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Freshwater Lake Survey: SACs and SSSIs

Final Report to English Nature

Contract No. EIT 20/23/03

S. Luckes, H. Bennion & L. Carvalho

July 2000

Environmental Change Research Centre
University College London
26 Bedford Way
London
WC1H 0AP

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Sally Luckes, Helen Bennion & Laurence Carvalho

Environmental Change Research Centre
University College London
Contact: l.carvalho@ucl.ac.uk

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Project Background

This is the final report to English Nature on Contract No: EIT 20/23/03 "Freshwater Lake Survey: SACs and SSSIs".

The objectives of the contract were to:

1. Produce a database of lakes within SSSIs, giving details of lake size, reasons for designation, vegetation type, and if known, brief information on impacts and current management
2. Assemble plant records from lake surveys and identify vegetation types
3. Derive a priority set of sites recommended for in-lake and/or catchment surveys
4. Prepare detailed dossiers on nine candidate SAC sites, incorporating proposed generic conservation objectives and management recommendations

This report is largely concerned with the fourth objective, the SAC site accounts. The appendices provide guidance on using the accompanying lakes database (Appendix 1), output on priority sites requiring survey work (Appendix 2), and vegetation types represented in SSSI lakes (Appendix 3).

In summary, the contract highlighted a lack of data on current conservation interest and water quality both for particular cSAC sites and many of the remaining SSSI sites. The majority of vegetation surveys were carried out between 1977-1986; very few have been undertaken within the last 5 years. There is a clear urgent need for more regular survey and monitoring at both cSAC sites and other SSSI sites to provide up-to-date information on England's lake resource and its current ecological status.

Of the cSAC habitats, the most threatened appears to be the "hard oligo-mesotrophic waters with benthic vegetation of *Chara* formations". This is a rare habitat type within the UK and both English cSAC representatives (Malham Tarn and Hawes Water) show clear declines in conservation interest.

Oak Mere

1. Site Details (General)

Site Name: Oak Mere

Open Water Name: Oak Mere

County: Cheshire **District:** Vale Royal

English Nature Region: West Midlands Region

Date Notified (under 1981 Act): 24 Jan 1986 **Date of last revision**: 30 Sep 1994

National Grid Reference: SJ 574 679 **Ordnance Survey Sheet 1;50,000:** 117

Geographical Co-ordinates: 53° 12´ N; 2° 38´ W

2. Conservation Interest

Oak Mere has been selected for cSAC status as a high quality example of "Oligotrophic waters containing very few minerals of Atlantic sandy plains with amphibious vegetation: *Lobelia*, *Littorella* and *Isoetes*" (Annex I EC Habitats Directive). This is a rare habitat type throughout the Atlantic biogeographic region of Europe and also in the UK, as it is restricted to sandy plains that are acidic and low in nutrients. The only known high quality examples of this habitat type occur on fluvio-glacial deposits on the Cheshire Plain and in the New Forest and, and on more recent sand deposits of marine origin in the Outer Hebrides. Only three sites that are considered to represent high quality examples of this habitat type have been identified in these regions (Oak Mere, Hatchet Pond and South Uist Machair) and all three sites have been selected as cSACs (JNCC, 1999). It should be noted, however, that although this plant community has declined greatly in many parts of lowland Europe (Arts *et al.*, 1990), it is still widespread and locally abundant in oligotrophic waters in mountainous areas.

The habitat type is characterised by the presence of Littorelletalia-type vegetation. Such vegetation is characterised by the presence of water lobelia, *Lobelia dortmanna*, shoreweed *Littorella uniflora*, quillwort *Isoetes lacustris* or spring quillwort *I. echinospora*. Only one species needs to be present to conform with the definition of this Annex I type and typically the vegetation consists of zones in which the individual species form submerged, mono-specific lawns. The associate species, *Isoetes lacustris* and *Lobelia dortmanna*, are currently only present in UK lowlands in the lochs on South Uist. *I. lacustris* was recorded at Oak Mere by Chris Newbold, whether it remains needs further investigation. Oak Mere has an exposed sandy littoral which favours the dominance of *L. uniflora* over *L. dortmanna* (Rodwell, 1995). The site consists of Oak Mere itself and a small area of surrounding land, which at the northern end includes a small basin mire, fen, and wet woodland.

Of additional note at the site is the abundance of the nationally rare, narrow small reed (*Calamagrostis stricta*) at the northern end of the basin. Two aquatic invertebrates (the diving beetle *Ilybius subaeneus* and the water boatman *Sigara semistrata*) and the development of blooms of the colonial green alga, *Botryococcus braunii* are also listed as features of interest on the SSSI notification.

Oak Mere is unusual among the lakes of the region (North West Midland meres), and of lowland lakes in general, in that it is acidic and of extremely low alkalinity. It is this unusual chemistry, alongside the sandy substrate, that maintains favourable conditions for *L. uniflora* dominance over other aquatic plants.

3. General Limnology

The limnology of the lake has been studied in detail by Carvalho (1993) with additional accounts of hydrology (Carvalho & Moss, 1999; Savage *et al.*, 1992; Seymour 1992), plankton communities (Galliford, 1954; Lind, 1944; 1951; Lind & Galliford 1952; Reynolds & Allen, 1968; Swale, 1968), and Corixidae (water boatmen) (Savage, 1986; 1990; Savage & Pratt, 1976). General physical site details are provided in table 1.

Table 1: Oak Mere site details

Altitude (m a.s.l)		73
Surface Area (ha)	(See Note 1)	18-22
Maximum Depth (m)	(See Note 1)	7-8
Mean Depth (m)	(See Note 1)	1.5-1.7
Volume (m^3)	(See Note 1)	$(3.1\text{-}3.3) \times 10^5$
Catchment Area (ha)	(See Note 2)	20-90

Note 1: Values given are ranges covering the period between January 1990 and April 1992 when large changes in water level were observed (Taken from Carvalho, 1993).

Note 2: A range is given due to the difficulties in defining the catchment area to the south of Oak Mere (see Carvalho, 1993).

In terms of maintaining its conservation interest, the most important feature of Oak Mere is the unusual hydrology and water chemistry for a lake in a lowland setting. Hydrological data reveals that Oak Mere is a surface manifestation of the water table (Seymour, 1992). The lake's acid status is due to the fact that Oak Mere lies at the top end of the hydrological gradient and is fed largely by direct rainfall and drainage from a small sandy catchment at its southern end (Carvalho, 1993). Variability in climate (effective moisture), therefore, has a large impact on the water level, chemistry and biology of the lake and can obscure or exaggerate acidification or eutrophication trends (Carvalho & Moss, 1999).

4.1 Conservation Interest (with reference to SAC conservation objectives)

4. Current Status (Conservation Interest & Water Quality)

Aquatic plant surveys have been carried out in October 1979 (Wiggington, 1980), September 1987 (Wiggington, 1989), July 1990 (Carvalho, 1993) and July 1996 (Bennion *et al.*, 1997). *L. uniflora* is recorded as abundant in all surveys. A worrying trend is the appearance of *Juncus bulbosus* at the site (seen in 1992 by Carvalho and recorded at the site by Monteith in 1996 (Bennion *et al.*, 1997) (See section 5. Threats to conservation interest). More quantitative monitoring of aquatic vegetation is necessary to compare with the SAC conservation objectives (selected areas of shoreline with >30 % cover *L. uniflora* and low % cover of *Juncus bulbosus* (Carvalho & Monteith, 1999)) and particularly to set a baseline by which any changes in *L. uniflora* or *J.bulbosus* can be assessed.

The single record of *Isoetes* recorded by Chris Newbold suggests that this species of interest may also be present in low numbers. A more detailed survey of deeper waters is required to confirm whether this plant is still present at the site.

4.2 Water Quality (with reference to SAC water quality targets)

Full detailed chemistry data is provided in Carvalho (1993), Carvalho & Moss (1999) and Savage *et al.* (1992). The mean and ranges of parameters of most interest are provided below (Table 2)
Oak mere can be classified as a eutrophic lake based on total phosphorus concentrations (OECD classification), a mesotrophic lake based on its annual mean chlorophyll a concentration (OECD classification), or an oligotrophic lake based on its aquatic plant community (Palmer *et al.*, 1992)

	Annual Mean (Apr 1990-Mar 1992)	Range (Jan 1990–Apr 1992)
pH	5.4	4.6-6.9
Total phosphorus (μg/l)	61	26-120
Chlorophyll *a* (μg/l)	7	0-30

Table 2: Oak Mere water chemistry (Data from Carvalho, 1993)

Water quality data is absent or scarce for the other lowland UK SAC sites representing this habitat type. Because of this lack of data, Carvalho & Monteith (1999) did not define exact water quality targets that represented favourable conditions for this SAC type. A low pH (<7) and low total phosphorus concentration (<20 μg/l) combined, hypothetically represent favourable conditions (based on upland sites containing this vegetation community). Carvalho & Monteith (1999) do point out that, at any one site, several variables combined may represent favourable conditions whilst other parameters may be less important. At Oak Mere, for example, the total phosphorus concentration (annual mean 61 μg/l) is much higher than would normally be considered favourable, but its low pH, combined with the sandy substrate, restricts other macrophyte species. The pH of Oak Mere inherently varies with climate, and could on occasions exceed pH 7. What is important is that it does not show a sustained increasing trend over several years. Total phosphorus concentrations may be difficult to reduce but should similarly show no sustained increasing trend.

4.3 Trends in Water Quality (Palaeolimnology & Historical Records)

A palaeolimnological analysis was carried out by Bennion *et al.* (1997) to assess any acidification trends. No clear sediment accumulation rate was present, however, making interpretations problematic. A second analysis of a core taken south of the deepest point is currently underway and appears to show an improved stratigraphic profile (Simon Denison, *pers. comm.*).

5 Threats to Conservation Interest & Management Recommendations

No eutrophication problem affecting the aquatic plant community is apparent. Geese and other bird numbers are far too low to be of any significance in terms of enrichment. The major sources of nutrients are likely to be from direct rainfall and drainage from the catchment. Because of the sandy nature of the catchment, buffer strips may have little effect on reducing nutrients from drainage. It is, therefore, important that nutrient loadings to the catchment should be kept to a minimum. Hydrological data reveals that an area south west of the lake, between Heatherdale (SJ 568 677) and Glen Royal (SJ 577 673), is the source of most drainage water. Therefore, restrictions on development, particularly regarding septic tank drainage and fertiliser inputs, should be focused in this area.

It is possible that atmospheric deposition is the major source of nitrogen to the site. It is this source of nutrient and acidity that has led to the development of dense stands of *J. bulbosus* and suppression of *L. uniflora* and *L. dortmanna* at many sites in the Netherlands (Arts *et al.*, 1990; Roelofs, 1983). Liming of acidified lakes has also had this response (Roelofs *et al.*, 1994). The calculated freshwater critical load for Oak Mere suggests that this site is sensitive to acid deposition from atmospheric sources (UK Freshwater Critical Loads database, ECRC, University College London). The sensitivity combined with elevated acid deposition levels in this region (Vincent *et al.*, 1996) suggest that acidification impacts are highly plausible at this site. The sensitivity of this site to nitrogen deposition should certainly be explored further. Regular quantitative monitoring of aquatic vegetation is also necessary to assess any increasing trend in *J.bulbosus* at the expense of *L. uniflora*. It must be noted that variability in climate (effective moisture) has been shown to obscure or exaggerate acidification or eutrophication trends at this site (Carvalho & Moss, 1999) and so should be taken into account when analysing monitoring data.

Long-term climate changes are likely to be the greatest threat to the site. As Oak Mere is a surface manifestation of the glacial sands aquifer, the effects of abstraction in the catchment should be monitored and managed carefully. Climate change impacts on the pH and nutrient status, but is likely to have the greatest impact on the macrophyte community by reducing the littoral area available for colonisation. The bathymetry of Oak Mere is such that a small reduction in water level results in a large reduction in lake surface area and, therefore, a large loss in available littoral habitat (Carvalho, 1993). As the conservation interest is maintained by the low pH of the site, pumping of base-rich groundwater (as has happened in the past) is not the solution to any sustained decline in water level.

6.1 Current Monitoring

6. Monitoring

The Environment Agency and landowners carry out monitoring of pH and water level informally at Oak Mere. This monitoring should be formalised alongside vegetation monitoring.

6.2 Future Monitoring

Mid-summer macrophyte surveys should be carried out at Oak mere 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 (*L. uniflora*, *Isoetes* spp., *J. bulbosus*). 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 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 at least bi-monthly, every year. This higher frequency of water chemistry monitoring is required to obtain accurate representation of annual mean values. More frequent monitoring of pH and water level by the Environment Agency is beneficial in the case of Oak Mere because of its extreme sensitivity.

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.

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New Forest (Hatchet Pond)

1. Site Details

Site Name: New Forest

Open water name: Hatchet Pond

County: Hampshire/Wiltshire **District:** New Forest

English Nature Region: Hampshire & Isle of Wight

Date Notified (Under 1981 Act): 7 May 1987 **Date of last revision**: 28 Feb 1996

National Grid Reference: SU 298081

Ordnance Survey Sheet: 1:50,000; 195,196

2. Conservation Interest

Hatchet Pond is in fact three small man-made ponds lying in the southern part of the New Forest SSSI. It has been selected for cSAC status as a high quality example of "Oligotrophic waters containing very few minerals of Atlantic sandy plains with amphibious vegetation: *Lobelia*, *Littorella* and *Isoetes*" (Annex I EC Habitats Directive). This is a rare habitat type throughout the Atlantic biogeographic region of Europe and also in the UK, as it is restricted to sandy plains that are acidic and low in nutrients. The only known high quality examples of this habitat type occur on fluvio-glacial deposits on the Cheshire Plain and in the New Forest and, and on more recent sand deposits of marine origin in the Outer Hebrides. Only three sites that are considered to represent high quality examples of this habitat type have been identified in these regions (Hatchet Pond, Oak Mere and South Uist Machair) and all three sites have been selected as cSACs (JNCC, 1999). It should be noted, however, that although this plant community has declined greatly in many parts of lowland Europe (Arts *et al.*, 1990), it is still widespread and locally abundant in oligotrophic waters in mountainous areas. One of the ponds at Hatchet Pond is an oligotrophic water body amidst wet and dry lowland heath that has developed over fluvial deposits. It has, therefore, been selected as a rare southern example of this community.

The habitat type is characterised by the presence of Littorelletalia-type vegetation. Such vegetation is characterised by the presence of water lobelia, *Lobelia dortmanna*, shoreweed *Littorella uniflora*, quillwort *Isoetes lacustris* or spring quillwort *I. echinospora*. Only one species needs to be present to conform with the definition of this SAC type and typically the vegetation consists of zones in which the individual species form submerged, mono-specific lawns. The associate species, *Isoetes lacustris* and *Lobelia dortmanna*, are currently only present in UK lowlands in the lochs on South Uist. Shoreweed, *Littorella uniflora*, is, however, abundant in the shallow margins of Hatchet Pond.

Of additional note at the site are isolated populations of northern species including bog orchid *Hammarbya paludosa* and floating bur-reed *Sparganium angustifolium* (JNCC, 1999). These northern species are found alongside rare southern species such as Hampshire-purslane *Ludwigia palustris*; Hatchet Pond representing the last known British locality for *L. palustris* (Ratcliffe, 1977). Hatchet Pond therefore has considerable conservation value as it represents a southern example of the SAC habitat type in which northern species, more common in the uplands of the UK, co-exist with southern species (JNCC, 1999).

The wetland habitats of the New Forest SSSI also form the most important single suite of habitats for dragonflies in Britain with twenty seven breeding species, including the rare Southern Damselfly *Coenagrion mercuriale*. Hatchet Pond itself, however, has a relatively poor invertebrate community. A number of species characteristic of base-poor conditions, such as *Sympetrum scoticum* and *Sigara scotti*, can be found. Hatchet Pond also supports the introduced North American triclad, *Dugesia tigrina* and the duck mussel *Anodonta anatina* (Ratcliffe, 1977).

The New Forest SSSI in general represents the largest area of *"unsown"* vegetation in lowland England (English Nature, 1996). It contains a large range of habitats which are rare in lowland western Europe, including lowland heath, valley and seepage step mire and ancient pasture woodland including riparian and bog woodland (English Nature, 1996).

