Improvement Programme for England's Natura 2000 Sites (IPENS) – Planning for the Future IPENS060

Design of a vegetation monitoring scheme for the Border Mires

Border Mires, Kielder – Butterburn Special Area of Conservation (SAC)

First published 04 September 2015

www.gov.uk/government/publications/improvement-programme-for-englands-natura-2000-sites-ipens

Environment Agency

NATURAL ENGLAND

This project is part of the IPENS programme (LIFE11NAT/UK/000384IPENS) which is financially supported by LIFE, a financial instrument of the European Community'.

Foreword

The **Improvement Programme for England's Natura 2000 sites (IPENS)**, supported by European Union LIFE+ funding, is a new strategic approach to managing England's Natura 2000 sites. It is enabling Natural England, the Environment Agency, and other key partners to plan what, how, where and when they will target their efforts on Natura 2000 sites and areas surrounding them.

As part of the IPENS programme, we are identifying gaps in our knowledge and, where possible, addressing these through a range of evidence projects. The project findings are being used to help develop our Theme Plans and Site Improvement Plans. This report is one of the evidence project studies we commissioned.

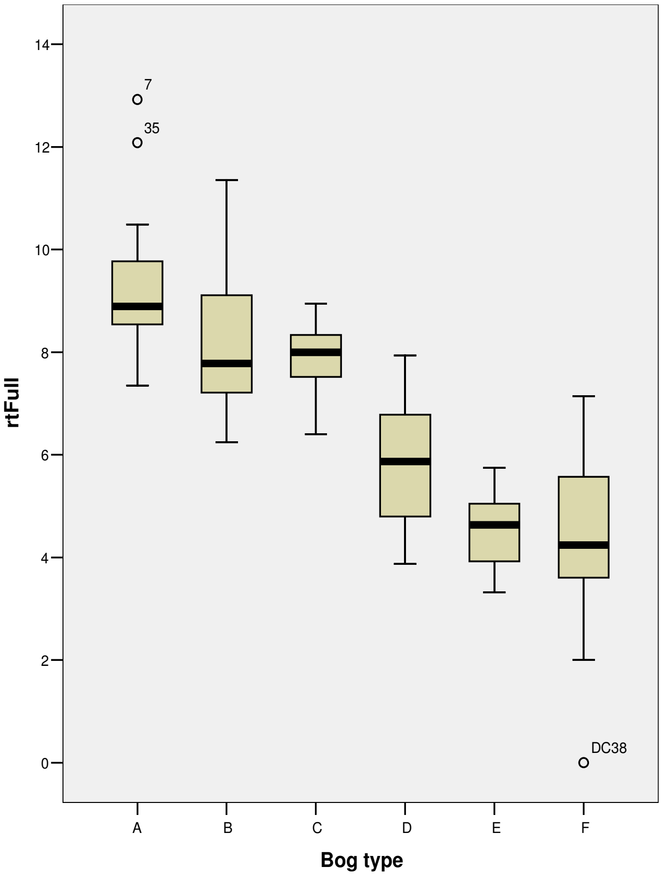
The Border Mires, Kielder – Butterburn Special Area of Conservation (SAC) includes a complex of blanket and intermediate mires within the large-scale plantation of Kielder Forest in the north of England. Monitoring recovery towards good ecological condition in the Border Mires is complicated by the vast range of mire types within the SAC complex. LIFE funded restoration work between 1998 and 2010 trialled different harvesting techniques during the deforestation of important mire lenses. The Border Mires SAC provides an opportunity to establish baselines and compare success rates of mire recovery from different harvesting techniques, compared to intact mires, and therefore inform best practice/techniques for the future.

This project was commissioned to design a Bog Quality Index. This uses a robust, repeatable methodology that will allow long term trends in habitat change to be statistically monitored by all partner organisations and future graduate studies in a comparable way. The methodology has wider implications for the monitoring of other blanket / intermediate mire sites, such as Bolton Fell and Walton Moss SAC.

Natural England Project officer: Emma Austin, **emma.austin@naturalengland.org.uk**

ISBN 978-1-78354-236-9

Design of a vegetation monitoring scheme for the Border Mires



Comparison of bog quality index scores (full method) for 6 types of bog from 'mixed bog' dataset

2m x 2m quadrat with 16 cells in recovering bog vegetation at Stanley Moss

PTYXIS ECOLOGY
3 Railway Cottages
Lambley
CA8 7LL
T – 01434 321199
M – 07884 160756
E – enquiries@ptyxis.com
W – www.ptyxis.com

Author
John O'Reilly BA(Ed) MSc MIEEM CEnv

Table of contents

Summary

The Border Mires SAC includes a large number (perhaps 60 to 100) of relatively intact raised/intermediate bogs on deep peat, as well as large tracts of hillside blanket bogs and smaller areas of other types of mire. The mires on deep peat in particular are the outstanding feature of the SAC.

A proposed vegetation monitoring scheme is outlined here, which is focussed mainly on monitoring the deep peat sites, but caters for blanket bog sites also. It was desired that the scheme be repeatable, statistically robust, cater for as many mire types as possible and that the direction of change could be related to favourable condition. It was also requested that ideally the scheme should be simple enough so that surveyors without much botanical expertise could do it.

As we were not confident that a very simplified scheme would be worthwhile, we designed a scheme that we were confident would work (the **full** method) and then tested the reliability of three simpler variations (**intermediate**, **simple** and **minimal**) of this scheme on three separate datasets of bog vegetation quadrats. This also allowed us to investigate how many samples should be taken in any one survey and what effect stratifying sites into areas of different vegetation had.

We have incorporated the idea of a **bog quality index**, based on positive and negative indicator species. The bog quality index gives a single measure of the nature conservation quality of the bog, which can then be used to assess if or how the quality changes after doing a repeat survey.

Our main recommendations include:

- Accurate baseline surveys are the key starting point, so that sites can be stratified in the most useful way;
- The **full** method appears to be reliable, useful and reasonably statistically powerful;
- Ideally, at least the first time a site is surveyed the full method should be used;
- If short cuts are to be taken, then the **minimal** method could be used. It appears to perform almost as well as the **simple** method and takes much less survey effort.

The main chapters of a report provide a rationale for how we approached the task and discuss the main issues that were encountered. The proposed survey methodologies themselves are included in the appendices.

1 Introduction

1.1 The border mires

1.1.1 The term 'the border mires' refers to a large series of mires in Cumbria and Northumberland, close to the Scottish border. Different organisations have interpreted the term 'the border mires in different ways in the past, to include different (but overlapping) sets of sites. Sometimes the term has been used narrowly, to include only the raised or intermediate mires on deep peat, which are a particularly special feature of the mires in this area. Other uses of the term are broader, encompassing other mire types including, blanket mires on shallower peat on hill slopes, as well as a small number of valley mire and calcareous mire sites.

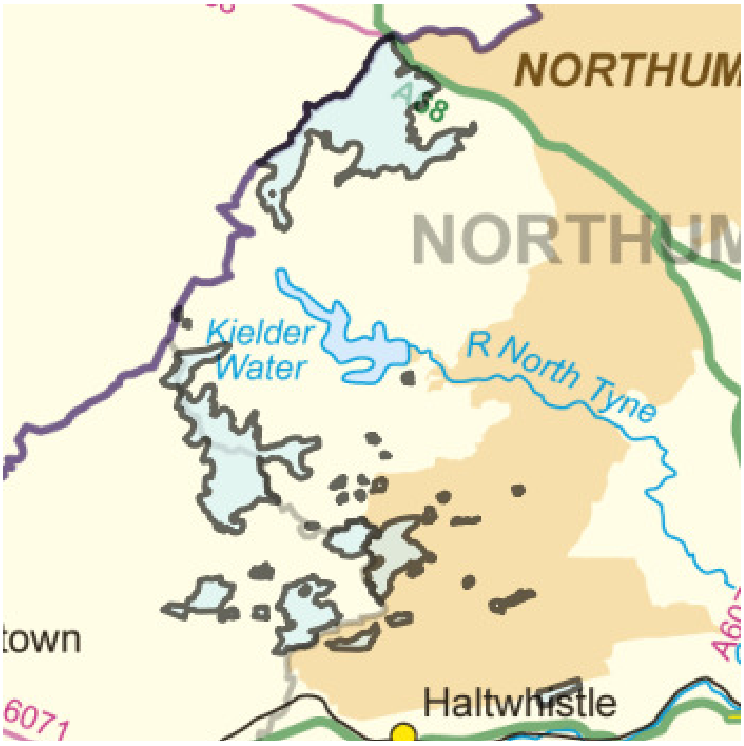


Fig 1: Location of sites included in the Border Mires SAC

1.1.2 For the purposes of this report the definition of 'the border mires' used, is that of **the border mires SAC**. The locations and rough boundaries of this SAC are shown in Fig 1 above. The larger polygons on this map are sites which are predominantly blanket mire, although these sometimes include smaller areas of mire on deep peat. The smaller polygons in the south-east are mostly raised/intermediate mires on deep peat. The SAC series also includes a small number of valley mire sites of various vegetation types. Some of the Cumbrian sites within the SAC in particular, include small areas of calcareous mires of various types.

1.1.3 The border mires SAC is comprised of the following SSSIs:

- Butterburn Flow
- Caudbeck Flow
- Kielderhead and Emblehope Moors
- Kileder Mires
- Lampert Mosses
- Muckle Moss
- Spadeadam Mires

1.2 Vegetation types

1.2.1 The proposed monitoring scheme presented here focuses mainly on the deep peat sites. On many of these sites, relatively large areas of the (National Vegetation Classification) NVC type M18a occur. M18a is high-quality bog vegetation, typical of intact, wet bogs on deep peat. It is characterised by extensive carpets of peat-forming *Sphagnum* species such as *Sphagnum papillosum*, *Sphagnum magellanicum* and *Sphagnum capillifolium*, with an often sparse and open vascular plant layer, including cross-leaved heath, heather, common cottongrass, hare's-tail cottongrass, bog asphodel, sundew, cranberry and bog rosemary.

1.2.2 On the more degraded deep peat sites, other types of bog vegetation may occur, but most or all of these degraded sites probably have potential to revert to M18a. These other bog vegetation types can also occur around the drier edges of the good quality M18a sites. They mainly include M18b, M19a and M19b, with forms of M20 of M25a on the most degraded sites, or in narrows bands around the driest edges of the better bogs.

1.2.3 A modified version of the proposed monitoring scheme also caters for blanket mire vegetation. Most of this blanket mire vegetation is the NVC type M19b. This is usually dominated by mixtures of heather, hare's-tail cottongrass and *Sphagnum capillifolium*.

1.2.4 The vegetation of the high-quality, deep peat sites can be relatively homogeneous over large areas, with most of the variation confined to the drier edges or, to areas that have had more dramatic management intervention in the past. The blanket mire sites on the other hand are often quite heterogeneous. Occasionally, extensive stands of relatively homogeneous M19b are encountered, but often there is a mosaic of vegetation types, including various types of dry (mainly H12) and wet (mainly M15) heath, flushes (often acid flushes including various types of M6, M23 or M4) or acid grasslands (mostly U4, U5 or U6). A blanket mire 'site' may sometimes only have blanket mire vegetation in less than half of its total area.

1.3 Management history

1.3.1 Many of the border mires sites have had atypical management histories in recent decades compared to mires in other areas. Most of the sites lie within Kielder Forest and some of the Cumbrian sites are within the Spadeadam military training area. In terms of mire conservation, this atypical management history has had both advantages and disadvantages. In the past, some areas of mire were ploughed and planted with conifers and attempts were made to prepare many other areas of mire for planting by digging drains. Since the early 1990s much restoration work has been carried out, removing conifers and blocking drains. Much of this was done as part of a major EU LIFE-funded project.

1.3.2 Most of the sites have also been protected from the excessive grazing and burning management associated with agricultural and grouse-moor management typical of other areas. The majority of the sites have not had significant grazing or burning for many decades.

1.4 Terminology

1.4.1 To avoid repetition, the following definitions are used throughout the report:

- **Blanket bog** = M19 heather/hare's-tail cottongrass/*Sphagnum capillifolium* vegetation on slopes
- **Border mires** = The Border Mires SAC
- **Lagg** = flush/poor-fen vegetation (often M4, M6, M23 or M25a) outside the **rand** zone of **wet bogs**, where there is some water movement. Sometimes natural, sometimes along drains, sometimes a mixture of both. Sometimes channels of similar vegetation types snake through parts of the main mire expanse.
- **Main mire expanse** = wettest part (apart from bog pools) of **wet bog** in the centre, ideally occupying most of the bog area apart from the edges and ideally M18a vegetation.
- **Rand** = drier vegetation (often M18b, M19a, M20 or M25a) towards edges of **wet bogs**. On degraded **wet bogs** the majority of the mire may be like **rand** vegetation.
- **Statistical power** = the likelihood that we can say that the averages from two sets of sampled data are different, if the true averages really are different.
- **Valley mire** = large mire in a valley, with some water movement. This water movement is often not obvious. Variable vegetation types, including some similar to wet bogs (M18a, M18b, M21b) and others similar to lagg flushes (M4, M6, M25a).
- **Wet bog** = raised/intermediate bog on deep peat, away from sloping ground with M18a vegetation in the main mire expanse or, with potential to revert to M18a vegetation.

1.5 Requirements of the monitoring tool

1.5.1 Following various discussions in autumn 2014 Ptyxis Ecology was asked by Natural England for:

> "*The design of a long-term, repeatable monitoring tool for the mires, incorporating the idea of a Bog Quality Index, that will allow for the variation between the complex of mires to be accounted for, whilst also indicating the direction of change in relation to favourable condition.*"

1.5.2 During the discussions between Natural England and Ptyxis Ecology at the start of the contract, it was stated that the method should be statistically robust. So there were four key requirements:

1. Repeatable (and statistically robust);
2. Incorporate Bog Quality Index;
3. Works for all relevant mire types;
4. Direction of change can be related to favourable condition.

1.5.3 The first requirement is straightforward enough, providing that sound principles of ecological monitoring design are followed. The second requirement, the bog quality index, was an idea proposed by Ptyxis Ecology, which is explained in section 4.

1.5.4 The third requirement is potentially problematic if the whole range of mire types in the SAC were included. As the types of valley mires and calcareous mires are limited in extent and variable within the SAC, it was decided to limit the monitoring tool to **wet bogs** and **blanket bogs** only.

1.5.5 The fourth requirement may also be problematic. ‘Favourable condition’ on SSSIs is assessed using the Common Standards Monitoring (CSM) framework developed by JNCC. The monitoring methodologies based on this framework have several characteristics that conflict with the desire for a repeatable, statistically robust tool. These issues are discussed in more detail in section 7. Because of these difficulties, it was thought undesirable to use the CSM methods as a starting point, but the proposed monitoring tool is informed by (and attempts to encompass the main elements of) the relevant CSM methods. Once two surveys of a site have been done using the proposed monitoring tool, an assessment of whether the site is improving, stable or getting worse can be made. This assessment can then be directly related to the condition status of the SSSI.

1.6 Simplifying the survey methodology

1.6.1 During the discussions at the start of the contract, Northumberland Wildlife Trust asked that the survey method should be simple enough so that generalist ecologists or students without specialist botanical identification skills could do it. Natural England also thought that this approach would be useful, so that a wider range of staff would be capable of doing the survey.

1.6.2 Ideally, every survey would be simple, but this constraint potentially introduces a considerable amount of complexity in the design and data analysis stages. If on the other hand, only botanically competent surveyors were used, then the design of the monitoring tool could be quite straightforward by following well-established principles for sound design of ecological monitoring schemes.

1.6.3 However, using a survey tool that avoids difficult plant groups and tedious survey methodologies is by definition, likely to result in reduced accuracy and therefore lower statistical power, i.e. less chance of showing that a change has occurred if the vegetation has changed. This issue is magnified in mire habitats compared to many other habitats, as a relatively large proportion of the species involved are either bryophytes or sedges. Any simplified survey method is therefore limited to a relatively small number of vascular plant species that are more easily identified.

1.6.4 Because of these potential problems we were not at all confident at the start that a simplified method would be useful enough to be worthwhile. Therefore we spent a relatively large proportion of the time testing different versions of the proposed survey tool using various bog vegetation datasets. This meant that there was less time available to research other existing bog monitoring methodologies, although we did include some of this.

1.7 Principles of sound design of vegetation monitoring scheme

1.7.1 Initially we may consider two important questions when designing a monitoring scheme:

1. Does the scheme work? I.e. will we get a useful result after doing the work?
2. Can we simplify the scheme, to save money, or so that less qualified surveyors can do the work?

1.7.2 A ‘yes’ to the first question is essential, while a ‘yes’ to the second one is ideal, but not essential. To design a successful scheme therefore, we must start by designing a scheme that works. We can then see if simplified versions of the scheme also work.

1.7.3 We could approach the task from the other way around, by designing a simple scheme and then modifying it until we have a scheme that works. However, this approach is likely to be less efficient and less guaranteed to work well.

1.7.4 Here we outline the principles we followed in designing the border mires monitoring tool. Much of this section builds on ideas from Bonham (2013), Chalmers & Parker (1986), Hill *et al*. (2005), Sutherland (1996) and Wheater *et al*. (2011).

1.7.5 Ten characteristics of successful vegetation monitoring schemes:

1. Clear, measurable and specific targets;
2. Few targets (ideally just one or two);
3. How the data will be analysed is considered <u>before</u> the field method is designed;
4. Repeatable method: If two surveyors were to do the survey independently, they should get more or less the same results. If not, then the method is flawed and may lead to misleading conclusions;
5. Data are from measurements or counts and <u>not</u> from estimates of %cover;
6. Scientifically valid method: Scientific validity has many aspects, but here we are particularly interested in eliminating any unacceptable (i.e. potentially misleading) types of bias in how the survey is conducted;
7. Sites/habitats are stratified to reduce variance;
8. Sample size is big enough to give a reasonable level of statistical power;
9. Field method is easy to understand and apply;
10. Field method is not too time-consuming.

1.7.6 Four characteristics of unsuccessful vegetation monitoring schemes:

1. Data analysis not considered until <u>after</u> the survey;
2. Trying to answer too many questions;
3. Methodology is too complex or time-consuming;
4. Lack of resources or commitment.

1.7.7 The best, most accurate methods are often time-consuming, involving counting or measuring, rather than estimating. But a balance has to be struck between being good enough and being too complex, time-consuming, or tedious. If a method is too complex or too tedious, it is likely to encourage a higher rate of recording errors. Also, if a method is too time-consuming it may encourage rushing, which in turn may increase the error rate. The right balance to aim for is a method which is as simple as possible, while still answering the question adequately.

1.8 What to monitor?

1.8.1 We are aiming to measure the quality/condition of the mire habitats, so there are two main aspects we could focus on: vegetation composition and; habitat structure.

1.8.2 Differences in plant species composition could potentially give us a lot of useful information. If we list all plant species found in a sample unit, with some measure of abundance or cover, this allows us to:

- Calculate species-richness or species diversity;
- Measure changes in abundance/cover of indicator species, which may tell us something important about habitat quality;
- Calculate various other potentially useful ecological indices (e.g. Ellenberg indices), which may help us relate changes in the vegetation to management and environmental factors.

1.8.3 Most of the more useful measures derived from species data require all species to be recorded. Simpler methods recording a limited list of species, can give us useful information on important indicator species only.

1.8.4 In many situations biodiversity will be enhanced if there is greater diversity of both **habitat structure** within particular habitats, and **habitat types** within the area of interest. For border mires sites on deep peat, we are not usually interested in diversity of habitat types. In fact we normally want as much of the area of interest as possible to be occupied by one habitat type, namely M18a.

1.8.5 However, a M18a site that has more diversity of positive habitat structures within it (such as pool and hummock patterning), will be more valuable for biodiversity than a more featureless M18a site. Some types of habitat structure may be regarded as undesirable, e.g. drains, blocks of planted conifers, etc.

1.8.6 Therefore, a comprehensive monitoring scheme may need to measure both plant species composition and habitat structure. The CSM methods for bogs measure both aspects, but do so in a complicated way that lacks statistical power. In our proposed method we focus mainly on the plant species composition element and we have tested how well our proposed method performs using three different bog vegetation quadrat datasets. We also propose a method for measuring positive and negative aspects of habitat structure using a single, simple index. However, we did not have any data with which to test this habitat structure method. A pilot study to test the usefulness of this aspect of the methodology is recommended.

1.9 Testing the proposed bog vegetation monitoring tool

1.9.1 There were four main reasons why it was useful to test the proposed monitoring tool using some existing bog vegetation datasets:

1. To see if the proposed **bog quality index** (and other ecological indices) provided useful data from full bog vegetation quadrats;
2. To gain insight into the levels of stratification that may be needed on border mires sites;
3. To estimate the sample sizes that may be needed;
4. To compare the performances of the **full** method with three simpler variations of the **full** method.

1.9.2 We used three different datasets to test the methods, namely the **Stanley Moss**, **mixed bogs** and **blanket bog mosaic** datasets.

1.9.3 The **Stanley Moss** dataset was baseline data from a bog vegetation monitoring scheme of a degraded raised bog site undergoing restoration management (O'Reilly 2014). This site shared many characteristics with degraded border mire sites undergoing restoration. The data comprised lists of all vascular plants, bryophytes and lichens for each quadrat, with counts of how many cells (out of 16) per quadrat each species was observed in. 62 quadrats were used from this dataset. This dataset was assumed to be reasonably typical of a degraded **wet bog** site from the border mires.

1.9.4 The **mixed bogs** datasets comprised 89 vegetation quadrats recorded by the author from various sites in northern England and southern Scotland. The quadrats chosen were from vegetation types typical of **wet bog** sites in the border mires. The numbers of quadrats from each of the vegetation types chosen were roughly in proportion to the relative frequency of each vegetation type within **wet bogs** in the border mires. This dataset was assumed therefore to be reasonably typical of the range of variation of vegetation types typical of **wet bogs** in the border mires, including high quality to more degraded sites. However, frequency/count data from cells within the quadrats were not available for this dataset. The %cover of each species in the quadrat had been estimated and for this exercise these data were simplified to the 10-point, Domin scale.

1.9.5 The **blanket bog mosaic** dataset comprised 133 vegetation quadrats recorded by the author from various sites in northern England and southern Scotland. The quadrats chosen were from vegetation types typical of the mosaics found in **blanket bog** sites in the border mires. The numbers of quadrats from each of the vegetation types chosen were roughly in proportion to the relative frequency of each vegetation type within **blanket bog** sites in the border mires. This dataset was therefore assumed to be reasonably typical of the range of variation of vegetation types in a typical large **blanket bog** site in the border mires. Again, only %cover data (converted to the Domin scale here) were available for this dataset.

1.10 Methodologies used for statistical analyses

1.10.1 The methodologies used for the data exploration and statistical analyses of the three datasets described above are outlined in Appendices A, B and C.

1.10.2 The four bog quality indices, the four Ellenberg indices, Simpson's Reciprocal Index, the Suited Species Grazing index and the sample size calculations were done manually using standard formulae in **Microsoft Office Excel 2007**. The histograms, box and whisker plots, and normal probability plots were produced in **SPSS 13.0 for Windows**. The Shapiro-Wilk tests were also done in SPSS. The scatterplots were produced and the linear regression analyses done in **Genstat 10th Edition**.

1.11 Structure of this report

1.11.1 In sections 2 to 8 of this report we present the proposed monitoring methodology and discuss some of the important issues that were considered when designing the methodology. We refer to specific results from testing the three datasets in appendices A, B and C where appropriate.

1.11.2 Section 2 covers baseline mapping and stratifying sites. The field survey methodology is covered in section 3. We discuss the proposed bog quality index and other ecological indices in section 4. Issues around adapting the field method for generalist surveyors are discussed in section 5. A proposed methodology for monitoring habitat structure is outlined in section 6. We discuss how the proposed methods fit with CSM methods in section 7. Finally our main recommendations are summarised in section 8.

1.11.3 The various instructions for surveyors in how to carry out the monitoring surveys are contained in appendices E, F, G and H.

2 Baseline mapping and stratification

2.1 Why is stratification needed?

2.1.1 The main aims of stratifying a site are to:

1. Ensure that different areas can be reported on separately;
2. Reduce variation within any one area, so that it is more likely that changes over time can be spotted.

2.1.2 Regarding the first aim, we need to decide how many different areas we wish to report on from any one site. On some sites there may just be one large area covering the main mire expanse. On other sites, different parts of the mire may have had different management histories and the only way we can validly report on these different areas separately is by treating them separately from the start. On other sites the quality of the bog vegetation may vary from one part of the mire to another and if these different vegetation types can be mapped reasonably accurately, it may be useful to treat them as different monitoring areas.

2.1.3 When statistically analysing monitoring data from a site from two different surveys, we are often interested in comparing the average scores for whatever we are interested in from the different surveys. In many situations the range of scores we get in the two surveys will overlap. If the two sets of scores are so variable that they overlap to a large extent it will be very difficult (or impossible) for us to know if the two average scores really are different or not. If on the other hand the range of scores in each of the surveys is narrower, then if the two areas really are different we are likely to get a much smaller area of overlap between the two sets of scores. This allows us to be more confident that any apparent difference between the average scores really does represent a real difference. In technical terms this means we have more **statistical power**.

2.2 Results from testing the mixed bog and blanket bog mosaics data

2.2.1 In appendix B we examined the impact on statistical power of stratifying the **mixed bog** dataset in two different ways (see page 71). We used a standardised method to estimate the number of samples (quadrats) we would need to achieve a reasonable level of statistical power. We calculated the sample sizes needed separately for measuring several different things: four variations of the bog quality index; plus six other ecological indices. We categorised the vegetation types included in the mixed bog dataset into six types, ranging from the highest quality bog vegetation (type A) to the lowest quality degraded bog vegetation (type B).

2.2.2 If we took a scattergun approach to our monitoring and recorded quadrats randomly from anywhere in the bog, then we are likely to include samples from all of the different types of vegetation present, so our dataset will be quite variable. This leads to lower statistical power which makes it difficult to say if anything has changed when we repeat the survey. From our analyses in appendix B, the higher quality bog types were considerably less variable on average for almost all of the various indices we tested. The lowest quality bog vegetation was almost as variable as the whole dataset was.

2.2.3 These results demonstrated that if we stratify our sites by accurately mapping the different types of vegetation of interest and if we focus mainly on the most interesting vegetation types, then we should have a much better chance of spotting real changes than we would if we did not stratify the sites.

2.3.4 These results also tell us that if we do want to include the lower quality bog vegetation in our monitoring, then we may need to do more quadrats than normal in these areas to achieve reasonable levels of statistical power. Ideally we could avoid these areas by focussing only on the better quality bog vegetation, but there are a few of reasons why it may sometimes be important to include these areas:

1. The majority of the bog may be quite degraded on some sites;
2. On sites with better quality vegetation, discrete sections of the bog may be degraded (e.g. from past forestry management), but may have potential to revert to high quality bog;
3. On sites with both high quality and poorer quality bog vegetation, it would add to our overall understanding of the site, if we were able to analyse results from both areas separately.

2.3.5 In appendix C we examined the impact on statistical power of stratifying the **blanket bog mosaic** dataset (see page 98). Again, we used the same standardised method to estimate the number of samples (quadrats) we would need to achieve a reasonable level of statistical power. We categorised the vegetation types included in the blanket bog mosaic dataset into eight broad habitat types, including various types of bog vegetation, as well as other vegetation types typically found in large blanket bog sites.

2.3.6 Accurately mapping the extent of bog vegetation in large blanket bogs sites is a laborious operation and it is seldom done well. Our results from appendix C show that it is likely to save resources in the long run, if an accurate mapping exercise is carried out initially, as then the resulting defined monitoring areas are likely to be much less variable than if the whole area was surveyed using a scattergun approach.

2.3.7 Resources for doing an accurate one-off mapping exercise are often difficult to secure and so some monitoring schemes attempt to avoid the problem by introducing extra rules for where the surveyor should sample from. In these cases instead of using randomly generated locations, the surveyor may be instructed to go to a randomly generated location and then find the nearest area with bog vegetation to sample from. This may seem like a good solution, but it is not, as it introduces an unacceptable level of bias in the sampling. E.g. if parts of the bog has become so degraded that it is now a form of U6 acid grassland and we do not survey from this U6 vegetation, we lose valuable information on the extent of degradation or recovery on that site. The danger of following an approach like this is that the survey results may be so unreliable as to be a complete waste of resources.

2.3.8 The results in appendix C show that focussing only on the bog vegetation, rather than all vegetation types within a blanket bog site, means we have more statistical power and therefore need fewer quadrats. These results also show that the proposed bog quality index for blanket bogs did not distinguish well between blanket bog and wet heath vegetation. This is a further argument for why accurately mapping the bog areas is a good idea before the monitoring commences.

2.3.9 The baseline mapping involved in stratifying the sites is perhaps the single most important aspect of the whole monitoring scheme. It only has to be done once, but if it is not done accurately, it is likely to cause problems for the entire duration of the monitoring scheme. It is important that only experienced and conscientious surveyors are used for the baseline mapping. A map that is done well is valuable, but a map that is done ‘half as well’ is likely to be worthless at best, but probably misleading.

2.4 Mapping monitoring zones on wet bogs in the border mires

2.4.1 See appendix E for the full step-by-step instructions for baseline mapping and stratifying. The main mire expanse may include one, two or three different types of bog vegetation, with the wettest (best) type in the centre and drier types towards the edges. There may be a gradual transition from one to the other, or the boundaries between them may be distinct. On relatively undisturbed bogs the rand zone may be narrow, but it depends on the local topography, as sometimes an area of blanket bog can join onto a wet bog.

Table 1: Typical types of bog vegetation on wet bogs in the border mires

NVC type	Description	Part of mire
M18a	Continuous carpet of *Sphagnum* with only patchy dwarf shrubs above. Lots of *Sphagnum papillosum*, *S. magellanicum*, *S. capillifolium* and *S. tenellum*	Main mire expanse (centre)
M18b	Mixtures of *Sphagnum* species and feather mosses with more vigorous dwarf shrubs. Not as much *S. magellanicum*.	Main mire expanse
M19a	Mixtures of heather, cross-leaved heath, hare's-tail cottongrass and *S. capillifolium*. Little or no *S. papillosum* or *S. magellanicum*	Main mire expanse or rand
M19b	Like M19a, but no cross-leaved heath and often not as much *Sphagnum*.	Rand (or blanket bog)
M25a (or M20)	Dominated by purple moor-grass (or hare's-tail cottongrass in M20), with little or no dwarf shrub. Some *Sphagnum* may be present, but usually not the species listed above.	Rand
Various, e.g.: M4, M6, M23, S9, S10	Rushy, or sedgy vegetation, sometimes over a sloppy, green *Sphagnum* carpet	Lagg (similar to vegetation of some valley mires)

2.4.2 The first five vegetation types in the table are listed in descending order of vegetation quality, starting with the wettest type typically found in the centre of good bogs. The sixth type is not bog vegetation at all, just associated with the edges of bogs.

2.4.3 **Aim of mapping exercise**
To define (map) the areas of interest for monitoring. These mapped areas are to be used as the basis for <u>all</u> subsequent monitoring surveys.

2.4.4 **Number of different zones to map**
On some sites we may need only **one zone** defining the extent of the main mire expanse. If there is a band of different rand vegetation on the edges, this may not need to be included if it is narrow and unlikely to have potential to become as high quality as the main mire expanse.

2.4.5 On other sites, the best quality main mire expanse vegetation may occupy a relatively small area in the centre and be surrounded by a wide band of rand-type vegetation. This large rand zone may be degraded due to past management. Much of this area may have high potential to become higher quality bog vegetation in future. In this case, the **two zones** should be mapped separately.

2.4.6 We should only need **three or more zones** for sites that either have had some major restoration work done recently (e.g. recently cleared of conifers as part of a bog restoration programme) or, have potential for restoration work in future. If different restoration/management treatments are to be applied and it is of interest to compare them, then we would have to map each of these areas accurately as separate zones.

2.4.7 **NB** It is important to remember that an equal survey effort is required for each additional separate monitoring zone, so although more separate zones potentially give more useful information, they also require more work. Additional zones should not be split off from existing zones unless there is a good reason to do so.

2.5 What about NVC mapping?

2.5.1 A good way of defining the monitoring zones would be to do a detailed NVC survey first and then use the NVC map to define the monitoring zones.

2.5.2 If resources were available for full NVC surveys this would have the following advantages over just mapping the key monitoring zones.

- The boundaries of the monitoring zones derived from the NVC map will probably be more accurate, as more time would have been spent on detailed mapping in the field.
- Small, atypical areas such as bands of rushy flush vegetation within the main mire are more likely to be picked up in a full NVC survey.
- These first two points would help in reducing variability within the monitoring data for each zone, as it would then be less likely that a quadrat would land on non-target vegetation. This in turn leads to higher statistical power.
- The monitoring scheme is unlikely to focus much (if at all) on narrow bands of rand vegetation or on lagg vegetation on the edges of the bogs. A NVC survey of the sites could include these areas, which would help in our overall understanding of the entire mire complexes in addition to the main monitoring priorities.
- Standard NVC quadrat data of the main vegetation types would help to describe the typical vegetation types and typical transitions found in the Border Mires in a standardised way. The proposed monitoring survey uses a different methodology for recording quadrat data, so would not be directly comparable to other NVC surveys.

2.5.3 However, it should be possible to map the monitoring zones accurately without mapping all of the NVC types, as long as relatively experienced vegetation surveyors are used. If resources are tight, it may be best to concentrate on this simpler approach initially. Further NVC mapping could be added later if more resources became available.

3 Vegetation monitoring field method

3.1 Choosing sampling points

3.1.1 In most ecological monitoring schemes it is normally best to monitor every time at the same set of fixed points. This involves permanently marking the fixed points with something on the ground that can be re-found. Options include buried pieces of metal or posts.

3.1.2 This approach means that the statistical analysis can use methods for **matched pairs**, which give more statistical power than other methods. With **matched pairs** we assess the differences between one survey and another at each fixed location and we compare the average of these differences to zero. So we have just one set of observations to deal with namely, the differences.

3.1.3 If on the other hand we sample from different sets of random locations each time, then we compare the average from one set to the average from the other. So in this case we have two sets of observations to deal with. Two sets of observations generally include more random variation than one set of observations, which is why this approach is less powerful than the **matched pairs** approach.

3.1.4 However, for a number of reasons, we do not propose using the matched pairs approach here:

1. Metal markers are easily lost when buried in soft wet peat, as they tend to sink;
2. Buried metal markers can be difficult to relocate in dense heathery vegetation, as the metal detector may not get close enough to the marker to detect it;
3. Alternatively we could use posts, but placing a large number of posts on the bog surfaces would be unsightly;
4. Some authors (e.g. Hill *et al*. 2005) advise against using permanent plots on bogs, as re-surveying at the same locations may cause an unacceptable amount of localised trampling.

3.1.5 The approach we recommend for most sites is to sample from a set number of random points within each stratum. Instructions for how to generate and locate random points are given in appendix F. The idea is that by sampling randomly from within each stratum our sample will be representative of the average conditions in that stratum, providing that our sample is large enough.

3.1.6 On some sites different approaches may be useful. For instance on some sites there may be a relatively small area of high quality vegetation in the centre of the main mire expanse, with the quality of the vegetation gradually deteriorating towards the edges of the mire, in all directions. In this situation, instead of random sampling, surveying at fixed intervals along transects going from the centre outwards could be a useful approach. The data resulting from such an approach would give more flexibility for data analysis. E.g. if the vegetation on the outside improved over time gradually from the centre outwards, the transect approach would allow us say just how far out from the centre the vegetation had improved after each survey. It should be borne in mind however, that transect data along gradual ecotones like this can be quite complicated to analyse.

3.1.7 Another possible scenario which might benefit from a non-random approach would be a regular pattern of drains (that are to be blocked), leading to repeated stripes of two to three distinct types of vegetation across the mire. In this situation we could sample equally from each distinct vegetation type by locating our sampling points at fixed distances from the drains. Another potentially useful approach could involve a number of transects aligned perpendicularly to the drains. As the vegetation may change quite quickly over a short distance from the drains, the sampling could be done in a series of adjacent quadrats along the transects.

3.1.8 It is not possible to recommend any of the approaches mentioned in the last two paragraphs without actually visiting individual sites to see what is most suitable on each site. Deciding between these approaches really would have to be done on a case-by-case basis (perhaps by the surveyor who does the baseline mapping of the site). We anticipate that the stratified random approach outlined in 3.1.5 should be sufficient in most cases. The other more complex approaches (3.1.6 and 3.1.7) should probably only be considered if there is a very strong reason to do so on a particular site. Also, if the same stratified random approach is used for every site, then comparisons between sites would be possible, whereas if different approaches are used on different sites, it is less likely that valid comparisons between sites could be made.

3.2 Quadrat recording – what species to record

3.2.1 The most straightforward method is to record all species in the quadrats including vascular plants, bryophytes and macrolichens. This approach leads to a more precise bog quality index than using a limited list of indicator species alone (see appendices A, B & C). It also allows us to calculate other useful ecological indices such as the Ellenberg indices, various species diversity indices, etc.

3.3 Quadrat recording – size of quadrat

3.3.1 We propose using quadrats of 1m x 1m. We also considered quadrats of 2m x 2m. These larger quadrats have some advantages, e.g. the larger size probably gives a more representative sample of the vegetation. However, the larger quadrats are more time-consuming to survey. 1m x 1m quadrats may give a better balance between representativeness and practicality.

3.4 Quadrat recording – cover/frequency/abundance

3.4.1 We propose dividing the quadrat into 16 equal-sized cells and counting how many cells each species occurs in. This is a more reliably repeatable method than any method involving estimating %cover. The method would be even better if we divided the quadrat into even more cells. A commonly used method involves a 5 x 5 grid, giving 25 cells. But 25 cells takes longer to survey than 16 cells. We judge 16 cells to be adequate and this method worked well in a previous survey carried out by us (see appendix A).

3.5 Full instructions and short cuts

3.5.1 For full step-by-step instructions for the **full** field method, see appendix F.

3.5.2 We have also investigated the impact of various short-cuts that could be taken with the method (see appendices A, B & C) and we include proposals for a simpler method using a short list of indicator species in section 5.

4 Bog quality index and other useful ecological indices

4.1 Why a bog quality index?

4.1.1 Various standard measures of species-richness and species diversity are well established (Magurran 2004). One of the more useful of these measures is **Simpson's index of diversity** (expressed here in the reciprocal form). In general, in most habitats, samples that have higher diversity scores will be of greater nature conservation interest. However, we cannot always rely on this simple rule of thumb, as disturbed habitats are often more diverse than pristine habitats. E.g. if a bog is disturbed, most of the species that previously occurred will still be present (even if several of them occur at lower cover) and additional 'weedy' species will also colonise due to the changed conditions.

4.1.2 Therefore the diversity measure gives us useful information, but on its own it is not enough. E.g. see the plots on pages 41, 64 and 91 comparing diversity scores with bog quality scores for three different bog datasets. There is little, if any, relationship between the two measures, so that samples scoring highly for diversity may not be of particularly high quality.

4.1.3 Various other ecological indices (e.g. see Hill *et al*. 2004, Hill *et al*. 2007 and Critchley 2000) have become popular in recent years in ecological studies. These indices allow vegetation samples to be allocated values on numerical scales describing various ecological attributes. Thus we can say how the sample compares to other samples in terms of soil fertility, pH, wetness, suitedness to grazing, etc. All of these indices are potentially informative and using a combination of these gives us ecological insight into our samples. If changes have occurred from one survey to another in one or more of these indices, we can often hypothesise on the causes of the change, depending on which particular indices have changed and in which direction.

4.1.4 However, our main question of interest is often to do with habitat quality; e.g. is the vegetation higher quality, lower quality or the same quality as before? None of the above indices answer this question directly. Some indices come close to answering this specific question. E.g. the best bogs are probably those that are the wettest, the most acid and the least nutrient-rich, but already we have used three separate measures to describe quality in this example. This is why we propose that a separate bog quality index would be useful for monitoring changes on the border mires. It relates more directly to our main question of interest.

4.2 Assessing habitat quality using indicator species

4.2.1 The concept of indicator species has long been used in ecological studies. The CSM monitoring methods use short lists of indicator species (both positive and negative) to assess habitat quality, although they do so in a complex way that lacks statistical power.

4.2.2 In recent years the BSBI's axiophyte project see http://www.bsbi.org.uk/axiophytes.html has promoted the use of axiophytes (positive indicator species) for assessing site quality. The idea is to simply count how many axiophytes are found on a site and this number helps in assessing site quality when comparing sites

4.2.3 Similarly, surveys conducted by the Nature Conservancy Council (NCC) in the 1980s and 1990s frequently used standard recording cards with different quality weightings given to different species. A crude assessment of site quality was then possible by adding up all of the species scores for the site.

4.2.4 The author developed a similar system for comparing the quality of hay meadows using positive and negative indicator species given different weightings (O'Reilly 2008, O'Reilly 2011). This method had greater precision that the NCC and BSBI approached described above, as seven different weightings were possible for each species, whereas the NCC methods usually used 3 and the BSBI method just 2. The hay meadow quality index scoring system was similar to the bog quality index presented here.

4.2.5 However, a drawback of all three methods described above was that in each case a 'site' or a 'field' was the survey unit. Thus a site with several low quality habitats could get a higher score than a site with one very high quality habitat. Methods like this work much better when the survey unit is relatively small and standardised, such as by using quadrats.

4.2.6 We did internet and academic literature searches to see if anything similar to our proposed **bog quality index** using indicator species had been developed elsewhere in Britain. Some approaches to monitoring bogs using indicator species were found, but they were all quite simplistic, mostly quite similar to the approach taken in CSM methods.

4.2.7 Similar methods to the **bog quality index** proposed here have been used in North America (Andreas *et al*. 2004, Bourdaghs 2004). A Floristic Quality Assessment Index (FQAI) has been used successfully for assessing wetlands in the Great Lakes region since the late 1970s. The FQAI uses a **weighted averaging** approach, i.e. the species abundance score is multiplied by it's weighting and then the average for the sample is calculated by dividing the sum of these scores by the total of the species abundance score for the sample.

