# Developing a monitoring strategy and protocol for National Trust freshwaters

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## Summary

The National Trust has identified a need to monitor the condition of freshwater habitats on its estate in order to:

a) Determine the status of freshwater habitats as important wildlife features in their own right;

b) Assess freshwater quality as an indicator of how well the National Trust is manging the land and soils on its properties.

Overall the objective is to evaluate two kinds of changes: (i) improvement (or deterioration) within the National Trust estate, which will be assessed by comparing the monitored sites at time point 1 ($t_1$) with their condition at a second time point 2 ($t_2$), probably on a 5 year monitoring cycle; (ii) the status of National Trust properties compared to the rest of the landscape, which will be assessed by comparing the data collected on National Trust land with the condition of sites in national monitoring programmes using the same methods.

In developing this programme of monitoring the Trust has adopted a tiered approach to freshwater monitoring. Tier 1 will use data from existing national monitoring programmes undertaken by statutory agencies where available collected mainly for Water Framework Directive (WFD) and other statutory monitoring purposes. Tier 2 will complement this information with new data - the main subject of this report - based on a 1 km square stratified sampling approach covering smaller non-WFD waters (ponds, small lakes, streams) which make a substantial contribution to freshwater biodiversity and freshwater ecosystem services. Tier 3 will comprise monitoring that enables individual properties to assess the condition of their waterbodies and Tier 4 comprises detailed bespoke monitoring of specific projects (e.g. natural flood management projects).

The focus of the present report is: (i) the development of the Tier 2 methodology with recommendations for a national monitoring programme, (ii) the identification of opportunities for volunteer-based monitoring in Tier 3. The report describes the type and approximate abundance of different kinds of freshwater habitats on the National Trust estate, the monitoring methods that could be applied to assess the condition of these waterbodies and the advantages and disadvantages of professional and volunteer-based methods. Recommendations are also made on counting pond numbers, which are an important metric of landscape quality (it is not expected that stream length will change).

Power analysis is used to assess the numbers of sample locations needed to detect a given level of change, and the implications that this analysis has for cost and organisation of surveys. Alternative water pollution and biological quality metrics which could be used for assessing the status of freshwaters are reviewed and their costs and benefits evaluated. The analysis takes account of the fact that budgets are unlikely to be as large as those available to statutory bodies but must still generate statistically credible data. The relative skill levels required for different monitoring methods, and their suitability for professional and volunteer surveyors, are also evaluated. We have also assessed the role of new environmental DNA (eDNA) techniques for the National Trust. eDNA methods have been applied successfully to the monitoring of the great crested newt, and are now being introduced for other groups (e.g. fish).

Considering costs and benefits, it is recommended that Tier 2 biological monitoring focuses on wetland and aquatic plants with surveys undertaken professionally. Water quality monitoring should initially be based on the rapid assessment of nitrate and phosphate pollution using Kyoritsu PackTest kits. Diatoms, macroinvertebrates and fish surveyed using traditional methods normally require professional biologists to be applied effectively and are comparatively expensive. There should be further exploration of the use of environmental DNA methods, especially for fish, amphibians and single endangered invertebrate species as part of further partnership work.

It is recommended that for Tier 3 volunteers should be encouraged to monitoring single endangered species. Experience from the HLF funded ‘People, Ponds and Water’ project

shows that volunteers can monitor the status of such species. Volunteers should also be encouraged to monitor water quality with rapid test kit methods.

The National Trust should also encourage and support volunteer species recording of all relevant freshwater groups feeding into national species mapping projects. A short guide with links to all appropriate recording schemes could be prepared to provide a simple signposting service for those interested in biological recording. For monitoring freshwater invertebrates, there should be further evaluation of rapid invertebrate survey methods such as the RiverFly partnership method.

Costs of the survey options are presented and the main delivery options described. Specific recommendations for the design and implementation of the monitoring programme are listed below. The proposed work on National Trust properties also provides substantial opportunities for encouraging partner organisations to participate in a national-level monitoring programme on small waterbodies.

## Recommendations

**Recommendation 1:** We recommend that National Trust encourages recording of all of freshwater biota which currently have active monitoring groups (e.g. dragonflies, cladocerans, water plants) to add to inventories of these species. At individual sites information on changes in species occurrence, distribution and abundance are likely to be useful for site management even though they are unlikely to provide monitoring data that can be used to report on the overall condition of the Trust’s freshwaters.

**Recommendation 2.** We recommend that freshwater species of conservation concern should be mapped across the National Trust estate as part of a process to identify Important Freshwater Areas on the Trust’s land.

**Recommendation 3.** We recommend that to provide an initial assessment of the extent of water pollution on National Trust properties, Kyoritsu rapid nutrient PackTest kits are used to measure nitrate and phosphate levels. These test kits have been widely used by both volunteer and professional biologists in Freshwater Habitats Trust’s Clean Water for Wildlife project, including on National Trust properties.

**Recommendation 4:** We recommend that the standard PondNet survey of environmental variable for ponds is used, incorporating information requirements identified recently by Natural England for standing waters. We also recommend that a recording form for running waters that incorporates requirements of Natural England for assessing the condition of priority streams is developed for the present project.

**Recommendation 5**. For widespread monitoring on National Trust properties, metrics based on wetland plants are the only traditional biological survey method which can be easily applied at large numbers of sites at relatively low cost.

**Recommendation 6:** Ponds should be counted by censusing waterbodies on each National Trust property rather than by taking a sampling approach, such as that used in PondNet or the Countryside Survey.

**Recommendation 7:** We recommend that PackTest kits are used to evaluate changes in water quality on the National Trust estate, noting the limitations given in Section 5.2.2 about the type of monitoring questions which can be answered with the test kits.
**Recommendation 8:** Wetland plants provide an effective group for assessing change in small running and standing waters and should be adopted as a monitoring metric provided they can be recorded professionally.

**Recommendation 9:** If additional funds are available, or there are other opportunities for establishing diatom monitoring programme, monitoring with this metric is potentially is good option.

**Recommendation 10:** We recommend that the Riverfly score would be worth further investigation provided that there was further analysis of its inherent variability. Additionally, it would be worth assessing first whether there were likely to be substantial impacts on running waters on the National Trust estate which could be amenable to improvement before implementing a programme of volunteer surveys which might lack the power to detect anything other than very substantial changes in the invertebrate fauna.

**Recommendation 11:** We do not recommend undertaking fish surveys routinely on Tier 2 waterbodies on the National Trust estate unless eDNA techniques become available. Fish survey work may be needed in Tier 4 projects.

**Recommendation 12:** We recommend that for the taxa for which standard recording schemes are available surveyors should be strongly encouraged to work with national recording schemes and Local Environmental Records Centres to collect records for these groups.

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# 1. Introduction

## 1.1 Background

The National Trust's 10 year strategy includes a number of ambitious targets for the way in which it manages its land and delivers a healthy, beautiful, natural environment. To measure and track progress with this strategy a range of metrics and monitoring approaches are being developed. In many cases these are being developed as part of existing national recording schemes (e.g. national butterfly and plant monitoring schemes). The advantage of linking to these existing schemes is that tested methods exist, there are established reporting and archiving processes and it is possible to place National Trust land within a national context.

There is currently no equivalent national scheme for freshwaters and hence the Trust has identified the need to develop its own approach to monitoring the status of freshwaters across the National Trust estate.

There are two interrelated aims for the proposed freshwater monitoring:

a) To determine the status of freshwater habitats as important wildlife features in their own right;

b) To determine freshwater quality as an indicator of how well the National Trust is manging the land and soils on its properties.

At present there are no targets that are specific to (fresh)water so the aim is to provide a general assessment of the status of Trust waterbodies.

In response to a series of initial proposals, the National Trust programme board has agreed that the Trust should adopt a tiered approach to monitoring freshwaters (Figure 1). The Trust will adopt a two-tier approach to national freshwater monitoring which uses statutory agency information on rivers, streams and lakes where data are already collected, typically as part of Water Framework Directive (WFD) monitoring (Tier 1), complemented by a 1 km square stratified sampling approach across National Trust land to assess the condition of smaller running and standing waters (Tier 2). A wide range of information suggests that these smaller waters, which were largely omitted from WFD programmes and of which there are large numbers, make a substantial contribution to freshwater biodiversity and the delivery of freshwater ecosystem services (see, for example, Clarke, 2015 and Biggs et al. 2017). In parallel the Trust also aims to develop some basic guidance for properties wishing to undertake their own assessment of freshwaters (Tier 3) and for those with bespoke project monitoring requirements (Tier 4).

Larger and more significant waterbodies are typically covered in the monitoring programmes of the statutory agencies, primarily for the EU Water Framework Directive[1]. These programmes are intended to assess a range of biological and water chemistry parameters to determine the status of a waterbody, built around the concept of the extent to which waterbodies deviate from the natural background or 'reference condition'. There are five status classes (high, good, moderate, poor and bad) and the default target is for good status, in which the 'biological quality elements….show low levels of distortion resulting from human activity, **but deviate only slightly** from those normally associated with the surface water body type under undisturbed conditions'[2].

Even though there are currently expected to be substantial cutbacks in the monitoring undertaken by the statutory agencies, this monitoring programme will remain the most

[1]Given the investment in monitoring programmes and the need to report on river and lake health it seems unlikely that Brexit will have an impact on EU WFD monitoring, at least in the short-medium term.
[2]http://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF

extensive and detailed analysis of National Trust freshwaters for the foreseeable future. In theory it should provide information on algae, large water plants, aquatic invertebrates and fish at all sites and, even though a large minority of sites still lack all the biological measures, the information provided is of a good standard. It is proposed that the National Trust use these data to provide an assessment of condition where possible.

These external data can only be used for larger or more significant waterbodies (e.g. SSSIs) and in such cases National Trust may only have control over a small proportion of the catchment. As such a tiered approach to freshwater assessment is proposed:

Tier 1) National scale analysis of statutory data to report on larger National Trust waterbodies (requires ‘rules’ to be developed e.g. NT WFD waters could be defined as rivers or lakes where the Trust owns > 25% of the catchment).

Tier 2) Stratified sampling of smaller National Trust waterbodies (headwater streams, small lakes, less than 50 ha in area, and ponds) based on national monitoring scheme methods (derived from approaches developed in Defra’s Countryside Survey). This work should be a mixture of professionally conducted and volunteer-led data collection, the latter where it is clear that volunteer data can provide statistically credible data able to help detect trends in the status of habitats or specific freshwater species.

Tier 3) Property level, volunteer led monitoring of freshwaters using simple assessment methods. (This is supplementary to the national monitoring and is proposed only where properties wish to adopt this).

Tier 4) Bespoke monitoring of particular projects through partnership initiatives which is often likely to be undertaken professionally (e.g. Holnicote natural flood management project).

These four tiers are described in more detail in the rest of this paper. It is important to note that tiers 1 and 2 are proposed as the national approach for measuring water outcomes. Tier 3 property level monitoring is intended to inform property level work but could provide useful context and additional confidence around our national approach. Tier 4 project monitoring falls outside the scope of strategy outcome measurement but is important for wider advocacy, influence and credibility. Figure 1 overleaf outlines the overall approach.

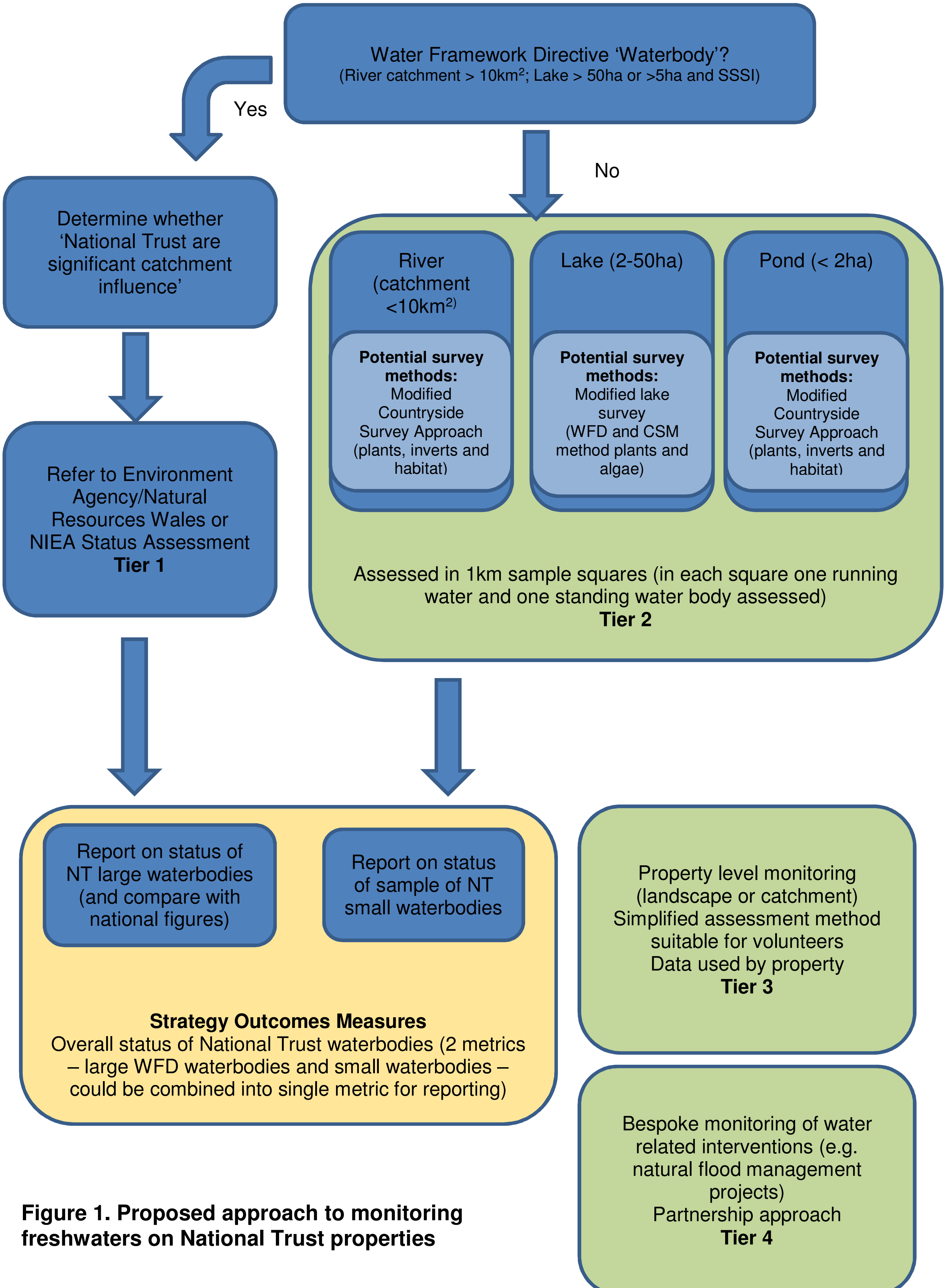


**Figure 1. Proposed approach to monitoring freshwaters on National Trust properties**

## 1.2 National Statutory Data (Tier 1)

National Trust has already begun to link Water Framework Directive data to National Trust property data for England. Data for Wales is readily available but work is needed to secure and interpret data for Northern Ireland. Once the Trust has established which waterbodies it wishes to include, and linked these to statutory data, it will be possible to run reports as needed.

This will enable the Trust to compare the status of its waterbodies with the national average and can easily provide regional breakdowns. Many factors affecting the status of waterbodies may be beyond the Trust's immediate control but some simple analysis of national figures will allow results to be presented with appropriate contextual information.

The development of a reporting approach for these Tier 1 data will be undertaken internally by National Trust and is not considered further in this report.

## 1.3 Stratified Sampling Process (Tier 2)

It is acknowledged that Water Framework Directive data only covers some waterbodies (i.e. is skewed towards so-called 'main river' and larger lakes) and a national overview of freshwaters will require additional information. To monitor the large number of smaller streams, ponds, small lakes and ditches on National Trust land the approaches adopted by Countryside Survey (CS) and the Glastir Monitoring and Evaluation Programme (GMEP) have been explored as a basis for the National Trust programme. Both approaches target 1 km squares and for the freshwater aspects of the survey one pond and one headwater stream are assessed.

In the present report the details of such an approach are further developed using statistical power analyses as the basis for identifying the number of survey sites needed to detect different levels of change.

There are a number of options for sampling but a degree of expertise and training will be required. Sampling could be undertaken either by professional surveyors (either in-house or external partners) or, for some determinands, trained volunteers.

The present report evaluates the advantages and disadvantages of these two alternative approaches, particularly building on the experience of the Freshwater Habitats Trust which has undertaken both national professional and large-scale citizen science-based freshwater surveys.

## 1.4 Property Engagement (Tier 3)

The proposed approach is focused on securing a national (England, Wales and Northern Ireland) picture of freshwater status across National Trust properties. The sampling approach means that only a minority of properties will actually be monitored but it is anticipated that many will be interested in tracking the health of their waterbodies and may have keen and willing volunteers. Freshwater monitoring is very popular with volunteers and the proposed approach is amenable to simplification and scaling down. As such a third tier of data collection has been considered in which National Trust properties can collect additional data to track their own freshwaters.

A more basic volunteer based approach run by properties would have two functions: a) be a valuable engagement and participation tool and b) provide properties with some basic data about the status of their waterbodies alongside national data. Further National Trust internal work is required to develop this approach. As part of the Riverlands project development the National Trust are working with partner organisations to build on existing citizen science initiatives for freshwater and this work could be rolled out more widely.

Opportunities for training of volunteers in monitoring methods are discussed in more detail in Section 8.

## 1.5 Bespoke Project Monitoring (Tier 4)

Where the National Trust is undertaking innovative land or water management work it has been recognised that it is important to try and monitor the effect of this with well-designed experiments (e.g. Before-After-Control-Impact design) or monitoring. The Trust will rarely have the resources to do this alone so will need to develop partnerships with other organisations and academics.

National Trust experiences with the Holnicote natural flood management project show that appropriate monitoring can result in projects becoming powerful advocacy tools with widespread interest from government, NGOs and other land managers. Sound evidence is critical in securing wider uptake of such measures. A similar outcome occurred with work on landscape level freshwater biodiversity, undertaken by Freshwater Habitats Trust on and around the Buscot and Coleshill Estate in Oxfordshire, the results of which have become widely cited by freshwater scientists around the world (Williams et al., 2004)

Some recommendations on the principles of monitoring and data collection for evaluating innovative land and water management interventions are given in Section 8.

# 2. Aims

The current project provides a range of costed options for monitoring freshwaters across the National Trust estate at the Tier 2 level. We expect that the work will also help the development of guidance for Tier 3 and Tier 4.

The project had the following objectives:

- To determine the likely scale of monitoring required to provide a robust assessment of change in National Trust freshwaters during the life of the strategy and beyond (10-20 years);
- To explore a range of monitoring options and estimate the broad costs and benefits of these options;
- To recommend monitoring approaches and data collation/analysis options.

The work reported here has six main components.

### 1. Review the scale of NT freshwaters requiring monitoring

The number of freshwaters of each type that comprise the National Trust freshwater resource is analysed (the population to be monitored). The analysis focuses on ponds, small lakes, ditches and streams not monitored by the statutory agencies.

These waterbodies, which are the focus of the Tier 2 survey effort, are primarily those that are ***not*** currently assessed by the statutory agencies (Tier 1).

For rivers, streams and ditches publicly available OS Vector Map District data were used to assess the size of the total resource. For ponds, a national dataset was derived from OS MasterMap data under licence to Natural England. For lakes location information from the GB Lakes database developed by the Environment Agency was used. The extent of rivers, streams and lakes classified under Water Framework Directive was assessed using datasets downloaded from the Environment Agency website. The National Trust estate was identified using a GIS layer made available by the National Trust.

Data were available only for England and Wales. No analysis of waterbodies in Northern Ireland was undertaken.

### 2. An evaluation of the range of different options for carrying out monitoring.

The options for carrying out monitoring on freshwaters are briefly reviewed and evaluated including:

- Professional versus volunteer monitoring;
- The role of simple water quality test kits versus professional laboratory analysed samples;
- The value of different biotic groups and indices for monitoring trends in the condition of freshwater habitats (e.g. algae, invertebrates, vascular plants);
- The advantages and disadvantages of recording community metrics, indicator species and individual species;
- The role of novel and emerging techniques (e.g. eDNA).

As part of the monitoring process for land management each National Trust property is also expected to undertake a land condition assessment (LCA) at each point of major change. The current LCA methodology includes descriptions for different levels of water health (see Appendix 2).

The potential to incorporate freshwater assessment into the land condition assessment process are evaluated.

### 3. To determine, using power analyses, the sampling requirements for the range of difference approaches

Existing datasets (e.g. Countryside Survey plant data, Environment Agency national diatom dataset, Freshwater Habitats Trust PSYM dataset) were used, where available, to determine the number of samples required to provide a representative assessment of freshwaters across the National Trust estate at a given level of statistical power.

The analysis also considered different approaches to stratifying the sampling design (e.g. single national sample, country stratification, upland vs lowland stratification).

### 4. Develop a matrix of options with details of costs, frequency, delivery options (e.g. professional versus volunteer)

A matrix of survey options, with alternative delivery methods, is described and presented with indicative costs and a simple assessment of the relative merits or otherwise of each approach.

### 5. Recommend options for collating, analysing and archiving data

Opportunities to feed data into existing recording schemes are described, and options explored for data collation. Recommendations are also made for potential approaches to data analysis and reporting.

### 6. Make suggestions for monitoring particular sites or particular interventions

As national monitoring scheme do not automatically capture change and inform management at key sites, recommendations about particular monitoring needs for key sites are made and other opportunities to capture useful information identified (e.g. through the Riverlands programme).

# 3. A review of the scale of National Trust freshwaters requiring monitoring

## 3.1 What are freshwaters?

In this report we use the following definitions of waterbodies, most of which were first developed by Brown *et al*. (2006):

| | |
|---|---|
| Ponds | Waterbodies between 25 $m^2$ and 2 ha in area which may be permanent or seasonal (Collinson *et al*., 1995). Includes both man-made and natural waterbodies. |
| Lakes | A body of water >2 ha in area (Moss *et al*., 1996). Includes reservoirs and gravel pit lakes. |
| Streams | Small lotic waterbodies created mainly by natural processes. Marked as a single blue line on 1:25,000 Ordnance Survey (OS) maps and defined at this map scale by OS as being less than 8.25 m in width. Streams differ from ditches by: (i) usually having a sinuous planform; (ii) not following field boundaries, or if they do, pre-dating boundary creation; (iii) showing a relationship with natural landscape contours, e.g. running down valleys. |
| Rivers | Larger lotic waterbodies, created mainly by natural processes. Marked as a double blue line on 1:25,000 OS maps and defined by the OS as greater than 8.25 m in width at this map scale. |
| Ditches | Man-made channels created primarily for agricultural purposes, and which usually: (i) have a linear planform; (ii) follow linear field boundaries, often turning at right angles; (iii) showing little relationship with natural landscape contours. |
| Springs | Locations where groundwater emerges for at least some part of the year to make a surface water flow (Biggs *et al*., 2016). |
| Flushes | Areas where the flow of ground water onto the surface is more diffuse, either below a spring or where water flows widely over the surface of saturated ground rather than in a well-defined channel. Flushes can be areas of open, stony ground with only a sparse plant cover or have a complete and often dense cover of flowering plants, usually sedges or rushes, with the bryophytes forming a ground layer under this canopy (Plantlife, 2009). |

Other wetlands, such as fens and mires, are not included in the present project.

**Table 1. Length / number of waterbodies on the National Trust estate in England and Wales, monitored and unmonitored by Environment Agency**

| Waterbody type | Number or length in km | Monitored (length, km or number) | Unmonitored (length, km or number) |
|---|---|---|---|
| Rivers and streams | 708 km | 708 km | - |
| Non-WFD linear water courses (includes rivers, streams and ditches)[1] | 6683 km | - | 6683 km |
| Ponds | 3766 | Not known | |
| Lakes | 97 | 57 | 40 |

**[1]Linear waterbodies are the combined OS waterline and water surface area layers. The surface area segments treated as rivers, streams or ditches were 5000 m or longer and those having length/area ratios of less than or equal to 5.**

## 3.2 Waterbodies on the National Trust estate

The National Trust has around 7000 km of linear waterbodies (rivers, streams, ditches) on its estate and about 4000 ponds and lakes.

### 3.2.1 River, streams and ditches

Of the linear watercourses, the ecological quality of just over 700 km on the National Trust estate are classified under the Water Framework Directive. There are about 6700 km of unmonitored watercourses on the National Trust estate shown by Ordnance Survey mapping. This high proportion of unmonitored compared to monitored linear watercourses is normal for the British landscape.

In this analysis, for simplicity we did not separate linear waterbodies into rivers, streams and ditches. Classification of waterbodies into these three categories would require more detailed GIS work than was possible within the time constraints of the present project.

### 3.2.2 Ponds and lakes

Ordnance Survey mapping shows c.3700 ponds on National Trust properties. Very few of these ponds are regularly monitored with a small number included in existing Freshwater Habitats Trust surveys (e.g. Flagship sites such as Cock Marsh, Runneymede and the Begwyns).

Ordnance Survey mapping shows just under 100 lakes (standing waters of 2 ha or more in area) on National Trust property. More than half of these waterbodies are included within the Water Framework Directive monitoring network.

We did not include springs and flushes as water layer information that is publicly accessible does not contain information on these features.

The broad distribution of the rivers and streams classified under the Water Framework Directive on National Trust properties is shown in Figure 2. The broad distribution of all lakes on National Trust properties is shown in Figure 3. Named lakes on National Trust properties are listed in Table 2 and those monitored under the Water Framework Directive and located on National Trust properties in Table 3.

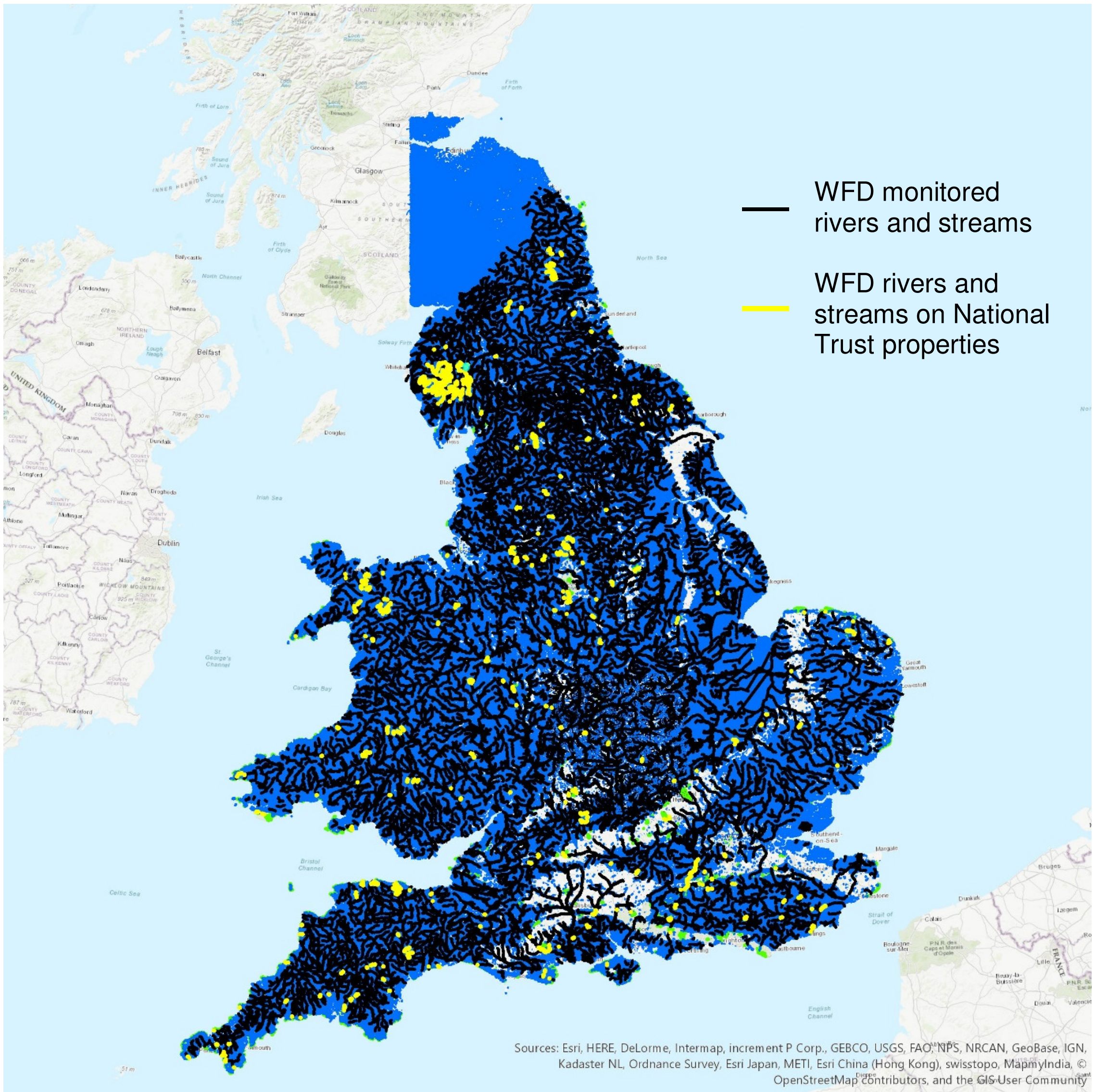


**Figure 2. Broad distribution of Water Framework Directive classified rivers and streams on National Trust properties.**

Rivers and streams highlighted in yellow are monitored under Water Framework Directive and lie within National Trust property boundaries. Waterbodies in black are monitored for Water Framework Directive and lie outside the National Trust estate. There are 296 separate stream and river waterbodies on National Trust estate land with a total length of 708 km (Table 1).

