Monitoring the Floating Water-plantain

Luronium natans

Conserving Natura 2000 Rivers

Monitoring Series No. 9

Monitoring the Floating Water-plantain

Conserving Natura 2000 Rivers Monitoring Series No. 11

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Conserving Natura 2000 Rivers

This protocol for monitoring the floating water-plantain (*Luronium natans*) has been produced as part of **Life in UK Rivers** – a project to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites. The project's focus has been the conservation of rivers identified as Special Areas of Conservation (SACs) and of relevant habitats and species listed in annexes I and II of the European Union Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) (the Habitats Directive).

One of the main products is a set of methods for monitoring species and habitats, which complements reports containing the best available information on their ecological requirements. Each report has been compiled by ecologists who are studying these species and habitats in the UK, and has been subject to peer review, including scrutiny by a Technical Advisory Group established by the project partners. In the case of the monitoring techniques, further refinement has been accomplished by field-testing and by workshops involving experts and conservation practitioners.

Conservation strategies have also been produced for seven different SAC rivers in the UK. In these, you can see how the statutory conservation and environment agencies have developed objectives for the conservation of the habitats and species, and drawn up action plans with their local partners for achieving 'favourable conservation status'.

Life in UK Rivers is a demonstration project and, although the reports have no official status in the implementation of the directive, they are intended as a helpful source of information for organisations trying to set conservation objectives and to monitor for 'favourable conservation status' for these habitats and species. They can also be used to help assess plans and projects affecting Natura 2000 sites, as required by Article 6.3 of the directive.

Favourable conservation status

The purpose of designating and managing SACs is to maintain at, or restore to, 'favourable conservation status' the habitats and species listed on annexes I and II of the directive.

The conservation status of a natural habitat can be taken as favourable when:

- Its natural range and areas it covers within that range are stable or increasing.
- The specific structure and functions necessary for its long-term maintenance exist and are likely to exist for the foreseeable future.
- The conservation status of its typical species is favourable.

The conservation status of a species may be taken as favourable when:

- Population data indicate that the species is maintaining itself on a long-term basis as a viable component of its natural habitats.
- The species' natural range is neither being reduced nor is likely to be reduced for the foreseeable future.
- There is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

The conservation status of a species or habitat has thus to be assessed across its entire natural range within the European Union, in both protected sites and the wider countryside, and over the long term.

Monitoring techniques

The Habitats Directive requires the condition of the habitats and species for which a Special Area of Conservation has been designated to be monitored, so that an evaluation can be made of the conservation status of these features and the effectiveness of management plans. An assessment of conservation status must, therefore, be applied at both site and network level.

Standard monitoring methods and a coherent assessment and reporting framework are essential to allow results to be both compared and aggregated within and across EU member states.

While the directive outlines the data reporting required from member states at a national level, it did not set out detailed assessment techniques for data collection at habitat and species level.

The Conserving Natura 2000 Rivers series of monitoring protocols seeks to identify monitoring methods and sampling strategies for riverine species and the *Ranunculus* habitat type that are field-tested, cost-effective, and founded on best scientific knowledge.

Titles in the monitoring and ecology series are listed inside the back cover of this report, and copies of these, together with other project publications, are available on the project website: www.riverlife.org.uk.

Contents

1 Introduction

The floating water-plantain (*Luronium natans*) is a small aquatic plant belonging to the family Alismataceae. It is endemic to Europe, where it is virtually confined to Britain, France, the Netherlands, Germany and Poland. It is believed to be declining in many parts of its range.

L. natans can exist in a number of different growth forms, which allows it to colonize a variety of habitats. These range from upland lakes and small, fast-flowing streams to deep, sluggish rivers and their backwaters, to temporary pools, as well as canals, ditches, reservoirs, ponds and peat cuttings. *L. natans* appears to be tolerant of a range of dissolved chemicals, but is sensitive to competition from larger species that may increase in response to eutrophication, acidification, biological invasion and natural succession. The loss or reduction in the disturbance regime (for example, grazing, water-level fluctuations, flood scouring, dredging and boat traffic) that would normally arrest succession is particularly significant. However, populations of *L. natans* in lowland regions also tend to be more dynamic, reflecting the scale and rate of underlying landscape processes. The ecological requirements of *L. natans* are reviewed in detail by Lansdown & Wade (2003).

In the UK, 14 sites or site complexes have being proposed as Special Areas of Conservation (SACs) solely or partly for *L. natans*. These range from upland, oligotrophic lakes, lowland mesotrophic lakes and upland rivers to canals and heathland pools. Many catchments, however, contain populations that fall outside SAC boundaries but are nevertheless important in terms of the overall status of the species in the UK. Critically, an integrated approach to monitoring retains the concept of connectivity among sites of different types.

This monitoring protocol is designed to allow rapid assessment of the condition of *L. natans* populations in candidate SACs (cSACs) (sites proposed as SACs). With such information conservation agencies can assess risk, prioritise future management and evaluate the effectiveness of that management. It will also enable agencies to report to the European Commission on the conservation status of the species at a national level.

The protocol will also assist surveyors to monitor populations that fall outside cSAC boundaries, and undertake baseline surveys of sites that fulfil the ecological requirements of *L. natans*. This will provide information about a wider range of populations and contribute to a more comprehensive understanding of the ecology of this species in the UK.

This protocol provides a methodology for:

- Assessing the conservation status of *L. natans* in the various aquatic habitats in which it occurs within cSACs in Britain.
- Establishing trends in population size.
- Collecting ecological information to refine suggested targets for population attributes.

It is important to emphasise that our knowledge of some aspects of the life history and ecological requirements of *L. natans* is still severely lacking. Therefore, we recommend best practice based on available knowledge, with the caveat that targets will probably need to be revised in the light of new information on ecology and distribution. Not all aspects of the monitoring protocol have been adequately field tested. Therefore, suggestions are made for testing techniques and feeding results back into target-setting and condition assessment.

Common standards have been provided that allow the condition of populations of protected species to be classified as one of the following:

- Favourable
- Unfavourable
  - – Declining
  - – No change
  - – Recovering.

It is frequently assumed that there is a simple equilibrium between the composition of a community, or the attributes of a particular population, and the local environment. On this basis, the measurement of selected environmental variables independent of the target species might be deemed adequate for condition assessment. Similarly, measurements of population or community attributes alone ought to reflect environmental determinants. In reality there is often a significant mismatch between species and environment that demands that attention be paid simultaneously to both environmental variables and the target species or community.

For example, plant communities exhibit a high degree of inertia to some long-term directional environmental changes, and may technically be in favourable condition even when environmental attributes are suboptimal. Conversely, as a result of historic factors (such as management or a climatic extreme) or dispersal limitation, a species or community may be judged to be in unfavourable condition even when the ambient environmental conditions appear to be favourable. This latter case will also arise when one-off instantaneous measures of environmental attributes fail to reflect the overall environmental regime. Consequently, in defining condition, it is imperative to consider both the existing state of the population and whether there are current or future threats to it.

This protocol provides a survey and sampling methodology for specific monitoring of *L. natans* populations in different habitats. Populations are monitored against targets for generic attributes that are compatible with guidance by the Joint Nature Conservation Committee (JNCC) for monitoring vascular plant populations (Sydes 1999). Section 7 provides details of data required to assess current or future risks to these populations. Data on supporting habitat features form an integral part of the condition assessment. They will also assist in the interpretation of population-level data and allow informed decisions regarding the frequency of monitoring.

2 Preparation

2.1 Licensing

In the UK, *L. natans* is fully protected under Schedule 8 of the Wildlife and Countryside Act, 1981 (as amended 1992). This reflects its protection under Appendix 1 of the Bern Convention and Annex IV of the European Commission Habitats Directive.

A licence to handle or uproot *L. natans* must be obtained from English Nature, the Countryside Council for Wales or Scottish Natural Heritage well in advance of fieldwork (note that this is distinct from licences issued by the Department of the Environment, Food and Rural Affairs [DEFRA] for development work). When monitoring is undertaken by direct observation or counting, and there is no intention to disturb the plant, it should be acceptable to work unlicensed. Grapnel sampling, however, (for example of a canal in which *L. natans* occurs) is subject to licence. Surveyors should contact the relevant conservation agency for advice on licensing.

2.2 Identification

L. natans is notoriously difficult to identify. In upland lakes, submerged rosettes not examined directly might be mistaken for *Isoetes* spp. In canals and lowland rivers or lakes, confusion is possible with several widely distributed species, especially juvenile plants of *Sparganium emersum* and *Alisma* spp. In canals, several species of *Sagittaria* (for example, *S. natans*) also form linear-leaved rosettes with stolons that closely resemble *L. natans*. In shallow pools. *L. natans* may be mistaken by inexperienced recorders for several species, including *Baldellia ranunculoides*, *Limosella aquatica* or *Ranunculus flammula*. In this habitat, *L. natans* and *B. ranunculoides* may grow as intermixed stands.

In general, few of these other species form extensive lawns of basal rosettes and are easily distinguished from *L. natans* when in flower or fruit. In upland lakes, however, surveyors should be aware that *B. ranunculoides* may also form extensive submerged stands in identical habitats to those used by

L. natans and can only be reliably separated from *L. natans* by the distinctive coriander-like smell of its crushed leaves.

This protocol is intended to offer a consistent and reliable approach to surveying *L. natans* that yields standardised data that can be used to assess population trends within UK cSACs. In all cases the effectiveness of the proposed method is conditional on the surveyors being familiar with the type of overall habitat, the growth form and preferred growing conditions of *L. natans* in that particular habitat, the use of any specialised equipment and any special safety considerations. Demonstration, training and familiarisation exercises will be necessary to meet these requirements.

2.3 Health and safety considerations

Health and safety procedures for working in or alongside water must be strictly followed. It is recommended that a basic risk assessment is written for each site and signed for legal compliance. Measures relevant to surveying particular habitats should be noted in the appropriate sections. However, the following general advice applies.

- Surveyors should work in pairs at all times, even when carrying out bank-based procedures or initial exploratory visits to sites.
- All surveyors should be accomplished swimmers.
- A full first-aid kit and mobile phone should be carried at all times. If the surveyor is working on or in water, one mobile phone should be kept on land.
- If working in water deeper than knee depth, a dry suit will be the safest, warmest and most practical clothing. If a dry suit is not used it is essential to wear a life jacket.
- If a boat is required, all surveyors must first have attended a small boat handling course.
- Waterproof gloves are useful to reduce heat loss and injuries to hands, particularly when surveying by snorkelling.
- At large sites change tasks after two hours to maintain efficiency and reduce fatigue.
- Intensive surveys may require three to eight hours to undertake, depending on the size and complexity of the site. Surveyors should be adequately prepared for unexpected weather conditions. Glare from the water surface may contribute to sun stroke under prolonged sunny conditions. All surveyors should carry adequate sweet food rations and a hot drink.
- Surveyors working in remote sites should leave details at a central office of their expected location and time of finishing. They should then telephone the office upon leaving the site.

2.4 Access

In order to maintain goodwill and for health and safety purposes it is essential to obtain permission well in advance of entering private land. Area offices will maintain registers of landowners within cSACs and their local contacts.

2.5 Precautions

A number of introduced invasive species, including *Elodea* spp. and *Crassula helmsii*, pose a severe threat to the long-term status of *L. natans* if their colonisation is allowed to proceed unchecked. If surveying sites where these pervasive species are established, personnel should take particular care in washing any footwear or sampling gear on site to minimise the spread of these species to new locations.

3 Key monitoring targets

3.1 Ecological requirements

In defining key monitoring targets it is necessary to briefly consider the growth forms and habitats in which *L. natans* is found within the UK. *L. natans* occurs in lakes, canals, drains and ditches, rivers (including intermittently connected waterbodies) and shallow pools (including dune slacks and moorland and heathland pools). The various growth forms exhibited by *L. natans*, and the conditions under which they most frequently occur, are well described by Lansdown & Wade (2003). They suggest that three basic reproductive strategies may usefully be recognised – perennial vegetative, perennial flowering, and annual flowering – and these can, to some extent, transcend simple habitat divisions (see Table 1).

Table 1. Distribution of principal growth strategies of *L. natans* with regard to habitat. Shaded cells denote the key habitat x growth strategy combinations on which monitoring protocols concentrate.

Habitat/ strategy	Oligotrophic lakes	Mesoeutrophic lakes	Canals	Ditches/ drains	Rivers	Shallow, fluctuating pools
Perennial vegetative	++++	++	++		++++	
Perennial flowering	+	++++	++++	+++	+(+++)[2]	+
Annual flowering	+	+(+++)[1]	+	++	+	++++

[1]The annual flowering state may temporarily be very abundant during periods of water level draw-down, for example in reservoirs. In such instances the protocol designed for shallow pools should be implemented.

[2]Floodplain waterbodies with intermittent connections to a main river will function as periodically scoured standing waters and are likely to contain perennial flowering populations of *L. natans*.

3.2 Targets for population attributes

Generic guidance relating to vascular plants is available on targets for various population attributes (for example, Sydes 1999). These attributes include:

- Number of populations at a site.
- The sizes of these populations.
- Trends in population size.
- Evidence of regeneration.

Given the morphological and ecological plasticity of *L. natans*, it is clear that defining common targets for these generic attributes that embrace all the growth forms and the habitats in which they are found is a challenge. Targets must be locally determined and refined following field trials. Site-specific targets must also be developed after baseline surveys, and we recommend that these targets should be consolidated after three years. Nevertheless, the following targets are suggested (Table 2), subject to testing and revision.

Table 2. Population attributes and generic targets for favourable condition.

Attribute	Target to achieve favourable condition
Number of populations per site (3.2.1)	A site should contain two or more discrete populations. Opportunities for interchange among populations are preserved
Population size (3.2.2)	Populations either cover, on average, >20% of the area of the habitat patches in which they occur, or, when not directly observable, are present within >20% of point samples collected from suitable habitats. For many UK rivers where it occurs, lower percentages of cover are more typical. In canals and ponds, which are subject to rapid successional change, available habitat (open water or wet mud) should account for two thirds or more of the basic site area.
Population trend (3.2.3)	No severe population fluctuations (>50% decline in the total number of occupied samples) between visits. Total sample occupancy or cover across all occupied patches should not decrease by >25% per visit for two successive sampling occasions.
Evidence of regeneration (3.2.4)	Occupied habitat patches should include plants of a range of sizes. Perennial populations: evidence of two or more reproductive strategies within the SAC as a whole. Annual populations: >50% of the sampled quadrats that contain *L. natans* should also contain plants with fruiting heads.

3.2.1 Number of populations

In this report, 'populations' are regarded as discrete clusters of plants less than 50 m apart. In terms of population stability, it is clearly advantageous for a site to contain more than one population. This means that, within a site, at least two distinct patches of suitable habitat are being occupied (regardless of the total number or extent of such patches). A 'site' is defined here as the whole cSAC, or the collection of monitoring units designed to assess that cSAC.

Suitable habitat is difficult to define precisely, partly due to our incomplete knowledge of the autecology of this species, and partly because *L. natans* clearly tolerates a wide range of conditions, which make it difficult to identify the key drivers in habitat choice. However, it is usually possible to describe conditions under which *L. natans* is unlikely to be found. Guidance on what constitutes suitable habitat within the major environments in which *L. natans* is found is provided in Section 7.

