.