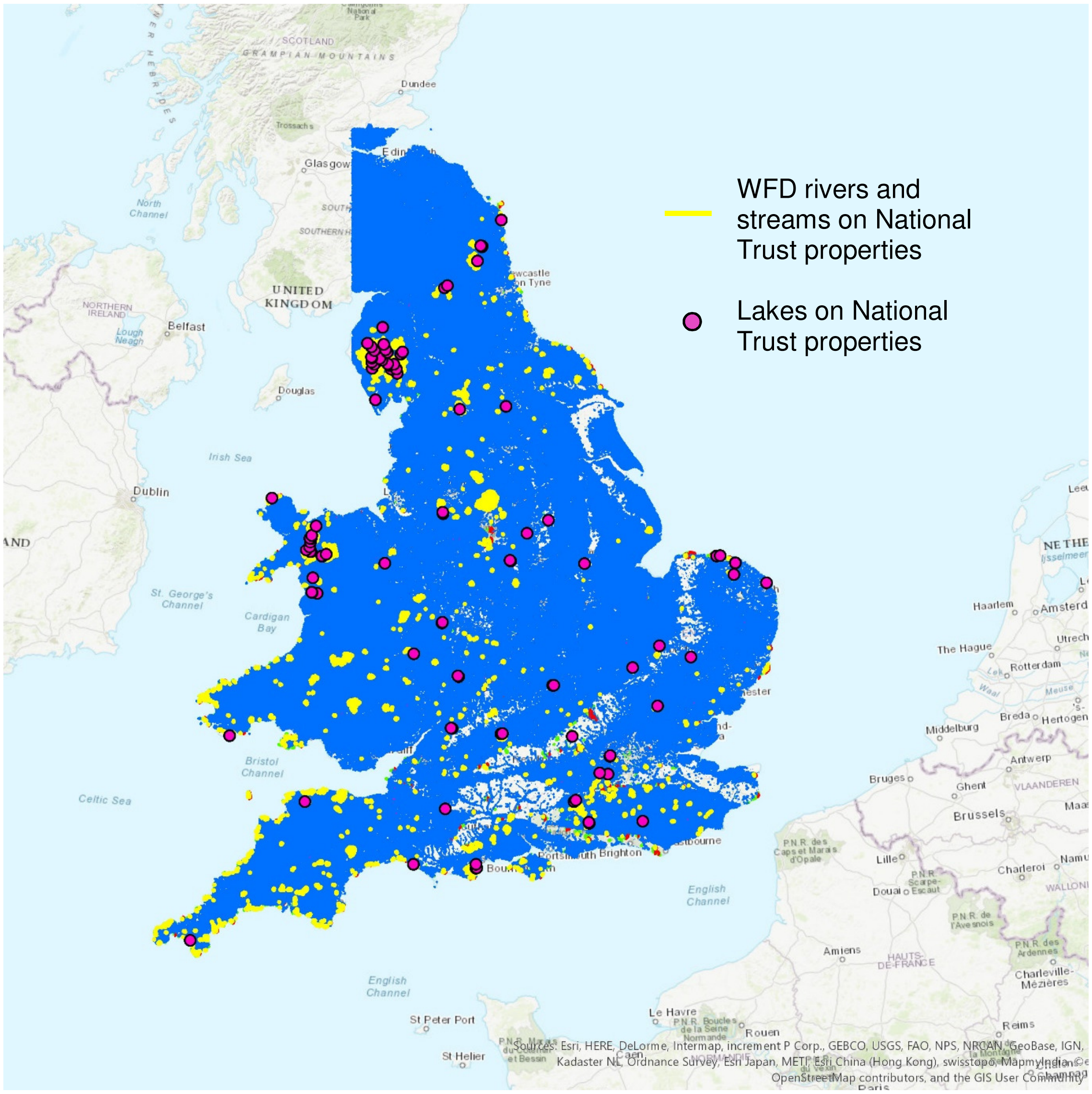


**Figure 3. Broad distribution of lakes (standing waters greater than 2 ha in area) on National Trust properties.**

There are 97 separate lakes on National Trust properties, shown as red circles (Table 2). Water Framework Directive monitored streams and rivers on the National Trust estate are highlighted in yellow.

**Table 2. Lakes on the National Trust estate in England and Wales, derived from GB Lakes database**

| Lake | Lake | Lake |
|---|---|---|
| Angle Tarn | Loughrigg Tarn | Unnamed lake at SO883442 |
| Berrington Pool | Low Tarn | Unnamed lake at SO879446 |
| Blea Tarn | Loweswater | Unnamed lake at TL332517 |
| Blelham Tarn | Malham Tarn | Unnamed lake at TL818604 |
| Bosherton Lily Ponds | Melchett Mere' | Unnamed lake at TL556698 |
| Broomlee Lough | Moss Eccles Tarn | Unnamed lake at SO744888 |
| Brothers Water | Nelly's Moss Lakes | Unnamed lake at SO747892 |
| Brownsea Island Lake | Nelly's Moss Lakes | Unnamed lake at TG176292 |
| Burnmoor Tarn | Over Water | Unnamed lake at SK933381 |
| Buttermere | Oxford Water | Unnamed lake at SJ269386 |
| Cemlyn Bay Nature Reserve' | Rothley Lakes | Unnamed lake at TG190388 |
| Clumber Lake | Scoat Tarn | Unnamed lake at SK317403 |
| Crag Lough | Sprinkling Tarn | Unnamed lake at SK311408 |
| Crummock Water | Tarn Hows | Unnamed lake at SH746444 |
| Derwent Water | Tatton Mere | Unnamed lake at TG062447 |
| Ffynnon Lloer | The Lake | Unnamed lake at SE280691 |
| Frensham Great Pond | The Loe | Unnamed lake at SD190748 |
| Frensham Little Pond | Wast Water | Unnamed lake at NU068026 |
| Great Barnett | Watendlath Tarn | Unnamed lake at NU241241 |
| Great Pond | Yew Tree Tarn | |
| Horsey Mere | Unnamed lake at SZ034850 | |
| Bosherton Lily Ponds | Unnamed lake at SY508879 | |
| Little Langdale Tarn | Unnamed lake at SU971221 | |
| Little Sea | Unnamed lake at SU969231 | |
| Llyn Anafon | Unnamed lake at TQ418239 | |
| Llyn Bochlwyd | Unnamed lake at ST772340 | |
| Llyn Conwy | Unnamed lake at SS604401 | |
| Llyn Cwmffynnon | Unnamed lake at TQ129630 | |
| Llyn Dinas | Unnamed lake at TQ060641 | |
| Llyn Gwynant | Unnamed lake at TQ145778 | |
| Llyn Idwal | Unnamed lake at TQ148784 | |
| Llyn Llagi | Unnamed lake at SU831944 | |
| Llyn y Bi | Unnamed lake at SU237966 | |
| Llyn y Gadair | Unnamed lake at SU248969 | |
| Llyn yr Adar | Unnamed lake at SO829009 | |
| Llynnau Cregennen | Unnamed lake at SO820013 | |
| Llynnau Cregennen | Unnamed lake at TL540198 | |
| Llynnau Gamallt | Unnamed lake at SP678370 | |

**Table 3. Lakes monitored by the Environment Agency or Natural Resources Wales on the National Trust estate in England and Wales for WFD**

| Lake | Lake |
|---|---|
| Ardingly Reservoir | Llynnau Gamallt |
| Blea Tarn | Loweswater |
| Blelham Tarn | Malham Tarn |
| Bosherton Lily Ponds (Central Arm) | Melchett Mere |
| Bosherton Lily Ponds (Eastern Arm) | Over Water |
| Bosherton Lily Ponds (West Arm and Central) | Scoat Tarn |
| Broomlee Lough | Staunton Harold Reservoir |
| Brothers Water | Tarn Hows |
| Burnmoor Tarn | Tatton Mere |
| Buttermere | The Loe |
| Clumber Lake | Ticknall Quarries |
| Clumber Park Lake West | Ullswater |
| Cod Beck Reservoir | Wast Water |
| Coniston Water | Wessenden Head Reservoir |
| Crag Lough | Wessenden Reservoir |
| Crummock Water | Windermere (N Basin) |
| Derwent Water | Windermere (S Basin) |
| Elter Water | |
| Ennerdale Water | |
| Esthwaite Water | |
| Fontburn Reservoir | |
| Frensham Great Pond | |
| Frensham Little Pond | |
| Grasmere | |
| Hayeswater | |
| Horse Coppice Reservoir | |
| Horsey Mere | |
| Kedleston Hall Lower Lake | |
| Little Langdale Tarn | |
| Little Sea | |
| Llyn Anafon | |
| Llyn Bochlwyd | |
| Llyn Conwy | |
| Llyn Cregennen Lower | |
| Llyn Cregennen Upper | |
| Llyn Cwmffynnon | |
| Llyn Gwynant | |
| Llyn Idwal | |
| Llyn Llagi | |
| Llyn Ogwen | |

# 4. Options for carrying out monitoring of National Trust freshwater habitats

## 4.1 Introduction to monitoring methods

Monitoring of the water environment has traditionally been led in England and Wales by statutory agencies assessing the effect of pollution on rivers, larger streams and canals. The first comprehensive national survevs in England and Wales using biological metrics to assess the condition of rivers date back to the 1970s (Department of the Environment and The Welsh Office, 1971), although earlier regional surveys had been undertaken. There has also been a long tradition of assessing the composition and abundance of fish populations for the purpose of promoting and managing fisheries.

More recently, since about the mid-2000s, traditional approaches focused on pollution control have developed, under the auspices of the Water Framework Directive, to be concerned more with maintaining the overall ecological health of freshwaters. The Water Framework Directive has established in practice a broadly adopted scientific view that protecting the water environment should be evaluated against objective baselines, variously called 'minimally impaired conditions' or 'reference conditions'.

The regulations developed in the Water Framework Directive are amongst the most comprehensive and demanding in the world. However, they were largely conceived and put into place before a wide body of work which has demonstrated the importance of small waterbodies, both flowing and still, which it is increasingly clear play a major role in protecting freshwater biodiversity and influencing the way freshwater ecosystem services are delivered and exploited (Biggs *et al.* 2017). The importance of small waters began to be noticed in the mid-1990s and gathered speed with research undertaken in the early 2000s. The importance of small waters was first recognised in UK legislation by the inclusion of ponds and headwaters as Priority Habitats in 2006 Natural Environment and Rural Communities Act. Since then, policy has continued to develop in this area as a wider range of people and organisations have become interested in the role and importance of smaller waters.

Although current state-led monitoring of the water environment in England and Wales is amongst the best developed in the world, and the network of monitored sites extensive, large parts of the water environment are still little, if at all, monitored. The condition of these overlooked, mainly smaller, waterbodies is assessed from a rather patchy network of monitoring programmes, mainly implemented through the Countryside Survey and related work, and more recently through the PondNet programme established by Freshwater Habitats Trust, building on earlier projects.

Monitoring of the water environment has contrasted with that of the land environment in being largely undertaken by professional organisations. Unlike the land environment, volunteer naturalists have played a smaller part to date in evaluating the condition of freshwaters and the status of freshwater species. There have been no regular updates of the condition of freshwater habitats undertaken by NGOs and, with the exception of water birds, no regular updates by NGO-based projects of the status of individual species of conservation concern, other than otter and water vole.

As a consequence, describing adequately the status of freshwater habitats and species in assessments such as the State of Nature report has been difficult. Overall, a large proportion of the water environment, and most freshwater species of conservation concern, are not monitored and evaluations based mainly on the river and large lake network are often unrepresentative of the freshwater environment and its biodiversity as a whole.

In many landscapes this leads to high quality smaller waters, both still and flowing, being under-represented leading to insufficient attention being paid to their importance and protection. Conversely, the focus on larger waters typically facing the most intractable problems limits progress on ‘easy wins’ such as protecting and building downstream from clean headwaters, building out from freshwater biodiversity hotspots through floodplain and wetland restoration or creating new clean water habitat by making unpolluted ponds or adding new physical habitat (woody vegetation, diversified channel structures) to unpolluted rivers.

With a trend towards increasing involvement of non-specialists and ‘citizen scientists’ in monitoring there has been a growing interest in volunteer recording of freshwaters. For a range of freshwater species and species groups several recording schemes provide information which is used to establish conservation status. However, with the exception of some water birds, until recently none of the surveys undertaken by volunteers have had sufficient repeatability and statistical power to provide data which can be reliably used by policy makers, regulators or land managers to assess trends in waterbody or species status.

## 4.2 ‘Professional’ monitoring methods

The most widely used professional biological survey methods for assessing the condition of freshwater habitats are based on aquatic macroinvertebrates, larger water plants, algae and fish, and they are now the main biological metrics now of the Water Framework Directive (Table 4).

The longest established of these are macroinvertebrate survey methods. Assessment of fish populations has a slightly different tradition compared to plant and invertebrate-based monitoring in as much as it has been focused more on the status of individual species of interest to anglers, rather than the condition of fish assemblages. Special monitoring programmes of salmonid fish of particular concern, such as Atlantic Salmon, are undertaken by professional surveyors and provide some of the most detailed information on any species.

The technical skills and time needed to make assessments using these methods makes them largely unsuitable for non-specialists if reliable monitoring data are required. Simplifications of invertebrate survey methods have been developed (e.g. Riverfly surveys, Big Pond Dip freshwater invertebrate survey) but they have had little detailed methodological testing to date. None as yet provide data that can be used to measure trends in the quality of the water environment.

## 4.3 Volunteer-based freshwater survey schemes

Volunteer-based freshwater recording schemes are primarily focused on species, and only two current surveys provides long-term trend data: the BTO-led Wetland Bird Survey (often known by its acronym WeBS) and the Waterways Breeding Bird Survey. The recently established PondNet great crested newts eDNA survey also provides the foundation for long-term trend monitoring having now completed its first three years, with further survey work planned for 2018. This survey also provides technically credible national statistics for England.

### 4.3.1 BTO wetland and water bird surveys

The BTO Wetland Bird Survey is concerned with larger coastal and inland wetland sites, including some National Trust properties. More relevant to most National Trust estates is the Waterways Breeding Bird Survey which has reported trends in the populations of water birds since 1998. Despite the quality of this recording scheme it appears to lead to little practical action, and surprisingly few organisations other than BTO promote its use for assessing the status of freshwaters.

### 4.3.2 Surveys of other groups

Volunteer-based recording schemes currently include schemes concerned with invertebrates (e.g. dragonflies, water beetles, cladocerans), vascular and lower plants, amphibians and mammals. Data on dragonflies are sufficiently numerous for long-term trends to be estimated since 1980 (Cham *et al.* 2014).

**Table 4. Species and species groups which have existing (a) professional and (b) volunteer-led recording schemes**

| (a) Professional monitoring of freshwater biota | |
|---|---|
| Aquatic macroinvertebrates | Mainly recorded at family level in surveys undertaken by statutory agencies.<br>Countryside Survey headwater project worked at species level and is the only national stream monitoring programme to have worked consistently at species level.<br>In lakes, chironomid pupal exuviae used to assess lake condition |
| Zooplankton | The animal plankton of lakes are amongst the most intensively studied animals in the world by professional freshwater biologists. However, for various reasons they have not yet been routinely adopted for monitoring schemes in Europe, although lake biologists have indicated strong benefits of such an approach (Jeppesen et al. 2011) |
| River plants, including non-vascular plants | Regular monitoring started with Water Framework Directive |
| Diatoms and phytoplankton | Regular monitoring started with Water Framework Directive |
| Fish | Extensive programmes of survey undertaken by statutory agencies but mostly do not provide monitoring trend data, except for salmon and sea trout. |
| Salmon, Arctic Charr, other fish rare species | Individual monitoring of salmon and sea trout provides detailed trend data but no other widespread fish are monitored in a way which provides national or regional trend data.<br>Rare fish with limited distributions have some regular site specific monitoring programmes. |

**Table 4. Species and species groups which have existing (a) professional and (b) volunteer-led recording schemes (continued)**

| (b) Volunteer-based schemes | |
|---|---|
| Water and wetland birds | Well-developed population trend scheme for widespread wetland species and species associated with 'waterways'. There is also a large-scale and long-established programme monitoring major coastal and inland waterbird sites and many conservation bodies are involved in work to protect these species and their habitats. Perhaps surprisingly, although waterway birds are amongst the best monitored freshwater biotic groups, very few practical programmes are specifically concerned with implementing measures to influence waterway bird populations (e.g. Dipper, Grey Wagtail, Common Sandpiper) even though a significant number are showing long-term declines. |
| Great Crested Newt | eDNA survey is first national survey to follow a stratified random design for an aquatic species. Other long-running species surveys have developed through more ad hoc structure although birds and otters have an element of structuring and a planned approach. |
| Amphibians | National Amphibian and Reptile Recording Scheme (NARRS) provides data on the status of the widespread amphibians other than Great Crested Newt. NARRS does not include Natterjack Toad which is monitored in a separate national scheme by Amphibian and Reptile Conservation. |
| Otter | Regular national recording scheme which has tracked recovery of population. Last surveyed in 2005. |
| Water vole | National scheme recording distribution with data used to assess trends although information not collected in a systematic (i.e. stratified random) design. |
| Dragonflies | The most popular group of aquatic invertebrates with well-developed distribution mapping based primarily on surveys of adult distribution patterns. Results have been used to assess long-term trends in species through interpretation of distribution data using advanced statistical techniques. |
| Water beetles | A well-established national recording scheme which provides a strong basis for assessing conservation status of species. For some species trends are apparent but has not yet been used to comment on broad trends for monitoring although it is quite likely it could be. |
| Cladocerans | A small national recording scheme which can provide information on the relative scarcity of species but not yet enough to describe trends.<br>See: http://www.boxvalley.co.uk/nature/cladocera/dmap.asp |

**Table 4. Species and species groups which have existing (a) professional and (b) volunteer-led recording schemes (continued)**

| (b) Volunteer-based schemes | |
|---|---|
| Diptera | A small group of highly skilled recorders come together as the Dipterists Forum running and contributing to monitoring schemes for several groups of flies that are associated with freshwater habitats. |
| Water plants including stoneworts and aquatic ferns. | Distribution mapping to create atlases provides data on the changes in distribution of wetland plants which can be used to categorise species of conservation concern. Newly established national monitoring programme (National Plant Monitoring Scheme) will probably not be specifically orientated to water sufficiently to capture changes in specific waterbodies. |
| Lower plants | Recording scheme enables conservation status of species to be determined but does not provide evidence for regular monitoring. |
| Algae | Recent development of the RAPPER app to record data on algal bloom occurrence (see https://www.ceh.ac.uk/news-and-media/news/bloomin-algae-new-app-help-reduce-public-health-risks-harmful-algal-blooms) |

**Recommendation 1:** We recommend that National Trust encourages recording of all of freshwater biota which currently have active monitoring groups (e.g. dragonflies, cladocerans, water plants) to add to inventories of these species. This should be done by facilitating access to National Trust properties and actively encouraging recording groups to visit the Trust's properties. At individual sites information on changes in species occurrence, distribution and abundance are likely to be useful for site management even though they are unlikely to provide monitoring data that can be used to report on the overall condition of the Trust's freshwaters.

## 4.4 Recording of species of conservation concern

As part of the Important Freshwater Areas project, Freshwater Habitats Trust, in consultation with relevant species specialists, has created a list of c1000 freshwater species of conservation concern (vascular plants, stoneworts, invertebrates, vertebrates) that is being used to identify sites of importance for freshwater biodiversity. Other data sources included in the Important Freshwater Areas process are habitat related Water Framework Directive information, PSYM surveys of ponds (Biggs et al., 2000), the locations of sites designated for the freshwater interest and environmental data (such as waterbodies with phosphorus levels at High status) which are often surrogates for the ecological quality of freshwaters.

Recording of species of conservation concern would provide a valuable focus for assessing the success in maintaining the distribution of sensitive freshwater biota and higher quality freshwater systems, for which the National Trust estate provides an important refuge.

As part of the PondNet programme specific monitoring techniques have been developed and tested for about 30 species which are suitable for volunteer monitoring. Details of these methods are shown in the relevant section of the Freshwater Habitats Trust website (see:

https://freshwaterhabitats.org.uk/projects/pondnet/survey-options/). Table  lists the currently (2017) identified species of conservation concern.

**Recommendation 2.** We recommend that freshwater species of conservation concern should be mapped across the National Trust estate as part of a process to identify Important Freshwater Areas on the Trust's land.

## 4.5 Monitoring water quality

England and Wales have a large scale programme of professional laboratory-analysed water quality monitoring for rivers and larger streams, some lakes and some specially protected smaller standing waters.

Despite this, most smaller streams, ditches, ponds and small lakes are never monitored, and very little is known about their current chemical quality or about trends in their chemical quality.

In the monitored network of running waters there is a long tradition of measuring the physical and chemical parameters indicative of organic pollution (dissolved oxygen levels, biochemical oxygen demand and ammonia) as well as nutrients and some heavy metals. Measures which describe the alkalinity/acidity of water (e.g. pH, conductivity) and concentrations of calcium and other dissolved ions which are not in themselves pollutants, are also commonly measured.

Typically to measures all of these determinands in a professional laboratory analysis costs £60-100 per sample, excluding the cost of collecting and transporting the samples.

Where funds are not available for laboratory analysis a useful start to understanding the extent of pollution can be made with rapid nutrient test kits which are used in the field and provide an assessment of water quality in a few minutes. Extensive use has been made of the PackTest nutrient kits produced by the Japanese company Kyoritsu in the Clean Water for Wildlife project, run as part of Freshwater Habitats Trust's 'People, Ponds and Water' project. This work is providing valuable data for evaluating the extent of nutrient pollution at thousands of sites across England and Wales. The use of the PackTest kits, and their reliability, has been described in detail in the Clean Water for Wildlife technical manual (Biggs et al. 2016).

Measurements of nutrients are a useful indicator of the presence of pollution because: (i) nutrients are important pollutants of freshwaters, (ii) very large numbers of waterbodies are affected by nutrients and (iii) they are more easily measured than other chemicals and provide a proxy for a range of pollutants. Where nutrient levels are elevated, other pollutants may also be present (e.g. pesticides from farmland, ammonia from sewage works, heavy metals from road runoff).

The Clean Water for Wildlife project has demonstrated the potential of this approach for evaluating water quality at both landscape and site scale. For example, the method has provided a clear indication of the extent of high quality waters across the New Forest (Figure 4), and how this contrasts with more intensive landscapes such as the R. Ock catchment in Oxfordshire (Figure 5).

At smaller scales there are many examples from all over the country of the use of the test kits to help with site management decisions. One recent set of samples collected at the National Trust Petworth Estate indicates some of the ways in which the kits can start to inform site management, laying foundations for more detailed chemistry (Figure 6).

At Petworth Park autumn measurement of nutrient levels on two lakes suggests that there is a point phosphate source in the inflow to Upper Pond, but phosphate sources are otherwise low. Nitrate is detectable in the inflows at several locations, but both nutrients are undetected in the lake outflows in the autumn. Further measurements in winter or early spring would be useful to assess whether there is seasonal variation.

Overall, the application of rapid nutrient test kits is opening-up new opportunities to democratise and empower both non-specialists and professional bodies in evaluations of the extent of water pollution. The rapid test kits are particularly important in monitoring smaller waters which are often excluded from statutory monitoring programmes.

**Recommendation 3.** We recommend that to provide an initial assessment of the extent of water pollution on National Trust properties, Kyoritsu rapid nutrient PackTest kits are used to measure nitrate and phosphate levels. These test kits have been widely used by both volunteer and professional biologists in Freshwater Habitats Trust's Clean Water for Wildlife project, including on National Trust properties.

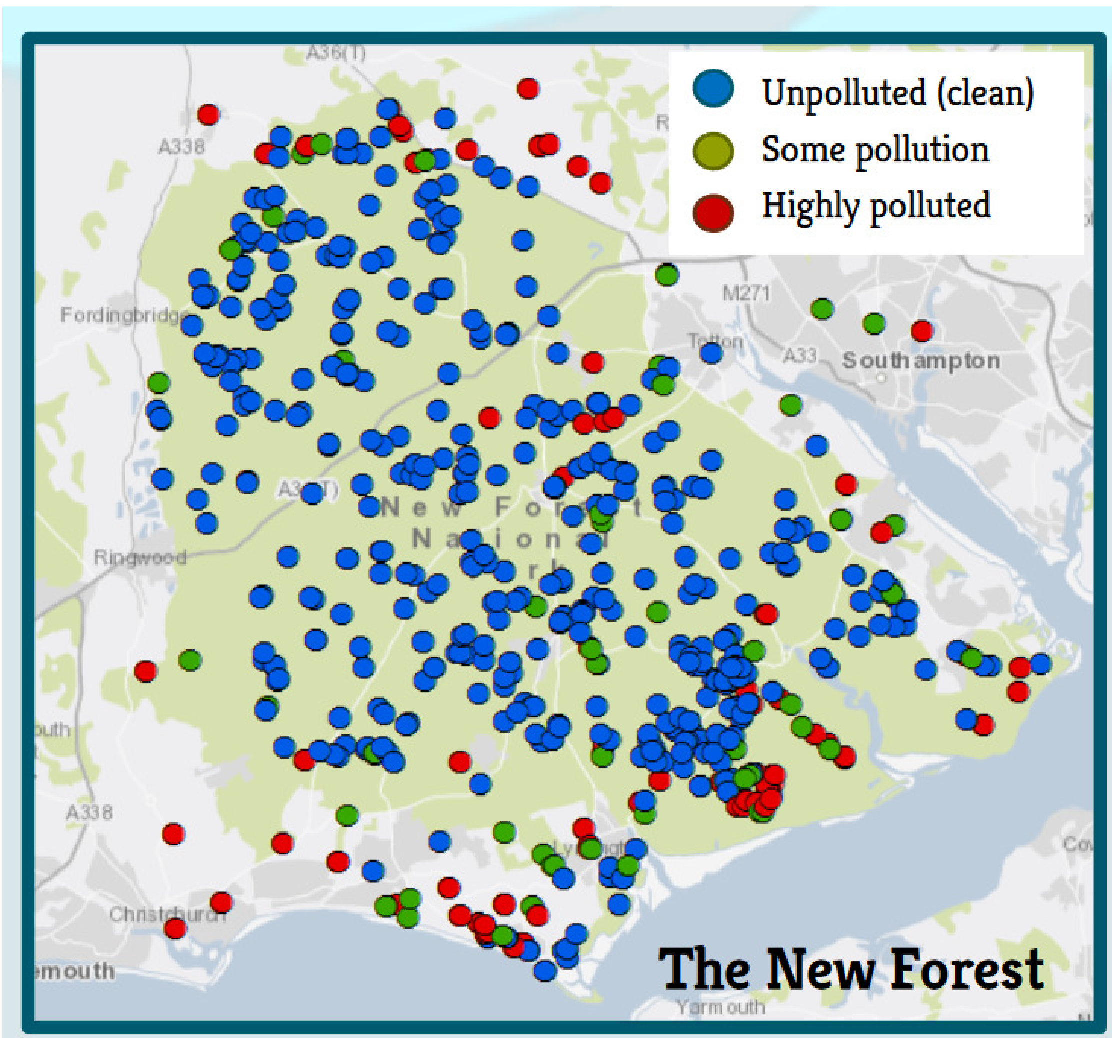


**Figure 4. Clean Water for Wildlife case study: the New Forest, spring 2016.**

The Clean Water for Wildlife test kits clearly show how water quality, measured in terms of nutrient levels, is high across the New Forest. There is probably no other area in lowland England with such a large concentration of clean water sites, and this large extent of water free from substantial pollution plays a major role in the continued exceptional biological quality of New Forest freshwaters.