A habitat patch might range in size from as little as 1 x 1 m (although this will probably be rare) to being equivalent to an entire site (for example, a 500 m length of un-navigated canal). There are two obvious exceptions to this:

- Suitable habitat and the species itself are continuously distributed over a single large area but discrete clusters of plants cannot be identified. *L. natans* may occur in this state in lakes, and it would not be desirable to regard a single large stand as inferior to a series of smaller fragments with the same basic distribution. A single population extending for >100 m parallel to the shore should therefore be regarded as favourable.
- The site itself is so small that even the most distant clusters could not be separated sufficiently widely to be considered as distinct populations. This will apply particularly to small, isolated pools in heathland or on lake/river floodplains. In such cases the best solution may be to regard the site or its population as part of a potential metapopulation. A more appropriate question is then to ask if other similar populations exist within a 5 km radius of

the site, or, alternatively, if there are larger lake or river populations present within 1 km with which the smaller population might potentially interact.

Lansdown & Wade (2003) advocate adopting a metapopulation approach to the assessment of favourable condition in *L. natans*. We support this approach in principle, because the importance of gene flow, habitat fragmentation and landscape dynamics embodied by a metapopulation approach deserve greater attention in plant conservation.

However, we also recognise that it will not be practical to monitor all individual populations or growth strategies in sites that are (potentially) inter-linked and might therefore be regarded as a metapopulation. Nevertheless, decisions on condition should take account of whether opportunities for populations to interact (via permanent or frequent hydrological connection or livestock or waterfowl movement) have been preserved, even though the extent to which these opportunities are realised may be unknown. Reference to large-scale maps (1:10 000) or recent aerial photography should assist in making such decisions.

In addition, when assessing condition, surveyors must consider the fact that some populations will exhibit extreme fluctuations for natural reasons – for example, severe floods or drought, and shifting patterns of grazing and succession may all create or destroy suitable *L. natans* habitat. Thus, in the case of a complex of lowland pools, for example, unless the intention is for interventionist management on a pond-by-pond basis, any decision on condition of one population should reflect the state of the wider complex. Similarly, in rivers where *L. natans* populations fluctuate to the point of extinction, such as the Rhone, the potential for recolonisation from upstream sources or periodically connected floodplain waterbodies must be considered. Therefore, in addition to the number of populations within a site, favourable condition requires potential connectivity of populations to have been preserved.

3.2.2 Population size

In modular organisms population size may be expressed as numbers of individuals. *L. natans* regenerates extensively by vegetative means, with the rosette forming the basic unit (this is the minimum size of vegetative fragment that can function as a viable dispersule). However, meaningful estimates of population size based on numbers of individuals are likely to be difficult to achieve in some habitats or without uprooting plants.

This particularly applies to perennial flowering populations, which (apart from flowering) are characterised by vigorous vegetative spread via stolons that ascend through the water column bearing chains of individually viable plantlets. In perennial vegetative populations, plants form extensive lawns in which rosette densities may exceed 2500–3000 per m^2. Moreover, population densities (rosettes per unit area) will vary widely between different habitats (or spatially within the same site, depending on local growing conditions). There is very little available information on the range of densities acquired, so it is difficult to recommend a generic population size, based on numbers of individuals, that could be accorded favourable status.

The size of a population may also be expressed via the extent of suitable habitat within a wider site, and the proportion of that habitat that is occupied. In large lakes, or when the plant can only be viewed remotely, determining the total extent of suitable habitat or the occupancy of this habitat will not be viable. A sub-sampling approach, focusing on and revisiting selected sheltered patches of lake-bed within the appropriate depth range, will therefore be required. Moreover, populations that use only a small proportion of the total available resource, yet are abundant where they occur (they use a large proportion of the area of the patch(es) in which they are present) may exhibit long-term stability, provided there is no net change in the suitability of these patches. In the case of shallow pools, and to a lesser extent canals, the occupancy of suitable habitat may remain stable or even increase, while the absolute area (as a percentage of the total site) is contracting due to succession by marginal vegetation. Under this scenario, a wet hollow measuring 1 x 1 m in the centre of a former pond filled with *L. natans* could theoretically be described as favourable unless assessment takes into account the historic maximum extent of suitable (shallow, open water/wet mud) habitat. The simplest approach to determining the limits of such sites and the extent of available habitat will be via examination of aerial photographs that readily distinguish between open water and emergent vegetation. Reference to historical pictures, if available, may provide information on the probable rates of habitat loss through succession, and the effectiveness of any past management in controlling this.

As a general guide it is suggested that populations in favourable condition will either cover, on average, >20% of the area of the habitat patches in which they occur, or, when not directly observable, will be present within >20% of point samples collected from occupied patches. The rationale is that when the proportion of suitable patches that are occupied is high, and when the frequency of plants per patch is high, then the overall population is in favourable condition. If few suitable patches are occupied and the frequency of plants within these patches is small, then the population should be considered unfavourable. Such populations will be particularly vulnerable when there is little or no prospect for colonisation from upstream sources.

This target may be modest when compared to very large populations established after interventionist management (for example, in recently dredged canals, populations may extend over several hundred metres, virtually covering the entire canal bed). However, such populations are rarely stable over the long term without repeated management, and it would therefore not be realistic to set targets for population sizes of this scale. In sites subject to rapid successional change (canals and ponds) it will also be necessary to estimate the extent of available habitat as a proportion of the original site boundary. To meet the target for available habitat, open water or wet mud (unvegetated by trees or emergent vegetation), should (provisionally) account for more than half of the original site area. Thus, a canal two-thirds filled by reed swamp would be considered unfavourable (even if the remaining open water was extensively colonised by *L. natans*), since this degree of encroachment would be regarded as a future threat to population stability. For UK rivers with *L. natans*, it is very rare to have even small reaches of watercourse with >20% cover, and such cover is typically limited to extremely small patches.

In terms of robustness of monitoring and minimising between-observer error, sampling based on presence/absence over a large number of small samples is preferable to assessment of cover or counts of individuals in a small number of large samples. Cover, in particular, is very strongly biased by the perception of the individual observer. There is a well-recognised underlying relationship between occupancy (or range size) and mean local abundance measured across those patches or samples in which a species is present. Using frequency of occurrence or occupancy (presence/absence) based on a fixed number of samples taken from suitable habitat is therefore suggested as being the most easily and widely applicable approach for robust assessment of population size.

3.2.3 Population trends

In the case of monitoring (as opposed to surveillance) it is necessary from the outset to be able to designate targets that the population and site must achieve to meet favourable condition. Thus, the application of condition assessments is an absolute rather than relative concept. However, after an initial survey, provided sufficient quantitative data are collected using repeatable techniques, population size can always be assessed relative to the original baseline. Targets may be different, depending on the habitat and population charcteristics. Over a series of assessments (at five- or six-year intervals) this will provide the evidence to determine whether the population or site is stable or subject to directional change. Qualifying labels such as declining, recovered or stable may then be added. The population trend will therefore be an important assessment criteria in subsequent monitoring cycles.

Any assessment of population trends should take into account stochastic fluctuations in population sizes in naturally dynamic habitats, such as river channels, since the disturbance events that induce major fluctuations may be key factors in maintaining the suitability of some habitats. It is therefore suggested that only severe population fluctuations (>50% decline in total number of samples in which the species is present between visits) should merit unfavourable condition. Annual monitoring of populations at one or two cSACs representative of different habitat types should, however, be considered, to calibrate the scale of natural population fluctuations. The threshold suggested may need to be revised on the basis of these results.

Population trends will be assessed more meaningfully over several consecutive monitoring cycles. Thus, as a supporting criteria, it is suggested that the occupancy should not decrease by >25% per visit for two successive sampling occasions. Time of year is a significant consideration, due to the contrasting effects of, for example, winter floods and summer growth. Assessments of population trends should therefore be based on visits made at least one year apart and at comparable times of year.

In habitats where interventionist management is required to maintain suitable habitat by reversing natural succession, a continuous decline over several monitoring cycles may be used to infer a requirement for repeated management. However, in lowland areas where populations are naturally dynamic, it may be appropriate to consider whether new populations have arisen locally, or other, existing populations have expanded, before adopting a preservationist approach to managing individual populations. In the case of geographically isolated populations this option will not apply.

3.2.4 Evidence of regeneration

Evidence of regeneration is provided by the existence of the reproductive strategy most pertinent to the ambient environmental conditions. Aside from this, it is difficult to specify the proportion of the overall population that should display a particular strategy, since this is likely to be very sensitive to small variations in water depth and recent weather conditions. The exceptions to this are deep-water lawns in upland lakes that are comprised exclusively of rooted basal rosettes. In this situation any trend towards clonal propagation via ascending stolons may indicate increasing water level fluctuations.

Similarly, in shallow pools, all plants should incorporate the annual flowering state. An increase in the presence of perennial vegetative plants may be associated with prolonged wetness or site permanence. Perhaps the simplest target that applies to both perennial and annual populations is the presence of a range of plant sizes, since this implies effective ageing and recruitment of plants.

In perennial populations, stability is aided by a range of reproductive strategies – in particular, some flowering, potentially outbreeding plants (flowering in Britain can occur between late May and early September). Thus, for example, in mesoeutrophic lakes and canals, there should always be some areas where water is sufficiently shallow and still for the development of ascending stolons bearing chains of plantlets, and for the production of floating leaves (or submerged, expanded leaves borne on long petioles) and flowers (although in deeper water these may be exclusively cleistogamous [permanently closed and self-fertilising]). For perennial populations, favourable condition should require evidence of two or more reproductive strategies within the cSAC as a whole.

In the case of populations of annual plants in shallow pools it is important to obtain evidence of sexual reproduction. The mere presence of plants is sufficient to confirm the quality of seed set from previous generations. However, the degree of seed dormancy in *L. natans* is unknown and repeated recruitment from the seedbank without effective replenishment will reduce the long-term stability of the population.

Although flowers are often the most striking feature of annually reproducing populations, counting flowers is unlikely to be a meaningful way of assessing condition, since flowers are highly ephemeral and are not a good indicator of the quality of seed set. Consequently, it is more useful to confirm the existence of full seed heads. As a provisional target for annual outbreeding populations, it is suggested that, using the method for assessing population size, >50% of the sampled quadrats that contain *L. natans* should also contain plants with fruiting heads in summer.

3.3 Suitability of monitoring targets

Monitoring targets are likely to be somewhat arbitrary and must (initially) be based on best judgement since, in many cases, the optimal growth conditions or optimal population state are poorly known, and even with the benefit of further research, may still prove hard to define.

Most information on the ecology of *L. natans* is observational, anecdotal, qualitative, or site- and habitat-specific and was not collected for the purposes of condition assessment. Any interpretation of the suggested targets must bear in mind the limitations of the available data. Thus, for example:

- What total area of submerged stand or number of rosettes constitutes a minimum viable population ?

- What extent of bare ground or associated species within a bed is acceptable, and how much poses a risk to stand integrity?
- What should be regarded as a desirable lower rooting depth for plants in an upland lake, and what lower rooting depth suggests that the underwater light climate has deteriorated unacceptably?
- How many plants in a temporary pool must flower and set seed to avoid net depletion of the seed bank?

Surveillance of sites and populations as a component of the three- to six-year monitoring cycle may provide the sort of information needed to answer some of the above questions, if data from several sites are critically assessed, or some sites are intensively surveyed over consecutive years. Without the benefit of this hindsight it is best to accept that interim definitions of favourable condition will inevitably need to be flexible.

Testing survey methods will not in itself confirm the appropriateness of the criteria to which these methods are designed to be sensitive. In the same context, when setting target conditions, ranges must be sufficiently broad to reflect our lack of knowledge and to be attainable, but at the same time not vary so widely that they are insensitive to meaningful change in the status of populations or growing conditions. The complementary use of habitat and direct population assessment provides a pragmatic solution to this problem until the knowledge gaps can be plugged.

Consequently, in carrying out the monitoring exercise it is important to collect targeted quantitative data that might initially appear to extend beyond the minimum data requirements for condition assessment. Such data are necessary to refine our understanding of limiting factors and population trends, and thereby improve the quality of the monitoring procedure, both generally and for the particular site being monitored.

4 Timing and frequency

4.1 Timing of surveys

In permanent waterbodies the basal rosettes of *L. natans* are winter green. However, to record evidence of regeneration, obtain sufficient data on associated vegetation, and complete surveys under reasonably comfortable conditions, surveys should be carried out between late June and mid-September. Within this period, do not survey during heavy rain or strong winds, as visibility in the water column is extremely limited in such conditions. Similarly, surveys should also not be undertaken for at least 24 hours after heavy rainfall. Still and cloudless summer days provide the best conditions for monitoring, and it should then be possible to determine condition in rivers and small standing waters by direct observation from the bank without recourse to the full survey methods described below.

In temporary waterbodies the timing of surveys is much more critical, since plants are intolerant of prolonged desiccation. Depending on weather conditions over the previous month, surveys of such sites are best completed between late May and mid-June. If effective regeneration is occurring it should be observable during this period. However, observers should be aware that most amphibious mud species are highly responsive to short periods of suitable water levels and weather. Assessment of populations in temporary waterbodies would therefore be more reliable if based on three short visits at two weekly intervals during May and June than a single one-off visit.

4.2 Frequency of monitoring

4.2.1 Baseline surveys

Baseline surveys of all sites should be undertaken within a single summer season if at all possible. At previously unsurveyed sites there is a far greater chance of detecting *L. natans* when growing conditions (light, water depth, flow stability, etc.) have been favourable. In the event of prolonged poor weather in late spring, consideration should be given to delaying surveys for a few weeks. Baseline surveys of all cSACs should be repeated at least once every 12 years (every second monitoring cycle) – although in the case of canals, where population sizes may change rapidly in response to anthropogenic impacts, more frequent baseline monitoring should be considered.

4.2.2 Monitoring

Small populations in shallow pools that are liable to dramatic fluctuations in size should initially be monitored annually for a five-year period. In sites that are classified as favourable at the end of this period the monitoring interval may be increased to six years. The scale of fluctuations in river populations is unclear. It would be desirable to monitor at least one such population annually for a five-year period, or, failing this, to monitor one population more frequently over a one- or two-year period, to determine susceptibility of population size to intermittent high-flow events.

In lakes or rivers monitoring should be undertaken at six-yearly intervals, unless populations are classified as unfavourable on an initial visit. If threats to supporting habitat features are identified, or if there is a consistent decline in population size (even if this is too small to merit unfavourable condition) three-yearly monitoring should be instituted. In canals intensive monitoring should be undertaken on a three-yearly basis.

If interventionist management is initiated as a result of identifying threats to supporting habitat features, condition assessment should be postponed for three years. This will allow the minimum expected seed dormancy period for *L. natans* to elapse before assessing the effectiveness of management introduced (Lansdown & Wade 2003).

5 Survey techniques

5.1 General

The design of a suitable monitoring protocol requires that specific targets are identified for each habitat to define favourable condition, taking account of the limitations on surveying posed by different habitats. Appendix 1 attempts to define, based on our current understanding, the typical population attributes and preferred habitat of *L. natans* within the major environments in which it is found. It also highlights criteria that can be monitored with the survey methods and technology currently available.

The section below details the proposed survey technique for each of the main habitats of *L. natans*, and includes any necessary justification. A more precise sampling strategy and suggestions for testing are described in Section 6.

For practical reasons, survey and monitoring protocols are largely designed around the anticipated physical constraints (for example, site area and water depth) presented by a given habitat and thus relate to the most typical population strategy or combination of strategies employed by plants growing in that habitat. However, survey and monitoring protocols also need to be flexible for two reasons. First, marked environmental changes at a site may induce a major shift in the representation of the different reproductive strategies. Thus, for example, permanent reservoirs, canal channels and fish ponds normally characterised by perennial flowering plants would, under draw-down conditions, more closely resemble shallow temporary pools and may then (temporarily) be dominated by annual flowering plants.