4.2.8 The weightings in the FQAI are based on a coefficient of conservatism (C of C) scale from 0 to 10. Species scoring 0 are those with a very broad ecological tolerance, that can grow in many different habitats and are good at colonising new sites. Species scoring 9 or 10 on the other hand are those with a much narrower ecological tolerance, usually only growing the in same small set of habitats all of the time. The FQAI does not include non native species, but it includes native vascular plants and bryophytes. The C of C scores do not take into account how common the plant is overall, or whether or not it has any conservation designation.

4.2.9 As Andreas *et al*. (2004) explain, the initial assigning of the C of C scores to species involves some subjectivity, but once these scores have been assigned, the method is then applied objectively and consistently each time. This front-loaded subjectivity is also a feature of the Ellenberg indices and suited species indices.

4.2.10 Bourdaghs (2004) combined quality and diversity in a single index, the Floristic Quality Index (FQI) by multiplying the mean C of C by the square root of species richness. He found that both indices worked well in separating sites of different quality, but that the combined index (FQI) performed better.

4.3 Our proposed bog quality index

4.3.1 For the proposed bog quality index we have followed a similar approach to the FQAI index, and our index combines quality with species-richness. Our approach differs from the FQAI/FQI approach in the following ways:

- Our scale for the species quality weightings is a six-point scale from -1 to 4;
- The assignment of weightings to species considered both ecological range (preference for high quality habitats) and rarity, although in practise almost all of the rare species also had a narrow ecological range, preferring only the better quality bogs;
- We have included non-native species of vascular plants and bryophytes;
- We have included macrolichens that are commonly found on bogs;
- We propose using one scale, calculated simply by multiplying the species weighting by its frequency score and adding these result together for all of the species in the sample. This means that species-rich quadrats will tend to get higher **bog quality** scores on average.

4.3.2 When developing the bog quality index, at first we took a more complicated approach to calculating the scores. This method used both diversity and habitat quality. For each sample we calculated Simpson's reciprocal index and a weighted average based on the bog quality weightings for species. Then we raised the **Simpson** score to the power of the weighted average quality score. However, in the end we settled on the simpler approach described above and when both methods were compared the results were similar.

4.3.3 This simpler approach to the calculations also made the *full* bog quality index more comparable with the **intermediate** and **simple**/**minimal** approaches, as similar methods were used to calculate each of them.

4.4 Species quality weightings:

4.4.1 Scores for each species are on a six-point scale from -1 to 4. The 'better' species score higher. See Table 2 below for explanation of the different score categories and some examples.

Table 2: Explanatory notes for species quality weightings

Score	Explanatory notes	Examples
-1	**Negative indicators** • If these species are found in a bog in our area, they indicate a degraded bog. • Some species included here may be typical of M25a rand vegetation.	*Agrostis capillaris* *Chamerion angustifolium* *Juncus effusus* *Molinia caerulea* *Picea sitchensis* *Sphagnum fallax*
0	**Neutral species*,*** either: • May grow in bogs, but tell us nothing about quality, or; • More typical of other habitats. A sign that quadrat landed on non-target vegetation, rather than bog has degraded, or; • In good quality bogs, but also common in wet heath, which could be degraded bog.	*Campylopus flexuosus* *Carex echinata* *Eriophorum vaginatum* *Hypnum jutlandicum* *Sphagnum fimbriatum* *Trichophorum germanicum* *Vaccinium myrtillus*
1	**Bog species**, either:	*Calluna vulgaris*

	• Typical of M19b blanket bog and not found as often in other habitats, or; • Found in M19, but not in M20 or M25, or; • Found in M18, but also in various other mires.	*Calypogeia muelleriana* *Eriophorum angustifolium* *Sphagnum capillifolium* *Sphagnum cuspidatum*
2	**Good bog species** • typical of M18b, M19a or M19c and not usually found much in M19b, M20 or M25	*Cephaloziella connivens* *Erica tetralix* *Rubus chamaemorus* *Sphagnum papillosum* *Vaccinium oxycoccos*
3	**Very good bog species**, • found most often in good quality M18a and not often found in other bog types	*Andromeda polifolia* *Drosera rotundifolia* *Odontoschisma sphagni* *Sphagnum magellanicum*
4	**Rare bog species** which are also confined to good quality bogs	*Carex pauciflora* *Drosera anglica* *Rhynchospora alba* *Sphagnum austinii* *Sphagnum fuscum*

4.4.2 The full species lists used for this analysis with the weightings applied are included in appendix D. This scoring system was tested and appeared to work well on the **Stanley Moss** dataset (appendix A) and the **mixed bog** dataset (appendix B).

4.4.3 However the system did not work well as well on the **blanket bog mosaic** data. Heathland quadrats scored quite highly and were not well-separated from the blanket bogs. This is problematic as some forms of degraded blanket bog have similar characteristics to heathland vegetation.

4.5 Adjustments to species weightings for blanket bog sites

4.5.1 The following adjustments to the standard scoring system were made to deal with this, but this adjusted scoring system should <u>only</u> be used on blanket bog sites. Also, it would not be valid to compare the scores from a wet bog using the standard system with a blanket bog using this adjusted system. To avoid confusion, it would be best to give these two systems different names, e.g. **wet bog quality index** and **blanket bog quality index**.

4.5.2 For the **blanket bog quality** index the species quality weightings of the following species were **reduced by 1**, as they are more or less equally typical of good dry heath and good bog sites:

Barbilophozia floerkei	*Dicranum scoparium*	*Plagiothecium undulatum*
Calluna vulgaris	*Diplophyllum albicans*	*Pleurozium schreberi*
Cladonia arbuscula	*Empetrum nigrum*	*Ptilidium ciliare*
Cladonia portentosa	*Hylocomium splendens*	*Racomitrium lanuginosum*
Cladonia uncialis	*Lepidozia reptans*	*Rhytidiadelphus loreus*
Danthonia decumbens	*Lophozia ventricosa*	*Vaccinium vitis-idaea*

4.5.3 The species quality weightings of the following species were **reduced by 1**, as they are more or less equally typical of good wet heath and good bog sites:

Erica tetralix *Eriophorum angustifolium*

4.5.4 The species quality weightings of the following species were **reduced by 2**, for similar reasons as above:

Hypogymnia physodes *Sphagnum tenellum* *Trichophorum* x *foersteri*
Narthecium ossifragum

4.5.5 The species quality weightings of the following species were **increased by 1**, as they are more typical of blanket bog than of heathland sites:

Rubus chamaemorus *Sphagnum capillifolium* *Sphagnum russowii*

4.5.6 After these adjustments the **blanket bog mosaic** data were re-analysed (see appendix C). This time dry heath samples were well-separated from blanket bog samples on average, but despite the adjustments, wet heath samples were not very well-separated from blanket bog samples. These adjustments for blanket bogs also mean that the potential range of scores is smaller than with the standard method, so this method may not be as statistically powerful. Unfortunately therefore, even with the adjusted method, the **blanket bog quality index** does not appear to work as well on blanket bogs as the **wet bog quality index** does on wet bogs.

5 Adaptations for non-specialist surveyors

5.1 General approach followed

5.1.1 One of the requirements of the contract was to try to make the field method simple enough so that a generalist surveyor without the full range of botanical identification skills could do it. We devised three methods that were simpler than the **full** method, in that they used shorter lists of indicator species: the **intermediate**, **simple** and **minimal** methods.

5.1.2 The **intermediate** and **simple** methods were similar to the **full** method in that species were counted in 16 cells in each quadrat, whereas the **minimal** method just recorded presence in the whole quadrat.

5.1.3 For the **intermediate** method a list of the 93 most likely species was used. The idea was that only these 93 species and no others are recorded. Many of these 93 species are bryophytes or sedges, but if it was planned to get an inexperienced surveyor to survey a lot of sites, it may be possible to train them to recognise these 93 species reasonably accurately in a reasonably short time. It would probably not be worthwhile however to train surveyors in this method if they were only going to survey one or two sites.

5.1.4 The **simple** and **minimal** methods use a much shorter list of 20 species (or 17 species for the blanket bog method). Most species on the list are flowering plants, which in theory should be easy to recognise, although some inexperienced surveyors may not be able to tell all of the dwarf shrubs apart. It should be possible to train most inexperienced surveyors to an adequate level to do this survey with one short training session. However, surveyors who don't know enough species to be able to do the **intermediate** survey are likely to have a relatively high rate of identification errors even with this very simplified method using 20 species.

5.1.6 For the **intermediate**, **simple** and **minimal** methods, we used reduced lists of positive and negative indicator species, which were subsets of the **full** list.

5.1.7 The relative performance of the **full**, **intermediate**, **simple** and **minimal** methods were compared with different bog datasets in appendices A, B and C to see if short cuts with the method were possible while still giving adequate results. See appendix D for the species included in each of these lists.

5.1.8 **Principles used to decide which species to include on the short list**

- All species scoring zero were not needed, as they make no difference to the **simple** or **minimal bog quality index** for the quadrat;
- No bryophytes included, except for 'red or chunky *Sphagnum*';
- No grasses, sedges or rushes included, except for common cottongrass and large rushes as a group;
- Many species scoring -1 from the main list were omitted, if they were not typical bog species, in order to keep the list simple and short;
- All of the high quality rare species omitted, as these will not crop up often and if they were included and surveyors recorded them by mistake, this would make a very big difference to the score for that quadrat.

5.2 Predictive accuracy of the three shorter methods for all 3 datasets

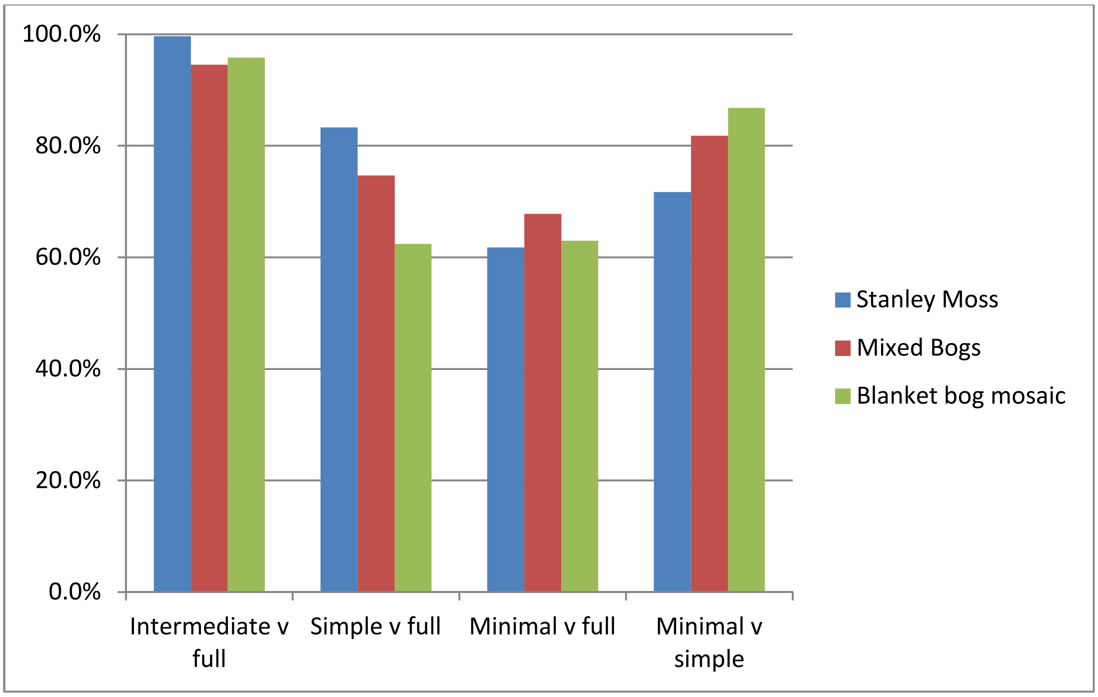


Fig 2: Comparison of *r*-squared values from linear regression models comparing the four methods

Table 3: *r*-squared values from linear regression models comparing the four methods

Comparison	Stanley Moss	Mixed bogs	Blanket bog mosaic	Average*
Intermediate x full	99.6%	94.5%	95.8%	97%
Simple x full	83.3%	74.7%	62.4%	73%
Minimal x simple	61.8%	67.8%	63.0%	64%
Minimal x simple	71.7%	81.8%	86.8%	80%

*The figures here for average *r*-squared values have no real meaning and should not be taken too literally. They are calculated here to give a very rough idea of the average performance of the different methods

5.2.1 *R*-squared values were also calculated for **simple vs. intermediate** and **minimal vs. intermediate**, but these results are not included here as they add little to the analysis.

5.2.2 In general the *intermediate* method predicted the scores from the **full** method quite accurately, but there was evidence that the highest and lowest scores were not predicted as accurately as those in the middle.

5.2.3 The **simple** method was more accurate than expected in predicting the scores from the **full** method, although there was quite a bit of variation (*r*-squared values between 62% and 83%). Considering that the **simple** method is such a pared down version of the **full** method this level of predictive power is not bad.

5.2.4 The **minimal** method performed only slightly worse than the **simple** method, which again was a surprise, considering that it is simplified even further than the **simple** method. In the analysis of the **mixed bog** and **blanket bog mosaics** data there was little to choose between the **simple** and **minimal** methods.

5.3 Statistical power of the four different methods

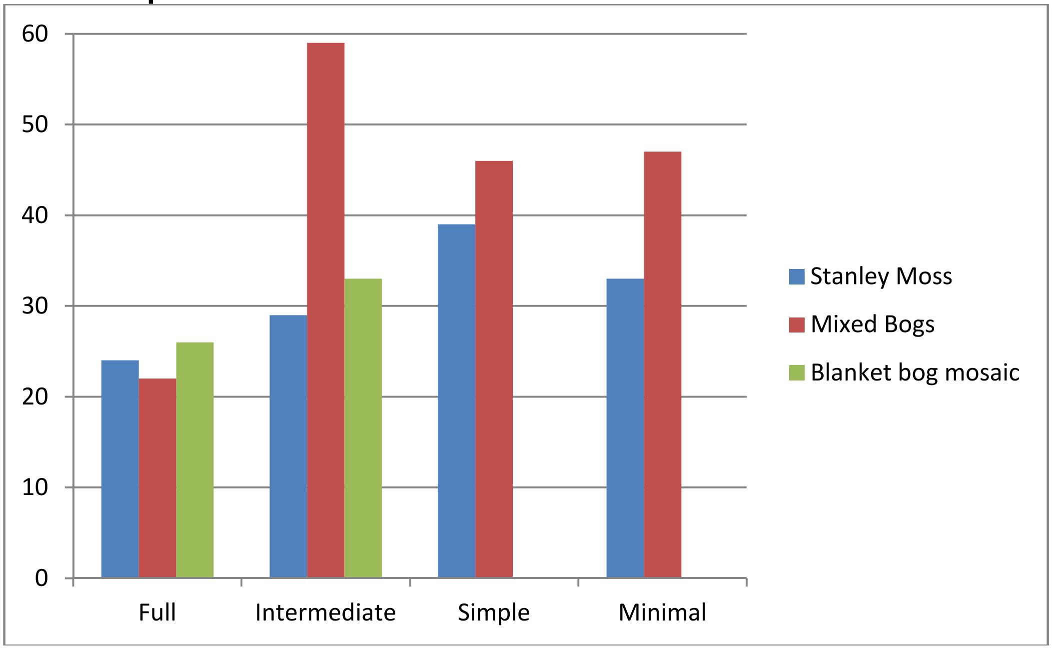


Fig 3: Comparison of predicted sample sizes needed for the four different methods, based on the variance found in the three datasets

Table 4: Predicted sample sizes needed for the four different methods, based on the variance found in the three datasets

Method	Stanley Moss	Mixed bogs	Blanket bog mosaic	Average*
Full	24	22	26	24
Intermediate	29	59	33	41
Simple	39	46	23**	43
Minimal	33	47	35**	40

*Again, the figures here for average sample sizes needed should not be taken too literally. They are calculated here to give a very rough idea of the average performance of the different methods

** Valid sample size calculations were not possible here, so these figures are under-estimates of the true number of samples needed

5.3.1 These sample size predictions were all calculated in the same standardised way, as outlined in appendix A. The 95% significance level was used and the calculations were based on 80% power to detect a difference of 20% from the mean with the data standardised so that the lowest observed value was zero and the data followed a normal distribution.

5.3.2 The **full** method consistently required smaller samples that the other methods, which is unsurprising as it is by definition more accurate than the other methods. The **intermediate** method was not very different from the **full** method with two of the datasets, but it required more than twice as many samples as the full method for the same power with the **mixed bogs** dataset.

5.3.3 The **simple** and **minimal** methods appeared to require up to twice as many samples as the **full** method on average. Surprisingly, there was no clear evidence as to which of the **simple** or **minimal** method was more powerful.

5.4 Statistical power for assessing change using other ecological indices

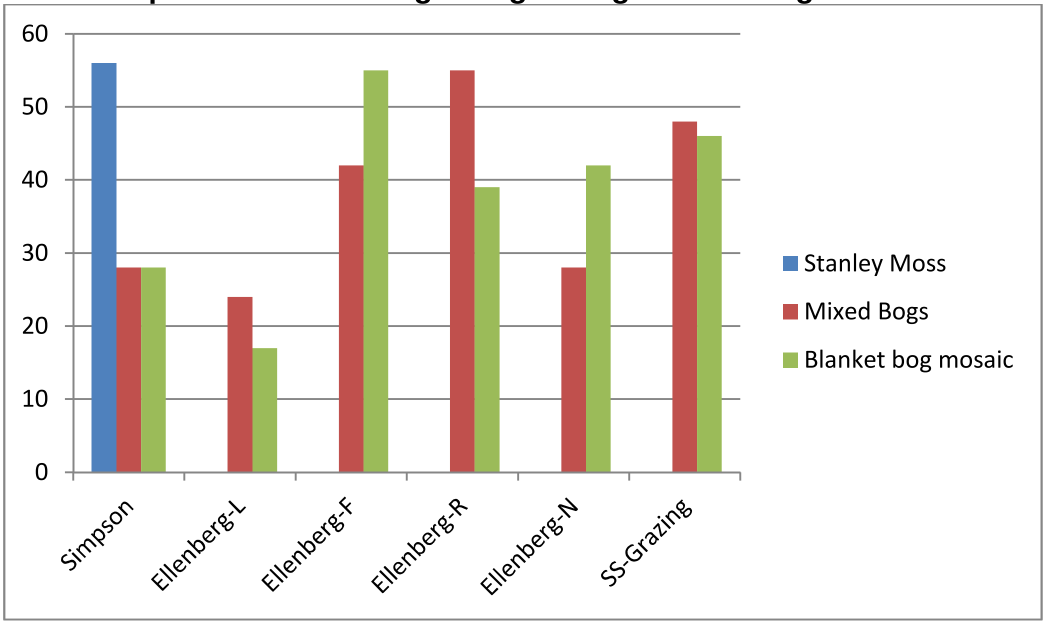


Fig 4: Comparison of predicted sample sizes needed for six ecological indices, based on the variance found in the three datasets

Table 5: Predicted sample sizes needed for six ecological indices, based on the variance found in the three datasets

Method	Stanley Moss	Mixed bogs	Blanket bog mosaic	Average*
Simpson	56	28	28	38
Ellenberg-L		24	17	21
Ellenberg-F		42	55	49
Ellenberg-R		55	39	47
Ellenberg-N		28	42	35
SS grazing		48	46	48

*Again, the figures here for average sample sizes needed should not be taken too literally. They are calculated here to give a very rough idea of the average performance of the different methods.

5.4.1 These figures are based on unstratified sampling, so the true samples sizes needed may be smaller, providing that sites are adequately stratified.

5.4.2 The relatively high number of samples predicted for **Simpson** in the **Stanley Moss** data suggests that bigger sample sizes may be needed for degraded sites.

5.4.3 Overall the predicted sample sizes needed for these indices were mostly similar in magnitude to the samples sizes predicted for the **full** and **simple** methods above. There was quite a bit of variation, suggesting that to be on the safe side, if we want a reasonable level of statistical power for all of the indices we are interested in, then we should err on the side of more rather than fewer samples. 40 to 50 samples with the full method should give us useful data most of the time, but it may be possible to achieve adequate statistical power for most of the indices with fewer samples

5.5 Other issues to consider when comparing the four variations of the method

5.5.1 **NB** It is only valid to calculate any of these ecological indices when using the **full** method. This is a serious drawback of the **intermediate**, **simple** and **full** methods.

5.5.2 To compare the four methods fully, some additional issues should also be considered. Inexperienced surveyors are likely to have a higher error rate in their identifications than experienced surveyors even when using relatively short lists of indicator species. There are several reasons why this may be so:

1. Their ID skills are poorer to start with;
2. They are likely to be less motivated to get the ID right (if they were more motivated their ID skills would already be better);
3. They may get bored or tired with the repetitious nature of the survey sooner, as they will not be used to doing this kind of work.

5.5.3 The results summarised above comparing the four different methods were all based on survey data from the same experienced surveyor. Hence these results may give an overly-optimistic assessment of how well the intermediate, simple and minimal methods perform due to the issues discussed in the previous paragraph.

5.6 Main conclusions from comparing the four methods

5.6.1 The main conclusions are:

- **Full** method is more powerful, more accurate and requires fewer samples;
- **Intermediate** method seems good, but has some serious disadvantages;
- **Simple** and **minimal** methods performed better than expected and there was little to choose between them;
- As **minimal** method is relatively undemanding, do a decent sample each time – say at least 60;
- Predicted sample sizes needed for bog quality index and the various ecological indices were reasonably consistent;
- 40 (or 50) samples recommended at least the first time the **full** survey is done;
- If **full** survey is repeated, best to do a similar number the second time, but a smaller sample (say 30) may be adequate.

5.6.2 As the **minimal** method involves recording a subset of the species from the **full** method, the **full** method can also be used to calculate the **minimum bog quality index**. So if the **full** method is done the first time a site is surveyed, then change can be assessed after the second survey if either the **full** or **minimal** method is used the second time. However, if only the **minimal** method is done the first time, then we are limited to using the **minimal** method to assess change the next time.

6 Monitoring habitat structure

6.1 Why monitor habitat structure?

6.1.1 A monitoring system based only on vegetation composition could be criticised for being too narrow. Plant species composition is an important aspect of biodiversity both directly and indirectly, by providing food plants for a range of animal species. However, habitat structure is also important for biodiversity, e.g. a bog with a more heterogeneous structure may provide a greater range of niches for animal and plant species than one with a more homogeneous structure.

6.1.2 The CSM monitoring methods measure attributes of both plant species composition and habitat structure, but they do so in a complicated way which makes it difficult to demonstrate if conditions have changed or not. We propose a simple method for assessing habitat structure here by counting how many positive and negative habitats structure features there are in four **quarters** at each sampling point and expressing the results as a single number each time.

6.1.3 The data from this could be used in several different ways, including:

- The **average quadrat habitat structure scores** from one survey can be compared with a later survey of the same site to see if the habitat structure has improved, stayed the same or got worse;
- It may be of interest to compare the **average quadrat habitat structure scores** from different sites;
- The **total** number of occurrences of each of the **individual habitat features** from all of the quadrats from one survey can be compared with a later survey of the same site. This would give us binomial data which is normally not very powerful, but we would have a reasonably large sample size by totalling the scores for all quadrats together. E.g. if we recorded 40 quadrats and we assess the feature in each quarter at each quadrat, our sample size is 4 x 40 = 160, which is probably enough for the data to be useful.

6.2 Assessing habitat structure in the field.

6.2.1 For the full field methodology instructions see appendix H and for the field recording sheet and definitions of each of the positive and negative habitat features see Appendix J.

6.2.2 At each vegetation quadrat, the surveyor inserts 4 canes, 10m from the quadrat, to the north, south, east & west. These canes roughly mark a large circle of about 20m diameter, with the quadrat at the centre. The 4 canes on the outside plus the central quadrat divide the big circle into 4 quarters. For each of these quarter circles, the surveyor ticks off each of the following positive and negative habitat features that are present. So any one feature can get between 0 and 4 ticks for a quadrat. If just one example is present in a quarter, that is enough to get a tick. When the fourth quarter has been completed the number of positive ticks are totalled for all of the positive features together and the number of negative ticks are totalled for all of the negative features together. The total for negative features is subtracted from the total for positive features to get the **habitat structure score** for the quadrat.

6.2.3 This method requires little or no expertise and can be carried out concurrently with either the **full** or **minimal** vegetation quadrat surveys.

6.2.4 Positive habitat features:

- *Sphagnum* (or other moss?) hummock
- Patch of spongy *Sphagnum*
- Bog Pool/*Sphagnum* hollow
- Variable vegetation height
- Natural flush/lagg vegetation
- Cover of moss layer more than 50%
- Two high value indicators present

6.2.5 Negative habitat features:

- Unblocked or partially blocked drains
- Track caused by trampling
- Signs of recent burning
- Conifer
- Signs of overgrazing
- Erosion
- Presence of grass
- Presence of stumps, brash or logs
- One plant dominating

6.2.6 Note: We have included indicators of adverse burning and grazing here. These may not seem relevant to many of the border mires sites currently, but we don't know what will happen in future.

7 Compatibility with CSM methods

7.1 Characteristics of (and problems with) CSM method

7.1.1 Two CSM methods are potentially relevant to the wet bogs and blanket bogs of the border mires, those for **lowland raised & blanket bog** and **upland blanket & valley bog** (see appendix I). Simplified versions of these CSM methods are compared in table 6 below.

Table 6: CSM methods for monitoring bog vegetation in SSSIs

Attribute	Lowland raised & blanket bogs	Upland blanket & valley bog
Habitat extent	1. Extent of bog 2. Extent of pools 3. Extent of lagg	1. No decline in extent of 'feature'
Habitat composition	1. Proportion of site from main mire 2. Proportion of site lagg 3. Proportion of site pools	
Local distinctiveness: microtopography	1. No reduction in extent of microtopographic features	
Habitat/vegetation structure	1. Maintain hummock/hollow/ pool structure 2. Bare ground < 10%	1. < 33% of last year's dwarf shrub growth browsed 2. In pioneer regrowth, < 66% of last year's dwarf shrub growth browsed 3. No signs of burning into moss layer or bare peat from burning 4. No signs of burning or disturbance on sensitive areas 5. < 10% disturbed bare ground or showing signs of active drainage from ditches or tracks 6. < 10% Sphagnum cover disturbed
Physical structure: peat erosion		1. Extent of eroding peat less than extent of stable, newly deposited peat and new growth of bog vegetation
Veg composition: positive indicators	1. At least 3 of 4 common bog indicator species constant, but with < 80% cover 2. No single species > 50% 3. At least 1 high value indicator at least frequent 4. At least 2 high value *Sphagnum*s constant and with > 20% cover 5. *S. cuspidatum*/*pulchrum* at least occasional	1. At least 6 indicators present 2. At least 50% of veg should consist of at least 3 high value indicators 3. *Sphagnum* cover should not be only *S. fallax* 4. No one common bog species to be > 75% cover
Veg composition: negative indicators	1. Negative indicators (grasses & weeds) < 1% cover 2. Non-native invasives no more than rare	1. Non-natives < 1% cover 2. Trees/shrubs < 10% cover 3. Grasses & weeds < 1% cover

	3. *Polytrichum* spp. no more than occasional 4. On mire expanse trees/shrubs no more than rare and < 5% cover 5. On rand trees/shrubs < 10% cover	
Local distinctiveness: rare/scarce species	Set targets locally: 1. Maintain existing pops of rare species 2. Maintain community transitions	

7.1.2 The CSM methods are based around the concept of **favourable condition**, which is defined as a set of minimum and maximum **thresholds** or **targets.** There are several separate targets and each one has to be assessed individually. Some targets are in fact combinations of two or more targets. Overall the methodology is comprehensive, but complex.

7.1.3 The methods were not designed with statistical robustness in mind and many of the targets are difficult or impossible to analyse statistically. Many of the targets are based on presence/absence and so yield binomial data. **Binomial data from small samples** inherently gives low statistical power, making it difficult to come to a conclusion from a sample survey on an individual site unless very dramatic changes have taken place.

7.1.4 Most other targets involve estimating %cover. This method is particularly prone to error due to recorder variation. In addition, in ecological studies %cover estimates often involve a large proportion of 0% scores (or sometimes a large proportion of 100% scores). These data are far from straightforward to analyse. Usually specialist techniques such as **zero-inflated Poisson models** are needed and even then the data often have inherently low statistical power.

7.1.5 Overall, the CSM method gives the manager of an individual site virtually no reliable information on that site. It could be argued that the CSM methods may give useful information on a national or regional scale, if data from a large number of sites are pooled. However, this relies on the assumption that the methods are not inherently biased, which may or may not be true.

7.1.6 In summary, the CSM methods have several serious drawbacks and in our opinion it would never be advisable to use the CSM method as a starting point when designing a robust, repeatable, monitoring scheme for monitoring individual sites.

7.2 Compatibility between this proposed method and the CSM methods

7.2.1 We have not attempted to make the proposed monitoring method directly comparable with the CSM method due to the disadvantages of CSM methods discussed above. Instead we have attempted to measure most of the same attributes in ways that lead to more useful and more powerful data.

7.2.2 With the CSM methods, some of the various favourable condition categories give an indication of whether the condition of the site is improving, declining or stable. However, these results are crude and may not be reliable. There is inherently a high risk that apparently different results from one survey to the next may just be due to random variation. Furthermore, in recent years, changes were made to the method of assigning condition categories, which undermined the already questionable methodology. The category **unfavourable recovering** is now routinely applied to unfavourable sites that are in some kind of agri-environment or SSSI management agreement, regardless of the actual results of the CSM survey (Kirby 2011).

7.2.3 So the two methods are comparable only in that:

1. A similar set of attributes is considered in both methods;
2. The overall result of both gives an idea of whether the site is getting better, worse or is stable, with the caveat that the result from the CSM survey may not be reliable.

7.2.4 We cannot see any way of making this proposed methodology more compatible with CSM than this, without seriously undermining the usefulness of the proposed method.

8 Conclusions and recommendations

8.1 Overall approach

8.1.1 We have attempted to design a method that will yield data that can be easily managed and that give a good chance of ascertaining whether a site is improving, deteriorating or stable from one survey to another. So in theory the **full** method should be reasonably statistically robust and powerful. In order to do this, we have considered how the data may be statistically analysed following repeat surveys of sites, although we do not report on this in detail here.

8.1.2 We have considered other methods of monitoring bogs and used those ideas which we thought were most useful. E.g. we have attempted to include all of the attributes covered in the CSM methods and the proposed bog quality index builds on previous methods that use indicator species, especially some successful methods used in North America.

8.1.3 Recording full vegetation quadrats is an integral part of the method, which allows us to calculate various standard ecological indices. These indices are particularly useful in that they will allow us to relate any changes to potentially important management and/or environmental factors.

8.2 Bog quality index

8.2.1 The bog quality index gives us a way of directly assessing the nature conservation quality of a site. Although the other standard ecological indices are relevant and useful, none of them assess habitat quality directly. The concept of a habitat quality index has been used successfully by the author before in hay meadows and similar indices have been used successfully in mire habitats in North America.

8.3 Baseline survey/stratification

8.3.1 The baseline survey maps provide the basis for stratifying the sites. This is the single most important aspect of the whole monitoring process and so it is vital that only experienced and competent surveyors are used. This baseline mapping only has to be done once, providing it is done properly.

8.3.2 Stratifying sites into two or more monitoring parcels, allows us to assess changes separately in each of the parcels. This may be useful where different parts of the site have been subject to different management regimes, or where different parts of the site have different types of vegetation.

8.3.3 An important outcome of the baseline mapping is to define the extent of the area of interest on the site, which will allow us to comment in future on any changes to extent of the habitat of interest. It also serves as an accurate definition of the areas to monitor. Stratifying variable sites into two or more monitoring parcels should result in less variation within each monitoring parcel, which in turn should lead to higher statistical power.

8.4 Comparison of the four variations on the method

8.4.1 The **full** method is best in that:

1. It gives more accurate results;
2. It results in more statistically powerful data;

3. The field identification and recording error rates are likely to be lower;
4. There are many more useful options available at the data analysis stage.

8.4.2 It is recommended that the **full** survey method is always used the first time a site is surveyed. If short cuts have to be made, it would be better to survey fewer sites well using the **full** survey method, or else use the **minimal** method on second or third surveys of sites.

8.4.3 The **intermediate** survey method appeared to perform quite well overall. However it was unpredictable with the best and worst quadrats and it has the major disadvantage that none of the other useful ecological indices can validly be used with these data. It would be feasible to train a keen, but inexperienced surveyor to recognise all of the species on the **intermediate** list over a few weeks or months. If there are ever plans to employ an inexperienced surveyor to work more or less full time on monitoring the border mires, then it may be worthwhile training them up to use the intermediate method. If several inexperienced surveyors were to be used for relatively short time periods then it would probably not be a good use of resources to use the **intermediate** method. The **minimal** method would be more suitable in those cases.

8.4.4 Both the **simple** and **minimal** methods appeared to perform reasonably well considering how simplified those methods were. There was little to choose between the **simple** and **minimal** methods in terms of performance. The **simple** method is probably at least five times more time-consuming than the **minimal** method in the field. There seems little to gain from using the **simple** method, so if short cuts are used after the first survey, the **minimal** method is recommended, with the caveat that the results are unlikely to be as reliable or as powerful as the **full** method. Any surveyors using the **minimal** method will need some training and ID support in order to minimise the field identifications error rate.

8.4.5 However, on **blanket bog** sites, it appears that neither the **simple** nor the **minimal** method do a good job. So for those sites, it is probably best to only use the **full** method.

8.5 Recommended sample sizes

8.5.1 Ideally samples of 50 quadrats per stratum on each site should be surveyed at least on the first **full** survey. Fewer samples may sometimes be adequate, but this is not guaranteed. Once a few sites have been surveyed it is recommended that post-hoc power analyses be carried out to see what levels of statistical power were actually achieved with the real survey data. The recommended sample sizes could then be reviewed.

8.6 Size of the overall task of monitoring all of the border mires

8.6.1 If we only consider the **wet bogs**, there are probably somewhere between 60 and 100 individual sites involved. Each of these individual sites is likely to require somewhere between two and three strata on average. So as a rough estimate, to survey all of the wet bog sites once, may involve between 150 and 200 surveys.

8.6.2 The most efficient and cost-effective way of achieving this in a reasonable amount of time would be for one of the partner organisations employ an experienced surveyor to work full-time on border mires monitoring for a number of years. The ideal candidate could do the baseline surveys, the monitoring surveys, the data entry, the data management and the statistical analyses. It would probably be feasible for a competent surveyor to complete the baseline surveys and initial round of monitoring surveys of all of the **wet bog** sites within three to five years.

8.6.3 It may not be feasible to employ someone to work full-time on this, but none of the alternatives are likely to be as good. Contracting the work out would be more expensive, more disjointed and the quality of the work would be more variable. Getting students or volunteers to do surveys is not likely to go anywhere near completing even a quarter of the task and the quality of the work is likely to be poor overall.

8.7 Summary of main recommendations:

1. In order to make the overall task manageable, prioritise the wet bog sites and concentrate on getting all of those surveyed once first;
2. Stratifying sites into separate zones of differing vegetation will usually result in more powerful and more useful data;
3. Always use experienced, competent surveyors for the baseline mapping;
4. Within each site, prioritise the monitoring effort only on the parts of the site of most interest;
5. Use the **full** method, with a relatively large sample size the first time a site is surveyed;
6. Aim for 50 quadrats per monitoring stratum initially;
7. Once a few sites have been surveyed carry out a power analysis on the survey data and adjust the recommended sample sizes up or down accordingly;
8. If inexperienced surveyors are used in future, the **minimal** method could be used for any surveys after the first survey of a site, but bear in mind that the results are less likely to be reliable;
9. If blanket bog sites are included in the monitoring, use the **full** method as it does not appear that the **simple** or **minimal** methods are reliable enough on blanket bogs
10. The cheapest and most efficient way to carry out adequate surveys on a large proportion of the sites would be to employ an experienced surveyor to work full-time on the border mires monitoring for a number of years;
11. Only consider using the **intermediate** survey if there are plans to use a single relatively inexperienced surveyor to cover a large number of sites over a long time period.

References

Andreas B.K., Mack J.J. & McCormac J.S. 2004. *Floristic Quality Assessment Index (FQAI) for vascular plants and mosses for the State of Ohio.* Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio.

Bourdaghs M.R. 2004. *Properties and performance of the floristic quality index in Great Lakes coastal wetlands.* University of Minnesota, MSc Thesis.

Critchley C.N.R. 2000. Ecological assessment of plant communities by reference to species traits and habitat preferences. *Biodiversity and Conservation.* 9:87-105.

Dytham C. 2011. *Choosing and using statistics. A biologist's guide.* 3rd Edition. Wiley-Blackwell.

Hill D., Fasham M., Tucker G., Shewry M. & Shaw P. 2005. *Handbook of Biodiversity Methods. Survey, Evaluation & Monitoring.* Cambridge.

Hill M.O., Blackstock T.H., Long D.G. & Rothero G.P. 2008. *A checklist and Census Catalogue of British and Irish Bryophytes. British Bryological Society.* Middlewich, Cheshire.

Hill M.O., Preston C.D., Bosanquet S.D.S & Roy D.B. 2007. *Bryoatt. Attributes of British and Irish Mosses, Liverworts and Hornworts.* Centre for Ecology & Hydrology. Monks Wood, Cambridgeshire.

Hill M.O., Preston C.D. & Roy D.B. 2004. *Plantatt. Attributes of British and Irish Plants: Status, Size, Life History, Geography and Habitats.* Centre for Ecology & Hydrology. Monks Wood, Cambridgeshire.

JNCC. 2004. *Common Standards Monitoring Guidance for Lowland Wetland* (version August 2004). JNCC, Peterborough.

JNCC. 2009. *Common Standards Monitoring Guidance for Upland Habitats* (version July 2009). JNCC, Peterborough.

Kirby, K. 2011. Condition of England's SSSIs. *British Wildlife* 22: 224.

Magurran A.E. 2004. *Measuring Biological Diversity.* Blackwell

O'Reilly J. 2008. Hay Time: Restoring upland hay meadows in the North Pennines AONB. In: Cherrill A., Pullan S. & Jefferson R. *The Ecology and Management of Grasslands in North East England.* Proceedings of the 1st conference of the North East section of the Institute of Ecology and Environmental Management.

O'Reilly J. 2011. *An analysis of survey data from upland hay meadows in the North Pennines AONB.* Natural England Commissioned Report NECR069.

O'Reilly J. 2014. *Stanley Moss: NVC survey and baseline vegetation monitoring.* Unpublished report by Ptyxis Ecology for Durham Wildlife Trust.

Smith C.W., Aproot A., Coppins B.J., Fletcher A., Gilbert O.L., James P.W. & Wolseley P.A. 2009. *The lichens of Great Britain and Ireland.* British Lichen Society. London.

Sokal R.R. & Rohlf. F.J. 2012. *Biometry* (4th Ed.). Freeman. New York.

Stace C. 2010. *New Flora of the British Isles.* 3rd Edition. Cambridge.

Sutherland W.J. 1996. *Ecological census techniques: a handbook*. Cambridge University Press.

Wheater C.P., Bell J.R. & Cook P.A. 2011. *Practical field ecology: a project guide.* Wiley-Blackwell.

Appendix A: Exploring the Stanley Moss dataset

The **Stanley Moss** dataset was baseline data from a bog vegetation monitoring scheme of a degraded raised bog site undergoing restoration management (O'Reilly 2014). This site shared many characteristics with degraded border mire sites undergoing restoration, although the vegetation was a bit more 'lowland' in character. The data comprised lists of all vascular plants, bryophytes and lichens for each quadrat, with counts of how many cells per quadrat (out of 16) each species was observed in. 62 quadrats were used from this dataset.

This dataset was assumed to be reasonably typical of the types of data we might expect from a degraded **wet bog** site from the border mires using the proposed monitoring tool.

For each quadrat, the following indices were calculated:

- Full bog quality index;
- Intermediate bog quality index;
- Simple bog quality index;
- Minimal bog quality index;
- Simpson's reciprocal index (species diversity).

These derived values for each quadrat formed the datasets that were then tested. The following investigations were performed:

- First we investigated if each dataset could be transformed to something close to a normal distribution;
- We then compared pairs of indices using scatterplots and linear regression to see how closely one index could be predicted from another, and whether or not each index ranked the quadrats in the expected order;
- Finally, based on the variance found in the datasets, we calculated (in a standardised way) the samples sizes needed in order to have 80% power to detect a difference of 20% from the original mean.

The quadrats in this dataset were categorised into four types: **wet bog** (5 quadrats); **heathy bog** (32 quadrats); **cottongrass bog** (5 quadrats) and; **heath** (20 quadrats). Although the quality varied somewhat within each category, on average, any bog quality index that worked well should have ranked the **wet bogs** the highest. It is not very obviously clear in which order the remaining three categories should be ranked, but **heathy bogs** should probably be ranked next best after **wet bogs** and **cottongrass bogs** should probably be ranked lowest.