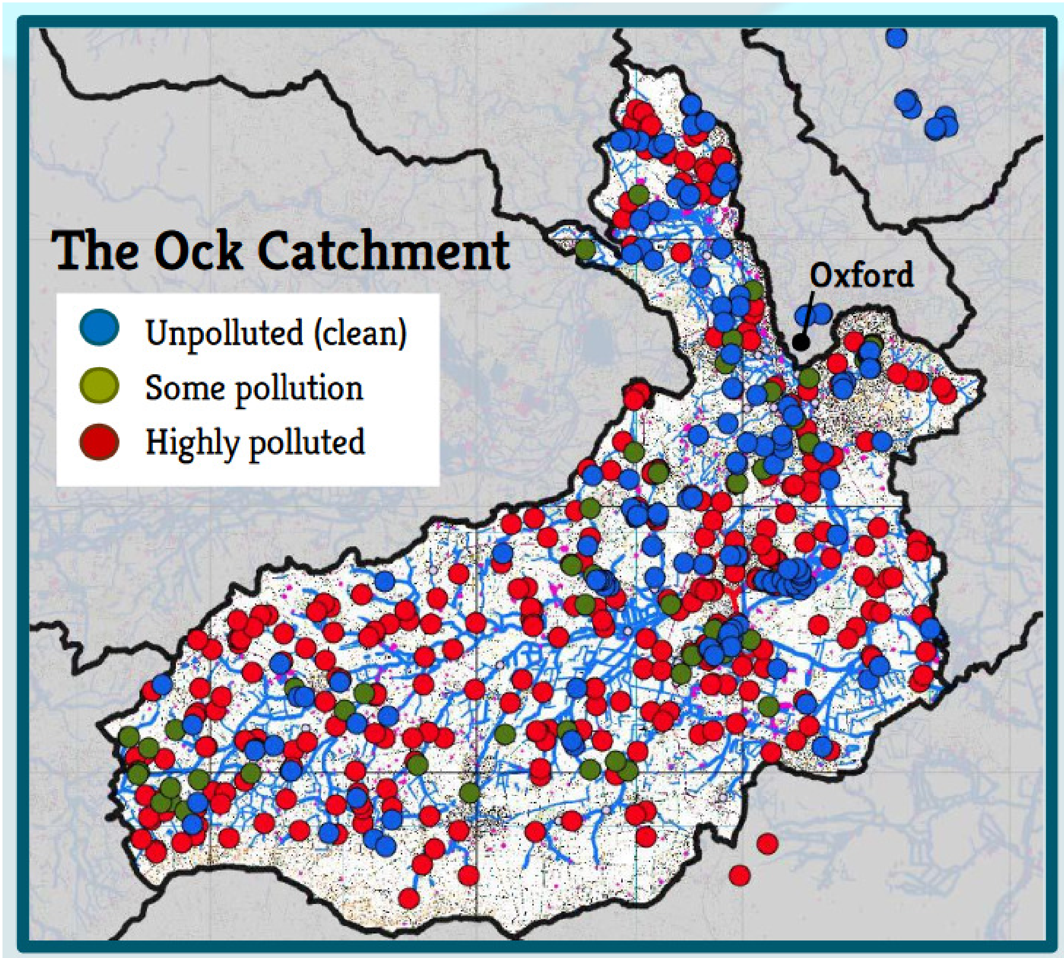


**Figure 5. Clean Water for Wildlife case study: the R. Ock catchment, Oxfordshire.**

The R. Ock catchment is typical of much of lowland England in that clean water is largely confined to ponds and lakes, within high quality fens (SACs and SSSIs), some ditches and some headwater streams in woodland. An important use of the test kits is to indicate the extent of clean water in landscapes where their distribution was not previously identified, and to provide a rapid overview of the water quality of the whole catchment.

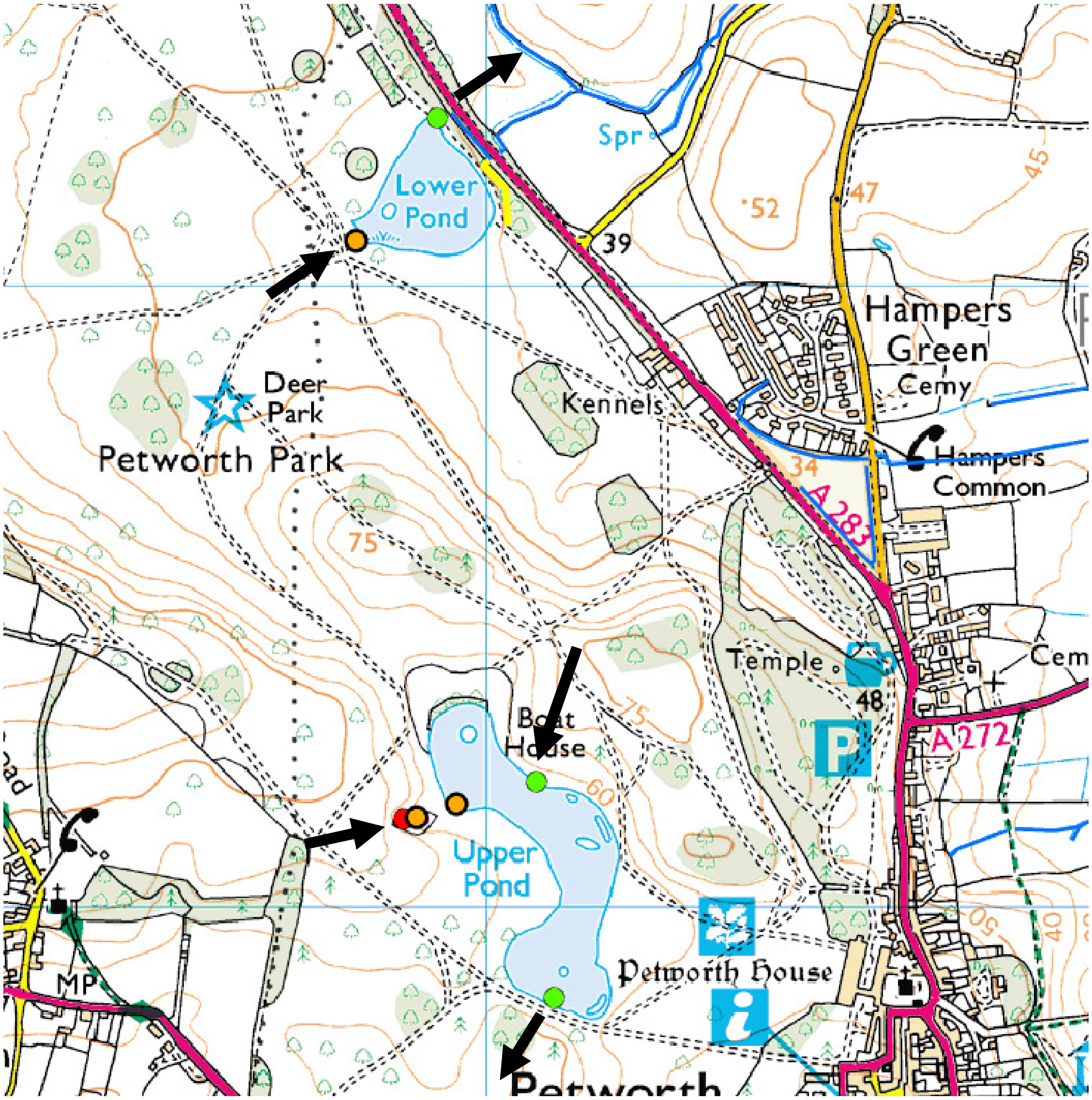


**Figure 6. Nutrient monitoring data from the Petworth Estate collected as part of the Clean Water for Wildlife project by National Trust volunteer Stephen Newton.**

Two surveys in autumn 2017 suggest that nitrate levels fall as water passes through the Upper and Lower Ponds. Arrows indicate inflow and outflow locations from the two waterbodies (which are technically lakes at 6 ha and 3 ha in area).

## 4.6 Advantages and disadvantages of professional and non-technical methods

In this section the main advantages and disadvantages of different monitoring methods for freshwaters are briefly review. Conclusions about the effectiveness of different approaches are presented.

### 4.6.1 Professional versus volunteer surveyors

**Professional surveyors**

Measures which involve a good taxonomic understanding of a range of taxa and experience of survey methods normally require professional biologists, or those with professional level experience. For biological surveys, this means that metrics based on listing species or taxa (e.g. PSYM, the Predictive System for Multimetrics for assessing ponds and small lakes up to 5 ha; RICT, the River Invertebrate Classification Tool used by the statutory agencies) are normally undertaken by professional staff. Freshwater monitoring has a substantial number of these metrics and a rigorously defined set of standards and methods, often governed by ISO or CEN standards[3].

The use of professional surveyors should ensure repeatable surveys, a good standard of survey with between-operator error reduced, a detailed grasp of the monitoring objectives and sufficient time to undertake demanding surveys. The only exception to this general rule at present is the recording of birds where a large body of skilled amateurs exists and it is generally accepted that volunteers can be trained to record a wide range of species.

**Volunteer surveyors**

Volunteer surveyors are likely to be more numerous than professional surveyors but mostly have less time, substantially less experience and less-developed skills than professional surveyors.

Volunteers do not require payment but organising volunteer surveys usually requires at least as much effort as organising professional surveys, and in cost terms the differences between the two may not be all that significant. A potential advantage of using volunteer surveyors is that for some funders (especially the Heritage Lottery Fund) it is possible to count some surveyor time as equivalent to a cash funding contribution.

Volunteers are more likely to be suited to surveys which do not require wide taxonomic experience – making single species, or surveys involving a small number of taxa (say, less than 10) more suitable for this group. Even in this situation it is important to quality assure work as finding cryptic species may still be a skill which requires considerable practice. Recent experience indicates that volunteers working in freshwater find testing water for pollution interesting and satisfying, including collecting eDNA samples for later analysis. Many surveyors enjoy collecting freshwater invertebrate samples from rivers and ponds but undertaking this work in way which provides valuable data, when compared to the widely used professional pond net invertebrate sampling methods, remains problematic. In the PondNet project it has also been possible to get small numbers of volunteers engaged in looking for individual rare species and for amphibians, with the recording of frogspawn a popular activity.

It is often exaggerated how effective volunteers are in recording freshwater biota. Lessons from the PondNet project are, therefore, important in understanding what volunteers find more difficult, where it has been more difficult to get volunteers to undertake comprehensive plant surveys and invertebrate surveys. In contrast, the collection of eDNA and other water samples has proved highly successful, allowing the establishment of the world's first national monitoring programme for a protected species, the great crested newt, using eDNA.

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[3]ISO = International Organization for Standardization; CEN = European Committee for Standardisation.

Volunteers usually require more support than professional surveyors, commonly needing to be ‘part of the team’, something which is implicit in a professional organisation but which requires substantial support and effort to replicate for volunteers.

**What is a volunteer?**
There is a considerable gradation in what constitutes ‘volunteers’. The long tradition of conservationists doing work for the love of the activity means that highly skilled professional biologists may be available as volunteers. However, such people usually only make up a small part of the labour force in volunteer monitoring projects. Despite this, the contribution to be made by highly skilled specialists at sites with which they have a particular engagement should not be overlooked, and may be important at critical locations.

### 4.6.2 Simple water quality test kits compared to laboratory analysis

Recently there has been considerable interest in the use of ‘quick’ water test kits. Projects run by Freshwater Habitats Trust and Earthwatch have introduced the use of these kits by volunteers to evaluate the occurrence of water quality and, particularly, nutrient pollution (see Section 4.5 above). A detailed evaluation of the Kyoritsu nitrate and phosphate test kits was undertaken by Freshwater Habitats Trust as part of a project funded by Earthwatch and later the HLF (Biggs *et al*. 2016).

Detailed comparisons of the PackTest kits with laboratory analysed water samples showed that, overall, the kits can separate clean and polluted sites with sufficient reliability. Sites where the kits show no colour change are highly likely to be clean waterbodies with low nutrient levels (98% probability for phosphorus, 81% for nitrate). Sites with a moderate or strong colour change are highly likely to be polluted (95% probability for phosphate, 84% for nitrate). However, about a third to a half of the sites bordering the clean water boundary (phosphate: 0.02-0.05 mg $L^{-1}$, nitrate 0.2-0.5 mg $L^{-1}$) may be mildly polluted, rather than clean. This means that at landscape scale, the kits will slightly over-estimate the amount of clean water present, but they are highly unlikely to over-estimate the level of either phosphate or nitrate pollution in waterbodies. At sites which should naturally have very low nutrient levels - especially acid streams and lakes, both lowland and upland - they should be used with caution.

Overall, although it is important to recognise the limitations of the PackTest kits, our results suggest that they are a simple, rapid and cost-effective way to identify nutrient pollution, especially in large landscape-wide surveys where the costs of laboratory analysis are likely to be prohibitive. The kits are not recommended for ongoing monitoring to detect trends at a single site; in such cases more expensive laboratory based analysis will be required, unless the changes are expected to be very substantial. For example, a change in phosphate concentrations from 0.5 mg $L^{-1}$ down to 0.02-0.05 mg $L^{-1}$, should be reliably detected, but smaller changes are less likely to be detected, given the sensitivity of the test kits and the extent of natural variation.

A number of Rivers Trusts have also been using rapid water quality test methods and a resource pack has been produced introducing the many different types of water testing equipment available for use outside of the laboratory (The Rivers Trust, 2016).
In the Clean Water for Wildlife project large-scale surveys of whole catchments have provided important overviews of landscape and catchment level water quality at relatively low cost and these data are now beginning to inform practical conservation projects.

To date these methods have not been widely used to provide monitoring or trend data, mainly because they have only been very recently introduced and there has not yet been time to run programmes over a period of years to detect change. However, there is evidence that they can provide valuable data for the assessment of practical problems, providing datasets which cannot easily be obtained by other means. For example, in Greater London McGoff *et al*. 2017 have shown that, counter to expectations, substantial numbers of waterbodies with low levels of nutrient pollution occur, even within large metropolitan areas (Figure 7).

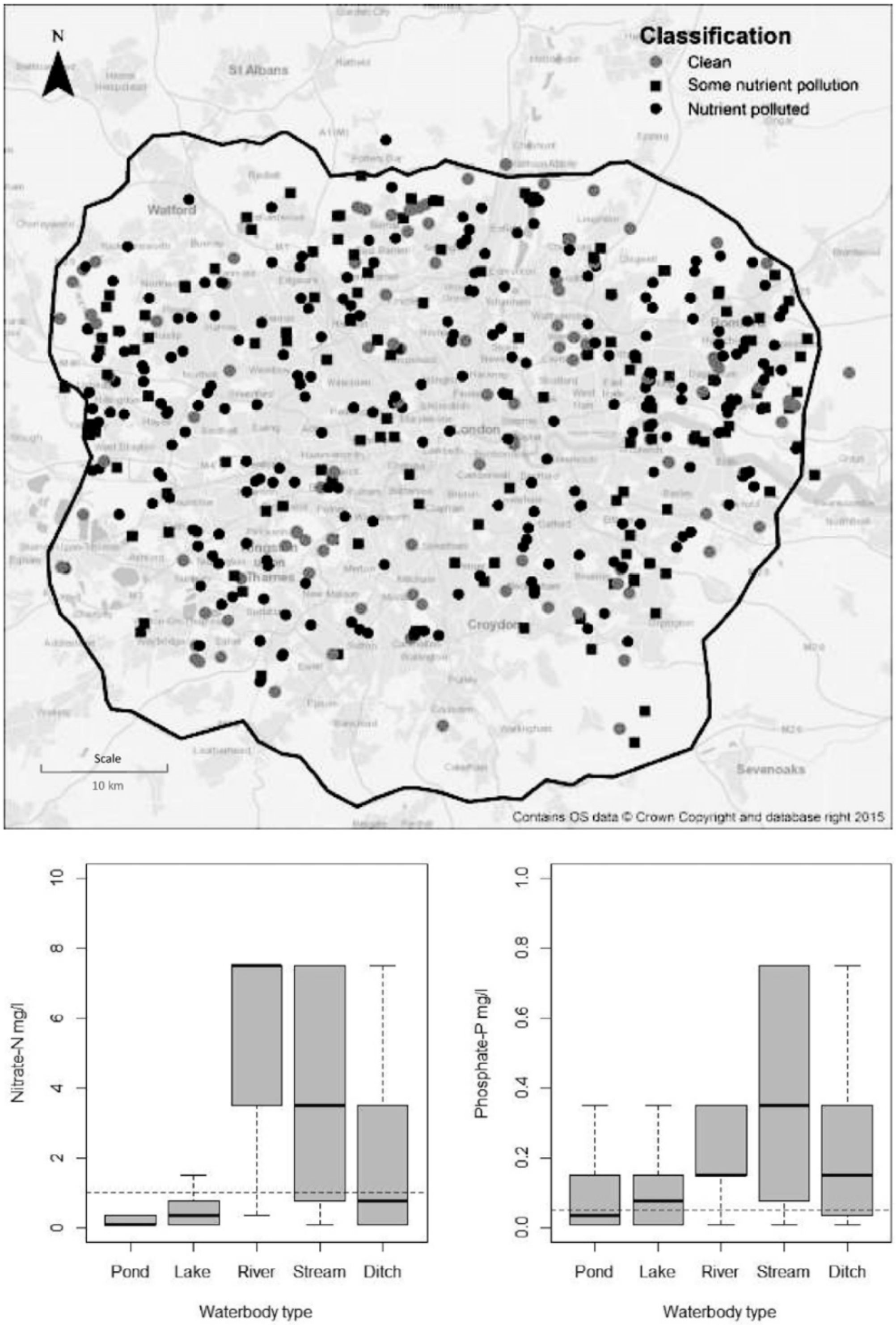


**Figure 7. Distribution of 'clean' and 'polluted' water in Greater London inside the M25 (from McGoff et al. 2017).**

Nutrient levels were significantly lower in standing waters (ponds and lakes) and in ditches.

### 4.6.3 Different biotic groups and indices (e.g. algae, invertebrates, vascular plants)

Four main biological groups are now widely monitored as part of Water Framework Directive and similar (e.g. PSYM) monitoring schemes: algae (including both diatoms and phytoplankton), the large aquatic invertebrates, vascular plants and fish (Table 5). The community metrics generated from surveys based on these four groups describe responses to organic pollution, nutrient pollution, the presence of toxins and habitat quality.

At present none of these metrics can be readily collected on a large scale by non-professional recorders. Equally, none of the metrics listed in Table 5 which can be collected by volunteers are currently used as part of formal monitoring projects, such as those required for Water Framework Directive reporting.

### 4.6.4 Community metrics, indicator species and individual species surveys

**Community metrics**

Community metrics (Table 5), which are typically derived from monitoring a suite of taxa (e.g. plant species, invertebrate families), are generally the most reliable measures for monitoring change, with high statistical power from relatively small samples. However, to be effective they must normally be created using data collected by professional surveyors.

One potential exception to this general rule is the Riverfly survey technique, in which 8 Order or Family level invertebrate groups are recorded and counted. Although widely used in involving people in checking the occurrence of severe water pollution events (e.g. Thompson *et al.* 2016), the method has not been formally evaluated against standard river invertebrate survey techniques as far as we are aware. A large set of data have been recorded and in Section 4 we have undertaken preliminary power analysis on these data. However, it should be noted that formal quality assurance of this technique is still required, something which would be valuable in the course of further application of the method.

**Indicator species**

There are a range of prominent, and usually easily identified, species which are sometimes described as ‘indicators’ of the health of freshwaters. Typical candidates for this role are large vertebrates (e.g. otter, salmon, water vole, great crested newt), *Gammarus* species and dragonflies, amongst others. In practice it is very difficult to demonstrate that protecting single indicator species has practically benefitted other groups or species and to achieve specific species or community objectives, it is normally best to focus on those specific objectives.

The otter is perhaps the best example of this phenomenon. During its post 1970 recovery (Crawford, 2011), there has been a collapse of the water vole population[4], salmon numbers have dropped substantially, many water plants have become much scarcer, several riverine birds have shown declining population trends (e.g. common sandpiper and grey wagtail) and while some warmer climate dragonflies have colonised Britain, other common and specialist species have become generally scarcer (Environment Agency, 2017; Stroh et al., 2014; Hayhow, 2017; Cham *et al.,* 2014)

At present there are no regularly reported indicator species methods for assessing the status of freshwaters so this approach will probably not be applicable to monitoring of National Trust properties.

[4]Along with water pollution and the loss of healthy river bank vegetation, the pressures from mink predation means we lost more than 90% of our water voles by the end of the 1990s. Source: https://ptes.org/campaigns/water-voles/

**Table 5. Commonly used community metrics for freshwater assemblages in the UK**

| Taxonomic group | Metric |
|---|---|
| Aquatic macroinvertebrates in rivers<br>Method: River Invertebrate Classification Tool (RICT) | • Biological Monitoring Working Party score (BMWP)<br>• Number of Taxa (NTAXA)<br>• Average Score per Taxon (ASPT)<br>It is also possible to generate SPEAR scores for assessing the likelihood of pesticide pollution, LIFE scores for assessing flow regimens and PSI scores for assessing the Proportion of Sediment-sensitive Invertebrates (PSI). |
| Aquatic macrophytes in lakes and rivers<br>Method: LeafPacs2 | Lakes<br>• Lake Macrophyte Nutrient Index (LMNI) – a taxon-specific nutrient response score.<br>• Number of functional groups of macrophyte taxa (NFG) - a diversity metric with individual taxa are allocated to one of 18 "functional groups"*<br>• Number of macrophyte taxa (NTAXA) - a diversity metric, the number of scoring taxa recorded in the field survey<br>• Mean percent cover of hydrophytes (COV) – derived from lake macrophyte survey data<br>• Relative percent cover of filamentous algae (ALG) – derived from lake macrophyte survey data<br>Rivers<br>• River macrophyte nutrient index (RMNI) – derived from the RMNI scores of the taxa recorded in the field survey. Taxon scores were derived for the earlier version of LEAFPACs as described in Willby et al (2012), and remain unchanged in this version.<br>• Number of macrophyte taxa (NTAXA) - a diversity metric, the number of scoring taxa recorded in the field survey, in this case only taxa which are considered truly aquatic, i.e. hydrophytes* are included<br>• Number of functional groups (NFG) – a diversity metric, individual taxa which are truly aquatic (i.e. hydrophytes) are allocated to 24 "functional groups"**,<br>• Cover of green filamentous algae (ALG) – this is the percentage cover of green filamentous algae over the whole of the surveyed section of river. |

**Table 5. Commonly used community metrics for freshwater assemblages in the UK (continued).**

| Taxonomic group | Metric |
|---|---|
| Rivers, stream and lakes<br>Method: Diatoms for Assessing River and Lake Ecological Quality (River DARLEQ2) | • Trophic Diatom Index (TDI). |
| Ponds and small lakes up to 5 ha<br>Method: Predictive System for Multimetrics (PSYM) | Index of Biotic Integrity (IBI), based on three plant and three macroinvertebrate metrics:<br>• F_COL: Number of water beetle families – a measure of edge habitat quality<br>• ASPT: a modified version of Average Score per Taxon reflecting sensitivity to all chemical pollutant, not oxygen levels<br>• F_OM: Number of dragonfly (Odonata) and alderfly (Megaloptera) families<br>• Number of submerged and emergent plant species (SM_NTX)<br>• Trophic ranking score for aquatic and emergent plants (TRS_ALL)<br>• Number of uncommon plant species ((PL_NUS) |
| Rivers and streams<br>Fisheries Classification Scheme 2 | No specific community metrics; fish communities usually described species-by-species |
| Ditches | No WFD compliant monitoring method available although field search techniques for invertebrates combined with plant surveys have been widely used (Palmer et al. 2013).<br>Freshwater Habitats Trust has undertaken pilot studies for the development of a reference system based approach for ditch assessment. |

**Individual species surveys**
Freshwater Habitats Trust has, as part of the Important Freshwater Areas project identified a set of species of freshwater species of conservation concern. Species are those which have a conservation status, with the list developed in consultation with national specialists. There are currently approximately 1000 species identified covering fish, amphibians and mammals, larger invertebrates, vascular plants, stoneworts and strictly aquatic bryophytes. The species of conservation concern list does not yet cover zooplankton groups, most algae or lichens. Those currently known from National Trust properties are listed in Table xx.

For virtually all of these species of conservation concern there are no current monitoring programme able to detect trends over reasonably short time periods. For most, of course, there is evidence of decline over the last 50 years, with these declines increasingly assessed using formal IUCN criteria.

In Phase 1 of the PondNet survey, monitoring methods for assessing the status of a small number of priority species, drawn from the much longer list of species of conservation concern have been developed and applied. These have been applied to:

- Adder's-tongue Spearwort
- Brown Galingale
- Coral Necklace
- Greater Water-parsnip
- Medicinal Leech
- Pillwort
- Starfruit survey
- Three-lobed Water-crowfoot
- Tubular Water-dropwort
- Yellow Centaury
- Fairy Shrimp
- Pond Mud Snail
- Tadpole Shrimp
- Common toad
- Great crested newt.

In each case, the objective of these surveys has been to make an assessment of the ***abundance*** of the species as this greatly increases the power of analyses. Indeed for rare species analyses undertaken as part of the development of PondNet indicated that, in many cases, when presence/absence only data were used it would be necessary to survey very large numbers of sites to detect change at a reasonable level (e.g. a 30% change in occupancy with 70% power), and in some cases more sites than the species now occurred at (Williams *et al.* 2012). For example, the number of ponds required to monitor Tubular Water-dropwort exceeded 3500 even at the lowest level of power (60%) detecting the biggest change (50%). Similarly, for Pillwort, which is currently known from about 200 1 km squares in England, power analysis suggests that surveys of all ponds in each of 7852 1 km grid squares would be needed to detect a 30% change at 70% power using presence / absence data alone. This is substantially more than the species actually occurs in.

Details of the PondNet survey methods are listed in Appendix 4.

### 4.6.5 Novel and emerging techniques (e.g. eDNA).

There is growing interest in new monitoring methods which may be appropriate for use with both volunteer and professional surveyors. These include the use of camera traps for nocturnal or reclusive species (especially mammals), surveying birds by recording sounds (e.g. Darras *et al*., 2017) and near continuous recording of bat calls (see Norfolk Bat Survey: http://www.batsurvey.org/). Linking all of these techniques in the potential for use by non-specialists is that the survey method does not rely on a taxonomically expert observer to collect the raw survey data. This allows such non-specialists to potentially collect biologically credible data, one of the major limitations of citizen-based surveys.

Amongst the most promising of these to date is the use of environmental DNA (eDNA) which could contribute to a revolution in freshwater biodiversity monitoring. The eDNA approach has been successfully implemented to assess national great crested newt distribution and species distribution trends with the first three years now completed of a national monitoring programme (Freshwater Habitats Trust, unpublished data).

## 4.7 Collecting environmental data

In assessing the condition of freshwater habitats it is valuable for a number of different reasons to be collecting environmental data about waterbodies at the same time as biological data. Environmental data can help to:

- Explain why species are present (or absent) at a particular site
- Indicate the occurrence of pollution problems or physical environmental factors which may be causing site degradation or explain observed problems (e.g. algal blooms, presence of indicators of specific types of pollution)
- Allow the physical and chemical quality of waterbodies to be compared to other areas/landscapes
- Provide important informati0on that can guide site management.
- Provide an initial indication of problems which may require deeper investigation (e.g. quick test kits can reveal broadly whether pollution is occurring which requires more detailed investigation).