Secondly, high spatial heterogeneity raises the prospect of coexistence by plants exhibiting different growth strategies. Lansdown & Wade (2003) argue that the opportunities for genetic exchange or long-term stability presented by even very small populations displaying reproductive strategies different from those of the core population must be recognised and preserved. For example, in shallow temporary pools the potential for unpredictable events to disrupt seasonal cycles of flowering and seed production is considerable. Therefore, any vegetatively reproducing plants growing in deeper permanent water may be an important stabilising feature. In the same way, small pools periodically connected to a river channel may serve as an important refugia from which plants may recolonise the main channel after disturbance by extreme flow events.

It is important to appreciate that the approaches suggested will only yield data that are comparable over time for samples collected at the same site or between sites from the same habitat type. Due to differences in, for example, sampling efficiency, area sampled by the survey method suggested and levels of spatial aggregation, it will NOT be possible, or appropriate, to compare frequency of occurrence in sites representing different types of habitat.

To assess the population attribute targets set out in Section 3.2, surveys must:

- Identify the extent of potentially suitable habitat within a site.
- Determine whether or not this habitat is occupied and how plants are dispersed between different habitat patches.
- By fixed-effort sampling determine the extent of occupancy of patches in which plants are present, as an indicator of population size.
- Compare measures of population size collected on successive monitoring occasions to identify population trends.
- Record evidence of sexual or vegetative propagation as an indication of population viability.

5.2 Potential and recommended survey methods

5.2.1 Shore-based survey methods

5.2.1.1 Lakes

The monitoring technique used most widely for collecting data on aquatic plant communities of standing waters is undoubtedly that developed originally by the Nature Conservancy Council (NCC) and then refined over several decades by NCC/Scottish Natural Heritage during the course of the Scottish Loch Survey (Lassiere 1998). Essentially, this entails circumnavigating the waterbody on foot, recording macrophyte distribution within the shallower part of the littoral zone (<0.6 m deep) by eye, and using a double-headed rake on a 10 m rope to sample the deeper parts. The abundance of all species is assessed subjectively on a DAFOR scale (Dominant, Abundant, Frequent, Occasional or Rare).

In upland lakes *L. natans* sometimes occurs as extensive lawns of submerged basal rosettes in water up to 3 m deep (and possibly deeper in some sites, depending on water transparency). In most cases, the only evidence of such plants to shore-based observers will be as accumulations of plants in strandline vegetation left after storms (although the absence of *L. natans* from strandline material cannot be considered diagnostic). The probability of reliably sampling *L. natans* in deep lakes using shore-based methods must therefore be considered weak, and regular use of rakes to sample areas of fine sediment within sheltered bays should be a basic minimum method. Frequently, however, the topography of the lake bed and shoreline will preclude this. By contrast, in smaller and shallow (max depth <1.5 m) sites, direct visual observation will offer coverage of most suitable habitat.

5.2.1.2. Canals

Towpath-based walking surveys have been widely used for describing the abundance and distribution of aquatic vegetation in canals. Although mapping or assessment of abundance by eye has been used, this approach alone consistently under-samples the submerged vegetation in even the clearest waters and is of little use in turbid waters. It must therefore always be complemented by the regular use of a grapnel or rake. The narrow width of the channel and the angle of the observer mean that available habitat can be sampled quickly and flexibly with this combined method, and it is consequently the preferred approach for baseline surveys.

5.2.1.3 Rivers

The monitoring technique used most widely in Britain for collecting data on riverine macrophyte communities is probably that developed by Holmes *et al*. (1999) or some variant of this method. Extensive surveys of riverine vegetation in Europe were also carried out by Haslam (1987) who based her surveys on visual assessments of cover from bridges. This approach is unlikely to be effective for surveying *L. natans* in UK rivers, however, because of the variety of growth forms and difficulty of identification, and the range of habitats.

A more recent survey technique developed by Holmes *et al*. (1999) (to support the use of river macrophytes as trophic indicators for site monitoring in accordance with Urban Waste Water Treatment Directive) is based on the original approach, but is applied to 100 m reaches. It uses a finer resolution assessment of cover (a nine-point scoring system) and is more explicit in the derivation of cover scores. This requires walking a reach and using a grapnel to sample deeper water. This method is intended to be used within the channel rather than on the bank, from where it is not possible to adequately sample the range of available habitats except in very small streams. The instream use of this method is advocated as part of the baseline survey methodology.

5.2.2 Underwater cameras, bathyscopes, glass-bottomed buckets

Underwater viewing devices are generally employed from a boat and range from glass-bottomed buckets to bathyscopes and submersible video cameras, to remotely operated vehicles. Underwater photography is a flexible, non-destructive technique that is effective at low light intensities, can cover large areas when plants occur at low densities, and can be operated safely and simply from a small boat.

Digital technology provides a fixed record that may subsequently be subjected to more sophisticated image-analysis techniques, which would allow formal quantification of attributes such as leaf density or extent of bare ground. It is therefore recommended that underwater digital videography (UDV) is used for surveying lake populations, since this offers net advantages over other lake-based sampling methods. The major disincentive to the use of this approach is the initial cost of purchasing equipment. However, such equipment could be shared and used in the monitoring of other species, such as *Najas flexilis*, to which similar survey constraints apply.

5.2.3 Use of grapnels, rakes, grabs

Mechanical devices such as grapnels and grabs allow the remote sampling of habitats that are inaccessible to bank-based observers and which cannot be viewed satisfactorily from a boat, principally due to water depth. These also have the advantage of providing a physical sample that can be examined directly and sorted into component species. Small, unobtrusive species that may be missed by other techniques can potentially be recovered through mechanical means.

Unfortunately, the efficiency of sampling with such methods varies between habitats (such as depending on substrate texture) and species (for example, depending on depth of rooting or ease of breakage).

Consequently, in spatially heterogeneous habitats these methods may only yield qualitative data. Of additional concern is the danger that grabs or rakes can fragment slow-growing deep-water beds of isoetids (including *L. natans*), thus making them more vulnerable to wave erosion or invasion by other, less desirable species. Therefore, in open standing waters this technique is recommended only when conditions preclude the use of submersible cameras or snorkelling.

In more spatially homogenous environments such as canals, and especially those that are already subject to light boat traffic and management by dredging or weed cutting, this method offers the safest and most flexible approach to the assessment of aquatic vegetation composition and abundance.

5.2.4 Use of SCUBA and snorkelling

The use of SCUBA enables the collection of detailed formal quantitative data (for example, biomass from small quadrats), direct observation of plants and better placement of *L. natans* stands within the context of associated vegetation and lake bed features. However, the costs entailed by safety requirements in terms of personnel, limited available expertise, difficulty of transporting equipment to remote sites and limited spatial coverage that can be achieved within a waterbody, are considered to be major disadvantages.

Snorkelling offers a more flexible approach that is less restrictive in terms of safety and equipment requirements. However, snorkelling is not a viable option for covering very large areas, is physically tiring, especially in cold conditions, and is effectively restricted to observation of plants in water shallower than 2 m. Additionally, snorkelling is less amenable to the collection of quantitative data unless timed or fixed-area searches are carried out.

It is an attractive option, however, for the monitoring of riverine populations liable to be under-sampled by other approaches, and for which boat-based sampling cannot be justified. Snorkelling is particularly effective at low water velocities in modest-sized (>20 m width) channels or in rivers with significant areas of deep water overlying fine sediment.

Table 3. Summary of suggested survey methods for use in baseline surveying (B) or quantitative monitoring (M) of *L. natans* in its major habitats.

Method/Habitat	**Uplan**		**Lowlan**		**Riv**		**Can**		**Temp poo**	
	B	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**
Bank-based										
1. Strandline	*		*							
2. Visual assess					**		**	**	**	**
3. Grapnel/rake	*		*				**	**		
Boat-dependent										
1. Camera/ bathyscope	**	**	**	**	*	*				
2. Rake		*	*							
Snorkelling		*	*	*	**	**				

Preferred methods are indicated by a double asterisk. A single asterisk is used to denote supporting methods or those that may be used as an alternative ONLY if local conditions dictate.

6 Sampling strategy

6.1 Lakes

6.1.1 Baseline survey

In selecting upland sites for surveying from which there are no previous records of *L. natans*, priority should be given to larger waterbodies with relatively extensive littoral zones, or to clusters of smaller sites (>1 ha) more than 1 km apart. *L. natans* is unlikely to occur in small, isolated, high-altitude (>300 m) lakes, or pool complexes on upland blanket bog. Consultation of maps and aerial photographs is an essential part of the site-selection process. Particular attention should be given to catchment topography (valley-floor lakes rather than those in steep-sided, rocky basins) and the existence of emergent vegetation or beds of nymphaeids (both of which are both readily visible from good-quality aerial photographs). Previously unsurveyed lakes meeting these criteria, and which are situated in mid- or north Wales, the Lake District, Dumfries and Galloway or the midwest coast of Scotland, should be prioritised.

If selecting sites in the field, or when there is some background botanical data, the presence of a combination of nymphaeids (*Nuphar lutea* or *Nymphaea alba*), *Sparganium* spp. (*S. emersum* or *S. angustifolium*), larger submerged *Potamogeton* spp. (such as *P. alpinus*, *P. praelongus*, *P. lucens* or *P. gramineus*) or *Elatine hexandra* are more likely to indicate favourable conditions than a flora composed exclusively of the suite of classic oligotrophic lake species (*Isoetes* spp., *Littorella* spp., *Lobelia* spp., *Juncus bulbosus*, *Potamogeton polygonifolius*, *Callitriche hamulata* and *Myriophyllum alterniflorum*).

Finding *Luronium* in lakes
The most likely areas of upland lakes in which to find *L. natans* are sheltered bays and around river inflows where fine sediment tends to accumulate. Highly exposed, eroding shorelines or rocky outcrops should be avoided. Plants are more likely to occur at depths in the range 1–3 m than in very shallow water. *L. natans* is more likely to occur amongst diverse elodeid or natopotamid vegetation with an understorey of *Isoetes* than on gravelly substrates in association with *Littorella* and *Lobelia*.

In valley-floor lakes that feed low-gradient river systems, if there is suitable habitat (see Section 6.2) immediately downstream (<1 km from a lake outflow) it is highly likely that such habitat will be occupied by *L. natans* if it is present in the upstream standing waterbody. A rapid technique for confirming the presence of the plant in a lake would therefore be to target suitable riverine habitat before beginning a full lake survey.

A baseline survey requires circumnavigating the waterbody in a boat or inflatable. In large sites (>25 ha) an outboard motor will allow rapid movement between potentially favourable locations and more time to focus on these. The baseline survey is designed to establish the presence of *L. natans* (strandline surveys are a supplementary option) and the overall dispersion of plants.

The simplest and most effective approach is to navigate close to the shore, zigzagging between 1 m and 3 m depth. At this stage, depending on water surface conditions, incident light and water transparency (secchi disc depth >5 m), direct observation from the side of the boat may suffice to establish the presence and broad-scale distribution of *L. natans*. This will particularly be the case in sheltered or more productive lakes, where ascending stolons and plants with expanded leaves should be visible in water 1–2 m deep. If the water is rippled, or it is overcast, raining, or transparency is low (for example, due to suspended peat particulates), it will be necessary to use an underwater camera.

The location of all stands should be recorded using a GPS and indicated on a 1: 10,000 scale map photocopied onto waterproof paper. It is not necessary to map the precise extent of every stand. However, stands should be ranked based on a subjective visual assessment of extent and coverage to enable the three best localities to be selected and revisited for subsequent detailed assessment. All other species recorded during the survey should be scored according to the DAFOR scale.

Failure to locate any plants using this technique in a waterbody from which there are recent records must be interpreted carefully. It may prove especially difficult to relocate plants in large, deep waterbodies containing only small populations. A supplementary measure would be to examine strandline vegetation. Since the basal rosettes of *L. natans* are evergreen, the most effective time to employ this method would be in early spring when material detached by winter storms has accumulated, and canopy forming deciduous species have yet to become re-established.

For example, in Loch Tay in central Scotland, there are large, fully submerged beds of *Baldellia ranunculoides* (Sue Scott, pers. comm.) growing as lawns of basal rosettes very similar to those formed by *L. natans*. In April 2002, extensive mounds composed almost completely of uprooted rosettes of *B. ranunculoides* occurred along several hundred metres of shoreline (Nigel Willby, pers. obs). Similarly, in other loch surveys, species including *Najas flexilis* and *Potamogeton* x *griffithii* have been obtained from strandline material when it has proved impossible to locate rooted stands of these species using intensive lake-based sampling methods. In some cases, for example when there are major time constraints or limited access prevents the use of a boat, strandline surveys may be the only realistic rapid option for detecting the presence of *L. natans*.

The baseline survey is likely to be adequate to provide information on gross change in population status in lakes based on the overall distribution of the plant within the waterbody, but will not be sufficiently sensitive to smaller changes in abundance within preferred habitats. It is suggested that the baseline survey is repeated every other monitoring cycle, or approximately every 10–12 years.

6.1.2 Intensive survey and monitoring

The intensive survey will focus on the three best localities within the waterbody as identified by the baseline survey, based on the apparent size of the *L. natans* populations observed across a range of patches, or, failing this, the relative suitability of the habitat as described above. These localities should have a minimum separation of approximately 100 m of shoreline. The information required to identify optimum localities may already be available through previous recording of lake vegetation that meets similar standards to those required for the baseline survey technique suggested here.

These three localities represent fixed units to be resampled in subsequent monitoring cycles, and for consistency are referred to as 'habitat patches'. They must be given unique descriptor codes, and a GPS reading should be taken from the midpoint of each patch to aid subsequent relocation. The area of assessment within each patch should extend for 50 m parallel to the shoreline and between the 1m and 3 m depth contours.

The purpose of the intensive survey is to quantify the level of occupancy of suitable habitat (note that this information will initially be available from the baseline survey, but in future monitoring cycles must be based on the occupancy of the three best patches) and the size of the population based on extent and continuity of cover within these patches. Visual evidence based on photographs is also used to assess regenerative status. The maximum depth of rooting in each occupied patch is determined by demarcating the cable supporting the camera probe in 10 cm intervals and ensuring that the cable is, as far as possible, vertical at the time of measurement.

In each patch the preferred approach is to row in one direction, maintaining a depth of 2–3 m and return along the patch at a depth of 1–2 m. The underwater camera can be trawled from the boat at a fixed depth above the bed.

There are effectively two options for the use of the camera. The first relies on trawling above the lake bed with continuous inspection of the video images by one surveyor while the second is rowing/steering. Table 4 offers a range of potential stand characteristics and appropriate labels. This is a qualitative classification that will be influenced by variation between observers, although such variation ought to be small in the case of experienced individuals. The second alternative is to operate the camera to capture still images at randomly distributed points within the habitat patch in the same way that a quadrat is used. The qualitative classification might, for example, be calibrated against counts of presence/absence within a fixed number of standard-sized viewing frames, and/or against densities of rosettes per frame. Without direct experience of the use of the latest underwater digital cameras in lakes it is difficult to assess the practicality of this option although presence/absence counts would certainly be possible.

Table 4. Examples of qualitative and quantitative descriptors of stand quality in lakes (subject to verification and testing).