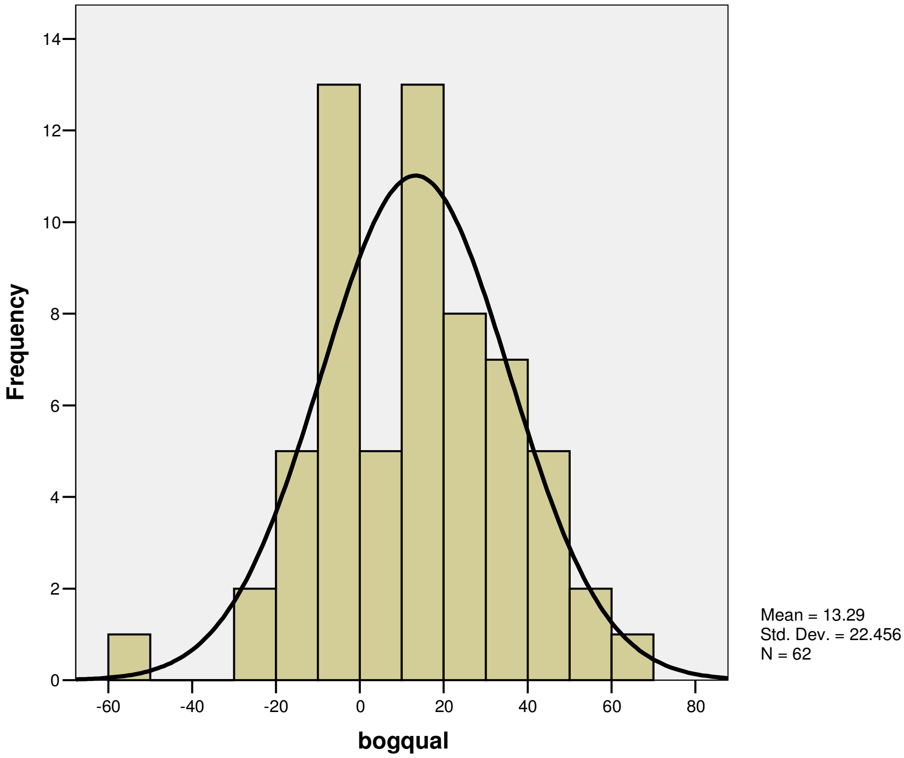
In this dataset there were **76** species recorded in all that were used to calculate the **full** bog quality index from the original raw data. When the **intermediate** species list was used this original list of 76 species was reduced down to **50** species. Only 9 species from the **simple** list were present in the dataset, so only these **9** were used to calculate the **simple** and **minimal** index scores.

Investigating normality
Each dataset was assessed to see if a normal distribution was plausible. We constructed histograms, normal probability plots and residual plots. We also conducted Shapiro-Wilk tests. If a normal distribution was not plausible from the raw data we tried transformations. Usually either the raw data or the transformed data was normal, but in a few cases they were not.

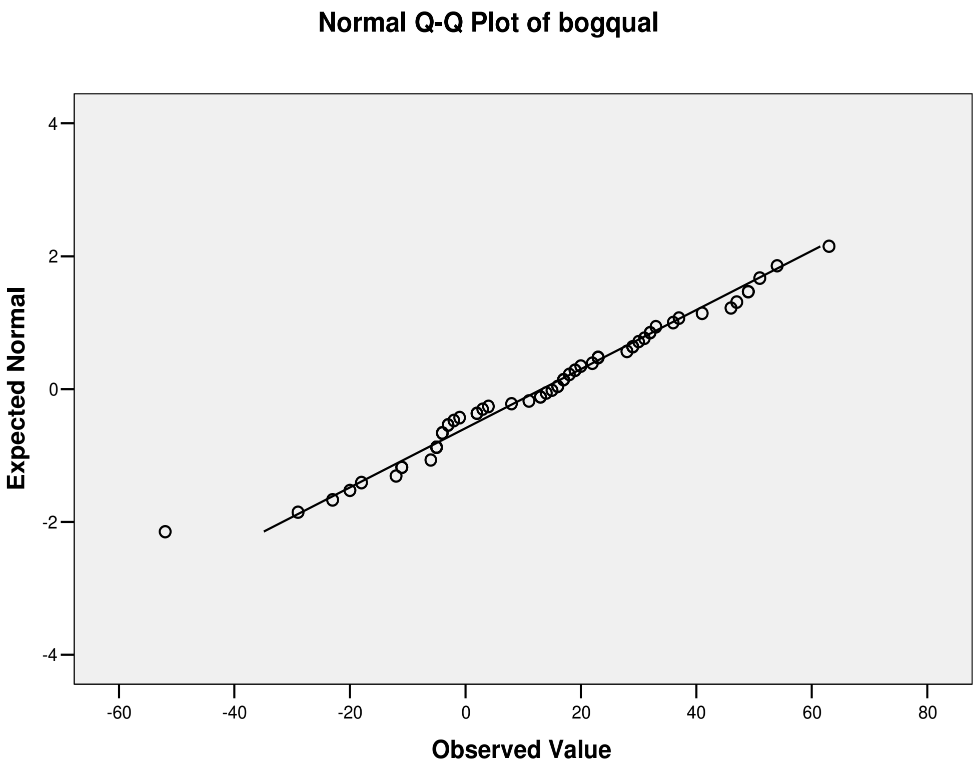
We have not included all of these plots here, as they mainly looked quite similar and there were a lot of them. The first example on the next page shows a histogram and normal probability plot giving little evidence against a normal distribution. After this first example, other plots were included only if they could not be transformed to normal distributions.

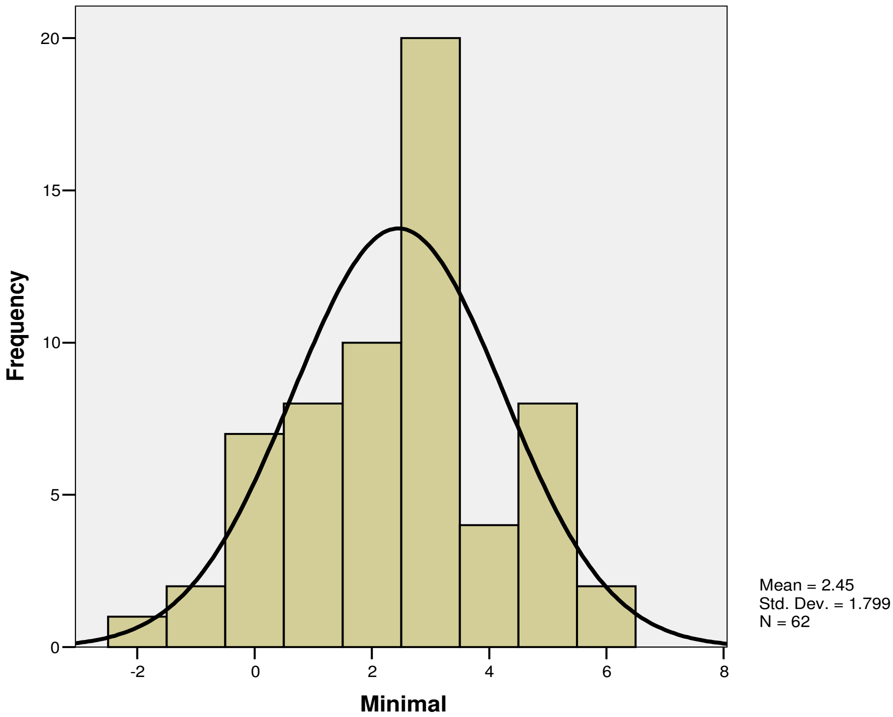
Summary of normality analyses

Method	Transformation	Normal?	Notes
Full	-	Yes	
Intermediate	-	Yes	
Simple	-	Yes	
Minimal	-	No	9 observed values only

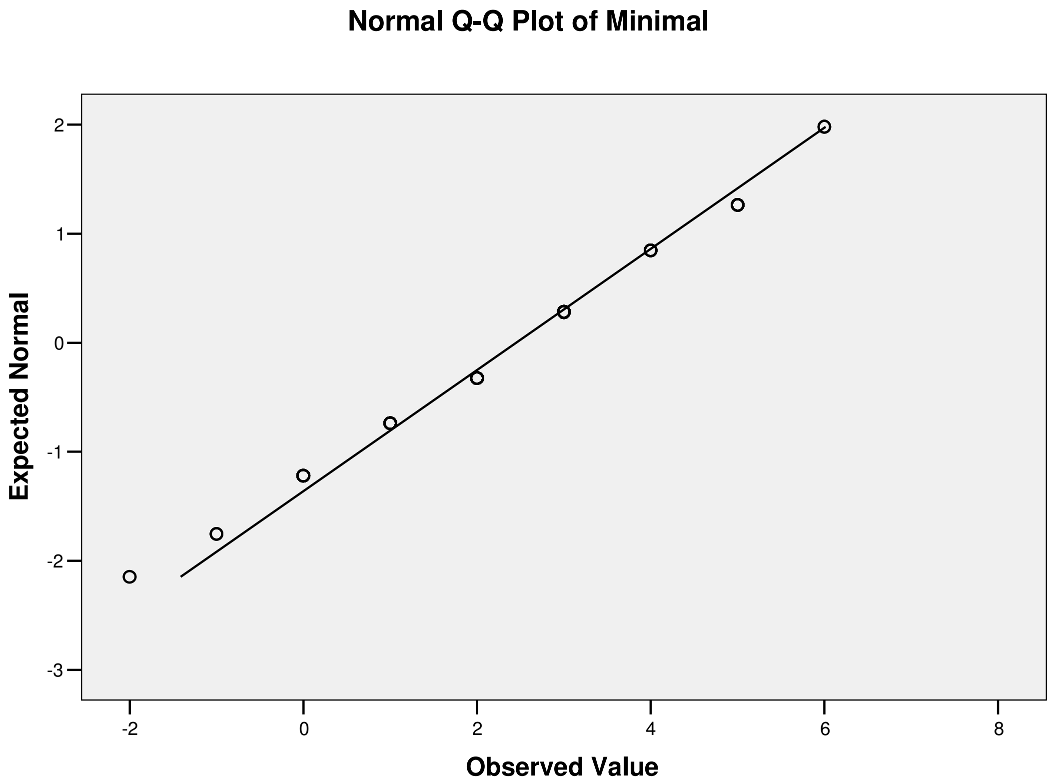


Full bog quality index – normal distribution looks plausible without transformations





Minimal bog quality index: shape not far off normal distribution, but data take only one of nine values



Scatterplots and linear regression

Several pairwise comparisons are made here, to see:

- How closely one index predicted the scores of another, and;
- How well each index ranked the different categories of vegetation types in the expected order.

Scatterplots are presented showing the scores for all of the quadrats of one index against another. The index on the ***y*-axis** is the one we are attempting to predict from the index along the ***x*-axis**. The quadrats appear as different coloured symbols depending on which main vegetation category they belong to.

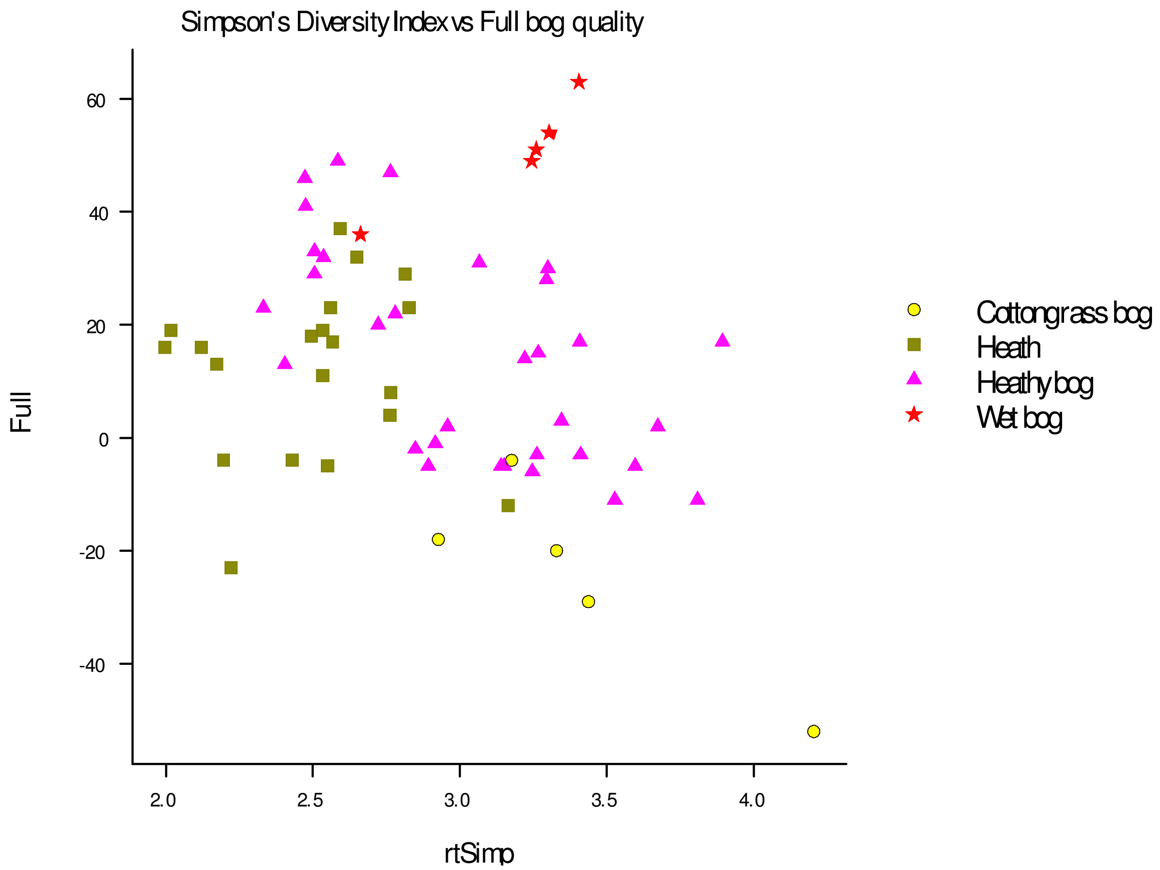
If one index predicted the scores of another closely then there should not be much scatter in the plot. Instead most of the points should line up along a diagonal line from the bottom left of the plot to the top right.

The % variance explained (or *r*-squared value) tells us how much of the total variability within the dataset was explained by the imaginary regression line. If the plotted points lay mostly close to a straight line, this value will be close to 100% and if there was little if any relationship between the two indices (i.e. lots of scatter) then this value will be close to 0%. Any % variance explained value over 60% suggested a reasonably strong relationship and anything over 80% was very strong.

Occasionally a *p*-value is given for a test of the null hypothesis that the slope of the regression line is not zero, i.e. that there is virtually no relationship between the two indices being compared. In most cases, there were clear relationships between the indices and the *p*-value was usually $p < 0.001$. These very low *p*-values were not included here to avoid repetition.

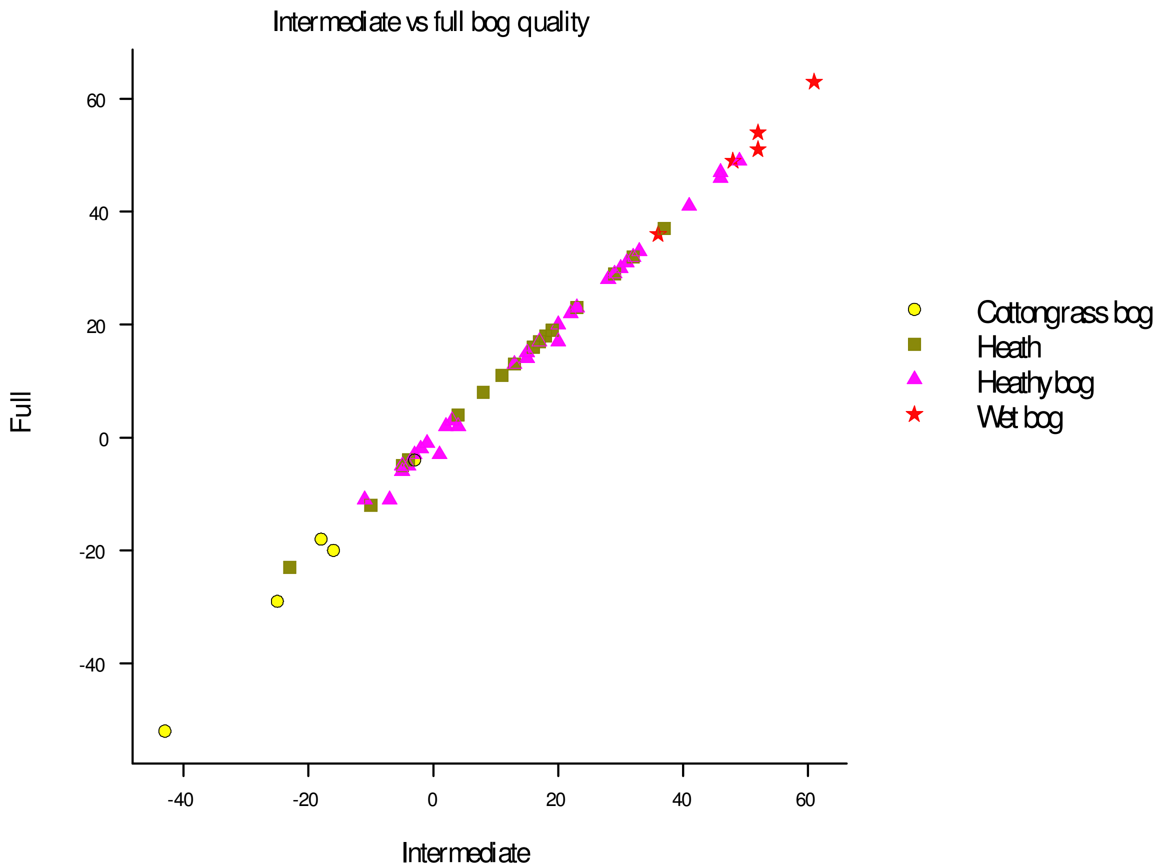
The % variance explained values and the *p*-values mentioned above came from running a linear regression model on the two indices after transforming the data to normal distributions if necessary. We also checked these linear regression models by inspecting the residual plots to check the model assumptions, especially the assumptions that the residuals were normally distributed and had constant variance. We describe any major deviation from the linear model that arose from such checks.

The scatterplots were inspected by eye to see how the different categories of vegetation types were ranked using each index. If the index on the ***y*-axis** was a good way of ranking the quadrats in terms of quality, then the **wet bogs** should appear at or near the **top** of the plot and the **cottongrass bogs** should appear at or near the **bottom** of the plot. Similarly, if the index on the ***x*-axis** was a good way of ranking the quadrats in terms of quality, then the **wet bogs** should appear at or near the **right-hand side** of the plot and the **cottongrass bogs** should appear at or near the **left-hand side** of the plot.



Little or no relationship between diversity scores and quality scores. Only 6.7% variance explained by regression line and only moderate evidence (*p* = 0.023) against the null hypothesis that the slope of the regression line was not zero.

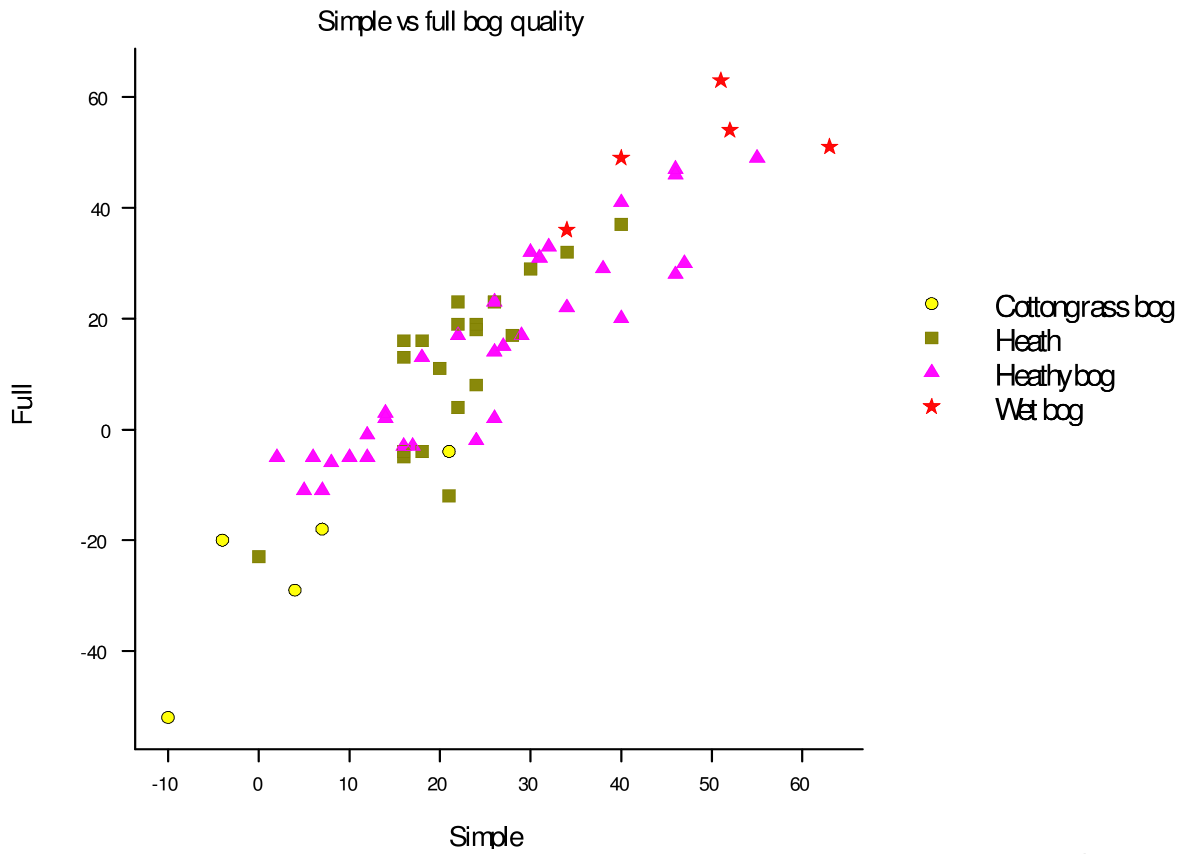
The bog quality index was clearly a better way of scoring the **wet bogs** higher and **cottongrass bogs** lower. This plot shows that diversity does not tell us much if anything about quality and this is why a separate bog quality index is needed. E.g. the most diverse quadrat (yellow dot on bottom-right of plot) using **Simpson** gets the lowest score of all for **quality**.



% variance explained = 99.6% which is as close to perfect as we could expect. A very strong positive relationship. Many quadrats in fact got exactly the same score with both methods.

The residual plots show some evidence against the simple linear model, probably because there were so many scores that were the same, and of the remainder, both the quadrats with negative and positive scores using the **full** index had scores of lesser magnitude using the **intermediate** index. Also, the negative scores tended to differ more on average, as more of the species with negative quality scores were omitted from the **intermediate** method. This means that although predictions based on the **intermediate** index were usually very accurate, when they were not accurate they differed from the expected values in an unpredictable way.

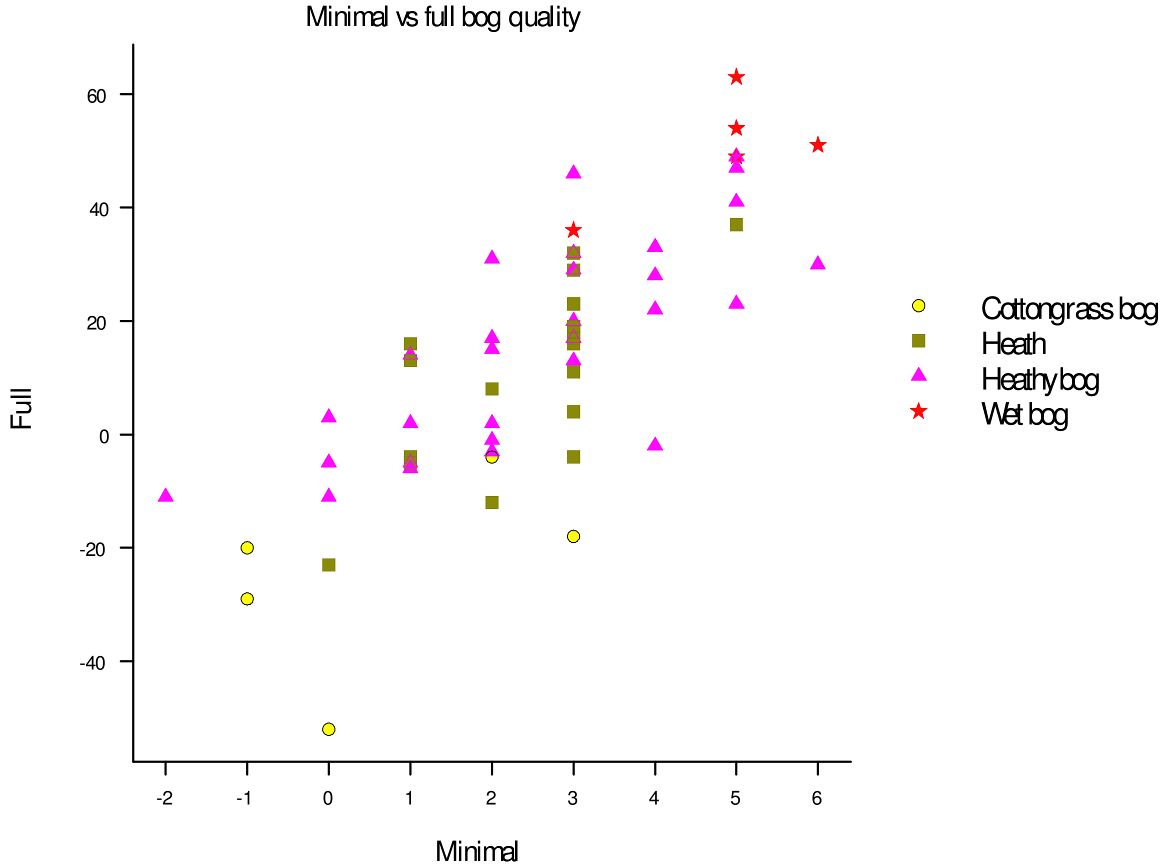
Both methods appeared to rank the quadrats equally well, as they were almost identical.



% variance explained = 83.3% which is really very good for such a simple method! Quite a strong positive relationship between the two methods.

Some evidence that the residuals were not normally distributed, so the validity of predictions based on the simple method could be questioned.

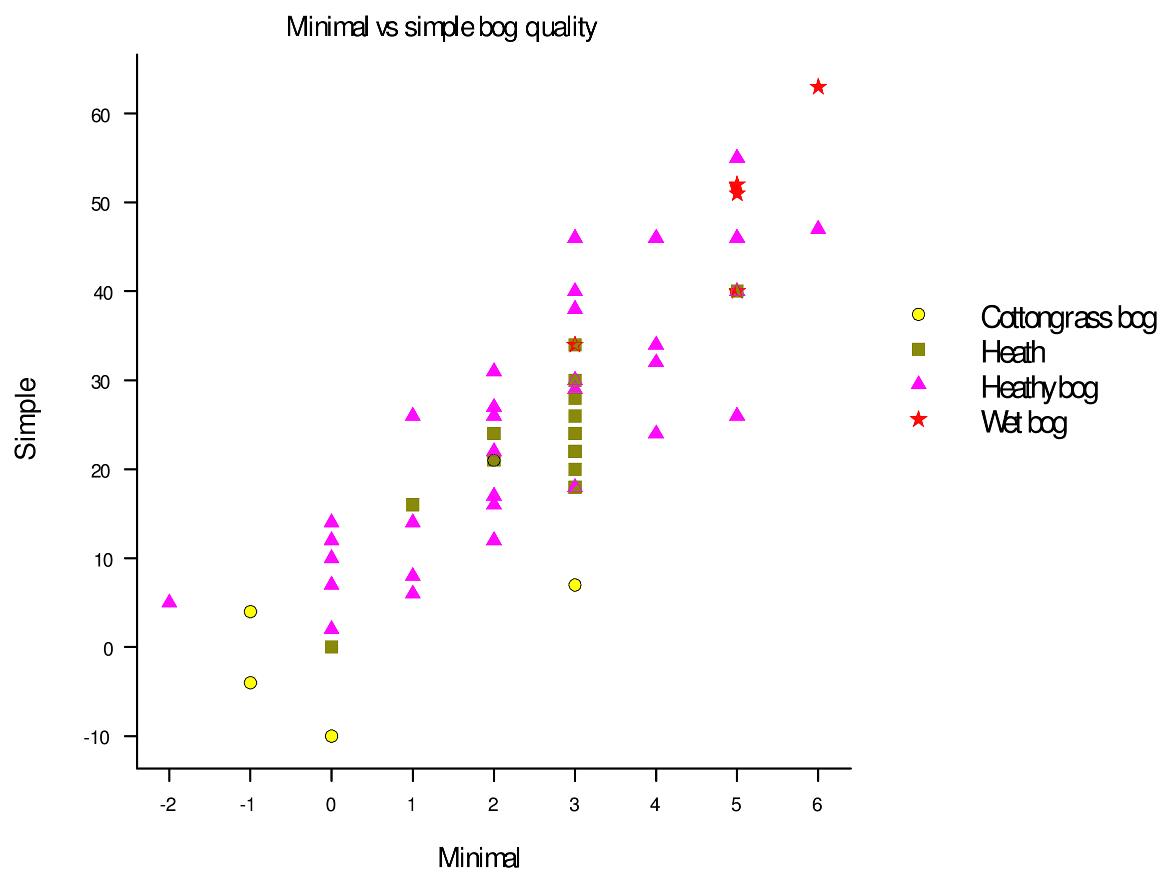
The full method clearly ranked the **wet bogs** higher and the **cottongrass bogs** lower. They were nor ranked as well on average with the simple method.



% variance explained = 61.8% which is good for such a simple method. A clear positive relationship between the two methods, although unsurprisingly, we have much more spread in the data than before.

Model checking revealed no major problems with normality or constancy of variance in the residuals.

The full method clearly ranked the **wet bogs** higher and the **cottongrass bogs** lower.



% variance explained = 71.7%, so there was quite a difference in these two methods based on whether or not the frequency data were included.

Model checking revealed no major problems with the residuals.

The simple method seemed to rank the **cottongrass bogs** better, but there appeared to be little to choose between the methods for ranking the **wet bogs**.

Discussion of Stanley Moss data results
So far, we have seen that no matter which type of quality index we calculate, each dataset was reasonably close to a normal distribution.

There was little if any relationship between diversity and habitat quality based on indicator species, so to get the best picture of overall quality, we need to consider both. However, we cannot calculate a diversity index in any meaningful way based on partial quadrats using only indicator species, so for the **intermediate**, **simple** and **minimal** methods we are limited to the quality index based on the indicator species only.

If all methods ranked the quadrats in the same order, then when the scores from two methods were plotted against each other, we would get a scatterplot with points along a straight line going diagonally upwards. The relationship between the **intermediate** and **full** methods almost followed a perfect straight line. However, even the **simple** and **minimal** methods were reasonably closely correlated with the **full** method. The **full** and **intermediate** methods appeared to rank the best and worst quadrats in a better order than the **simple** and **minimal** methods did. When the **simple** and **minimal** methods were compared the ranking from the **simple** method seemed slightly better.

Measures	%variance explained
Diversity vs. full	7%
Intermediate vs. full	100%
Simple vs. full	83%
Minimal vs. full	62%
Simple vs. intermediate	84%
Minimal vs. intermediate	61%
Minimal vs. simple	72%

So superficially it appears that the **intermediate** method may do a very good job at predicting **full** quality and the **simple** and **minimal** methods were not bad considering how simplified these methods are.

We may ask if they are good enough to be adequate? We could go some way to answering this by comparing the statistical power obtained from the different indices.

Below we calculate samples sizes required to detect a difference of 20% from the mean. We use the 95% significance level and 80% for the level of power we require in both methods.

Some of our variables (e.g. the four bog quality indices) can take both positive and negative values, so they are ratio variables. Simpson's index is an interval variable, i.e. it has a minimum possible value. This means that it is difficult to compare the power obtained from the five methods in a meaningful way. For the comparison below, we have taken the minimum value in each case to equal absolute zero for that index and so we have transformed the observed values by subtracting this minimum value from all values. Only then have we calculated the (standardised) mean. These figures should therefore be taken as a rough guide only.

Sample sizes needed to achieve 80% power to detect a difference of 20% from the original (standardised) mean.

Method	Sample size
Full	24
Intermediate	29
Simple	39
Minimal	33
Simpson	56

So there was not a huge difference in the power achieved using the different indices, but on average the **full** and **intermediate** methods were more powerful, as we would expect (as they are more precise). It was surprising that the **minimal** method appeared to be a bit more powerful than the **simple** method, but this may just be due to random variation in this case.

Appendix B: Exploring the 'mixed bog' dataset

The **mixed bogs** datasets comprised 89 vegetation quadrats recorded by the author from various sites in northern England and southern Scotland. The quadrats chosen were from vegetation types typical of **wet bog** sites in the border mires. The numbers of quadrats from each of the vegetation types chosen were roughly in proportion to the relative frequency of each vegetation type within **wet bogs** in the border mires.

This dataset was assumed to be reasonably typical of the range of variation of vegetation types typical of **wet bogs** in the border mires, including high quality to more degraded sites.

However, frequency/count data from cells within the quadrats were not available for this dataset. The %cover of each species in the quadrat had been estimated and for this exercise these data were simplified to the 10-point, Domin scale.

For each quadrat, the following indices were calculated:

- Full bog quality index;
- Intermediate bog quality index;
- Simple bog quality index;
- Minimal bog quality index;
- Simpson's reciprocal index (species diversity);
- Ellenberg L (light) index;
- Ellenberg F (wetness) index;
- Ellenberg R (reaction, i.e. pH) index;
- Ellenberg N (nitrogen, i.e. fertility) index;
- SS (suited species) Grazing index.

These derived values for each quadrat formed the datasets that were then tested. The following investigations were performed:

- First we investigated if each dataset could be transformed to something close to a normal distribution;
- We then displayed box and whisker plots of the scores for each index from the six different vegetation types, to see whether or not the indices ranked the different types in the expected order, and whether or not the different types were clearly separated using these indices;
- We then compared pairs of indices using scatterplots and linear regression to see how closely one index could be predicted from another, and whether or not each index ranked the quadrats in the expected order;
- Then, based on the variance found in the datasets, we calculated (in a standardised way) the samples sizes needed in order to have 80% power to detect a difference of 20% from the original mean;
- Finally, we investigated the samples sizes that would be needed if the sites had been stratified in several different ways.

The quadrats in this dataset were categorised into six types, A to F; with type A corresponding roughly to the best quality wet bog vegetation and type F roughly corresponding to the lowest quality bog vegetation. **Type A** included M17a (6 quadrats) and M18a (18 quadrats). **Type B** included M18b (3 quadrats) and M19a (13 quadrats). **Type C** included M19b (10 quadrats) and M19cii (1 quadrats). **Type D** included 'M19-ns' (5 quadrats) a form of M19 without any *Sphagnum* and 'M19-Sf/Pc' (11 quadrats) a form of M19 with a moss layer dominated by *Sphagnum fallax* and *Polytrichum commune*. **Type E** included three types of M20 (7 quadrats). **Type F** included M25a (13 quadrats).

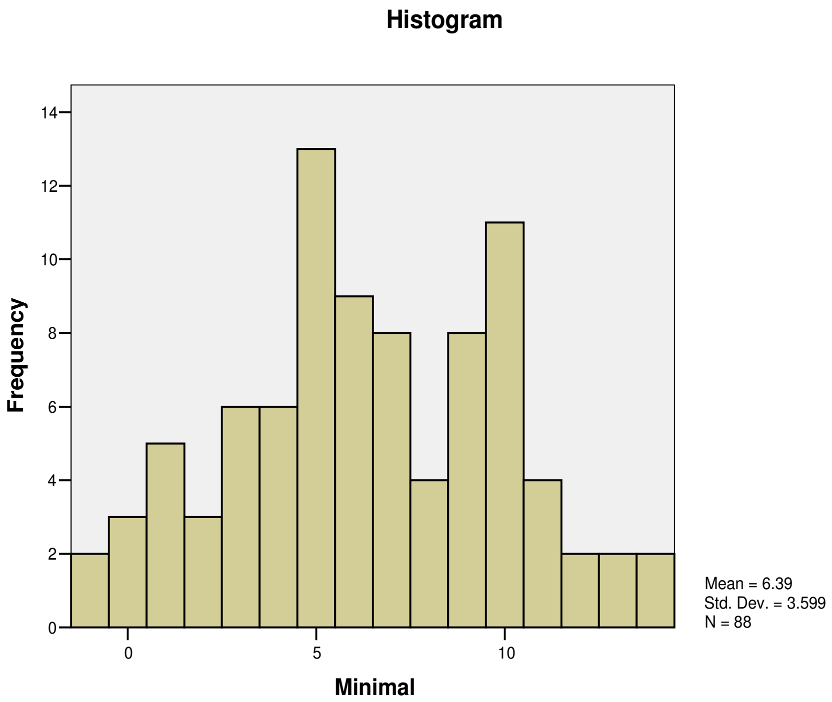
In this dataset there were **108** species recorded in all that were used to calculate the **full** bog quality index from the original raw data. When the **intermediate** species list was used this original list of 108 species was reduced down to **70** species. 15 species from the simple list were present in the dataset, so these **15** were used to calculate the **simple** and **minimal** index scores.

Investigating normality

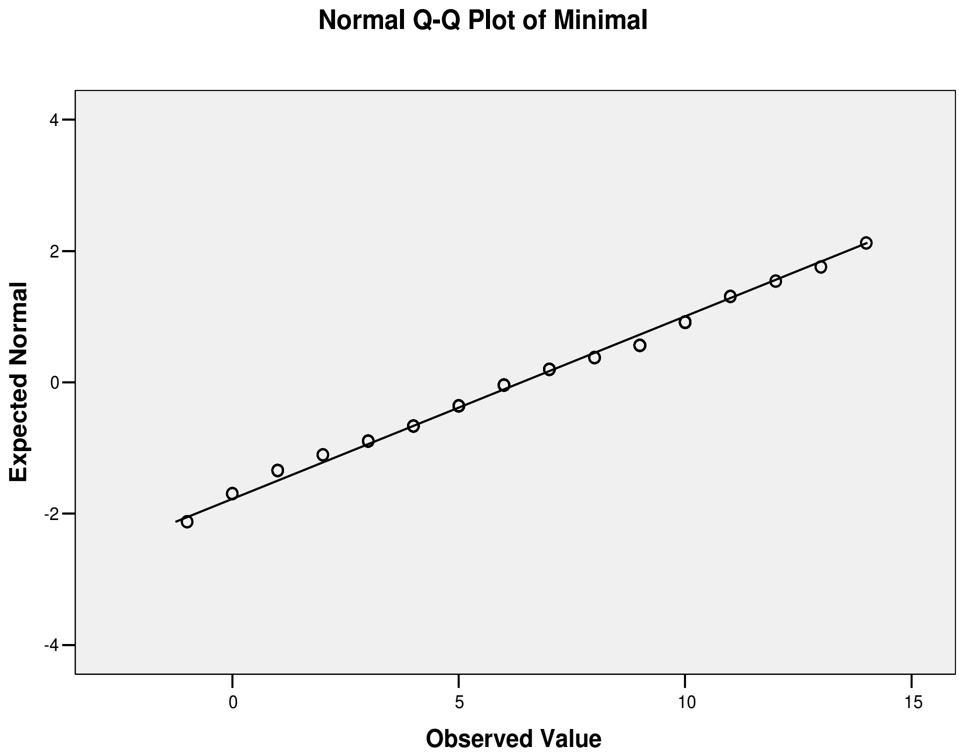
Each dataset was assessed to see if a normal distribution was plausible. We constructed histograms, normal probability plots and residual plots. We also conducted Shapiro-Wilk tests. If a normal distribution was not plausible from the raw data we tried transformations. Usually either the raw data or the transformed data was normal, but in a few cases they were not.

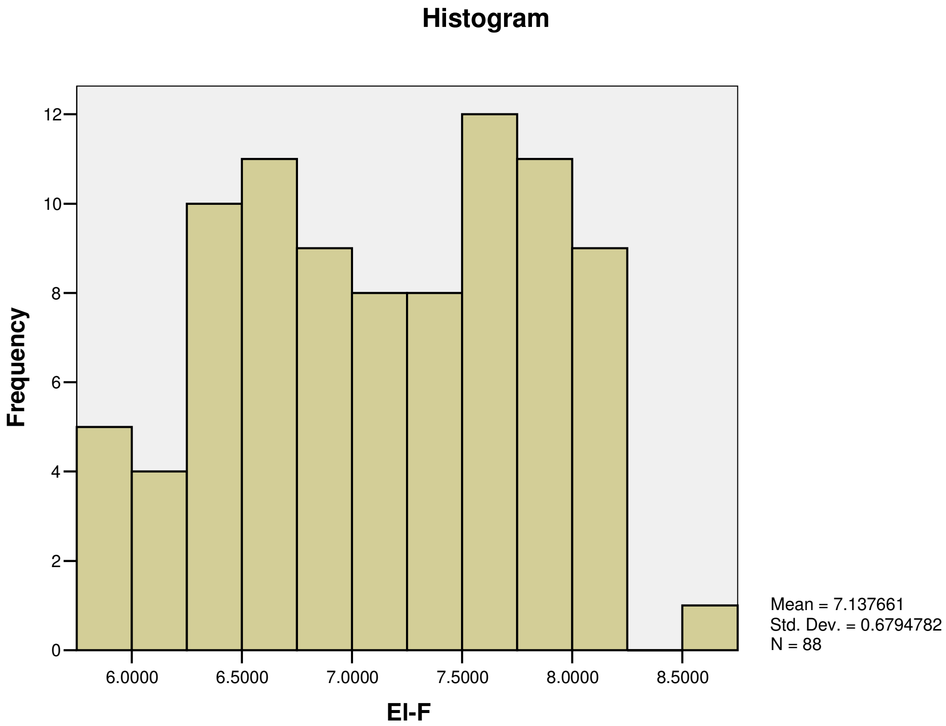
We have not included all of these plots here, as they mainly looked quite similar and there were a lot of them. Only those plots which display some evidence against the assumption of a normal distribution are included here.