Standard environmental data, such as that collected in PondNet, provides a straightforward basis for describing the physical and chemical condition of ponds. Such recording can be undertaken by volunteers if training is given. Such data can also be used to provide information on priority habitat requirements for standing waters (ponds and lakes) needed by Natural England (Table 6). A standard set of environmental parameters for priority streams and rivers has also recently been proposed by Natural England.

**Recommendation 4:** We recommend that the standard PondNet survey of environmental variable for ponds is used, incorporating information requirements identified recently by Natural England for standing waters. We also recommend that a recording form for running waters that incorporates requirements of Natural England for assessing the condition of priority streams is developed for the present project.

The PondNet survey form also includes data needed for great crested newt Habitat Suitability Assessment. A link to the survey form is shown in Appendix 5.

**Table 6. Natural England priority habitat data requirements for standing waters**

| Element | Attribute | Existing data sources | Method | New data required (if any) | Statistical approach |
|---|---|---|---|---|---|
| Landscape connectivity | Number of ponds | Countryside Survey | Counts in 1km$^2$ survey squares are extrapolated to national scale. Losses and gains in pond numbers between surveys can be similarly extrapolated. Data can be stratified by pond size and land use. Urban areas not included. | Countryside Survey needs to be continued | Representative sampling |
| Naturalness of water quality regime | Nitrate and phosphate concentration | Countryside Survey, PondNet | Sites are classified into 5 classes according to whether they exceed the NPS nutrient thresholds. | Countryside Survey and/ or PondNet need to be continued. Turbidity scales should be aligned. The use of nutrient field test kits may allow more frequent sampling in a representative subset of ponds in either network. | Representative sampling |
| | Turbidity | | There are no data on turbidity from current survey programmes. | | |
| | ANC | | There are no ANC data from either network; currently limited to alkalinity and pH measurements. | ANC should be added to any future Countryside Survey pond water quality analysis particularly those in low alkalinity areas | |
| Naturalness of hydrological regime | Presence of ditches and water control structures | None, Countryside survey and PondNet record some hydrological features but they are not adequate to assess naturalness. | Presence of artificial inflows, outflows and any water level control structures need to be recorded | Discussions are underway to introduce this to PondNet. It should also be included in any future Countryside Survey | Representative sampling |

**Table 6. Natural England priority habitat data requirements for standing waters (continued)**

| Element | Attribute | Existing data sources | Method | New data required | Statistical approach |
|---|---|---|---|---|---|
| Naturalness of the hydrosere | Natural pond base<br>Natural shoreline<br>Semi natural land use 5m from pond edge<br>Semi natural land use at 100m from pond edge | Partially covered in Countryside Survey and PondNet<br>PondNet, Countryside Survey | Individual ponds are classified into 5 classes according to how many of the 4 components are modified/managed. | Countryside survey and/ or PondNet need to be continued. Both surveys need to clearly report on shoreline modifications and naturalness of the pond base. | Representative sampling |
| Shading | Percentage of pond margin overhung by trees or percentage of perimeter shaded | PondNet, Countryside Survey | The percentage shading is used to classify ponds into 5 classes, with no inference to quality. The aim is to be able to report on the diversity of the extent of shading across the whole habitat resource. | Countryside Survey and/ or PondNet need to be continued | Representative sampling |
| Grazing | Grazing intensity score | PondNet, Countryside Survey | The intensity of grazing score is used to classify ponds into 5 classes, with no inference to quality. The aim is to be able to report on the diversity of the intensity of grazing across the whole habitat resource. | Countryside Survey and/ or PondNet need to be continued | Representative sampling |
| Characteristic assemblages | PSYM score | PondNet, Countryside survey | The PSYM score is used to classify individual ponds into 5 quality classes. | Countryside Survey and/ or PondNet need to be continued, ideally to include pond macroinvertebrate survey | Representative sampling |
| Non-native species | Number of non-native species | PondNet, Countryside survey | The number of invasive species (0,1,2,3,>3) is used to classify individual ponds into 5 classes. | Countryside Survey and/ or PondNet need to be continued. Currently mostly relevant to plants, but should include fauna | Representative sampling |

## 4.8 National Trust Land Condition Assessment

As part of the monitoring process for land management each National Trust property is expected to undertake a land condition assessment (LCA) at each point of major change. This means that LCA will be applied periodically across the National Trust estate but not in a regular or systematic manner.

The current LCA methodology includes descriptions for different levels of water health (see Appendix 2).

## 4.9 Application of standard biological metrics on National Trust land

All of the traditional biological metrics now widely used in Britain for assessment of freshwater ecological quality are potentially suitable for assessing freshwater habitat quality on the National Trust estate. However, all of these methods also require professional surveyors to implement them effectively and will need to be prioritised in terms of cost-effectiveness. Costs per sample are summarised in Table 9.

Broadly speaking costs of standard biological metric generating methods increase in the following order:

**Least expensive** - Diatoms<Wetland Plants<Macroinvertebrates<Fish - **Most expensive**

In practice, of these methods only the wetland plants and macroinvertebrates have been widely applied to different waterbody types using a standard method. At present although diatom and fish survey methods have been applied to the full range of smaller waters of concern in this report, they have not yet been widely tested. For example, pilot project using diatoms to assess ponds have been undertaken but no systematic surveys have yet been reported in Britain. Likewise, although fish biologists do undertake surveys on ponds, there are no standard methods yet available (e.g. Perrow and Thomlinson 2000; Stefanoudis et al. 2017).

**Recommendation 5**. For widespread monitoring on National Trust properties, metrics based on wetland plants are the only traditional biological survey method which can be easily applied at large numbers of sites at relatively low cost.

# 5. Power analysis of the sampling requirements for different monitoring approaches

## 5.1 Design of the survey

To provide national statistics on the status of freshwater habitats and species on National Trust properties it will be desirable to stratify the choice of sites in terms of:

- National Trust region or country (i.e. England versus Wales).
- Waterbody type (ponds and streams/ditches)
- Upland versus lowland environments, where there may be substantial differences in the effect of land use, geology and climate on waterbody quality.

It may also be desirable to report separately on these different strata (e.g. providing separate results for England and Wales). However, this increases sample sizes, effectively requiring a doubling of the number of sites to be visited, and may be beyond the scope of the project. The implications for reporting in two countries or in two different broad landscape types are discussed below.

Overall, surveys which revisit the same 1 km square / waterbodies (i.e. paired analyses) have greater power to detect change i.e. a smaller number of sites are needed to detect a given level of change. If completely random selections of sites are made during each survey cycle, sample numbers increase substantially.

In this report we have evaluated the power of two broad types of test:

1. Metrics based on multiple species or measures e.g. PSYM score, BMWP score, great crested newt Habitat Suitability Index which are less inherently variable and require smaller sample sizes.

2. Tests of the presence of single species or single chemicals which generally are much more variable and require higher numbers of samples to assess significance of change. Surveys with large numbers of zero values also generate large sample sizes to detect change. For species which are not widespread this requires measurements of abundance, the approach adopted in the PondNet project, in order to generate practical sample sizes.

### 5.1.1 What type of change are we analysing?

There are two types of change which monitoring of the National Trust estate can evaluate:

- Change on the National Trust estate over time
- The status of the National Trust estate compared to the rest of the water environment.

**Change on the National Trust estate over time**

Evaluating change on the National Trust estate over time requires repeat surveys at time $t_1$ and time $t_2$. There are some advantages to undertaking complete surveys at two discrete times, following the Countryside Survey model with, for example, all sites surveyed in one calendar year and a second survey 5-7 years later, also undertaken in a single calendar year. Although this gives a clear temporal snapshot it can be difficult to organise such surveys, not least because of the substantial resource requirements of completing a national survey in one year. In the present context, funds are not available for two such time-limited surveys.

An alternative to this approach, which needs fewer samples annually, is a trend analysis with a smaller number of sites surveyed every year, repeated over a number of years to detect trends. A disadvantage of this approach is trends may only become apparent after some years, and it can be difficult to determine survey power as comparable data will not usually be available to base the survey design on.

In the in the following sections we have provided examples of both options although a trend analysis is the more practically feasible as insufficient resources are available to undertake two national surveys at 5-7 year intervals.

**The status of the National Trust estate compared to the rest of the water environment**
In order to assess the quality of habitats or the status of species it is recommended that the National Trust waterbodies and species are compared with relevant national recording and monitoring surveys. Table 7 summarises the monitoring programmes or metrics with which National Trust sites should be compared.

Comparison with other national monitoring programme trends also provides an element of 'control' indicating the direction and extent of changes in the wider countryside. For streams standard monitoring data collected by Environment Agency and Natural Resources Wales provides an indication of the extent to which National Trust properties are achieving or exceeding standards in the rest of the countryside.

For ponds, trends on National Trust land should be compared either with on-going monitoring undertaken in Freshwater Habitats Trust as part of the PondNet project or CEH projects continuing the Countryside Survey approach.

For most species of conservation concern trends on National Trust properties will have to be compared with PondNet data. As funding for PondNet is not guaranteed, the precise form of comparisons is yet to be determined.

**Table 7. National monitoring programme data with which monitoring on National Trust estates will be compared**

| Waterbody type or species type | Data with which results will be compared |
|---|---|
| **Streams/ditches** | Trends will be compared with Environment Agency and Natural Resources Wales national monitoring programmes primarily in terms of species richness and trophic ranking metrics. Where possible, sites will also be classified in WFD terms. |
| **Ponds** | Sites will be classified in terms of PSYM plant metrics, the same approach as is used in the Countryside Survey. |
| **Species** | |
| Amphibians | If national trend monitoring of amphibians, compare with PondNet / NARRS trends. |
| Birds | Waterways Birds Survey data. |
| Other species of conservation concern | For most other species it is not yet clear whether national species specific trend monitoring programmes will be continued on sufficient scale to report annual trends. |

## 5.2 Questions addressed by the survey

In this section the questions about the Tier 2 waterbodies which the survey is intended to answer are briefly reviewed. A summary is given in Table 9. In each section we also suggest a target or objective of environmental management that is the main reason for the monitoring work.

Overall, data provided by the survey will allow the following questions about the quality of freshwaters on the National Estate properties to be evaluated:

- Are pond numbers increasing or decreasing on the National Trust estate and are pond numbers greater than countryside average? Numbers of small lakes are unlikely to change substantially and an inventory of these waterbodies can probably be maintained using Ordnance Survey maps. Small running waters are unlikely to change substantially so we do not recommend regular monitoring of numbers or length.
- Is nutrient pollution on the National Trust estate increasing or decreasing? How does water quality in small waters on the National Trust estate compare to the rest of the landscape?
- Is wetland plant richness increasing or decreasing, and how are other biological metrics changing which can be assessed using plants (e.g. evidence of nutrient enrichment) changing?
- How are populations of single species of conservation concern changing e.g. pillwort, great crested newt. Species for which evidence is available **to represent the National Trust estate as a whole** will largely depend on the extent to which the volunteer PondNet monitoring programmes can be maintained and developed.

Changes in communities of algae, aquatic invertebrates and fish could potentially be assessed in Tier 2 waters but will require significantly greater funding than is currently available.

### 5.2.1 Pond numbers, and numbers of other waterbodies

**Question 1: Are pond numbers increasing or decreasing on the National Trust estate?**
The number of ponds, particularly those which have clean water, is an important metric of freshwater landscape quality. As ponds are easily created and destroyed, numbers are quite dynamic. Following many years of losses as agriculture intensified, numbers are now increasing at national level.

Assessing pond numbers on the National Trust estate is best addressed simply by censusing ponds i.e. counting all the ponds on an estate, rather than basing estimates on samples. As ponds are quite easy to count, volunteers, rangers or estate managers can be trained to collect and update this. Note that training ***is*** required to recognise ponds consistently particularly to correctly record smaller seasonal waters, to distinguish ponds from other wetland habitats and to ensure that late succession ponds are not recorded as 'lost'. Published Ordnance Survey maps, and satellite maps on the Internet can be used as a starting point for estimating pond numbers but are (a) often out of date and (b) poor for distinguishing ponds in woods, and seasonal ponds.

The practical target which is being monitored is to at least double pond numbers.

**Question 2. Are pond numbers greater than countryside average?**
Comparing pond density to other published information is a straightforward way of assessing whether the National Trust estate has more ponds than similar landscape types in the wider countryside. The countryside averages for pond density in England, Wales and Scotland are shown in Table 8. Analysis of existing Countryside Survey data indicates that over the period 1998 to 2007 the power of the analysis to detect change in pond number at Great Britain level was 72.5% and detected an increase in pond density of from 1.86 to 2.10 ponds per $km^2$, a 17% change.

**Table 8. Pond densities in England and Wales in 2007, the most recent national estimate made as part of the Countryside Survey (Williams *et al.* 2010)**

| Country | Density (ponds / $km^2$) | Total number (range) |
|---|---|---|
| **England** | 1.83 (range: 1.53-2.14) | 234,000 (195,000-272,000) |
| **Wales** | 2.24 (range 1.23-3.70) | 47,000 (26,000-78,000) |

**Numbers of other small waterbodies**
Numbers of small lakes are easily described from maps. The size cutoff between ponds and lakes (2 ha) means that virtually all lakes will be shown on OS maps. Where new waterbodies (e.g. gravel pit lakes) have been created on properties it should be easy to keep an inventory of these waters.

It is probably not necessary to assess the length or area of linear waterbodies as they change only slowly in extent.

### 5.2.2 Waterbody pollution

Pollution in the majority of small waterbodies is not monitored although data from the Countryside Survey and, more recently, from the Water Friendly Farming Project, have provided laboratory quality analysis of nutrient levels in headwater streams, ditches and ponds at national and landscape levels. In the last 5 years, rapid nutrient test kits produced by Japanese company Kyoritsu have been used in projects run by Earthwatch and the Freshwater Habitats Trust to introduce large scale nutrient testing by volunteers.

We have evaluated sample sizes needed to detect change in water quality using volunteer collected data from the national Clean Water for Wildlife survey, and the professional Countryside Survey and Water Friendly Farming project. In both cases these approaches have focussed on nutrient pollution as indicators of the extent of pollution.

Volunteer data sets can address two question on National Trust properties:

**Question 1. Is diffuse nutrient pollution increasing or decreasing on the National Trust estate?**

To detect trends in water quality with the Kyortisu Packtest kits will require that waterbodies show quite substantial changes in nutrient concentrations, probably in the range of 30-50% of the mean across whole landscapes. For example, across the South Midlands great crested newt District License pilot project area, pond nitrate concentration as measured with a single PackTest sample were generally low with 84% of c500 ponds surveyed falling into the lowest category of <0.2 mg $L^{-1}$ nitrate-N. The overall mean nitrate-N concentration was 0.28 mg $L^{-1}$ nitrate-N, suggesting that to detect a change in nitrate concentrations at landscape level in this area would require that average pond nitrate concentrations would need to fall to 0.20-0.21 mg $L^{-1}$ nitrate-N to be detected as a significant change (see Section 5 below, power analysis).

Modelling a simple practical scenario (Figure 8) suggests that a landscape-wide pond creation scheme could create such a change, indicating that this could be detected with the PackTest kits. Assuming a landscape with 100 ponds, with nitrate concentrations in the same proportions as the South Midlands area, if pond numbers were doubled in that area, and most of the new ponds were in the two 'clean water' categories (<0.2 mg $L^{-1}$ and 0.2-0.5 mg $L^{-1}$), the mean nitrate N concentration would fall from 0.29 to 0.21 mg $L^{-1}$, close to the levels at which power analysis indicates that a significant difference could be detected with reasonable power. Such a change – doubling pond numbers across a landscape area, is a quite plausible scenario at local scale. For example, in the Water Friendly Farming project pond creation has approximately doubled pond numbers in the 10 $km^2$ experimental catchment where habitat creation work is being undertaken.

On the National Trust estate this implies that a quite substantial programme of pond creation would be needed to drive a detectable change in waterbody chemistry using the PackTest kits. However, the level needed is in line with the doubling of pond numbers recommended in the Million Ponds Project.

Measuring water quality trends with laboratory analysed samples does not improve the ability to detect change **when using single annual snapshot samples** (Table 10).

Detecting change in smaller numbers of waterbodies may be possible if more frequent sampling is undertaken seasonally, reducing the variability of the individual measurements. As the use of the PackTest kits is developed it would be worth evaluating their potential to detect change at smaller numbers of sites by increasing the number of samples.

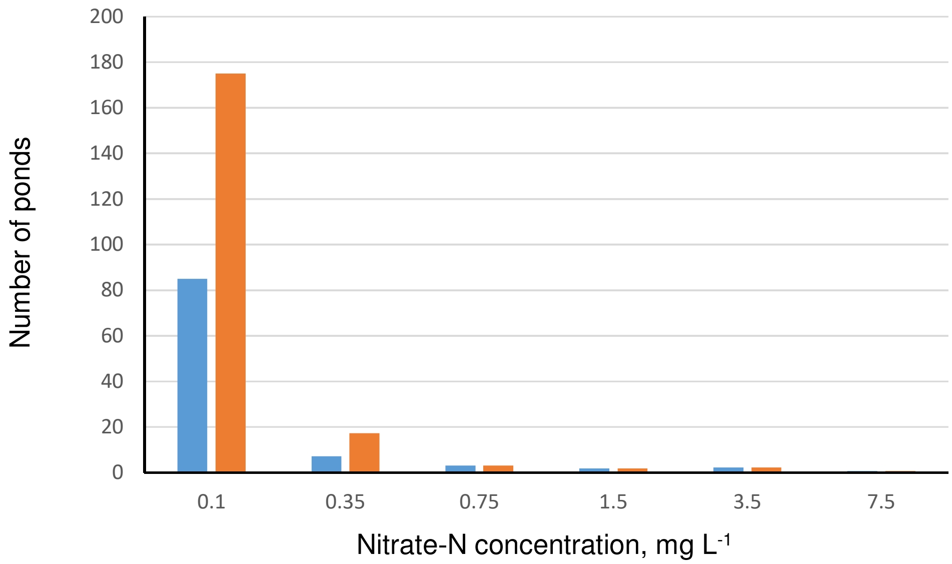


**Figure 8. A simple modelled example of the ability of PackTest nutrient kits to detect landscape wide change in nitrate levels.**

Assuming that 100 ponds (blue bars) fell into the seven PackTest categories in the proportion observed in the South Midlands Great Created Newt District Licensing pilot area, adding 100 new ponds to this landscape (orange bars), all of which fell into the two 'clean water' categories, would lead to a landscape-wide reduction in mean nitrate-N concentration from 0.29 mg $L^{-1}$ to 0.21 mg $L^{-1}$. Power analysis suggests that PackTest analyses would have sufficient power in a sample of c500 waterbodies to identify such a trend as statistically significant.

**Question 2. How does water quality in small waters on the National Trust estate compare to the rest of the landscape?**

Landscape wide comparisons with other areas of the country can be made at a variety of spatial scales with the Kyoritsu kits. For example, comparison with the New Forest dataset (Figure 4) allows National Trust properties sampled with the Kyoritsu kits to be compared with a landscape with a very high proportion of exceptionally clean waterbodies. For intensively managed landscapes the proportions of water bodies in different chemical classes can be compared to case studies from the River Ock (Figure 5) or Greater London (Figure 6). It would also be possible to compare National Trust properties with the nutrient sampling of the stratified random sample of ponds visited nationally for PondNet.

**The practical change that water quality monitoring is assessing**

The main practical objective that water quality monitoring with volunteer collected PackTest data is being used to assess is the creation or restoration of clean water (in the strict sense of WFD High status or equivalent). This will normally mean clean water pond creation and in some cases pond management, although changes in water quality from pond management (e.g. desilting) are generally likely to be shorter-lived unless catchment issues have been addressed.

In theory, PackTest kits could be used to assess changes in the degree of nutrient pollution in running waters. However, in practice, the number of locations where large enough improvements occur to be detected by the kits seems likely to be limited. Locations where PackTest kits might detect change include locations where substantial nutrient point sources are removed from streams or ditches and where there are major landuse changes, influencing whole waterbody catchments, such as ditches or streams rising in fields converted from arable to non-intensive grass (e.g. a maize field to grass reversion).

Where changes in diffuse nutrient pollution levels are more subtle, effective detection is still likely to require laboratory based monitoring programmes which are only likely to be undertaken in Tier 4 type projects.

Although the PackTest kits are only likely to detect substantial changes in water quality, biological data, especially wetland plants, may be more revealing. Aquatic plants are very sensitive to nutrient loadings and, assuming that sensitive species are present in the area to colonise monitored waterbodies, can give a good indication of the extent of nutrient pollution. In this way, biological monitoring can complement chemical monitoring and give initial indications of likely causes of environmental problems.

### 5.2.3 Biological quality of water bodies in the National Trust estate

Practically it is most effective to consider the biological quality of National Trust waterbodies using two types of data: surveys of wetland plants, which should be undertaken professionally, and surveys of individual species of conservation concern which can potentially be undertaken by volunteers in a co-ordinated network based around the PondNet project. The National Trust survey would also provide the opportunity to extend volunteer monitoring of species of conservation concern to smaller running waters and ditches.

The questions which can be addressed with this information are:

**Question 1. Is plant richness or community quality increasing?**
Using plant community data it is possible to assess trends in species richness and derive metrics which are compatible with Water Framework Directive where appropriate. For ponds comparisons can be made with National Pond Survey species richness and conservation value data and PSYM assessments. The power of analyses is good (see Table 10). With aquatic and wetland plant community data it is also possible to derive Trophic Ranking Scores to assess nutrient status.

For individual species there is a good likelihood that individual amphibian species could be assessed, particularly the occurrence of great crested newts or the occurrence of individual endangered plants, such as Pillwort, Brown Galingale or Tubular Water-dropwort.

**Assessment of animal groups.** If it is possible to introduce eDNA sampling to the volunteer programme it would then become possible to address questions of the change in the status of fish populations, although this requires separate funding. The power of other more costly measures has also been evaluated and is discussed further below. We have also evaluated the power of Riverfly monitoring which indicates that if large changes are seen the method theoretically has good power to detect change. However, although the change detectable, 10% difference in the mean Riverfly score, such a change requires quite substantial impacts on, or improvements in, the fauna. Although it is easy to imagine such changes on the occasional National Trust property, perhaps following a severe local organic pollution event, for such impacts and changes to occur on a large scale on the National Trust estate seems unlikely.

**Question 2. How do National Trust waterbodies compare with the wider environment?**
As noted above plant data allows the biological quality of National Trust properties to be compared with results from a range of other national projects including the National Pond Survey, Countryside Survey and Water Framework Directive monitoring.

**Table 9. Questions to be answered by the proposed National Trust monitoring programme**

| Question | Waterbody type | Objective | Metric | How measured | Statistical design | Comparison with rest of landscape |
|---|---|---|---|---|---|---|
| **Physical and chemical parameters** | | | | | | |
| Is number of ponds increasing? | Ponds | At least double pond numbers, mainly by creating new clean water ponds | Number of ponds on each estate | Count number of ponds on estate at $t_1$ and $t_2$ | Census approach (i.e. count all the ponds); a sampling approach is not needed | Compare with estimates from PondNet |
| Is diffuse nutrient pollution increasing or decreasing? | Ponds<br>Streams<br>Rivers when not monitored by EA<br>Lakes, when not monitored by EA<br>Ditches | Reduce nutrient levels, with 'clean water' (i.e. High status) the main objective | Nitrate concentration in National Trust waterbodies assessed using rapid test kits<br>Phosphate concentration in National Trust waterbodies assessed using rapid test kits | Record pollutant in stratified random sample of habitats at $t_1$ and $t_2$ | Compare means from paired samples at $t_1$ and $t_2$ | For waterbodies monitored with rapid test kits, compare to other WaterNet data<br>WFD monitored waterbodies: compare with EA published data |

**Table 9. Questions to be answered by the proposed National Trust monitoring programme (continued)**

| Question | Waterbody type | Objective | Metric | How measured | Statistical design | Comparison with rest of landscape |
|---|---|---|---|---|---|---|
| **Community measures** | | | | | | |
| **Plants**<br>Is plant richness or community quality increasing? | Ponds<br>Streams<br>Ditches | Plant community quality achieves High status or equivalent | PSYM metrics<br>LEAFPACS metrics<br>Note both measures can include Trophic Ranking Score | Record plants in stratified random sample of habitats at $t_1$ and $t_2$ | Compare means from paired samples at $t_1$ and $t_2$ | Compare to National Ponds Survey for ponds.<br>Compare streams and rivers to WFD derived datasets<br>Compare ditches to reference quality sites. |
| **Algae**<br>Is Trophic Diatom Index changing? | Streams | Diatom community quality achieves High status | DARLEQ2 metrics | Sample algae in stratified random sample of habitats at $t_1$ and $t_2$ | Compare means from paired samples at $t_1$ and $t_2$ | Compare to WFD diatom results nationally |
| **Invertebrates**<br>Is invertebrate assemblage diversity or quality increasing? | Ponds<br>Streams<br>Ditches | Invertebrate assemblage achieves high status or equivalent | PSYM scores<br>RICT scores<br>PSYM-type metrics | Survey invertebrates in stratified random sample of habitats at $t_1$ and $t_2$ | Compare means from paired samples at $t_1$ and $t_2$ | Compare to National Ponds Survey for ponds.<br>Compare streams and rivers to WFD derived datasets<br>Compare ditches to reference quality sites. |

**Table 9. Questions to be answered by the proposed National Trust monitoring programme (continued)**

| Question | Waterbody type | Objective | Metric | How measured | Statistical design | Comparison with rest of landscape |
|---|---|---|---|---|---|---|
| **Fish** | | | | | | |
| Is fish species richness increasing? | Streams<br><br>Ponds | Increase abundance / richness of appropriate species for waterbody | Richness or biomass | Standard electrofishing methods<br><br>May be surveyed using eDNA | Compare means from paired samples at $t_1$ and $t_2$ | Richness and biomass data can be compared with standard EA data, although these can be hard to access |
| **Single species (two examples of contrasting localised and widespread species are given)** | | | | | | |
| Pillwort | Ponds<br><br>Lakes | Increase in abundance | Extent of plant stands | Abundance survey | Compare means from paired samples at $t_1$ and $t_2$ | |
| Great crested newt | Ponds | Increased pond occupancy | Number of occupied ponds on property | eDNA sampling or traditional survey methods | Compare means from paired samples at $t_1$ and $t_2$ | If data are available compare to national PondNet survey or NARRS[5]. |
| Other species may be possible depending on extent of volunteer engagement and amount of eDNA survey practicable. | | | | | | |

[5]NARRS = National Amphibian and Reptile Recording Scheme.

## 5.3 Selecting methods: power analysis and cost

Power analysis was undertaken on a range of datasets to evaluate the potential of different survey approaches to assessing freshwater species abundance and habitat ecological quality on the National Trust estate. These were:

- Pond numbers
- Nitrate and phosphate concentrations, using PackTest kits or laboratory analysed data
- Wetland plants at species level
- Diatoms
- Macroinvertebrates at family level and species level
- Rapid invertebrate assessment using Riverfly taxonomic level
- Fish species richness and abundance
- Amphibian species richness
- Examples of individual species of conservation concern

Power analysis was used to determine the sample size needed to detect changes in abundance and pond occupancy. Type II errors (β) may occur if there is a failure to reject the null hypothesis, when in fact the alternative hypothesis is true. Power (1-β) is the probability of detecting an effect if one exists in the population, and is largely dependent on sample size N, effect size and levels of variance in sample groups σ2.

Power analysis was undertaken using G*Power, a free software package. Results of the analyses are discussed in the following sections below and summarised in Table 10.

Sample sizes for a range of power values (typically 60-95%) and levels of change (typically 10%-80% change in means) were calculated (see Appendix 1). In each case, sample sizes for p values of 0.05 and 0.1 were evaluated. For simplicity, sample sizes in Table 10 are based on the widely accepted standard of 70% power to detect a 30% change, unless otherwise noted.