Score	Description (based on 'trawling')	Description based on random point
1: Poor	Scattered rosettes at one or more discrete points.	1/10 frames occupied; 1–4 rosettes per frame/
2: Fair	Scattered rosettes occurring more or less continuously for >10 m.	2/10 frames occupied; 1–4 rosettes per frame.
3: Good	Fragmented more or less pure stands (>1 x 1m) interspersed with scattered rosettes extending for >20 m.	3/10 frames occupied; 2–4 rosettes per frame plus 2/10 frames with >5 rosettes per frame.
4: Excellent	Pure stands more or less continuous for >20 m.	7/10 frames occupied; >5 rosettes per frame.

The above classification is merely a suggestion that requires validating in the field and for different sizes of viewing frames (dictated by lens size and height above bed at which images are collected). A standardised sample effort of 20 samples per patch is suggested to maintain comparability and taking into account confidence limits associated with a threshold probability of occurrence of 20% (see Appendix 2). It is unlikely that more intensive sampling is sustainable unless images can be collected, scanned by the surveyor and then discarded in a matter of seconds. To assess supporting habitat characteristics additional data on associated vegetation and substrate properties must be collected when using the underwater camera (see Section 7.1).

Even when *L. natans* is directly visible from the surface, UDV may still offer a more convenient means of collecting quantitative data. The main uncertainty is whether or not the use of a camera is hindered by the height and density of associated vegetation in more productive or very sheltered lakes. If this proves to be the case the alternatives are to take a standard number of repeat rake samples (20 throws) in each patch, or to use snorkelling. However, rake sampling is selective and potentially destructive to slow-growing, deep-water beds of isoetids, while snorkelling is depends on high water clarity, and collecting quantitative samples with a standard level of sampling efficiency is likely to be difficult (see Section 5). Collection of quadrat data by snorkelling is effective in water <1 m deep. Consequently, the use of snorkelling as a substitute to UDV would probably require swimming fixed-length or fixed-time transects from shallow to deep water.

6.1.3 Translation of generic population targets for lake populations

To determine an appropriate sampling strategy it is important to interpret the generic targets for lakes as follows:

- *L. natans* is present in >2 habitat patches within the waterbody. Where a cSAC comprises a complex of small waterbodies, *L. natans* should occur in at least two discrete waterbodies if this condition cannot be met within any single one.
- In at least two habitat patches the condition of stands as defined in Table 4 is good or excellent, OR the average percentage frequency of plants in samples taken from occupied patches is >20%.
- Mean maximum depth of rooting over all occupied stands decreases by <10% between monitoring cycles.
- The stand quality in any occupied patch does not decline by >1 band between monitoring cycles (for example, good can decline to fair but not poor), OR the average percentage frequency or estimated cover of plants in samples taken from occupied patches does not fall by an absolute value of >50%.
- The condition of stands as defined in Table 4, OR the average percentage frequency or cover of plants in samples taken from occupied patches does not fall by >25% between consecutive monitoring dates.
- In all patches where plants are present there is evidence of clonal propagation in the form of surface (or partially buried) runners or stolons (sometimes referred to as pseudostolons) connecting rosettes. Some terminal stolons may terminate in vegetative buds. In naturally more productive or less disturbed lakes there should be evidence of surface or submerged flower development and the widespread presence of ascending stolons bearing chains of plantlets. At the level of the cSAC the population should include rosettes covering a range of sizes and demonstrating different reproductive strategies.

Summary of procedure for assessment of *L. natans* in lakes

Baseline

- Circumnavigate waterbody in boat, concentrating on areas of fine substrate at water depths of 1–3 m.
- Use underwater digital videography (UDV) or snorkel and grapnel where conditions dictate.
- Record all species on DAFOR scale.
- Roughly map distribution of all beds of *L. natans* on 1:10,000 scale map and GPS locations.
- If *L. natans* is undetectable at a site with recent previous records carry out strandline survey in March/April.

Monitoring

- Sample three pre-selected habitat patches within lake.
- Navigate in transects at 1 and 3 m depth or take 20 spot samples in each patch using UDV and record presence of *L. natans*, evidence of regeneration, and associated species in each sample.
- Measure maximum depth of *L. natans* colonisation in each patch.
- Note stand quality (Table 4).
- To assess environmental conditions record secchi disc depth, frequency of unvegetated patches or litter coverage and frequency of spot samples dominated by canopy forming species.

6.2 Rivers

6.2.1 Baseline survey

In cSAC rivers for which *L. natans* is a qualifying feature, beyond the basic presence of the species little may be known of the overall size and distribution of the population. Consequently, a baseline survey will be necessary. The purpose of this part of the survey is to confirm the (continued) presence of *L. natans*, obtain information on its overall dispersion within the cSAC (how many discrete clusters of plants can be identified and their maximum spatial separation), and to provide data on supporting habitat characteristics through the assessment of the composition and abundance of associated vegetation.

On present evidence *L. natans* occurs much more sparingly in riverine habitats in Britain than in the rest of Europe, especially France and Germany, and generally under more strictly slow-flowing conditions (< 10 cms^{-1}). Arguably however, existing survey methods have not been optimal for detecting the perennial vegetative form in which *L. natans* predominantly occurs when growing in flowing water. Hence, the present situation may be an underestimate or may obscure a significant long-term decline in the abundance of this species within riverine habitats in the UK. There would, for example, seem to be a high potential for discovery of additional colonies in low-energy streams and lake outflows in Wales, and other populations on the Dee and Teifi may await discovery.

The design of a suitable protocol to assess whether riverine populations of *L. natans* are in favourable condition is dictated by the conditions under which the species occurs. There is relatively little variation among the type of rivers in which *L. natans* occurs or is likely to occur in Britain – all are low-gradient, medium-sized rivers, with fine, often peaty sediment, situated in upland catchments and likely to support a diverse and fairly extensive rooted aquatic vegetation. They include backwaters with a permanent connection to a main channel, which may not itself offer suitable habitat.

Water depth (as opposed to water velocity or channel size) is the main constraint on surveying. Due to the nature of its preferred hydraulic habitat (mostly smooth flow over a fine stable bed), *L. natans* is unlikely to occur at water depths much shallower than 0.5 m and, if water clarity permits, may occur in

Finding *L. natans* in rivers

L. natans is most likely to be found in slowly flowing, low-gradient, well-vegetated mesotrophic rivers in western Britain. Plants are most likely to occur on finer, peaty sediment where flow is sluggish, and will generally be found in water >0.5 m deep. However, plants have occasionally been observed in fast runs in deep water, where there is little turbulence and the bed is very stable. Associated vegetation is likely to be diverse, including a range of nymphaeids and large emergent species. Valley-bottom wetlands with an intact sinuous river channel downstream of a lake are likely to be most favoured. Fluvial waterbodies within the floodplain that are connected to the channel during high flows should also be checked. Where *L. natans* occurs in rivers in mid- and north Wales it exists as small, highly aggregated groups of basal rosettes growing sparsely in relatively stable, fine, mineral or peaty sediments present in slowly flowing water, or amid open stands of other rooted species in slacks.

water deeper than 1 m. Consequently, safe and effective surveying will depend on observers wearing drysuits. Some of these populations occur in sites with highly peat stained water and are invisible without snorkelling or the use of an underwater camera. Many populations are also highly localised and confined to short sections of rivers so sampling at very large scales will be too coarse to detect changes in the population or adjacent habitats. Many of these populations are also very small and therefore vulnerable to natural fluvial dynamics. However, it is unclear whether they are remnants of larger populations, are stable or might expand given suitable recruitment opportunities.

Potential sites can be selected from 1:10,000-scale Ordnance Survey maps in conjunction with good-quality aerial photography. Particular attention should be given to stream gradient, existence of connected waterbodies, extent of floodplain, channel sinuosity and engineering features. Valley-floor wetlands with sinuous, low-gradient, unengineered channels connected to large standing waters are the most promising sites. Potential sites might also be selected through reference to the River Habitat Survey (RHS) database managed by the Environment Agency.

If sites are to be selected in the field, or there is some background data on plant species composition, the presence of *Littorella* spp., *Apium inundatum*, *Eleogiton fluitans*, *Potamogeton alpinus*, *Sparganium angustifolium* (or *S. emersum*), *Nymphaea* spp. or *Nuphar lutea* are all favourable indicators. Emergent species such as *Sparganium erectum* or *Schoenoplectus lacustris* in conjunction with the above species are also likely to indicate areas of suitable rooting medium, although in areas of stable habitat they may be potential competitors. Channels supporting only the bare core of upland aquatic vascular plants (*Callitriche hamulata*, *Juncus bulbosus*, *Myriophyllum alterniflorum* and *Potamogeton polygonifolius*) are unlikely to be suitable.

The initial extensive survey comprises a wading and snorkelling search of the whole cSAC, concentrating most effort in each reach within the cSAC that has been identified from maps or a site visit as providing potentially suitable habitat. Note locations of suitable habitats and the presence of *L. natans* on maps, and survey 100 m reaches of such sites when compiling species lists and cover values.

Subsequent monitoring sites should only consist of 100 m sections of river. If the location of the main population is already known then this should form the centre of a reach. The baseline survey should aim to cover all potential habitat within the cSAC (whether or not it is known to support *L. natans*) and should be repeated on a 12–year basis. Thus, depending on the size of the cSAC and the type of instream habitat, the number of reaches to be surveyed might range from as few as one into double figures, and reaches may be consecutive or some distance apart. The position of all reaches should be described in relation to permanent features (bridges, pylons, etc.) and a GPS reading should be taken at the centre of the reach.

Observations should be made by wading and in deeper peaty water (when *L. natans* is often invisible when viewed from above the surface) by using a mask and snorkel. Instead of surveying along transects criss-crossing the channel, it is more effective to focus on areas with low water velocities and fine bed material, and to search examples of these systematically. All species present should be recorded using the standard nine-point cover scale (Holmes et al. 1999) (Table 5).

When undertaking cover-based assessments of vegetation within rivers it is important to adhere closely to the standard MTR method. When evaluating cover, especially within sparsely vegetated sites, there is a tendency to overestimate values if they are not applied critically. Surveyors should pay attention to the size of the reach and the area to which a particular cover value equates. Within a 100 m reach that is 14 m wide, a cover of 5% (point 4 on the scale) requires that a species covers 70 square metres of riverbed. The total area of numerous small patches, or the length of margin colonised and the average width of the stand must therefore be considered before awarding a cover score (see Figure 1).

Table 5. Scale points for describing vegetation cover on rivers.

Point on scale	Percentage cover	Equivalent area of 100m reach, 14m wide (m^2)
1	<0.1	<1.4
2	0.1–1	1.4–14
3	1–2.5	14–35
4	2.5–5	36–70
5	5–10	71–140
6	10–25	141–350
7	25–50	351–700
8	50–75	701–1050
9	>75	>1051

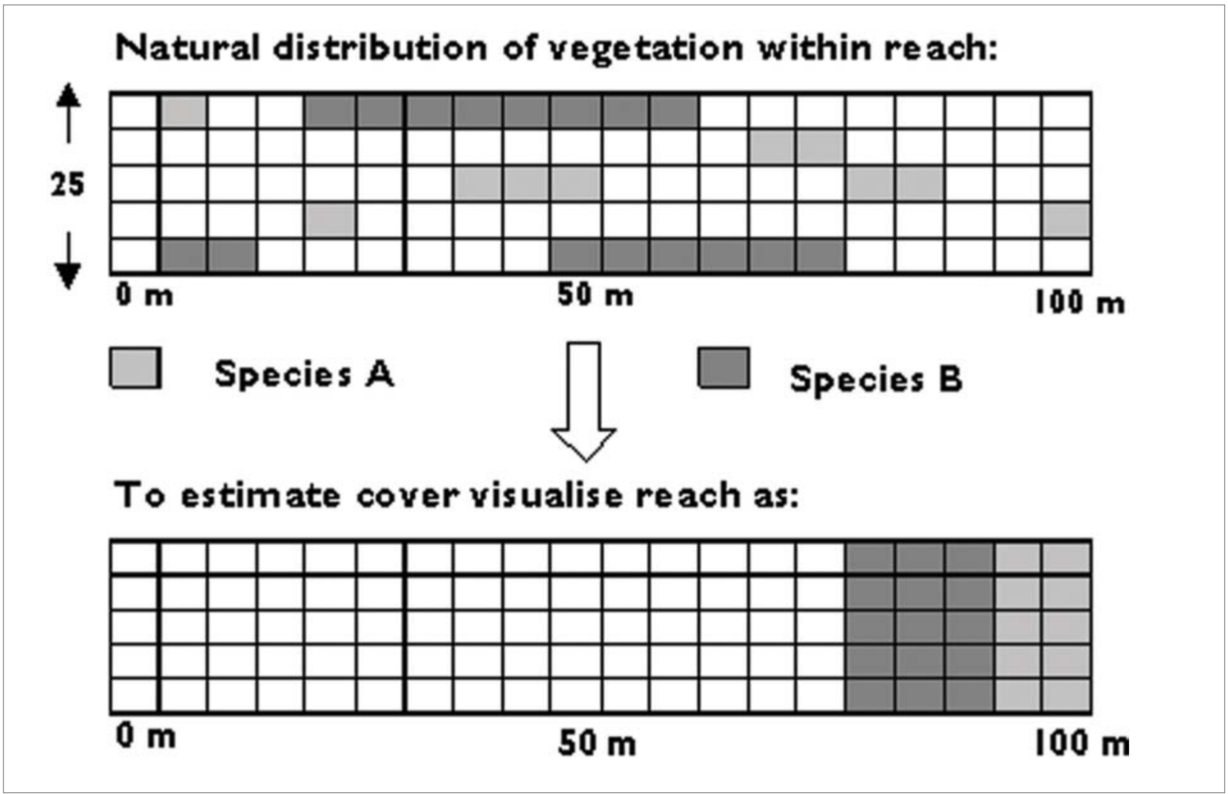

Figure 1. Describing vegetation within a reach using cover scores.

The number of discrete examples of potentially suitable habitat (areas with slow flows <10 cm s^{-1}, deep water >0.5 m, and fine substrate) and their total extent (as a percentage of the channel area) in each reach should be recorded and mapped. Occupancy (as presence only) of these habitat patches by L. natans should also be recorded.

As part of the extensive survey a rapid assessment should be made of the aquatic vegetation of any standing water features, such as oxbow pools, that occur in adjacent areas of fen or swamp, and which might potentially be connected with the main channel during periods of over-bank flow. The same nine-point cover scale should be used as for the main channel. The presence of extant populations of *L. natans* in such sites is obviously a positive feature (in such habitats plants should be readily detectable in summer by floating leaves and flowers), but the potential value of these sites, whether occupied or not, is also important.

6.2.2 Intensive survey and monitoring

The intensive survey focuses on a subsample of patches of suitable habitat that are identified during the initial baseline survey. The purpose of this survey is to roughly quantify the overall population size and to provide information on regenerative status, frequency and identity of immediate associates and habitat features.

The survey should focus on what the surveyors consider to be the three best examples of potentially useable habitat (although when occupancy of favourable habitat is poor these examples obviously may not all support *L. natans*). Depending on the extent and distribution of suitable habitat, these patches may lie within the same, consecutive and widely separated reaches. Habitat availability permitting, patches should be located in different reaches. In the event that an entire reach comprises suitable habitat, it may be subdivided into patches equivalent to three channel widths in length.