Method	Transformation	Normal?	Notes
Full	square root	Yes	
Intermediate	-	Yes	
Simple	-	Yes	
Minimal	-	Yes	But only 16 distinct values
Simpson	natural log	Yes	
Ellenberg-L	-	Yes	
Ellenberg-F	-	?	May be bimodal
Ellenberg-R	reciprocal	Yes	
Ellenberg-N	-	Yes	
SS grazing	-	Yes	

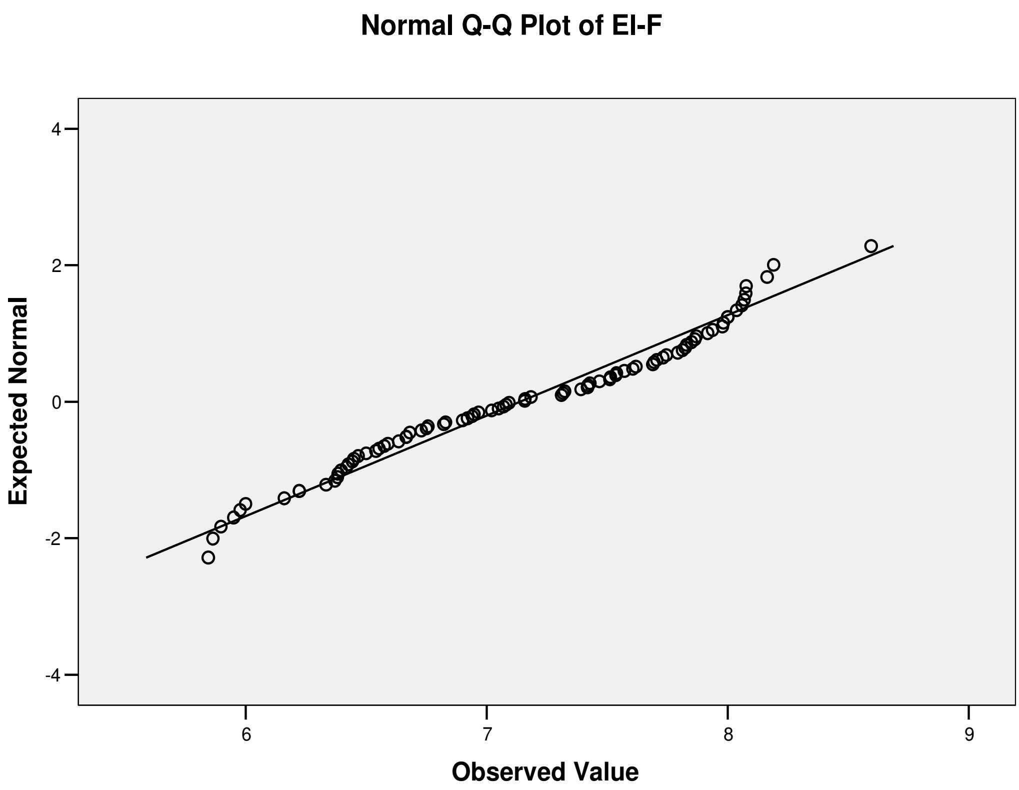


Minimal bog quality index: normal distribution looks just about plausible without transformations, but there are only 16 different values taken by the observed data.





Ellenberg L index: – possibly bimodal distribution, but not too far off normal distribution. Transformations do not help here.

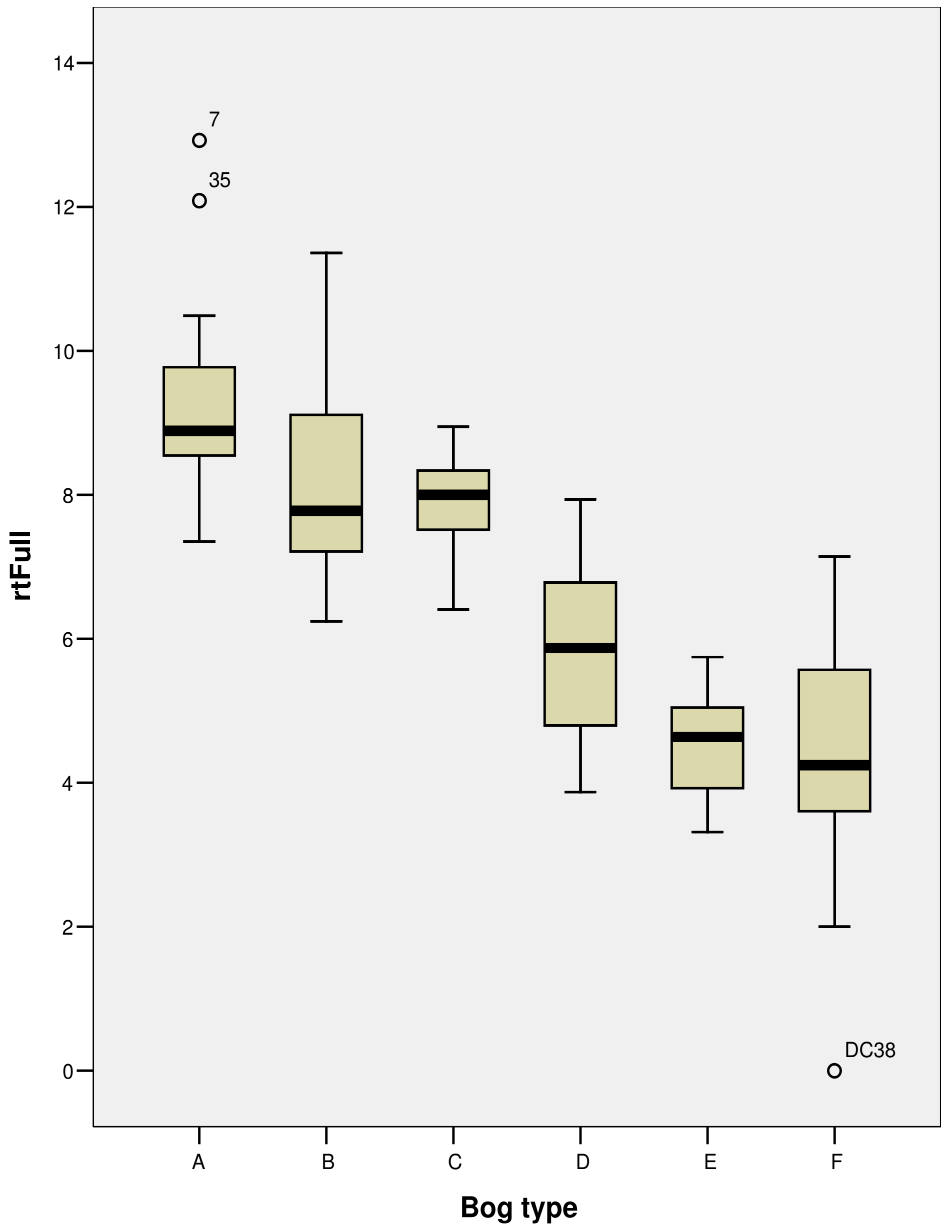


Comparing boxplots of the scores for each of the six different bog categories

Box and whisker plots are included below for each of the indices. Each plot summaries the range of scores for that index in each of the six different bog vegetation categories, which can then be easily compared by eye.

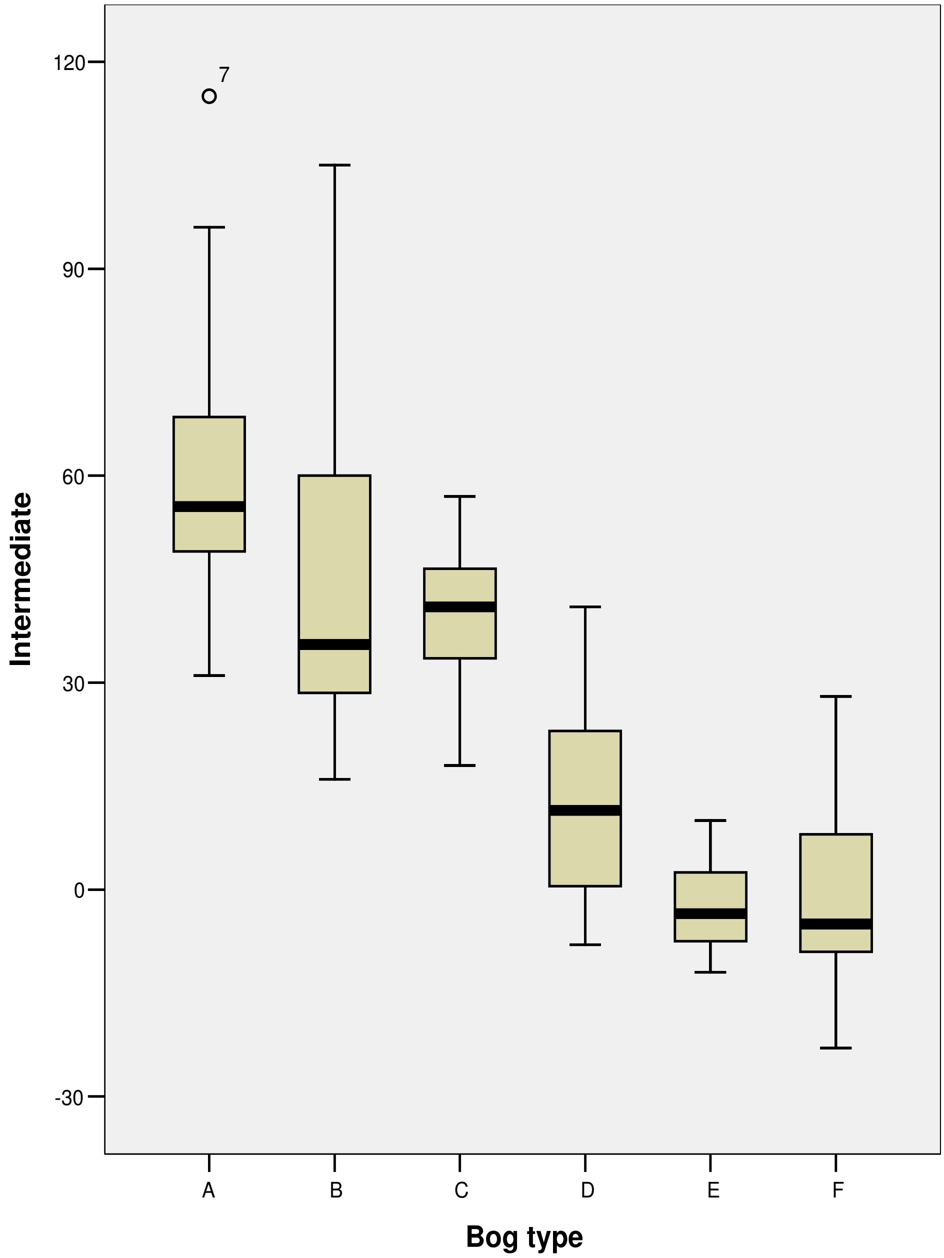
The purpose of this analysis was to get a rough idea as to whether or not the various indices were good ways of separating bog types of different quality. We could have included more formal tests here (such as Analysis of Variance followed by appropriate post-hoc tests or multiple regression) for testing for differences but this was thought to be unnecessary as the plots showed clear differences in most cases.

For the various versions of the bog quality index, if they all worked well, then all four of them should rank type A highest on average and then each subsequent type slightly lower down to type F being the lowest. The other ecological indices may not separate the six different types in such a regular and predictable way, but what is important with these, is that there are some clear differences evident.



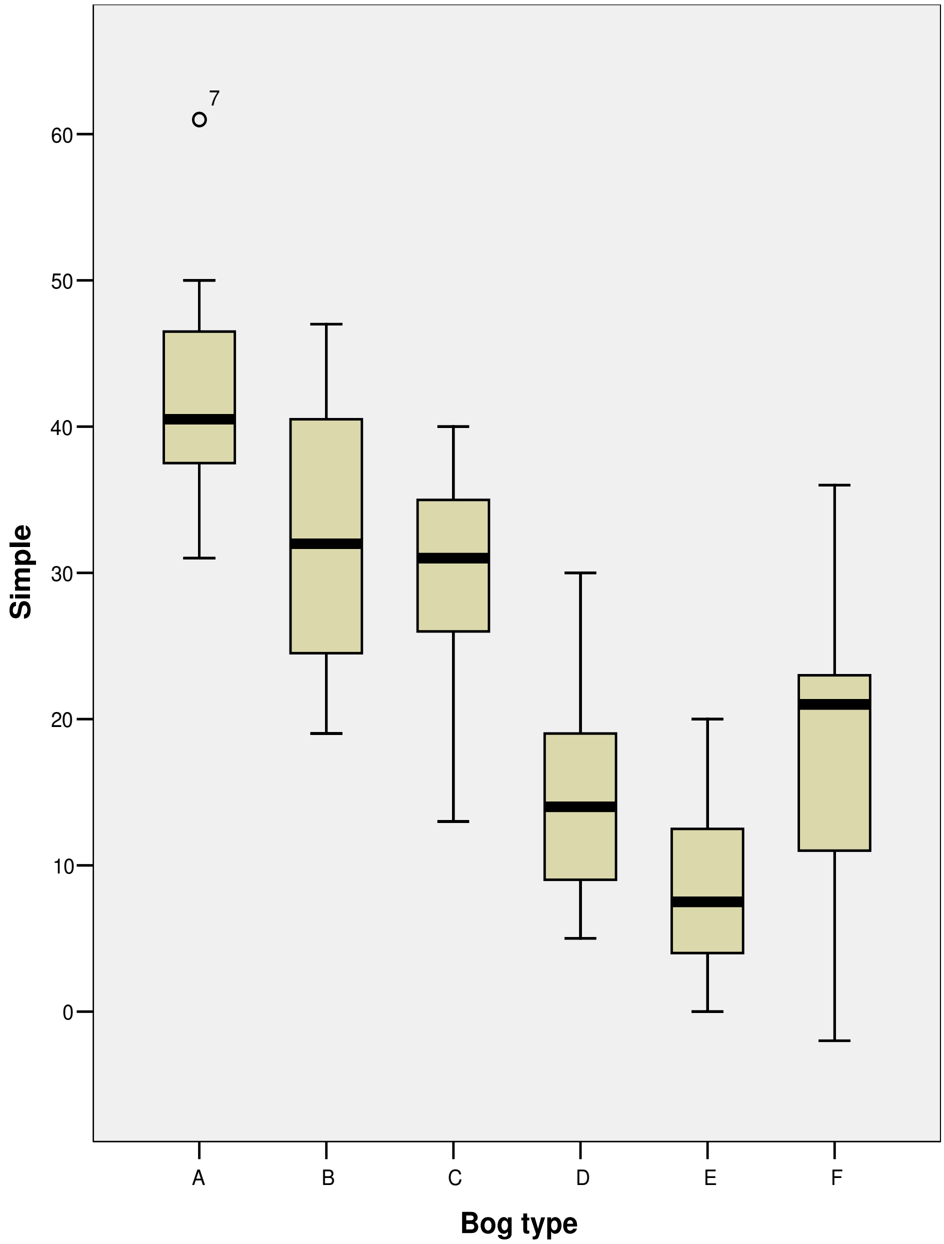
Comparison of **full bog quality** scores (square root transformation) for different bog types.

Bog types were ranked more or less in the expected order of quality, though there seemed little difference between the scores for types B and C. Overall, this was an encouraging result and gives us some confidence that the bog quality index may be useful.



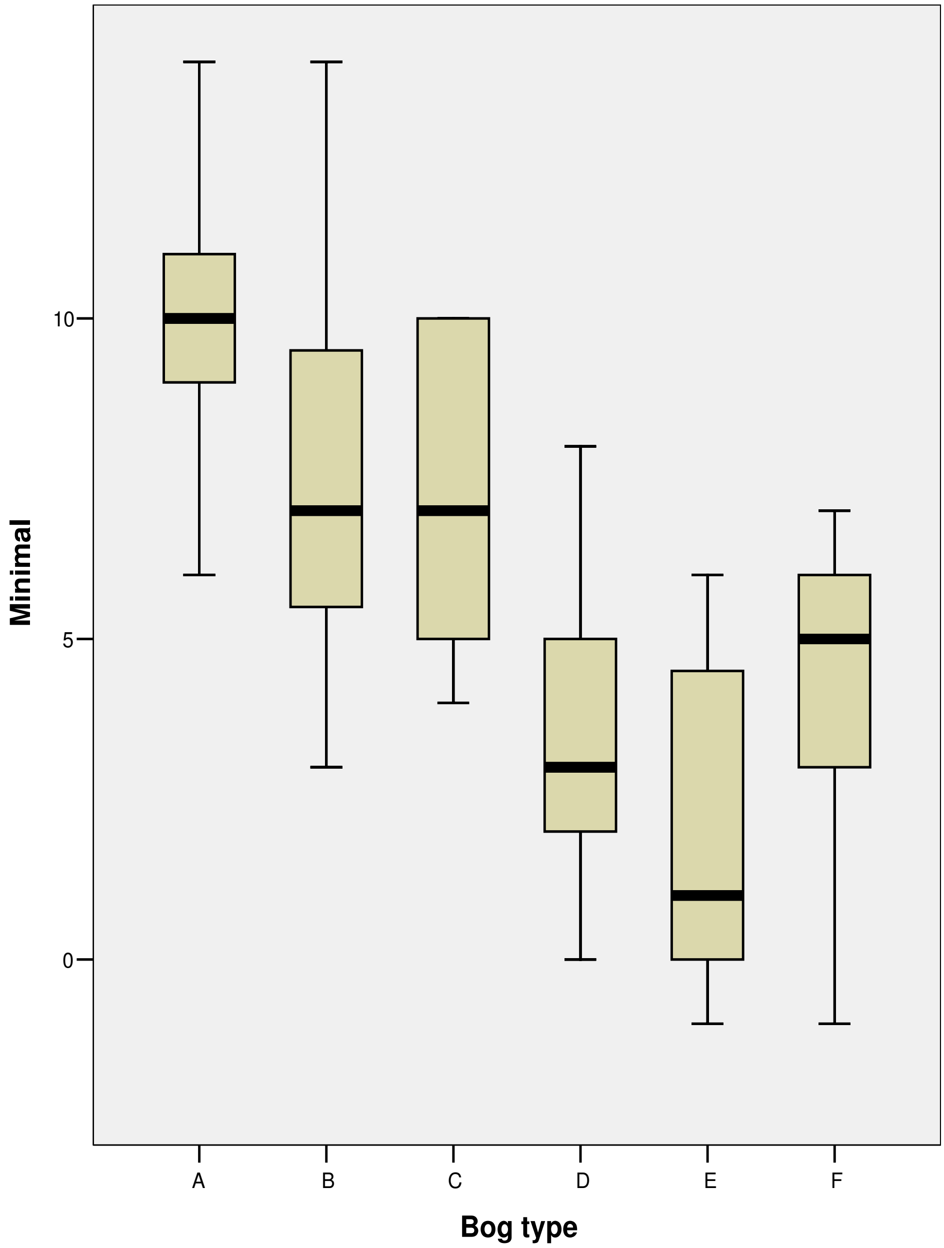
Comparison of **intermediate bog quality** scores for different bog types.

This ranking seemed very similar to that from the **full bog quality** index, except that the relative magnitude of variance may be higher with the **intermediate** index. If this is so, it would result in lower statistical power.



Comparison of **simple bog quality** scores for different bog types

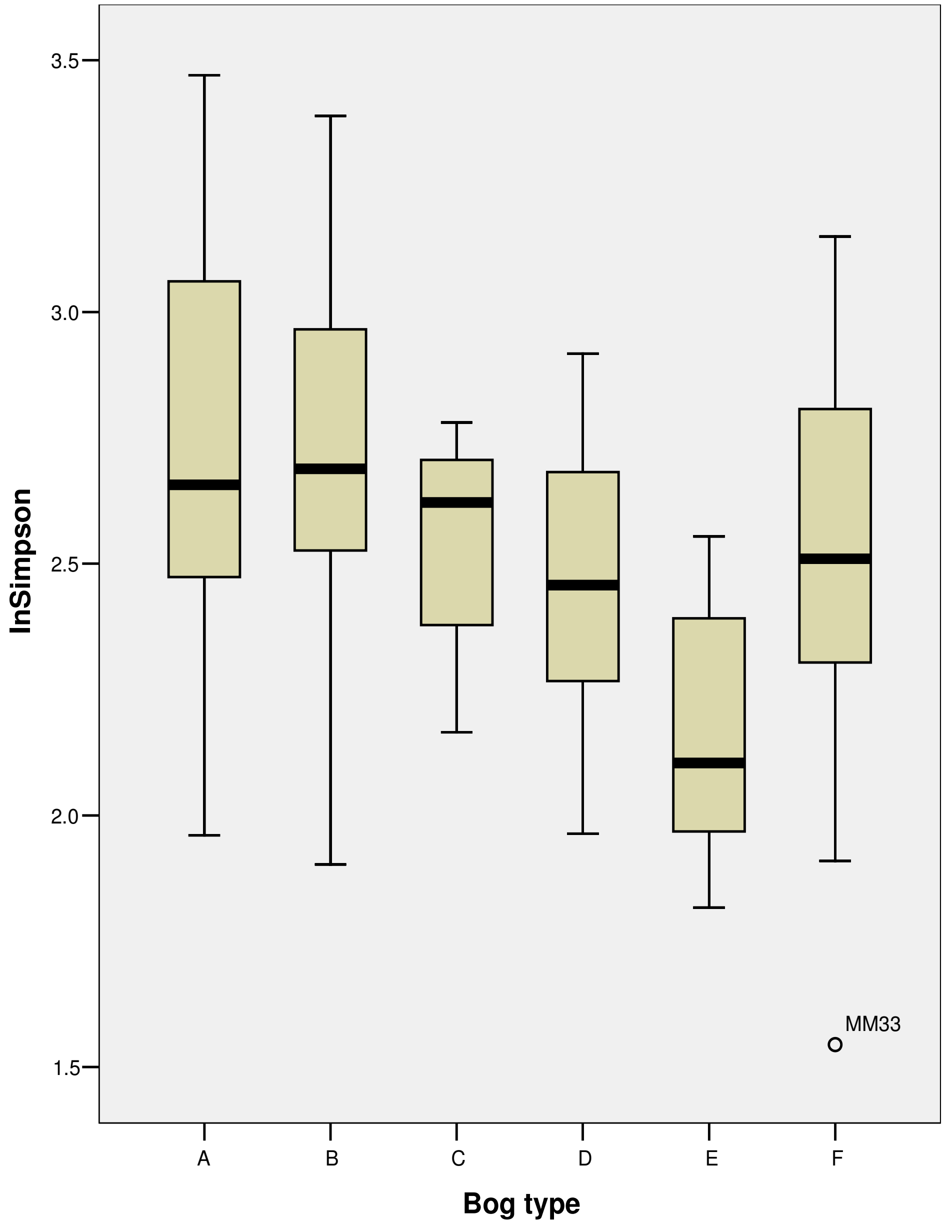
The ranking from the simple index was again very similar to the rankings from the **full** and **intermediate** indices. The main difference was that bog type F scored higher with the **simple** method. This could be problematic, as bog type F is a common vegetation type on the drier edges of bogs (rand) in the border mires.



Comparison of **minimal bog quality** scores for different bog types

The minimal index seemed to rank the bog types in a similar way to the **simple** index. However the scores for bog type F were relatively even higher with the **minimal** index and they overlapped with bog types B and C. Also the relative variance seemed higher with the **minimal** index compared to the **simple** index.

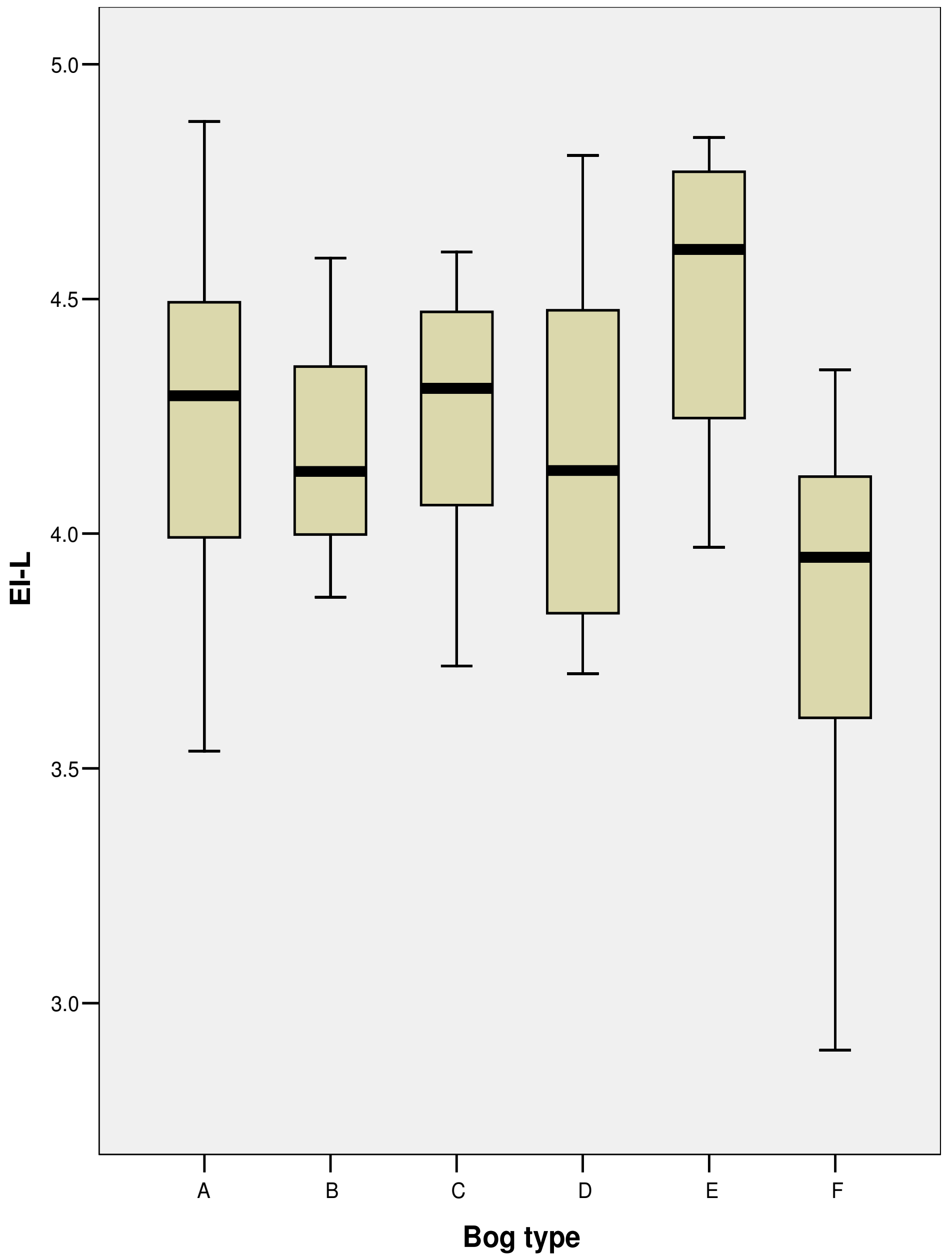
NB the remaining indices can only be calculated when using the **full** method



Comparison of **Simpson's Reciprocal Index** (natural log transformation) scores for different bog types

There was a lot of overlap between the different bog types here and relatively high variance within each type. This shows that a bog quality index may be more informative that a simple diversity index.

Only bog type E (less diverse) appeared to be clearly different from other bog types here.



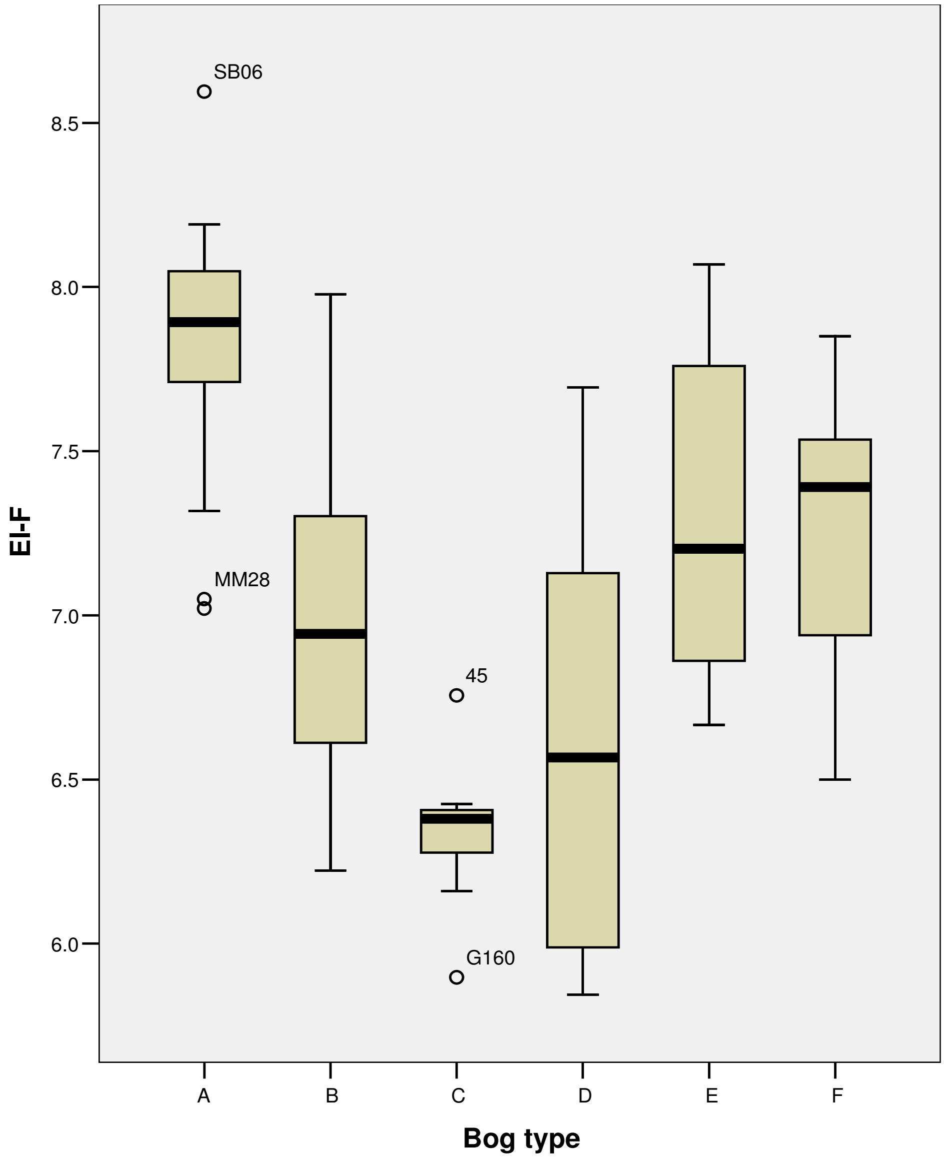
Comparison of **Ellenberg L** (light) index scores for different bog types

This did not appear to be as useful as some of the other Ellenberg indices.

Bog types A, B, C and D appear to be quite similar.

Bog type E appeared to get higher scores on average. This suggests that bog type E had conditions more suitable to plants needing more light on average – the sward may have been shorter and may have had more unshaded gaps.

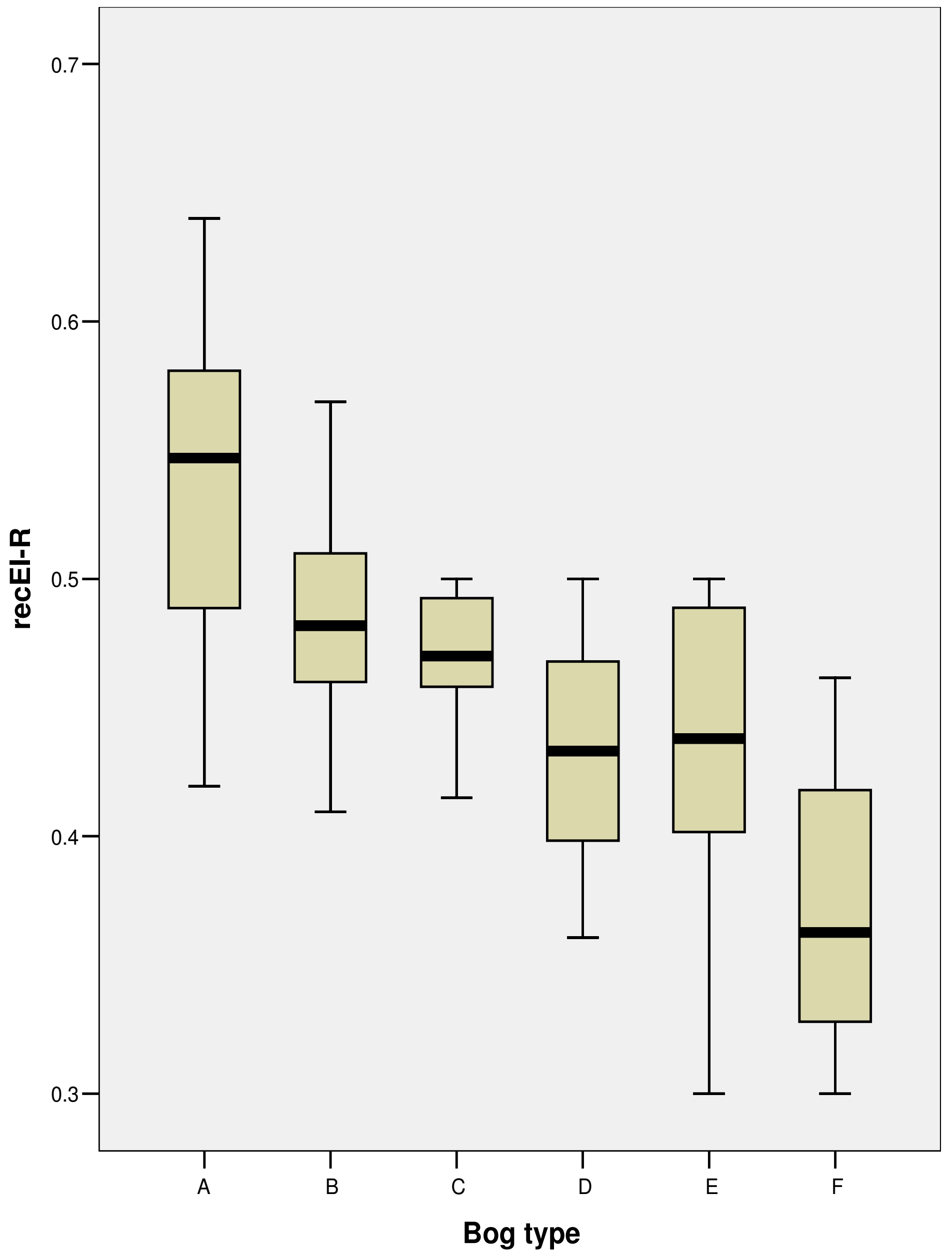
Bog type F appeared to get lower scores on average. This suggested that bog type F had conditions more suitable for plants suited to growing in shade – a taller sward with few gaps.



Comparison of **Ellenberg F** (wetness) index scores for different bog types

There appeared to be clearer differences here between the different bog types, although some types had relatively high variance.

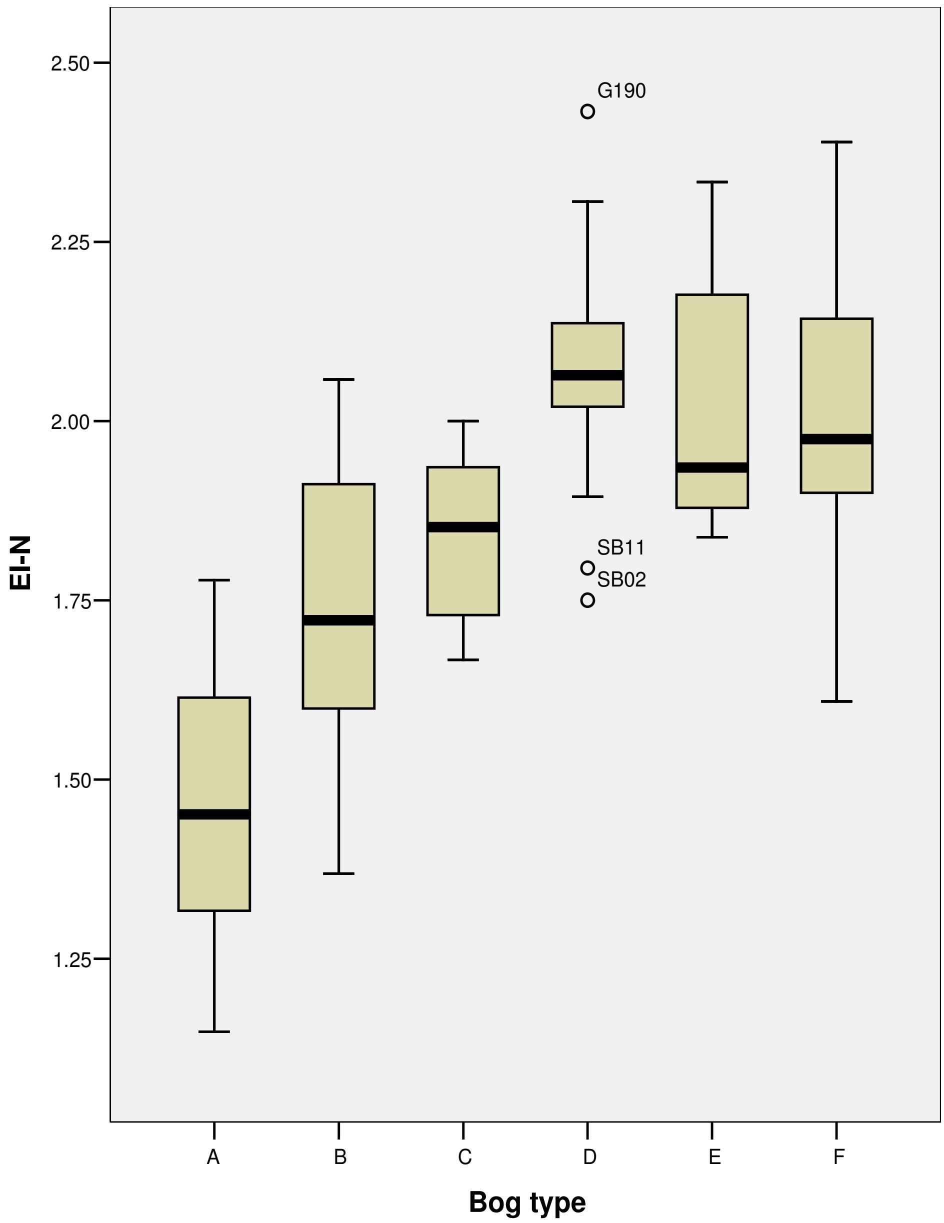
Looking at bog types A, B, C and D, the trend was in the expected direction. Bog type A was clearly the wettest type of these four and bog type B was the next wettest. However, bog types E and F also scored quite highly for wetness. So if we were to use this wetness index only without stratifying the sites, we would have to be careful in how we interpret the results.



Comparison of **Ellenberg R** (reaction – i.e. pH) (reciprocal transformation) index scores for different bog types

Clearly a potentially useful index. The trend was exactly as we would expect, from bog type A being the most acid, to bog type F being the least acid.

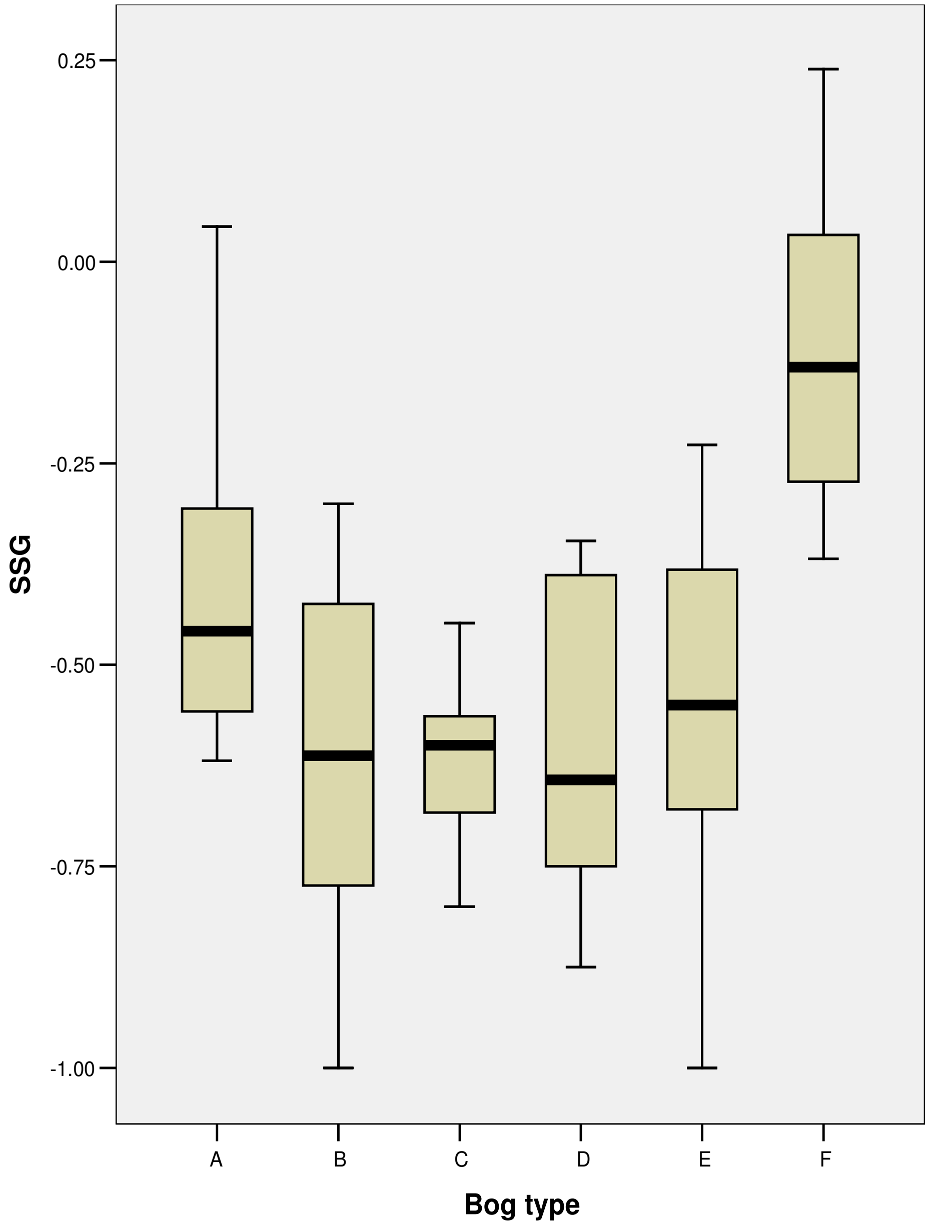
However, the index may work best at the extreme ends of the scale. The four bog types in the middle overlapped considerably, so big changes may be needed before they show up as being significant.