Approximate costs of each sampling method are also reviewed and summarised in Table 10. Costs are derived from various recent or current projects undertaken by Freshwater Habitats Trust.

### 5.3.1 Pond numbers

PondNet and Countryside Survey record pond numbers by counting ponds in a sample of 1 km squares. However, this method is hard to apply to National Trust properties which vary considerably in size and are often irregular in shape, not filling whole 1 km squares.

For this reason it is proposed that pond numbers are simply counted on properties i.e. censused. Numbers are therefore absolute values and do not require power analysis to estimate samples sizes to detect trends.

**Recommendation 6:** Ponds should be counted by censusing waterbodies on each National Trust property rather than by taking a sampling approach, such as that used in PondNet or the Countryside Survey.

### 5.3.2 Water quality

For both PackTest kits and laboratory analysed nutrient samples, return visits to the same sites (i.e. paired analysis) have greater power than random samples in which each survey is based on a new random set of sites.

For both ponds and streams, low hundreds of sample sites (range 109-405) are needed to detect changes in nitrate and phosphate levels at 70% power to detect a 30% change.

Numbers of sample sites for laboratory analysed samples are generally significantly greater than for PackTest kits, with more than 1000 paired sites needed, except for Total P measured in ponds.

**Recommendation 7:** We recommend that PackTest kits are used to evaluate changes in water quality on the National Trust estate, noting the limitations given in Section 5.2.2 about the type of monitoring questions which can be answered with the test kits.

### 5.3.3 Wetland plants

Power analysis of sample sizes needed to assess change in wetland plant assemblages has been based on two approaches:

- Multi-species assessments such as PSYM score, species richness, conservation value or LEAFPACS metrics.
- Single species monitoring which may be more suitable for volunteer groups where the relevant species are present. In the case of uncommon species, monitoring should focus on assessing species abundance because this reduces the number of zero values typical of presence/absence datasets which lead to the need for very large sample sizes.

Stream and pond power analyses were based on Countryside Survey data collected in 2007. We have assumed that the power analysis results for streams can be used to indicate the ditch power analysis. Note that small lakes up to 5 ha in area can be incorporated in PSYM analysis which includes small waterbodies up to this size. A separate analysis was not undertaken for larger lakes as we recommend that such lakes are evaluated on a case-by case basis using standard WFD methods.

For both streams and ponds less than 100 sample sites are needed to give 70% power to detect a 30% change in mean numbers of species (Table 10). Around 150 sites are needed to detect a 20% change. These changes are equivalent to 1 or 2 species gained or lost on average.

**Recommendation 8:** Wetland plants provide an effective group for assessing change in small running and standing waters and should be adopted as a monitoring metric provided they can be recorded professionally.

### 5.3.4 Diatoms

Sample sizes for diatom surveys are based on detecting change in the TDI metric. Standard monitoring methods for diatoms are only currently available for streams so it has not been possible to calculate a sample size for ponds.

Power to detect change using the TDI index is very good, but it should be noted that quite substantial changes in nutrient levels are likely to be needed to see significant changes in the TDI value. Thus in the PARIS project a rough halving of SRP was needed to reduce TDI by 10% (Figure 9) (Harper et al. 2009).

Total sample size needed for diatoms is less than 100 to detect a 10% change with 70% power. Given that diatom analysis is relatively inexpensive it is worth considering this metric as an adjunct to large wetland plants.

**Recommendation 9:** If additional funds are available, or there are other opportunities for establishing diatom monitoring programme, monitoring with this metric is potentially is good option.

**Figure 9. Relationship between Trophic Diatom Index (TDI) and percentage pollution tolerant valves (%PTV) against soluble reactive P (SRP).**

SRP is mean concentration in water samples collected 2 weeks prior to biological sample, spring and autumn 2005. (TDI $r^2$=+0.61, $p < 0.005$, %PTV $r^2$=+0.59, $p < 0.005$). TDI = blue diamonds; %PTV = red triangles. From Harper *et al.* 2009.

### 5.3.5 Rapid invertebrate assessment using Riverfly taxonomic level

Power analysis of Riverfly data was undertaken using data available for 1 January to 31 December 2016 on the Riverfly website at http://www.riverflies.org/open-data.

The analysis indicates that around 150 sites would be needed to detect a 30% change in the Record Score. However, it is worth noting that to achieve a 30% change in the Record Score requires a substantial change in the invertebrate fauna – probably the complete loss of more than one order of invertebrates. Figure 10 shows an example of a Record Score for a site which indicates that a 30% change in score would probably need the complete loss and or substantial reduction of two Families or Orders of caddis, mayflies, stoneflies or Gammaridae. Such a change in response to reducing river pollution levels indicates that only substantial changes in quality could be detected using this method.

| | | Example month | | Month 1 | | Month 2 | | Month 3 | |
|---|---|---|---|---|---|---|---|---|---|
| | Date | 27/06/2015 | | | | | | | |
| | Recorded by | B Fitch & A Menzies | | | | | | | |
| | | Est. number* | Score | Est. number* | Score | Est. number* | Score | Est. number* | Score |
| Caddisflies | Cased caddisfly | 20 | 2 | | | | | | |
| | Caseless caddisfly | 2 | 1 | | | | | | |
| Up-wing flies | Mayfly (Ephemeridae) | 10 | 2 | | | | | | |
| | Blue-winged olive (Ephemerellidae) | 20 | 2 | | | | | | |
| | Flat-bodied stone clinger (Heptageniidae) | 100 | 3 | | | | | | |
| | Olives (Baetidae) | 4 | 1 | | | | | | |
| Stoneflies | Stoneflies (Plecoptera) | 3 | 1 | | | | | | |
| Freshwater shrimp | Freshwater shrimp (Gammaridae) | 8 | 1 | | | | | | |
| | **ARMI score** | 13 | | | | | | | |
| | Additional observations/notes | Fly hatches observed. River level: LHB 200mm, Middle 350mm, RHB 150mm. | | | | | | | |

**Figure 10. An example of a Riverfly Record Score.**

Eight Orders and Families of invertebrates are recorded and their abundance on a log scale used to calculate a score: 1-9 individuals score 1, 10-99 = 3, 100-999 = 3, 1000 and above = 4. For further information see the Riverfly website.

**Recommendation 10:** We recommend that the Riverfly score would be worth further investigation provided that there was further analysis of its inherent variability. Additionally, it would be worth assessing first whether there were likely to be substantial impacts on running waters on the National Trust estate which could be amenable to improvement before implementing a programme of volunteer surveys which might lack the power to detect anything other than very substantial changes in the invertebrate fauna.

### 5.3.6 Macroinvertebrates at family level and species level

**Species level analysis**

Numbers of samples needed to detect change in species-level freshwater macroinvertebrate metrics is surprisingly modest, with less than 30 samples needed to detect a 30% change with 70% power. However, changes of 30% in invertebrate species metrics are likely to require substantial improvements to waterbodies. It probably more realistic to consider the sample sizes needed to detect a 10-20% change in species richness which would require around 100 sampling locations in both streams and ponds.

In practice the costs of such work make it unlikely that this work could be undertaken in the near future except as part of a larger national programme to assess waterbody quality in a professional survey.

### 5.3.7 Fish species richness and abundance

Data from surveys of headwater streams in the Water Friendly Farming project area were used to evaluate sample sizes needed to detect a 30% change in fish species richness with 70% power. Data were available only for streams.

A paired analysis required less than 50 samples to detect a 30% change, with the number rising to 100 or more sites for 10-20% change (Appendix Table A15).

Fish surveys are expensive and it is possible that new eDNA techniques could replace traditional fish surveys, at least to detect species presence/absence. Freshwater Habitats Trust is currently preparing to test these fish eDNA methods but at present there are no data available on which to base power analysis.

**Recommendation 11:** We do not recommend undertaking fish surveys routinely on Tier 2 waterbodies on the National Trust estate unless eDNA techniques become available. Fish survey work may be needed in Tier 4 projects.

### 5.3.8 Amphibian species richness

At present in Britain no multi-species amphibian metrics are routinely calculated, with monitoring essentially revolving around individual surveys of the 5 widespread native species (Common Frog, Common Toad and the three species of newts). Sample sizes for these species individually are discussed further below. More intensive monitoring of the small number of sites with Natterjack Toad is also undertaken.

With the advent of eDNA metabarcoding it may soon be possible to quickly generate a multi-species metric for amphibians routinely. Freshwater Habitats Trust is planning to test such a metric in the near future. However, at present, no data are available to run a power analysis for a multi-species amphibian metric.

For great crested newt it is possible to assess:

- Pond occupancy using eDNA combined with traditional methods
- Abundance, as we believe volunteer groups could also estimate population numbers by counts if trained and co-ordinated under the auspices of the PondNet/NARRS national monitoring programme.

It is also quite straightforward for volunteers to record common toad using traditional methods of searching for spawning adults, spawn strings and larvae which are comparatively easily distinguished from frog tadpoles. Data from common toad monitoring could be compared with NARRS survey data.

### 5.3.9 Individual species of conservation concern

For ponds, single species monitoring methods have now been developed for a number of species of conservation concern.

Sampling strategies were developed for national level monitoring for several of these in the course of the PondNet project (Ewald *et al.,* 2013) and the results of this work are summarised for key species. Power analysis undertaken for PondNet can be applied to the National Trust estate and can be used to address two questions:

1. Is the species increasing or decreasing on the National Trust property

2. Is the trend different to that seen in the rest of the landscape.

Examples of two localised species, as well as great crested newt and common toad, are discussed further below.

**Pillwort**
For pillwort, the methodology which produced the highest level of power for any given sample size was estimating the percentage cover of Pillwort within its available niche. To achieve 70% power, with 30% change between years, 75 ponds would need to be surveyed. If the same ponds were revisited (matched pairs) the number of samples required was only 39 ponds.

**Tubular Water-dropwort**
Differences between methods to achieve the same level of power for Tubular Water-dropwort were less marked than for Pillwort. Abundance, measured as the percentage in cover of the whole pond, the percentage cover of the available niche and measures of density within the 75 $cm^2$ quadrat resulted in similar numbers of ponds to achieve the same level of power. To detect 30% change, this was around 100 ponds (matched pairs) and 200 ponds (independent samples).

## 5.4 Other recording options

There should be general encouragement of biological recording on the National Trust estate.

A short guide with links to all appropriate recording schemes could be prepared to provide a simple signposting service for those interested in biological recording.

This would help to encourage co-operation, data sharing and development of volunteers moving between groups and building their interests and skills. It could also be used to signpost the work of organisations offering training in identification of freshwater species such as Freshwater Biological Association and Field Studies Council. We suggest that this could be developed as a small part of further work on PondNet and its extension to habitats other than ponds.

**Table 10. Summary of power analyses. Unless otherwise stated values are 70% power to detect a 30% at p value of = 0.05**

| Metric | Ponds | | Streams | | Volunteer/ Professional | Cost per sample |
|---|---|---|---|---|---|---|
| | **Paired samples at $t_1$ and $t_2$** | **2 random samples at $t_1$ and $t_2$** | **Paired samples at $t_1$ and $t_2$** | **2 random samples at $t_1$ and $t_2$** | | |
| Pond numbers | Census – count all ponds | | n/a | n/a | Volunteer | Volunteer support time |
| Nitrate PackTest kits (Clean Water for Wildlife data) | 368 | 1926 | 109 | 429 | Volunteer | £1.50 |
| Phosphate PackTest kits (Clean Water for Wildlife data) | 309 | 1615 | 405 | 1612 | Volunteer | £1.50 |
| Total N – lab snapshot (CS2007 data) | 1703 | 8930 | 1471 | 5879 | Vol collect; Professional analysis | £7.50 |
| Total P – lab snapshot (CS2007 data) | 300 | 1566 | 1635 | 6535 | Vol collect; Professional analysis | £7.50 |
| Wetland plants -70% power, 30% change (CS2007 data) | 74 | 220 | 56 | 220* | Professional | £120 (FHT) |
| Wetland plants - 70% power, 20% change (CS2007 data) | 164 | 494 | 125 | 494* | Professional | £120 (FHT) |
| Diatoms - 70% power, 30% change change (EA 2016 monitoring data) | No current method | No current method | 9 | 42 | Possibly volunteer: sampling Professional sample identification | £60 to identify samples for TDI score (Bowburn Consultancy) |
| Diatoms - 70% power, 10% change (EA 2016 monitoring data) | No current method | No current method | 71 | 365 | Possibly volunteer: sampling Professional sample identification | £60 to identify samples for TDI score (Bowburn Consultancy) |
| Rapid invert taxon richness 80% power; 10% change (Riverfly data) | No current method (note FHT has 12 taxon Big Pond Dip but need to redesign) | | 129 | 510 | Volunteer | Volunteer support time |

**Table 10. Summary of power analyses. Unless otherwise stated values are 70% power to detect a 30% at p value of = 0.05 (continued)**

| Metric | Ponds | | Streams | | Volunteer/ Professional | Cost per sample |
|---|---|---|---|---|---|---|
| | **Paired samples at $t_1$ and $t_2$** | **2 random samples at $t_1$ and $t_2$** | **Paired samples at $t_1$ and $t_2$** | **2 random samples at $t_1$ and $t_2$** | | |
| Invertebrate species richness - 70% power, 30% change (NPS data ponds; CS 2007 data for streams) | 15 | 55 | 24 | 48 | Professional | Stream: tbc<br><br>Pond: tbc |
| Invertebrate species richness - 70% power, 10% change (NPS data ponds; CS 2007 data for streams) | 120 | 474 | 102 | 416 | Professional | Stream: tbc<br><br>Pond: tbc |
| Fish species richness (Water Friendly Farming data – professional electric fishing) | No data currently available for analysis | | 45 | n/a | Professional | £600/site (Econ – Martin Perrow) |
| Fish species richness – eDNA Test kits from Spygen | No data currently available for analysis | | No data currently available for analysis | | Volunteer collect; Professional analysis | £250 (for 10+ sites) for analysis |
| Amphibian species richness – eDNA from Spygen | No data currently available for analysis | | No data currently available for analysis | | No data currently available for analysis | £250 (for 10+ sites) |

*Note that sample sizes for stream and pond wetland plants with two independent samples are coincidentally the same.

**Table 10. Summary of power analyses. Unless otherwise stated values are 70% power to detect a 30% at p value of = 0.05 (continued)**

| Metric | Ponds | | Streams | | Volunteer/ Professional | Cost per sample |
|---|---|---|---|---|---|---|
| | **Paired samples at $t_1$ and $t_2$** | **2 random samples at $t_1$ and $t_2$** | **Paired samples at $t_1$ and $t_2$** | **2 random samples at $t_1$ and $t_2$** | | |
| **Protected species** | | | | | | |
| Great crested newts | Assess counts on c50% the NT sites with volunteers. Alternatively, undertaken eDNA surveys (50 sites would cost c£6000-7000).. | | Not applicable | | Volunteers or professional | Volunteer support time |
| Pillwort | 39 | 75 | Not applicable | | Volunteers or professional | Volunteer support time |
| Tubular Water-dropwort | 100 | 200 | Not applicable | | | Volunteer support time |
| Other species<br><br>A mix of traditional and eDNA methods | PondNet methods | | Methods under development | | Volunteers<br><br>Volunteer Co-ordination cost | Volunteer support time |

**Table 11. Key to detailed power analyses in Appendix 1**

| Table number | Description | Region | Data used | Design | Page no. |
|---|---|---|---|---|---|
| **A** 1.1 | Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in nitrate concentrations in ponds | England + Wales | Clean Water for Wildlife survey 2016 | Independent | |
| **A** 1.2 | Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in nitrate concentrations in ponds | England + Wales | Clean Water for Wildlife survey 2016 | Matched pairs | |
| **A** 1.3 | Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in nitrate concentrations in ponds | England + Wales | Countryside Survey 2007 | Independent | |
| **A** 1.4 | Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in nitrate concentrations in ponds | England + Wales | Countryside Survey 2007 | Matched pairs | |
| **A** 1.5 | Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in phosphate concentrations in ponds | England + Wales | Clean Water for Wildlife survey 2016 | Independent | |
| **A** 1.6 | Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in phosphate concentrations in ponds | England + Wales | Clean Water for Wildlife survey 2016 | Matched pairs | |
| **A** 1.7 | Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in phosphate concentrations in ponds | England + Wales | Countryside Survey 2007 | Independent | |
| **A** 1.8 | Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in phosphate concentrations in ponds | England + Wales | Countryside Survey 2007 | Matched pairs | |
| **A** 1.9 | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in nitrate concentrations in streams | England + Wales | Clean Water for Wildlife Survey 2016 | Independent | |
| **A** 1.10 | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in nitrate concentrations in streams | England + Wales | Clean Water for Wildlife Survey 2016 | Matched pairs | |

**Table 11. Key to detailed power analyses in Appendix 1 (continued)**

| Table number | Description | Region | Data used | Design | Page no. |
|---|---|---|---|---|---|
| **A** 1.11. | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in nitrate concentrations in streams | England + Wales | Countryside Survey 2007 | Independent | |
| **A** 1.12. | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in nitrate concentrations in streams | England + Wales | Countryside Survey 2007 | Matched pairs | |
| **A** 1.13. | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in phosphate concentrations in streams | England + Wales | Clean Water for Wildlife Survey 2016 | Independent | |
| **A** 1.14. | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in phosphate concentrations in streams | England + Wales | Clean Water for Wildlife Survey 2016 | Matched pairs | |
| **A** 1.15. | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in phosphate concentrations in streams | England + Wales | Countryside Survey 2007 | Independent | |
| **A** 1.16. | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in phosphate concentrations in streams | England + Wales | Countryside Survey 2007 | Matched pairs | |
| **A** 2 | Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in wetland plant species richness | England + Wales | Countryside Survey 2007 | Matched pairs | |
| **A** 3 | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in wetland plant species richness | England + Wales | Countryside Survey 2007 | Matched pairs | |
| **A** 4 | Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in wetland plant species richness | England + Wales | Countryside Survey 2007 | Independent | |
| **A** 5 | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in wetland plant species richness | England + Wales | Countryside Survey 2007 | Independent | |

**Table 11. Key to detailed power analyses in Appendix 1 (continued)**

| Table number | Description | Region | Data used | Design | Page no. |
|---|---|---|---|---|---|
| **A** 6 | Streams: Power analysis of sample size required at $time_1$ and $time_2$ to detect a change in Trophic Diatom Index 3 | England + Wales | Environment Agency national monitoring programme 2016 data | Independent | |
| **A** 7 | Streams: Power analysis of sample size required at $time_1$ and $time_2$ to detect a change in Trophic Diatom Index 3 | England + Wales | Environment Agency national monitoring programme 2016 data | Matched pairs | |
| **A** 8 | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in Riverfly ARMI monitoring score | England + Wales | Riverfly survey 2016 | Matched pairs | |
| **A** 9 | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in Riverfly ARMI monitoring score | England + Wales | Riverfly survey 2016 | Independent | |
| **A** 10 | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in stream macroinvertebrate taxon richness | England + Wales | Countryside Survey 2007 | Matched pairs | |
| **A** 11 | Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in stream macroinvertebrate taxon richness | England + Wales | Countryside Survey 2007 | Independent | |
| **A** 12 | Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in pond macroinvertebrate species richness | England + Wales | Countryside Survey 2007 | Matched pairs | |
| **A** 13 | Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in pond macroinvertebrate species richness | England + Wales | Countryside Survey 2007 | Independent | |

**Table 11. Key to detailed power analyses in Appendix 1 (continued)**

| Table number | Description | Region | Data used | Design | Page no. |
|---|---|---|---|---|---|
| **A** 14 | Fish in streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in fish species richness in streams | England + Wales | Water Friendly Farming project 2012 and 2013 | Independent | |
| **A** 15 | Fish in streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in fish species richness in streams | England + Wales | Water Friendly Farming project 2012 and 2013 | Matched pairs | |

# 6. Options for collating, analysing and archiving data

In this section opportunities to feed data into existing recording schemes are reviewed as well as potential approaches to data collation, data analysis, reporting and archiving.

## 6.1 Existing recording schemes

The NT should help recording groups to focus on particular sites by highlighting interesting species or recording opportunities.

**Recommendation 12:** We recommend that for the taxa for which standard recording schemes are available (see Table 4) surveyors should be strongly encouraged to work with national recording schemes and Local Environmental Records Centres to collect records for these groups. Special attention should be payed to the species of conservation concern listed in Table 12.

A checklist of activities and processes to be put in place to encourage recording should include:

- Promoting the use of iRecord for ad hoc casual records
- Encourage Recording Schemes to suggest that local recorders visit NT properties.
- Suggesting that to each property that they should be in contact with recording Schemes and Local Environmental Records Centres.
- Establish agreements with schemes to return data to National Trust at regular intervals if this is not already done.

## 6.2 Data collation

### 6.2.1 Habitat related data and species of conservation concern monitoring

Pond and water quality data should be added to the WaterNet database which is designed to hold the type of data being collected in the present project (see example of water quality data in Figure 11). The WaterNet database is publicly accessible and will be supported in the long-term by Freshwater Habitats Trust.

For other waterbodies, Freshwater Habitats Trust is currently planning further development of the WaterNet database to handle data from a range of waterbody types. Initially the aim will be to incorporate small streams and ditches. Small lakes can effectively be covered by the existing database. These developments are part of planned new projects (note that funding will need to be raised to do this work so this is not included in the present project).

In the short term, the professional stream datasets collected in the present work can be collated in standard Excel spreadsheets. These can be shared and made available to all users via the Freshwater Habitats Trust website.

Eventually it may be useful for the WaterNet database to provide facilities to hold data collected using standard WFD methods waterbodies. This may be useful to hold data from waterbodies surveyed using WFD methods which are not part of survey programmes managed by the statutory agencies. For example, data from small lakes in the size range 5-50 ha which may not be part of routine monitoring programmes could be stored either by the statutory agencies or in the WaterNet database.

Advantages of this approach are that the database has been designed specifically for the purpose of handling the type of biological and environmental data being collected by the present work, it is designed to be fully accessible to the public and users (although data can be kept confidential). The database is being completed as part of current HLF funded work. Disadvantages of this approach are that further (planned) development work is needed to incorporate streams and ditches. Also there will be an on-going need to raise funds to maintain the database, although as a core activity of Freshwater Habitats Trust a range of funding streams should be available to support the activity.

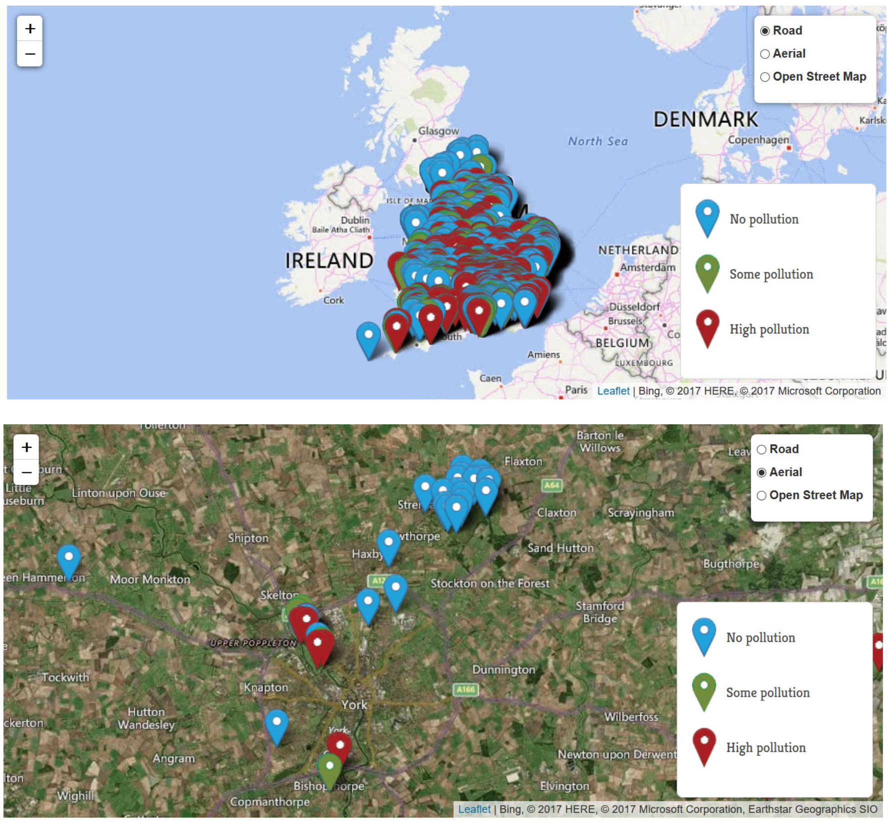


**Figure 11. Example screen shots from the WaterNet database showing Clean Water for Wildlife records.**

(a) Screen shot of opening page of Clean Water for Wildlife. So far c6000 of c10,000 records are on-line (b) Strensall Common north-eat of York is a Flagship Ponds site and a local clean water hot spot.

### 6.2.2 Other data management solutions

It may be worth investigating options to store small waterbody data in the Catchment Data Explorer. However, at present this database does not present detailed site or biological data but provides summaries of WFD scores and other administrative data. It does not provide information on lakes, even where these are WFD waterbodies.

Advantages of this approach are that the system would be integrated with the state sector. At present the substantial practical disadvantages are that none of the data currently being collected can be handled by the Environment Agency system and would require considerable development work.

A third strategy would be to store data long-term with the Freshwater Biological Association. The advantage of this would be that the Freshwater Biological Association has a long history of storing and making data available. The main disadvantage would be that there is no current database run by the FBA that could hold the data in the way that the WaterNet database is designed to do, meaning that a new system would be needed to create an online facility.

## 6.3 Data analysis

For data analysis and reporting, for the professional wetland plant survey, we would recommend a short annual update summarising project progress and interesting observations, followed by a major report after 5 years.

The programme could form the basis for a new multi-partner annual/biannual State of Freshwater Wildlife/Habitats/Ecosystems report.

## 6.4 Archiving data

There are several options for archiving the data from the water quality and wetland plant surveys. These could include:

- Producing regular GIS downloads for National Trust.
- Placing all data on WaterNet which is in the public domain.
- Regular data downloads to standard formats such as Excel or Access. These should be archived on National Trust servers and Freshwater Habitats Trust, and could also potentially be placed on the servers of the Freshwater Biological Association. In general, our approach would be to ensure that data were widely distributed on the Internet as this seems the most likely route for ensuring that data will survive in the long-term.
- It would perhaps also be worth considering place results on the NERC data repository could also be considered, although this may change in the near future.
- Produce long-term data management plan.

As part of the work of the survey we would produce a simple long-term data management plan at the end of Year 1 of the project.

# 7. Suggestions for monitoring particular sites or particular interventions

A national monitoring scheme is unlikely to be sufficient to capture the effect of changes made to land and water management intended to restore and improve the water environment at key sites. For this reason more detailed Tier 4 monitoring of key sites and programmes (e.g. through the Riverlands programme) is also needed. Brief recommendations are made about particular monitoring needs for this level of the monitoring programme.

The Trust already has an excellent track record of involvement in ground-breaking freshwater research and there are options for a variety of more advanced site specific projects covering many aspects of the National Trust interests. The main principles of this monitoring are briefly discussed below.

## 7.1 Management interventions

Management interventions – such as those at Holnicote (natural flood management), Coleshill (river restoration) and techniques applied under the Water Friendly Farming programme run by Freshwater Habitats Trust and Game & Wildlife conservation Trust – often require bespoke and detailed monitoring programmes to obtain reliable evidence of their effect. For such projects, the main principles for securing good evidence are:

- Good before monitoring with before and after and controls if possible using the BACI (Before-After-Control-Impact) design. Such programmes can be expensive and it is often better to focus monitoring efforts on to a small number of sites to get usable results from a few locations, rather than spread effort too thinly getting unusable data from a lot of sites.
- Partnerships. For similar reasons, it is often beneficial to develop projects in partnership so that resources can be better focused to make a real impact rather than trying to spread resources too thinly.
- Ensuring that the potential to incorporate data into models is taken into account to allow exploration of other scenarios or extend beyond the monitored period (the latter may be especially useful for interventions that affect hydrology).

## 7.2 Sites

The Trust is likely to have a significant number of sites (low 10s of sites) at which monitoring of water environment projects could generate nationally and internationally significant information on the effects of management to protect freshwater ecosystems and resources. This work could include important baseline datasets that of general relevance to the management of freshwaters including tracking change over time, reviewing the effects of land management and detecting changes driven by external drivers (pressures, climate change).