3. General Limnological and Catchment Details

Hatchet Pond was created artificially between 1789 and 1810. It has an open water area of 16 ha and a maximum water depth of 3.5 m. It lies at an altitude of 35 m a.s.l. on sandy soils and gravels. It is surrounded by heathland and scrub with some mixed woodland north of the pond (Chitolie, 1992). There is farmland to the east of the pond and two car parks are present adjacent to the pond.

4.1. Conservation Interest (with reference to SAC conservation objectives)

4. Current Status

An aquatic macrophyte survey was carried out in July 1996 by Don Monteith (Bennion *et al.*, 1997). *L. uniflora* was present at the site as short swards along much of the shoreline with selected areas having >30 % cover (Monteith, *pers. comm.*), which is the recommended target for this SAC feature (Carvalho & Monteith, 1999).

The lake as a whole was characterised by two community types. In the main section a submerged littoral association of *Littorella uniflora*, *Myriophyllum alterniflorum*, *Elodea canadensis* and the charophyte

Nitella translucens was dominant with occasional stands of *Potamogeton crispus*. *Eleocharis acicularis*, *Elatine hexandra* and *Ludwigia palustris* were locally abundant amongst the shallow areas of the eastern part of the lake, and grew in association with *Hypericum elodes*. In the north end of the pond, the most diverse aquatic vegetation is found, including stands of emergent vegetation. The dominant species within this community is *Menyanthes trifoliata* with *Typha latifolia* and *Equisetum fluviatile* being locally abundant. A range of other species were also present including *Luwigia palustris*, *Potamogeton natans*, *Sagittaria sagittifolia*, *Sparganium angustifolium,* a pink-petalled hybrid of *Nymphaea alba*, *Scirpus fluitans, Juncus bulbosus* var. *fluitans* and *Elodea canadensis*.

The conservation objectives for this feature (Carvalho & Monteith, 1999) state that a high % cover of *Juncus bulbosus* or a high % cover of elodeid vegetation (e.g. *E. canadensis* and *M. alterniflorum*) indicate less than favourable conditions (high % *J. bulbosus* associated with acidification by nitrogen; high % elodeids associated with eutrophication). No quantitative data exists for the extent of these species. More quantitative vegetation monitoring is required to assess trends in the abundance of *L.uniflora* compared with these species.

Ratcliffe (1977) lists *Pilularia globulifera* at the site, however, this species was not found during the 1996 survey by Monteith. Although evidence exists for the loss of this species from several sites, it is thought that its current UK distribution is generally fairly stable (Preston & Croft, 1997). A further survey is needed to determine whether this species has been lost from the site.

4.2 Water Quality (with reference to SAC water quality objectives)

Water samples were taken from Hatchet Stream (the inflow?) from 1979-1983. Mean water chemistry is listed in Table 1.

pH	7.2
Conductivity (μS cm $^{-1}$)	127
Nitrate-nitrogen (mg l^{-1})	0.17
Orthophosphate-phosphorus (μg l^{-1})	11

Table 1: Mean water chemistry of Hatchet Stream, sampled by the NRA from 1979-1983

Historical water chemistry data for Hatchet Pond itself is non-existent, making comparisons of the current status of the lake with water quality targets impossible. If the stream chemistry reflects the lake chemistry then the pH is slightly above the recommended water quality objective for this SAC feature (pH <7, Carvalho & Monteith, 1999). Additionally, it was recommended that total phosphorus concentrations should be <20 μg/l (Carvalho & Monteith, 1999). Baseline monitoring of the water chemistry of the pond is clearly needed.

4.3 Trends in Water Quality (Palaeolimnology)

A palaeolimnological study was carried out on Hatchet Pond by Bennion *et al.*, (1997). Diatom-based transfer functions were used to quantitatively reconstruct the total phosphorus and pH history of the lake. A palaeolimnolgical study was also carried out by Chitolie (1992) who examined both pollen and diatoms to determine recent environmental changes in Hatchet Pond. This report focuses on the more quantitative study carried out by Bennion *et al.* (1997):

An 88 cm sediment core was taken from a depth of 3.3 m representing the deepest part of the lake. The dating indicated that the sediments in Hatchet Pond had been subject to mixing and focusing. The diatom analysis showed that only small changes had occurred in species composition over the period represented by the core (post 1900 period). The TP reconstruction indicates a very slight increase in nutrient status in recent decades and no marked changes in pH over the last century. To confirm the accuracy of the diatom-inferred histories, baseline annual mean water chemistry data for the lake is required to compare with diatom-inferred values from the surface sediment.

4.4 Summary of current status

Limited vegetation and chemistry data is available to assess the current status of the lake. Palaeolimnological analyses have, however, been carried out to assess acidification and eutrophication trends (Bennion *et al.*, 1997). They show that Hatchet Pond has maintained a mesotrophic status for at least the last century and that there is evidence of slight nutrient enrichment during the last three decades. No acidification trend was apparent.

5 Threats to Conservation Interest & Management Recommendations

Eutrophication is probably the greatest threat to the SAC feature (*L. uniflora* population) at this site. Baseline surveys of vegetation and chemistry and regular monitoring are urgently required to assess whether any sustained trends threaten the conservation interest. Particular attention should be given to the % cover of *L. uniflora* compared with that of *M. alterniflorum* and *E. canadensis*, particularly the latter which is a highly competitive species as nutrient concentrations increase and is not a typical associate of the *Littorella-Lobelia* community (Rodwell, 1995).

A nutrient budget for the catchment should be carried out to determine the major sources of nutrients. If a sustained enrichment trend is established, management can then be more effectively targeted.

It is possible that atmospheric deposition is the major source of nitrogen to the site. It is this source of nutrient and acidity that has led to the development of dense stands of *J. bulbosus* and suppression of *L. uniflora* and *L. dortmanna* at many sites in the Netherlands (Arts *et al.*, 1990; Roelofs, 1983). Liming of acidified lakes has also had this response (Roelofs *et al.*, 1994). The sensitivity of this site to nitrogen deposition should be explored further.

6.1 Current Monitoring

6. Monitoring

There is no current regular monitoring of the site.

6.2 Future Monitoring

Mid-summer macrophyte surveys should be carried out 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, therefore, surveys should be carried out along selected depth transects that span the populations of interest (*L. uniflora, E. canadensis, M. alterniflorum, J. bulbosus*), 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 the 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 at least bi-monthly, every year. This higher frequency of water chemistry monitoring is required to obtain accurate representation of annual mean values.

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

References

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Wast Water

1. Site Details

Site Name: Wast Water

Open water name: Wast Water

County: Cumbria **District:** Copeland

English Nature Region: North West

Date Notified (Under 1981 Act): 1987 **Date of last revision**: 1987

National Grid Reference: NY 165 060

Ordnance Survey Sheet: 1:50,000: 89

2. Conservation Interest

Wast Water in the Cumbrian Lake District, England is chosen as a candidate Special Area of Conservation (cSAC) as a relatively large and deep example of an oligotrophic water body in a mountainous area. Specifically it is a representative of the habitat type "oligotrophic waters in medio-European and perialpine areas with amphibious vegetation: *Littorella* and *Isoetes* or annual vegetation on exposed banks (*Nanocyperetalia*)" (EC Habitats Directive). This type of water body occurs in the majority of Member States and is relatively abundant in the more mountainous areas of Europe. In the UK this freshwater habitat type is largely confined to the mountainous regions of the north and west and is characterised by two intergrading types: oligotrophic and mesotrophic waters (JNCC 1999). Wast Water represents the oligotrophic end of this gradient.

The clear, low alkalinity water which characterises this habitat type contain low to moderate levels of plant nutrients and supports a vegetation community characterised by short perennial vegetation, with shoreweed *Littorella uniflora* being considered a defining component. This species often occurs in association with water lobelia *Lobelia dortmanna*, bog pondweed *Potamogeton polygonifolius*, quillwort *Isoetes lacustris*, bulbous rush *Juncus bulbosus*, needle spike-rush *Eleocharis acicularis*, alternate water-milfoil *Myriophyllum alterniflorum* and floating bur-reed *Sparganium angustifolium.*

Wast Water has been selected as a representative from the principle mountainous area in England. It was chosen as a relatively large and deep example where water quality is high and the characteristic plant species are abundant. An association of *Littorella uniflora* and *Lobelia dortmanna* dominates the shallow waters (below 2.5m), with *Isoetes lacustris* dominating the deeper waters below 3.5 m (Bennion *et al.,* 1997). Other species characteristic of rocky, oligotrophic lakes are present including bulbous rush *Juncus bulbosus*, alternate water milfoil *Myriophyllum alterniflorum*, awlwort *Subularia aquatica* and the stonewort *Nitella flexilis* var. *flexilis.* Least bur-reed *Sparganium natans* and floating bur-reed *S. angustifolium* also occur in more sheltered bays and are typical of more mesotrophic situations. Blunt-leaved pondweed *Potamogeton obtusifolius* has been recorded and bog pondweed *P. polygonifolius* occurs in the steam outlets.

The nationally rare Arctic charr *Salvelinus alpinus* also occurs in the lake and strengthens the sites conservation status (JNCC 1999).

Wast Water has a very sparse littoral fauna, both numerically and in terms of diversity with species typical of rocky oligotrophic waters (Ratcliffe, 1977). The only gastropods recorded are the wandering snail *Lymnaea peregra* and river limpet *Ancylus fluviatilis*. *Erpobdella octoculata* is the only leech and *Polycelis nigra* the only triclad recorded at the site. A few species of caddis, mayfly and stonefly constitute the remaining littoral fauna (Ratcliffe, 1977).

3. General Limnological and Catchment Details

Wast Water is situated in the Cumbrian Lake District, near the south-west boundary of the National Park. It lies at an altitude of 61m at the bottom of a mountainous catchment which includes the south and west slopes of Pillar, Great Gable, Scafell, and to the immediate south-east the classical geomorphological feature of Wasdale Screes which extend beneath the surface of the lake. Rocky substrates predominate along much of its shoreline.

The lake itself is the largest (290 hectares) and least productive example of its type in England, and is also the deepest with a maximum depth of 78.6 metres (mean depth 39.7 m). Its catchment has the lowest percentage of cultivated land of any of the Lake District lakes, comprising largely unmodified upland grassland and bare rock. The lake water is extremely low in nutrients and dissolved minerals and is very clear (Notification sheet, 1987).

4 Current Status

4.1. Conservation Interest (with reference to SAC conservation objectives)

A macrophyte survey was carried out on Wast Water in July 1996 by Don Monteith (Bennion *et al.*, 1997). Selected areas of shoreline generally <2.5 m depth had >30 % cover of both *L. uniflora* and *L. dortmanna* and selected areas in deep water (>3.5 m depth) had >75 % cover of *Isoetes* spp. (Monteith, *pers. comm.*), which are the recommended targets for this SAC feature (Carvalho & Monteith, 1999). The 1996 survey appears very similar to earlier surveys carried out between 1975 and 1980 (Stokoe, 1983), suggesting that the macrophyte composition has not changed in recent decades.

The conservation objectives for this feature (Carvalho & Monteith, 1999) state that a high % cover of *Juncus bulbosus* or a high % cover of elodeid vegetation (e.g. *M. alterniflorum*) indicate less than favourable conditions (high % *J. bulbosus* associated with acidification by nitrogen; high % elodeids associated with eutrophication). These species are both present, generally becoming dominant between 2.5-3.5 m water depth. There currently appears to be no threat from these species although, no baseline quantitative data exists of their coverage from which change can be assessed.

4.2. Water Quality (with reference to SAC water quality objectives)

pH	6.8
Conductivity ($\mu S\ cm^{-1}$)	46
Total Nitrogen ($mg\ l^{-1}$)	0.47
Total Phosphorus ($\mu g\ l^{-1}$)	<10

Table 1: Mean annual water chemistry data based on monthly samples (1995-1996) taken by the Environment Agency from the River Irt (the lake outflow) (taken from Bennion *et al.*, 1997)

These water quality measurements compare favourably with those recommended for this SAC habitat type (pH <7, TP <20 ($\mu g\ l^{-1}$) (Carvalho & Monteith, 1999).

4.3. Trends in Water Quality (Paleolimnology)

A palaeolimnological study was carried out on Wast Water with an aim of reconstructing any past changes in the nutrient concentrations of the lake (Bennion *et al.*, 1997). Diatom-based transfer functions were used to quantitatively reconstruct the total phosphorus and pH history of the lake. The study revealed that little change had occurred in the diatom flora in the period of 1850-1995 with

Cyclotella species dominating the assemblages throughout. The TP and pH reconstructions confirmed that Wast Water has not experienced either enrichment or acidification over the last 150 years and has maintained oligotrophic conditions, with an average concentration of 3.5 μg TP^{-1} estimated for this period (Bennion *et al.*, 1997). The diatom-inferred pH also remained around 6.8-7.0 indicating that there has been no change in acidification status of the site and agreed with pH values recorded by Pearsall (1930) and Bennion *et al.* (1997). The close match between the measured and the diatom-inferred values suggests the reconstructions are very reliable. ^{210}Pb dating of the sediment cores also revealed that the sediment accumulation rate has not changed in the last 150 years, with a mean sedimentation rate of 0.07 cm y^{-1} (Bennion *et al.*, 1997).

4.4 Summary of current status

The vegetation, water quality and palaeolimnological data confirm the pristine and near natural state of Wast Water. They highlight that there has been little impact from anthropogenic influences in recent decades and that the conservation interest is currently under no serious threat.

6.1 Current monitoring

6. Monitoring

The NERC Centre for Ecology & Hydrology (CEH) laboratories at Windermere monitor Wast Water every five years as part of their quinquennial monitoring programme of the Cumbrian lakes (1995 and 2000 are the most recent sampling years). Chemical and algalogical parameters are sampled every 3 months for one year to obtain annual means.

6.2. Future monitoring

Mid-summer macrophyte surveys should be carried out 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, therefore, surveys should be carried out along selected depth transects that span the populations of interest (*L. uniflora, L. dortmanna*, *I. lacustris*, *J. bulbosus*, *M. alterniflorum*), 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 the 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 at least bi-monthly, every year. This higher frequency of water chemistry monitoring is required to obtain accurate representation of annual mean values.

7. Recommendations for management

The conservation objective of oligotrophic to mesotrophic lakes in mountain areas is to maintain them in favourable condition to support the notified features of interest. Wast Water currently displays near natural conditions. It is important that regular monitoring is maintained more frequently than every 5 years in order to detect any systematic trends in the plant community or water quality that could affect its near pristine status.

8. References

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Bassenthwaite Lake

1. Site Details

Site Name: Bassenthwaite Lake

Open Water Name: Bassenthwaite Lake **Area:** 668 ha

County: Cumbria **District:** Allerdale

English Nature Region: North West Region, Kendal Office

Date Notified (Under 1981 Act): 1984 **Date of last revision:** 1994

National Grid Reference: NY 214 296

Ordnance Survey Sheet: 1:50,000: 89, 90 **1:10,000**: NY 13 SE; NY 22 NW; NY 23 SW

2. Conservation Interest

Bassenthwaite lake is a National Nature Reserve owned and managed by the Lake District National Park Authority (LDNPA). It has been designated as a candidate Special Area of Conservation (SAC) representing a high quality example of an "Oligotrophic water in medio-European and perialpine areas with amphibious vegetation: *Littorella* and *Isoetes* or annual vegetation on exposed banks (*Nanocyperetalia*)" (EC Habitats Directive: Annex I). In the UK, this freshwater type is largely confined to the mountainous regions of the north and west and is characterised by two intergrading types: oligotrophic and mesotrophic waters; Bassenthwaite Lake represents the more enriched mesotrophic end of the gradient.