Comparison of **Ellenberg N** (nitrogen – i.e. fertility) index scores for different bog types

Another potentially useful index. Looking initially at the first four bog types, the trend was exactly as we would expect. Bog type A was the least nutrient-rich and bog type D the most nutrient-rich. Also the differences between these four types mostly seem clear.

Again, as with the Ellenberg F index, the situation was a bit complicated because bog types E and F scored lower than bog type D. Again care will be needed with interpreting results because of this, especially if sites are not stratified.



Comparison of **Suited Species Grazing index** scores for different bog types

We would expect to get similar results here to the results we got from the **Ellenberg L** index, because species suited to grazing should also on average, be suited to short swards and species less suited to grazing should on average, be suited to more shaded situations.

The result from bog type F gave a consistent message from both indices but the results from bog type E did not.

However, this may be expected to be the least precise of all of the ecological indices, as it used data from vascular plants only. This potential drawback with this index may be particularly relevant to bogs, as bryophytes are such a significant proportion of the vegetation. Also, some of the species weightings used in this index seem to be counter-intuitive, so it may not be as reliable as the Ellenberg indices.

Scatterplots and linear regression

Several pairwise comparisons were made here, to see:

- How closely one index predicted the scores of another, and;
- How well each index ranked the different categories of vegetation types in the expected order.

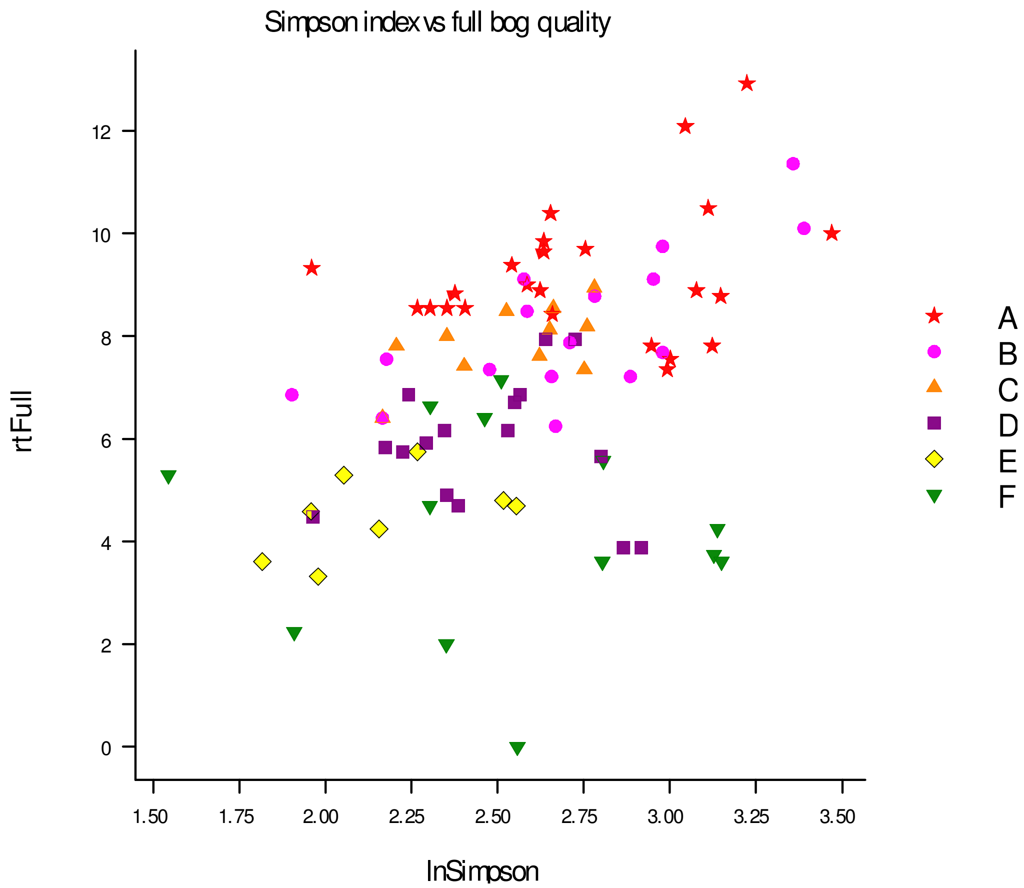
Scatterplots are presented showing the scores for all of the quadrats of one index against another. The index on the ***y*-axis** is the one we are attempting to predict from the index along the ***x*-axis**. The quadrats appear as different coloured symbols depending on which main vegetation category they belong to.

If one index predicted the scores of another closely then there should not be much scatter in the plot. Instead most of the points should line up along a diagonal line from the bottom left of the plot to the top right.

The % variance explained (or *r*-squared value) tells us how much of the total variability within the dataset was explained by the imaginary regression line. If the plotted points lay mostly close to a straight line, this value will be close to 100% and if there was little if any relationship between the two indices (i.e. lots of scatter) then this value will be close to 0%. Any % variance explained value over 60% suggested a reasonably strong relationship and anything over 80% was very strong.

The % variance explained values came from running a linear regression model on the two indices after transforming the data to normal distributions if necessary. We also checked these linear regression models by inspecting the residual plots to check the model assumptions, especially the assumptions that the residuals were normally distributed and had constant variance. We describe any major deviation from the linear model that arose from such checks and occasionally include the residual plots where these may be informative.

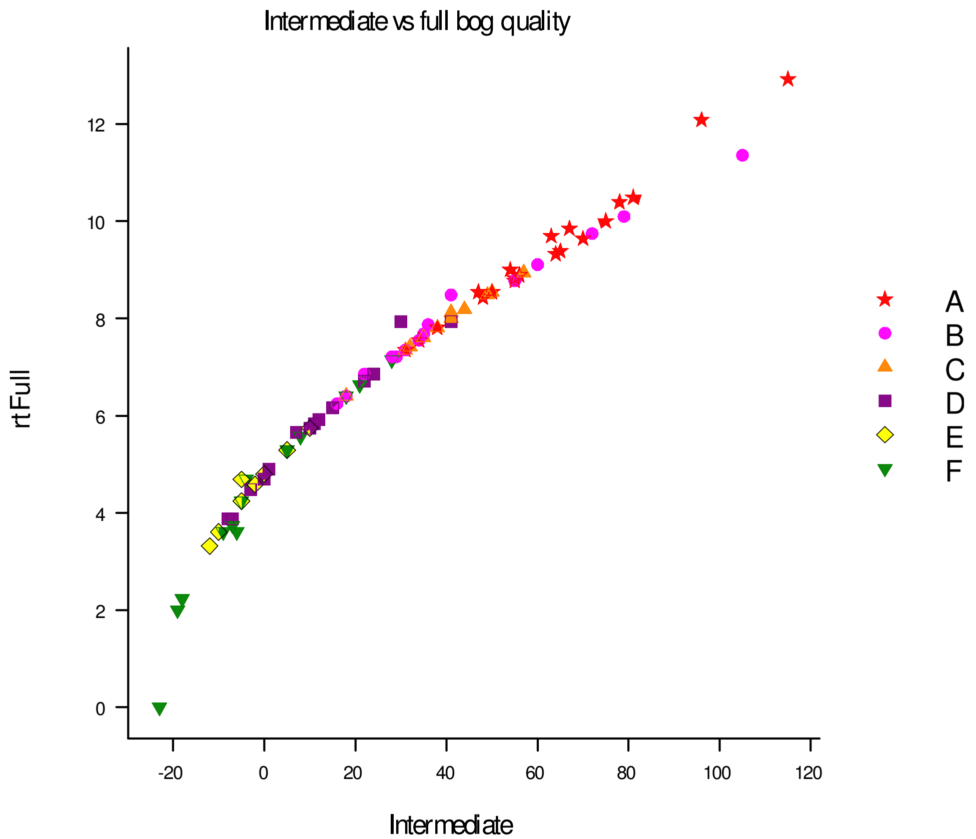
The scatterplots were inspected by eye to see how the different categories of vegetation types were ranked using each index. If the index on the ***y*-axis** was a good way of ranking the quadrats in terms of quality, then **type A** quadrats should appear at or near the **top** of the plot and **type F** quadrats should appear at or near the **bottom** of the plot. Similarly, if the index on the ***x*-axis** was a good way of ranking the quadrats in terms of quality, then **type A** quadrats should appear at or near the **right-hand side** of the plot and **type F** quadrats should appear at or near the **left-hand side** of the plot.



Stronger suggestion of a relationship this time than with the **Stanley Moss** data. Still only 16.2% variance explained by regression line, so the relationship was weak at best.

The residual plots showed no great evidence that the model is not a reasonable one.

The **bog quality index** was clearly a much better way of scoring the best bogs higher and less interesting bogs lower.

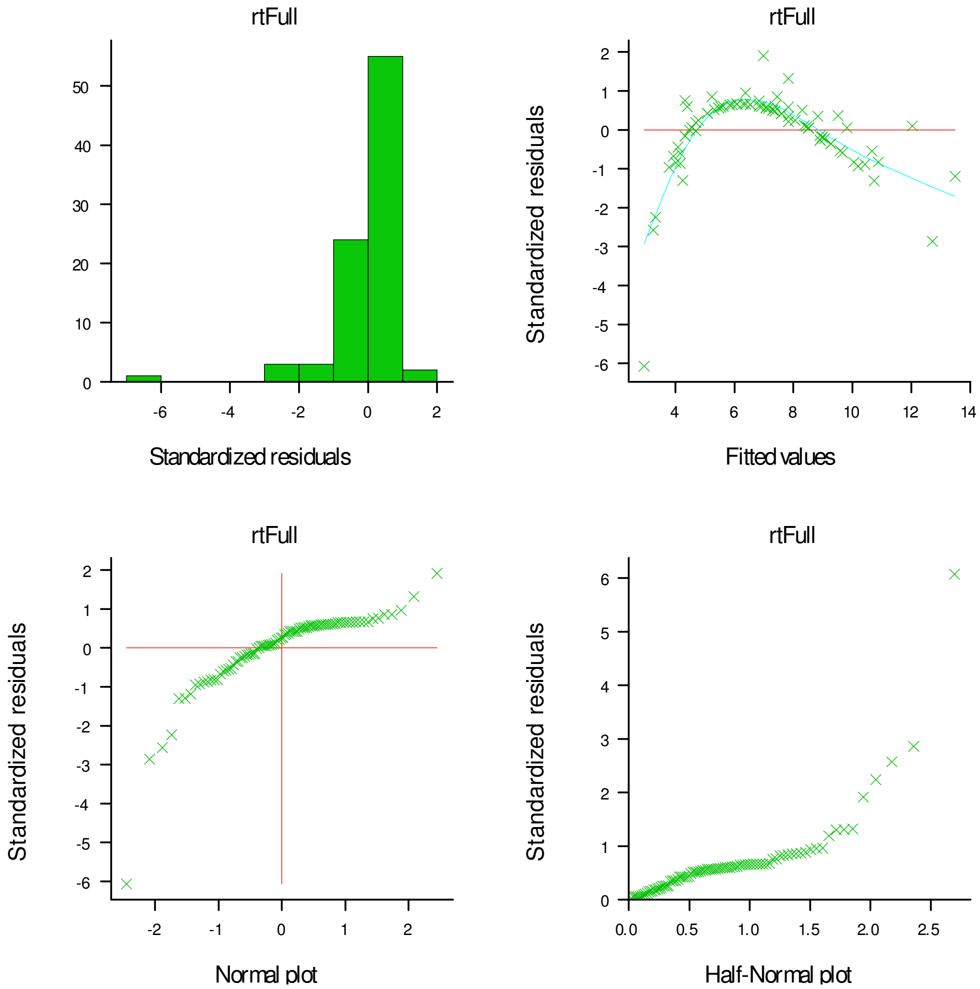


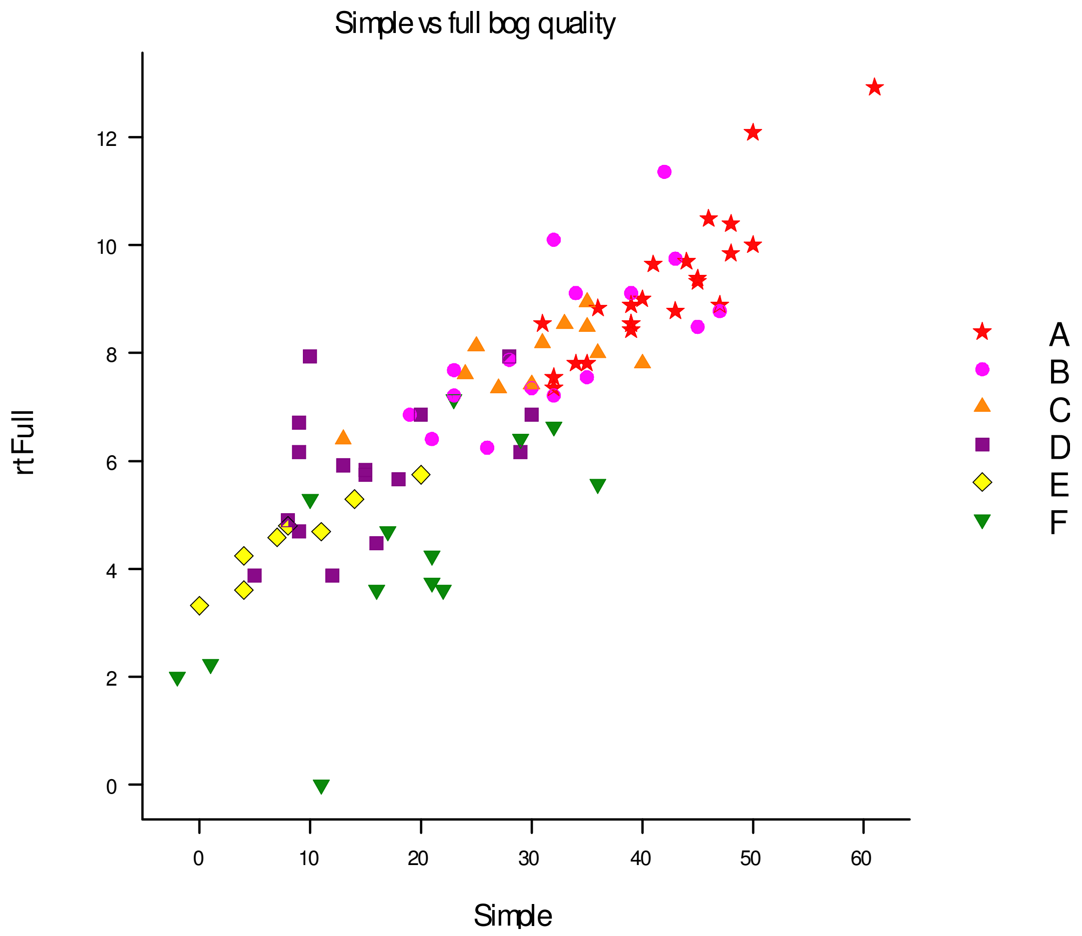
A very close relationship between these two, as we would expect, but it appeared to be *S*-shaped, rather than straight. This may be because on average, quadrats scoring at either extreme end of the scale with the **full** method, tend to include species not included in the **intermediate** method more often than quadrats with middling scores. This suggested that although the **intermediate** method gave almost the same result most of the time, it was less sensitive for extremely good or extremely bad quadrats.

The percentage variance explained by the regression line was 94.5% from a linear regression model, but there was strong evidence that a straightforward linear model was not appropriate here (see plots on next page).

So although there was a very strong relationship between these two methods, when the scores did differ, they differed in a complicated and unpredictable way compared to the other comparisons of methods described below.

Residual plots from **intermediate** vs. **full** bog quality linear regression comparison



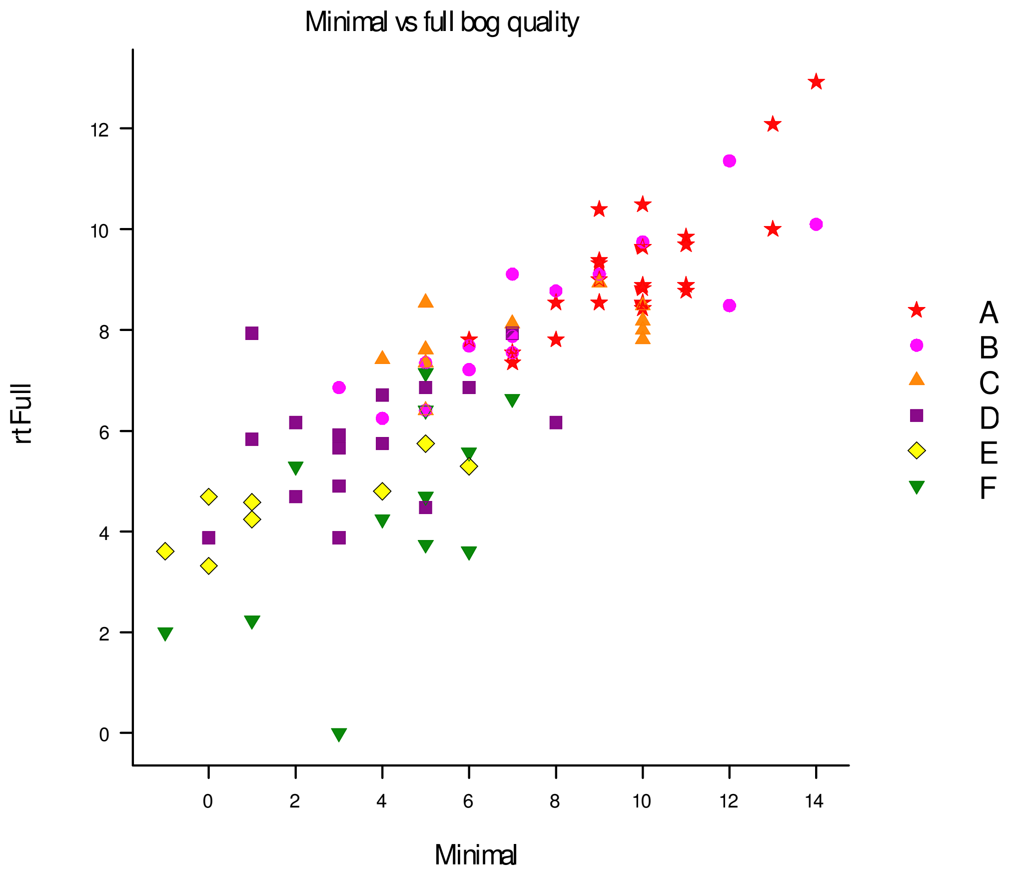


Considering how simple the **simple** method was, the relationship between the scores from the **simple** and **full** methods seemed remarkably strong. There appeared to be little obvious difference between the methods in how well they ranked the different bog types. Only bog types D and F seem to be ranked less consistently by the **simple** method.

The percentage variance explained by the regression line from a simple linear regression model was 74.7% which seemed really quite high, considering how simple this **simple** method is!

The residual plots showed no great cause for concern regarding whether or not the model was appropriate. There was a suggestion that the residuals may not have been normally distributed, but the deviation from normality was not great.

The simple method seemed to perform much better here than we had anticipated.

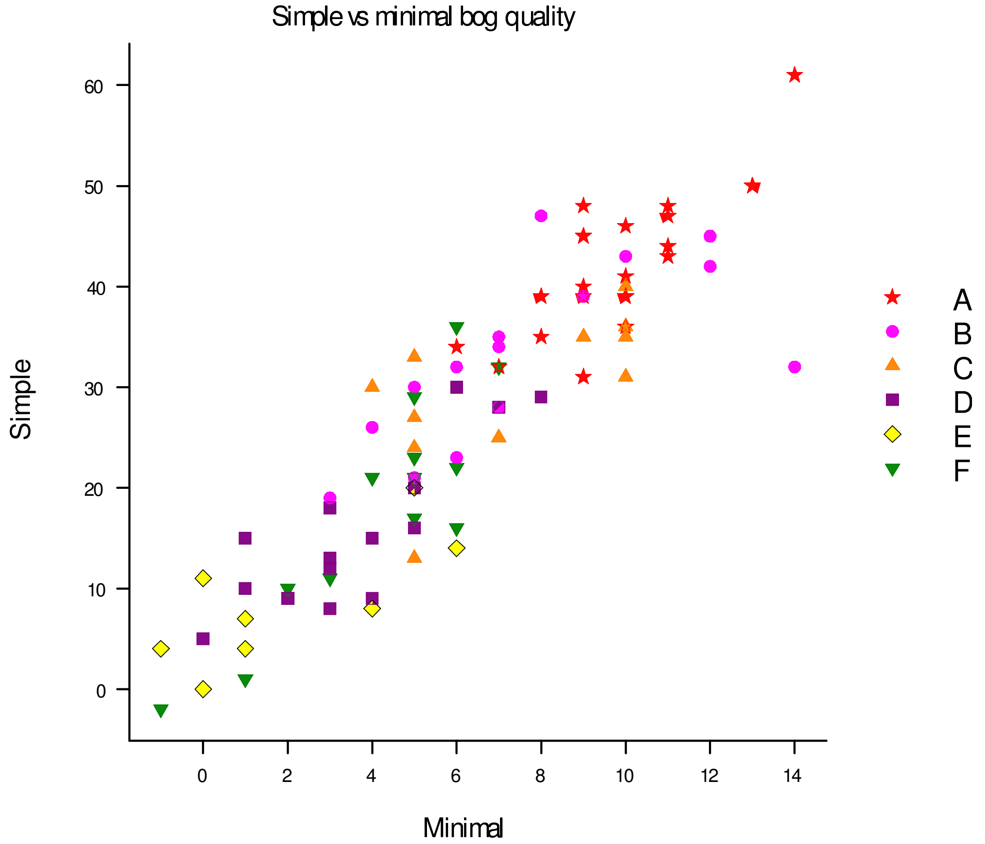


The strength of the relationship between the **minimal** and **full** methods seemed surprisingly strong. It did appear this time as if the **minimal** method was not nearly as good as the **full** method in ranking the quadrats from the different bog types in the expected order. However, the ranking achieved by the minimal method was not disastrous.

The percentage variance explained by the regression line from a simple linear regression model was 67.8% which seemed really quite high considering what we are comparing here, and was far higher than we had expected.

The residual plots showed no cause for concern regarding whether or not the model was appropriate.

The minimal method also seemed to perform much better than we had anticipated!



A fairly strong relationship between these two methods, as we would expect. Difficult to work out if one method was better than the other at ranking the different types. 81.8% variance explained by regression line, which suggested that the two methods were not very different.

No reason to question the appropriateness of the model from the residual plots.

Discussion of the mixed bog data results
So far, we have seen that no matter which type of quality index we calculate, each dataset was close to a normal distribution (or could be transformed to a normal distribution).

There was a weak relationship between diversity and habitat quality based on indicator species, so to get the best picture of overall quality, we need to consider both. However, we cannot calculate any diversity index in any meaningful way based on partial quadrats using only indicator species, so for the **intermediate**, **simple** and **minimal** methods we are limited to the quality index based on the indicator species only.

If all methods ranked the quadrats in the same order, then when the score from two methods are plotted against each other, we would get a scatterplot with points along a straight line going diagonally upwards. The relationship between the **intermediate** and **full** methods almost followed a perfect straight line, except at the extreme ends where the relationship was complicated. However, even the **simple** and **minimal** methods were reasonably closely correlated with the **full** method. The **full** and **intermediate** methods appeared to rank the best and worst quadrats in a better order than the **simple** and **minimal** methods did. When the **simple** and **minimal** methods were compared there seemed little to choose between them.

Measures	%variance explained
Diversity vs. full	16%
Intermediate vs. full	95%
Simple vs. full	75%
Minimal vs. full	68%
Simple vs. intermediate	77%
Minimal vs. intermediate	73%
Minimal vs. simple	82%

So superficially it appeared that the **intermediate** method may do a very good job at predicting **full** quality and the **simple** and **minimal** methods were not bad considering how simplified these methods were.

We may ask if they are good enough to be adequate? We could go some way to answering this by comparing the statistical power obtained from the different indices.

Below we calculate samples sizes required to detect a difference of 20% from the mean. We use the 95% significance level and 80% for the level of power we require in both methods.

Some of our variables (e.g. the four bog quality indices and the SSG index) can take both positive and negative values, so they are ratio variables. The other ecological indices are interval variables, i.e. they have a minimum possible value. This means that it was difficult to compare the power obtained from the four methods in a meaningful way. For the comparison below, we have taken the minimum value in each case to equal absolute zero for that index and so we have transformed the observed values by subtracting this minimum value from all values. Only then have we calculated the (standardised) mean. These figures should therefore be taken as a **rough guide only**.

Sample sizes needed to achieve 80% power to detect a difference of 20% from the original (standardised) mean.

Method	Sample size
Full	22
Intermediate	59
Simple	46
Minimal	47
Simpson	28
El-L	17
El-F	55
El-R	39
EL-N	42
SSG	46

The **full** method appeared to have considerably more power than the **intermediate** method. The **minimal** and **simple** methods had similar levels of power and had more power than the **intermediate** method.

Statistical power from stratified dataset
Here we calculated sample sizes needed based on stratifying the data in two different ways. We standardise the mean of each variable in the same way as described above and we used the same significance level and power level to detect a difference of 20% from the (standardised) mean.

In our first stratification, we divided our original sample of 88 quadrats from 6 bog types into two strata: 51 samples from types A, B and C, and; 37 samples from types D, E and F. We may expect the latter group to have higher variance and therefore require more sampling.

Sample sizes needed to achieve 80% power to detect a difference of 20% from the original (standardised) mean.

Method	Types A, B & C	Types D, E & F
Full	5	22
Intermediate	17	58
Simple	12	61
Minimal	16	59
Simpson	20	36
El-L	11	27
El-F	50	58
El-R	15	53
EL-N	50	10
SSG	32	56

Focussing on the first stratum that includes only the better bog types would mean that the sample sizes needed are considerably smaller. This was strong evidence to suggest that stratifying sites before surveying is a good idea!

There appeared to be little difference on average between the sample sizes needed without stratification and the sample sizes needed for only bog types D, E and F together. It was not surprising that these bog types were more variable. If we want to be able to assess change on these lower quality bog types then we will probably need relatively bigger samples.

In our second stratification, we divided our original sample of 88 quadrats from 6 bog types into three strata: 40 samples from types A and B; 27 samples from types C and D, and; 21 samples from types E and F.

Method	Types A & B	Types C & D	Types E & F
Full	6	10	29
Intermediate	18	32	73
Simple	10	40	82
Minimal	15	47	71
Simpson	21	14	54
El-L	12	14	36
El-F	25	115	22
El-R	15	15	89
EL-N	62	10	13
SSG	33	35	35

The results of the second stratification confirmed and emphasised the main patterns seen in the first stratification. There were some moderately dramatic fluctuations in number of samples needed for Ellenberg F, Ellenberg R and Ellenberg N, depending on how we stratified the samples, but the results were more consistent for the other indices.

The main messages are:

- The **full** method consistently performed better than the **intermediate**, **simple** or **minimal** methods, no matter how we stratified the sample;
- The **intermediate** method may have been less powerful than (or similarly powerful to) the **simple** and **minimal** methods on average;
- There seemed to be little difference in power between the **minimal** and **simple** methods;
- The better bog types were less variable and therefore required smaller samples than the more degraded types of bog;
- From all of the analyses there were few predicted samples sizes that were very large, suggesting that the method may work well in giving us 80% power to detect a difference of 20% from the standardised mean.

Appendix C: Exploring the 'blanket bog mosaic' dataset

The **blanket bogs mosaic** datasets comprised 133 vegetation quadrats recorded by the author from various sites containing extensive areas of blanket bog in northern England and southern Scotland. The quadrats chosen were from a wide range of vegetation types that were typical of sites containing blanket bogs, similar to the large blanket bog sections of SSSIs in the border mires. The numbers of quadrats from each of the vegetation types chosen were roughly in proportion to the expected relative frequency of each vegetation type within large **blanket bog** sites in the border mires.

This dataset was assumed to be reasonably typical of the range of variation of vegetation types typical of large **blanket bog** sites in the border mires, including various types of bog vegetation and other vegetation types such as acid grassland, heath and flush.

Once again, frequency/count data from cells within the quadrats were not available for this dataset. The %cover of each species in the quadrat had been estimated and for this exercise these data were simplified to the 10-point, Domin scale.

For each quadrat, the following indices were calculated:

- Full bog quality index;
- Intermediate bog quality index;
- Simple bog quality index;
- Minimal bog quality index;
- Simpson's reciprocal index (species diversity);
- Ellenberg L (light) index;
- Ellenberg F (wetness) index;
- Ellenberg R (reaction, i.e. pH) index;
- Ellenberg N (nitrogen, i.e. fertility) index;
- SS (suited species) Grazing index.

These derived values for each quadrat formed the datasets that were then tested. The following investigations were performed:

- First we investigated if each dataset could be transformed to something close to a normal distribution;
- We then displayed box and whisker plots of the scores for each index from the eight different broad habitat types, to see whether or not the indices ranked the different types in the expected order, and whether or not the different types were clearly separated using these indices;
- We then compared pairs of indices using scatterplots and linear regression to see how closely one index could be predicted from another, and whether or not each index ranked the quadrats in the expected order;
- Then, based on the variance found in the datasets, we calculated (in a standardised way) the samples sizes needed in order to have 80% power to detect a difference of 20% from the original mean;
- Finally, we investigated the samples sizes that would be needed if the sites had been stratified in several different ways.

The quadrats in this dataset were from a more heterogeneous dataset to those studied before. They were categorised into eight broad habitat types: **wet bog** (M18 & M19a) – 7 quadrats; **blanket bog** (M19) – 43 quadrats; **cottongrass bog** (M20) – 7 quadrats; **wet heath** (M15b & M15d) – 5 quadrats; **dry heath** (H9, H10, H12, H18 & H21) – 37 quadrats; ***Molinia* vegetation** (M25) – 10 quadrats; **flushes** (M2, M6, M10, M15a, M23) – 10 quadrats; and **acid grassland** (U2, U4, U5 & U6) – 14 quadrats. The proportions of the individual NVC types in each category were chosen roughly to reflect the expected proportions of these vegetation types in a typical, large and diverse site with extensive blanket bog. Once the number of quadrats required for each NVC type had been fixed, the individual quadrats used were chosen from the author's vegetation quadrats database using random numbers.

In this dataset there were **219** species recorded in all that were used to calculate the **full** bog quality index from the original raw data. When the **intermediate** species list was used this original list of 219 species was reduced down to **87** species. 14 species from the simple list were present in the dataset, so these **14** were used to calculate the **simple** and **minimal** index scores.

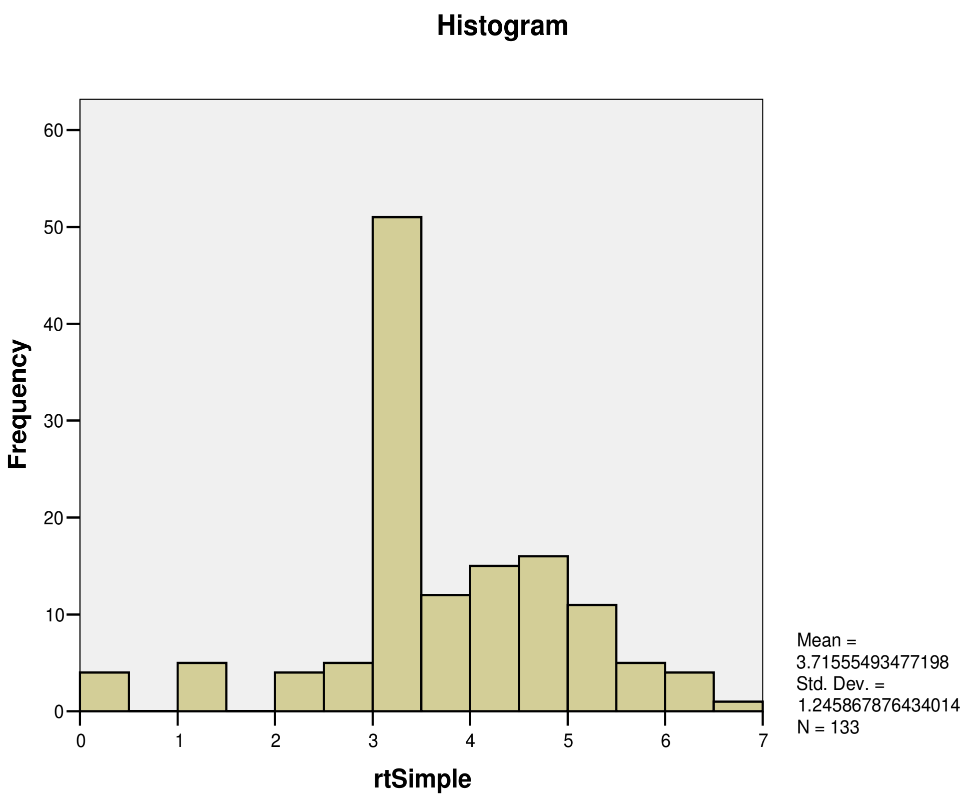
Investigating normality

Each dataset was assessed to see if a normal distribution was plausible. We constructed histograms, normal probability plots and residual plots. We also conducted Shapiro-Wilk tests. If a normal distribution was not plausible from the raw data we tried transformations. Usually either the raw data or the transformed data was normal, but in a few cases they were not.

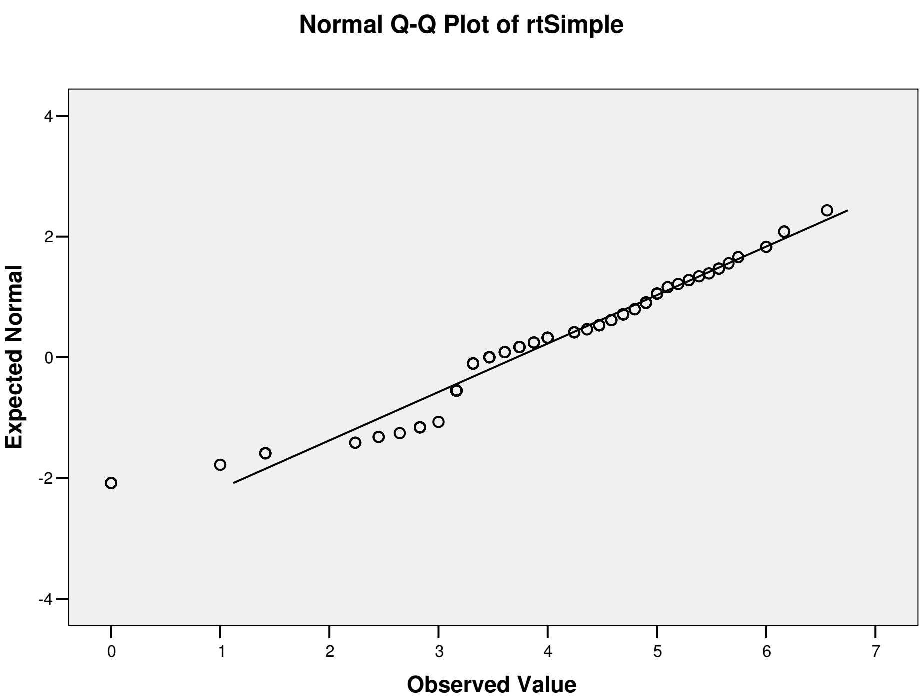
We have not included all of these plots here, as they mainly looked quite similar and there were a lot of them. Only those plots which displayed some evidence against the assumption of a normal distribution were included here.

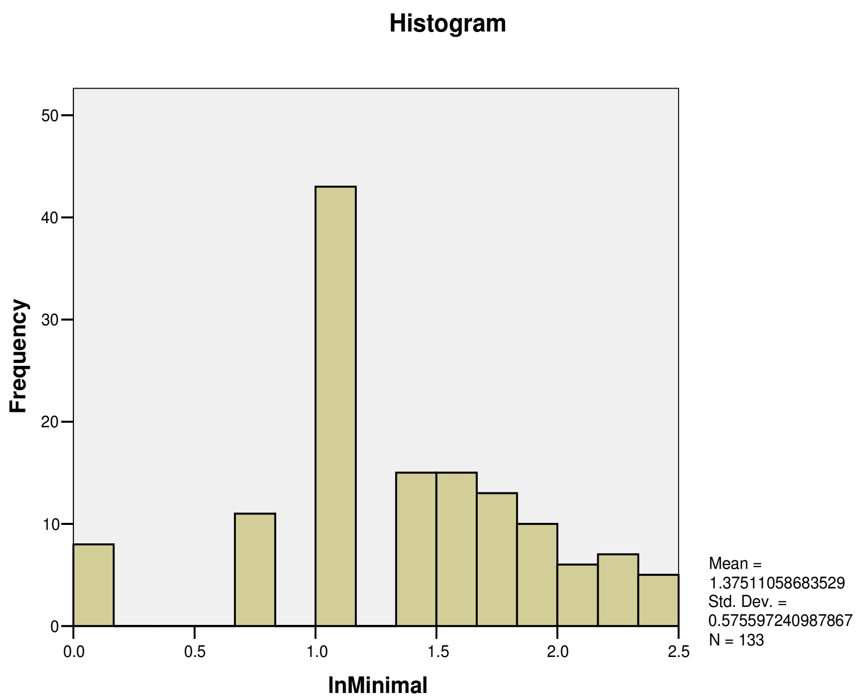
Method	Transformation	Normal?	Notes
Full	-	Yes	
Intermediate	-	Yes	
Simple	square root	No	Dataset contains too many zero values
Minimal	natural log	No	Dataset contains too many zero values
Simpson	natural log	Yes	
Ellenberg-L	-	Yes	
Ellenberg-F	-	?	May be bimodal
Ellenberg-R	reciprocal of square	Yes	
Ellenberg-N	natural log	Yes	
SS grazing	reciprocal	Yes	

It may be possible to address all of the issues flagged up in the notes column here by stratifying, as then we could end up with more homogeneous datasets and our bog quadrats of interest would have fewer zero scores. Furthermore, if we stratified the sites in this way prior to surveying, we are unlikely to need to use so many data transformations for the other variables.

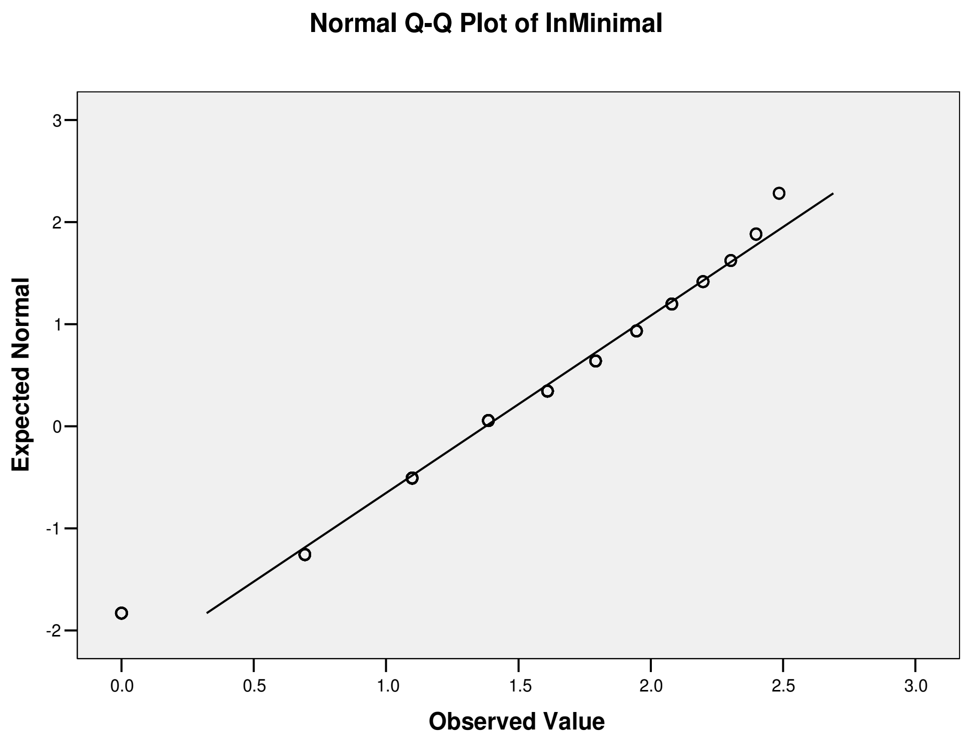


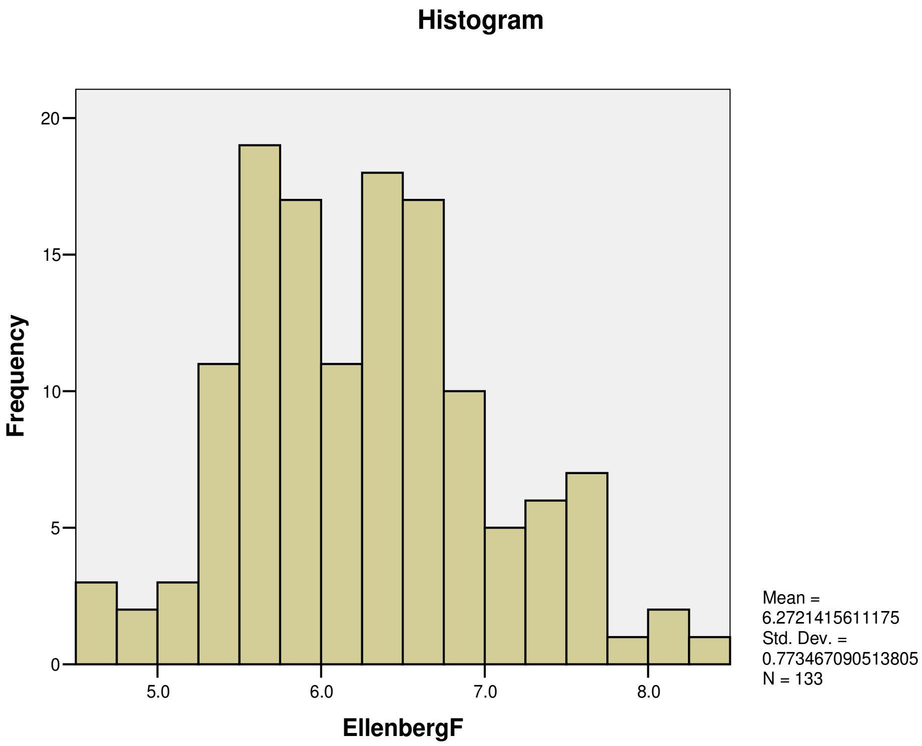
Simple bog quality index – dataset included 39 zero values, which made transformations to normal distribution impossible. The closest we got was by using the square root transformation, which gave us a distribution which at least was more symmetric.