Specific sites which have already provided nationally and internationally important data include:

- Holnicote Estate natural flood management work
- Coleshill Estate river restoration and catchment freshwater biodiversity work.

There are also likely to be sites where work to protect specific endangered species could also contribute to better general understanding of the threats to freshwater biota generally including (but not limited to):

- Lizard temporary ponds water plants

- Protecting and restoring high quality small lakes: e.g. Studland in Dorset, Lake District tarns (e.g. Burnmoor Tarn).
- Fen restoration in Wicken area in Cambridgeshire.

## 7.3 Species

National Trust properties support a large number of species of conservation concern. There are many opportunities to monitor the practical work in progress or needed to protect these species. Amongst potentially dozens of species four examples which have emerged from the PondNet programme are noted to exemplify the potential.

### 7.3.1 Great crested newt and common toad

National monitoring of the great crested newt as a volunteer eDNA-based survey has been established under PondNet in 2105-17. In 2018 this work is expected to continue and it may be worth assessing the potential for developing an eDNA-based survey of great crested newts on Trust property to complement this programme. Volunteers enjoy collecting eDNA samples and datasets can be reliably compared with the national dataset.

The existing great crested newt eDNA programme provides metrics which are well suited to Trust properties, particularly the number of ponds occupied per square km which give a good estimate of the strength of populations and the quality of ponds in a landscape. Thus at present, in 1 km squares with great crested newts on average about half of all ponds are occupied. National Trust properties could assess themselves against this value as a target, aiming to achieve greater than 50% pond occupancy as a measure of success in maintaining strong newt populations. Note that such targets could be achieved either by pond management or pond creation.

Common toads are probably declining more noticeably than great crested newts at present. Although still comparatively frequent in the north, in the south they are probably found in similar numbers of ponds as great crested newts (Wilkinson and Arnell, 2013).

Although detecting common toads using traditional survey methods is comparatively simple, it would be of interest to use eDNA multi-species tests to assess this species, alongside the other widespread amphibian species.

### 7.3.2 Starfruit

As a result of the PondNet work on Flagship sites which support Starfruit, including the National Trust property at Headley Heath, specialists involved in the management of the species are planning a workshop in 2018 to tackle the practical and monitoring issues facing this species. It is likely that National Trust properties will continue to provide important practical information about this most sensitive of the so-called ‘mud plants’ which depend on high quality seasonal and gently grazed ponds.

### 7.3.3 Brown Galingale

National Trust owns the site at Cock Marsh in Buckinghamshire which has the UKs strongest population of this highly endangered sedge. Freshwater Habitats Trust is planning to continue partnership monitoring and protection of this plant as part of its Flagship Ponds programme, and the site provides an outstanding model of the subtleties of managing high quality ponds.

**Table 12. Species of conservation concern recorded on the National Trust estate**

| Species | Number of properties where found |
|---|---|
| **Species highlighted in bold may be suitable for volunteer monitoring** | |
| Aeshna isosceles | 2 |
| Agabus (Gaurodytes) conspersus | 1 |
| Agabus melanarius | 4 |
| Agabus uliginosus | 2 |
| Agabus unguicularis | 2 |
| Anacaena bipustulata | 12 |
| Aphrosylus mitis | 1 |
| **Arvicola amphibius** | **24** |
| Arvicola terrestris | 4 |
| **Austropotamobius pallipes** | **23** |
| Bagous limosus | 1 |
| Barbastella barbastellus | 3 |
| Beris clavipes | 4 |
| Beris fuscipes | 7 |
| Berosus (Berosus) affinis | 1 |
| Berosus affinis | 4 |
| Berosus signaticollis | 4 |
| **Blysmus compressus** | **1** |
| **Bufo bufo** | **63** |
| Carex vulpina | 1 |
| Cercyon convexiusculus | 5 |
| Cercyon depressus | 1 |
| Cercyon tristis | 1 |
| Chaetarthria simillima | 1 |
| **Chara fragifera** | **2** |
| **Chirocephalus diaphanus** | **4** |
| Cicendia filiformis | 1 |
| Coregonus lavaretus | 1 |
| **Cottus gobio** | **6** |
| **Cyperus fuscus** | **1** |
| Cyperus longus | 9 |
| **Damasonium alisma** | **1** |
| Deronectes latus | 2 |
| Deschampsia setacea | 1 |
| Dicranota gracilipes | 1 |
| Dixa maculata | 1 |
| Donacia impressa | 1 |
| Donacia thalassina | 1 |
| Drupenatus nasturtii | 2 |
| Dytiscus circumflexus | 5 |
| Elatine hexandra | 1 |
| Eleocharis acicularis | 1 |
| Enochrus affinis | 1 |
| Enochrus halophilus | 2 |

**Table 12. Species of conservation concern recorded on the National Trust estate (continued)**

| Species | Number of properties where found |
|---|---|
| **Species highlighted in bold may be suitable for volunteer monitoring** | |
| Enochrus ochropterus | 1 |
| Gnaphalium uliginosum | 41 |
| Gyrinus minutus | 1 |
| Gyrinus urinator | 1 |
| Haliplus (Haliplinus) heydeni | 2 |
| Hebrus pusillus | 1 |
| Helochares lividus | 5 |
| Helochares punctatus | 3 |
| Helophorus (Atracthelophorus) arvernicus | 1 |
| Helophorus dorsalis | 1 |
| Helophorus griseus | 1 |
| **Hydaticus seminiger (easy to identify water beetle)** | **2** |
| **Hydrocharis morsus-ranae** | **6** |
| Hydrocyphon deflexicollis | 1 |
| Hydroporus longicornis | 1 |
| Hydroporus longulus | 3 |
| Hydroporus marginatus | 1 |
| Hygrotus (Hygrotus) decoratus | 1 |
| Hypericum undulatum | 6 |
| Ilybius aenescens | 1 |
| Ilybius guttiger | 1 |
| Isoetes lacustris | 2 |
| Juncus capitatus | 3 |
| Lemna gibba | 5 |
| Limonia trivittata | 1 |
| Lipsothrix errans | 2 |
| **Littorella uniflora** | **3** |
| **Luronium natans** | **2** |
| Lycopodiella inundata | 3 |
| Mentha pulegium | 2 |
| Mentha suaveolens | 4 |
| Mentha suaveolens x longifolia = M. x rotundifolia | 1 |
| **Myotis bechsteinii** | **1** |
| Natrix natrix | 10 |
| Nebrioporus (Nebrioporus) depressus | 1 |
| **Nyctalus noctula** | **11** |
| Nymphoides peltata | 2 |
| Ochthebius marinus | 1 |
| **Oenanthe fistulosa** | **5** |
| Oreodytes davisii | 1 |
| Orthonevra geniculata | 1 |
| Oxycera morrisii | 1 |
| Oxycera pygmaea | 1 |

## Table 12. Species of conservation concern recorded on the National Trust estate (continued)

| Species | Number of properties where found |
|---|---|
| **Species highlighted in bold may be suitable for volunteer monitoring** | |
| Persicaria mitis | 1 |
| **Pilularia globulifera** | **1** |
| **Pipistrellus pygmaeus** | **3** |
| Potamogeton alpinus | 1 |
| **Potamogeton gramineus** | **1** |
| Potamogeton gramineus x lucens = P. x angustifolius | 1 |
| Potamogeton lucens | 1 |
| Potamogeton perfoliatus | 4 |
| Pyrola rotundifolia subsp. maritima | 1 |
| Ranunculus penicillatus subsp. penicillatus | 1 |
| Rhinolophus hipposideros | 5 |
| Rhynchospora alba | 2 |
| Ruppia cirrhosa | 2 |
| Salmo salar | 2 |
| Scleranthus annuus subsp. annuus | 1 |
| Scorzonera humilis | 1 |
| **Sium latifolium** | **1** |
| Sphagnum sp. | 6 |
| Spirodela polyrhiza | 1 |
| Stratiomys potamida | 2 |
| Stratiotes aloides | 2 |
| Tasiocera robusta | 1 |
| Teucrium scordium | 1 |
| **Triturus cristatus** | **9** |
| Utricularia vulgaris s.s. | 1 |

# 8. Develop a matrix of options with details of costs, frequency and delivery options (professional versus volunteer)

## 8.1 Frequency of survey

### 8.1.1 Water quality

For Tier 2 monitoring it is recommended that water quality surveys are undertaken at the wetland plant monitoring sites at the same time as plant survey data are collected (i.e. a 5-year rolling programme). This will provide a broad indication of nitrate and phosphate levels at the monitored sites, typically sufficient to group sites into broad categories of clean, moderately polluted and polluted. However, unless sites are subject to very pronounced change (e.g. dredging of very silty polluted ponds, removal of septic tank nutrient sources on small streams) it is unlikely that there will be substantial changes seen in water quality at these locations.

At the Tier 3 sites (i.e. the individual properties) volunteers will be encouraged to undertake landscape-wide survey of waterbodies on their sites. We would suggest that water bodies are resurveyed at 3-5 yearly intervals, with sites being revisited to maximise statistical power to detect change. As far as possible surveyors should be encouraged to revisit at the same time of year. Sampling will primarily be intended to characterise pollutant levels in the landscapes but if substantial changes are made to waterbodies, or new waterbodies are created, it is possible that changes will be detected.

We suggest that situations where volunteers are particularly encouraged to undertake monitoring would include:

- Initial reviews of landscape-wide water quality encompassing all waterbodies
- Repeat surveys of high quality water bodies to provide some potential early warning of deterioration, although it must be noted that to detect an increase in nutrient levels will indicate quite substantial deterioration.
- Monitoring of waterbodies which have been subject to significant management. Such monitoring will be to some extent experimental as at present we have little experience of the sensitivity of the test kits to detecting change in these locations.

It is likely that volunteers and site managers will find other situations where the test kits are useful as experience of using them grows.

### 8.1.2 Wetlands plants

For the wetland plant monitoring programme of we would recommend a 5 year rolling programme with the objective of surveying sufficient sites over 5 years to provide the number of samples needed to give analyses sufficient statistical power to detect change.

For plants a 5 year programme of survey is short enough to treat samples as coming from the same time period. Although there is variability between years, repeat surveys in the Water Friendly Farming landscape over three years show that patterns across these landscape are broadly similar over such a time period, with detectable change occurring after interventions.

Monitoring data collected over the first 2-3 years could also be used to assess the potential for detecting trends over a shorter period, and potentially reducing sample size.

**(a)**

**(b)**

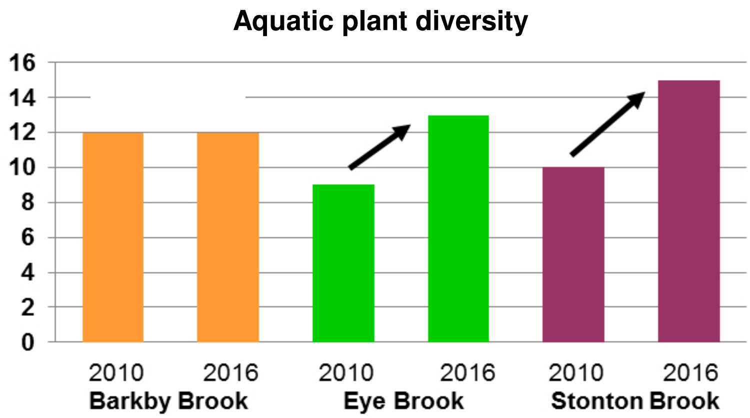


**Figure 12. Aquatic plant diversity trends in the Water Friendly Farming project.**

(a) Trends over the first three baseline years of the project were consistent in different waterbody types and (b) following introduction of clean water ponds a quick and landscape wide response was observed in aquatic plant species richness.

## 8.2 Cost summary

Costs are shown in Table 13 for a programme combining volunteer water pollution monitoring, monitoring of selected species of conservation concern, and professional monitoring of wetland plants.

Costs of a broader programme involving professional sampling of diatoms and freshwater invertebrates are given in Table 14. These programmes would only be possible as part of a larger separately funded programme.

**Table 13. Costs of the base programme of volunteer water pollution assessment, monitoring of species of conservation concern and professional wetland plant survey**

| Activity | Notes (including day rates) | Sites / day | Ponds | Streams | Days | Cost | Per year cost over 5 years |
|---|---|---|---|---|---|---|---|
| ***Water testing*** | | | | | | | |
| Test kits: £3/site | £3.00 | | 500 | 500 | | **£3,000** | £600 |
| ***Fieldwork*** | | | **Days/site** | | | | |
| Plant survey | £300/day | 4 | 100 | 100 | 50 | | |
| Travel | Hours | 1 | 14 | 14 | 29 | | |
| | | | | | 79 | **£23,571** | £4714 |
| Travel | 50 miles/site | | | 5000 | | **£2,000** | £400 |
| Accommodation | 20 nights | | | 20 | | **£1,200** | £240 |
| | | | | | | | £5354 |
| ***Analysis*** | | | | | | | |
| Data entry | £300/day | 30 | 3.3 | 3.3 | | **£2,000** | £400 |
| Analysis | | 10 | | | | **£3,000** | £600 |
| Reporting and dissemination | | 10 | | | | **£3,000** | £600 |
| | | | | | **Sub-total** | **£37,771** | |
| ***Volunteer work*** | | **Training sites** | **Meetings** | **Days/site** | | | |
| Volunteer co-ordination | £250/day | 20 | 20 | 2 | | **£10,000** | £2,000 |
| Travel and accommodation costs | c.£100/ meeting | | 20 | | | **£2000** | £500 |
| | | | | | **Total** | **£49,771** | £9,954 |
| | | | | | **VAT is 0% if a grant** | | |

**Table 14. Additional professional and volunteer monitoring of diatoms, macroinvertebrates and other groups**

| Activity | Details | Sites per day | Staff cost / day | Subtotal | Cost per year over 5 years |
|---|---|---|---|---|---|
| Diatom survey | Collection | 5 | £250 | £5,000 | £1,000 |
| | Identification | | £60 | £6,000 | £1,200 |
| | Travel, accommodation | | | £2,000 | £400 |
| | Analysis & Reporting | 10 | £350 | £3,500 | £700 |
| | | | | **£16,500** | £3,300 |
| Invertebrate samples: 50 ponds, 50 streams | Collection | 5 | £250 | £5,000 | £1,000 |
| | Processing | 0.5 | £250 | £50,000 | £10,000 |
| | Identification | 0.5 | £350 | £70,000 | £14,000 |
| | Analysis | 20 | £350 | £7,000 | £1,400 |
| **Total cost** | | | | **£132,000** | £26,400 |

## 8.3 Delivery options

The delivery options for the monitoring of National Trust properties will combine professional and volunteer surveyors, building on Freshwater Habitats Trust extensive experience of large scale professional surveys (e.g. Countryside Survey, National Pond Survey) and novel volunteer-based monitoring, such as great crested newt eDNA work as part of PondNet and the Clean Water for Wildlife water pollution monitoring programme.

The broad structure of the proposed work is summarised in Figure 13.

### 8.3.1 Professional surveyors

**Wetland plant surveys**

The core of Tier 2 monitoring will use professionally undertaken standard wetland plant survey techniques to assess pond and stream aquatic biodiversity, following methods developed for Countryside Survey and landscape-wide biodiversity studies (e.g. techniques applied in Williams et al. 2004).

At the sites visited we will also routinely collect standard environmental data from both still and running waters. We will also collect PackTest nitrate and phosphate data.

**Other biotic groups if funds become available**

Wetland plants provide a cost effective way of assessing the condition of freshwaters and allow diagnosis of environmental stressors (e.g. nutrient pollution). However, a substantially more nuanced view of freshwater quality is obtained by considering other biotic groups, including those routinely considered under Water Framework Directive (i.e. invertebrates, algae, fish) and individual protected species. During 2018 we will work together with National Trust and other partners to explore the potential for a new national monitoring programme for small waters including these groups, and for protected freshwater species.

We expect this work to combine a mixture of professional and volunteer programmes, particularly involving the use of eDNA.

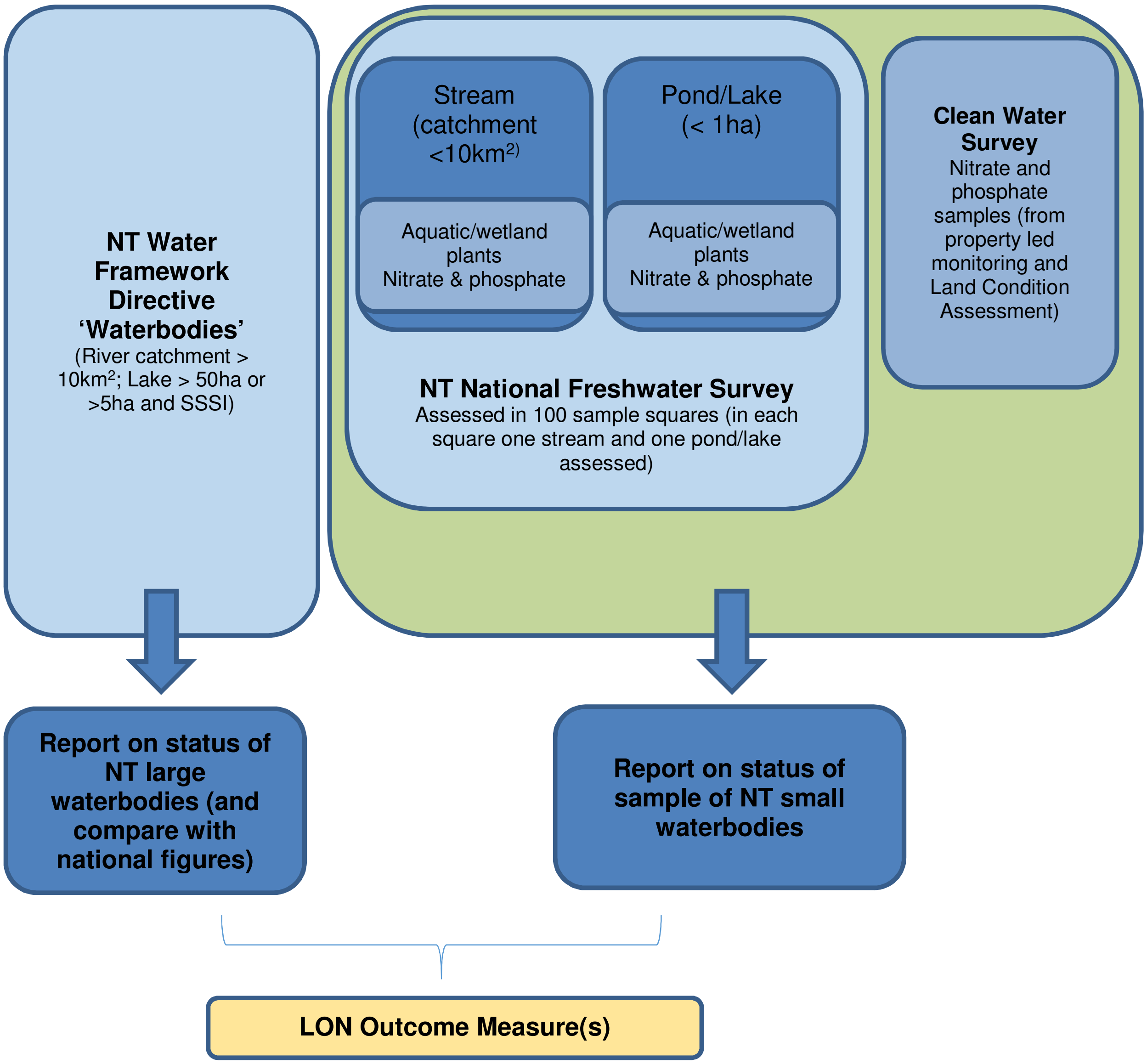


**Figure 13. Schematic of proposed monitoring approach**

### 8.3.2 Volunteers with professional co-ordination

To get the most from volunteers it is valuable to provide professional co-ordination and guidance as part of developing a community of surveyors. We suggest that people interested in collecting data voluntarily on National Trust properties are built into a national monitoring programme framework, continuing and extending the work of PondNet and the Clean Water for Wildlife survey. As part of the training component of the proposed work we will set volunteers up to collect data from the waterbodies on the estate they are interested in and provide simple feedback on the implications of the results.

The three main component we expect to focus on will be:

- Water quality surveys: we will encourage National Trust properties to collect estate wide data on the condition of all waters following the model developed in PondNet and other catchment projects (e.g. R. Ock).
- Environmental data describing waterbodies (initially ponds; later running waters and ditches): as well as collecting pond data it may be valuable to initiate some pilot work assessing headwater streams as this information is of interest to Naturel England.
- Individual species of conservation concern using traditional methods (e.g. pillwort, brown galingale) or eDNA.

### 8.3.3 Tier 3 monitoring

We will run Tier 3 monitoring training opportunities for volunteers at National Trust properties. This will cover water quality, amphibians and environmental data initially. If possible we will also provide training for specific endangered species where volunteers are able to provide useful data on protected species.

### 8.3.4 Tier 4 monitoring

Some recommendations on the principles of monitoring and data collection for evaluating innovative land and water management interventions are given in Section 7. Tier 4 monitoring requires technical professional inputs and will be developed on a case by case basis.

Interesting and potentially influential monitoring programmes are likely to develop from innovative practical management programmes such as work to increase landscape wide freshwater biodiversity at the Coleshill estate (e.g. replicating on a larger scale what has been done in the Water Friendly Farming project) or work to understand the benefit of river restoration at Coleshill, and to develop solutions to increase those benefits.

The National Trust would also be in a good position to test innovative solution to current intractable water management problems, particularly those involving diffuse pollution.

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# Appendix 1. Power analysis tables

**Table A1.1. Ponds: power analysis of sample size required at $Time_1$ and $Time_2$ to detect a change in nitrate concentrations in ponds**

Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Results from Clean Water for Wildlife Survey 2016
Stratification – None
Design – Independent

| $\alpha_{0.05}$ | % change | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 13748 | 3439 | 1529 | 861 | 552 | 384 | 283 | 217 |
| **65** | 15437 | 3861 | 1717 | 967 | 619 | 431 | 317 | 243 |
| **70** | 17322 | 4332 | 1926 | 1084 | 695 | 483 | 355 | 273 |
| **75** | 19478 | 4871 | 2166 | 1219 | 781 | 543 | 399 | 306 |
| **80** | 22027 | 5508 | 2449 | 1379 | 883 | 614 | 452 | 346 |
| **85** | 25197 | 6301 | 2801 | 1577 | 1010 | 702 | 516 | 396 |
| **90** | 29488 | 7373 | 3278 | 1845 | 1181 | 821 | 604 | 463 |
| **95** | 36467 | 9118 | 4054 | 2281 | 1461 | 1015 | 746 | 572 |
| **$\alpha_{0.10}$** | **% change** | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 10107 | 2528 | 1124 | 633 | 406 | 282 | 208 | 159 |
| **65** | 11564 | 2892 | 1286 | 724 | 464 | 323 | 237 | 182 |
| **70** | 13204 | 3302 | 1468 | 827 | 530 | 368 | 271 | 208 |
| **75** | 15095 | 3775 | 1679 | 945 | 605 | 421 | 309 | 237 |
| **80** | 17350 | 4339 | 1929 | 1086 | 695 | 483 | 355 | 272 |
| **85** | 20175 | 5045 | 2243 | 1262 | 808 | 562 | 413 | 317 |
| **90** | 24033 | 6009 | 2672 | 1503 | 963 | 669 | 492 | 377 |
| **95** | 30370 | 7594 | 3376 | 1899 | 1216 | 845 | 621 | 476 |

**Table A1.2. Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in nitrate concentrations in ponds**

Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Results from Clean Water for Wildlife Survey 2016
Stratification – None
Design – Matched pairs

| $\alpha_{0.05}$ | % change | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 2529 | 633 | 282 | 159 | 103 | 72 | 53 | 41 |
| **65** | 2893 | 724 | 323 | 182 | 117 | 82 | 60 | 47 |
| **70** | 3303 | 827 | 368 | 208 | 133 | 93 | 69 | 53 |
| **75** | 3775 | 945 | 421 | 237 | 152 | 106 | 78 | 60 |
| **80** | 4339 | 1086 | 483 | 273 | 175 | 122 | 90 | 69 |
| **85** | 5045 | 1262 | 562 | 317 | 203 | 142 | 104 | 80 |
| **90** | 6009 | 1503 | 669 | 377 | 242 | 168 | 124 | 95 |
| **95** | 7594 | 1899 | 845 | 476 | 305 | 212 | 156 | 120 |
| $\alpha_{0.10}$ | % change | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 1654 | 414 | 185 | 104 | 67 | 47 | 35 | 27 |
| **65** | 1950 | 488 | 217 | 123 | 79 | 55 | 41 | 31 |
| **70** | 2289 | 573 | 255 | 144 | 92 | 64 | 48 | 37 |
| **75** | 2685 | 672 | 299 | 169 | 108 | 75 | 56 | 43 |
| **80** | 3163 | 791 | 352 | 199 | 127 | 89 | 65 | 50 |
| **85** | 3770 | 943 | 420 | 236 | 152 | 106 | 78 | 60 |
| **90** | 4610 | 1153 | 513 | 289 | 185 | 129 | 95 | 73 |
| **95** | 6009 | 1503 | 668 | 376 | 241 | 168 | 123 | 95 |

**Table A1.3. Ponds: power analysis of sample size required at $Time_1$ and $Time_2$ to detect a change in nitrate concentrations in ponds**
Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Results from Countryside Survey 2007
Stratification – None
Design – Independent

| $\alpha_{0.05}$ | % change | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 63777 | 15946 | 7088 | 3988 | 2553 | 1774 | 1304 | 998 |
| **65** | 71610 | 17904 | 7958 | 4478 | 2866 | 1991 | 1463 | 1121 |
| **70** | 80356 | 20090 | 8930 | 5024 | 3216 | 2234 | 1642 | 1258 |
| **75** | 90358 | 22591 | 10042 | 5649 | 3616 | 2512 | 1846 | 1414 |
| **80** | 102187 | 25548 | 11356 | 6389 | 4089 | 2840 | 2087 | 1599 |
| **85** | 116892 | 29225 | 12990 | 7308 | 4678 | 3249 | 2388 | 1828 |
| **90** | 136799 | 34201 | 15202 | 8552 | 5474 | 3802 | 2794 | 2139 |
| **95** | 169181 | 42297 | 18800 | 10576 | 6769 | 4701 | 3455 | 2645 |
| $\alpha_{0.10}$ | % change | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 46886 | 11723 | 5211 | 2932 | 1877 | 1304 | 958 | 734 |
| **65** | 53644 | 13412 | 5962 | 3354 | 2147 | 1491 | 1096 | 840 |
| **70** | 61254 | 15315 | 6807 | 3830 | 2452 | 1703 | 1251 | 958 |
| **75** | 70029 | 17508 | 7782 | 4378 | 2803 | 1947 | 1431 | 1096 |
| **80** | 80488 | 20123 | 8944 | 5032 | 3221 | 2237 | 1644 | 1259 |
| **85** | 93597 | 23400 | 10401 | 5851 | 3745 | 2601 | 1912 | 1464 |
| **90** | 111494 | 27874 | 12389 | 6970 | 4461 | 3098 | 2277 | 1743 |
| **95** | 140896 | 35225 | 15656 | 8807 | 5637 | 3915 | 2877 | 2203 |