Areas selected for detailed sampling must be clearly indicated on baseline survey maps, since these will form repeat monitoring sites (fluvial dynamics permitting). Each patch must be given a unique descriptor code and a GPS reading taken at its mid-point. In general, it is preferable to focus on areas close to the channel margins where stream power is reduced during high-flow events and populations are therefore likely to be largest or most persistent.

Note that in speculative baseline surveys of potential sites, it is still of value to undertake the intensive survey even when the initial extensive survey has failed to reveal the presence of *L. natans*. This is because it reduces the chance of overlooking small very localised clusters of plants and may offer reasons for the failure of the plant to occupy apparently suitable habitat (for example, pre-emption by other species, low bed stability, poor rooting medium).

The intensive survey requires manual searching by snorkelling when water depths exceed 0.7 m, unless clarity is exceptionally high (under low-flow conditions on a sunny, windless day, monitoring of rivers where plants occur exclusively in shallow water may be undertaken by wading or from the bank without any specialised equipment). However, as an alternative, the use of underwater digital cameras advocated for lake monitoring will also be trialled for use in streams. Wading is not a suitable method when the bed is silty. Since the principal population attribute to be assessed is population size, simple observation of suitable habitat by snorkelling does not readily lend itself to the collection of quantitative data. There are therefore several options:

- **Counts of numbers of individuals**. Rivers are perhaps the one habitat type in which it is realistic to make some sensible estimate of the actual number of submerged rosettes, since stands are mostly small and fragmented. A value of 100 plants, while arbitrary, does take account of the growth characteristics and dispersion of plants in rivers and their potential vulnerability, but would need to be tested. Populations larger than this should be estimated as numbers on a log scale. However, when the area of suitable habitat is large, reliable counts of highly dispersed populations may be difficult to obtain. Estimates should then be made on a log scale relating approximated numbers of plants to orders of magnitude.
- **Measures of frequency of occurrence** (regardless of number of individuals or their coverage) in small, standard-size quadrats (such as 20 x 20 cm) placed randomly within patches of potential habitat. This approach is most directly compatible with that used in other habitats. It is also readily suited to collection of data on supporting habitat features in the form of associated vegetation and extent of bare ground. The major difficulty of employing this approach in rivers is that populations range widely in size from small, highly dispersed populations in the main channel to dense coverage in some backwaters. In main channels, there is consequently a high probability of failing to record the plant in routine point samples collected from patches in which it is known to occur.
- **Snorkelling over repeated transects** (although this would be difficult in very small habitat patches) or a number of fixed-time manual searches adjusted to the size of the habitat patch. This approach is more difficult to standardise in terms of the area searched and the efficiency of detecting plants, but may be better suited to low density, highly dispersed populations.

- **The simplest option** that is adaptable to a range of situations, surveyors and equipment, although not the most robust approach, is visual assessment of cover within clearly delimited patches of suitable habitat using standard cover scores. Ambiguity over the use of cover scores needs to be assessed in the field using different observers before adopting this approach.

6.2.3 Specific survey and safety considerations

- All the rivers in which *L. natans* is recorded from the UK are in westerly upland catchments with rapid surface runoff and are therefore subject to flashy flow regimes. During spates, average depth and flow velocity may increase by more than three-fold, while peat-derived turbidity may remain sufficiently high to restrict observation of submerged plants for 24 hours or more after the flood peak has passed. All surveys must therefore be conducted under base flow conditions preferably between mid-July to late August.
- It should be noted that at some sites cavitation of the peat bed has resulted in water depth within pools in the range 2–3 m. It will therefore be preferable to wear a drysuit for all surveys and this will be obligatory for intensive surveys.
- Sites that provide areas of suitable habitat may also contain areas with turbulent flow and exposed boulders, or these types of condition may be encountered when accessing potentially suitable reaches. It is therefore recommended that surveyors wear hard hats to minimise the risk of head injury.

6.2.4 Translation of generic population targets for riverine populations

To determine an appropriate sampling strategy it is important to interpret the generic targets for rivers as follows:

- *L. natans* is present in a minimum of two patches within the cSAC at least 50 m apart.
- The mean abundance of plants per patch is >50, giving a minimum total population size of 100 plants OR the average percentage frequency of occurrence of plants in samples taken from occupied patches, or visually estimated cover, is >20%.
- The average percentage frequency or cover of plants across the three habitat patches does not fall by an absolute value of >50%.
- The average percentage frequency or cover of plants across the three habitat patches does not fall by >25% between consecutive monitoring dates OR there is no consecutive decline in the number of habitat patches within the cSAC that are occupied (based on comparison of results of baseline surveys).
- In all patches where plants are present there is evidence of clonal propagation in the form of surface (or partially buried) runners or stolons connecting rosettes. Some terminal stolons may end in vegetative buds.

Summary of procedure for assessing *L. natans* in rivers

Baseline

- Identify all potential habitats within the whole cSAC and sample these as 100 m reaches.
- Within each reach carry out searches by a combination of wading and snorkelling and record all species and assign abundance on a nine-point scale (MTR standard).
- Record the approx extent of areas combining slow flow (<10 cm s^{-1}), deep water (>0.5 m) and fine substrate.
- All surveys should be carried out under low flow conditions from mid-July to late August.

Monitoring

- Sample three pre-selected habitat patches within the cSAC, preferably belonging to separate reaches.
- In each patch assess the abundance of *L. natans* based on either a count of the no. of plants, a visual assessment of cover, or 20 spot samples using UDV (to be trialled). Also record evidence of regeneration.
- Record cover or frequency of associated species in each patch.
- For assessment of supporting environmental conditions record, in each patch, secchi disc depth (or whether bed is visible from surface), frequency of unvegetated patches and litter coverage and coverage of canopy forming and emergent species in each patch.
- Due to the lack of knowledge on the stability of *L. natans* populations in discrete reaches of rivers, sampling some sites with suitable habitat but lack of *L. natans* is recommended.

6.3 Canals

6.3.1 Baseline survey

A methodology relating specifically to the condition assessment of canals has been developed separately (Eaton & Willby 2002). In the case of *L. natans*, this should be sufficient to confirm the presence of the species and the limits of its distribution, and to aid the selection of representative sites for intensive monitoring. Briefly, this survey is a walking, towpath-based survey of a site, usually 500 m in length, which is delimited by locks or bridges. The length sampled must be clearly described with reference to local landmarks (such as bridge or lock numbers) and from a GPS reading taken at the mid-point of the section. The surveyor moves along the towpath of a canal, making simple, continuous observations of the vegetation and pausing at intervals to record representative short sections in more detail, though still only qualitatively. The emphasis is on covering an extensive length of waterway and detecting as many of the species present as possible. Thus, it is part of the method to stop and investigate any place where subjective observation indicates special features that may be of conservation interest, in addition to the representative short sections being recorded at regular intervals.

The main value of the regular, intensively recorded short sections is to focus the surveyor's attention at intervals on the whole ecosystem cross-section, and to ensure that the submersed vegetation, which is often invisible to the bankside observer, is adequately sampled. These short sections produce approximately standard descriptive units of survey that can later be compared visually to see whether there are any major disjunctions in vegetation quality along the canal.

For submerged vegetation, direct visual observation is unreliable as a way of detecting species, and even in very clear water a grapnel with cord at least half the width of the channel should be used to collect samples for bankside checking at 50–100 m intervals.

These sections are walked slowly, and records are made of all emergent, floating-leaved and submerged species. Abundances within the section are recorded using the following DAFOR scale, which has been commonly used in canal surveys:

- D – Dominant (over 70 % cover)
- A – Abundant (30-70 % cover)
- F – Frequent (10-30 % cover)
- O – Occasional (3-10 % cover)
- R – Rare (less than 3 % cover).

Cover here is relative to the area of water between the two banks. The offside vegetation should be examined with binoculars where direct observation does not yield clear identification of its species composition. Additionally, the offside vegetation should be accessed where possible at bridges and locks and examined directly, paying particular attention to species at the back of the reed fringe and in any cattle-poached areas.

The baseline survey needs to adequately describe the general status of *L. natans* within the cSAC as a whole, and therefore requires comprehensive coverage of the whole length of channel. Previous experience suggests that well-trained surveyors should be able to cover about 4 km per day. Baseline surveys of larger sites, such as the Montgomery and Rochdale canals, will therefore present a fairly substantial undertaking. Baseline surveys of canal cSACs should be undertaken every six years.

The distribution of *L. natans* within the canal system is fairly well known, with core populations on the Montgomery, Rochdale and Cannock Extension canals (all of which lie within cSACs) and smaller populations on other canals within the Greater Manchester and Huddersfield area. However, the status of small populations on canals that connect with these waterways (such as the Bridgewater Canal, the Calder and Hebble Navigation, and the northern parts of the Birmingham Canal Navigations) should be clarified.

6.3.2 Intensive survey and monitoring

The intensive survey focuses on canal reaches in which there are recent or former records of *L. natans*. The intensive survey protocol for canals is somewhat different from lakes and rivers, since the entire canal cross-section theoretically offers suitable habitat. Hence, the concept of habitat patches is inapplicable. For consistency, the intensive sampling reach will comprise a 150 m section of canal. This survey unit is 50% longer than the MTR survey unit for rivers (Holmes *et al.* 1999), and is recommended because of its previous widespread use in canal surveys.

Each reach must be given a unique descriptor and be described as above. This is an intensive, semi-quantitative analysis of a selected short length of canal, referred to here as a monitoring unit, and is carried out every three years. The emphasis is on determining vegetation composition and quantity within the unit, in a highly standardised, objective and hence reproducible manner. Repeated application of this method will therefore produce data that can be used with a high degree of confidence in comparisons between canals and in comparisons over time of individual units if they are re-surveyed repeatedly. There should be a minimum of three units per cSAC, chosen on the basis of the baseline survey to be representative, and to avoid major perturbations (such as marinas, pollution point sources, scheduled dredging works).

However, except in very small sites (<5 km long) we recommend monitoring five units every cycle to allow for any temporary loss of units caused by any essential unplanned maintenance works. Condition is based on values averaged across the number of units studied. In the event of an unplanned perturbation affecting one or two units, monitoring at these locations should be suspended for two growth seasons.

The intensive survey is a slight refinement of the procedure recommended for condition assessment of canal Sites of Special Scientific Interest (SSSI) that are notified for their aquatic vegetation, but is designed to be compatible with that procedure. Collection of samples to estimate population number and size is based on use of a grapnel and direct observation. Twenty grapnel samples are collected per length, spaced at randomly generated intervals. This is twice the sampling effort proposed for SSSI condition monitoring (although the data obtained can be used directly for that purpose), and also provides some of the information required on supporting habitat features (principally on associated vegetation).

To sample submerged canal vegetation where *L. natans* may be present but cannot be seen or recorded from the towpath, throw and haul back across the channel bed a standard grapnel attached to 6 m of strong cord, at a horizontal angle of 90° to the water's edge (see Eaton & Willby 2002). If there is a nearside emergent fringe, the grapnel should be lifted out vertically when it reaches the outer edge of the fringe, using a pole with a forked end to catch the cord (this is to avoid losses from the grapnel by dragging it through the emergent vegetation or damaging that vegetation). Allow the grapnel and recovered material to drain for one minute, discard any non-aquatic plant matter such as leaf litter, twigs or stones, then weigh the grapnel and its plants (to the nearest 0.1 kg using an angler's spring balance). Separate the sample into its component species (paying careful attention to the possible presence of small fragments of charophytes or filiform *Potamogeton* species within large quantities of species such as *Ceratophyllum* or *Elodea*). Estimate visually the percentage of total weight taken up by each species. Occasionally, substantial amounts of soil lodge amongst the vegetation. Carefully rinse this off on the bank, allowing one minute's drainage time after the last dipping before weighing. Record the weight of the grapnel. If the grapnel tines have become distorted, these must be straightened before the collection of another sample.

Grapnel sampling can also be used to determine the frequency of occurrence of *L. natans* within the length. It should be noted that the standard egg-whisk-shaped grapnel provides a good aggregate sample of aquatic vegetation, but is influenced by plant growth form and the resistance of plants to breakage or uprooting. As such, the standard grapnel is well suited to sampling most aquatic species found in canals, but is not the optimal design for collecting small isoetid-like species such as *L. natans*. A double-headed rake may be a more effective device if the desire is purely to establish the presence of *L. natans* within a sampling transect, because uprooted rosettes are likely to be retained more effectively. The cost of this increased efficiency is more destructive harvesting of *L. natans*, although it is debatable whether this has markedly adverse ecological consequences in an environment that may support very large populations or may be subject to far more traumatic losses through management or boat traffic.

If a rake is used this sampling must be considered additional to the site condition monitoring process. When collecting samples the angle of the observer relative to the canal water surface means that under favourable viewing conditions (low turbidity, strong incident light and low coverage of canopy forming species) *L. natans* will often be directly visible. Even if plants are not recovered with a grapnel it is worth scanning the water surface (use close-focusing binoculars if necessary) because plants that are uprooted as the grapnel drags over the canal bed, but are not retained by it, are very buoyant and float readily to the surface.

For emergent vegetation, record species and estimate visually their percentage covers in the area encompassed by lines 1 m either side of the point (a 2 m wide band), extending from the channel edge to the furthest point into the channel occupied by emergent plants, separately for each side of the channel. Estimate the distance (m) each emergent fringe extends out into the channel. This information is required for estimating the extent of available habitat.

For floating-leaved vegetation, record species and visually estimate the total area (m^2) occupied by each within the area encompassed by lines 1 m either side of the point (a 2 m wide band), extending between the outer edges of the emergent vegetation on the two sides of the channel.

The population size aspect of favourable condition assessment for canal populations is based on percentage frequency of occurrence within a standard number of point samples. It should be emphasised that this is an entirely different parameter from that used in recent models designed to predict impacts of changing boat traffic or management on aquatic vegetation in canals, which are based on the probability of occurrence (simply being present) within a standard canal length.

6.3.3 Translation of generic population targets for canal populations

To determine an appropriate sampling strategy it is important to interpret the generic targets for canals as follows:

- The extent of suitable habitat within a site amounts to greater than half the site area (in effect this means that for a 12 m wide canal, the central open water channel should be at least 6 m wide, and consequently the average width of reed fringe may be up to 3 m per bank).
- Within the cSAC, or at least one monitoring unit, *L. natans* is present in grapnel samples or can be viewed directly at sample collection points >50 m apart.
- The average percentage frequency of occurrence of plants in an occupied monitoring unit is >20% (see Appendix 3).
- The average percentage frequency of plants does not fall by an absolute value of >50% between monitoring cycles.
- The percentage frequency of plants in samples taken from the sampled length does not fall by >25% between consecutive monitoring dates. It should be noted, that within the context of population trends in canals, 'wall to wall' populations found at some sites should not be seen as the norm or a monitoring target. These populations are rarely stable over the long term and appear to belong to an intermediate stage in post-dredging succession, perhaps prolonged in some cases by low water fertility or artificially low water levels. Gradual contraction of such populations is thus a natural event unless they are periodically 'reset' by operational management.
- At >50% of the sample points from which *L. natans* is collected, some plants bearing floating leaves and/or flowers are detectable within an area that extends 1 m either side of the line of the grapnel sample and the full distance across the channel.

Summary of procedure for assessment of *L. natans* in canals

Baseline

- Undertake a walking survey of the entire cSAC, working in units of bridge lengths or 500 m, noting vegetation composition, and carrying out short, intensive surveys with a grapnel. Repeat every six years.