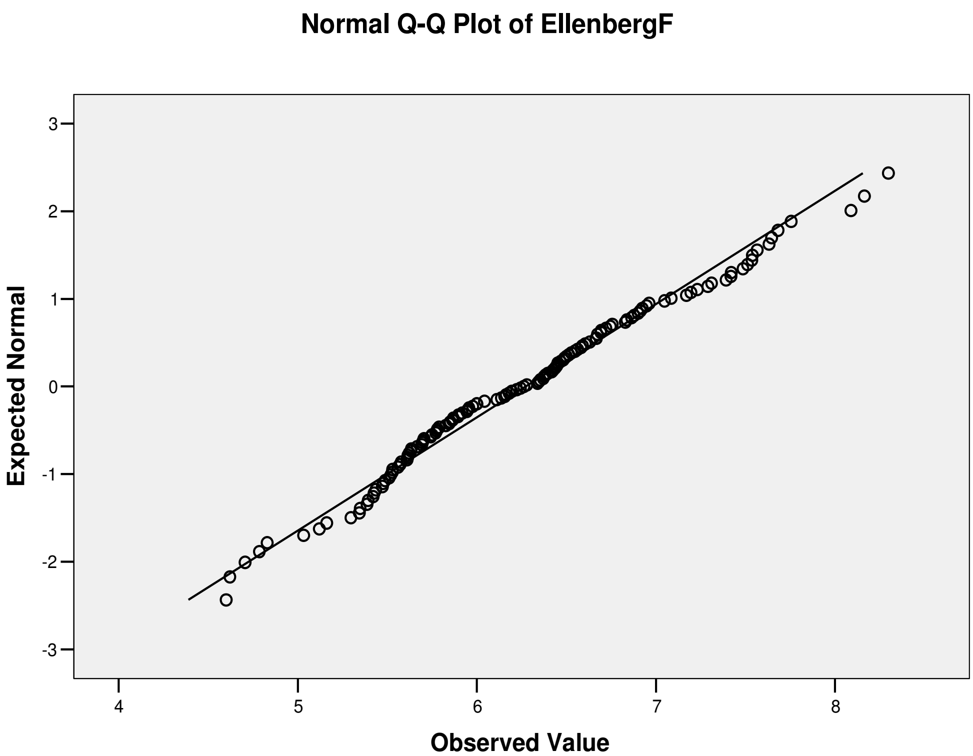


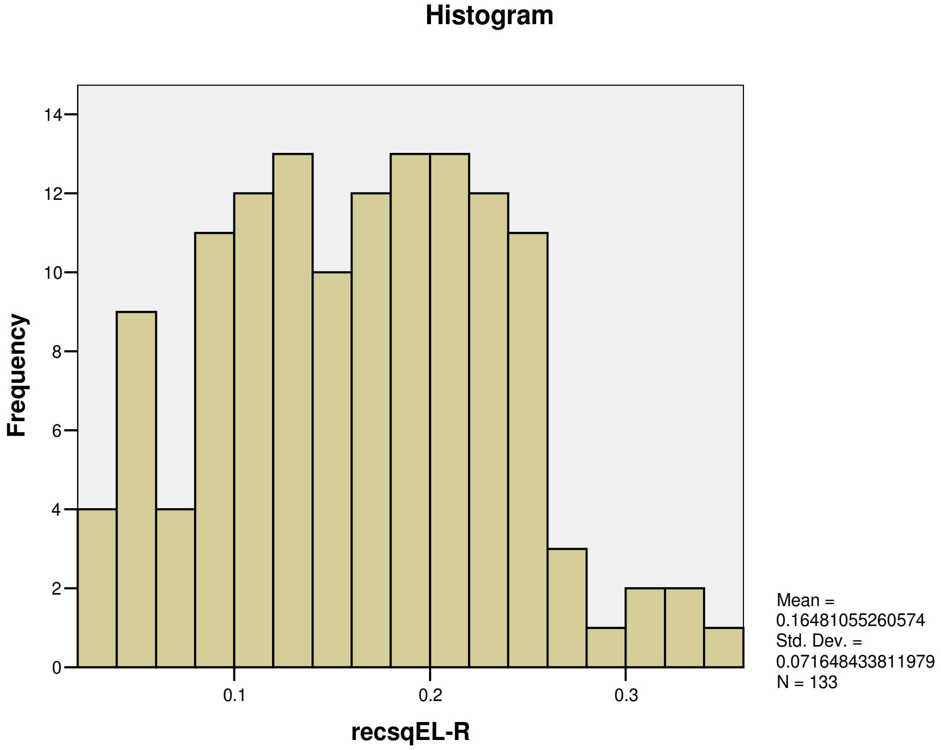
Minimal bog quality index: – again we had a large proportion of zero values (43 out of 133 this time), so transformations did not help make the data follow a normal distribution. Using the natural log transformation we got a peculiarly-shaped distribution which was vaguely symmetric.



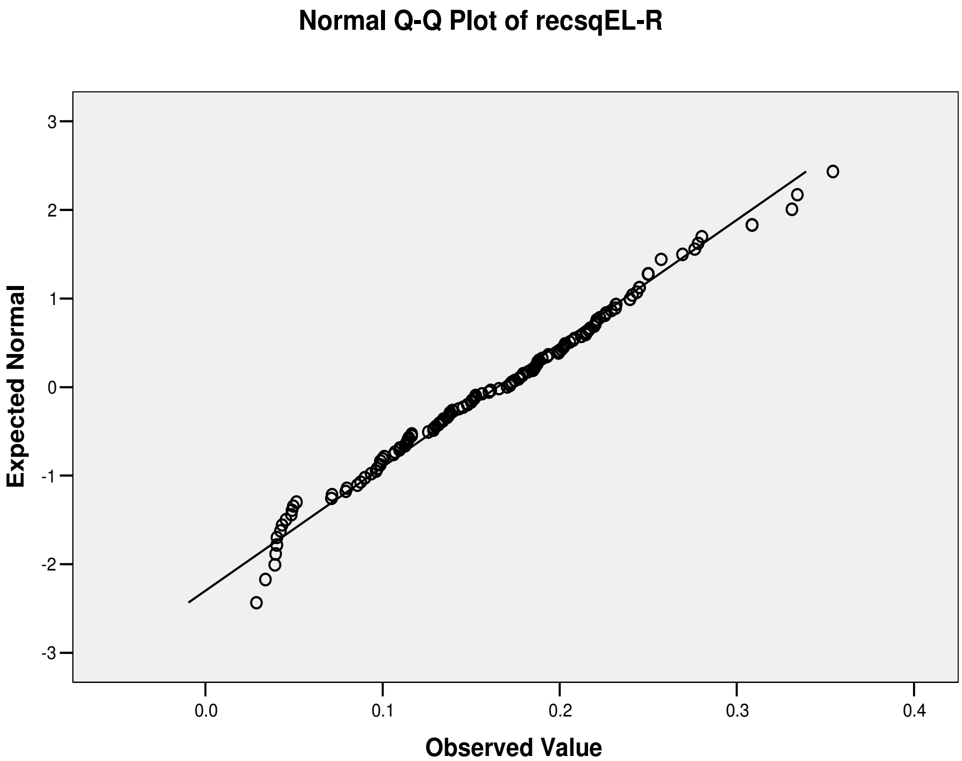


Ellenberg F index: – possibly bimodal distribution, but not too far off normal distribution. Transformations did not help.





Ellenberg R index: – normal distribution looked just about plausible with reciprocal of square transformation



Summary of issues raised so far with the blanket bog mosaic data
These data from the **blanket bog mosaic** habitats (and using the **blanket bog** version of the bog quality indices) were more problematic than the **Stanley Moss** and **mixed bog** datasets were.

More transformations were required here to get the data to follow normal distributions, which suggested that the **blanket bog** method may not be as predictable or as reliable as for the **wet bogs**.

The **simple** and **minimal** indices were particularly problematic. Both had a high proportion of zero values, which would make data analysis awkward. If these data were anlaysed we would be limited to using non-parametric tests. In the sample size calculations below, our predicted samples sizes for the **simple** and **minimal** indices were over-optimistic, as it would not be valid to calculate sample sizes needed in this way with data that were not normally distributed.

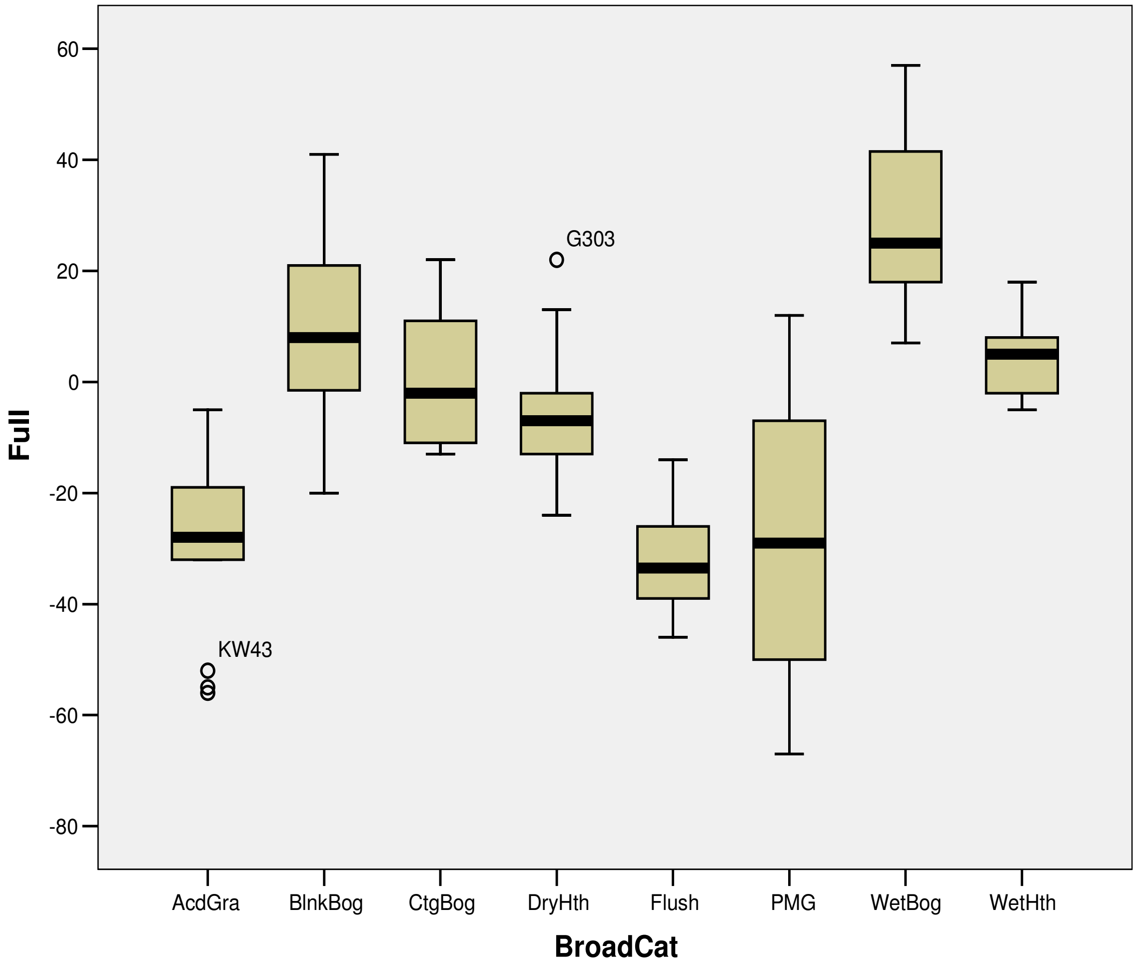
There were two main issues causing the problems here:

1. The dataset contained more variation of vegetation types and so each individual index was likely to be more variable than it would be if we were focussed on a narrower range of bog types.
2. The **blanket bog** versions of the bog quality indices were less sensitive than the original version (designed for the **wet bogs**). With the **blanket bog** version, we got a smaller range of scores, so it was likely that it would be more difficult to separate good quadrats from not so good quadrats.

Comparing boxplots of the scores for each of the eight different broad habitats
Box and whisker plots are included below for each of the indices. Each plot summarises the range of scores for that index in each of the eight different broad habitat categories, which can then be easily compared by eye.

The purpose of this analysis was to get a rough idea as to whether or not the various indices were good ways of separating bog types of different quality from each other and from habitats other than bogs. We could have included more formal tests here (such as Analysis of Variance followed by appropriate post-hoc tests or multiple regression) for testing for differences, but this was thought to be unnecessary as the plots showed clear differences in most cases.

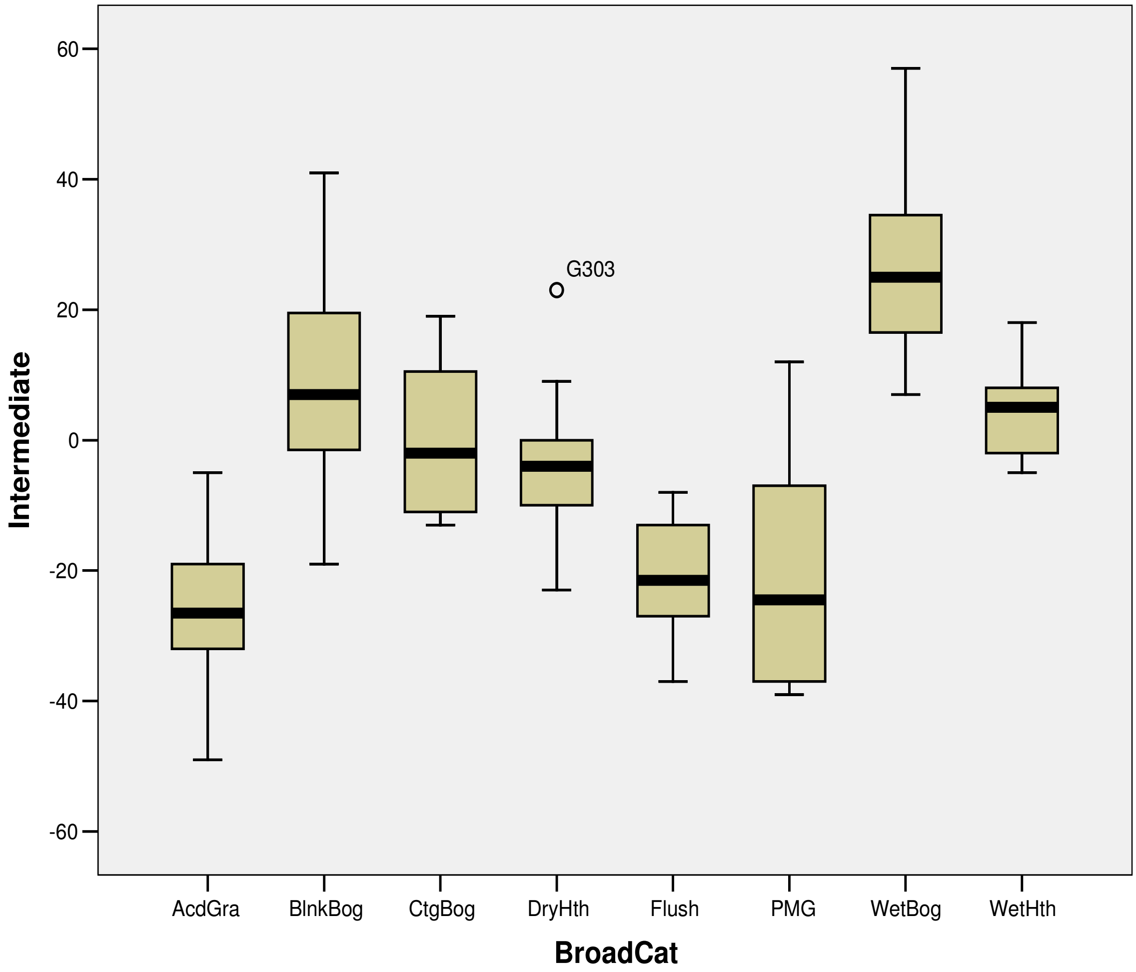
For the various versions of the bog quality index, if they all worked well, then all four of them should rank **wet bogs** highest on average, followed by **blanket bogs**, with all other habitats ranked lower. It may not matter so much what order the remaining broad habitats were ranked in. The other ecological indices may not rank the bog categories as the highest or lowest scoring groups, but what is important with these is that there are some clear differences evident.



Comparison of **full bog quality** scores for different habitat types.

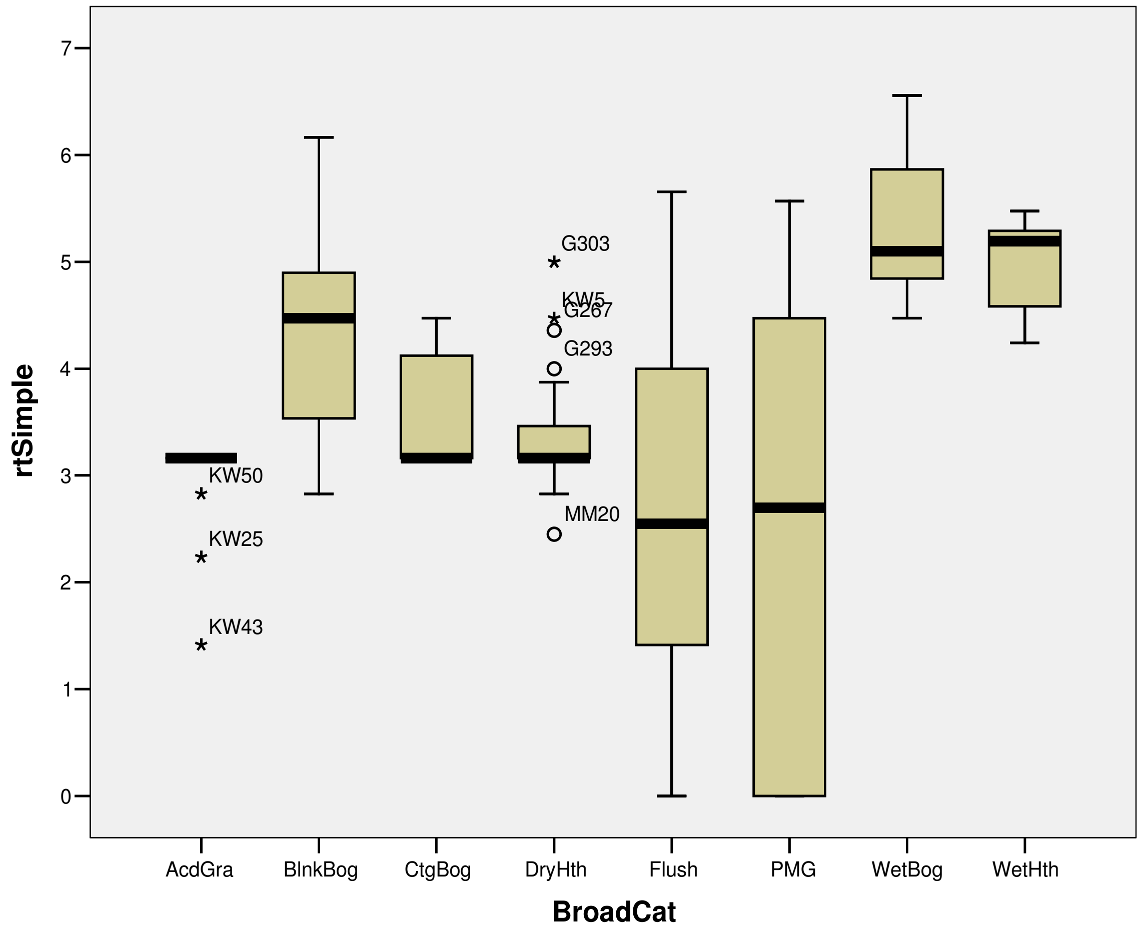
Wet bogs were clearly ranked highest. Blanket bogs came second on average but there was a good deal of overlap between **blanket bogs**, **cottongrass bogs** and **wet heaths**. **Dry heaths** also overlapped with **cottongrass bogs** and **wet heaths**, but not so much with **blanket bogs**. The other habitats, **acid grassland**, **flushes** and ***Molinia* vegetation** mainly had quite low scores, but the ***Molinia*** category had a lot of variation within it.

This ranking was not bad, but there was some evidence to suggest that the **blanket bogs** (the main bog type of interest here) were not very clearly separated from the **cottongrass bogs** and **wet heaths** using the **blanket bog** version of the **full bog quality** scoring system. This does not give quite as good a result as the equivalent plot from the **mixed bog** dataset (see page 53) using the original version of the full bog quality scoring system. It is good though that the **blanket bogs** were fairly clearly separated from the **dry heaths**, as these are likely to be the two most common habitats in these sites and a change from **blanket bog** to **dry heath** vegetation would be undesirable.



Comparison of **intermediate bog quality** scores for different bog types.

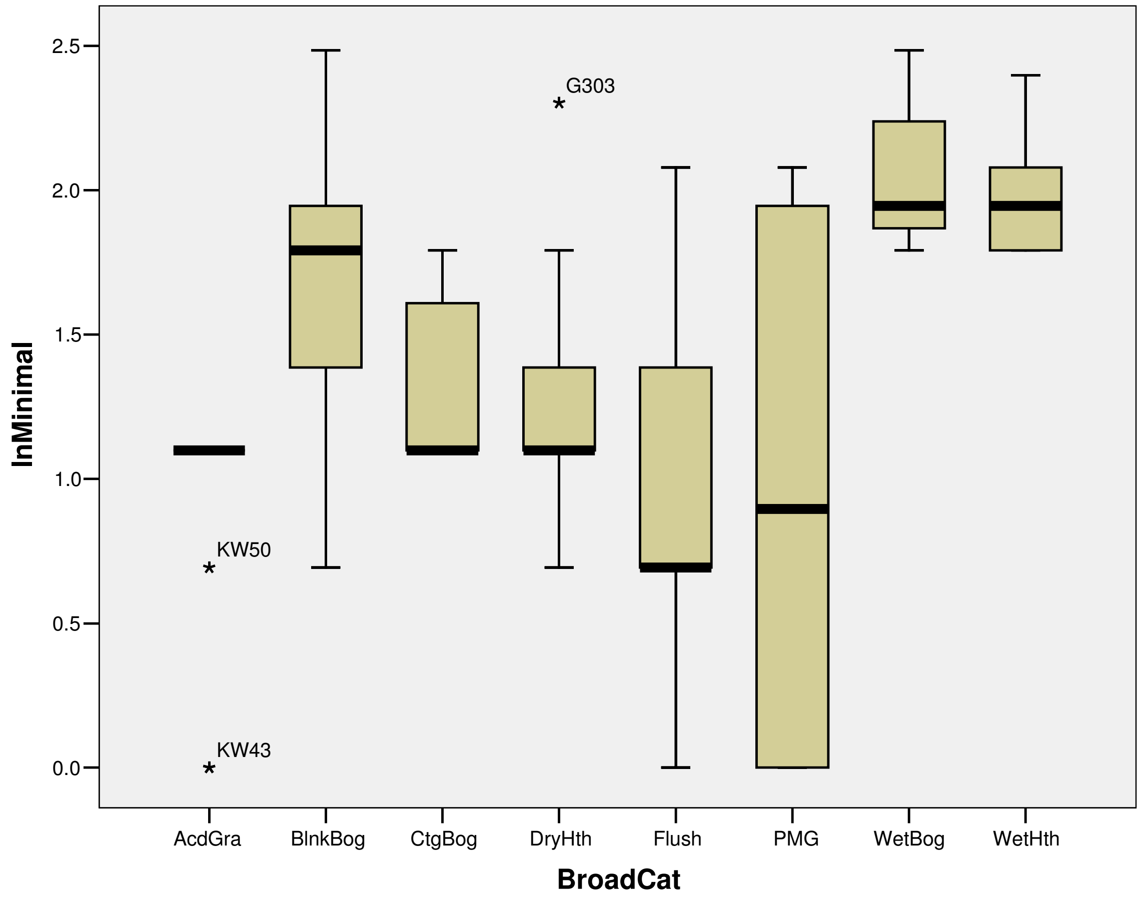
This ranking seemed very similar to that from the **full bog quality** index. It was difficult to spot any major differences between the two plots, suggesting that the **intermediate** index may have worked as well as the **full** index.



Comparison of **simple bog quality** (square root transformation) scores for different bog types

Quite a disappointing result here. It looked as though the **simple** index may not have worked at all well in **blanket bog mosaic** habitats. This time **wet bogs** overlapped quite a bit with **wet heaths**. **Blanket bogs** also overlapped to a greater extent with more habitats. The variance in **flush** and ***Molinia*** habitats was so great as to potentially be quite problematic.

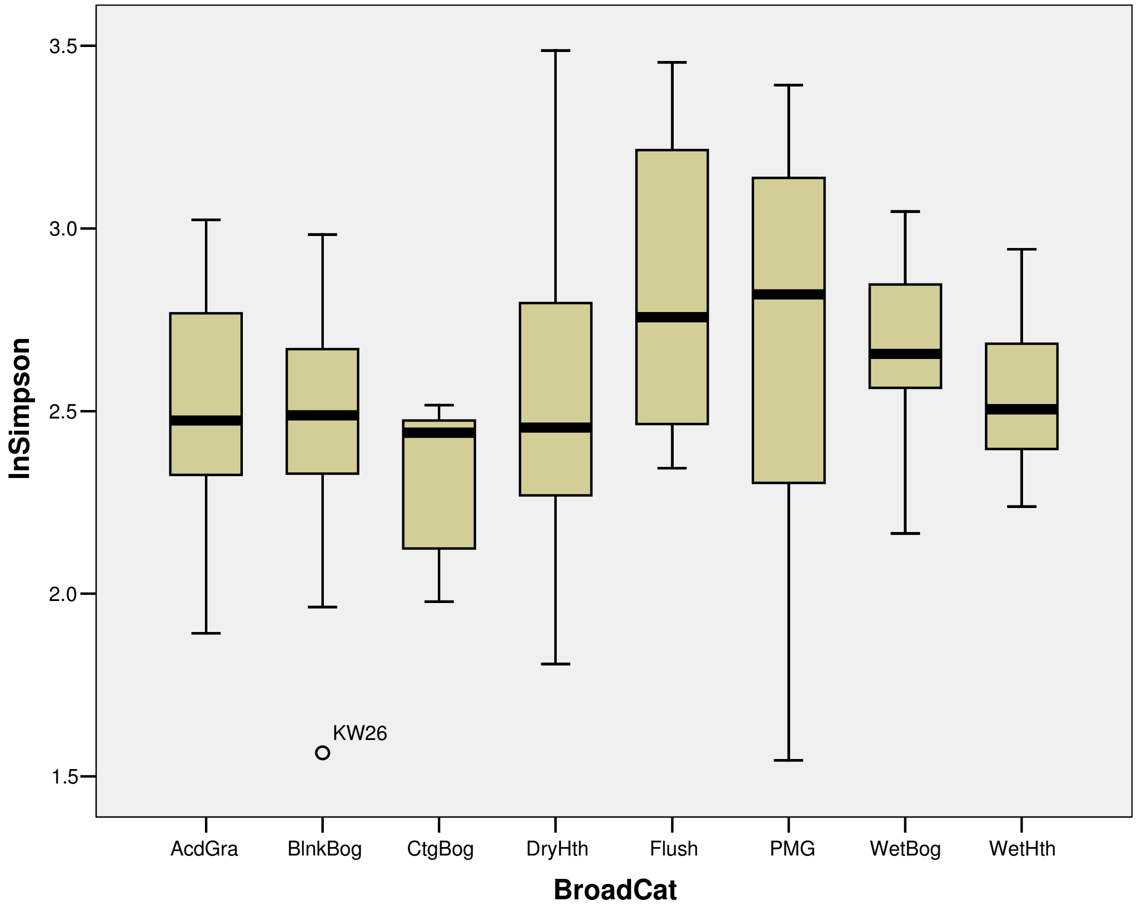
Just from this initial analysis it appeared that it may not be useful to use the **simple** approach on **blanket bog** sites.



Comparison of **minimal bog quality** (natural log transformation) scores for different bog types

The **minimal** index ranked the bog types in a similar way to the **simple** index. If anything, the expected separation between the different habitat types was a bit worse than the result from the **simple** index.

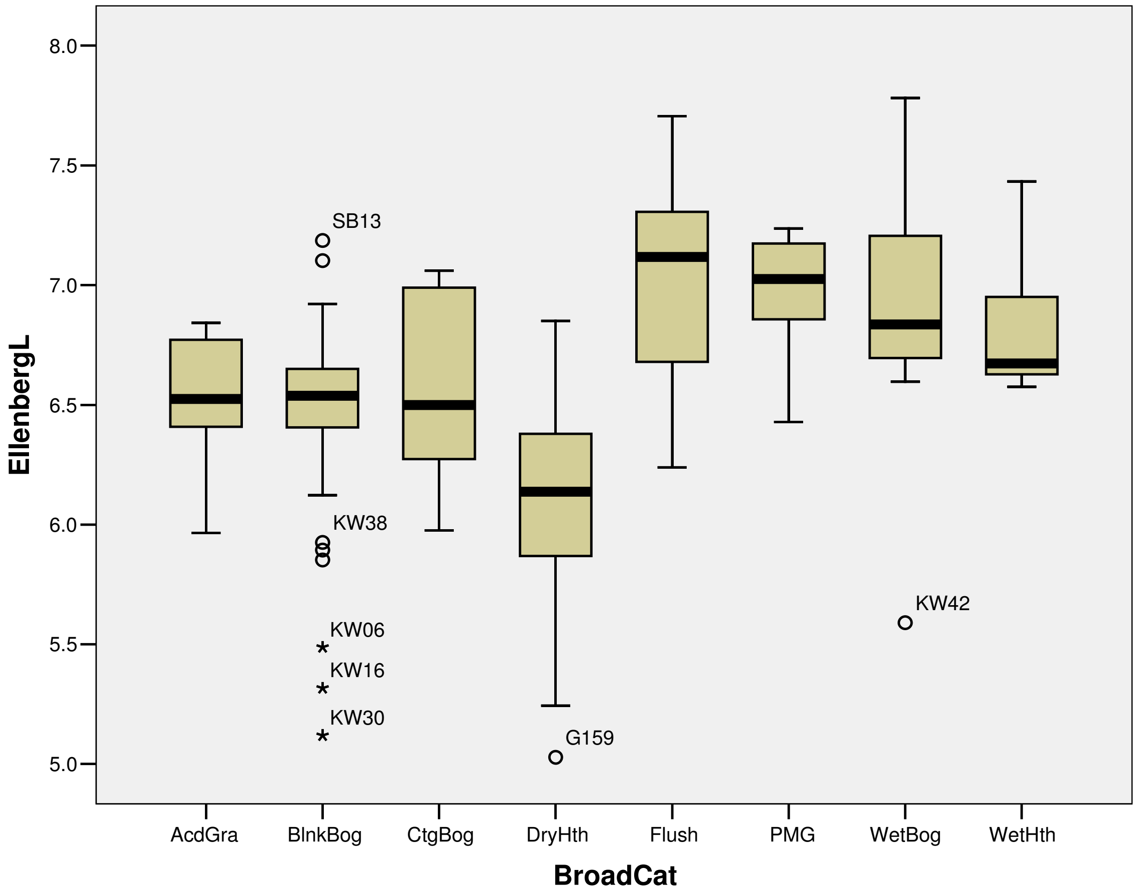
NB the remaining indices can only be calculated when using the **full** method



Comparison of **Simpson's Reciprocal Index** (natural log transformation) scores for different bog types

There was a lot of overlap between the different habitat types here and there was relatively high variance within some types. This showed that a **bog quality index** may be more informative that a **diversity index.**

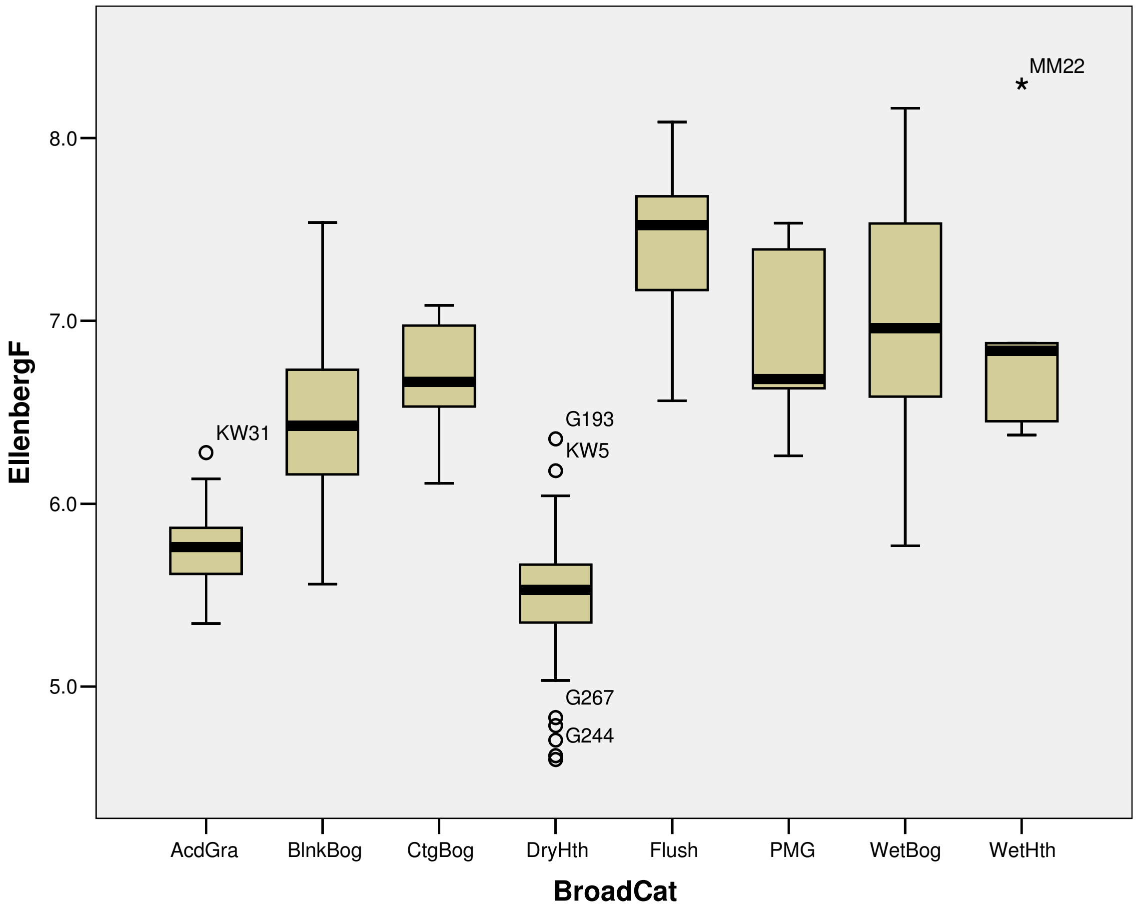
The **wet bogs** were a bit more diverse on average than the **blanket bogs**, but there was a lot of overlap. Many of the other habitat types were not clearly separated.



Comparison of **Ellenberg L** (light) index scores for different bog types

This did not appear to be as useful as some of the other Ellenberg indices.

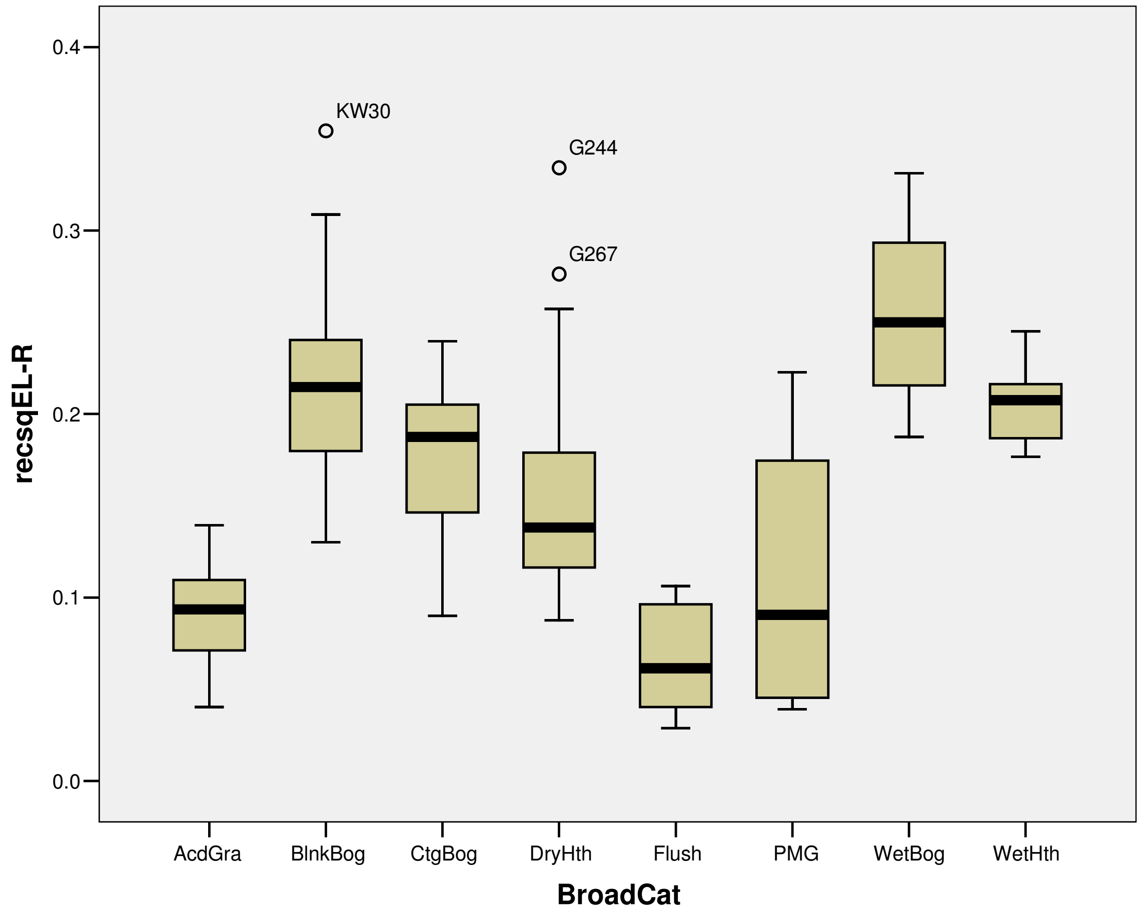
Wet bogs had higher light scores than **blanket bogs** on average, as we would expect and **blanket bogs** also seemed to be separable from **dry heaths**. The other habitats overlapped with these in quite a complex way.



Comparison of **Ellenberg F** (wetness) index scores for different bog types.

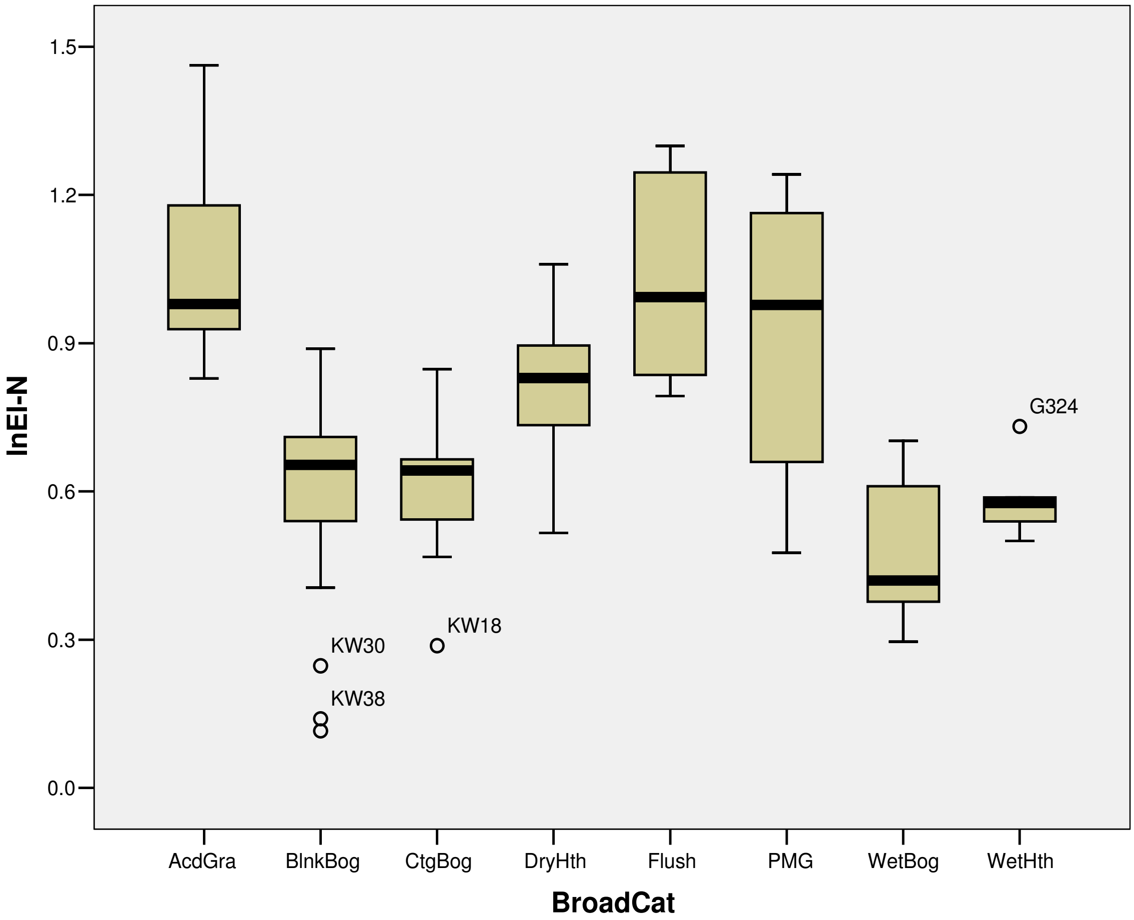
There appeared to be clearer differences here between the different bog types, although some types (e.g. **wet bogs**) had relatively high variance.