The clear, low alkalinity water which characterises this habitat type contain low to moderate levels of plant nutrients and supports a vegetation community characterised by short perennial vegetation, with shoreweed *Littorella uniflora* being considered a defining component. This species often occurs in association with water lobelia *Lobelia dortmanna*, quillwort *Isoetes lacustris*, bulbous rush *Juncus bulbosus*, needle spike-rush *Eleocharis acicularis*, alternate water-milfoil *Myriophyllum alterniflorum* and floating bur-reed *Sparganium angustifolium.*

Bassenthwaite Lake has a diverse aquatic macrophyte assemblage. There is a clear distinction between the species poor, steeply shelving, exposed west shore and the north, east and south shores which are more gently sloping and include a number of sheltered bays. *L. uniflora* occurs in shallow water particularly along the southern shore alongside *M. alterniflorum* and *P. gramineus*. *Isoetes lacustris* occurs in deeper water alongside *Nitella flexilis* var. *flexilis*. The lake is of particular importance for the wide variety of pondweeds (*Potamogeton* species) that occur including perfoliate pondweed, *P. perfoliatus*, small pondweed, *P. berchtoldii* and curled pondweed, P. *crispus* which are widespread. Species dominating more locally include red pondweed, *P.alpinus,* various leafed pondweed, *P.*

gramineus and lesser pondweed, *P.pusillus*. A variety of other submerged plant species occur in the lake including more unusual species such as autumnal water-starwort, *Callitriche hermaphroditica* as well as the six-stamened waterwort *Elatine hexandra*. A significant recent discovery, not recorded at notification, is the nationally scarce floating water plantain, *Luronium natans*, a species listed in Annex II of the EC Habitats Directive.

Bassenthwaite Lake also has extensive undisturbed shorelines consisting of shingle, gravel and soft peat stretches. These shorelines represent transitional habitats ranging from open water to emergent vegetation dominated by reed fringe/wet woodland of willow and alder. These hydroseral successions are particularly well developed around the northern and southern ends of the lake and constitute an outstanding conservation feature of the site (Notification, 1994). The fringing habitats support the nationally rare slender rush (*Juncus filiformis*) on the stony shores and the most extensive populations in England of water sedge, *Carex aquatilis*. The main emergent plant, however, consists of reed canary grass, *Phalaris arundinacea* with limited areas of common reed, *Phragmites communis*. More locally abundant species include bulrush, *Schoenoplectus lacustris*, bottle sedge, *Carex rostrata,* bladder sedge, *Carex vesicaria* and common spike rush, *Eleocharis palustris* (Notification, 1994).

Bassenthwaite Lake also contains one of only two UK populations of the vendace (*Coregonus albula*). This is the rarest freshwater fish in Britain and is a protected species under Schedule 5 of the Wildlife and Countryside Act (1981). The lake is also used by salmon and Brook lampreys which are both listed in Annex II of the Habitats Directive.

3. General Limnological and Catchment Details

Bassenthwaite Lake is located approximately 4 km north of Keswick in a wide, formally glaciated valley between the Thornthwaite and Skiddaw Fells. Since its late glacial origin it has been separated from Derwent Water by the formation of an alluvial fen (Pearsall & Pennington, 1973). The lake lies at a relatively low altitude (69 m) with much of the catchment to the north below 100m. It is a large lake (5.28 km^2) with a maximum depth of 21 m, but an average depth of only 5.3 m. As a result, the lake is polymictic, not maintaining stable thermal stratification during summer due to constant mixing by winds (Morrison, 1997). It has a large catchment area (238 km^2) and as a result is subject to rapid throughflow of water (30 days mean retention time) and wide fluctuations in water level (Kadiri & Reynolds, 1993). Much of the catchment is forested with the two large plantations of Dodd Wood and Thornwaite Wood.

3.1. Site Use

The National Parks Authority has owned Bassenthwaite Lake since 1979. Since 1980, the NPA has been keen to promote nature conservation and have introduced policies to allow only those recreational activities which do not conflict with the primary nature conservation objective (LDNPA, 1999). The principle recreational uses are sailing, angling, canoeing, windsurfing, picnicking and bird watching. Recreational opportunities are, however, limited because of the private ownership of adjacent land as well as the fluctuating water levels (LDNPA, 1999).

4.1. Conservation Interest

4. Current Status

An aquatic macrophyte survey was carried out in July 1996 by Don Monteith (Bennion *et al.,* 1997). The community represented a mesotrophic water body (Type 5a following Palmer, 1982) with species present similar to those described at notification. There, therefore, appears to have been little impact on the aquatic plant community interest. An additional survey was carried out for the LDNPA in 1997. This also indicated that in general the species composition had remained fairly stable since 1979, although in some individual bays, species composition had changed. A significant discovery was the nationally scarce floating water plantain, *Luronium natans*, a species listed in Annex II of the EC Habitats Directive (LDNPA, 1999).

These recent surveys do, however, reveal dense stands of Canadian pondweed, *Elodea canadensis*, and perfoliate pondweed, *Potamogeton perfoliatus*, in deeper water. The former species in particular is more typical of eutrophic waters and very competitive; its abundance needs regular monitoring. The invasive species, New Zealand pygmy weed, *Crassula helmsii*, has also recently established and again requires regular monitoring and control of its spread.

4.2. Current Water Quality

Water Chemistry Variable	*Result*
pH	7.3
Conductivity	74 $\mu S\ cm^{-1}$
Total nitrogen	0.80 $mg\ l^{-1}$
Total phosphorus	25 $\mu g\ l^{-1}$

Table 1: Mean annual water chemistry data collected for the Environment Agency, based on monthly samples (1995-1996) taken from the lake outflow (at Ouse Bridge) (data cited in Bennion *et al.,* 2000)

The pH and TP concentrations are slightly above the water quality objectives recommended for this SAC lake type (pH <7.0, TP <20 μg/l) (Carvalho & Monteith, 1999).

4.3. Trends in Water Quality (Palaeolimnology)

A palaeolimnological study was carried out on Bassenthwite Lake by Bennion *et al.,* (1997). Diatom-based transfer functions were used to quantitatively reconstruct the total phosphorus history of the lake. The sediment accumulation rate appears to have increased markedly between 1900-1940 and this increase has continued until to the present day (Bennion *et al.,* 1997). There was also a clear change in the diatom assemblages over the period represented by the core (c.1710-1995). The section representing pre-1860 was dominated by species characteristic of oligo-mesotrophic waters (*Achnanthes minutissima* and *Synedra nana*). A characteristic species of mesotrophic waters (*Fragilaria crotonensis*) then appears in the sediments representing 1860 onwards and increases towards the top of the core, and a species typical of eutrophic conditions (*Stephanodiscus hantzschii*) was present in the sediments representing 1960-1990 (Bennion *et al.,* 1997).

The diatom-inferred TP reconstruction confirmed the lake's mesotrophic status pre-1860 with stable concentrations of c.20 $\mu g l^{-1}$. This was followed by an increase to 31μg l^{-1} between 1860-1960, and a marked increase from 1970-1985 reaching a maximum of 58 μg l^{-1} in the mid-1980s. The DI-TP values of the upper two core samples (post-1990) show a decrease to c. 30 μg l^{-1} (Bennion *et al.,* 1997). The DI-TP values of the surface sample shows good agreement with the measured TP values for 1995-1996 (Table 1) which ranged from 10-65 μg l^{-1}. The palaeolimnological analysis clearly indicates a progressive enrichment of the site over the last 150 years, particularly during the 1970s and 1980s

4.3. Summary

Bassenthwaite Lake appears to have undergone significant enrichment this century. The conservation interest has been maintained, although, the spread of more invasive aquatic plants needs to be monitored and checked.

5.1 Eutrophication

5. Threats to Conservation Interest

Eutrophication is the major threat to the site's conservation interest. Not only is it a significant threat to the SAC aquatic plant interest, but symptoms of increased algal growth also threaten the nationally threatened vendace population. Vendace are thought to have become extinct at two Scottish sites as a result of eutrophication (Maitland & Lyle, 1991) so it is imperative that the water quality is improved to prevent further loss. The high flushing rate of the lake is thought to have played a key role in minimising eutrophication effects (LDNPA, 1999). A nutrient budget of the catchment demonstrates the importance of both sewage effluent and agricultural inputs to the lake (May *et al.*, 1995). In 1995, phosphorus stripping was introduced at Keswick STW, which serves a summer population of 26,000 people (Carvalho & Moss, 1996). This process removes a large proportion of the phosphate from this source which should, therefore, lead to a significant reduction in nutrient load. The Environment Agency is carrying out further work to identify any additional sources of phosphorus with the aim of reducing loads further (LDNPA, 1999).

There is evidence of physical damage to the site from increasing organic sediment inputs. This is thought to be affecting vendace spawning beds and may also be affecting the aquatic plant community. Whether this increase is due to enhanced catchment inputs or internal productivity changes is as yet unclear. The palaeolimnological study by Bennion *et al.* (2000) revealed that an increasing sedimentation rate commenced in the early part of the 20^{th} century and is not a recent phenomenon.

5.2. Coarse fish

Populations of introduced coarse fish are also probably affecting the vendace population through competition and predation of eggs. The significance of this impact is as yet unknown.

5.3 Road Spillage

The water quality at Bassenthwaite Lake has also suffered as a result of spillage from the nearby major road, the A66. An emergency plan has been set up by the Environment Agency to reduce any spillage effects caused by road traffic accidents. This plan has been developed in association and agreement with local authorities and local emergency teams (LDNPA, 1999). As part of the plan, interceptor tanks have been installed throughout 1996 and 1998 to collect any road spillage from both accidents and general use.

6. Monitoring

6.1 Current monitoring

The NERC Centre for Ecology & Hydrology (CEH) laboratories at Windermere monitor the chemistry of Bassenthwaite Lake every fortnightly under contract from the Environment Agency as part of the EA's responsibility under the Urban Waste Water Treatment Directive.

6.2 Future monitoring

The current chemical monitoring by CEH is more frequent and more extensive than the SAC guidelines (see below) and should be supported at such a high profile threatened site. This monitoring does not, however, include aquatic macrophyte surveys which should be carried out according to the guidelines described below:

Mid-summer macrophyte surveys should be carried out 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, therefore, surveys should be carried out along selected depth transects that span the populations of interest (*L. uniflora, L. dortmanna*, *I. lacustris*, *Luronium natans*), 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 the 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 at least bi-monthly, every year.

7. Recommendations for Management

It is vital to the survival of the vendace and the SAC aquatic plant communities that the nutrient coincentrations of Bassenthwaite Lake are reduced. Regular monitoring of water chemistry and plant communities is essential to detect trends. It is important that the current monitoring schemes are supplemented with regular vegetation surveys following the SAC guidelines (Carvalho & Monteith, 1999). Further attempts to reduce other point and diffuse sources of nutrients should be supported.

8. References

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Clarepool and Abbots Moss

1. Site Details

	Clarepool Moss	Abbots Moss
County	Shropshire	Cheshire
District	North Shropshire	Vale Royal
English Nature Office	West Midlands	West Midlands
Date Notified (Under 1981) Act):	1983	24 Jun 1984
Date of last revision	-	30 Sep 1994
National Grid Reference	SJ 424343	SJ 597691
Ordnance Survey Sheet (1:50,000)	126	117, 118

2. Conservation Interest

Clarepool and Abbots Moss have been designated as a candidate Special Area of Conservation (SAC) as they contain rare examples of dystrophic lakes in a lowland setting. Dystrophic lakes are listed in Annex I of the EC Habitats Directive, however, within the EC their current status is relatively unknown (JNCC, 1999). In Britain, dystrophic lakes are widespread on blanket bog systems in the north-west but are scarce in southern Britain, present only in lowland regions on raised bog systems on glacial plains and valley bottoms. The dystrophic pools of Clarepool and Abbots Moss, therefore, have been selected for SAC status because of the rarity of this waterbody type in lowland Britain (JNCC, 1999).

The SAC encompasses three pools, one at Clarepool Moss and the remaining two at Abbots Moss. The pools at Abbots Moss represent more typical base-poor dystrophic lakes. The pool at Clarepool Moss represents a more unusual dystrophic pool because of its base-rich status with a varied and diverse flora and fauna. At Clarepool Moss, the pool and its entire basin are internationally important for nature conservation.

The dystrophic lakes at these sites are all associated with Schwingmoor development, a characteristic of this habitat type in the West Midlands. Schwingmoor is an advancing floating raft of *Sphagnum*, often containing *Eriophorum angustifolium* bog pool community, which grows from the edge of the pool and can completely cover over the pool, and the site has also been selected for this feature (Transition mires and quaking bogs) in its own right.

2.1 Vegetation

Dystrophic lakes are acidic, characterised by a high humic content, and consequently are poor in plant nutrients. They, therefore, have a species poor flora and often lack a littoral because of the strong light attenuation.

2.1.1 Clarepool Moss

Clarepool Moss has a very small area of open water (100 m by 80 m) which has developed in part as a Schwingmoor. Within the area of open water itself, no floating or submerged vegetation has been recorded. The eastern edge of the pool is surrounded by nutrient-poor fen in which royal fern (*Osmunda regalis*), *Juncus effusus* and *Potentilla palustris* are present. This grades into alder and birch carr. On the western side of the pool, *Carex paniculata* tussocks and *S. recurvum* lawns occur (Ratcliffe, 1977).

The vegetation of the basin mire adjacent to the Schwingmoor consists of birch and pine woodland on a *Sphagnum recurvum* lawn with crowberry (*Empetrum nigrum*). Open areas of *Sphagnum* bog occur with characteristic species such as cranberry (*Vaccinium oxycoccus*), the nationally scarce bog rosemary (*Andromeda polifolia*) and sundew (*Drosera rotundifolia*) (Notification sheet).

2.1.2 Abbots Moss

Abbots Moss consists of a mature Schwingmoor in both of its basins. However, the site also consists of two dystrophic pools which are the focus of interest.

2.1.2.1 Gull Pool

Gull Pool is the larger of the two pools separated by a railway line and has distinctly varying plant communities. The south end of the pool consists of a very shallow depression, which has developed into a hummocked *Sphagnum recurvum* lawn with abundant cranberry. The development of the mire at the north end of the pool is, however, slight resulting in a large area of open water. The aquatic moss *Drepanocladus fluitans* dominates this open water area. A narrow margin of emergent vegetation exists which is dominated by the mosses *Sphagnum recurvum* and *Polytrichum commune*, marsh pennywort (*Hydrocotyle vulgaris*) and bottle sedge (*Carex rostrata*) with birch and willow occurring towards the landward side (Notification sheet, 1994).

2.1.2.2 Lily Pool

This is a deeper pool than Gull Pool. It holds a different community to that of Gull Pool as a result of the accumulation of more nutrients from its catchment. The areas of open water are characterised by enlarging rafts of *Sphagnum* with beds of white water lilies (*Nymphaea alba*). Lesser bladderwort (*Utricularia minor*) is abundant around the raft edges and is rare in Cheshire. The edges of Lily Pool are much more steeply sloping than Gull Pool with a higher rate of peat development. The edges are characterised by a marginal lawn of *Sphagnum*, which occasionally merges with the floating rafts (Notification sheet, 1994).

2.2 Invertebrates

The mosaics of open water, peatland habitats, fringing heathlands and woodlands of Clarepool and Abbots Moss attract a high diversity of invertebrate species, making the fauna a particularly important feature.

2.2.1 Clarepool Moss

Species typical of base-rich, weedy and fen habitats dominate the invertebrate population at Clarepool Moss (Ratcliffe, 1977). These include *Asellus meridianus*, *Cloeon dipterum*, *Holocentropus picicornis* as well as the corixids *Sigara dorsalis*, *Callicorixa praeusta*, *Hesperocorixa linnei*, *H. sahlbergi* and *Corixa punctata* (Ratcliffe, 1977). A range of dragonflies and caddis flies are present, such as *Erythromma najas*, as well as rare water beetles such as *Acilius sulcatus* (Notification sheet, 1994).

2.2.2 Abbots Moss

Abbots Moss is a nationally important site for invertebrate species. This is exemplified by Gull Pool being the county's most important dragonfly and damselfly site. Here, 14 species and 11 breeding species have been recorded (Wallace, 1982). These include the rare downy emerald (*Cordulia aenea*), the nationally rare whitefaced-dragonfly (*Leucorrhinia dubia*) and the black darter (*Sympetrum danea*). The adjacent South and Shemmy Mosses provide habitat for 148 species of spiders, which include two national rarities (Notification sheet, 1994).

2.3 Birds

Clarepool and Abbots Moss have important ornithological interest attracting stonechat, lesser-spotted woodpecker and sparrow hawk.

3. General Limnology

	Clarepool Moss Pool	Gull Pool	Lily Pool
Open water area	0.4 ha	?	?
Maximum Depth	2.2 m	?	?
Catchment	Woodland, scrub, grassland and arable	?	?
Site ownership	Private	Forestry Commission (9 ha) and the Scout Association (24 ha)	

4. Current Status (Conservation Interest and Water Quality)

4.1. Conservation Interest

4.1.1. Clarepool Moss

An aquatic macrophyte survey was last carried out in September 1995 by Don Monteith (Bennion *et al.*, 1997). No floating or submerged vegetation was supported in the pool. It was, however surrounded by *Juncus effusus*, *Carex paniculata*, *Molinia* and some *Sphagnum* (Bennion *et al.,* 1997).