Monitoring

- Select a minimum of five units of 150 m distributed over the length of the SAC.
- In each unit perform 20 throws of a standard grapnel at random points, determine the weight and composition of aquatic vegetation, presence of *L. natans* and evidence of floating leaves and flowers.
- Record percentage cover of emergent species at each point for both sides of the channel Estimate the maximum extent of encroachment into the channel.
- Note water clarity (with secchi disc or whether bed at mid-point of channel is visible from bank), extent of tree shading and evidence of recent management. Repeat every three years.

6.4 Shallow pools

6.4.1 Baseline survey

Due to their size and water depth shallow pools present far fewer constraints on surveying and it will generally be feasible to view or directly sample all suitable habitat. If present, *L. natans* should therefore be detectable with a high degree of confidence. In this habitat the two major considerations are the timing of surveys (see 4) and the risk of confusion with other similar species (most notably *Baldellia*). Simple manual searches based on circumnavigating or transecting ponds will be adequate to determine presence. These are effectively an extension of shore-based survey methods for much larger standing waters. Simple visual assessments of abundance based on DAFOR or DOMIN scales may be undertaken but are likely to be too crude to reliably detect anything other than very gross changes in population size of either *L. natans* or its associates. Cover may be assessed by mapping the distribution of all individual stands but stand boundaries may be difficult to define, coverage within individual stands is likely to vary and mapping of vegetation as polygons has been shown to vary widely between observers. Cover based surveys using mapping by eye are therefore not recommended.

For sites with existing or recent records the basic approach is to circumnavigate the pond observing all areas of shallow open water and wet mud. Survey efficiency will be improved if it is feasible to walk parallel transects across the site. When there is wet mud habitat in which *Baldellia* is widespread it will be necessary to examine stands closely to verify the presence of *L. natans*. This will be most easily achieved if plants are examined after fruiting when the neat globular seed heads of *Baldellia* are immediately recognisable. In the case of non-fruiting stands crushed *Baldellia* leaves have a strong characteristic smell of coriander. For selecting previously unsurveyed sites, ponds on sandy or peaty substrate within 10km of known extant populations should be prioritised. Typical associated species in shallow pool habitats include *Apium inundatum*, *Eleogiton fluitans*, *Baldellia ranunculoides*, *Ranunculus aquatilis* agg., *Hypericum elodes*, *Juncus bulbosus, Eleocharis multicaulis* and *Glyceria fluitans*. The presence of at least four of these species within a 10 x 10 km square or in other nearby sites should therefore be regarded as a positive indicator if trying to prioritising areas for exploratory surveys. Using the New Atlas of the British & Irish flora (Preston *et al.*, 2002) it is possible to manipulate data to produce coincidence maps of the type required here.

It will be advantageous to have access to good quality recent aerial photographs for identifying other potential sites in the region (which may be too small, ephemeral or recently formed to appear on current OS maps) and which may not have been previously surveyed. Depending on water levels at the time surveys were carried out historical 1:10 000 scale maps may also provide information on the location of ponds not shown in more recent surveys.

On each visit it will be necessary to firstly mark clearly on an enlarged 1:10 000 scale map the extent of suitable habitat (i.e. shallow open water or exposed wet mud). To support this assessment a measurement should be made, using a surveyors tape, of the maximum dimension of the suitable habitat along a line that is clearly indicated on the map (in a concentric pond surrounded by reedswamp this would be the maximum distance between opposite faces of emergent vegetation).

6.4.2 Intensive survey and monitoring

Because pools offer relatively homogenous conditions and *L. natans*, if present, is generally abundant and readily visible, quadrat sampling is probably the most effective means of assessing population size and regeneration in small shallow pools. A relatively large number of small quadrats (20 x 20 cm) in which the presence or absence of plants and fruiting heads is determined is preferable to a small number of large units (e.g. 2 x 2 m) in which cover is assessed. Plants or fruits are less likely to be missed in small units and counts are less ambiguous than cover scores. Record presence-absence of plants in 20 randomly placed 20 x 20 cm quadrats located within areas of suitable habitat (up to 20 m x 20m). In large sites (>1 ha) this process should be repeated in 3 discrete areas of suitable habitat provided these exist. While carrying out surveys also record presence of flowering or fruiting plants. Quadrat survey data will also link to assessment of supporting habitat features. It will therefore be necessary to record presence or absence of associated species and bare ground.

6.4.3 Translation of generic population targets for shallow pool populations

- There are discrete clumps of plants >50m apart (in sites > 1ha) and/or *L. natans* is present in other shallow pools <5km away or other major habitats (lake, river, canal) <1km away.
- Suitable habitat (i.e. wet mud or open water) represents >two thirds of the total original site area.
- The mean probability of occurrence of plants based on random quadrat samples taken from suitable habitat is >20%.
- At >75% of the sample points from which *L. natans* is collected, plants bearing fruiting heads

are also observed (e.g. if *L. natans* is found at 12 out of 20 random quadrats sexual reproduction must be observable in >9 of these 12 quadrats).

- The % frequency of plants in quadrats taken from suitable habitat does not fall by an absolute value of >50% between monitoring cycles.
- The % frequency of plants in samples taken from the sampled length does not fall by >25% between consecutive monitoring dates

Summary of procedure for assessing *L. natans* in shallow pools

Baseline

- Circumnavigate pond.
- Measure maximum dimension of wet mud habitat and indicate on map broad areas in which *L. natans* occurs.
- In sites >1ha identify three representative patches for intensive monitoring.
- Determine location of next nearest extant populations. Repeat every six years.

Monitoring

- In each habitat patch record frequency of occurrence of *L. natans* in 20 randomly placed 20 x 20 cm quadrats and composition of associates.
- Record incidence of bare ground and plants bearing flowers and/or fruiting heads.
- Repeat every three years.

7 Environmental conditions

Monitoring of the environmental conditions associated with a given population may help to explain why that population is unfavourable or declining and thereby indicate an appropriate course of remedial action. Monitoring environmental conditions in conjunction in population attributes should therefore be regarded as a diagnostic tool.

In common with many aquatic plants *L. natans* has a wide ecological amplitude and a correspondingly high phenotypic plasticity when viewed at a species level. This is a typical response in plants that inhabit environments where there are strong spatial or temporal variations in resource supply. However, true plasticity within a population, which would require confirmation by manipulative experiments or genetic screening, is widely confused with morphological variability between populations distributed over an environmental gradient. Therefore defining limiting factors (i.e. the ranges of a variable where growth is clearly impeded) is both difficult and may arguably be of limited relevance to specific populations. In particular there is risk of overstating the ecological amplitude of a given population. Numerous simple transplant experiments confirm that growth form variation is environmentally induced. Yet if genetic diversity has been eroded by isolation or enforced clonality, the limits of tolerance to factors such as pH, metal concentrations, or grazing may prove much more restricted within discrete populations relative to the species as a whole.

In recommending targets for environmental conditions for specific habitat adequate allowance must be made of the limited state of our understanding of the main controls on this species. Consequently it is unclear if, given apparently functional populations, environmental conditions that are even quite adverse should have any influence on the condition status awarded to a population. We would suggest that environmental conditions would need to be overwhelmingly negative for a site with favourable population attributes to be described as unfavourable. Monitoring environmental conditions does offer a means of early detection of undesirable changes that may not yet have been translated to population level effects and from a conservation and management perspective is therefore worthwhile. Consequently sites with populations in favourable condition but some (not the majority) of environmental conditions in an unfavourable condition should have an unofficial 'warning' status.

The general evidence suggests that water chemistry cannot be inferred directly as a major determinant of habitat availability for *L. natans*. Associated vegetation, as well as the threats to optimal growing conditions (those associated with favourable condition) are often habitat-specific even if it is possible to generalise the population response to these threats (e.g. reduced cover in response to expansion of superior competitors). However, there are a number of overarching themes in terms of supporting habitat characteristics.

- **Substrate integrity** should be such that plants can remain firmly rooted and tolerate limited exposure to wave action, flood scouring or boat traffic. Conversely sediments should not be so coarse or embedded that rooting is impeded or moisture- retaining capacity is low when sediments are exposed. Without directly measuring variables such as particle size composition or organic matter concentrations the simplest indicators of suitable substrate integrity and cohesiveness are likely to be in the form of: (i) the presence of undecayed organic matter on the sediment surface (which is likely to indicate poorly structured, fluid, organic rich, and possibly anoxic sediment offering low uprooting resistance), and, (ii) the extent of bare mineral sediment (which in permanent waterbodies is likely to indicate either low sediment stability, high exposure, high siltation rates, low moisture retaining capacity or severe recent disturbance). The most effective way to assess these indicators will be in association with recording presence-absence of plants in point samples.
- **Water transparency** in permanent sites should be sufficient for net growth of plants. Increased turbidity (e.g. associated with wind- or boat-induced resuspension of sediment) or increased chlorophyll concentrations (e.g. associated with reduced turnover time or increased nutrient supply) that reduce the euphotic depth (the maximum depth at which net production can still occur) will therefore be negative indicators. Generally secchi disc depth will provide the simplest and most rapid assessment of the underwater light regime. In standing waters secchi disc depths should exceed 5m. In canals and rivers the bed of the channel at its deepest point (up to 1.5m) should be clearly visible to a bank-based observer. If this cannot be determined it should be checked by lowering a secchi disc into deep water, if necessary from a convenient bridge. Light is not generally a major determinant of aquatic vegetation composition within shallow streams, but within the context of slightly dystrophic streams and sluggish deep water mesohabitats it may exert a controlling influence on habitat occupancy if high light attenuation excludes plants from otherwise hydraulically suitable habitat.
- **Competition** for light, nutrients and rooting medium should be low. *L. natans* appears to be adversely effected by eutrophication, acidification or natural succession via the increased competitiveness of other species, in terms of shading, rather than any direct chemical effects. One of the simplest and most effective indicators of competitive intensity in vegetation is mean plant height. While it may not be practical to physically measure in cms the height of associated plants it is relatively simple to determine on a sample by sample basis whether the bulk of the vegetation in the sample is 'similar to or shorter than *L. natans* in height' or 'significantly taller than *L. natans* in height'. This is a simple generic indicator of competition that could be assessed across the full range of habitats. The presence of canopy forming species (*Elodea* spp., *Potamogeton natans*, *Myriophyllum* spp.) may lead to exclusion of *L. natans*; noting the presence and cover of species with this growth habit is a straightforward approach to monitoring potential competition for light. Biological invasion may increase competition on *L. natans* independently of any underlying environmental change. However, reference to height will remain an effective indicator of the scale of the invasion and its likely impacts.
- **Habitat connectivity** should be sufficient to facilitate the interchange of plants between sites or between habitat patches within a site. *L. natans* appears to disperse largely through the drift of uprooted basal rosettes that are sensitive to desiccation. In practice this means that the hydrological regime must not have been compromised to the extent that connectivity with other established or potential sites has been lost. In valley bottom wetlands this means that periodic inundation of the floodplain should be adequate to connect fluvial

waterbodies to the main river channel. In small pools potential vectors of longer range dispersal, (grazing livestock or waterbirds), should have constant access to the site. In canals the site must not be isolated by reedswamp or by dewatered lengths from the main line of the canal.

- **Associated species composition** may provide a useful indicator of the composition of the local species pool, the typicalness of the site, its position along a gradient of disturbance or productivity and of longer-term environmental change. Increases in some species might be interpreted as evidence of a shift towards less favourable conditions. Thus, the following are suggested as provisional indicators or unfavourable or impending unfavourable condition:
  - In naturally base-poor lakes, an abundance of *Juncus bulbosus* and submerged *Sphagnum* spp. may imply an increase in acidity or ammonium concentrations.
  - Expansion of grasses such as *Molinia caerulea* or *Deschampsia caespitosa* may indicate a shift towards more terrestrial conditions in temporary pools.
  - Increased coverage of plants by epiphytic algae, expansion of submerged beds of, for example, *Fontinalis antipyretica* or *Potamogeton perfoliatus*, or a general increase in plant height, may indicate increased nutrient availability.

  However, populations of many species show marked inter-annual fluctuations and any increase in their abundance would need to be seen and maintained over several consecutive monitoring cycles before being construed as indicating a general, sustained shift in conditions. Moreover, any floristic changes should be consistent with long term routine chemical monitoring data. The location of the nearest routine monitoring sites to an SAC, the length of record and long-term average and recent monthly values can often be provided by the local statutory environmental protection agency. Invasive, canopy-forming species, such as *Elodea* spp. or *Crassula helmsii*, may, under certain conditions, indicate increased risk of competitive displacement. However, *Elodea* spp. in particular are now extremely pervasive and it is impractical to specify their absence as a requirement of favourable condition. All canal sites would certainly fail on this criterion.

- **Indicators of community change** may be useful in determining shifts due to nutrient enrichment or acidification. Established trophic ranking scores should be used where available to interpret changes in vegetation community composition. In the UK the Mean Trophic Rank (Holmes *et al*. 1999) has been developed for rivers and there is a similar metric for lakes, DOME scores (Palmer *et al*. 1992). For shallow pool populations Ellenberg nitrogen scores are appropriate and adjusted indicator values for the British flora may be found at: www.ceh.ac.uk/products_services/publications/online/ecofact/vol2apdf/ellenberg.pdf

  A change of more than 10% in these scores between monitoring assessments might indicate a shift in trophic status and should be investigated. Targets for these scores have not been set here as it is recognised that the metrics may only be applicable to a limited geographical area. It should be noted that trophic indicator scores have not been empirically derived, and that unpublished tests suggest they are only moderately well correlated with data on water and sediment chemistry. We include this recommendation here in the anticipation that revised metrics based on field data will become available in the near future. These scores could be applied retrospectively to data collected as part of the assessment of favourable condition.

  Scores should be used in conjunction with water quality data where available to determine the nutrient status of sites and to monitor change. Given the susceptibility of *L. natans* to community changes resulting from eutrophication, it is desirable to set nutrient targets for sites based on levels expected for a 'good quality' example of the particular habitat type.

  Moreover, if the normal disturbance regime, (in terms of wave action, boat traffic, flood scouring or grazing etc), is maintaining these species in check their presence may not be detrimental to the condition of *L. natans*.

7.1 Lakes (including upland and lowland meso-eutrophic sites)

7.1.1 Assessment of supporting habitat characteristics

Collection of all data required will be coupled to the collection of point samples for monitoring population attributes. Thresholds relate to the average or maximum value measured across the three habitat patches. On each monitoring cycles it will be necessary to examine archived water chemistry data derived from routine sampling (see above). Major changes that would be regarded as a cause for concern would include average values for chemical data collected over the previous six years lying outside the normal range of values (for example, they would need to lie within the interquartile range calculated for the pre existing run of data).

It will also be necessary to inspect aerial photography and land use survey data to assess if there have been recent major changes in landuse of the upstream catchment. Major changes would be regarded as those that affected >10% of the catchment. Within the areas occupied by *L. natans* potential landuse changes evident from this type of data or from direct observation might include new areas of tree planting, extensive clear felling, peat cutting, reseeding or drainage of pasture. Land-use change may represent a long term, insidious threat to the stability of some populations (for example through nutrient enrichment, acidification or increased sediment loading), which may take some time to be translated into changes in chemical conditions or the associated vegetation. Major land-use changes should be interpreted as a warning sign of potentially adverse conditions in future monitoring cycles.