Wet bogs got higher wetness scores than **blanket bogs**, which got higher wetness scores than **dry heaths**. But **wet heaths** and **cottongrass bogs** overlapped with both **wet bogs** and **blanket bogs**. **Flushes** and ***Molinia* vegetation** could again be confounding variables, as they both got fairly high wetness scores.



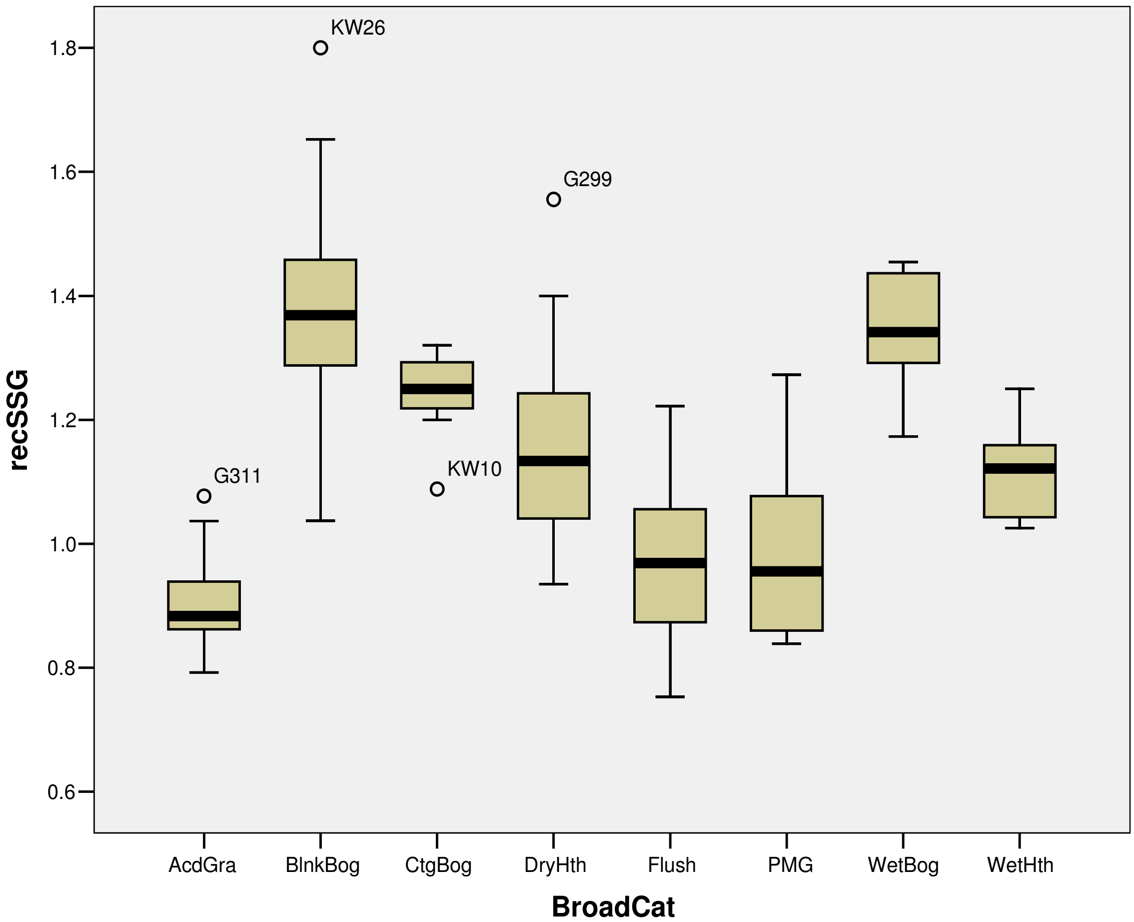
Comparison of **Ellenberg R** (reaction – i.e. pH) (reciprocal squared transformation) index scores for different bog types

A fairly good separation between some of the groups, but with some potentially confounding overlaps. **Wet bogs** were the most acid habitat, but there was a bit of overlap with **blanket bogs**. **Blanket bogs** overlapped a lot with **wet heath** and quite a bit with **cottongrass bogs**. **Dry heaths** were clearly separated from the **wet bogs** and **blanket bogs** though.



Comparison of **Ellenberg N** (nitrogen – i.e. fertility) index scores for different bog types

Another potentially useful index. The three types of bog along with **wet heath** formed an overlapping group, with **wet bogs** getting the lowest scores on average. This group was clearly separated from **dry heaths** and the other three habitats.



Comparison of **Suited Species Grazing index** scores for different bog types

We would expect to get similar results here to the results we got from the **Ellenberg L** index, because species suited to grazing should also on average, be suited to short swards and species less suited to grazing should on average, be suited to more shaded situations.

This was an interesting result, suggesting that this index may prove useful. Here the **wet heaths** were more clearly separated from the three bog types than they were in any of the previous plots using other indices. It was difficult to think of a logical ecological reason why this was so. This particular result may just be due to random variation this time, but nevertheless it may be useful and would be worth investigating further.

The three bog types overlapped quite a bit here, but they were separated pretty well from all the other habitats, apart from a bit of overlap between **dry heath** and **cottongrass bogs**.

Scatterplots and linear regression

Several pairwise comparisons were made here, to see:

- How closely one index predicted the scores of another, and;
- How well each index ranked the different categories of vegetation types in the expected order.

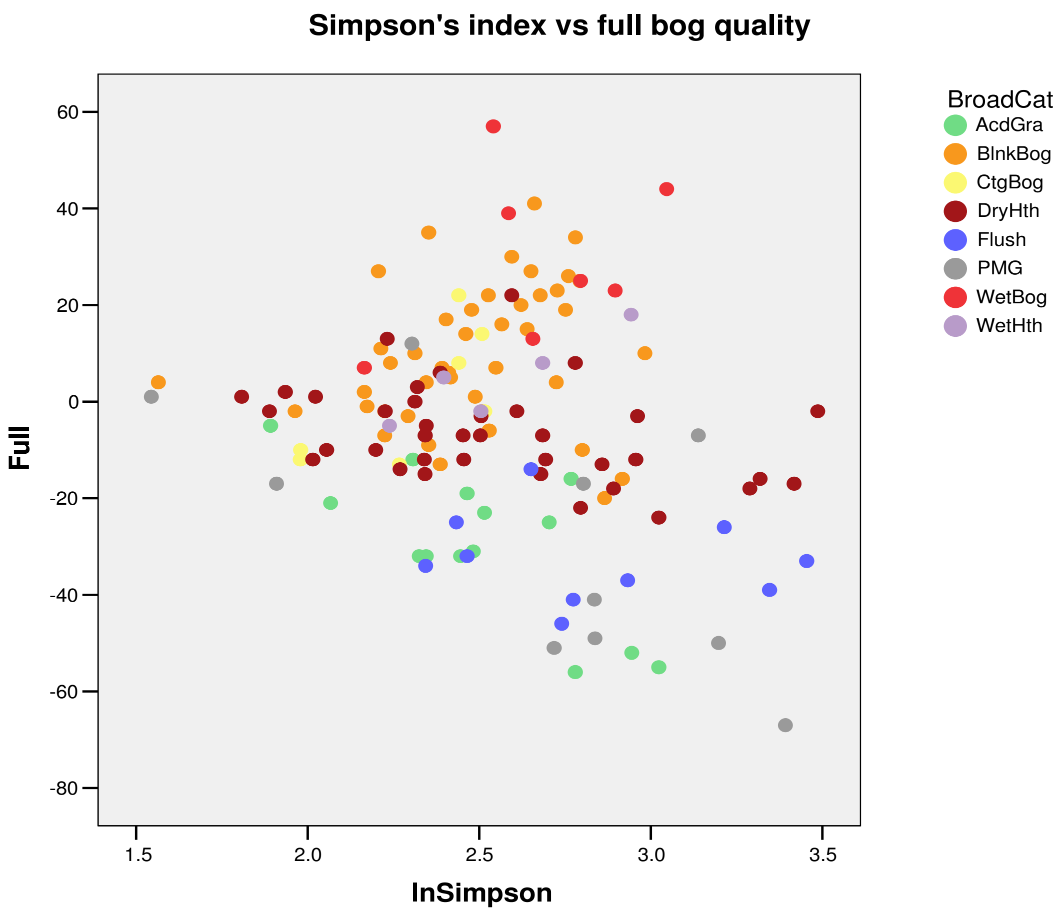
Scatterplots are presented showing the scores for all of the quadrats of one index against another. The index on the ***y*-axis** was the one we were attempting to predict from the index along the ***x*-axis**. The quadrats appear as different coloured symbols depending on which main vegetation category they belonged to.

If one index predicted the scores of another closely then there should not be much scatter in the plot. Instead, most of the points should line up along a diagonal line from the bottom left of the plot to the top right.

The % variance explained (or *r*-squared value) tells us how much of the total variability within the dataset was explained by the imaginary regression line. If the plotted points lay mostly close to a straight line, this value will be close to 100% and if there was little if any relationship between the two indices (i.e. lots of scatter) then this value will be close to 0%. Any % variance explained value over 60% suggested a reasonably strong relationship and anything over 80% was very strong.

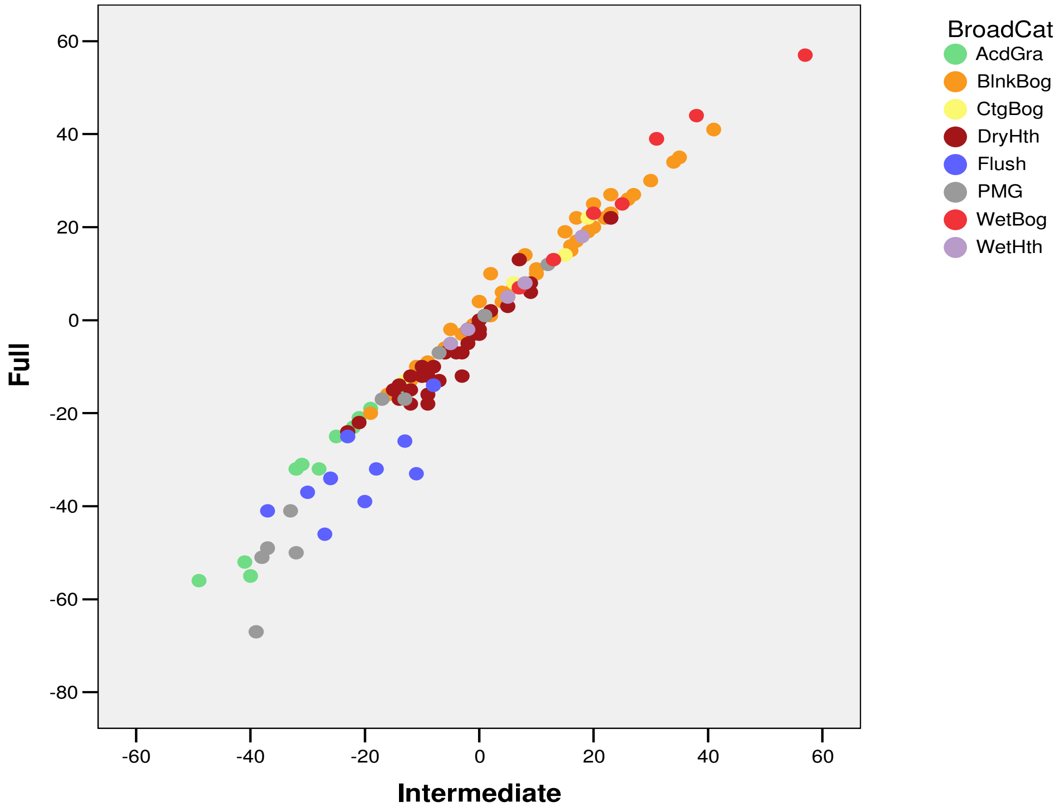
The % variance explained values came from running a linear regression model on the two indices after transforming the data to normal distributions if necessary. We also checked these linear regression models, by inspecting the residual plots to check the model assumptions, especially the assumptions that the residuals were normally distributed and had constant variance. We describe any major deviation from the linear model that arose from such checks and occasionally include the residual plots where these may be informative.

The scatterplots were inspected by eye to see how the different categories of vegetation types were ranked using each index. If the index on the ***y*-axis** was a good way of ranking the quadrats in terms of quality, then **wet bog** quadrats should appear at or near the **top** of the plot with **blanket bog** quadrats just **below** these. Similarly, if the index on the ***x*-axis** was a good way of ranking the quadrats in terms of quality, then **wet bog** quadrats should appear at or near the **right-hand side** of the plot with **blanket bog** quadrats just **to the left** of these.



Little suggestion of a strong relationship. Only 4.5% variance explained by regression line. The residual plots showed some evidence that the variance of the residuals was not constant, but this was just about acceptable, so the model may still be a reasonable one.

The bog quality index was clearly a much better way of scoring the bogs higher and other habitats lower.

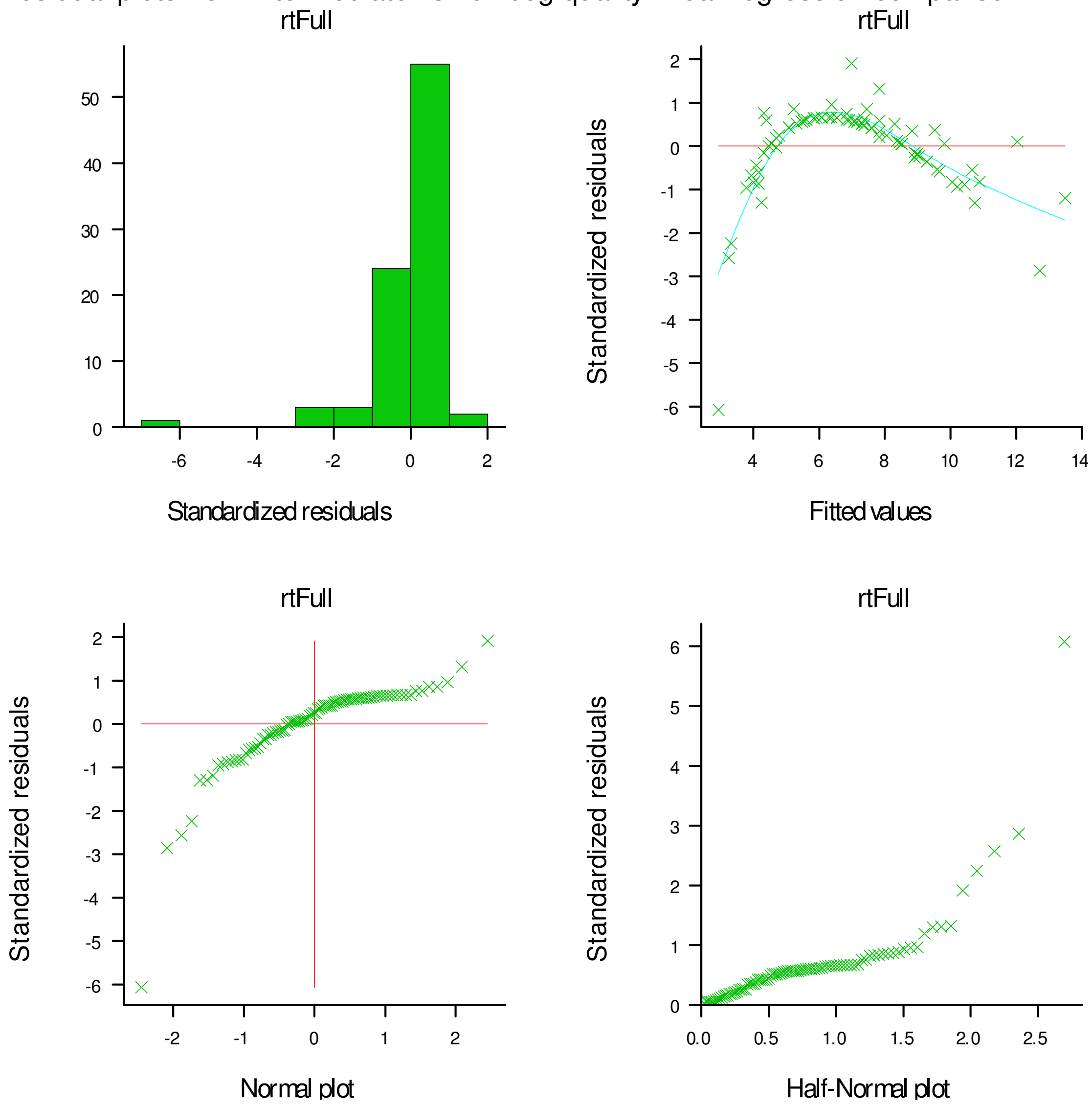


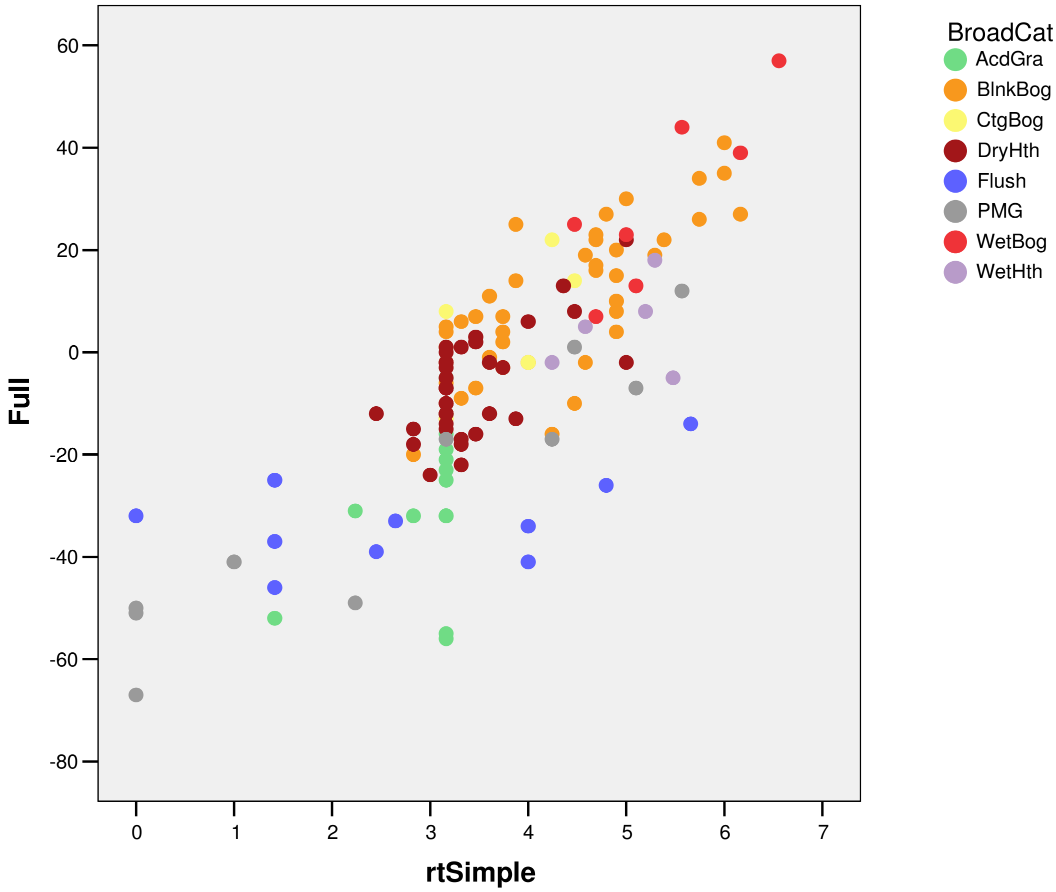
A very close relationship between these two, as we would expect, but as we found with the **mixed bog** data, the relationship appeared to be *S*-shaped, rather than straight.

The percentage variance explained by the regression line was 95.8% from a linear regression model, but there was strong evidence that a straightforward linear model was not appropriate here (see plots on next page).

So although there was a very strong relationship between these two methods, when the scores did differ, they differed in a complicated and unpredictable way compared to the other comparisons of methods described below. The relative ranking of the very best bog quadrats was lower with the **intermediate** method compared to the **full** method.

Residual plots from intermediate vs. full bog quality linear regression comparison

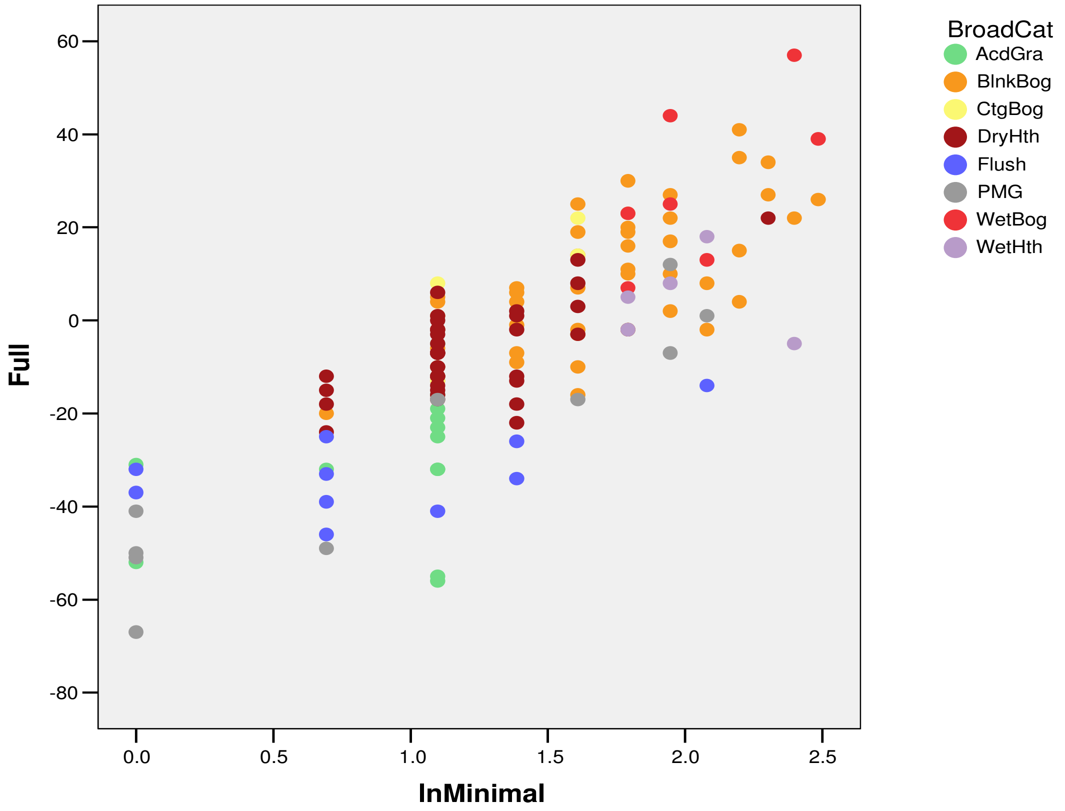




There was clearly a relationship between the two indices, but there was considerable spread and the percentage variance explained by the regression line was 62.4%. This was not as high as we achieved with the other datasets, but still it was not too bad considering how simple this index was.

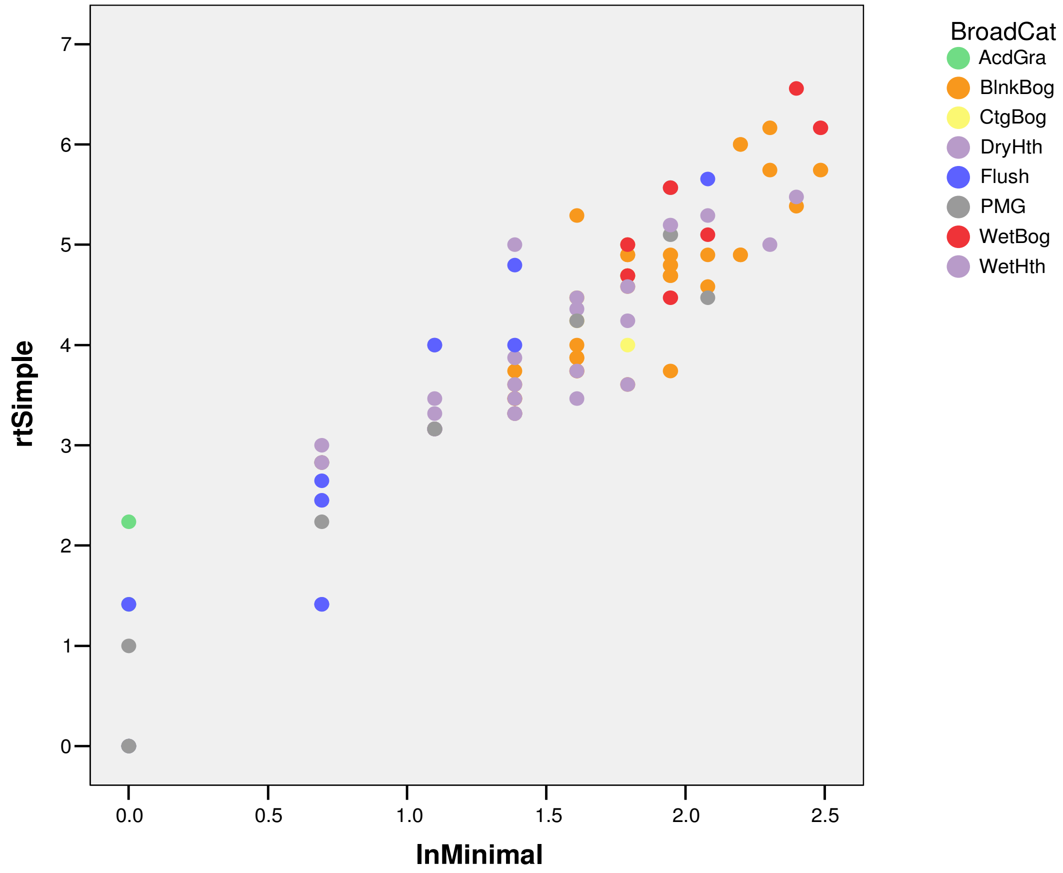
One clear result from the plot was that the **simple** index did not work at all well with habitats that were not bogs. This was unsurprising since it was based on a short list of bog indicator species. **Dry heaths** were mostly separated from the bogs fairly well, but more problematic was the higher relative scores that many of the **wet heath** quadrats got with the **simple** method.

Looking at just the top-right of the plot, suggested that apart from the **wet heath** issue, the **simple** index may not be as bad as it first appeared if we were to stratify these sites successfully, so that that sampling concentrated on bog quadrats only.



The **minimal** index was similar to the **simple** index in the strength of the relationship to the **full** index (63% of variance explained). The overall pattern shown in this plot brings out the same messages as discussed above for the **simple** vs **full** plot.

It appeared that if the **simple** index had any merit here, then the **minimal** index may have been just as good.



A strong relationship between these two methods as we would expect, with 86.8% of variance explained.

No really strong evidence to suggest that one of these indices performed better than the other. Several dots are obscured on this plot, as so many of the scores were identical. This makes interpreting the main patterns tricky.

There seemed to be a few small differences. The minimal index seemed to score some of the **dry heath** quadrats a bit higher, which would be undesirable. Also, **wet heaths** seemed to score higher on average in the **minimal** method than in the **simple** method which would also be undesirable. But on the other hand, **wet bogs** and **blanket bogs** also seemed to score relatively higher with the **minimal** rather than **simple** method

Discussion of the blanket bog mosaic data results
So far, we have seen that in this dataset we had some problems getting data to conform to normal distributions, due to the variation in the habitats sampled.

The **full** and **intermediate** bog quality indices seemed to rank the various habitats in a useful order most of the time. However, the separation between the different types was not as clear as we had with the **Stanley Moss** and **mixed bog** datasets, which of course were less variable. The **full** or **intermediate** indices seemed to work to some extent, but perhaps not as well as the original bog quality indices did with the other two datasets.

The **simple** and **minimal** indices did not look as useful this time. In particular, **wet heath** quadrats had a similar range of scores to many of the **bog** quadrats

If all methods ranked the quadrats in the same order, then when the scores from two methods were plotted against each other, we would get a scatterplot with points along a straight line going diagonally upwards. There was little relationship between diversity and bog quality, as we saw with the **Stanley Moss** and **mixed bogs** datasets. The relationship between the **intermediate** and **full** methods almost followed a perfect straight line, except at the extreme ends and the relationship at the ends was complicated. The **simple** and **minimal** methods were reasonably closely correlated with the **full** method, but not as close as in the **Stanley Moss** and **mixed bogs** datasets. The **full** and **intermediate** methods definitely ranked the bog quadrats higher more consistently than the **simple** and **minimal** methods did. When the **simple** and **minimal** methods were compared there seemed little to choose between them.

Measures	%variance explained
Diversity vs. full	5%
Intermediate vs. full	96%
Simple vs. full	62%
Minimal vs. full	63%
Simple vs. intermediate	59%
Minimal vs. intermediate	61%
Minimal vs. simple	87%

So again, superficially it appeared that the **intermediate** method may do a very good job at predicting **full** quality, but the **simple** and **minimal** methods looked less useful this time.

We may ask if they are good enough to be adequate? We could go some way to answering this by comparing the statistical power obtained from the different indices.

Below we calculate samples sizes required to detect a difference of 20% from the mean. We use the 95% significance level and 80% for the level of power we require in both methods.

Some of our variables (e.g. the four bog quality indices and the SSG index) can take both positive and negative values so they were ratio variables. The other ecological indices were interval variables, i.e. they have a minimum possible value. This meant that it was difficult to compare the power obtained from the four methods in a meaningful way. For the comparison below, we have taken the minimum value in each case to equal absolute zero for that index and so we have transformed the observed values by subtracting this minimum value from all values. Only then have we calculated the (standardised) mean. These figures should therefore be taken as a **rough guide only**.

We calculated the samples sizes needed based on all 133 samples from the whole dataset first and then we did several further calculations, based on narrowing down the range of habitats types more and more each time. The figures on the left of the table are those needed for an untargeted, unstratified survey, whereas the figures on the right are those needed when the survey has been stratified successfully after an accurate baseline survey.

Sample sizes needed to achieve 80% power to detect a difference of 20% from the original (standardised) mean.

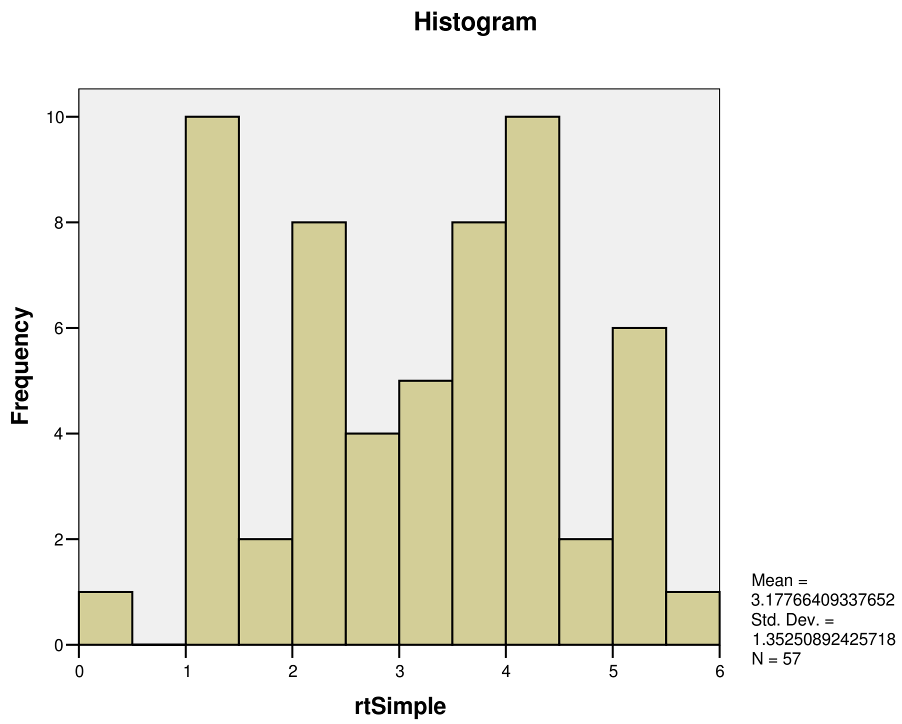
Vegetation type	All	Bog & heath (dry & wet)	Bog & wet heath	Bog (all types)	Blanket bog
No. of quadrats in sample	133	99	62	57	43
Full	26	11	9	9	8
Intermediate	33	16	14	15	13
Simple*	23	11	10	10	9
Minimal*	35	18	12	13	12
Simpson	28	25	18	18	17
EI-L	24	27	19	20	17
EI-F	42	44	16	15	12
EI-R	55	25	15	15	13
EL-N	28	22	23	25	22
SSG	48	23	14	11	11

The **full** method appeared to have a little more power than the **intermediate** method. The figures for the **simple*** and **minimal*** methods were overly optimistic, as neither of these could be satisfactorily transformed to a normal distribution.

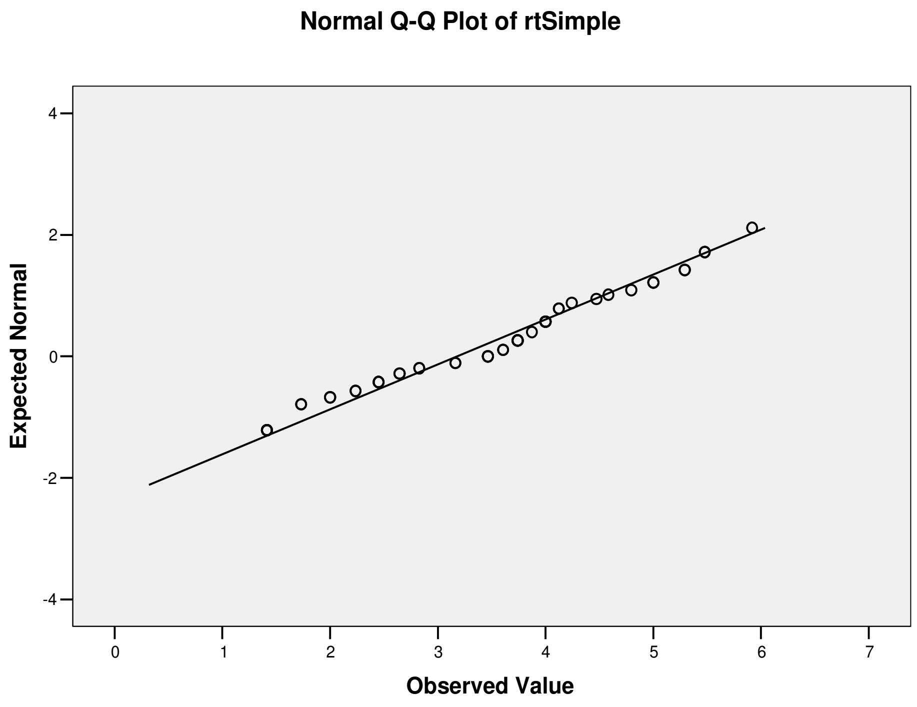
Overall, the predicted sample sizes needed were encouragingly (and surprisingly) low. The strong suggestion was that smaller samples may be needed for **blanket bogs** than for **wet bogs**.

Further benefits of stratification

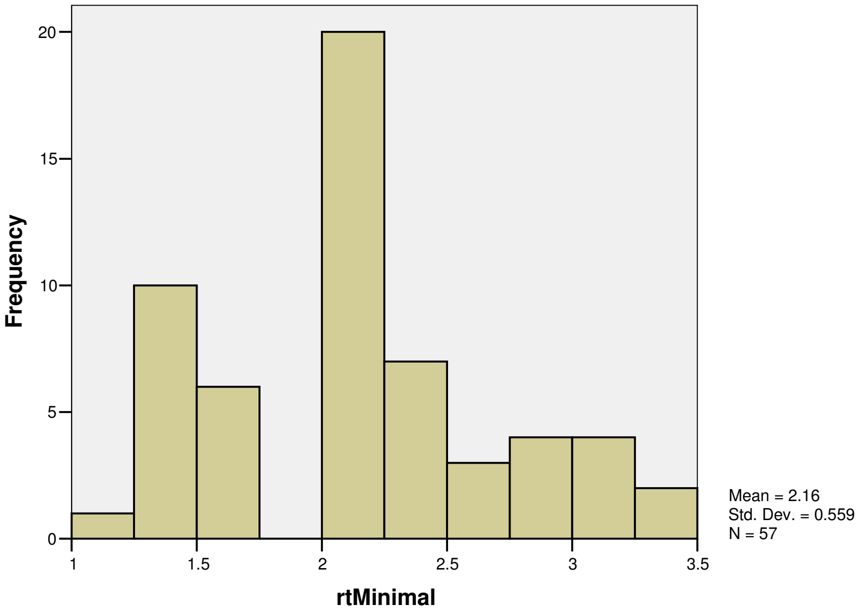
Above we discussed how it was impossible to transform the data from the **simple** and **minimal** index to normal distributions when we had data from an unstratified survey including random samples from various vegetation types present in a large blanket bog site. The plots on the next two pages show how it was possible to transform these data to something approaching normal distributions more closely if we did stratify the site before surveying. This analysis uses the 57 quadrats out of our original set of 133 quadrats which were bog vegetation of some kind.



The square root transformation of the scores from the **simple bog quality index** from only the bog quadrats had a funny shape, but a normal distribution was not completely implausible here. This time using only the bog quadrats, 10 out of 57 (roughly 18%) of the quadrats had zero scores, whereas when we used the full dataset, 39 out of 133 (roughly 29%) of the quadrats had zero scores.

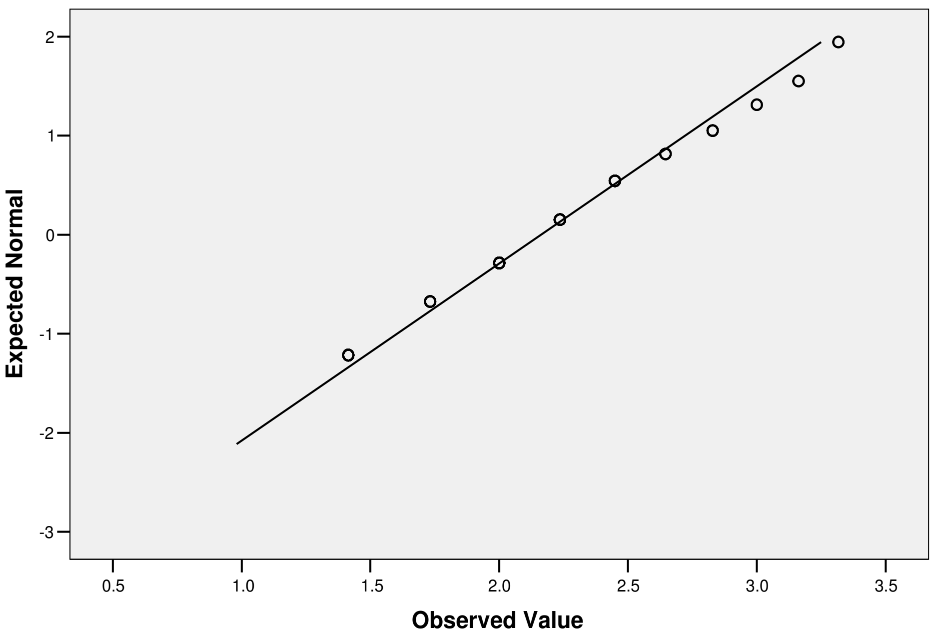


Histogram



Here again we had quite an irregular shape from the square root transformation of the minimal bog quality index scores from the bog quadrats only. But a normal distribution was much more plausible now than it was with the full dataset. We now have 10 out of 57 (roughly 18%) of the quadrats with zero scores, whereas when we used the full dataset, 43 out of 133 (roughly 32%) of the quadrats had zero scores.

Normal Q-Q Plot of rtMinimal



Appendix D: Standard species lists with quality weighting

Species weightings used for calculating the **wet bog quality** index.
(**NB** for the weightings used for the blanket bog method see page 106.)