There is no regular monitoring of the development of the Schwingmoor at the site to assess successional rates.

4.1.2. Abbots Moss

No recent aquatic macrophyte surveys of the pools have been undertaken, so the current aquatic vegetation status is uncertain. The development of the Scwingmoor is also unrecorded.

Much of the interest at Abbots Moss lies in its invertebrate populations. Detailed surveys are required to assess their current status.

4.2. Water Quality

An abundance of dissolved humic compounds and a low pH are characteristic of dystrophic lakes as they restrict bacterial metabolism, maintaining the dystrophic state. Targets for pH (generally <4.5) and dissolved inorganic carbon (>6 mg/l) have been outlined by Carvalho & Monteith (1999). Clarepool Moss is unusual in that it has a relatively base-rich water quality and higher pH (5.4 in 1955 recorded by Gorham (1957) due to greater water and nutrient inputs from groundwater sources. No recent water quality data exists for the pools on either Clarepool or Abbots Moss.

4.3. Trends in Water Quality (Palaeolimnology)

A palaeolimnological study was carried out on the pool at Clarepool Moss by Bennion *et al.* (1997) with the aim of reconstructing any past changes in pH and total phosphorus (TP) concentrations. A 100 cm sediment core was taken at a water depth of 2.1m. No clear dating record could, however, be obtained from the core, suggesting that consistent sediment accumulation was not present. All trends should, therefore be treated with caution. The TP reconstruction indicated that nutrient changes had occurred at Clarepool Moss. The diatom-inferred-TP concentrations increased from 7 $\mu g\ l^{-1}$ at the bottom of the core to 35 $\mu g\ l^{-1}$ at the 20 cm depth sample but then decreased again to 17 $\mu g\ l^{-1}$ in the surface sample. The TP model, however, was not developed for application to acid waters and these trends may simply be due to composition changes associated independently with pH changes (Bennion *et al.,* 1997). The pH reconstructions for Clarepool Moss ranged from 5.3-5.8 and these correlate with a spot sample taken by Gorham in 1955 of pH 5.4. No clear acidification trend was apparent up the core at Clarepool Moss, although, this may be a result of the inconsistent sediment accumulation pattern which may mask a real acidification trend (see section 5.3 for discussion of the acidification threat at Abbots Moss)

4.2.2. Summary

Bennion *et al.* (1997) believe that the diatom community changes down the core represent responses to pH changes, more than responses to nutrient concentrations. No current assessment of nutrient enrichment can, therefore, be made at Clarepool Moss. Diatom analysis did, however, confirm that the pool had always been acidic but due to poor sediment accumulation patterns no acidification trend was apparent.

5. Threats to Conservation Interest & Management Recommendations

5.1. Declining water levels and plant succession

5.1.1. Scrub/Wood Encroachment

Natural seral succession and colonisation of the *Sphagnum* raft by birch and pine is controlled by a management agreement. During periods of drought, however, sapling colonisation increases and they quickly establish dense stands (English Nature, 1997a; 1997b). In order to maintain the pools conservation interest, the seral succession must be managed effectively, particularly during drought periods.

5.1.2. Gravel Abstraction: Abbots Moss

Gravel and sand extraction has taken place near Abbots Moss. The continuation of this may be detrimental if extraction causes a lowering of the water level (Whild, Date Unknown).

5.2. Eutrophication

Particular concern has been expressed as to the impact on Clarepool Moss of agricultural runoff from nearby farmland. Fields of arable crops slope down towards the moss. Loadings to the fields should be managed carefully following ADAS guidelines. Drainage pathways and buffer zones should be investigated. Catchment studies could be carried out to identify main nutrient sources with an aim to reduce their impact.

5.3. Acidification

Abbots Moss lies within 2 km of Oak Mere, a water body classed as exceeded its critical load of atmospheric sources of acidity (UK Freshwater Critical Loads database, ECRC, University College London). There are indications that Oak Mere is showing symptoms of acidification. The proximity of

Abbots Moss to Oak Mere could suggest that Abbots Moss is sensitive to acidification too. The highly variable drift geology and complex hydrology of the area, however, makes this less certain. Further monitoring of water chemistry and catchment characteristics of Abbots Moss is, therefore, recommended to clarify its sensitivity to acidification.

5.4. Recreation

At Abbots Moss, the entire site is vulnerable to recreational disturbance due to the presence of the scout camp in the northern end of the site.

5.5. The Meres and Mosses Management Strategy

In 1993, the Meres and Mosses forum was established with an aim of exchanging information and views on the Meres and Mosses Management Strategy Document. It has the following long-term goal:

"..to achieve the restoration of the Meres and Mosses and their surrounding habitats in terms of their water quality, hydrology, habitat quality and management, and hence their biodiversity. This will be done through improved land-use and management of the sites themselves and the catchments in which they are situated" (Meres and Mosses Management Strategy Document).

The strategy highlights several important issues that should be considered in site management, including:

1. *Agriculture*
2. *Water Abstraction*
3. *Inappropriate and poorly managed recreational use of sensitive sites*
4. *The effects of urban, industrial and road development in catchments on water quality*

Site Management Statements have been produced for all landowners and involved parties. They explain the nature conservation interest of the site and the objectives relevant to that particular party. They also include agreed management objectives. Records of any management already carried out are also included.

5.6. Management carried out at Abbots Moss

- The drainage outfall from a septic tank which polluted Lily Pool was redirected in 1988
- A clearance of invasive trees took place in 1993 and 1995
- Scouts cleared fringing trees from the south-west side of Gull Pool in 1995
- Forest Enterprise cleared the conifer crops from a 10-25 m margin around the mosses in 1995/96
- BTCV cleared scrub from the two moss basins in 1994 and 1995
- Clear felling of the basin slopes adjacent to the mires has taken place in an attempt to reduce the potential threat of acidification from atmospheric sources.
- Management of the coniferous crop is ongoing under a Woodland Grant Scheme

5.7. Management carried out at Clarepool Moss

Terms and management objectives have been agreed with the owner. These include:

- Maintaining the dystrophic open water habitat by maintaining water levels and high water quality
- Maintaining the basin mire communities by maintaining appropriate water levels and by occasional scrub cutting to prevent succession
- Conserve populations of those plants and animals which are nationally rare, scarce or are county or national rarities

As a result of this management agreement, scrub clearance around the pool has taken place. The management agreement needs to be strengthened by providing more specific detail on appropriate water levels (at, or near, surface of the ground), water sources (originating mainly from atmospheric precipitation) and water quality (heavily stained, acid conditions, usually nutrient poor. Dissolved organic carbon >6 mg/l, pH generally <4.5, although the latter may be higher at Clarepool Moss)

6. Future Monitoring

Research into the dystrophic pools of Clarepool and Abbots Moss is characterised by a lack of data from which to compare any future trends. The key to future management is the monitoring of the pools and their catchments. Suggested actions outlined by Carvalho & Monteith (1999) are given below:

Mid-summer macrophyte surveys of the pools and Scwingmoor development should be carried out 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 map of the extent to Schwingmoor development and 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 (*Sphagnum* spp., *Nymphaea alba*, *Utricularia minor*, *Drepanocladus fluitans*). Additionally, therefore, surveys should be carried out along selected depth transects that span these 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). For small dystrophic pools this may need to be modified by recording species abundance (% cover) in samples at 20cm depth intervals from the shore along a minimum of three re-locatable. 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 water quality targets.

A detailed understanding of site hydrology is also necessary. The optimal hydrological regime should be assessed for the species of greatest conservation interest. If water levels are declining, potential losses from abstraction should be assessed and reduced.

At Abbots Moss in particular, regular quantitative monitoring of the invertebrate populations of interest should be carried out.

8. Conclusion

The open water pools at Clarepool and Abbots Moss represent dystrophic pools on a raised bog system. Natural seral succession and encroachment of the pools by birch and pine saplings presents a constant threat to the maintenance of their conservation interest. Further threats exist from runoff from agricultural land increasing the chance of the pools becoming eutrophic, acidification from atmospheric sources and recreational disturbances.

Monitoring of the pool's biological, chemical and physical status is, however, extremely poor. It is imperative that a detailed baseline survey takes place to assess the current conservation status and that regular water level, chemical and biological monitoring is established to assess any declining trends in water quality or species populations of interest. Only when further information is known can the established Meres and Mosses Forum ensure appropriate measures are being taken.

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Haweswater

1. Site Details (General)

Site Name: Gait Barrows

Open Water Name: Little Hawes Water

County: Lancashire **District:**

English Nature Region: North West Region

Date Notified (under 1981 Act): **Date of last revision:**

National Grid Reference: SD 481772 **Ordnance Survey Sheet 1;50,000:**

2. Conservation Interest

Haweswater has been selected for SAC status as it represents a high quality example of a "hard oligo-mesotrophic water with benthic vegetation of *Chara* formations" (Annex I EC Habitats Directive). This SAC type is characterised by base-rich waters (calcium or magnesium) that contain low to moderate levels of plant nutrients (nitrogen and phosphorus). Dense beds of stoneworts, *Chara* species, are considered the principle defining component of this SAC type (Palmer, 1999). This habitat type is scarce in the UK. Hawes Water is considered to be the best example of a lowland representative of this SAC type , owing to the clarity, low nutrient status and high calcium content of its water (JNCC, 1999).

Four species of stonewort have been recorded at Hawes Water. The rare stonewort *Chara rudis* and scarce species *C. hispida*, *C. aspera* and *C. pedunculata* are all known to have occured here, although a thorough survey in 1999 was unable to find the latter two species (Newbold, 1999). The site has also been notified for. a diverse range of other aquatic plants and animals, including shining pondweed (*Potamogeton lucens*), seven species of snail and eight species of mayfly. A rich emergent mixed fen community, alder and willow carr and woodland are also contained within the site.

3. General Limnological and Catchment Details

The lake lies upon deep lacustrine shell marl deposits up to 7.5 m in depth, overlain in places by peat Newbold, 1999). A bathymetric survey was carried out in 1993 (Raley, 1993 cited in Newbold, 1999) which found a maximum depth of 12.2 m. The shoreline shelves steeply down to 4 m with much of the lake area greater than 6 m in depth. The catchment area is difficult to define because of the limestone nature of the geology. The area does, however, include improved pasture, woodland and a few houses.

4. Current Status (Conservation Interest & Water Quality)

4.1 Conservation Interest (with reference to SAC conservation objectives)

An aquatic plant survey was carried out by Newbold (1999). The rare stonewort *Chara rudis* was restricted to the southern shore, by the jetty, at about 4 m depth. *C. hispida* var. *major* was found in shallow water along the eastern shore and *C. hispida* var. *hispida* was found in two small patches at the southern end and in the north-western corner. The *Chara* beds appeared to be much more restricted than a previous survey, carried out in 1984 using divers, which found extensive growths at depths exceeding 7 m (cited in Newbold, 1999). Other species of interest recorded by Newbold included the shining pondweed, *Potamogeton lucens*, common bladderwort, *Utricularia vulgaris* and beds of white and yellow water lily (*Nymphaea alba* and *Nuphar lutea* respectively).

Despite extensive searching, two previously recorded charophytes (*C. aspera* and *C. pedunculata*) and three species of pondweed (*P. natans, P. friesii* and *P. obtusifolius*) were not found. Additional worrying features recorded by Newbold (1999) was the coverage of sediments along the eastern shore of the filamentous alga, *Cladophora glomerata* and the presence of Nuttall's pondweed, *Elodea nuttallii*, both species typical of eutrophic water bodies.

4.2 Water Quality (with reference to SAC water quality targets)

No water quality data is presently available, although the lake is currently being researched by the University of Liverpool (Department of Geography). Palmer (1999) recommends that the site should show no sustained increase in TP or TN concentrations from year to year and maximum chlorophyll a concentrations should not exceed 20 $\mu g\ l^{-1}$.

4.3 Trends in Water Quality (Palaeolimnology & Historical Records)

No quantitative palaeolimnological studies have been carried out at the site. The University of Liverpool (Department of Geography) are currently carrying out qualitative sedimentary studies.

5 Threats to Conservation Interest & Management Recommendations

Eutrophication is probably the greatest threat to the site; charophytes thriving in low nutrient, clear water. The reduction in size and depth range of *Chara* beds, alongside increases in *Cladophora* and the presence of *E. nuttallii* can be considered as clear symptoms of eutrophication. The loss of two charophyte species could also be a response to enrichment. Newbold (1999) points out that the loss of three species of *Potamogeton* is, however, unlikely to be directly due to nutrient enrichment as all three species have been recorded at sites with high nutrient concentrations. Newbold (1999) states that there are no evident sources of nutrient pollution to the lake, although water is thought to seep in from a broad spring line along the eastern shore. Diffuse inputs from surrounding farmland and septic tank discharges cannot, therefore, be ruled out.

6.1 Current Monitoring

6. Monitoring

There is currently no regular monitoring of water chemistry or aquatic vegetation.

6.2 Future Monitoring

Regular monitoring of water chemistry, particularly nutrient concentrations, and aquatic vegetation is imperative at this site. Palmer (1999) outlines the monitoring protocols for this SAC type. This includes an annual summer survey providing a full species list for aquatic macrophytes as well as their relative abundances and a map of their distribution (Palmer, 1999). She also outlined bimonthly monitoring of secchi disc depth, alkalinity, total nitrogen, total phosphorus and chlorophyll *a*. The site should show no sustained increase in TP or TN concentrations from year to year and maximum chlorophyll a concentrations should not exceed 20 $\mu g\ l^{-1}$.

We would suggest two additions to this monitoring regime. Firstly data on pH, conductivity and water level should be included on the bimonthly chemistry monitoring. Secondly, vegetation surveys should additionally be carried out along selected depth transects that span the main populations of interest (all *Chara* species/varieties, all *Potamogeton* species and *E. nuttallii*). These can then be used 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 the transects.

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Malham Tarn

1. Site Details

SSSI name: Malham-Arncliffe

Open water name: Malham Tarn

County: North Yorkshire **District:** Craven

English Nature Region: North Yorkshire

Date Notified: 1955 **Date of revision:** 1988

National Grid Reference: SD 920676 **Ordnance Survey Sheet:** 98

2. Conservation Interest

Malham Tarn has been selected for SAC status as it represents a high quality example of a "hard oligo-mesotrophic water with benthic vegetation of *Chara* formations" (EC Habitats Directive). This SAC type is characterised by base-rich waters (calcium or magnesium) that contain low to moderate levels of plant nutrients (nitrogen and phosphorus). Dense beds of stoneworts, *Chara* species, are considered the principle defining component of this SAC type (Palmer, 1999). This habitat type is scarce in the UK. Malham Tarn has been selected as the best example of an upland *Chara*-dominated lake in England (JNCC, 1999).

The aquatic vegetation history of Malham Tarn has been well documented and the relative abundance and distribution of macrophytes has been shown to change considerably from year to year. The dominant species are the stonewort *Chara globularis*, spiked water-mil-foil (*Myriophyllum spicatum*), shining pondweed (*Potamogeton lucens*), Canadian pondweed (*Elodea canadensis*) and willow moss (*Fontinalis antipyretica*). All the main habitats associated with hydroseral development exist at the site from open water/swamp/fen/raised bog and lagg fen. The site also contains a wealth of invertebrate species. Thirty nine species of breeding caddis flies have been recorded including the Red Data Book species, the flightless *Agrypnia crassicornis* which within Britain has only been recorded at this site. Thirteen species of aquatic snails and mussels have also been recorded in the tarn, including eight of the sixteen British species of pea-mussel (*Pisidium* spp.). The lake also contains a population of the European crayfish *Austropotamobius pallipes*.

3. General Limnological and Catchment Details

The Malham-Arncliffe SSSI is underlain by Carboniferous Great Scar Limestone. A layer of glacial drift partially fills up an extensive basin to the immediate north side of the North Craven Fault. Malham Tarn constitutes the deepest part of an irregular depression in the hummocky surface of this glacial drift and the basin is almost completely surrounded by limestone.