**Table A1.4. Ponds: power analysis of sample size required at time$_1$ and time$_2$ to detect a change in nitrate concentrations in ponds**
Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Results from Results from Countryside Survey 2007
Stratification – None
Design – Matched pairs

| $\alpha_{0.05}$ | % change | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 11729 | 2933 | 1304 | 734 | 471 | 327 | 241 | 185 |
| **65** | 13416 | 3355 | 1492 | 840 | 538 | 374 | 275 | 211 |
| **70** | 15317 | 3830 | 1703 | 959 | 614 | 427 | 314 | 241 |
| **75** | 17510 | 4379 | 1947 | 1096 | 702 | 488 | 359 | 275 |
| **80** | 20124 | 5032 | 2237 | 1259 | 806 | 560 | 412 | 316 |
| **85** | 23401 | 5851 | 2601 | 1464 | 937 | 651 | 479 | 367 |
| **90** | 27875 | 6970 | 3098 | 1744 | 1116 | 776 | 570 | 437 |
| **95** | 35225 | 8807 | 3915 | 2203 | 1410 | 980 | 720 | 552 |
| $\alpha_{0.10}$ | % change | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 7669 | 1918 | 853 | 480 | 308 | 214 | 157 | 121 |
| **65** | 9044 | 2262 | 1006 | 566 | 363 | 252 | 185 | 142 |
| **70** | 10616 | 2655 | 1180 | 664 | 425 | 296 | 218 | 167 |
| **75** | 12454 | 3114 | 1385 | 779 | 499 | 347 | 255 | 195 |
| **80** | 14673 | 3669 | 1631 | 918 | 588 | 408 | 300 | 230 |
| **85** | 17489 | 4373 | 1944 | 1094 | 700 | 487 | 358 | 274 |
| **90** | 21383 | 5346 | 2377 | 1337 | 856 | 595 | 437 | 335 |
| **95** | 27874 | 6969 | 3098 | 1743 | 1116 | 775 | 570 | 436 |

**Table A1.5. Ponds: power analysis of sample size required at time$_1$ and time$_2$ to detect a change in phosphate concentrations in ponds**

Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Results from Clean Water for Wildlife Survey 2016
Stratification – None
Design – Independent

| $\alpha_{0.05}$ | % change in phosphate concentration | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 11522 | 2882 | 1282 | 722 | 463 | 322 | 237 | 182 |
| **65** | 12937 | 3236 | 1439 | 810 | 519 | 361 | 266 | 204 |
| **70** | 14517 | 3631 | 1615 | 909 | 583 | 405 | 298 | 229 |
| **75** | 16324 | 4082 | 1816 | 1022 | 655 | 455 | 335 | 257 |
| **80** | 18460 | 4617 | 2053 | 1156 | 740 | 515 | 379 | 290 |
| **85** | 21117 | 5281 | 2348 | 1322 | 847 | 589 | 433 | 332 |
| **90** | 24712 | 6180 | 2748 | 1546 | 990 | 688 | 506 | 388 |
| **95** | 30562 | 7642 | 3398 | 1912 | 1224 | 851 | 626 | 480 |
| $\alpha_{0.10}$ | % change in phosphate concentration | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 8470 | 2119 | 942 | 531 | 340 | 237 | 174 | 134 |
| **65** | 9691 | 2424 | 1078 | 607 | 389 | 271 | 199 | 153 |
| **70** | 11066 | 2767 | 1231 | 693 | 444 | 309 | 227 | 174 |
| **75** | 12651 | 3164 | 1407 | 792 | 507 | 353 | 260 | 199 |
| **80** | 14540 | 3636 | 1617 | 910 | 583 | 405 | 298 | 229 |
| **85** | 16908 | 4228 | 1880 | 1058 | 678 | 471 | 346 | 266 |
| **90** | 20141 | 5036 | 2239 | 1260 | 807 | 561 | 412 | 316 |
| **95** | 25452 | 6364 | 2829 | 1592 | 1019 | 708 | 521 | 399 |

**Table A1.6 .Ponds: power analysis of sample size required at time$_1$ and time$_2$ to detect a change in phosphate concentrations in ponds**
Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Results from Clean Water for Wildlife Survey 2016
Stratification – None
Design – Matched pairs

| $\alpha_{0.05}$ | % change in phosphate concentration | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 2120 | 531 | 237 | 134 | 86 | 60 | 45 | 35 |
| **65** | 2425 | 607 | 271 | 153 | 98 | 69 | 51 | 39 |
| **70** | 2768 | 693 | 309 | 174 | 112 | 78 | 58 | 45 |
| **75** | 3164 | 792 | 353 | 199 | 128 | 89 | 66 | 51 |
| **80** | 3636 | 910 | 405 | 229 | 147 | 102 | 76 | 58 |
| **85** | 4228 | 1058 | 471 | 266 | 170 | 119 | 88 | 67 |
| **90** | 5036 | 1260 | 561 | 316 | 203 | 141 | 104 | 80 |
| **95** | 6364 | 1592 | 708 | 399 | 256 | 178 | 131 | 101 |
| $\alpha_{0.10}$ | % change in phosphate concentration | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 1386 | 347 | 155 | 87 | 56 | 39 | 29 | 23 |
| **65** | 1634 | 409 | 182 | 103 | 66 | 46 | 34 | 26 |
| **70** | 1918 | 480 | 214 | 121 | 78 | 54 | 40 | 31 |
| **75** | 2250 | 563 | 251 | 141 | 91 | 63 | 47 | 36 |
| **80** | 2651 | 663 | 295 | 167 | 107 | 74 | 55 | 42 |
| **85** | 3160 | 791 | 352 | 198 | 127 | 89 | 65 | 50 |
| **90** | 3863 | 966 | 430 | 242 | 155 | 108 | 80 | 61 |
| **95** | 5036 | 1260 | 560 | 316 | 202 | 141 | 104 | 80 |

**Table A1.7. Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in phosphate concentrations in ponds**
Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Results from Countryside Survey 2007
Stratification – None
Design – Independent

| $\alpha_{0.05}$ | % change in phosphate concentration | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 11174 | 2795 | 1243 | 700 | 449 | 312 | 230 | 177 |
| **65** | 12546 | 3138 | 1396 | 786 | 504 | 350 | 258 | 198 |
| **70** | 14078 | 3521 | 1566 | 882 | 565 | 393 | 289 | 222 |
| **75** | 15830 | 3959 | 1761 | 991 | 635 | 442 | 325 | 249 |
| **80** | 17902 | 4477 | 1991 | 1121 | 718 | 499 | 367 | 282 |
| **85** | 20478 | 5121 | 2277 | 1282 | 821 | 571 | 420 | 322 |
| **90** | 23965 | 5993 | 2665 | 1500 | 961 | 668 | 491 | 376 |
| **95** | 29637 | 7411 | 3295 | 1854 | 1187 | 825 | 607 | 465 |
| $\alpha_{0.10}$ | % change in phosphate concentration | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 8214 | 2055 | 914 | 515 | 330 | 230 | 169 | 130 |
| **65** | 9398 | 2351 | 1045 | 589 | 377 | 262 | 193 | 148 |
| **70** | 10731 | 2684 | 1194 | 672 | 431 | 299 | 220 | 169 |
| **75** | 12268 | 3068 | 1364 | 768 | 492 | 342 | 252 | 193 |
| **80** | 14100 | 3526 | 1568 | 883 | 565 | 393 | 289 | 222 |
| **85** | 16397 | 4100 | 1823 | 1026 | 657 | 457 | 336 | 258 |
| **90** | 19532 | 4884 | 2171 | 1222 | 783 | 544 | 400 | 307 |
| **95** | 24682 | 6172 | 2744 | 1544 | 989 | 687 | 505 | 387 |

**Table A1.8. Ponds: power analysis of sample size required at time1 and time2 to detect a change in phosphate concentrations in ponds**

Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Results from Countryside Survey 2007
Stratification – None
Design – Matched pairs

| $\alpha_{0.05}$ | % change in phosphate concentration | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 2056 | 515 | 230 | 130 | 84 | 59 | 43 | 34 |
| **65** | 2351 | 589 | 263 | 148 | 95 | 67 | 49 | 38 |
| **70** | 2684 | 672 | 300 | 169 | 109 | 76 | 56 | 43 |
| **75** | 3068 | 768 | 342 | 193 | 124 | 87 | 64 | 49 |
| **80** | 3526 | 883 | 393 | 222 | 142 | 99 | 73 | 57 |
| **85** | 4100 | 1026 | 457 | 258 | 165 | 115 | 85 | 65 |
| **90** | 4884 | 1222 | 544 | 307 | 197 | 137 | 101 | 78 |
| **95** | 6172 | 1544 | 687 | 387 | 248 | 173 | 127 | 98 |
| $\alpha_{0.10}$ | % change in phosphate concentration | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 8214 | 2055 | 914 | 515 | 330 | 230 | 169 | 130 |
| **65** | 9398 | 2351 | 1045 | 589 | 377 | 262 | 193 | 148 |
| **70** | 10731 | 2684 | 1194 | 672 | 431 | 299 | 220 | 169 |
| **75** | 12268 | 3068 | 1364 | 768 | 492 | 342 | 252 | 193 |
| **80** | 14100 | 3526 | 1568 | 883 | 565 | 393 | 289 | 222 |
| **85** | 16397 | 4100 | 1823 | 1026 | 657 | 457 | 336 | 258 |
| **90** | 19532 | 4884 | 2171 | 1222 | 783 | 544 | 400 | 307 |
| **95** | 24682 | 6172 | 2744 | 1544 | 989 | 687 | 505 | 387 |

**Table A1.9. Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in nitrate concentrations in streams**
Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Results from Clean Water for Wildlife Survey 2016
Stratification – None
Design – Independent

| $\alpha_{0.05}$ | % change | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 3051 | 764 | 341 | 193 | 124 | 87 | 64 | 50 |
| **65** | 3426 | 858 | 382 | 216 | 139 | 97 | 72 | 56 |
| **70** | 3844 | 963 | 429 | 242 | 156 | 109 | 80 | 62 |
| **75** | 4322 | 1082 | 482 | 272 | 175 | 122 | 90 | 70 |
| **80** | 4888 | 1223 | 545 | 307 | 197 | 138 | 102 | 78 |
| **85** | 5591 | 1399 | 623 | 351 | 226 | 157 | 116 | 89 |
| **90** | 6543 | 1637 | 729 | 411 | 264 | 184 | 136 | 104 |
| **95** | 8091 | 2024 | 901 | 508 | 326 | 227 | 167 | 128 |
| $\alpha_{0.10}$ | % change | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 2243 | 562 | 251 | 142 | 91 | 64 | 47 | 37 |
| **65** | 2566 | 643 | 286 | 162 | 104 | 73 | 54 | 42 |
| **70** | 2930 | 734 | 327 | 184 | 119 | 83 | 61 | 47 |
| **75** | 3350 | 838 | 373 | 211 | 135 | 94 | 70 | 54 |
| **80** | 3850 | 964 | 429 | 242 | 155 | 108 | 80 | 62 |
| **85** | 4477 | 1120 | 499 | 281 | 180 | 126 | 93 | 71 |
| **90** | 5332 | 1334 | 594 | 335 | 215 | 150 | 110 | 85 |
| **95** | 6738 | 1686 | 750 | 422 | 271 | 189 | 139 | 107 |

**Table A1.10. Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in nitrate concentrations in streams**
Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Results from Clean Water for Wildlife Survey 2016
Stratification – None
Design – Matched pairs

| $\alpha_{0.05}$ | % change | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 764 | 193 | 87 | 50 | 33 | 23 | 18 | 14 |
| **65** | 858 | 216 | 97 | 56 | 36 | 26 | 20 | 15 |
| **70** | 963 | 242 | 109 | 62 | 40 | 29 | 22 | 17 |
| **75** | 1082 | 272 | 122 | 70 | 45 | 32 | 24 | 19 |
| **80** | 1223 | 307 | 138 | 78 | 51 | 36 | 27 | 21 |
| **85** | 1399 | 351 | 157 | 89 | 58 | 41 | 31 | 24 |
| **90** | 1637 | 411 | 184 | 104 | 67 | 47 | 35 | 28 |
| **95** | 2024 | 508 | 227 | 128 | 83 | 58 | 43 | 34 |
| $\alpha_{0.10}$ | % change | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 562 | 142 | 64 | 36 | 24 | 17 | 13 | 10 |
| **65** | 643 | 162 | 73 | 42 | 27 | 19 | 15 | 12 |
| **70** | 734 | 184 | 83 | 47 | 31 | 22 | 16 | 13 |
| **75** | 838 | 211 | 94 | 54 | 35 | 25 | 19 | 15 |
| **80** | 964 | 242 | 108 | 62 | 40 | 28 | 21 | 17 |
| **85** | 1120 | 281 | 126 | 71 | 46 | 33 | 24 | 19 |
| **90** | 1334 | 335 | 150 | 85 | 55 | 38 | 29 | 22 |
| **95** | 1686 | 422 | 189 | 107 | 69 | 48 | 36 | 28 |

**Table A1.11. Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in nitrate concentrations in streams**

Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Results from Countryside Survey 2007
Stratification – None
Design – Independent

| $\alpha_{0.05}$ | % change | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 41980 | 10497 | 4666 | 2626 | 1681 | 1168 | 859 | 658 |
| **65** | 47136 | 11786 | 5239 | 2948 | 1887 | 1311 | 964 | 738 |
| **70** | 52892 | 13225 | 5879 | 3308 | 2118 | 1471 | 1081 | 828 |
| **75** | 59476 | 14871 | 6610 | 3719 | 2381 | 1654 | 1216 | 931 |
| **80** | 67262 | 16817 | 7475 | 4206 | 2692 | 1870 | 1375 | 1053 |
| **85** | 76941 | 19237 | 8551 | 4811 | 3080 | 2139 | 1572 | 1204 |
| **90** | 90044 | 22513 | 10007 | 5630 | 3604 | 2503 | 1840 | 1409 |
| **95** | 111359 | 27841 | 12375 | 6962 | 4456 | 3095 | 2275 | 1742 |
| $\alpha_{0.10}$ | % change | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 30862 | 7716 | 3430 | 1930 | 1236 | 859 | 631 | 484 |
| **65** | 35310 | 8829 | 3925 | 2208 | 1414 | 982 | 722 | 553 |
| **70** | 40319 | 10081 | 4481 | 2521 | 1614 | 1121 | 824 | 631 |
| **75** | 46095 | 11525 | 5123 | 2882 | 1845 | 1282 | 942 | 722 |
| **80** | 52980 | 13246 | 5888 | 3313 | 2121 | 1473 | 1083 | 829 |
| **85** | 61608 | 15403 | 6847 | 3852 | 2466 | 1713 | 1259 | 964 |
| **90** | 73388 | 18348 | 8155 | 4588 | 2937 | 2040 | 1499 | 1148 |
| **95** | 92741 | 23186 | 10306 | 5798 | 3711 | 2578 | 1894 | 1450 |

**Table A1.12. Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in nitrate concentrations in streams**

Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Results from Results from Countryside Survey 2007
Stratification – None
Design – Matched pairs

| $\alpha_{0.05}$ | % change | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 10497 | 2626 | 1168 | 658 | 422 | 294 | 216 | 166 |
| **65** | 11786 | 2948 | 1311 | 738 | 473 | 329 | 242 | 186 |
| **70** | 13225 | 3308 | 1471 | 828 | 531 | 369 | 272 | 209 |
| **75** | 14871 | 3719 | 1654 | 931 | 597 | 415 | 305 | 234 |
| **80** | 16817 | 4206 | 1870 | 1053 | 675 | 469 | 345 | 265 |
| **85** | 19237 | 4811 | 2139 | 1204 | 771 | 536 | 395 | 303 |
| **90** | 22513 | 5630 | 2503 | 1409 | 902 | 627 | 461 | 354 |
| **95** | 27841 | 6962 | 3095 | 1742 | 1116 | 775 | 570 | 437 |
| $\alpha_{0.10}$ | **% change** | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 7716 | 1930 | 859 | 484 | 310 | 216 | 159 | 122 |
| **65** | 8829 | 2208 | 982 | 553 | 355 | 247 | 182 | 139 |
| **70** | 10081 | 2521 | 1121 | 631 | 405 | 281 | 207 | 159 |
| **75** | 11525 | 2882 | 1282 | 722 | 462 | 322 | 237 | 181 |
| **80** | 13246 | 3313 | 1473 | 829 | 531 | 369 | 272 | 208 |
| **85** | 15403 | 3852 | 1713 | 964 | 617 | 429 | 316 | 242 |
| **90** | 18348 | 4588 | 2040 | 1148 | 735 | 511 | 376 | 288 |
| **95** | 23186 | 5798 | 2578 | 1450 | 929 | 645 | 475 | 364 |

**Table A1.13. Streams: power analysis of sample size required at time$_1$ and time$_2$ to detect a change in phosphate concentrations in streams**

Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Results from Clean Water for Wildlife Survey 2016
Stratification – None
Design – Independent

| $\alpha_{0.05}$ | % change in phosphate concentration | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 46665 | 11668 | 5187 | 2918 | 1869 | 1298 | 954 | 731 |
| **65** | 52396 | 13101 | 5824 | 3277 | 2098 | 1457 | 1071 | 821 |
| **70** | 58795 | 14700 | 6535 | 3677 | 2354 | 1635 | 1202 | 921 |
| **75** | 66114 | 16530 | 7348 | 4134 | 2646 | 1838 | 1351 | 1035 |
| **80** | 74768 | 18694 | 8309 | 4675 | 2993 | 2079 | 1528 | 1170 |
| **85** | 85528 | 21384 | 9505 | 5347 | 3423 | 2378 | 1747 | 1338 |
| **90** | 100093 | 25025 | 11123 | 6258 | 4006 | 2782 | 2045 | 1566 |
| **95** | 123787 | 30948 | 13756 | 7739 | 4953 | 3440 | 2528 | 1936 |
| $\alpha_{0.10}$ | **% change in phosphate concentration** | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 34306 | 8578 | 3813 | 2145 | 1374 | 954 | 702 | 537 |
| **65** | 39251 | 9814 | 4362 | 2454 | 1571 | 1092 | 802 | 615 |
| **70** | 44818 | 11206 | 4981 | 2802 | 1794 | 1246 | 916 | 702 |
| **75** | 51239 | 12811 | 5694 | 3204 | 2051 | 1425 | 1047 | 802 |
| **80** | 58892 | 14724 | 6545 | 3682 | 2357 | 1637 | 1203 | 922 |
| **85** | 68483 | 17122 | 7611 | 4282 | 2741 | 1904 | 1399 | 1071 |
| **90** | 81578 | 20396 | 9065 | 5100 | 3264 | 2267 | 1666 | 1276 |
| **95** | 103091 | 25774 | 11456 | 6445 | 4125 | 2865 | 2105 | 1612 |

**Table A1.14. Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in phosphate concentrations in streams**
Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Results from Clean Water for Wildlife Survey 2016
Stratification – None
Design – Matched pairs

| $\alpha_{0.05}$ | % change in phosphate concentration | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 2877 | 721 | 321 | 182 | 117 | 82 | 61 | 47 |
| **65** | 3230 | 809 | 361 | 204 | 131 | 92 | 68 | 52 |
| **70** | 3625 | 908 | 405 | 228 | 147 | 103 | 76 | 59 |
| **75** | 4076 | 1020 | 455 | 257 | 165 | 115 | 85 | 66 |
| **80** | 4609 | 1154 | 514 | 290 | 186 | 130 | 96 | 74 |
| **85** | 5272 | 1319 | 588 | 331 | 213 | 148 | 110 | 84 |
| **90** | 6169 | 1544 | 687 | 387 | 249 | 173 | 128 | 98 |
| **95** | 7629 | 1909 | 849 | 479 | 307 | 214 | 158 | 121 |
| $\alpha_{0.10}$ | % change in phosphate concentration | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 2115 | 530 | 236 | 134 | 86 | 60 | 45 | 34 |
| **65** | 2420 | 606 | 270 | 153 | 98 | 69 | 51 | 39 |
| **70** | 2763 | 692 | 308 | 174 | 112 | 78 | 58 | 45 |
| **75** | 3158 | 791 | 352 | 199 | 128 | 89 | 66 | 51 |
| **80** | 3630 | 909 | 405 | 228 | 147 | 102 | 75 | 58 |
| **85** | 4221 | 1056 | 470 | 265 | 170 | 119 | 88 | 67 |
| **90** | 5028 | 1258 | 560 | 316 | 202 | 141 | 104 | 80 |
| **95** | 6353 | 1589 | 707 | 398 | 256 | 178 | 131 | 101 |

**Table A1.15. Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in phosphate concentrations in streams**

Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Results from Countryside Survey 2007
Stratification – None
Design – Independent

| $\alpha_{0.05}$ | % change in phosphate concentration | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 46665 | 11668 | 5187 | 2918 | 1869 | 1298 | 954 | 731 |
| **65** | 52396 | 13101 | 5824 | 3277 | 2098 | 1457 | 1071 | 821 |
| **70** | 58795 | 14700 | 6535 | 3677 | 2354 | 1635 | 1202 | 921 |
| **75** | 66114 | 16530 | 7348 | 4134 | 2646 | 1838 | 1351 | 1035 |
| **80** | 74768 | 18694 | 8309 | 4675 | 2993 | 2079 | 1528 | 1170 |
| **85** | 85528 | 21384 | 9505 | 5347 | 3423 | 2378 | 1747 | 1338 |
| **90** | 100093 | 25025 | 11123 | 6258 | 4006 | 2782 | 2045 | 1566 |
| **95** | 123787 | 30948 | 13756 | 7739 | 4953 | 3440 | 2528 | 1936 |
| $\alpha_{0.10}$ | % change in phosphate concentration | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 34306 | 8578 | 3813 | 2145 | 1374 | 954 | 702 | 537 |
| **65** | 39251 | 9814 | 4362 | 2454 | 1571 | 1092 | 802 | 615 |
| **70** | 44818 | 11206 | 4981 | 2802 | 1794 | 1246 | 916 | 702 |
| **75** | 51239 | 12811 | 5694 | 3204 | 2051 | 1425 | 1047 | 802 |
| **80** | 58892 | 14724 | 6545 | 3682 | 2357 | 1637 | 1203 | 922 |
| **85** | 68483 | 17122 | 7611 | 4282 | 2741 | 1904 | 1399 | 1071 |
| **90** | 81578 | 20396 | 9065 | 5100 | 3264 | 2267 | 1666 | 1276 |
| **95** | 103091 | 25774 | 11456 | 6445 | 4125 | 2865 | 2105 | 1612 |

**Table A1.16. Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in phosphate concentrations in streams**
Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Results from Countryside Survey 2007
Stratification – None
Design – Matched pairs

| $\alpha_{0.05}$ | % change in phosphate concentration | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 11668 | 2918 | 1298 | 731 | 469 | 326 | 240 | 184 |
| **65** | 13101 | 3277 | 1457 | 821 | 526 | 366 | 269 | 207 |
| **70** | 14700 | 3677 | 1635 | 921 | 590 | 410 | 302 | 232 |
| **75** | 16530 | 4134 | 1838 | 1035 | 663 | 461 | 339 | 260 |
| **80** | 18694 | 4675 | 2079 | 1170 | 750 | 521 | 383 | 294 |
| **85** | 21384 | 5347 | 2378 | 1338 | 857 | 596 | 438 | 336 |
| **90** | 25025 | 6258 | 2782 | 1566 | 1003 | 697 | 513 | 393 |
| **95** | 30948 | 7739 | 3440 | 1936 | 1240 | 862 | 634 | 486 |
| $\alpha_{0.10}$ | **% change in phosphate concentration** | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 8578 | 2145 | 954 | 537 | 344 | 240 | 176 | 135 |
| **65** | 9814 | 2454 | 1092 | 615 | 394 | 274 | 202 | 155 |
| **70** | 11206 | 2802 | 1246 | 702 | 450 | 313 | 230 | 176 |
| **75** | 12811 | 3204 | 1425 | 802 | 514 | 357 | 263 | 202 |
| **80** | 14724 | 3682 | 1637 | 922 | 590 | 410 | 302 | 231 |
| **85** | 17122 | 4282 | 1904 | 1071 | 686 | 477 | 351 | 269 |
| **90** | 20396 | 5100 | 2267 | 1276 | 817 | 568 | 418 | 320 |
| **95** | 25774 | 6445 | 2865 | 1612 | 1032 | 717 | 527 | 404 |

**Table A2. Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in wetland plant species richness**
Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Countryside Survey 2007
Stratification – none
Design – Matched pairs

| $\alpha_{0.05}$ | % change pond plant species richness | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 515 | 130 | 59 | 34 | 23 | 16 | 13 | 10 |
| **65** | 578 | 146 | 66 | 38 | 25 | 18 | 14 | 11 |
| **70** | 648 | 164 | 74 | 42 | 28 | 20 | 15 | 12 |
| **75** | 729 | 184 | 83 | 47 | 31 | 22 | 17 | 13 |
| **80** | 824 | 208 | 93 | 53 | 35 | 25 | 19 | 15 |
| **85** | 942 | 237 | 106 | 61 | 40 | 28 | 21 | 17 |
| **90** | 1102 | 277 | 124 | 71 | 46 | 33 | 25 | 19 |
| **95** | 1363 | 342 | 153 | 87 | 56 | 40 | 30 | 23 |
| $\alpha_{0.10}$ | % change pond plant species richness | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 379 | 96 | 43 | 25 | 17 | 12 | 9 | 7 |
| **65** | 433 | 109 | 49 | 28 | 19 | 14 | 10 | 8 |
| **70** | 494 | 125 | 56 | 32 | 21 | 15 | 12 | 9 |
| **75** | 565 | 142 | 64 | 37 | 24 | 17 | 13 | 10 |
| **80** | 649 | 163 | 73 | 42 | 27 | 19 | 15 | 12 |
| **85** | 754 | 190 | 85 | 49 | 32 | 22 | 17 | 13 |
| **90** | 898 | 226 | 101 | 57 | 37 | 26 | 20 | 16 |
| **95** | 1135 | 285 | 127 | 72 | 47 | 33 | 25 | 19 |

**Table A3. Streams: power analysis of sample size required at time$_1$ and time$_2$ to detect a change in wetland plant species richness**
Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Countryside Survey 2007
Stratification – none
Design – Matched pairs

| $\alpha_{0.05}$ | % change stream plant species richness | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 379 | 96 | 43 | 25 | 17 | 12 | 9 | 7 |
| **65** | 433 | 109 | 49 | 28 | 19 | 14 | 10 | 8 |
| **70** | 494 | 125 | 56 | 32 | 21 | 15 | 12 | 9 |
| **75** | 565 | 142 | 64 | 37 | 24 | 17 | 13 | 10 |
| **80** | 649 | 163 | 73 | 42 | 27 | 19 | 15 | 12 |
| **85** | 754 | 190 | 85 | 49 | 32 | 22 | 17 | 13 |
| **90** | 898 | 226 | 101 | 57 | 37 | 26 | 20 | 16 |
| **95** | 1135 | 285 | 127 | 72 | 47 | 33 | 25 | 19 |
| $\alpha_{0.10}$ | % change stream plant species richness | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 248 | 63 | 28 | 16 | 11 | 8 | 6 | 5 |
| **65** | 292 | 74 | 33 | 19 | 13 | 9 | 7 | 6 |
| **70** | 342 | 86 | 39 | 22 | 15 | 10 | 8 | 6 |
| **75** | 402 | 101 | 45 | 26 | 17 | 12 | 9 | 7 |
| **80** | 473 | 119 | 53 | 30 | 20 | 14 | 11 | 8 |
| **85** | 564 | 142 | 63 | 36 | 23 | 17 | 12 | 10 |
| **90** | 689 | 173 | 77 | 44 | 28 | 20 | 15 | 12 |
| **95** | 898 | 225 | 101 | 57 | 37 | 26 | 19 | 15 |

**Table A4. Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in wetland plant species richness**
Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Countryside Survey 2007
Stratification – none
Design – Independent

| $\alpha_{0.05}$ | % change pond plant species richness | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 1511 | 379 | 169 | 96 | 62 | 43 | 32 | 25 |
| **65** | 1728 | 433 | 193 | 109 | 71 | 49 | 37 | 28 |
| **70** | 1973 | 494 | 220 | 125 | 80 | 56 | 42 | 32 |
| **75** | 2255 | 565 | 252 | 142 | 92 | 64 | 47 | 37 |
| **80** | 2591 | 649 | 289 | 163 | 105 | 73 | 54 | 42 |
| **85** | 3013 | 754 | 336 | 190 | 122 | 85 | 63 | 49 |
| **90** | 3589 | 898 | 400 | 226 | 145 | 101 | 75 | 58 |
| **95** | 4535 | 1135 | 505 | 285 | 183 | 127 | 94 | 72 |
| $\alpha_{0.10}$ | % change pond plant species richness | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 988 | 248 | 111 | 63 | 40 | 28 | 21 | 16 |
| **65** | 1165 | 292 | 130 | 74 | 47 | 33 | 25 | 19 |
| **70** | 1367 | 342 | 153 | 86 | 56 | 39 | 29 | 22 |
| **75** | 1604 | 402 | 179 | 101 | 65 | 45 | 34 | 26 |
| **80** | 1889 | 473 | 211 | 119 | 76 | 53 | 39 | 30 |
| **85** | 2252 | 564 | 251 | 142 | 91 | 63 | 47 | 36 |
| **90** | 2753 | 689 | 307 | 173 | 111 | 77 | 57 | 44 |
| **95** | 3588 | 898 | 399 | 225 | 144 | 101 | 74 | 57 |