7.1.2 Supporting habitat characteristics for lake populations

(Upland lakes with perennial vegetative populations and mesotrophic lakes with annual flowering populations)

Habitat attribute	Targets	Method of assessment	Comments
Substrate	Extensive areas of stable fine gravel, sand or silt. Within patches: a) frequency of areas dominated by bare <20%. b) frequency of areas where substrate is smothered by plant litter <10%.	Visual observation of unvegetated areas (bare sediment or accumulation of undecayed litter) and plant leaf surfaces by UDV or snorkel.	Loss of fine sediment through wave-induced scouring can result in a reduction in suitable habitat. Conversely, an increase in fine sediment or organic matter at the sediment surface may lead to unstable rooting habitat or smother plants. Reference to changes in catchment land use from remote sensed data may indicate causes.
Water depth/flow regime	Range of water level changes associated with naturally oscillating unregulated lake.	Reference to existing water level data.	Impoundments, abstractions or flow diversions can result in changes to the magnitude or frequency of water level fluctuations. This in turn may lead to an increase or decrease in wave action and alter patterns of disturbance of littoral sediment. Changes in water level may result in a recession of the upper limits of rooting. Where data on water levels are not available, observation of strandline position relative to summer base levels will indicate the magnitude of seasonal water level changes.
Water quality	Water quality should represent high quality appropriate to the lake type with high light penetration. Secchi depth >4m (upland lakes)Secchi depth >3m (mesotrophic lakes).	Reference to existing water quality data. Measure secchi disk depth in all habitat patches.	A decrease in light availability brought about by eutrophication or high suspended sediment loads will reduce the lower limits of plant rooting and may lead to etiolation of plants. Eutrophication may lead to the increased incidence of phytoplankton blooms, increased epiphytic cover or an increase in more competitive species. Acidification may result in increases in *Juncus bulbosus* and *Sphagnum* spp., which could overgrow *L. natans* stands or cause a build up of plant litter.
Disturbance regime and interspecific competition.	Average frequency of samples dominated by canopy forming submerged species <20% Invasive plant species (particularly *Crassula helmsii*) absent.	Number of samples dominated by submerged vegetation significantly taller than *L.natans*.	Natural wind-induced wave action will restrict the growth of submerged canopy forming species which would otherwise compete with *L. natans*. Good signs are the presence of typical associates at edge of, or sparsely within, major lawns (e.g. *Isoetes, Littorella, Lobelia, Myriophyllum alterniflorum*, *Juncus bulbosus, Elatine hexandra, Nitella* spp. and in mesotrophic lakes a diverse *Potamogeton* flora – *P. alpinus, P. gramineus, P. praelongus, P. obtusifolius, P. lucens* plus hybrids).
Connectivity	Sufficient fluctuation in water levels to provide hydrological connection between main water body and smaller aquatic habitats within the riparian zone.	Determine existence of small floodplain pools and other water bodies from field observation and remote sensed data.Refer to data on water levels where available.	Any regulation that results in a loss of hydrological connectivity between waterbodies has the potential to isolate the main clonal population from surrounding subpopulations in which outbreeding plants may be found. This could result in a loss of marginal populations and erode genetic diversity.

7.2 Rivers

7.2.1 Assessment of supporting habitat characteristics

Within each reach a vegetation survey should be undertaken using the standard nine-point scale for cover scores suggested by Holmes (see Holmes *et al.* 1999). We advise against the use of recording cards with standard checklists since these almost inevitably prove incomplete and simply encourage mis-identification by less experienced observers.

Although *L. natans* occurs frequently in artificial sites in the case of rivers it is recommended that an assessment of habitat modification is undertaken as this will provide evidence of the extent to which hydrological connectivity has been compromised or potential refugia have been lost. The suggested format is to use the rules for the derivation of the Habitat Modification Score (HMS) provided in the River Habitat Survey handbook (Environment Agency 2003). This requires the assessment of various modifications (e.g. bank revetment, channel realignment) at 10 regularly spaced spot checks along a 500m reach. The 500m reach should be designated with regard to the disposition of the three habitat patches and should encompass at least one of these patches. The recording of modifications and the calculation of HMS is self-explanatory and does not specifically require the use of RHS accredited surveyors. However, the use of personnel that are at least familiar with RHS terminology would be beneficial. Additional observations should be made of the height of trash lines formed by over bank flows and the presence within this debris of normally rooted aquatic vegetation. These may be used to provide evidence of naturally fluctuating stream levels with stream power occasionally reaching sufficiently high levels for scouring of attached vegetation. This type of disturbance regime is likely to be essential for preventing encroachment of emergent vegetation or development of canopy forming species in the sluggish marginal habitats in which *L. natans* normally persists.

Collection of all other data required will be coupled to the collection of quadrat samples for monitoring population attributes. On each monitoring cycles it will be necessary to examine archived water chemistry data derived from routine sampling and to assess landuse maps for any evidence of major change in catchment landuse (see above). The average values for chemical data collected over the previous six years would need to fall within the normal range of values (e.g. they would lie within the interquartile range calculated for the pre existing run of data). Although relatively unlikely, any decrease in the average General Quality Assessment Score over a six year period relative to the previous six year period would be deemed unfavourable. Where flow data exist, examination of the daily mean flow record for the three months preceding sampling, may, if compared to the long term average record, help to account for any otherwise inexplicable changes in population size.

7.2.2 Supporting habitat characteristics for river populations (Perennial vegetative populations)

Habitat features	Target attributes	Method of assessment	Comments
Substrate	Marginal areas with stable fine gravel, sand or silt. Within sampled patches the average coverage of bare ground <30%. Area of bed in sampled areas with poorly integrated organic matter <10% .	Direct visual observation of unvegetated areas (bare sediment or accumulation of undecayed litter) and plant leaf surfaces by snorkel or UDC.	Extensive areas of bare ground may indicate unsuitable rooting medium or frequent scouring. Therefore changes to natural flow or sediment regimes have the potential to reduce available habitat. Accumulation of organic material at the sediment surface may result in poor rooting medium.
Water depth/flow regime	Slow moving water (<10 cm s^{-1}) in depth range 0.5–1m.	Direct measurement/ observation or through association with substrate parameters.	Changes to flow regimes or channel engineering have the potential to reduce hydraulic habitat heterogeneity and suitable *L. natans* habitat.
Water quality	Water quality should represent high quality appropriate to the river type with light penetration to the bed in suitable patches.	Reference to existing water quality data. Measure secchi disk depth in all habitat patches.	Highly turbid or coloured waters may limit the growth of plants and lead to reductions in stand area. Acidification or eutrophication may be responsible for reductions in water clarity. Eutrophication may lead increased epiphytic cover or an increase in more competitive species. Acidification may result in increases in *Juncus bulbosus* and *Sphagnum* spp., which could overgrow *L. natans* stands or cause a build-up of plant litter.
Disturbance regime	Natural frequency and duration of scouring high flow events leading to restricted growth of potential competitors.	Observation of elevation of trash lines relative to depth at bankful. discharge. Reference to relevant gauging station data.	Increases in the frequency of scouring flows may lead to the loss of stands. In contrast decreases in the frequency of high flows may allow more competitive species and emergent to establish in *L.natans* habitat.
Interspecific competition	Cover of emergent and canopy forming submerged species in sampled patches <20%.	Direct survey when monitoring populations.	Changes to habitat allowing submerged canopy-forming (e.g. *Elodea* spp., *Sparganium* spp., *P. natans*) or emergent species (*S. erectum, Schoenoplectus lacustris, Carex rostrata*) to encroach into suitable *L. natans* habitat may lead to decline of stands. Good signs are the presence of typical associates (*M.alterniflorum, J. bulbosus, Apium inundatum, P. alpinus, Nitella* spp.) and a high diversity plant community (e.g. average richness of aquatic and emergent species in 100m length during baseline survey >20).
Connectivity	Sufficient fluctuation in water levels to provide hydrological connection between channel and floodplain waterbodies.	Determine existence of small floodplain pools and other waterbodies from field observation and remote sensed data.	Any regulation or engineering that results in a loss of hydrological connectivity between the river channel and floodplain waterbodies or upstream lakes has the potential to isolate populations. Disconnection of main clonal population from surrounding subpopulations in which outbreeding plants may be found should be avoided and direct hydrological connections should be maintained. The presence of *L. natans* in suitable upstream habitats should be determined and potential barriers to propagule drift identified. A loss of connectivity with upstream populations could result in localised extinction during major disturbance with little prospect for natural recolonisation.

7.3 Canals

7.3.1 Assessment of supporting habitat characteristics

Most relevant information will be assessed through the recording of associated vegetation as part of the intensive survey. Undesirable effects of boat traffic through direct impacts or increased turbidity will be reflected in the total abundance and richness of the associated vegetation. However, it will also be necessary to directly record annual boat traffic (figures available from British Waterways), water clarity based on secchi disc depth and evidence of recent management (e.g. weed cutting or dredging). Routine monitoring of water chemistry at canal sites is also undertaken by EA/SEPA. On the basis of this data any decrease in the average General Quality Assessment Score over a six year period relative to the previous six year period would be deemed unfavourable.

7.3.2 Supporting habitat characteristics for canal populations (Perenniual flowering populations)

Habitat features	Target attributes	Method of assessment	Comments
Substrate	Marginal areas with stable fine gravel, sand or silt.	Direct visual observation of unvegetated areas (bare sediment or accumulation of undecayed litter) by direct observation or UDC.	In canals open to navigation boat traffic has the potential to cause substrate destabilisation as fine sediments are frequently remobilised. A lack of management (dredging) will result in an accumulation of fine sediments leading to a loss of suitable *L. natans* habitat and a possible contraction of stands. Increased siltation should be investigated and may result from changes in sediment supply to feeder streams or eutrophication. Excessive overhanging vegetation can result in increased leaf litter inputs to the sediment leading to poor rooting habitat.
Water depth/flow regime	Very slow moving water in depth range 0.5–1.5 m.	Direct measurement of depth in each monitoring units.	Reductions in water depth may appear to be beneficial to *L. natans* leading to increased incidence of flowering. However, such depth reductions have the potential to threaten populations by enabling the encroachment of emergents.
Water quality	Water quality should represent high quality appropriate to a standing waterbody with similar water supply. Light should penetrate to the bed in mid-channel.	Reference to existing water quality data. Measure secchi disk depth in monitoring units.	A decrease in light availability brought about by eutrophication or high suspended sediment loads will reduce the lower limits of plant rooting and may lead to etiolation of plants. Boat traffic has the potential to exacerbate suspended sediment problems and at high levels can lead to almost permanent turbid conditions. Eutrophication may lead to the increased incidence of phytoplankton blooms, increased epiphytic cover or an increase in more competitive species.
Disturbance regime and interspecific competition	Sufficient disturbance (via boat traffic or management) to restrict encroachment by emergents and displacement by canopy forming species.Cover of main canopy forming submerged species (e.g. *Elodea* spp., *Sparganium* spp., *P. natans*) <40%. Invasive plant species (particularly *C. helmsii*) absent.	Observation of stability of stands under known boat traffic and management regime. Direct survey when monitoring populations.	In canals the dredging regime and boat traffic act as the main disturbance mechanisms. In the absence of any disturbance emergents may rapidly encroach on open water habitat or canopy forming species may become dominant. This is a particular risk in canals with moderate sediment and nutrient loading. Conversely, high levels of boat traffic or intensive dredging may result in a habitat too unstable for plants to persist. As a guide, the average cover of emergent vegetation across all sampling points does not change by more than 20% between visits.Increases in the cover of canopy forming species, *Lemna* spp, or the presence of invasives (*Azolla* spp. *C. helmsii*, *M. aquaticum* and *Hydrocotyle ranunculoides*) may lead to the competitive exclusion of *L. natans* or a reduction in the vigour of plants.*L. natans* should be present within a diverse submerged flora including typical associates (*P. alpinus, P. compressus, P. perfoliatus, P. obtusifolius, P. berchtoldii, P. epihydrus* and, *P. praelongus, Nitella* spp. [incl. *N. mucronata*]. *C.hamulata, C. hermaphroditica*, and *R. circinatus*). On average, each 150 m unit should contain >7 submerged or floating-leaved species.
Connectivity	Maintenance of populations in upstream reservoirs or offline areas adjacent but not linked to canal	Determine existence of local populations in small pools/upstream feeders.	Any regulation which results in a loss of hydrological connectivity between water bodies has the potential to isolate the main clonal population from surrounding subpopulations in which outbreeding plants may be found. Intensive management upstream of the cSAC could remove sources of potential colonists. This could result in a loss of marginal populations and erode genetic diversity.

7.4 Shallow temporary pools

7.4.1 Assessment of supporting habitat characteristics

Most of the information required will be assessed through the recording of associated vegetation as part of the intensive survey. Thus, in recording point samples it will be necessary to record if a quadrat is dominated by bare ground or, alternatively, is fully vegetated. A simple assessment of the relative height of associated vegetation will also be required. Loss of species richness, or increased height of vegetation will be used to infer deteriorating growing conditions. This may be used to trigger an assessment of the need for interventionist management (for example, shallow dredging) if appropriate.

7.4.2 Supporting habitat characteristics for shallow pool populations (Annual flowering populations)

Habitat features	**Target attributes**	**Method of assessment**	**Comments**
Substrate	Marginal areas with stable sand or silt, subject to exposure and summer drying 25–50% of quadrats are dominated by bare ground.	Direct visual observation of unvegetated areas (bare sediment or accumulation of undecayed litter).	Loss of suitable habitat as a result of changes in management (e.g. grazing pressure) or accumulations of organic matter on the surface should be avoided. Such changes may lead to increased water retention and growth of taller wetland species or result in poor conditions for seedling recruitment.As a guide the maximum dimension of suitable habitat should not decrease by >20% between assessments.
Water depth/flow regime	Very shallow water (<20 cm) in early spring, drying to wet mud by late May and hardened surface pan by July.	Direct observation in May/June.	Inappropriate water levels may lead to either: desiccation early in the season prior to seed set, or to wetter conditions through the summer allowing the growth of competitive wetland species (e.g. *Glyceria fluitans*). In dry years (or where water availability is affected by abstraction or management) *L. natans* may suffer early die back. There may be re- growth from dormant seed bank in following season if conditions permit.
Water quality	Water supply to the site should be of high quality - circumneutral with low-moderate nutrient concentrations.	Reference to existing water quality data.	Eutrophication (e.g. through increased livestock densities or diffuse atmospheric or water pollution) may lead to the expansion of fast growing nitrophilous species. Acidification may result in increases in *J. bulbosus* and *Sphagnum* spp., which could overgrow *L. natans* stands or cause a build up of plant litter.
Disturbance regime and interspecific competition	No establishment of large emergents or woody species. <20% quadrats are dominated by vegetation taller than 20 cm. No *C. helmsii* present.	Record extent of bare ground during routine surveys of main habitat patches. Monitor rate of encroachment of emergent vegetation from margins of site.	There should be sufficient fluctuation in water levels and poaching by livestock to constrain growth of late season large emergent species and to prevent establishment of woody species. A reduction in disturbance may result in competitive exclusion by other wetland species. *L. natans* is likely to be particularly susceptible to: increases of large wetland emergent species; growth of *Salix, Alnus* and *Betula* spp seedlings; or invasions of *C. helmsii,* which may occupy similar habitats. Nutrient enrichment from diffuse sources may increase the growth of potential competitors.In good conditions L. natans is present in open structured amphibious wet mud vegetation including typical associated species (*A. inundatum, C. hamulata, Eleogiton fluitans, Baldellia ranunculoides, Ranunculus aquatilis, Potamogeton gramineus, Hypericum elodes, J. bulbosus, Eleocharis multicaulis* and *G. fluitans*). As a guide the diversity of aquatic vegetation in sampled areas should not decrease by >10% between assessments.
Connectivity	Sufficient local landscape dynamics to ensure creation of new sites if old sites are lost to succession	Determine extent of metapopulation, including sites outside SAC boundary and potential for exchange among sites	Any changes to land management practices both on site or to other nearby sites with *L. natans* populations could lead to a loss of local populations or reduction in the metapopulation. Disconnecting populations from surrounding subpopulations (hydrologically or ecologically) may result in a loss of genetic diversity.