The lake lies at an altitude of 375 m above sea level and represents the highest marl lake in Britain. It is a relatively large (61 ha), shallow lake with a maximum depth of 4.4m and mean depth of 2.4 m. The current level of the lake is raised artificially by 1.2 m using a sluice gate, which was constructed in 1791 and rebuilt in Victorian times (National Trust, 1999). The water in the Tarn is derived from a series of springs arising at the base of the limestone cliffs on the northern side of the basin. These originate from the junction of the Carboniferous limestone and the Silurian slates. Additional sources of water include run-off from adjoining agricultural land.

The catchment area is difficult to define because of the limestone nature of the geology. The area does, however, consist predominantly of unimproved grassland with a little improved grassland present near the lake. A Field Studies Centre (with 100 visitors in the summer) is located adjacent to the lake with other small settlements. The field centre has a small water treatment and septic tank system which eventually drain into the Tarn.

4. Current Status

4.1. Conservation Interest (with reference to SAC conservation objectives)

Macrophyte surveys have been carried out in 1995 by Monteith (Bennion *et al.,* 1997), 1985/86 by Ibal (1987) and 1965 by Holmes (1965). The Monteith and Ibal surveys both recorded dense stands of *Chara* sp. over large areas of the lake, whereas Holmes recorded *Chara* sp. as *'a dense cover over between a third and a quarter of the bed'* (National Trust pp. 20). This enhanced growth in recent decades is thought to have resulted from an increased nutrient load to the lake. In the most recent survey, Monteith recorded equally dense cover of *Elodea canadensis;* no previous survey has recorded such high cover for this competitive species (Bennion *et al.,* 1997). *Elodea canadensis* was first recorded in Malham Tarn in 1962 and has since increased in distribution and abundance (National Trust, 1999). It is a species typical of eutrophic lakes.

Several *Potamogeton* species recorded in 1965 by Holmes were also not recorded in the later surveys. This included *P. perfoliatus, P. berchtoldii, P. alpinus, P. pusillus and P. natans. P. lucens* was only recorded in isolated stands in both 1987 and 1995 (Ibal, 1987, Bennion *et al.,* 1997). Spiked water milfoil (*Myriophyllum spicatum*) was recorded in shallow waters in 1987 with a similar abundance to that of Holmes (1965). However, in 1995, this species was not recorded (Bennion *et al.*, 1997). These surveys, therefore, indicate a clear change in the aquatic plant composition that appear to represent a response to enrichment. The changes could, however, simply be interpreted as resulting from competition following the establishment of *Elodea canadensis*, a competitive invasive plant.

The conservation objectives laid down by Palmer (1999) suggest that beds of *Chara* species should cover at least 5 % of the vegetated zone and that they should be in good condition, free of filamentous and epiphytic growth. A variety of other native submerged and floating-leaved macrophytes should also be present including *Potamogeton* and *Myriophyllum* species and invasive plants such as *Elodea canadensis* should either be absent from the vegetation or not show any increased coverage from year to year. Malham Tarn is clearly showing a worrying trend with the disappearance of many *Potamogeton* species and expansion of *E. canadensis*, although the *Chara* beds have increased in abundance.

4.2. Water Quality

Detailed nutrient budgets of Malham Tarn have been carried out by the Freshwater Biological Association (Talling & Hilton, 1982, Talling, 1987). These indicate an increase in nitrate-nitrogen concentrations in the last forty years but do not provide any evidence of marked increases in phosphorus concentrations. Results from spot water samples more recently collected in 1993 (Carvalho & Moss, 1996) and 1995 (Bennion *et al.*, 1997) are presented in the table below:

	Inflow (Tarn Beck) 1993	Outflow 1993	Outflow 1995
pH	-	-	8.3
Total nitrogen (mg l^{-1})	-	-	0.9
Total phosphorus (μg l^{-1})	15	20	21

These suggest that Malham Tarn would still be classified as a mesotrophic lake according to the OECD classification (OECD, 1982). From the limited phosphorus data available, it is difficult to ascertain to what extent eutrophication has occurred at the site. Palmer (1999) does not provide TP targets for this SAC type. Individual site targets are recommended based upon baseline monitoring of the site. The site should, however, show no sustained increase in TP concentrations from year to year.

4.3. Trends in Water Quality (Palaeolimnology)

A palaeolimnological study was carried out on Malham Tarn by Bennion *et al.*, (1997). Diatom-based transfer functions were used to quantitatively reconstruct the total phosphorus history of the lake. The analysis indicated that there have only been slight changes in the diatom composition between 1770-1995 and there have been no clear species replacements. Diatom preservation was, however, poor and the diatom-TP transfer function greatly overestimated TP, reconstructing concentrations of 105 $\mu g\ l^{-1}$ c.1700, 150 $\mu g\ l^{-1}$ c.1800 and 1900 with a decrease to 88 $\mu g\ l^{-1}$ by 1995. These values are not comparable with measured TP data indicating the diatom model was not appropriate for this type of marl lake. The study did, however, show that the sediment accumulation rate was relatively uniform before 1970 (c.0.24 cm y^{-1}) but showed a significant increase since 1970 ($\geq$0.40 cm y^{-1}).

5. Threats to Conservation Interest

5.1 Eutrophication

The chemistry data suggests that the site is not yet severely impacted, although the vegetation data is suggesting significant ecological change that could be interpreted as a response to enrichment. The increase in nitrogen concentrations in Malham Tarn between 1949-1985 were initially thought to be a result of atmospheric pollution (Talling, 1987) but could equally be due to increased run-off from nearby farmland. Septic tank drainage inputs have also been highlighted as a potentially significant source of phosphorus and nitrogen (Carvalho & Moss, 1996). Both the expansion of visitors to the Field Centre and intensification of agriculture in the catchment need careful management. Work has been carried out to upgrade local septic tank systems and pollution from agricultural run-off is beginning to be tackled. The Field Studies Centre and the local English Nature office are adopting a precautionary approach and are attempting to reduce all artificial nutrient inputs from the catchment as much as possible (Evans, 1999).

6. Monitoring

6.1 Current monitoring

There is no regular monitoring programme for aquatic vegetation or water chemistry.

6.2 Future monitoring

Malham Tarn is clearly showing a worrying trend with the disappearance of many *Potamogeton* species and expansion of *E. canadensis*. Regular plant surveys are required to monitor these changes. More regular chemical monitoring is also required to assess whether these changes are associated with enrichment or simply a result of the change in the competitive environment following the establishment of *E. canadensis*.

Palmer (1999) outlines the monitoring protocols for this SAC type. This includes an annual summer survey providing a full species list for aquatic macrophytes as well as their relative abundances and a map of their distribution (Palmer, 1999). She also outlined bimonthly monitoring of secchi disc depth, alkalinity, total nitrogen, total phosphorus and chlorophyll *a*. The site should show no sustained increase in TP or TN concentrations from year to year and maximum chlorophyll a concentrations should not exceed 20 $\mu g\ l^{-1}$.

We would suggest two additions to this monitoring regime. Firstly data on pH, conductivity and water level should be included on the bimonthly chemistry monitoring. Secondly, vegetation surveys should additionally be carried out along selected depth transects that span the main populations of interest (*C. globularis, E. canadensis* and any other *Chara* or *Potamogeton* species). These can then be used 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 the transects.

8. References

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Breckland Meres

1. Site Details

Open water name	*Ringmere*	*Langmere*	*Fowlmere*	*Home Mere*	*Devil's Punch Bowl*
SSSI Name	East Wretham Heath	East Wretham Heath	Stanford Training Area	Stanford Training Area	Stanford Training Area
County	Norfolk	Norfolk	Norfolk	Norfolk	Norfolk
District	Breckland	Breckland	Breckland	Breckland	Breckland
English Nature Office	Norwich	Norwich	Norwich	Norwich	Norwich
Date Notified (Under 1981 Act):	1984	1984	1985	1985	1985
Date of last revision	-	-	-	-	-
National Grid Reference	TL 910882	TL 910882	TL 870940	TL 870940	TL 870940
Ordnance Survey Sheet					
1:50,000	144	144	144	144	144
1:10,000	TL 98 NW	TL 98 NW	TL 89 NW, NE, SW, SE TL 88 NE TL 99 NW, SW	TL 89 NW, NE, SW, SE TL 88 NE TL 99 NW, SW	TL 89 NW, NE, SW, SE TL 88 NE TL 99 NW, SW

2. Conservation Interest

The Breckland Meres have been selected for SAC status under the EC Habitats Directive for the feature "Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation". Along with associated Norfolk ditch systems, Hickling Broad, Upton and the Martham Broads, they represent the southern variant of this site type. In the UK, the characteristic submerged vegetation of these nutrient-rich waters consists largely of broad-leaved pondweeds, *Potamogeton* species, in association with a range of other macrophytes (Palmer, 1999). Within the UK at present, *Hydrocharition*-type vegetation is known to occur at only one lake in Anglesey and in Upper Lough Erne in Northern Ireland. This vegetation type (represented by the community *Hydrocharis morsus-ranae* with *Stratiotes aloides*) in British cSACs is now confined to ditch systems associated with the Norfolk Broads.

The Breckland Meres are a unique series of waterbodies, supplied from the chalk groundwater. They are characterised by their fluctuating water levels and consequently display a unique ecological system of aquatic and periodically inundated plant communities (SSSI Notification, 1984). The meres are naturally self-sustaining and therefore do not grow over or infill with sediment (Rothera, 1991). Instead, the fluctuating water levels of the meres continuously destroy existing vegetation and create areas for new colonisation (Rothera, 1991).

The meres support a variety of plant species dependent on the water level. At high water level, aquatic plants are abundant and include pondweeds (*Potamogeton* spp.), water crowfoots (*Ranunculus* spp.), and stoneworts (*Chara globularis*) (Watson, 1974). *Polygonum amphibium* and *Littorella uniflora* are also present. Of these, *P. gramineus* is a rare species as its distribution is declining in the UK but the meres favour its development due to their low nutrient status (Rothera, 1991). *Potamogeton x zizii* and *Littorella uniflora* are also nationally scarce species (Rothera, 1991). (Watson, 1974). Langmere is important for *P. lucens*, *P. gramineus*, *P. pectinatus* and *Polygonium amphibium* (Morgan & Britten, 1969), and the nationally rare Grass-leaved Water Plantain (*Alisma gramineum*) has also been recorded at the site. *P. lucens* occurs also at Ringmere (Morgan & Britten, 1969). A survey of Fowlmere in 1968 documented 100 % coverage of aquatic plants, including *Phalaris* at the edge, and a band of *Eleocharis palustris* and *Polygonum amphibium* with a central body of *Potamogeton lucens* and *Acrocladium* sp. (Morgan & Britten, 1969).

At low water level, the meres are characterised by concentric bands of vegetation communities. On the low shores, the common species include toad-rush (*Juncus bufonium L.*), marsh yellow cress (*Rorippa islandica*), bristle club-rush (*Isolepis setacea L.*), black medick (*Medicago lupulina L.), Myosotis caespitosa* and *M. scorpioides* (Watson, 1984). In addition to these species, *Rumex maritimus L.* (golden dock) and *Alopecursus aequalis*, two nationally rare plants have also been recorded (Rothera, 1991). When the meres dry out, five main species dominate the plant community. These include *Ranunculus sceleratus L.* (celery-leaved buttercup), *Myosoton aquaticum L.* (water chick-weed), *Agrostis tenuis Sibth* (common bent), *Phalaris arundinacea L.* (reed canary grass) and *Alopecurus aequalis* (orange fox tail grass) (Watson, 1974). The Breckland Meres SSSI also supports additional rare plants including *Physcomitrium eurystomum* and is thought to be the only British locality in which this species is found (Notification, 1984).

East Wretham Heath and Stanford Training Area SSSIs are of national importance for their invertebrate populations and are registered as Grade A in the Invertebrate Site Register report (87) (Rothera, 1991). The meres represent a large area of this interest with specific waterbodies such as Bagmore Pit being notified on account of their invertebrate interest. The fluctuating meres support rare species found in both permanent waters but more importantly species characteristic of dry periods (Rothera, 1991). The meres are dominated by the lower invertebrate groups which are able to withstand the dry phases (Watson, 1974). These include rotifers, micro-turbellaria and cladocera (Watson, 1974). Insects however are not as well represented because they must rely on adults recolonising the mere following a dry period (Watson, 1974). 12 Red Data Book species and 24 notable species are found on the meres (Rothera, 1991). The Breckland meres have an important ornithological interest, particularly for the waterfowl. They support breeding little grebe, tufted duck, gadwall and pochard. Langmere is reported to have a very high breeding density but in dry periods such as 1990, however, no breeding was recorded (Rothera, 1991).

3. General Limnological and Catchment Details

The underlying rock of the Breckland Meres consists of chalk, which is overlain by sands and gravels. The sand and gravel are locally separated from the chalk by boulder clay. The region is said to have a more extreme climate than other areas in Britain and has been described as semi-continental with low rainfall and temperatures (Rothera, 1991).

The meres consist of small, shallow waterbodies lying within the glacial sands and gravels. They are base rich because the sands and gravels are derived from a chalky till which also overlies chalk (Morgan & Britten, 1969). The unique characteristic of the meres is that their water level fluctuates markedly. These meres have no inflow or outflow and are fed solely from the groundwater chalk aquifer and precipitation (Rothera, 1991). The water levels, however, cannot directly be related to the precipitation (Morgan & Britten, 1969). Essentially, fluctuations in the water levels of the meres result from changes in the level of the chalk aquifer. The filling up and drying out of the meres occurs at different times for each waterbody with Langmere, Ringmere and Fowlmere drying out first, and subsequent filling up of the meres occurring in the reverse order (Rothera, 1991).

The water level fluctuations occur annually with a low water level in winter and a high level in mid summer as a result of the lag in the recharge from the winter precipitation (Rothera, 1991). The water levels also fluctuate over a longer time period with historical records indicating dry periods of up to three years as a result of low rainfall (Rothera, 1991). Examples of these periods include 1859-62, 1934-35, and 1973-74 (Rothera, 1991).

4. Current Status

4.1. Conservation Interest

The Breckland meres pose difficulties for aquatic macrophyte surveying due to their fluctuating water levels. Attempts have been made to survey the meres but problems arose because the sites have not been consistently wet since 1995 (Newbold, pers. comm.). The water levels have recently risen again, however, so it is anticipated that a plant survey can be successfully carried out in the summer of 2000. The completion of a successful invertebrate survey has also proved difficult as a result of the fluctuating water levels. Given that the invertebrate populations peak quite sharply, this peak is often missed. It is essential that any invertebrate survey being carried out on the Breckland meres is well designed to ensure all invertebrate species are accounted for (Rothera, 1999).

Abstraction of groundwater for spray irrigation

5. Threats to the Conservation Status

The principle threat to the conservation of the Breckland meres is the abstraction of water for spray irrigation. The water level is of primary ecological significance to the survival of the mere communities (Rothera, 1991) and the conservation interest will be threatened if there are sustained periods of drying out or wetting. English Nature has expressed concern over the abstraction licences which date back to the early 1970's, forming part of the Great Ouse Groundwater Scheme (Rothera, 1991). In addition to being a conservation concern, the abstraction issue is a political and economic one. Farmers are concerned about the potential crop and job losses if the abstraction licenses are refused (Rothera, 1991).

Climate Change

The additional threat of any future climate warming and specifically changes in effective rainfall threatens the conservation interest.

Eutrophication

There are also concerns as to whether the Breckland meres are suffering from eutrophication. Monitoring of groundwater and surface water quality is necessary to determine if the meres are at risk from eutrophication.

6. Monitoring

A Breckland Meres Policy has been introduced (NRA, 1991) which aims to prevent abstractions from significantly affecting the natural groundwater cycles (Rothera, 1991). This involves monitoring the groundwater level. Once the level falls below a threshold value, any abstraction must cease (Rothera, 1991).

English Nature are also supporting a scheme by which the source of the irrigation water is changed from groundwater to surface water from the Little Ouse (Rothera, 1991). This scheme has been agreed by all parties involved and should be coming into force shortly. It is imperative that the effects of this scheme are monitored.

7. Recommendations for Future Monitoring and Management

The Breckland Meres represent a unique ecological system which is becoming increasingly threatened by conflicting land uses (see section 6). Owing to the continuously fluctuating water levels, it is difficult to determine the impact of anthropogenic activity. This problem highlights the need for baseline and continual monitoring. The following guidelines should be followed (Palmer, 1999). It is imperative that complete macrophyte and invertebrate surveys are carried out when the water levels are high. The levels have recently risen and therefore this work must be carried out in the summer of 2000. Only when this has been successfully completed can the current conservation interest be determined accurately.