**Table A5. Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in wetland plant species richness**
Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Countryside Survey 2007
Stratification – none
Design – Independent

| $\alpha_{0.05}$ | % change stream plant species richness | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 1511 | 379 | 169 | 96 | 62 | 43 | 32 | 25 |
| **65** | 1728 | 433 | 193 | 109 | 71 | 49 | 37 | 28 |
| **70** | 1973 | 494 | 220 | 125 | 80 | 56 | 42 | 32 |
| **75** | 2255 | 565 | 252 | 142 | 92 | 64 | 47 | 37 |
| **80** | 2591 | 649 | 289 | 163 | 105 | 73 | 54 | 42 |
| **85** | 3013 | 754 | 336 | 190 | 122 | 85 | 63 | 49 |
| **90** | 3589 | 898 | 400 | 226 | 145 | 101 | 75 | 58 |
| **95** | 4535 | 1135 | 505 | 285 | 183 | 127 | 94 | 72 |
| $\alpha_{0.10}$ | **% change stream plant species richness** | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 988 | 248 | 111 | 63 | 40 | 28 | 21 | 16 |
| **65** | 1165 | 292 | 130 | 74 | 47 | 33 | 25 | 19 |
| **70** | 1367 | 342 | 153 | 86 | 56 | 39 | 29 | 22 |
| **75** | 1604 | 402 | 179 | 101 | 65 | 45 | 34 | 26 |
| **80** | 1889 | 473 | 211 | 119 | 76 | 53 | 39 | 30 |
| **85** | 2252 | 564 | 251 | 142 | 91 | 63 | 47 | 36 |
| **90** | 2753 | 689 | 307 | 173 | 111 | 77 | 57 | 44 |
| **95** | 3588 | 898 | 399 | 225 | 144 | 101 | 74 | 57 |

**Table A6. Streams: Power analysis of sample size required at $time_1$ and $time_2$ to detect a change in Trophic Diatom Index 3**

Analysis – Wilcoxon-Mann-Whitney test (two groups) Environment Agency national monitoring programme 2016 data
Data used – Environment Agency national monitoring programme 2016 data
Stratification – none
Design – Independent

| $\alpha_{0.05}$ | % change pond plant species richness | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 290 | 74 | 34 | 20 | 14 | 10 | 8 | 7 |
| **65** | 326 | 83 | 38 | 22 | 15 | 11 | 9 | 8 |
| **70** | 365 | 93 | 42 | 25 | 17 | 12 | 10 | 8 |
| **75** | 410 | 104 | 47 | 28 | 19 | 14 | 11 | 9 |
| **80** | 464 | 117 | 53 | 31 | 21 | 15 | 12 | 10 |
| **85** | 530 | 134 | 61 | 35 | 23 | 17 | 13 | 11 |
| **90** | 620 | 157 | 71 | 41 | 27 | 19 | 15 | 12 |
| **95** | 766 | 193 | 87 | 50 | 33 | 23 | 18 | 14 |
| $\alpha_{0.10}$ | % change pond plant species richness | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 213 | 54 | 25 | 15 | 10 | 8 | 6 | 5 |
| **65** | 244 | 62 | 28 | 17 | 11 | 9 | 7 | 6 |
| **70** | 278 | 71 | 32 | 19 | 13 | 9 | 8 | 6 |
| **75** | 318 | 81 | 37 | 21 | 14 | 11 | 8 | 7 |
| **80** | 365 | 92 | 42 | 24 | 16 | 12 | 9 | 8 |
| **85** | 424 | 107 | 48 | 28 | 19 | 13 | 10 | 8 |
| **90** | 505 | 127 | 57 | 33 | 22 | 16 | 12 | 10 |
| **95** | 638 | 161 | 72 | 41 | 27 | 19 | 15 | 12 |

**Table A7. Streams: Power analysis of sample size required at $time_1$ and $time_2$ to detect a change in Environment Trophic Diatom Index 3**

Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Environment Agency national monitoring programme 2016 data
Stratification – None
Design – Matched pairs

| $\alpha_{0.05}$ | % change pond plant species richness | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 54 | 15 | 7 | 5 | 4 | 3 | 3 | 3 |
| **65** | 62 | 17 | 8 | 5 | 4 | 3 | 3 | 3 |
| **70** | 71 | 19 | 9 | 6 | 5 | 4 | 3 | 3 |
| **75** | 81 | 21 | 10 | 7 | 5 | 4 | 3 | 3 |
| **80** | 92 | 24 | 12 | 7 | 5 | 4 | 4 | 3 |
| **85** | 107 | 28 | 13 | 8 | 6 | 5 | 4 | 4 |
| **90** | 127 | 33 | 16 | 9 | 7 | 5 | 4 | 4 |
| **95** | 161 | 41 | 19 | 12 | 8 | 6 | 5 | 4 |
| $\alpha_{0.10}$ | % change pond plant species richness | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 36 | 10 | 5 | 3 | 3 | 2 | 2 | 2 |
| **65** | 42 | 11 | 6 | 4 | 3 | 2 | 2 | 2 |
| **70** | 49 | 13 | 6 | 4 | 3 | 3 | 2 | 2 |
| **75** | 57 | 15 | 7 | 5 | 3 | 3 | 3 | 2 |
| **80** | 67 | 17 | 8 | 5 | 4 | 3 | 3 | 2 |
| **85** | 80 | 21 | 10 | 6 | 4 | 3 | 3 | 3 |
| **90** | 97 | 25 | 12 | 7 | 5 | 4 | 3 | 3 |
| **95** | 127 | 32 | 15 | 9 | 6 | 5 | 4 | 3 |

**Table A8. Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in Riverfly ARMI monitoring score**

Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Results from Riverfly survey 2016
Stratification – none
Design – Matched pairs

| $\alpha_{0.05}$ | % change stream macroinvertebrate taxon richness | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Power** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 319 | 81 | 22 | 11 | 7 | 5 | 4 | 4 | 4 |
| **65** | 358 | 91 | 24 | 12 | 8 | 6 | 5 | 4 | 4 |
| **70** | 401 | 102 | 27 | 13 | 8 | 6 | 5 | 4 | 4 |
| **75** | 451 | 114 | 30 | 15 | 9 | 7 | 5 | 5 | 4 |
| **80** | 510 | 129 | 34 | 16 | 10 | 7 | 6 | 5 | 4 |
| **85** | 583 | 147 | 38 | 18 | 11 | 8 | 6 | 5 | 5 |
| **90** | 682 | 172 | 45 | 21 | 13 | 9 | 7 | 6 | 5 |
| **95** | 843 | 212 | 55 | 25 | 15 | 11 | 8 | 7 | 6 |
| $\alpha_{0.10}$ | % change stream macroinvertebrate taxon richness | | | | | | | | |
| **Power** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 234 | 60 | 16 | 8 | 5 | 4 | 3 | 3 | 3 |
| **65** | 268 | 68 | 18 | 9 | 6 | 4 | 4 | 3 | 3 |
| **70** | 306 | 78 | 21 | 10 | 6 | 5 | 4 | 3 | 3 |
| **75** | 349 | 88 | 23 | 11 | 7 | 5 | 4 | 4 | 3 |
| **80** | 401 | 101 | 26 | 13 | 8 | 6 | 5 | 4 | 3 |
| **85** | 466 | 118 | 31 | 14 | 9 | 6 | 5 | 4 | 4 |
| **90** | 555 | 140 | 36 | 17 | 10 | 7 | 6 | 5 | 4 |
| **95** | 702 | 176 | 45 | 21 | 13 | 9 | 7 | 5 | 5 |

**Table A9. Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in Riverfly ARMI monitoring score**
Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Riverfly data 2016
Stratification – none
Design – Independent

| $\alpha_{0.05}$ | % change stream macroinvertebrate taxon richness | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Power** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 1270 | 319 | 81 | 37 | 22 | 15 | 11 | 9 | 8 |
| **65** | 1425 | 358 | 91 | 42 | 24 | 16 | 12 | 10 | 8 |
| **70** | 1599 | 401 | 102 | 46 | 27 | 18 | 13 | 11 | 9 |
| **75** | 1798 | 451 | 114 | 52 | 30 | 20 | 15 | 12 | 9 |
| **80** | 2033 | 510 | 129 | 58 | 34 | 23 | 16 | 13 | 10 |
| **85** | 2325 | 583 | 147 | 67 | 38 | 25 | 18 | 14 | 11 |
| **90** | 2721 | 682 | 172 | 78 | 45 | 29 | 21 | 16 | 13 |
| **95** | 3365 | 843 | 212 | 95 | 55 | 36 | 26 | 19 | 15 |
| $\alpha_{0.10}$ | % change stream macroinvertebrate taxon richness | | | | | | | | |
| **Power** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 933 | 234 | 60 | 27 | 16 | 11 | 8 | 7 | 6 |
| **65** | 1068 | 268 | 68 | 31 | 18 | 12 | 9 | 7 | 6 |
| **70** | 1219 | 306 | 78 | 35 | 21 | 14 | 10 | 8 | 7 |
| **75** | 1393 | 349 | 88 | 40 | 23 | 16 | 11 | 9 | 7 |
| **80** | 1601 | 401 | 101 | 46 | 27 | 18 | 13 | 10 | 8 |
| **85** | 1862 | 466 | 118 | 53 | 31 | 20 | 15 | 11 | 9 |
| **90** | 2217 | 555 | 140 | 63 | 36 | 24 | 17 | 13 | 10 |
| **95** | 2802 | 702 | 176 | 79 | 45 | 30 | 21 | 16 | 13 |

**Table A10. Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in stream macroinvertebrate taxon richness**

Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Results from Countryside Survey 2007
Stratification – none
Design – Matched pairs

| $\alpha_{0.05}$ | % change stream macroinvertebrate taxon richness | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Power** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 319 | 81 | 22 | 11 | 7 | 5 | 4 | 4 | 4 |
| **65** | 358 | 91 | 24 | 12 | 8 | 6 | 5 | 4 | 4 |
| **70** | 401 | 102 | 27 | 13 | 8 | 6 | 5 | 4 | 4 |
| **75** | 451 | 114 | 30 | 15 | 9 | 7 | 5 | 5 | 4 |
| **80** | 510 | 129 | 34 | 16 | 10 | 7 | 6 | 5 | 4 |
| **85** | 583 | 147 | 38 | 18 | 11 | 8 | 6 | 5 | 5 |
| **90** | 682 | 172 | 45 | 21 | 13 | 9 | 7 | 6 | 5 |
| **95** | 843 | 212 | 55 | 25 | 15 | 11 | 8 | 7 | 6 |
| $\alpha_{0.10}$ | % change stream macroinvertebrate taxon richness | | | | | | | | |
| **Power** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 319 | 60 | 16 | 8 | 5 | 4 | 3 | 3 | 3 |
| **65** | 365 | 68 | 18 | 9 | 6 | 4 | 4 | 3 | 3 |
| **70** | 416 | 78 | 21 | 10 | 6 | 5 | 4 | 3 | 3 |
| **75** | 476 | 88 | 23 | 11 | 7 | 5 | 4 | 4 | 3 |
| **80** | 547 | 101 | 26 | 13 | 8 | 6 | 5 | 4 | 3 |
| **85** | 635 | 118 | 31 | 14 | 9 | 6 | 5 | 4 | 4 |
| **90** | 757 | 140 | 36 | 17 | 10 | 7 | 6 | 5 | 4 |
| **95** | 956 | 176 | 45 | 21 | 13 | 9 | 7 | 5 | 5 |

**Table A11. Streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in stream macroinvertebrate taxon richness**
Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Countryside Survey 2007
Stratification – none
Design – Independent

| $\alpha_{0.05}$ | % change stream macroinvertebrate taxon richness | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 319 | 81 | 37 | 21 | 14 | 11 | 8 | 7 |
| **65** | 365 | 92 | 42 | 24 | 16 | 12 | 9 | 8 |
| **70** | 416 | 105 | 48 | 27 | 18 | 13 | 10 | 8 |
| **75** | 476 | 120 | 54 | 31 | 21 | 15 | 11 | 9 |
| **80** | 547 | 138 | 62 | 36 | 23 | 17 | 13 | 10 |
| **85** | 635 | 160 | 72 | 41 | 27 | 19 | 15 | 12 |
| **90** | 757 | 190 | 85 | 49 | 32 | 23 | 17 | 13 |
| **95** | 956 | 240 | 107 | 61 | 40 | 28 | 21 | 17 |
| $\alpha_{0.10}$ | **% change stream macroinvertebrate taxon richness** | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 209 | 53 | 24 | 14 | 9 | 7 | 6 | 5 |
| **65** | 246 | 62 | 28 | 16 | 11 | 8 | 6 | 5 |
| **70** | 288 | 73 | 33 | 19 | 13 | 9 | 7 | 6 |
| **75** | 338 | 85 | 38 | 22 | 15 | 10 | 8 | 7 |
| **80** | 398 | 100 | 45 | 26 | 17 | 12 | 9 | 7 |
| **85** | 475 | 119 | 54 | 31 | 20 | 14 | 11 | 9 |
| **90** | 580 | 146 | 65 | 37 | 24 | 17 | 13 | 10 |
| **95** | 756 | 190 | 85 | 48 | 31 | 22 | 16 | 13 |

**Table A12. Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in pond macroinvertebrate species richness**
Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Results from Countryside Survey 2007
Stratification – none
Design – Matched pairs

| $\alpha_{0.05}$ | % change stream macroinvertebrate taxon richness | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Power** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | | 96 | 25 | 13 | 8 | 6 | 5 | 4 | 4 |
| **65** | | 107 | 28 | 14 | 9 | 6 | 5 | 4 | 4 |
| **70** | | 120 | 32 | 15 | 10 | 7 | 6 | 5 | 4 |
| **75** | | 135 | 35 | 17 | 10 | 8 | 6 | 5 | 4 |
| **80** | | 152 | 40 | 19 | 12 | 8 | 6 | 5 | 5 |
| **85** | | 174 | 45 | 21 | 13 | 9 | 7 | 6 | 5 |
| **90** | | 203 | 52 | 24 | 15 | 10 | 8 | 6 | 6 |
| **95** | | 250 | 64 | 30 | 18 | 12 | 9 | 7 | 6 |
| $\alpha_{0.10}$ | % change stream macroinvertebrate taxon richness | | | | | | | | |
| **Power** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | | 70 | 19 | 9 | 6 | 4 | 4 | 3 | 3 |
| **65** | | 80 | 21 | 10 | 7 | 5 | 4 | 3 | 3 |
| **70** | | 91 | 24 | 12 | 7 | 5 | 4 | 4 | 3 |
| **75** | | 104 | 27 | 13 | 8 | 6 | 5 | 4 | 3 |
| **80** | | 120 | 31 | 15 | 9 | 6 | 5 | 4 | 4 |
| **85** | | 139 | 36 | 17 | 10 | 7 | 6 | 5 | 4 |
| **90** | | 165 | 42 | 20 | 12 | 8 | 6 | 5 | 4 |
| **95** | | 208 | 53 | 24 | 14 | 10 | 7 | 6 | 5 |

**Table A13. Ponds: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in pond macroinvertebrate species richness**

Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Countryside Survey 2007
Stratification – none
Design – Independent

| $\alpha_{0.05}$ | % change stream macroinvertebrate taxon richness | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 376 | 96 | 44 | 26 | 17 | 13 | 10 | 8 |
| **65** | 422 | 107 | 49 | 28 | 19 | 14 | 11 | 9 |
| **70** | 474 | 120 | 55 | 32 | 21 | 15 | 12 | 10 |
| **75** | 533 | 135 | 61 | 35 | 23 | 17 | 13 | 11 |
| **80** | 602 | 152 | 69 | 40 | 26 | 19 | 15 | 12 |
| **85** | 688 | 174 | 78 | 45 | 30 | 21 | 16 | 13 |
| **90** | 805 | 203 | 91 | 52 | 34 | 25 | 19 | 15 |
| **95** | 995 | 250 | 112 | 64 | 42 | 30 | 23 | 18 |
| $\alpha_{0.10}$ | % change stream macroinvertebrate taxon richness | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 277 | 70 | 32 | 19 | 13 | 9 | 8 | 6 |
| **65** | 316 | 80 | 36 | 21 | 14 | 10 | 8 | 7 |
| **70** | 361 | 91 | 41 | 24 | 16 | 12 | 9 | 8 |
| **75** | 413 | 104 | 47 | 27 | 18 | 13 | 10 | 8 |
| **80** | 474 | 120 | 54 | 31 | 20 | 15 | 11 | 9 |
| **85** | 551 | 139 | 63 | 36 | 24 | 17 | 13 | 10 |
| **90** | 656 | 165 | 74 | 42 | 28 | 20 | 15 | 12 |
| **95** | 829 | 208 | 93 | 53 | 35 | 25 | 19 | 15 |

**Table A14. Fish in streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in fish species richness in streams**
Analysis – Wilcoxon-Mann-Whitney test (two groups)
Data used – Results from Water Friendly Farming project 2012 and 2013
Stratification – None
Design – Independent

| $\alpha_{0.05}$ | % change | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 1617 | 406 | 182 | 103 | 67 | 47 | 35 | 27 |
| **65** | 1816 | 455 | 204 | 115 | 75 | 52 | 39 | 30 |
| **70** | 2037 | 511 | 228 | 129 | 83 | 59 | 44 | 34 |
| **75** | 2291 | 574 | 256 | 145 | 94 | 66 | 49 | 38 |
| **80** | 2590 | 649 | 290 | 164 | 106 | 74 | 55 | 43 |
| **85** | 2963 | 742 | 331 | 187 | 120 | 84 | 63 | 48 |
| **90** | 3467 | 868 | 387 | 219 | 141 | 98 | 73 | 56 |
| **95** | 4287 | 1073 | 478 | 270 | 173 | 121 | 90 | 69 |
| $\alpha_{0.10}$ | **% change** | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 1189 | 298 | 133 | 76 | 49 | 34 | 26 | 20 |
| **65** | 1360 | 341 | 152 | 86 | 56 | 39 | 29 | 23 |
| **70** | 1553 | 389 | 174 | 98 | 64 | 45 | 33 | 26 |
| **75** | 1775 | 445 | 199 | 112 | 72 | 51 | 38 | 29 |
| **80** | 2040 | 511 | 228 | 129 | 83 | 58 | 43 | 33 |
| **85** | 2372 | 594 | 265 | 150 | 96 | 67 | 50 | 39 |
| **90** | 2826 | 707 | 315 | 178 | 114 | 80 | 59 | 46 |
| **95** | 3570 | 894 | 398 | 224 | 144 | 101 | 74 | 57 |

**Table A15. Fish in streams: power analysis of sample size required at $time_1$ and $time_2$ to detect a change in fish species richness in streams**
Analysis – Wilcoxon signed-rank test (matched pairs)
Data used – Results from Water Friendly Farming project 2012 and 2013
Stratification – None
Design – Matched pairs

| $\alpha_{0.05}$ | % change | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 298 | 76 | 34 | 20 | 13 | 10 | 8 | 6 |
| **65** | 341 | 86 | 39 | 23 | 15 | 11 | 9 | 7 |
| **70** | 389 | 98 | 45 | 26 | 17 | 12 | 9 | 8 |
| **75** | 445 | 112 | 51 | 29 | 19 | 14 | 11 | 9 |
| **80** | 511 | 129 | 58 | 33 | 22 | 16 | 12 | 10 |
| **85** | 594 | 150 | 67 | 39 | 25 | 18 | 14 | 11 |
| **90** | 707 | 178 | 80 | 46 | 30 | 21 | 16 | 13 |
| **95** | 894 | 224 | 101 | 57 | 37 | 26 | 20 | 15 |
| $\alpha_{0.10}$ | % change | | | | | | | |
| **Power** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** |
| **60** | 195 | 49 | 22 | 13 | 9 | 6 | 5 | 4 |
| **65** | 230 | 58 | 26 | 15 | 10 | 7 | 6 | 5 |
| **70** | 270 | 68 | 31 | 18 | 12 | 8 | 7 | 5 |
| **75** | 316 | 80 | 36 | 21 | 14 | 10 | 7 | 6 |
| **80** | 373 | 94 | 42 | 24 | 16 | 11 | 9 | 7 |
| **85** | 444 | 112 | 50 | 29 | 19 | 13 | 10 | 8 |
| **90** | 542 | 136 | 61 | 35 | 23 | 16 | 12 | 9 |
| **95** | 707 | 177 | 79 | 45 | 29 | 21 | 15 | 12 |

# Appendix 2. National Trust Land Condition Assessment Guidance

| **Healthy: Water** | **LCA score 1** | **LCA score 2** | **LCA score 3** | **LCA score 4** | **LCA score 5** |
|---|---|---|---|---|---|
| | **Very good** | **Good** | **Moderate** | **Poor** | **Worst** |
| | **High quality water indicators throughout the year** | | **Generally acceptable** | **Significant scope for improvement** | **Fails Minimum Standard** |
| | **Very high quality indicators evident and abundant throughout year and no evidence of adverse impacts**<br><br>Confirmed by examination of water samples | **High quality indicators evident throughout year, limited or no evidence of adverse impacts**<br><br>Confirmed by observations | **Limited evidence of high quality indicators. Any adverse impacts are very localised and temporary**<br><br>Confirmed by observations | **Evidence of significant/ severe pollution and water quality issues. No high quality indicators present**<br><br>Confirmed by observations | **Evidence of issues or practices that could represent a breach of legal compliance and/or would result in serious reputational damage for the Trust.** *(Presumption that as a minimum all NT land must comply with legal and statutory cross compliance obligations, and any further unacceptable situations shown below)* |
| **Characteristic** | **detail** | **detail** | **detail** | **detail** | **detail** |
| **Guidance: Scores judged on visual assessment of watercourses and knowledge of seasonal impacts across range of streams, ditches and ponds.** | | | | | |
| **Point source pollution**<br>e.g. slurry; farm yard manure; dirty water; silage liquor; parlour washings; food processing waste. chemical and fuel pollutants, agricultural / industrial waste, domestic sewerage | No evident point source pollution. | No evident point source pollution. | Minor/short-lived point source pollution | **Significant** point source pollution entering watercourses and /or soakaways. | **Severe**/ **persistent** point source pollution entering watercourses and /or soakaways.<br>Signs include: foul smell, surface films, discolouration, sewage fungus etc. |
| **Farm Infrastructure Pollution Risk Assessment**<br>The risk posed by the condition of farm infrastructure combined with location and drainage that could allow the escape of hazardous material to enter drains or groundwater or a water body.<br>(See FIPRA score on MI dashboard). | **Negligible risk**<br>*(FIPRA SCORE 20-30)*<br>***or***<br>***no associated farm infrastructure present .***<br>*such as: silage clamps, slurry / FYM stores, dirty water stores, dipping facilities, agricultural fuel tanks, fertiliser and chemical stores.* | **Minor risk**<br>*(FIPRA score 30-40)* | **Moderate risk**<br>*(FIPRA score 40-60)* | **High risk**<br>*(FIPRA score 60-70)* | **Very high risk**<br>*(FIPRA score >70)* |

| | | | | | |
|---|---|---|---|---|---|
| Note: 1) *If FIPRA score >60 (High Risk), review FIPRA assessment by site visit and plan action to resolve issue, e.g. upgrade or decommission high risk infrastructure*<br>2) *If date of FIPRA assessment is >5 years old, plan to undertake reassessment of site.* | | | | | |
| **Siltation and turbidity** | High water clarity and clean gravels (where appropriate). No sign of soil erosion issues. | Turbidity issues limited to periods when very high rainfall coincides with limited ground cover (bare fields). No signs of silt accumulating in watercourses and no signs of erosion. | Turbidity issues limited to periods when very high rainfall coincides with limited ground cover (bare fields). In channel silt found in very slow water areas and dispersed during high flows. | Year round turbidity and/or high levels of fine silt smothering gravels. Obvious soil erosion issues which are impacting water courses. | Consistent with/attributable to severe pollution issues. |
| **Healthy: Water** (cont.) | **LCA score 1** | **LCA score 2** | **LCA score 3** | **LCA score 4** | **LCA score 5** |
| **Characteristic** | **detail** | **detail** | **detail** | **detail** | **detail** |
| **Biological indicators: Invertebrates**<br>*Note: some naturally low pH (acidic) waters will not support diverse aquatic invertebrates* | Abundant invertebrates across sensitive taxa (stoneflies, mayflies). | Abundant invertebrates but some highly sensitive taxa may be missing. | Moderate invertebrate diversity and abundance. | Limited (e.g. pollution tolerant), or absent aquatic invertebrate biodiversity. | Consistent with/attributable to severe pollution issues. |
| **Biological indicators: Plants and algae** | Diverse aquatic plant community (including mosses, liverworts and algae). In particular diverse range of submerged plants including sensitive species such as stoneworts. | Good range of aquatic plants present with different growth forms (submerged, emergent and floating). | Limited plant diversity and mainly emergent species present. Occasional algal problems e.g. late summer blooms. | Aquatic plants very limited (only one or two species present), or non-existent. Regular algal problems (filamentous or planktonic) e.g. green coloured water or dense floating mats of algae throughout the summer. | Consistent with/attributable to severe pollution issues. |

# Appendix 3. Examples of species of conservation concern for which survey methods have been developed as part of PondNet.

Links are provided to the species' recording forms on the Freshwater Habitats Trust website for selected species of conservation concern covered by the PondNet project.

- Adder's-tongue Spearwort: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/4-ADDERS-TONGUE-SPEARWORT-RARE-SPECIES-RECORDING-SHEET-FINAL.pdf
- Brown Galingale: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/6-BROWN-GALINGALE-RARE-SPECIES-RECORDING-SHEET-FINAL.pdf
- Coral Necklace: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/7-CORAL-NECKLACE-RARE-SPECIES-RECORDING-SHEET-FINAL.pdf
- Greater Water-parsnip: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/12-GREATER-WATER-PARSNIP-RARE-SPECIES-RECORDING-SHEET-FINAL.pdf
- Pillwort: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/21-PILLWORT-RARE-SPECIES-RECORDING-SHEET-FINAL.pdf
- Starfruit: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/25-STARFRUIT-RARE-SPECIES-RECORDING-SHEET-FINAL1.pdf
- Three-lobed Water-crowfoot: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/29-THREE-LOBED-WATER_CROWFOOT-RARE-SPECIES-RECORDING-SHEET-FINAL.pdf
- Tubular Water-dropwort: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/30-TUBULAR-WATER-DROPWORT-RARE-SPECIES-RECORDING-SHEET-FINAL.pdf
- Yellow Centaury: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/32-YELLOW-CENTAURY-RARE-SPECIES-RECORDING-SHEET-FINAL.pdf
- Medicinal Leech: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/17-MEDICINAL-LEECH-RARE-SPECIES-RECORDING-SHEET-FINAL.pdf
- Fairy Shrimp: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/9-FAIRY-SHRIMP-RARE-SPECIES-RECORDING-SHEET-FINAL.pdf
- Pond Mud Snail: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/22-POND-MUD-SNAIL-RARE-SPECIES-RECORDING-SHEET-FINAL.pdf
- Tadpole Shrimp: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/27-TADPOLE-SHRIMP-RARE-SPECIES-RECORDING-SHEET-FINAL.pdf
- Common toad: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/2-COMMON-TOAD-AND-COMMON-FROG-FINAL.pdf
- Great crested newt: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/3-eDNA-GREAT-CRESTED-NEWT-RECORDING-FORM-FINAL.pdf

# Appendix 4. PondNet pond habitat recording form

A link is given here to the to PondNet habitat recording form on the Freshwater Habitats Trust web site.

https://freshwaterhabitats.org.uk/wp-content/uploads/2015/03/1-POND-HABITAT-SURVEY-RECORDING-FORM-FINAL.pdf.