8 External data requirements

The requirement for access to data resources managed by the various statutory agencies has generally been minimised. However, there are a number of potential sources of information that may be useful in identifying potential sites for baseline survey, for estimating historic changes in the extent of suitable habitat, and for examining recent changes in supporting habitat features. Examples of these data sources in the UK are described below.

Data on water chemistry based on routine water sampling undertaken by the Environment Agency or SEPA and available on request from regional offices. The most valuable target variables to consider are nitrate, phosphate, calcium (or alkalinity), conductivity and pH. Data should be assessed as annual means. A data series of at least 10 years should be consulted before drawing any (tentative) conclusions on directional change in chemical status. If such data is unavailable for the specific site it may still be valuable to consult data for a comparable site elsewhere in the catchment or in a comparable neighbouring catchment.

Data on river flows collected by the Environment Agency or SEPA from gauging station records and managed and validated by CEH Wallingford (formerly Institute of Hydrology). Similarly where there is no gauging station on the same river analysis of flows in a nearby catchment may be useful to indicate if high flow events had been encountered recently prior to sampling. Ten year series or summary data should be consulted. Data collected for the most recent six months is usually held by the regional office for initial checking. Information on the location of the 1300 gauging stations on UK rivers and how to obtain data from the National River Flow Archive can be found at http://www.nwl.ac.uk/ih/www/research/iresearch.html

Digital land cover maps. Information on land cover maps for 1990 and 2000 produced as part of the Countryside Survey projects can be found at http://www.ceh.ac.uk/data/lcm/LCM2000.shtm and http://www.cs2000.org.uk/

Archived aerial photographic material held at regional offices. Aerial survey campaigns have often been commissioned as part of the process of designating an SAC.

Current and historic 1:10 000 scale maps. Sheets covering last century available for consultation in major libraries and on some internet sites. The EDINA digimap scheme allows access to the Ordnance Survey digital map data set and includes 1:10,000 vector data, 1:50,000 raster data and 1:50,000 topographic data for the UK. Subscription to this scheme is required but it may be available at regional headquarter offices.

River Habitat Survey databases held by CEH and the Environment Agency. Potential source of information for filtering choice of 500m lengths of rivers for baseline surveying.

Standing Waters Vegetation Survey databases. SNH and CCW contacts and database managers. Extensive surveys of standing waters in UK, including areas geographically suited to *L. natans*. Botanical and basic environmental data on c. 4500 sites, principally in Scotland. Maybe useful for initial filtering of sites within appropriate geographical areas for baseline surveys using typical associated species as indicators, or as a source of historical data.

Rivers Conservation database. Data on vegetation composition and physical habitat conditions for c. 2500 sites distributed across UK based on standard 500m reach surveys. Use for preliminary site selection and for historical data.

Threatened plants database. (http://www.tpdb.org/) Will provide information on the history and status of *L. natans* at other sites within a region. Probably required to answer questions relating to proximity of nearest extant populations.

The New Atlas of the British and Irish Flora (Atlas 2000) includes a CD-ROM that allows interactive use of data. As well as allowing printing of additional maps it is possible to incorporate overlays with environmental data and to produce coincidence maps. The main value of this resource is likely to be in targeting new survey sites.

9 Data analysis

No complicated data analysis is required for the interpretation of field data. The only calculations that are needed will be the determination of average frequency of occurrence across the different patches sampled.

Standard recording forms for each habitat should include checklists of species (with associated indicator scores) and checklists of variables to monitor in the field. They should include a standard table for recording data on frequency of occurrence of all species in each habitat patch sampled. Results from this table will direct the surveyor to cross-referenced questions on the favourable condition assessment form. An example form for canal habitats is provided which undertakes all necessary calculations via spreadsheet formulae and could be run easily in the field on a palm top.

10 References

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Appendix 1: Growth form, population attributes and preferred habitat of L. natans in its principal environments

Suitable objectives and criteria that are monitorable using available survey methods are also listed.

Strategy/habitat	Objectives	Monitorable criteria
Perennial vegetative		
1. Upland lakes Population: Large unbroken lawns of submerged rosettes extending for >20m of shoreline within the depth range 1–3 m, growing on fine sediment with low cover of typical associates. Habitat: High water clarity, extensive areas of fine sand and gravel, natural regime of water level fluctuations and wave action, low cover of canopy forming submerged species in deeper littoral zone, free from invasive species.	Maintain the population, in terms of extent and coverage within stands, in a state that is commensurate with the lake habitat type being in favourable condition (see targets for oligotrophic, dystrophic or mesotrophic lakes). Maintain or restore opportunities for interchange of material with other populations via direct hydrological connection. Maintain opportunities for recruitment of detached plants in shallow or terrestrial habitats associated with the waterbody.	i. Upper and lower depths of rooting of submerged beds. ii. Approx. length of equivalent shoreline along which beds extend. iii. Relative cover of plants, bare ground and associates in stands. iv. Presence of plants in strandline material including any evidence of recruitment. v. Existence of (theoretically) suitable habitats for alternative strategies adjacent to or downstream of waterbody. vi. Water secchi depth. vii. Presence of suitable rooting medium within appropriate depth range. viii. Presence and frequency of canopy forming species and invasives in adjacent vegetation and within the wider littoral zone. ix. Mean Trophic Rank (or equivalent index) based on lake or main stands or cover of acidophilous species. x. Morphometric criteria (e.g. root:shoot biomass of individual rosettes, leaf length/area).
Perennial vegetative		
2. Rivers Population: Small, widely distributed patches of plants (totalling >100 individuals) extending over >50m of channel with a high level of occupancy (>33%) of those mesohabitats that can support growth. Habitat: Virtually unmodified channel exhibiting natural fluvial dynamics under which preferred mesohabitats are both created and destroyed. Potential habitat (i.e. stable, fine areas of bed with sluggish flow within base flow secchi depth) accounts for >20% of reach area.	Maintain the reach in a state that is commensurate with the population being in favourable condition (and see targets for *Callitricho-Batrachian* riverine vegetation). Maintain or restore opportunities for interchange of material with upstream populations via direct hydrological connection through preservation or restoration of natural fluvial dynamics.	i. Total population size based on number of basal rosettes. ii. Length of reach within which *L. natans* is present. iii. Relative cover of plants, bare ground and associates in reach and within preferred mesohabitats. iv. Existence of occupied or theoretically suitable habitats within adjacent floodplain. v. Relative extent of preferred mesohabitats within sample reach. vi. Water secchi depth in pools. vii. Presence of suitable rooting medium within secchi depth.

Strategy/habitat	Objectives	Monitorable criteria
2. Rivers (continued) Low cover (total <2%) of invasives. High species and structural diversity of aquatic vegetation.	Maintain opportunities for recruitment of detached plants within floodplain waterbodies	viii. Presence and frequency of canopy forming species and invasives in preferred mesohabitats. ix. Total extent of emergent species within channel. x. Presence of trash-lines on banks within which rooted aquatic plant material occurs. xi. HMS based on RHS <5. xii. MTR based on 100 m reaches in which main habitat patches located. xiii. Morphometric criteria
Perennial flowering		
1. Meso-eutrophic lakes Population: Large lawns of submerged rosettes including plants with floating leaves, ascending stolons or cleistogamous flowers extending for >20m of shoreline within the depth range 1–3m, growing on fine sediment with medium cover of typical isoetid and potamid associates. Habitat: High water clarity, extensive areas of fine sand and gravel, natural regime of water level fluctuations and wave action, moderate cover of canopy forming submerged species in deeper littoral zone, free from invasive species.	Maintain the population, in terms of extent and coverage within stands, in a state that is commensurate with the lake habitat type being in favourable condition (see targets for mesotrophic lakes). Maintain or restore opportunities for interchange of material with other populations (e.g. downstream river sites) via direct hydrological connection. Maintain opportunities for recruitment of detached plants in shallow or terrestrial habitats associated with the waterbody.	i. Upper and lower depths of rooting of submerged beds. ii. Approx. length of equivalent shoreline along which beds extend. iii. Relative cover of plants, bare ground, litter, and associates in stands. iv. Presence of plants in strandline material including any evidence of recruitment. v. Existence of (theoretically) suitable habitats for alternative strategies adjacent to or downstream of water body. vi. Water secchi depth. vii. Presence of suitable rooting medium within appropriate depth range. viii. Presence and frequency of canopy forming species, filamentous algae and invasives in adjacent vegetation and within the wider littoral zone. ix. Mean Trophic Rank (or equivalent index) based on lake or main stands. x. Morphometric criteria
Perennial flowering		
2. Canals Population: Beds of plants extending for >50m of channel, occupying >20% of 2m strip (on one or both sides) adjacent to central channel with majority of shallow water sites supporting plants displaying flowers and/or floating leaves. Some pure beds of >2 x >2m in extent with <20% cover of associates. Submerged rosettes detectable in mid-channel by grapnelling.	Maintain the canal in a state that is commensurate with the canal being in favourable condition (see FCT for canals). Maintain adequate disturbance regime to resist competitive exclusion by canopy forming species or displacement by encroaching reedswamp.	i. Approx. length of channel along which beds extend. ii. Relative cover or frequency of plants, bare ground, litter, and associates in stands. iii. Presence of flowering or floating leaved plants in shallow marginal areas. iv. Water secchi depth and extent of tree shading.

Strategy/habitat	Objectives	Monitorable criteria
2. Canals (continued) Habitat: Extensive areas of fine stable mixed mineral substrate. High water clarity (bed in mid channel is visible from bank or bridge). Low or zero boat traffic (<500 passages per year). Large channel cross section. Low overall cover of emergents (<20% of channel) maintained by management or vertical bank profile. Typical associates and low frequency of stand dominance by invasives. Recent exotic species absent.	Maintain opportunities for flowering and for recruitment of detached plants in marginal areas	v. Presence and frequency of canopy forming species, filamentous algae and invasives in adjacent vegetation. vi. Extent of encroachment by emergent marginal vegetation. vii. Species richness of associated aquatic vegetation. viii. Biomass of associated aquatic vegetation based on grapnel sampling. ix. Mean Trophic Rank (or equivalent index) based on lake or main stands. x. Morphometric criteria
Annual flowering		
1. Shallow temporary pools Population: At least one discrete and more or less pure stand of plants >10 m^2 in extent. In summer this stand supports high density of flowering or seed set (i.e. 75% of 20 x 20 cm quadrats contain flowering or seeding plants); in early spring of subsequent year complete coverage in same area by basal rosettes. Nearby presence of other pools supporting populations in favourable condition and with which vectors for gene exchange still exist. Habitat: Typical winter-spring wet, summer-autumn dry seasonal cycle. Invasives absent. Low cover of later successional emergents (*Glyceria fluitans*, *Deschampsia caespitosa*) due to interventionist management or livestock poaching. High overall cover of typical suite of amphibious species.	Maintain the site in a state that is commensurate with it being in favourable condition (see FCT for relevant shallow temporary pool habitats). Maintain adequate disturbance regime through interventionist of site, through mowing, cutting, scrub clearance, deepening etc, livestock poaching, to resist competitive exclusion by reedswamp or terrestrial species, or ensure that suitable recruitment opportunities exist locally. Maintain opportunities for flowering and dispersal and interchange between sites within and beyond the complex by maintaining livestock, wildfowl access and open structured vegetation.	i. Approx. distribution of main stands within a pool or overall complex. ii. Relative cover or frequency of plants, bare ground, and associates in sample patches. iii. Frequency of flowering or seeding plants. iv. Cover of larger wetland or terrestrial species within stands. v. Extent of encroachment by emergent marginal vegetation into wet mud/shallow open water areas. vi. Species richness of associated amphibious vegetation. vii. Level of threat from alien invasive species, notably *C. helmsii*. viii. Ellenberg indicator scores for nitrogen (and reaction or pH) weighted by composition of associated vegetation.

Appendix 2: Determination of sampling effort

A 20% frequency of occurrence is suggested as the threshold for favourable condition for the attribute population size (p = 0.2). Assessment of frequency of occurrence depends on determination of presence-absence, which is a proportional value and therefore follows the binomial distribution.

Consequently, it is straightforward to determine the confidence limits associated with different proportions of positive values and for different sample sizes. These confidence limits can be used to determine, for a given sample size, how many samples should contain *L. natans*, to be reasonably certain that the threshold value is, in fact, being met.

Thus, for n = 20, at least seven samples would need to contain *L. natans* to be >95% certain that p = >0.2. For a sample size of 20 with p = 0.2 the probability of not recording *L. natans* at all is 1.2%. In other words, if the standard is met it is very unlikely that *L. natans* will be undetectable with the recommended 20 samples.

No. samples taken	**Probability of failing to record when p = 0.2**	**X when p = 0.2 for probability of success = 0.95.**	**Effective minimum number of presences to guarantee compliance**
8	0.1678	3.08	4
12	0.0687	4.34	5
20	0.0115	6.58	7
40	0.0001	11.80	12

Note: This example is only applicable to samples collected using similar methods and sampling areas and from sites where populations show the same degree of spatial aggregation.

Conserving Natura 2000 Rivers

Ecology Series

1 Ecology of the White-clawed Crayfish, *Austropotamobius pallipes*
2 Ecology of the Freshwater Pearl Mussel, *Margaritifera margaritifera*
3 Ecology of the Allis and Twaite Shad, *Alosa alosa* and *A. fallax*
4 Ecology of the Bullhead, *Cottus gobio*
5 Ecology of the River, Brook and Sea Lamprey, *Lampetra fluviatilis*, *L. planeri* and *Petromyzon marinus*
6 Ecology of Desmoulin's Whorl Snail, *Vertigo moulinsiana*
7 Ecology of the Atlantic Salmon, *Salmo salar*
8 Ecology of the Southern Damselfly, *Coenagrion mercuriale*
9 Ecology of the Floating Water-plantain, *Luronium natans*
10 Ecology of the European Otter, *Lutra lutra*
11 Ecology of Watercourses Characterised by *Ranunculion fluitantis* and *Callitricho-Batrachion* Vegetation

Monitoring Series

1 A Monitoring Protocol for the White-clawed Crayfish, *Austropotamobius pallipes*
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They can also be downloaded from the project website: www.riverlife.org.uk

The Life in UK Rivers project was established to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites.

Set up by the UK statutory conservation bodies and the European Commission's LIFE Nature programme, the project has sought to identify the ecological requirements of key plants and animals supported by river Special Areas of Conservation.

In addition, monitoring techniques and conservation strategies have been developed as practical tools for assessing and maintaining these internationally important species and habitats.

The floating water-plantain has a complex ecology and several reproductive strategies, enabling it to persist at suitable sites for hundreds of years.

However, due to the loss of its wetland habitat, the floating water-plantain is declining across its European range.

This report suggests monitoring methods that can be used to determine whether floating water-plantain populations are in favourable condition, and what conservation action is necessary for their survival.

Information on Conserving Natura 2000 Rivers and the Life in UK Rivers project can be found at
www.riverlife.org.uk

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