	Monitoring Recommendations	Guidelines
Macrophyte Survey	Establish a baseline botanical survey following the NCC lake survey methods (Lassiere, 1995). This should include a full species list for aquatic macrophytes as well as their relative abundances and a map of their distribution. This survey should be repeated annually in the summer to determine any change. A mean Trophic Ranking Score should be calculated.	Any Red List species of aquatic vascular plants or charophyte species should persist or increase in size. Alien plants should not increase or persist. A balance in the structure of the vegetation should be maintained. Phytoplanktonic algae blooms should not become persistent or dense. The dominant form of vegetation should not be filamentous algae. The mean TRS score should be between 7.5 -9.0 with any higher value indicating eutrophication.
	Carry out annual monitoring of any additional rare, protected or introduced populations of animals to determine a baseline survey. Further monitoring could be carried out annually for birds but may only be sufficient to monitor quinquennially for other populations.	
Invertebrate Survey	Carry out a baseline survey of invertebrates. This should be carried out quinquenially for the first year to assess the conservation status and to ensure that all species are accounted for. The presence of the species should be taken every 4 -5 years later.	The survey design should be carefully considered to ensure the peak is accounted for in the baseline survey.

The water quality must be monitored to determine whether eutrophication is an issue. A baseline initial survey for environmental variables should be undertaken (using the mean of at least 6 measurements per year from the middle of the lake) for one year to determine whether the recommended standards are met. These are listed in the following table, after Palmer (1999).

Environmental variables	Targets
Conductivity	There should be no sustained increase over the years.
Total phosphorus	If current TP level is up to 110 μg l^{-1} the target should be a maximum of 100 μg l^{-1}. If current TP levels exceed 110 μg l^{-1} a hindcasting exercise (Johnes *et al.*, 1994) should be undertaken and a baseline set at the highest value of 100 μg l^{-1} or the hindcasted baseline level.
Total nitrogen	If current total nitrogen is up to 3.3 mg l^{-1}, the baseline level should be 3.0 mg l^{-1}. If the current value exceeds 3.3 mg l^{-1} a hindcasting exercise should be undertaken and a baseline level set accordingly.
Secchi disc	The maximum depth at which the secchi disc remains visible (minimum value of 6 bimonthly measurements) should exceed 0.7 m in non-peaty areas and 0.5m in peaty stained waters.
Chlorophyll *a*	The chlorophyll *a* concentration for the meres should not exceed 75 μg l^{-1}.
Water Depth	The mean water depths over a sustained period (5 years) should show no pattern of decline.

A catchment survey is recommended. Owing to the concern over the impact of abstraction of groundwater for irrigation purposes, it is essential that this effect is monitored and quantified. Only when the exact effect is understood can any remedial action be taken. As described above, the Breckland Meres Policy has been introduced, aiming to switch the source of the irrigation water from groundwater to surface water. Once these measures are in place, the water levels should be carefully monitored to determine the implications and the benefits of this scheme.

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Upton and Martham Broads

1. Site Details (General)

Table 1: General Site Details

Open water name	*Upton Broad (Great & Little)*	*Martham Broads (North & South)*
County	Norfolk	Norfolk
District	Broadland	Broadland
English Nature Office	Norwich	Norwich
Date Notified (Under 1981) Act):	?	?
Date of last revision	?	?
National Grid Reference	TG 389134	TG 458201 (South)
(Of individual water bodies)		TG 458203 (North)
Ordnance Survey Sheet		
1:50,000	134	134
1:10,000	???	TG 42 SE
		TG 41 NE

2. Conservation Interest

Upton and Martham Broads have been selected for SAC status under the EC Habitats Directive for the feature 'Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*–type vegetation'. Along with associated Norfolk ditch systems, Hickling Broad and the Breckland Meres, they represent the southern variant of this site type. In the UK, the characteristic submerged vegetation of these nutrient-rich waters consists largely of broad-leaved pondweeds *Potamogeton* species in association with a range of other macrophytes. Within the UK at present, *Hydrocharition*-type vegetation is known to occur at only one lake in Anglesey and in Upper Lough Erne in Northern Ireland. This vegetation type (represented by the community *Hydrocharis morsus-ranae* with *Stratiotes aloides*) in British cSACs is now confined to ditch systems associated with the Norfolk Broads. The Upton Broad dyke system contains a very rich flora including *Stratiotes aloides*, *Butomus umbellatus* and *Sium latifolium*. The Norfolk Hawker *Aeshna isosceles*, one of the rarest British dragonflies, is confined to a small area of the Broads ditch systems, associated with *Stratiotes aloides* (Merritt *et al.*, 1996) and has been recorded at Upton and the Martham Broads.

Both Upton and the Martham Broads support the holly-leaved naiad *Najas marina* which, in places, forms dense stands. This species is listed in Annex II of the Habitats Directive as a threatened species (British Red List). Ratcliffe (1977) highlighted Upton Broad as the main site for this species, for which the Norfolk Broads are the only British locality. It was unknown in Britain until it was observed in Hickling Broad and Heigham Sound in 1883, and in Martham Broad in 1885 (Bennett, 1910). It was first found in Upton Broad in 1949 (George, 1992). The Martham Broads are important for their charophyte flora, which includes *Nitellopsis obtusa,* a species scarce throughout Europe.

George (1992) reports that Upton and the Martham Broads are amongst the few sites in Broadland that still support a well developed reedwamp in which saw-sedge predominates (*Cladium mariscus*). This community has been lost from the highly enriched broads. Upton Broad is also one of the few sites where *Typha angustifolia* stands and unusually large amounts of *Schoenoplectus lacustris* can be found. *Typha* was formerly abundant around the margins of almost all of the broads but there has been a progressive disappearance from most sites since the 1950s.

A variety of trophic states and salinities exist within this cSAC, Upton Broad being a fresh system, the Martham Broads being a brackish system, and the dykes representing a gradient. Thus both fresh and brackish floras are recognisable. In addition to its aquatic flora, the site is extremely important for its populations of aquatic and terrestrial invertebrates and is of great ornithological interest. Therefore, this cSAC with its complex of lakes and ditch systems exhibits a wide range of vegetation types, including special features of the habitat type, and has high conservation interest.

3. General Limnology

There are two bodies of water at the Upton Broad site, known as Great and Little Broads. Most of the data exist only for the Great Broad and, therefore, the use of the name Upton Broad in this report relates in almost all cases to data from the Great Broad. Upton Broad is spring-fed, receiving surface water from a very small local catchment in the valley of the River Bure and is surrounded by alder carr woodland and reed swamp. Much of the catchment is drained pastureland and is so small that local hamlets lie outside of its drainage area.

There are also two bodies of water in the Martham Broads, known as North and South Broad. Hydrologically, the upper Thurne, of which the Martham Broads form a part, is a complex system. Watson (1981) constructed a mathematical model and concluded that the Martham Broads received large inflows in winter, mostly from land drainage, and thus the system is well flushed. In contrast, during summer, inputs from the system are low and in drought years, a net water loss can occur. The North Broad is completely open and is fed by the river. In summer when water levels drop, there may be an additional input to the South Broad from groundwater sources. The South Broad is also partly spring-fed. General physical site details are provided in Table 2 and further details have been collated in George (1992).

Table 2: Physical Site Details

	Upton Broad (Great)	*Martham Broads*
Altitude	0 m	
Open water area	5.2 ha	7.3 ha (N); 8.7 ha (S)
Mean depth	1.3 m	1.0 m
Maximum depth	1.7 m	1.5 m
Site Uses	Angling	Nature conservation and angling

4. Current Status

4.1 Conservation Interest (with reference to SAC conservation objectives)

A true Phase I flora, comprising of stoneworts and low-growing waterweeds, can no longer be found in Broadland but Upton Broad, Martham North and South Broads (as well as the Blackfleet Broads) do still support some elements of this (George, 1992).

Upton Broad
The aquatic macrophyte composition of Upton Broad has been regularly monitored by the Broads Authority as part of the Norfolk Broads macrophyte monitoring programme since 1983. The submerged and floating leaved species list produced in their 1993 report (Kennison and Prigmore, 1994) is very similar to that produced by the survey of Bennion *et al.* (1997) described below. However, in 1993, *Potamogeton pectinatus* occurred in several locations and no charophytes were found (as was the case for 1992, despite previous records). Ratcliffe (1977) refers to *Nymphaea alba* and *Nuphar lutea* as being locally co-dominant, however there has been no recent record of the latter species at this site in recent years.

An aquatic macrophyte survey was undertaken by Bennion *et al.* (1997) in July 1996. The flora was generally typical of the more undisturbed Broadland sites in Norfolk although the submerged flora was relatively species poor. The most abundant submerged macrophyte was *Najas marina* which grows throughout the lake to a water depth of approximately 1.5 m and in places forms dense stands. *Potamogeton friesii* was found in an isolated location in the south-east of the site. The charophyte *Chara vulgaris* var. *vulgaris* was present in small quantities in a number of locations. The most recent survey by the Broads Authority (1998) reports no significant change from the previous surveys, with clear dominance by *Najas marina* and small percentage cover of *Nymphaea alba*, *Potamogeton pusillus* and *Zannichellia*. The surveys place Upton Broad in the Type 10B eutrophic category (Palmer, 1992).

The macrophyte surveys, in accordance with palaeolimnological studies of Upton Broad by Phillips *et al.* (1978), Moss *et al.* (1979), Stansfield *et al.* (1989), and Bennion *et al.* (1997) (see section 4.3), provide evidence of continued submerged plant abundance during the recent history of the broad. In their evaluation of the 1993 macrophyte data, Kennison & Prigmore (1994) described Upton Broad as belonging to the Phase I to Phase II group, sites which are species rich and generally little impacted by increased nutrient levels. It is often said that the site represents the type of condition which existed in many other Broads prior to the decline in submerged vegetation. A decline in the diversity of vegetation at Upton Broad has occurred, however, and there is currently poorer representation of all plant communities than in past (Jackson, 1978). A comparison of aerial photographs taken in 1946 and 1977 very clearly shows the loss of aquatic vegetation at Upton Broad over this period. For instance, the extent of floating 'hover', the fringing reed growing out from the rooted material at the edge of the lake basin, has declined. Studies have demonstrated that hover decline is positively correlated with maximum nitrate concentrations in the water (see Phillips, 1992). Jackson (1978) compared recent records with historical plant records for the site and demonstrated a gradual decrease in diversity between the late 1940s and the mid-1970s, accompanied by a switch in species composition sometime between 1952 and 1967. The most significant changes were the loss of *Myriophyllum verticillatum, Hydrocharis, Fontinalis, Lemna* spp and *Potamogeton obtusifolius* and the appearance of *Zannichellia, Potamogeton friesii* and *Sagittaria.* Since 1972, *Najas marina* has remained dominant but increasing instability in the other macrophyte species has been noted (Jackson, 1978). The extent of the filamentous alga, *Spirogyra* sp., has increased in recent years which could potentially threaten the continued success of the *Najas* (Phillips *et al.*, 1978).

Martham Broads
Martham South Broad has been regularly monitoring by the Broads Authority in recent years. According to the 1993 survey by Kennison and Prigmore (1994), the Broad is placed in the category of Phase I to Phase II Broads. A survey undertaken by Bennion *et al.* (1997) in September 1995 showed good agreement with the species list produced in the 1993 report. Open water across the south-eastern half of the broad was

dominated by charophyte beds composed of several *Chara* spp., including *Chara hispida*, *Chara apera* var *aspera* and *Chara vulgaris* var. *vulgaris,* along with the occasional *Myriophyllum spicatum*, *Zannichellia palustris* and *Potamogeton pectinatus*. In several locations adjacent to the eastern shoreline, *P. pectinatus* was locally abundant. The south-western end was dominated by a substantial bed of *Najas marina*. Specimens of *Nitellopsis obtusa*, a nationally rare stonewort, were recovered from within the main *Najas* bed. The two bays in the north-east contained the more diverse macrophyte assemblages. A mixed stand of *Nuphar lutea* and *Nymphaea alba* occupied the arm connecting the water body to the North Broad, and *Callitriche* sp. was locally abundant under the floating leaf canopy. A single individual of *Potamogeton perfoliatus* was recovered from a rake trawl in the open water of the main bay. Application of the scheme of Palmer (1992) types Martham South Broad as type 10, a eutrophic category.

Martham North Broad appears to have been surveyed less frequently but according to the 1993 survey by Kennison & Prigmore (1994), the North Broad supported similar aquatic macrophytes to the South Broad, including abundant *Chara hispida* and *Najas marina*, and occasional *Myriophyllum spicatum*, *Zannichellia palustris* and *Potamogeton pectinatus.* The North Broad had a greater extent of *Hippuris vulgaris* than the South Broad with a large stand at the south end in association with *Nuphar lutea* and some *Nymphaea alba*. The most recent macrophyte survey of Martham North Broad (Broads Authority, 1998) reveals a number of changes since the 1993 survey, most notably an increase in the frequency and extent of filamentous algae and *Chara intermedia*, and conversely a decrease in *Najas marina* and water lillies, though it is unclear whether this signals any real change in water quality. *Nitellopsis obtusa* was recorded in the 1998 survey.

A compilation of historical macrophyte records by Jackson (1981) documents the presence of charophytes, including *Nitellopsis obtusa*, in the Martham Broads since 1880, and numerous records from both the North and South Broads during the 1970s document a diverse and a productive macrophyte community (Jackson, 1978). Jackson (1978) concluded that there were few signs of any major loss of aquatic plants in the Martham Broads. There was some evidence to suggest inter-annual fluctuations in the abundance of both *Najas marina* and the charophytes in the South Broad, although this may have been due to seasonal variations owing to the different timings of the various surveys. It is interesting to note, however, that since Jackson's work in 1981, a number of species do appear to have been lost or have declined. In the surveys from the 1960s and 1970s, *Utricularia vulgaris* agg. with *Myriophyllum verticillatum* was described as abundant, whilst *Ceratophyllum demersum* was found in reasonable quantity. The first two of these have not been recorded in recent surveys and the latter has decreased to less than 5% cover. The Martham Broads, therefore, whilst still exhibiting a diverse aquatic macroflora, do appear to have experienced slight changes in their macrophyte flora. Nevertheless, there is no evidence to suggest significant environmental change over the last few decades, and the site meets the conservation objective of having a wide range of vegetation types (Palmer, 1999).

Upton and Martham Broads can be classified as eutrophic lakes based on their aquatic plant communities with mean TRS values (Palmer *et al.*, 1992) of ?? and 8.89, respectively. The conservation objectives for this habitat type specify a mean TRS score of 7.5-9.0 (Palmer, 1999) with mean values greater than 9 signifying possible over-enrichment. Neither of the sites, exceed this value.

In terms of emergent vegetation, Upton Broad is ringed by *Phragmites australis* dominated fen in which *Cladium mariscus* is also abundant. *Typha angustifolia* is also locally abundant in some locations and common associated fen taxa include *Iris pseudacorus*, *Oenanthe crocata*, *Lycopus palustris*, *Caltha palustris*, *Carex* spp. and *Mentha aquatica*. Martham South Broad is mostly fringed by *Phragmites australis* and *Cladium mariscus* dominated reed-swamp, although part of the shoreline on the south side is open deciduous woodland. These sites are important as this community has been lost from the highly enriched broads. It is important to note, however, that there has been a marked reduction in the extent of reedswamp even in these Broads. Boorman *et al.* (1979) observed considerable loss in reedswamp at Martham Broad and Upton Broad from examination of aerial photographs (see above for more detail on Upton Broad). The sites, therefore, fail to meet the conservation objectives for emergent vegetation whereby density should be maintained or increase (Palmer, 1999).

This SAC meets the objective of having a variety of salinities with presence of both fresh to brackish floras. The area of greatest concern is the decline in diversity and deterioration in the balance in the

4.2 Water Quality (with reference to SAC water quality targets)

structure of the vegetation in Upton Broad over recent decades.

The Environment Agency and Broads Authority have long term water chemistry datasets (for approximately the last twenty years) for a large number of the Norfolk Broads. The mean of parameters of water quality significance taken from the 1995-1996 survey are provided in Table 3.

Upton and Martham Broads can be classified as eutrophic lakes based on their TP concentrations (OECD, 1982). They do, however, lie almost at the boundary between mesotrophic and eutrophic waters with mean TP concentrations of c. 30-40 µg TP l^{-1}, and relative to other broads, they have low mean TP concentrations. Long-term data collected by the Environment Agency for Upton Broad (1978-1998) provides annual mean TP concentrations ranging from 23-67 µg TP l^{-1}, and monitored TP data over the period 1982-1992 for Martham South Broad gave an average TP concentration of c. 40 µg TP l^{-1} (provided by R. Starling, unpublished). There was no marked change in TP concentrations over these periods. A 1995/6 water quality survey of Martham South Broad by the Environment Agency recorded TP values ranging from 5 to 80 µg TP l^{-1} with a mean of 31 µg TP l^{-1}. Data for Martham North Broad (Moss, 1983) gives a mean TP value of 37 µg TP l^{-1}. The conservation objectives for this habitat type recommend site specific TP and TN targets and concentrations in both Upton and the Martham Broads (see Table 3) are well below the upper limits identified for these nutrients (means of 100 µg l^{-1} and 3 mg l^{-1} respectively) (Palmer, 1999).

Chlorophyll *a* concentrations are exceptionally low in Upton Broad (3 – 25 µg l^{-1} summer mean) and are almost entirely composed of very small flagellates and colonies of the cyanobacteria *Aphanothece stagnina* (G. Phillips, pers. comm.). The zooplankton is dominated by grazing cladocera (Phillips *et.al.*, 1996). It is unique among the Bure broads on account of its clear water and low phytoplankton crops. This may reflect the fact that it is a highly calcareous lake in which trace elements and phosphate are readily precipitated out with carbonate particles (Moss, *et al.*, 1979). Moss *et al.* (1996) reported maximum chlorophyll *a* concentrations for Martham Broad of 43 µg l^{-1} and long term data collected by the Environment Agency since 1982 shows values ranging from 1 to 40 µg l^{-1} (except for one maximum value in 1988 of c. 85 µg l^{-1}) with annual mean values of c. 20 µg l^{-1}. Martham South Broad is reported to have slightly higher water quality than the North Broad, most likely because the latter is connected more directly to the main river channel (Starling & Parmenter, 1998). Chlorophyll *a* concentrations for lakes of this habitat type should not exceed 75 µg l^{-1} and, therefore, levels at both Upton and Martham Broads are well below this limit.

The Martham Broads differ from most of the other waters in the broads in that they are slightly brackish. This is thought to be caused by the existence of a saltwater table at approximately the same level as the North Sea at low water and thus there is a direct underground connection between the sea and the groundwater (Pallis, 1911). Chloride concentrations are currently high in the Broad, ranging from 1000 to 2000 mg l^{-1} in the 1982-92 dataset (provided by R. Starling, unpublished). A target limit for conductivity has not been set due to saline influences in the southern variant of this habitat type.

Table 3 Water quality data recorded by Environment Agency (1995-96)

Water Quality Variable		*Upton Broad*	*Martham South Broad*
pH	units	8.7	8.2
conductivity	µS cm^{-1}	559	6090
alkalinity	mg $CaCO_3$	116	149
calcium	mg l^{-1}	72.5	316
total nitrogen	mg l^{-1}	1.4	1.1
total phosphorus	µg l^{-1}	38	31

4.3 Trends in Water Quality (Palaeolimnology & Historical Records)

Palaeolimnological studies were carried out on Upton Broad and Martham South Broad by Bennion *et al.* (1997) with the aim of reconstructing any past changes in water quality A 135 cm sediment core was taken using a piston corer at a water depth of 1.6 m from Upton Broad, and a 104 cm sediment core taken at a water depth of 1.0 m from Martham South Broad. A diatom-based transfer function was applied to the fossil diatom assemblages to quantitatively reconstruct total phosphorus (TP) concentrations.

Upton Broad

The surface substrate of Upton Broad was a soft, organic mud, striking bright green in colour, composed largely of the blue-green alga *Aphanotheca stagnina.* These surface layers appeared to be unstable and very possibly prone to resuspension during stormy weather. Diatoms were only well preserved above 40 cm. The assemblages had low diversity, being dominated by the same non-planktonic *Fragilaria* taxa throughout the core, species commonly found attached to either the sediments or macrophyte surfaces of shallow, alkaline waters. The TP reconstruction showed that the lake had high TP concentrations throughout the period represented by the sediment core (1877-1995), and indicated no change in the trophic status of the lake with values always c. 150 μg TP l^{-1}. However, these data must be viewed with caution in view of the low diversity of the diatom assemblage and the absence of planktonic taxa. The lack of planktonic forms in the sediments causes uncertainty over the results of the model because the relationship between non-planktonic taxa and open water nutrient concentrations is not as direct as that for planktonic forms (Bennion, 1995). The dominance of the benthic *Fragilaria* spp. could be because of the clear water conditions in Upton Broad which allow light to penetrate to the surface sediment so that benthic forms can grow there *in situ.* Likewise, the presence of epiphytic taxa in the diatom assemblages reflects the availability of submerged macrophytes to act as hosts. Bennion *et al.* (1997) suggest that these factors may explain why the model over-estimates TP values for Upton Broad.

Like all of the Broads, this lake has probably experienced some enrichment since 1935 (Moss *et al.*, 1979) but there has been no recent increase in the measured TP concentration despite the conversion of some pasture land to arable in 1989 (G. Phillips, pers. comm.). In a palaeolimnological study of Upton Broad by Phillips *et al.* (1978) and Moss *et al.* (1979), an increase in diatom concentrations and deposition rates (largely epiphytic taxa) was reported in the core from the mid-1930s, with a more marked increase from the 1970s. The authors suggested that the increase in fertility may have resulted from greater drainage to the lake from a piggery near the southern shore and to land fertilization.

Martham South Broad

There were analogue problems throughout the Martham South Broad core owing to the relative importance of brackish diatom species in the fossil assemblages that were not present in the freshwater calibration set. There were marked changes in the diatom species composition over the period represented by the 100cm core (post-1800 period). The bottom sample was dominated by the non-planktonic *Fragilaria* spp., typical of shallow, alkaline waters, with relatively high abundances of *Cocconeis placentula* and *Rhoicosphenia curvata*, species commonly found attached to plants in high conductivity waters. *Cymbella microcephala* and *Mastogloia smithii*, a brackish species, increased in importance at c. 1900. There was a further change by c.1950, where *Gomphonema angustatum* and *Achnanthes minutissima* also became important. *Fragilaria* spp. dominated the surface sample, although brackish species, especially *Amphora coffeaeformis,* were still present. The TP reconstruction indicated changes in the nutrient status of Martham South Broad but given the analogue problems, the diatom-inferred results were not considered to be reliable and only a qualitative interpretation of the species changes was made. Bennion *et al.* (1997) believe that the species shifts in the core are a response to changes in lake conductivity rather than nutrient concentrations because salinity is maintained by percolation under the coastal dunes bordering the North Sea. A number of the taxa in the fossil assemblages can tolerate highly conductive waters, e.g. *Cocconeis thumensis, Amphora coffeaeformis* and *Mastogloia smithii* and are therefore indicative of more saline periods in the lake's history, possibly due to sea water incursions.. *Mastogloia smithii* was also a major epiphyte in Hickling Broad, which is another broad with highly conductive waters (B. Moss, pers. comm.). Eminson (1978) reported a recent increase in diatom deposition in Martham Broad, and as for Upton Broad the assemblage was almost entirely comprised of non-plankonic taxa. This could signal an increase in productivity in the lake.

Water chemistry data collected during the late 1970s and early 1980s for the Martham Broads indicate that mean TP concentrations were c. 50 μg TP l^{-1} in the mid-1970s compared to mean values of c. 20 μg TP l^{-1} in the mid to late 1980s (Holdway *et al.*, 1978; Moss *et al.*, 1979). Mean chloride levels in the channel between the two broads rose from c. 1000 mg Cl^{-} l^{-1} in 1976 to c. 1600 mg Cl^{-} l^{-1} over the period 1980-82. These changes were brought about by the introduction in 1979 of a drainage improvement scheme to lower the water table in the Somerton Level, enabling grass marshland to be drained for arable farming. This resulted in substantial quantities of ochre, salt and nitrogen-laden water being released from the newly-drained marshes. The pumping station which drained Somerton Level discharged into Somerton Dyke, only 600 m upstream of the Martham Broads. The traces of iron ochre in the effluent were thought to contribute to the observed reduction in P in the Martham Broads at that time (George, 1992). The discharge was recognised as a conservation threat to the flora and fauna of the Broads, and thus in recognition of the sites's high conservation value, an improved system was later installed incorporating a weir to allow the discharge to sediment out before entering the Dyke. The system appeared to be successful as the Broads remained in good ecological condition. The TP concentrations subsequently increased slightly with current mean values of c. 30 μg TP l^{-1}.

Another palaeolimnological investigation of Martham South Broad, Upton Broad, as well as Hoveton Great Broad, was carried out by Stansfield *et al.* (1989). They analysed for pesticide pollution and their results showed low concentrations in Upton Broad and Martham South Broad sediment cores compared with those from Hoveton Great Broad. They attributed this to the fact that Hoveton Great Broad was connected to the River Bure system with a large arable catchment, whilst Upton Broad is isolated from the river system and Martham South Broad's catchment was dominated by marshland until the late 1970s.

5. Threats to Conservation Interest

Eutrophication

Studies by Phillips (1976) and subsequent work by Moss and colleagues suggest that the switch from Phase II to Phase III occurs once annual mean TP concentrations exceed c. 100 μg l^{-1}. The TP concentrations in Upton and the Martham Broads are still well below these levels and currently show no signs of an increase. It will be important, however, to continue to monitor the phosphorus concentrations in the lakes, especially in view of the observed decrease in macrophyte diversity in Upton Broad, and the decline of reedswamp and increase in filamentous algae at both sites.

Most eutrophication management in Broadland has been concerned with controlling phosphorus concentrations because it has been shown to be the limiting nutrient and is easier to control, given that it originates largely from point sources (Phillips, 1992). The amount of nitrogen in the Broadland waterways is also of concern, however, and concentrations are greater than in the past. Water chemistry data collected by the Environment Agency since 1982 indicates an increase in total oxidised nitrogen (TON) concentrations in Upton Broad from an annual mean of c. 0.2 mg l^{-1} in 1981 to c. 1.3 mg l^{-1} in 1994. If TON continues to increase, then the ecology of the Broad could be affected (see section on macrophyte changes in 4.1). Chlorophyll a concentrations in Upton Broad also showed an upward trend from 1991 with annual means increasing from c. 5 μg l^{-1} to c. 15μg l^{-1} in 1997. These concentrations are still low and fall well below the acceptable target for this habitat type, but there is clearly a need to closely monitor any changes in future years.

Land drainage schemes and water abstraction

As mentioned in section 4.3, the introduction of drainage schemes can pose a conservation threat. The improvement of a dyke to the southwest of Upton Broad in 1989 resulted in direct entry of enriched agricultural drainage waters into the Broad. In 1995 a bypass channel was created to retain water at the same height as the Broad and thus prevent any flow between the channel and the lake. However, recent work reports that this is now operating as a drain and its future management is being investigated. The Martham Broads may be affected by water abstraction as there is an established relationship between increasing salinity in the Thurne catchment and increased water abstraction in the area (Starling & Parmenter, 1998). Any new developments must undergo a thorough environmental risk assessment prior to implementation.

Pesticides

As described in section 4.3, palaeolimnological studies, whilst not conclusive, suggested that pesticide pollution could potentially impact upon on the macrophytes of the broads (e.g. Stansfield *et al.*, 1989).

Angling

As the lakes within this cSAC are used for angling, it is important that the fishing pressure is managed.

Acidification

Acidification is not a threat to these sites because they are very well buffered with current mean pH values of c. 8.0.

Climate change and sea level rise

Global warming may be a potential threat as drier, warmer summers could reduce the flushing rate and thereby increase the salinity of the Martham Broads. Relative sea level rise in the area could also potentially impact upon the Martham Broads. The likelihood of saline incursion into the broads and the likelihood of flood events is thought to be steadily increasing (Starling & Parmenter, 1998). The affects and the timescales of such changes are uncertain at present but it is probable that there will be no discernible impact over the next fifty years.

6. Monitoring

6.1 Current Monitoring

The Environment Agency (formerly the National Rivers Authority) is carrying out a long term monitoring programme in the Norfolk Broads which includes a range of chemical determinands, among them TP, TON, chlorophyll *a*, Secchi disc transparency and zooplankton composition. Water chemistry data exist from approximately the late 1970s. Starling & Parmenter (1998) report that for Martham South Broad this programme involves fortnightly water sampling in summer and monthly sampling in winter.

Annual aquatic macrophyte surveys have been carried out by the Broads Authority since 1982. These employ a double-headed rake towed behind a boat along a series of transects. The same transects are used during each survey. Macrophyte survey data are available for some years prior to the annual monitoring programme: for example, 1938, 1949, 1952, 1968, 1972, 1974-1977 for Upton Broad, and 1968, 1971-73, and 1975-77 for the Martham Broads.

Upton Broad is one of the Environmental Change Network freshwater sites. The network involves sampling of surface water chemistry (major ions quarterly, continuous pH, temperature, conductivity and turbidity, and temperature and oxygen profiling); invertebrates every three or five years; macrophytes every three or five years; and zooplankton, phytoplankton, periphyton and chlorophyll *a* four times per year.

The water levels at the Martham Broads are monitored by the Honorary Warden. Water level is particularly critical for management of the reed because cutting cannot take place when winter water levels exceed 18 inches above datum (Starling & Parmenter, 1998).

The extent of current monitoring of the dyke systems is uncertain, The Environment Agency and English Nature carried out a Marsh Dyke Water Quality Survey in 1998 and vegetation surveys were undertaken in 1988-89 and in 1996-1997 (cited in Minns, 1999).

6.2 Future Monitoring

All of the current monitoring programmes should continue. In view of the eutrophication concerns, it is essential to continue to monitor the key nutrients, phosphorus and nitrogen, and the productivity of the lakes via chlorophyll *a* measurements. The variation in conductivity should be monitored to establish baselines. This is particularly important for the Martham Broads so that degree of salinisation can be assessed and for the Broadland ditches where a range of conductivities (500-1500 $\mu S\ cm^{-1}$) is recommended to conserve plant diversity.

Annual botanical monitoring of a sample of the Broadland ditches should be carried out as they represent *Hydrocharis morsus-ranae* vegetation with *Stratiotes aloides*, an important component of this habitat type (Palmer, 1999). A survey using the standard NCC method (Alcock & Palmer, 1985) is recommended to establish a baseline for future monitoring. This should be repeated every year for a randomly chosen 10% of the original ditches surveyed, to assess overall change.

The extent and composition of the emergent vegetation should be monitored, as it is an integral part of the ecosystem. Furthermore, it is important for filtering out nutrient run-off from the catchment and is therefore useful in preventing any further nutrient enrichment.

Annual monitoring for presence and extent of rare plants is recommended (e.g. *Najas marina*). This is particularly important given the recent concerns over the increase in filamentous algae and the possible impact on *Najas*.

The waterbodies are very shallow and therefore lake levels should be monitored by means of a depth gauge. The sedimentation rates and rate of vegetational succession should be monitored as the aquatic flora is dependent on the areas of clear, open water at the sites.

7. Recommendations for Management

Broadland as a whole is an extremely well managed region and a considerable amount of management has already taken place at Upton and the Martham Broads. Therefore, only a small number of additional recommendations are given here. See Starling & Parmenter (1998) for a detailed management plan for Martham Broads and Marshes.

An ultimate conservation target in the Broads would be the re-establishment of a rich *Hydrocharis morsus-ranae* assemblage in the lakes themselves. Today this special feature of this habitat type is confined to the ditch systems. These latter systems must be managed in such a way that their diversity is maintained. Cleaning is recommended to achieve representation of a wide variety of stages in the succession from emergent dominated ditches to channels with at least 30% open water (Palmer, 1999).

The survival of many of the plant and animal communities of this cSAC is dependent upon the maintenance of the present water regime. Therefore, the site must be managed so that the present salinity levels and nutrient concentrations of the waters are not significantly altered. Given that this SAC does not receive any direct effluent from sewage, the major nutrient pollution source of concern is diffuse from agricultural drainage. The creation of buffer strips to reduce the impact of land drainage is recommended but the restricted use of artificial fertilisers and pesticides in the catchments would be a preferred management option. Any further intensification of arable farming in the catchments should be discouraged.

Careful management of the dykes which can bring agricultural drainage water into the Broads is needed. It is essential to reduce problems such as that arising at Upton Broad from the dyke improvement and consequent bypass channel construction (see section 5). The environmental impact of any planned drainage schemes should be fully assessed to ensure that the rich communities of the Norfolk dykes are conserved and that there is no impact on the Broads into which the dykes flow. Water abstraction licenses should be re-evaluated as part of the SAC review (Starling & Parmenter, 1998).

There is no suggestion at present that the sediments of either Upton or the Martham Broads should be dredged.

8 References

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Appendix 1: Open Water SSSI Database Guidelines

The database is currently held in two formats:

(1) A Microsoft Excel workbook that contains 3 spreadsheets: "All sites", "Plant data" and "High Interest".

"All sites" contains general information on all SSSIs with open water habitat.

"High Interest" contains general information on SSSIs that have been designated as "high aquatic interest"

"Plant data" includes macrophyte species data (including DAFOR abundance values) from the surveys carried out by Margaret Palmer *et. al.* in the 1970's and 80's held by the Biological Record Centre. The spreadsheet only includes the submerged and floating leaved vegetation.

(2) Three tab delimited text files (allsites.txt, plantdat.txt, high.txt) that can be imported into any word processor or database software. The three files contain the same information as in (1) above.

The following is a guide to the column headings in these data tables:

Column 1: County Key

This contains English Nature's county code

Column 4: Open water name

This refers to the name or type of water body within the SSSI, referred to in the database.

Column 5: SAC

This indicates whether the site is proposed to become a SAC site.

Column 6: Grid Ref

The national grid reference for the centre of the SSSI (not the water body)

Column 7: Area (ha)

The area of the SSSI in hectares.

Column 8: OW Area

The area of the open water body in hectares (unless otherwise stated).

Column 9: Ecosystem

The ecosystem characteristics of the SSSI.

Column 10: Nutrient Status

The nutrient status at the time of notification

Column 11: Impacts for the 'High' Sites.

This used Carvalho & Moss (1996), Bennion *et al.,* (1997), Moss *et al.,* (1992) and UWRG (1999) to provide known details of the impacts certain sites have been subject to.

The 'High' sites were categorised according to:

1. Eutrophication **(EUTR)**
2. Acidification **(ACID)** This information was obtained from GIS work carried out by UWRG (1999). It provides a basic indication of the acidification status of the waterbodies. Further work by UWRG could provide additional information on their acidification status.
3. Recreation **(RECR)** (including angling)
4. Hydrological Change **(WATER)**
5. **OTHER** (oil pollution, (date) road building, refuse, toxic spills)

Further details of the specific impacts are given after the above general codes.

Column 12: Original Aquatic Interest.

The sites were split into one of the following categories based on Carvalho *et al.*, (1996).

High: The site is noted for aquatic species that are sensitive to water quality/quantity change, such as submerged aquatic plants, benthic invertebrates and fish. **Medium:** Notable interest is for wetland areas adjacent to the open water or for species not directly affected by water quality, such as birds. **Low:** The site is not notified for its aquatic interest. (Carvalho & Moss 1996)

The database entry concentrated solely on the 'High' sites from this point.

Column 13: Current Aquatic Interest

For the sites where sufficient information was available the current aquatic interest was given as one of the following categories based on Carvalho *et al.*, (1996)

No Change Observed: no change that could be attributable to eutrophication **Reduced:** changes in aquatic community attributable to eutrophication. **Recovered:** the site has shown improvements in it's eutrophication condition. **Unknown:** the current status is unknown

Column 14: Veg Type

This categorises the open water into one of ten plant types according to Palmer (1992). This column was only filled in for sites in which information on the plant surveys is available from one of the above reports or from the plant cards obtained from the BRC.

Column 15: Veg Survey Reference

This shows the date and the name of the surveyor/report.

'Palmer' refers to the plant survey cards obtained from the BRC. Further details as to the actual surveyor and date are given on sheet 2 (plant survey card details).

Column 16: In-lake survey

This indicates whether there is a need for an in-lake survey. A cut off date of 1990 was used. Any sites with plant surveys before this date require an in-lake survey.

Y = Yes **N = No**

Column 17: Reason (In-lake survey)

This gives the reason for the need for an in-lake survey. This information was obtained from the above reports, UWRG (1999) and local EN teams.

Column 18: Catchment Survey

This indicates whether there is a need for a catchment survey. This used information from Carvalho *et al.*, (1996), Bennion *et al.*, (1997), Moss *et al.*, (1992), UWRG (1999) and local EN teams.

Y = Yes **N = No**

Column 19: Reason (Catchment Survey)

This gives the reason for the need for a catchment survey. This information was obtained from the above reports, UWRG (1999) and local EN teams.

Column 20: Conservation Measures

This indicates any conservation measures that have been carried out on the open water. This information was obtained from the above reports and local EN teams.

Column 21: Recommendations

This shows any recommendations which have been suggested for the open water to reduce/prevent any further damage. This information was obtained from Carvalho *et al.*, (1996), Bennion *et al.*, (1997), Moss *et al.*, (1992), UWRG (1999) and local EN teams.

Column 22: P Effect
Column 23: Water levels
Column 24: W Effect
Column 25: R Effect

These columns are the columns present on the original English Nature database. They were not modified because the sources of the information were not clear

Note:

Any details not in the above format are from the original table. The sources of these details are not known. The blanks in the database indicate a lack of records at that particular site at present. Further details are unknown.

Plant Survey Cards

This spreadsheet contains the plant survey details from the surveys carried out by Margaret Palmer *et. al.* in the 1970's and 80's held by the Biological Record Centre. The spreadsheet only includes the submerged and floating leaved vegetation. The following columns represent individual plant species and a code is given as to their abundance at the site. The codes are as follows.

D = dominant
A = abundant
F = frequent
O = occasional
R = rare
C = common
P = present (no abundance code on sheet)
LC = locally common
LA = locally abundant
LF = locally frequent

References

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Appendix 2: Priority List of Lakes requiring In-lake (Vegetation) or Catchment Surveys

The following list of priority sites were selected from SSSI sites with high aquatic conservation interest.

A site was designated as requiring an in-lake survey if the site had not had a plant survey in the last ten years (since 1990).

A site was designated as requiring a catchment survey if there were reports on the site file or in Carvalho & Moss (1994) that suggested investigation of catchment sources of pollution should be carried out.

The English Nature database provides more detail on the reasons for the surveys.

All SAC sites were by default designated as requiring in-lake vegetation and catchment surveys. The SAC site dossiers give further background to these decisions.

SSSI Name	Open Water Name	In lake	Catchment Survey
Abbots Moss	Pools including Gull Pool and Lily Pool.	Y	Y
Alderfen Broad		N	Y
Alvecote Pools	"Pretty Pigs, Mill and Upper Pools. Gilman's pool, Railway ,	Y	N
Ant Broads & Marshes	"Sutton Broad, "	Y	N
Ant Broads & Marshes	Cromes Broad	N	Y
Bassenthwaite Lake		Y	Y
Big Pool & Browarth Point		Y	Y
Bittell Reservoirs	Lower Bittell Reservoir	Y	Y
Bittell Reservoirs	Upper Bittell Reservoir	Y	Y
Black Firs & Cranberry Bog	Black Mere	Y	Y
Blackbrook Reservoir		Y	Y
Blelham Tarn & Bog			Y
Bomere, Shomere Pools	Bomere, Shomere and Betton Pool	Y	N
Brothers Water		Y	Y
Bure Broads & Marshes	Hoveton Great Broad	N	Y
Buttermere		Y	Y
Calthorpe Broad		Y	Y
Carnkief Pond		Y	Y
Chasewater Heaths	Chasewater Reservoir and outflow	Y	N
Claife Tarns & Mires	" Hodson's Tarn, Three Dubs Tarn"	Y	
Claife Tarns & Mires	"Moss Eccles Tarn, "	Y	N
Clarepool Moss		Y	N
Clayhanger		Y	Y
Coate Water	Coate Water	Y	Y
Coleshill & Bannerly Pools	Coleshill and Bannerly Pools	No	Y

Appendix 2: Priority List of Lakes requiring In-lake (Vegetation) or Catchment Surveys

Combs Reservoir		N	Y
Decoy Carr, Acle	dykes	Y	Y
Derwent water (proposed)	Derwent water	Y	Y
Dozmary Pool		Y	Y
Dungeness	Open Pits	Y	
East Wretham Heath	"Lang Mere, Ring Mere"	Y	Y
Edgbaston Pool		Y	Y
Ensors Pool		Y	Y
Esthwaite Water		Y	N
Fenemere		N	Y
Fleet Pond		Y	Y
Gait Barrows	Hawes Water	Y	Y
Glemsford Pits (Part in Suffolk)		Y	N
Godstone Ponds	"Bay Pond, Glebe Water, Leigh Place Pond"	Y	Y
Gormire	Gormire Lake	Y	Y
Great Pool - Tresco		Y	Y
Groby Pool & Wood	Groby Pool	N	Y
Heath Lake		Y	?
Hedgecourt	Hedgecourt Lake	Y	N
Higher Moors & Porth Hellick Pool		Y	Y
Honeybrook Farm	small lake	Y	N
Houghton Regis Marl Lakes		Y	Y
Littleworth Common	Littleworth Common Ponds	Y	Y
Loe Pool		Y	N
Lydford Railway Ponds		Y	Y
Maer Pool	Maer Pool	Y	Y
Marton Pool, Chirbury		Y	Y
Mickletown Ings		Y	N
Morley Brick Pits		Y	N
Oak Mere		Y	Y
Pool of Bryher & Popplestone Bank		Y	Y
Quoisley Meres	"Quoisley Big Mere,"	Y	Y
Quoisley Meres	Quoiseley Little Mere	Y	Y
Rainworth Lakes	"Rainworth Lake, Lily Pond, Bradder's Pond"	Y	N
Roman Wall Loughs	Crag and Broomlee Loughs	Y	N

Appendix 2: Priority List of Lakes requiring In-lake (Vegetation) or Catchment Surveys

Roman Wall Loughs	Greenlee Loughs	Y	N
Scotney Castle		Y	?
Semerwater		Y	Y
Slapton Ley	Higher and Lower Leys	Y	N
Sprats Water & Marshes	"Sprats Water and drainage dykes, small ponds"	Y	Y
St Neots Common	Series of Ditches	Y	Y
Stanford Training Area	"Home Mere, West Mere, Bagmore Pit, Smokers Hole, Warren	Y	Y
Stow Cum Quy Fen	Pools	Y	Y
Stubbers Green Bog	pool	Y	N
Sundon Chalk Quarry		Y	Y
Sutton Park	"Longmoor Pool, Powell's Pool, Blackroot pool, Keeper's Pool,	Y	Y
Tabley Mere	Tabley Mere	N	Y
Tarn Hows	The Tarn	Y	Y
Tatton Meres	Melchett Mere	Y	Y
Tatton Meres	Tatton Mere	N	Y
The New Forest	Hatchet Pond	Y	Y
Thompson Water, Carr & Common	Thompson Water	Y	Y
Thurstonfield Lough		Y	Y
Ticknall Quarries		Y	N
Toddbrook Reservoir (Part in Cheshire)		N	Y
Ullswater (proposed)	Ullswater	Y	Y
Upton Broads & Marshes	Upton Broad	N	Y
Walland Marsh	Dykes	Y	Y
Wasing Woods & Ponds	"Fish Pond, Fish Pond."	Y	N
Wast Water		Y	Y
Westwick Lakes	"Perch Lake,"	Y	Y
Westwick Lakes	Captain's Pond	N	Y
Westwick Lakes	Little Perch Lake		Y
Westwood Great Pool		Y	N
Whitmoor Common	"Brittens Pond, smaller pond"	Y	Y
Woodwalton Fen	two meres and network of ditches.	Y	N
Wraysbury & Hythe End Gravel Pits		Y	?
Yare Broads & Marshes	"Broads and dykes (Surlingham Broad,)"	N	Y

Appendix 3: English Nature Database: Vegetation Types represented in SSSI lake sites

Vegetation Type	SSSI Name	Open Water Name
1	Shapwick Heath	Open Ditches
1 or 8 (North Pond)	Scotton & Laughton Forest Ponds	North Pond
1,3,4,5,9	Swanholme Lakes	Series of pits
1 & 5	Wasing Woods & Ponds	"Fish Pond, Fish Pond."
1 & 2 (Woolmer Pond)	Woolmer Forest	Woolmer Pond & Cranmer Pond
2	Biddulph's Pool & No Man's Bank	"Biddulphs Pool, "
2	Biddulph's Pool & No Man's Bank	No Man's Bank
2	Derwent water (proposed)	Derwent water
2	Hayle Kimbro Pool (Part of West Lizard)	
2	Stover Park	Stover Pond
2	The New Forest	Hatchet Pond
2, 8 & 10	Yardley Chase	"Yardley Chase Ponds, North End (1)"
2 or 3	Englemere Pond	
3	Buttermere	
3	Claife Tarns & Mires	"Moss Eccles Tarn, "
3	Oak Mere	
3	Tarn Hows	The Tarn
3	Wast Water	
4	Blackbrook Reservoir	
4	Dozmary Pool	
4	Ullswater (proposed)	Ullswater
5	Abbots Moss	Pools including Gull Pool and Lily Pool.
5	Bassenthwaite Lake	
5	Blelham Tarn & Bog	
5	Over Water	
5 (Bromlee Lough)	Roman Wall Loughs	Crag and Broomlee Loughs
5 (Palmer 1977) 10B (Bennion et al., 1995)	Upton Broads & Marshes	Upton Broad
5A	Esthwaite Water	
5A	Roman Wall Loughs	Greenlee Loughs
5A	Sundon Chalk Quarry	
5A (No 4), 9 or 10 (No. 3)	Tetney Blow Wells	
8	Bar Mere	
8	Berrington Pool	
8	Berrington Pool	

Appendix 3: English Nature Database: Vegetation Types represented in SSSI lake sites

8	Betley Mere (Also In Staffs)	
8	Bomere, Shomere Pools	Bomere Pool
8	Clumber Park	Clumber Lake
8	Cole Mere	
8	Fenemere	
8	Fleet Pond	
8	Hatch Mere	
8	Maer Pool	Maer Pool
8	Oss Mere	
8	Quoisley Meres	"Quoisley Big Mere,"
8	Tabley Mere	Tabley Mere
8	White Mere	
8 (East Pond)	Scotton & Laughton Forest Ponds	East Pond
8 (West Pond)	Scotton & Laughton Forest Ponds	West Pond
9	"The Mere, Mere"	"The Mere, "
9	"The Mere, Mere"	Little Mere
9	Alresford Pond	
9	Calthorpe Broad	
9	Hawes Water	Hawes Water
9	Scout & Cunswick Scars	Cunswick Tarn
9	Skelsmergh Tarn	
9	Slapton Ley	Higher and Lower Leys
9 & 10	Cotswold Water Park	
10	Bittell Reservoirs	Lower Bittell Reservoir
10	Bittell Reservoirs	Upper Bittell Reservoir
10	Houghton Regis Marl Lakes	
10	Langtoft Gravel Pits	
10 (Palmer), 5a (Bennion et al., 1995)	Malham-Arncliffe (Malham Tarn)	Malham Tarn
10	Marton Pool, Chirbury	
10 (Rainworth Lake), 2 (Lily Pond)	Rainworth Lakes	"Rainworth Lake, Lily Pond, Bradder's Pond"
10	Sea Bank Clay Pits	
10	Sunbiggin Tarn & Moors & Lt. Asby Scar	Sunbiggin Tarn
10	Tattershall Old Gravel Pits	
10	Tatton Meres	Tatton Mere
10	Thompson Water, Carr & Common	Thompson Water

Appendix 3: English Nature Database: Vegetation Types represented in SSSI lake sites

10	Westwood Great Pool	
10	Woodwalton Fen	two meres and network of ditches.
10 (Home Mere)	Stanford Training Area	"Home Mere, West Mere, Bagmore Pit, Smokers
10 (Strumpshaw Broad)	Yare Broads & Marshes	Strumpshaw Broad
10B	Hell Kettles	Croft Kettle' and 'Double Kettle'
10B	Semerwater	