Scientific name	Common name	Full	Intermediate	Simple
Acer pseudoplatanus	Sycamore	-1		
Achillea millefolium	Yarrow	-1		
Achillea ptarmica	Sneezewort	-1		
Agrostis canina	Velvet bent	0	0	
Agrostis capillaris	Common bent	-1	-1	
Agrostis stolonifera	Creeping bent	-1		
Agrostis vinealis	Brown bent	-1		
Ajuga reptans	Bugle	-1		
Andromeda polifolia	Bog rosemary	3	3	3
Aneura pinguis	a liverwort	-1		
Angelica sylvestris	Wild angelica	-1		
Anthoxanthum odoratum	Sweet vernal-grass	-1	-1	
Arrhenatherum elatius	False oat-grass	-1		
Atrichum undulatum	a moss	-1		
Aulacomnium palustre	a moss	1	1	
Barbilophozia floerkei	a liverwort	2		
Bellis perennis	Daisy	-1		
Betula pendula	Silver birch	0		
Betula pubescens	Downy birch	0	0	
Brachytheciastrum velutinum	a moss	-1		
Brachythecium rivulare	a moss	-1		
Brachythecium rutabulum	a moss	-1	-1	
Bryum capillare	a moss	-1		
Calliergonella cuspidata	a moss	-1	-1	
Calluna vulgaris	Heather	1	1	1
Caltha palustris	Marsh marigold	-1		
Calypogeia azurea	a liverwort	2		
Calypogeia fissa	a liverwort	1		
Calypogeia fissa/muelleriana	a liverwort		1	
Calypogeia muelleriana	a liverwort	1		
Campanula rotundifolia	Harebell	-1		
Campylopus flexuosus	a moss	0	0	
Campylopus introflexus	a moss	-1	-1	
Campylopus pyriformis	a moss	0	0	
Cardamine pratensis	Cuckooflower	-1		
Carex binervis	Green-ribbed sedge	-1		
Carex canescens	White sedge	1	1	
Carex demissa	Common yellow-sedge	-1		
Carex dioica	Dioecious sedge	0		
Carex echinata	Star sedge	0	0	
Carex flacca	Glaucous sedge	0		
Carex hostiana	Tawny sedge	0		
Carex lepidocarpa	Long-stalked yellow-sedge	0		
Carex leporina	Oval sedge	-1		
Carex limosa	Bog-sedge	4	4	
Carex magellanica	Tall bog-sedge	4	4	
Carex nigra	Common sedge	-1	-1	
Carex pallescens	Pale sedge	-1		
Carex panicea	Carnation sedge	0		
Carex pauciflora	Few-flowered sedge	4	4	
Carex pilulifera	Pill sedge	-1		

Scientific name	Common name	Full	Intermediate	Simple
Carex pulicaris	Flea sedge	0		
Carex rostrata	Bottle sedge	0	0	
Cephalozia bicuspidata	a liverwort	0	0	
Cephalozia connivens	a liverwort	2	2	
Cephalozia macrostachya	a liverwort	4		
Cephaloziella divaricata	a liverwort	0		
Cerastium fontanum	Common mouse-ear	-1		
Ceratodon purpureus	a moss	-1		
Chamerion angustifolium	Rosebay willowherb	-1	-1	-1
Cirsium palustre	Marsh thistle	-1	-1	-1
Cladonia arbuscula	a lichen	2		
Cladonia cervicornis	a lichen	0		
Cladonia chlorophaea	a lichen	0		
Cladonia ciliata	a lichen	0		
Cladonia coniocraea	a lichen	0		
Cladonia diversa	a lichen	0		
Cladonia fimbriata	a lichen	0		
Cladonia furcata	a lichen	0		
Cladonia macilenta	a lichen	0		
Cladonia polydactyla	a lichen	0		
Cladonia portentosa	a lichen	2		
Cladonia pyxidata	a lichen	0		
Cladonia rangiformis	a lichen	0		
Cladonia sp. (bushy)	a lichen		2	2
Cladonia sp. (squamules)	a lichen	0		
Cladonia squamosa	a lichen	0		
Cladonia uncialis	a lichen	3		
Cladopodiella fluitans	a liverwort	3		
Climacium dendroides	a moss	-1		
Comarum palustre	Marsh cinquefoil	0		
Crustose lichens	a lichen	0		
Ctenidium molluscum	a moss	0		
Cynosurus cristatus	Crested dog's-tail	-1		
Dactylorhiza maculata	Heath spotted-orchid	1		
Dactylorhiza purpurella	Northern marsh-orchid	1		
Dactylorhiza sp.	an orchid	1		
Danthonia decumbens	Heath-grass	1		
Deschampsia cespitosa	Tufted hair-grass	-1	-1	
Deschampsia flexuosa	Wavy hair-grass	-1	-1	
Dicranella heteromalla	a moss	0	0	
Dicranoweisia cirrata	a moss	-1		
Dicranum leioneuron	a moss	4		
Dicranum scoparium	a moss	1	1	
Digitalis purpurea	Foxglove	-1	-1	-1
Diplophyllum albicans	a liverwort	1		
Drosera anglica	Great sundew	4	4	
Drosera rotundifolia	Round-leaved sundew	3	3	3
Dryopteris carthusiana	Narrow buckler-fern	0		
Dryopteris dilatata	Broad buckler-fern	-1		
Empetrum nigrum	Crowberry	2	2	2
Epilobium palustre	Marsh willowherb	-1		
Epilobium parviflorum	Hoary willowherb	-1		
Equisetum arvense	Field horsetail	-1		
Equisetum fluviatile	Water horsetail	0		
Equisetum palustre	Marsh horsetail	-1		

Scientific name	Common name	Full	Intermediate	Simple
Erica cinerea	Bell heather	0		
Erica tetralix	Cross-leaved heath	2	2	2
Eriophorum angustifolium	Common cottongrass	1	1	1
Eriophorum vaginatum	Hare's-tail cottongrass	0	0	
Euphrasia agg.	an eyebright	0		
Festuca ovina	Sheep's-fescue	-1	-1	
Festuca rubra	Red fescue	-1	-1	
Ficaria verna	Lesser celandine	-1		
Fissidens adianthoides	a moss	0		
Galium palustre	Marsh bedstraw	-1	-1	
Galium saxatile	Heath bedstraw	-1	-1	
Galium uliginosum	Fen bedstraw	-1		
Gymnocolea inflata	a liverwort	2	2	
Hieracium agg.	a hawkweed	0		
Holcus lanatus	Yorkshire-fog	-1	-1	
Holcus mollis	Creeping soft-grass	-1	-1	
Hydrocotyle vulgaris	Marsh pennywort	-1		
Hylocomium splendens	a moss	2	2	
Hypnum cupressiforme	a moss	0		
Hypnum imponens	a moss	3		
Hypnum jutlandicum	a moss	0	0	
Hypochaeris radicata	Cat's-ear	-1		
Hypogymnia phsyodes	a lichen	2		
Juncus acutiflorus	Sharp-flowered rush	-1	-1	
Juncus articulatus	Jointed rush	-1		
Juncus bulbosus	Bulbous rush	0		
Juncus conglomeratus	Compact rush	-1		
Juncus effusus	Soft-rush	-1	-1	
Juncus sp. (big rushes)	a big rush			-1
Juncus squarrosus	Heath rush	-1	0	
Kindbergia praelonga	a moss	0		
Kurzia pauciflora	a liverwort	2		
Larix sp.	a larch	-1		
Larix/*Picea*/*Pinus* sp.	a conifer		-1	-1
Lepidozia reptans	a liverwort	1		
Leucobryum glaucum	a moss	2	2	
Lophocolea bidentata	a liverwort	0	0	
Lophozia ventricosa	a liverwort	1	1	
Lotus corniculatus	Common bird's-foot-trefoil	-1		
Lotus pedunculatus	Greater bird's-foot-trefoil	-1		
Luzula campestris	Field woodrush	-1		
Luzula multiflora	Heath woodrush	-1	-1	
Luzula sylvatica	Great woodrush	-1		
Lysimachia nemorum	Yellow pimpernel	-1		
Marsupella emarginata	a liverwort	-1		
Micarea leprosula	a lichen	0		
Mnium hornum	a moss	0		
Molinia caerulea	Purple moor-grass	-1	-1	
Mylia anomala	a liverwort	3	3	
Myrica gale	Bog-myrtle	1		
Nardia scalaris	a liverwort	-1		
Nardus stricta	Mat-grass	-1	-1	
Narthecium ossifragum	Bog asphodel	2	2	2
Neottia cordata	Lesser twayblade	3	3	3
Odontoschisma sphagni	a liverwort	3	3	

Scientific name	Common name	Full	Intermediate	Simple
Orthodontium lineare	a moss	-1		
Oxalis acetosella	Wood-sorrel	-1		
Oxyrrhynchium hians	a moss	-1		
Pedicularis palustris	Marsh lousewort	-1		
Pedicularis sylvatica	Lousewort	-1		
Pellia sp.	a liverwort	-1		
Peltigera sp.	a lichen	-1		
Philonotis calcarea	a moss	0		
Philonotis fontana	a moss	0		
Phleum pratense	Timothy	-1		
Picea abies	Norway spruce	-1		
Picea sitchensis	Sitka spruce	-1		
Pilosella officinarum	Mouse-ear hawkweed	-1		
Pinus contorta	Lodgepole pine	-1		
Pinus sylvestris	Scots pine	-1		
Plagiomnium elatum	a moss	0		
Plagiomnium undulatum	a moss	-1		
Plagiothecium undulatum	a moss	1	1	
Plantago lanceolata	Ribwort plantain	-1		
Pleurozium schreberi	a moss	1	1	
Poa annua	Annual meadow-grass	-1		
Poa pratensis	Smooth meadow-grass	-1		
Poa trivialis	Rough meadow-grass	-1		
Pohlia melanodon	a moss	-1		
Pohlia nutans	a moss	-1		
Polytrichastrum formosum	a moss	0		
Polytrichastrum longisetum	a moss	-1	-1	
Polytrichum commune	a moss	-1	-1	
Polytrichum juniperinum	a moss	-1		
Polytrichum piliferum	a moss	-1		
Polytrichum strictum	a moss	2	2	
Potentilla erecta ssp. *erecta*	Tormentil	-1	-1	
Potentilla erecta ssp. *strictissima*	Tormentil	-1		
Prunella vulgaris	Selfheal	-1		
Pseudoscleropodium purum	a moss	-1	-1	
Pteridium aquilinum	Bracken	-1	-1	-1
Ptilidium ciliare	a liverwort	1		
Quercus petraea	Sessile oak	-1		
Quercus robur	Pedunculate oak	-1		
Racomitrium ericoides	a moss	-1		
Racomitrium lanuginosum	a moss	3	3	
Ranunculus acris	Meadow buttercup	-1		
Ranunculus flammula	Lesser spearwort	-1		
Ranunculus repens	Creeping buttercup	-1		
Rhynchospora alba	White beak-sedge	4	4	
Rhytidiadelphus loreus	a moss	2	2	
Rhytidiadelphus squarrosus	a moss	-1	-1	
Riccardia chamedryfolia	a liverwort	1		
Riccardia latifrons	a liverwort	4		
Riccardia sp.	a liverwort	1		
Rubus chamaemorus	Cloudberry	2	2	2
Rubus fruticosus agg.	Bramble	-1	-1	-1
Rumex acetosa	Common sorrel	-1	-1	
Rumex acetosella	Sheep's-sorrel	-1		
Scapania nemorea	a liverwort	0		

Scapania undulata	a liverwort	0		
Scorpidium cossonii	a moss	0		
Scorzoneroides autumnalis	Autumn hawkbit	-1		
Selaginella selaginoides	Lesser clubmoss	0		
Silene flos-cuculi	Ragged-Robin	-1		
Sorbus aucuparia	Rowan	0	0	
Sphagnum angustifolium	a moss	0		
Sphagnum austinii	a moss	4	4	
Sphagnum balticum	a moss	4		
Sphagnum capillifolium	a moss		1	
Sphagnum capillifolium ssp. *capillifolium*	a moss	1		
Sphagnum capillifolium ssp. *rubellum*	a moss	1		
Sphagnum cuspidatum	a moss	1	1	
Sphagnum fallax	a moss	-1	-1	
Sphagnum fimbriatum	a moss	0	0	
Sphagnum fuscum	a moss	4	4	
Sphagnum girgensohnii	a moss	0	0	
Sphagnum inundatum	a moss	-1		
Sphagnum magellanicum	a moss	3	3	
Sphagnum palustre	a moss	-1	-1	
Sphagnum papillosum	a moss	2	2	
Sphagnum quinquefarium	a moss	0		
Sphagnum russowii	a moss	1	1	
Sphagnum sp. (red or chunky)	a red or chunky *Sphagnum*			2
Sphagnum squarrosum	a moss	-1		
Sphagnum subnitens	a moss	0	0	
Sphagnum tenellum	a moss	2	2	
Stellaria alsine	Bog stitchwort	-1		
Stellaria graminea	Lesser stitchwort	-1		
Stellaria media	Common chickweed	-1		
Succisa pratensis	Devil's-bit scabious	-1		
Taraxacum agg.	Dandelion	-1		
Tetraphis pellucida	a moss	0		
Thuidium tamariscinum	a moss	0	0	
Thymus polytrichus	Wild thyme	0		
Trichophorum cespitosum	Northern deergrass	4		
Trichophorum germanicum	Deergrass	0		
Trichophorum sp.	a deergrass		0	
Trichophorum x *foersteri*	Hybrid deergrass	2		
Trifolium pratense	Red clover	-1		
Trifolium repens	White clover	-1		
Triglochin palustris	Marsh arrowgrass	-1		
Vaccinium myrtillus	Bilberry	0	0	
Vaccinium oxycoccos	Cranberry	2	2	2
Vaccinium vitis-idaea	Cowberry	2	2	2
Valeriana dioica	Marsh valerian	-1		
Viola palustris	Marsh violet	-1		
Viola riviniana	Common dog-violet	-1		

Species weightings used for calculating the **blanket bog quality** index.
(Weightings which are different from those used in the **wet bogs** method are highlighted.)

Scientific name	Common name	Full	Intermediate	Simple
Acer pseudoplatanus	Sycamore	-1		
Achillea millefolium	Yarrow	-1		
Achillea ptarmica	Sneezewort	-1		
Agrostis canina	Velvet bent	0	0	
Agrostis capillaris	Common bent	-1	-1	
Agrostis stolonifera	Creeping bent	-1		
Agrostis vinealis	Brown bent	-1		
Ajuga reptans	Bugle	-1		
Andromeda polifolia	Bog rosemary	3	3	3
Aneura pinguis	a liverwort	-1		
Angelica sylvestris	Wild angelica	-1		
Anthoxanthum odoratum	Sweet vernal-grass	-1	-1	
Arrhenatherum elatius	False oat-grass	-1		
Atrichum undulatum	a moss	-1		
Aulacomnium palustre	a moss	1	1	
Barbilophozia floerkei	a liverwort	1		
Bellis perennis	Daisy	-1		
Betula pendula	Silver birch	0		
Betula pubescens	Downy birch	0	0	
Brachytheciastrum velutinum	a moss	-1		
Brachythecium rivulare	a moss	-1		
Brachythecium rutabulum	a moss	-1	-1	
Bryum capillare	a moss	-1		
Calliergonella cuspidata	a moss	-1	-1	
Calluna vulgaris	Heather	0	0	
Caltha palustris	Marsh marigold	-1		
Calypogeia azurea	a liverwort	2		
Calypogeia fissa	a liverwort	1		
Calypogeia fissa/muelleriana	a liverwort		1	
Calypogeia muelleriana	a liverwort	1		
Campanula rotundifolia	Harebell	-1		
Campylopus flexuosus	a moss	0	0	
Campylopus introflexus	a moss	-1	-1	
Campylopus pyriformis	a moss	0	0	
Cardamine pratensis	Cuckooflower	-1		
Carex binervis	Green-ribbed sedge	-1		
Carex canescens	White sedge	1	1	
Carex demissa	Common yellow-sedge	-1		
Carex dioica	Dioecious sedge	0		
Carex echinata	Star sedge	0	0	
Carex flacca	Glaucous sedge	0		
Carex hostiana	Tawny sedge	0		
Carex lepidocarpa	Long-stalked yellow-sedge	0		
Carex leporina	Oval sedge	-1		
Carex limosa	Bog-sedge	4	4	
Carex magellanica	Tall bog-sedge	4	4	
Carex nigra	Common sedge	-1	-1	
Carex pallescens	Pale sedge	-1		
Carex panicea	Carnation sedge	0		
Carex pauciflora	Few-flowered sedge	4	4	
Carex pilulifera	Pill sedge	-1		
Carex pulicaris	Flea sedge	0		
Carex rostrata	Bottle sedge	0	0	

Scientific name	Common name	Full	Intermediate	Simple
Cephalozia bicuspidata	a liverwort	0	0	
Cephalozia connivens	a liverwort	2	2	
Cephalozia macrostachya	a liverwort	4		
Cephaloziella divaricata	a liverwort	0		
Cerastium fontanum	Common mouse-ear	-1		
Ceratodon purpureus	a moss	-1		
Chamerion angustifolium	Rosebay willowherb	-1	-1	-1
Cirsium palustre	Marsh thistle	-1	-1	-1
Cladonia arbuscula	a lichen	1		
Cladonia cervicornis	a lichen	0		
Cladonia chlorophaea	a lichen	0		
Cladonia ciliata	a lichen	0		
Cladonia coniocraea	a lichen	0		
Cladonia diversa	a lichen	0		
Cladonia fimbriata	a lichen	0		
Cladonia furcata	a lichen	0		
Cladonia macilenta	a lichen	0		
Cladonia polydactyla	a lichen	0		
Cladonia portentosa	a lichen	1		
Cladonia pyxidata	a lichen	0		
Cladonia rangiformis	a lichen	0		
Cladonia sp. (bushy)	a lichen		1	1
Cladonia sp. (squamules)	a lichen	0		
Cladonia squamosa	a lichen	0		
Cladonia uncialis	a lichen	2		
Cladopodiella fluitans	a liverwort	3		
Climacium dendroides	a moss	-1		
Comarum palustre	Marsh cinquefoil	0		
Crustose lichens	a lichen	0		
Ctenidium molluscum	a moss	0		
Cynosurus cristatus	Crested dog's-tail	-1		
Dactylorhiza maculata	Heath spotted-orchid	1		
Dactylorhiza purpurella	Northern marsh-orchid	1		
Dactylorhiza sp.	an orchid	1		
Danthonia decumbens	Heath-grass	0		
Deschampsia cespitosa	Tufted hair-grass	-1	-1	
Deschampsia flexuosa	Wavy hair-grass	-1	-1	
Dicranella heteromalla	a moss	0	0	
Dicranoweisia cirrata	a moss	-1		
Dicranum leioneuron	a moss	4		
Dicranum scoparium	a moss	0	0	
Digitalis purpurea	Foxglove	-1	-1	-1
Diplophyllum albicans	a liverwort	0		
Drosera anglica	Great sundew	4	4	
Drosera rotundifolia	Round-leaved sundew	3	3	3
Dryopteris carthusiana	Narrow buckler-fern	0		
Dryopteris dilatata	Broad buckler-fern	-1		
Empetrum nigrum	Crowberry	1	1	1
Epilobium palustre	Marsh willowherb	-1		
Epilobium parviflorum	Hoary willowherb	-1		
Equisetum arvense	Field horsetail	-1		
Equisetum fluviatile	Water horsetail	0		
Equisetum palustre	Marsh horsetail	-1		
Erica cinerea	Bell heather	0		
Erica tetralix	Cross-leaved heath	1	1	1

Scientific name	Common name	Full	Intermediate	Simple
Eriophorum angustifolium	Common cottongrass	0	0	
Eriophorum vaginatum	Hare's-tail cottongrass	0	0	
Euphrasia agg.	an eyebright	0		
Festuca ovina	Sheep's-fescue	-1	-1	
Festuca rubra	Red fescue	-1	-1	
Ficaria verna	Lesser celandine	-1		
Fissidens adianthoides	a moss	0		
Galium palustre	Marsh bedstraw	-1	-1	
Galium saxatile	Heath bedstraw	-1	-1	
Galium uliginosum	Fen bedstraw	-1		
Gymnocolea inflata	a liverwort	2	2	
Hieracium agg.	a hawkweed	0		
Holcus lanatus	Yorkshire-fog	-1	-1	
Holcus mollis	Creeping soft-grass	-1	-1	
Hydrocotyle vulgaris	Marsh pennywort	-1		
Hylocomium splendens	a moss	1	1	
Hypnum cupressiforme	a moss	0		
Hypnum imponens	a moss	3		
Hypnum jutlandicum	a moss	0	0	
Hypochaeris radicata	Cat's-ear	-1		
Hypogymnia phsyodes	a lichen	0		
Juncus acutiflorus	Sharp-flowered rush	-1	-1	
Juncus articulatus	Jointed rush	-1		
Juncus bulbosus	Bulbous rush	0		
Juncus conglomeratus	Compact rush	-1		
Juncus effusus	Soft-rush	-1	-1	
Juncus sp. (big rushes)	a big rush			-1
Juncus squarrosus	Heath rush	0	0	
Kindbergia praelonga	a moss	0		
Kurzia pauciflora	a liverwort	2		
Larix sp.	a larch	-1		
Larix/*Picea*/*Pinus* sp.	a conifer		-1	-1
Lepidozia reptans	a liverwort	0		
Leucobryum glaucum	a moss	2	2	
Lophocolea bidentata	a liverwort	0	0	
Lophozia ventricosa	a liverwort	0	0	
Lotus corniculatus	Common bird's-foot-trefoil	-1		
Lotus pedunculatus	Greater bird's-foot-trefoil	-1		
Luzula campestris	Field woodrush	-1		
Luzula multiflora	Heath woodrush	-1	-1	
Luzula sylvatica	Great woodrush	-1		
Lysimachia nemorum	Yellow pimpernel	-1		
Marsupella emarginata	a liverwort	-1		
Micarea leprosula	a lichen	0		
Mnium hornum	a moss	0		
Molinia caerulea	Purple moor-grass	-1	-1	
Mylia anomala	a liverwort	3	3	
Myrica gale	Bog-myrtle	1		
Nardia scalaris	a liverwort	-1		
Nardus stricta	Mat-grass	-1	-1	
Narthecium ossifragum	Bog asphodel	0	0	
Neottia cordata	Lesser twayblade	3	3	3
Odontoschisma sphagni	a liverwort	3	3	
Orthodontium lineare	a moss	-1		
Oxalis acetosella	Wood-sorrel	-1		

Scientific name	Common name	Full	Intermediate	Simple
Oxyrrhynchium hians	a moss	-1		
Pedicularis palustris	Marsh lousewort	-1		
Pedicularis sylvatica	Lousewort	-1		
Pellia sp.	a liverwort	-1		
Peltigera sp.	a lichen	-1		
Philonotis calcarea	a moss	0		
Philonotis fontana	a moss	0		
Phleum pratense	Timothy	-1		
Picea abies	Norway spruce			
Picea sitchensis	Sitka spruce	-1		
Pilosella officinarum	Mouse-ear hawkweed	-1		
Pinus contorta	Lodgepole pine	-1		
Pinus sylvestris	Scots pine	-1		
Plagiomnium elatum	a moss	0		
Plagiomnium undulatum	a moss	-1		
Plagiothecium undulatum	a moss	0	0	
Plantago lanceolata	Ribwort plantain	-1		
Pleurozium schreberi	a moss	0	0	
Poa annua	Annual meadow-grass	-1		
Poa pratensis	Smooth meadow-grass	-1		
Poa trivialis	Rough meadow-grass	-1		
Pohlia melanodon	a moss	-1		
Pohlia nutans	a moss	-1		
Polytrichastrum formosum	a moss	0		
Polytrichastrum longisetum	a moss	-1	-1	
Polytrichum commune	a moss	-1	-1	
Polytrichum juniperinum	a moss	-1		
Polytrichum piliferum	a moss	-1		
Polytrichum strictum	a moss	2	2	
Potentilla erecta ssp. *erecta*	Tormentil	-1	-1	
Potentilla erecta ssp. *strictissima*	Tormentil	-1		
Prunella vulgaris	Selfheal	-1		
Pseudoscleropodium purum	a moss	-1	-1	
Pteridium aquilinum	Bracken	-1	-1	-1
Ptilidium ciliare	a liverwort	0		
Quercus petraea	Sessile oak	-1		
Quercus robur	Pedunculate oak	-1		
Racomitrium ericoides	a moss	-1		
Racomitrium lanuginosum	a moss	2	2	
Ranunculus acris	Meadow buttercup	-1		
Ranunculus flammula	Lesser spearwort	-1		
Ranunculus repens	Creeping buttercup	-1		
Rhynchospora alba	White beak-sedge	4	4	
Rhytidiadelphus loreus	a moss	1	1	
Rhytidiadelphus squarrosus	a moss	-1	-1	
Riccardia chamedryfolia	a liverwort	1		
Riccardia latifrons	a liverwort	4		
Riccardia sp.	a liverwort	1		
Rubus chamaemorus	Cloudberry	3	3	3
Rubus fruticosus agg.	Bramble	-1	-1	-1
Rumex acetosa	Common sorrel	-1	-1	
Rumex acetosella	Sheep's-sorrel	-1		
Scapania nemorea	a liverwort	0		
Scapania undulata	a liverwort	0		
Scorpidium cossonii	a moss	0		

Scientific name	Common name	Full	Intermediate	Simple
Scorzoneroides autumnalis	Autumn hawkbit	-1		
Selaginella selaginoides	Lesser clubmoss	0		
Silene flos-cuculi	Ragged-Robin	-1		
Sorbus aucuparia	Rowan	0	0	
Sphagnum angustifolium	a moss	0		
Sphagnum austinii	a moss	4	4	
Sphagnum balticum	a moss	4		
Sphagnum capillifolium	a moss		2	
Sphagnum capillifolium ssp. *capillifolium*	a moss	2		
Sphagnum capillifolium ssp. *rubellum*	a moss	2		
Sphagnum cuspidatum	a moss	1	1	
Sphagnum fallax	a moss	-1	-1	
Sphagnum fimbriatum	a moss	0	0	
Sphagnum fuscum	a moss	4	4	
Sphagnum girgensohnii	a moss	0	0	
Sphagnum inundatum	a moss	-1		
Sphagnum magellanicum	a moss	3	3	
Sphagnum palustre	a moss	-1	-1	
Sphagnum papillosum	a moss	2	2	
Sphagnum quinquefarium	a moss	0		
Sphagnum russowii	a moss	2	2	
Sphagnum sp. (red or chunky)	a red or chunky *Sphagnum*			2
Sphagnum squarrosum	a moss	-1		
Sphagnum subnitens	a moss	0	0	
Sphagnum tenellum	a moss	0	0	
Stellaria alsine	Bog stitchwort	-1		
Stellaria graminea	Lesser stitchwort	-1		
Stellaria media	Common chickweed	-1		
Succisa pratensis	Devil's-bit scabious	-1		
Taraxacum agg.	Dandelion	-1		
Tetraphis pellucida	a moss	0		
Thuidium tamariscinum	a moss	0	0	
Thymus polytrichus	Wild thyme	0		
Trichophorum cespitosum	Northern deergrass	4		
Trichophorum germanicum	Deergrass	0		
Trichophorum sp.	a deergrass		0	
Trichophorum x *foersteri*	Hybrid deergrass	0		
Trifolium pratense	Red clover	-1		
Trifolium repens	White clover	-1		
Triglochin palustris	Marsh arrowgrass	-1		
Vaccinium myrtillus	Bilberry	0	0	
Vaccinium oxycoccos	Cranberry	2	2	2
Vaccinium vitis-idaea	Cowberry	1	1	1
Valeriana dioica	Marsh valerian	-1		
Viola palustris	Marsh violet	-1		
Viola riviniana	Common dog-violet	-1		

Appendix E: Instructions for stratifying sites prior to baseline surveys

NB this process should be done once and once only for each site, providing that it is done properly. If while surveying a site, the baseline mapping turns out not to be accurate enough, it is best to start the whole process again from scratch, but it should usually be possible to avoid doing this by only ever using experienced surveyors for the baseline mapping.

Before the fieldwork:

- Consult any available vegetation maps (e.g. from FC, NE or NWT files or the Roger Smith NVC maps) defining the extent of the mire, based on peat depth, etc.
- Print out an aerial photograph(s) of the site. I find printing the photo so that a 1km x 1km square fits on an A4 sheet of paper to be useful – this scale is not too small and not too big.
- Use a GIS to add 100m grid lines from the OS grid to the photo before printing it out.
- Label these lines with their OS numbers before going in field.
- If colours on the aerial suggest distinct mire types, draw provisional boundaries before the fieldwork onto the photo. Try to do this as much as possible, but be open to change your mind if you find something different in the field.

Mapping in the field:

- Draw boundaries between the zones directly onto the paper copy (with grid lines) of the aerial.
- Walk the whole site to check if the boundary between the vegetation types suggested by the aerial photo corresponds to what you find in the field.
- When in doubt, check your precise position on the bog by taking a 10-figure GPS grid reference and work out where you are on the aerial photo by referring to the grid lines on your printed aerial.
- If you are lucky, you may find there is an exact correspondence between clear changes in colour on the photo and changes in vegetation on the ground.
- Important aspects of bog vegetation that may help in drawing boundaries include:
    - the types and overall cover of *Sphagnum*;
    - the density of dwarf shrub growth and;
    - the cover and 'tussockiness' of hare's-tail cottongrass.
- If two types of vegetation appear to be clearly distinct with a clear boundary between them, then map them separately. If you decide later that these two types are just variations of one broad zone, you can always lump them together at that stage.
- If two types are clearly present, but gradually change from one to the other, map them separately if possible and describe the transition.
- If there is a mosaic or a transition that is too complicated or too gradual to map accurately, it is probably best to map it all as one variable zone.
- Any atypical areas within the mapped monitoring zones such as rushy flushes or large bog pools, should be mapped, so that they can be excluded from the monitoring zones. If atypical areas like this are visible on the aerial, then map them. If they are too small, or too narrow to be visible on the aerial, then don't map them.

Field notes:

- Write one or two sentences describing the pattern of vegetation types in each separate monitoring zone. Always best to do this when you are on the site as, if you are like me, you will have forgotten all about it by the time you get home, even though you think you will remember!

- Was the vegetation more or less homogeneous, or more variable?
    - Was there a gradual change from the centre outwards – if so describe it simply, e.g. less *Sphagnum*, more heather, etc.
    - Was there some other type of pattern? e.g. complex mosaic, regular pattern along drains, etc.
- This information will be helpful in deciding how best to locate the quadrats in the monitoring survey, so that it is done in the most useful way.

After the fieldwork: GIS work.

- Decide on how many strata are most useful/important for this site.
- Remember that the more strata you have, the more work will be required each time, so only include extra strata if there is a good reason to do so.
- Using the boundaries drawn on the printed aerial, digitise the boundaries between the strata you have decided to use on a GIS.
- Include a field in the GIS table for labelling which stratum each polygon belongs in. There may be more than one polygon in a single stratum on some sites, but for many of the border mires sites, the maps should be relatively simple.
- Make sure that you digitise any atypical areas that occur within a larger polygon of bog vegetation and delete these small areas from that stratum on the GIS.
- This final GIS map should be saved and then this should be used as the baseline for the stratification of the site for <u>all</u> future surveys of the site. Under no circumstances should there ever be any exceptions to this! If the position or shape of the original survey polygon is altered after the monitoring has started, it could undermine the validity of the whole scheme.
- Overlay a regular grid with 10m intervals on your baseline polygons and save the areas of the grid that overlap with the baseline polygons.
- Each of the 10m x 10m squares can then be numbered, so that you can use random numbers to select random sampling points from your baseline survey polygon, but you are not quite ready to do this numbering yet.
- In order to avoid sampling from transitional areas between vegetation types, it may be best to delete all of the squares on the outside of each polygon. At the very least you should delete all partial squares on the outside that have say, less than 80% of the square within the polygon.
- Great care is needed with this, as there may be several very tiny partial squares on the outside that are difficult to spot. If these were left in they could be very troublesome. When you are almost finished deleting the partial squares, you could increase the thickness of the borders so that it is easier to spot any tiny partial squares that remain.
- Once you have deleted all of the partial squares on the outside of the polygons, generate eastings and northings for the centre point of each remaining square and add these to the GIS table. At this point the GIS data table should have at least 3 columns: stratum, easting and northing.
- Export this table to Excel, sort the table by stratum and add in a unique reference number for each square in each stratum.
- The eastings and northings can be converted to 10-figure grid references at this stage if necessary
- These lists of grid references for each stratum should be saved and then used for generating random sampling points for all future surveys of the site. Once again, under no circumstances should there ever be any exceptions to this!

Appendix F: Instructions for full vegetation field survey methodology

Before the fieldwork:

- When you are ready to do a survey or a resurvey, choose the appropriate number of 10-fig grid references for each stratum from the baseline lists of 10m squares using random numbers.
- Do not attempt to resurvey at the same grid references on more than one survey – instead choose a new random sample each time the site is surveyed.
- Display all of the random locations to be surveyed with their reference numbers on a GIS aerial photo of the site. Print this out for use in the field.
- Download these random grid refs with their reference numbers into a GPS
- Many of the sites involved are remote, so if surveyors are to work alone, make sure there is an adequate lone working procedure in place.
- In particular, surveyors should expect to have no mobile phone coverage and plan accordingly.
- Make sure all surveyors can navigate using a map and compass.
- Inform the Forestry Commission, the RAF and other landowners of when and where you plan to survey if it involves their land.

You will need the following in the field:

- 10 bamboo canes, each 1m long, with 4 canes clearly marked at 25cm intervals and one cane clearly marked (e.g. with alternating different coloured paint) at 10cm intervals;
- GPS, with random survey locations downloaded into the memory;
- Hand lens;
- Identification guides/books;
- Plastic bags and paper packets for collecting plant specimens for identifying difficult species;
- Adequate clothing and footwear for surveying in the uplands in poor weather;
- Lunch and drinks;
- Survival bag, personal first aid kit and whistle;
- OS map, compass and torch;
- Spare batteries;
- Clipboard and pens/pencils;
- Recording sheets (see appendix J);
- If you are also doing the habitat structure survey, you will need a measuring tape that extends at least 10m.

In the field

- **NB** If this is the first time the site has been surveyed and after completing a number of quadrats you find that more than two have landed at atypical vegetation for that stratum, then it is likely that the mapping used for the stratification was inadequate. If this happens it is best to stop surveying and do a proper baseline map of the site instead – otherwise you will just be wasting even more resources.
- Refer to your printed aerial of the site with the random sampling locations marked and work out a sensible route for covering the sampling points efficiently.
- Use the **Goto** function of your GPS to find the first random point to be surveyed. When you get within 20m of the location slow down and stop when you get to within 1m.

- **NB** your exact stopping position should be determined only by referring to the GPS and not by looking at what the vegetation is like (but don't forget to look where you are going if there are bog pools or blocked drains about!).
    - If before you arrive at your stopping position you can see that the quadrat will be wholly or partly within a bog pool, blocked drain full of water or, on a track, you need to choose an alternative sampling point. **NB** these are the only exceptions – all other habitats should be sampled regardless of the vegetation present.
    - To choose an alternative sampling point, pick the first available random number between 1 and 4 on your recording sheet (1 = north, 2 = east, 3 = south, 4 = west).
    - Go to the edge of the pool/drain/track on the side in the direction you have chosen from the original stopping point. Walk in that direction for five normal sized paces and then stop. This is the new sampling point.
- Where the toe of your left boot has landed is the bottom-left corner of your quadrat, so place the first cane (with 25cm intervals) from your left toe away from you in the direction you are facing.
- Place the second cane from your left toe at right angles to the first cane towards the right.
- Complete the 1m square with the other two canes marked at 25cm intervals.
- Place the remaining 6 canes in the appropriate places (3 going up, 3 going across) within the quadrat, so that the quadrat is divided in 16 equal-sized cells.
- If you are in heathery vegetation, you may need to thread the canes through the heather, rather than laying them on top.
- Fill in the boxes at the top of the recording sheet: 'Site', 'Stratum', 'Surveyor', 'Date', 'Q.ref.' (quadrat reference number) and 'Type' (circle which type of bog you are on).
- Begin with the cell on the bottom-right of the quadrat and tick off all of the species that occur in the cell. The species does not necessarily have to be rooted in the cell. As long as some parts of the plant are visible in the cell, it counts.
- Survey each cell in turn in the same way systematically until all 16 have been surveyed.
- When species are found that are not on the list on the recording sheet, add these species names to the end of the list and tick off the appropriate box for that species in that cell.
- If species are found which cannot be identified with certainty in the field;
    - Collect a specimen and put it in a plastic bag (vascular plants), or paper packet (bryophytes and lichens);
    - Label the packet with the quadrat reference number and cell number and label it with a unique species reference, such as 'species A', 'species B', etc.;
    - Add this unique species reference to the species list on the recording form and tick the appropriate box for that species in that cell;
    - If the same unknown species is found in another cell in the same quadrat and you are sure it is the same thing, there is no need to collect an extra specimen – just tick the appropriate box for that species in that cell.
- When you have finished surveying the quadrat, count how many ticks (out of 16) each species got and put these figures in the 'TOT' column.
- Finally, cross through or circle the quadrat reference number on your aerial so that you can keep track of which quadrats have been surveyed.

Soon after the fieldwork:

- A filing system should be set up to store the paper recording forms for easy retrieval.
- Ideally, each completed paper form should be photocopied immediately after each survey, so that there are at least two sets of the original forms, each kept in separate locations.
- Under no circumstances should the original paper field forms ever be discarded. Errors inevitably creep into all databases and the paper forms will be the only way of checking many of these errors in future.
- As soon as possible after the field survey any unidentified specimens should be identified.
- As each specimen is identified, its unique species reference should be replaced by the species name on all of the original field forms where it appears.
- **NB** In order to minimise errors, it is vital that this identification stage is completed before the data entry stage.

Data entry

- Before entering any data, decide on a data entry system. E.g. will the data be stored on spreadsheets, or will a relational database be used? Databases are more flexible and more efficient, but not everyone has the relevant experience to manage databases.
- Set up a clear protocol for managing the data, covering issues including: data structure; unique record identifiers; checks prior to data entry; checks during data entry; protocol for recording missing values; checks after data entry; training of users of the database; back-up procedures, etc.
- For advice on good practises for data management see publications on 'Help on data management' and 'Guides on using Excel for statistics' by Reading University's Statistical Services Centre at http://www.reading.ac.uk/ssc/n/publicat.htm#c.
- Make sure that every user of the database is fully informed of the protocols and is competent to use the system.
- One suggested format for data entry for each species in each quadrat is as follows:

Site name	Site No.	Type	Stratum	Strat No.	Q.ref	Recorder	Date	Species	Count
Bog flow	001	1	Main	1	01	Jane Bloggs	01/07/2015	Erica tetralix	10
Bog flow	001	1	Main	1	01	Jane Bloggs	01/07/2015	Calluna vulgaris	16

- The 'Type' column is for recording whether the site is a **wet bog** or a **blanket bog**, as different weighting are given to the indicators species for either type.
- The entries in the first nine columns will be exactly the same for each species found in that quadrat, so all of these entries can be entered in one go.
- Here, each of the categorical variables (site name, stratum and recorder) is given a unique number.
- Unique numbers can also be used for species entries and there are several existing standard numbering systems available for species.
- The unique record reference in this case is a combination of 'Site No.' + 'Strat No.' + 'Q.ref' + the unique species number.
- It is usually useful to have separate columns for 'day', 'month' and 'year' as well as, or instead of 'date'.

Calculating derived values for quadrats

- Once all of the species data have been entered for a quadrat, the derived values can be calculated. Most of the statistical analyses will be based on these derived values, rather than on the individual species data.
- Normally it is much more efficient to calculate the derived values for many different quadrats at the same time. There are several different ways of doing this and the best way will depend upon whether spreadsheets or a database is being used and on how familiar the user is with the different functions available in their spreadsheet or database software.
- Another option may be to use other software packages that calculate these derived values automatically. However this may not be an efficient way of doing it as more than one software package will be needed to calculate all of the derived values and different data entry formats may be required for each package.
- It is straightforward to calculate all of the derived values using basic formulae in Excel.
- The **full bog quality index** is calculated by multiplying each species frequency score for the quadrat by its quality weighting (either using the **wet bog** or **blanket bog** quality weightings as appropriate) and adding the resulting values for all the species in the quadrat together.
- The four **Ellenberg indices** and the **Suited species-grazing** index are all calculated in the same way. Multiply the species frequency scores by the species weighting for the index you are calculating. Add these together and divide by the sum of all of the species frequency scores for the quadrat. This method gives a **weighted average** for the index for each quadrat.
- The calculations for **Simpson's reciprocal index** are a little more complicated. Let *n* be the number of cells that an individual species was found in. Let *N* be the total of all the *n* values of all species in the quadrat. For each species calculate

$$\frac{n(n-1)}{N(N-1)}.$$

- Then add these scores from all species in the quadrat. This number should be between 0 and 1.
- Finally divide 1 by the number you got at the last step. This final number should be between 1 and the total number of species in the quadrat.

Calculating a minimal bog quality index from a full survey:

- If an Access database is used, all of the following calculations can be done automatically.
- Identify the indicator species present in the quadrat from the appropriate (**wet bog** or **blanket bog**) **minimal** species list.
- There are four species groups to consider:
  - ***Cladonia*** **sp. (bushy)** - include any of the following: *Cladonia arbuscula*, *C. ciliata*, *C. portentosa*, *C. uncialis*;
  - **Conifer (any species)** – include any conifer species, e.g. *Larix*, *Picea*, *Pinus*, *Pseudotsuga*, or any other;
  - **Rush sp. (large rush)** – include any of the following: *Juncus effusus*, *J. conglomeratus*, *J. acutiflorus* or *J. articulatus*;
  - ***Sphagnum*** **sp. (red/chunky)** – include any of the following (but no others): *Sphagnum austinii*, *S. capillifolium*, *S. magellanicum*, *S. molle*, *S. palustre*, *S. papillosum*, *S. quinquefarium*, *S. russowii*, *S. subnitens*.

• Add the quality weightings of all the species present in the quadrat. This is the **minimal bog quality** index score for the quadrat

Appendix G: Instructions for minimal vegetation field survey methodology

Before the fieldwork:

- Remember that if this is the first time that the site has been surveyed it is much more useful to do the **full** survey, rather than the **minimal** survey.
- When you are ready to do a survey or a resurvey, choose the appropriate number of 10-fig grid references for each stratum from the baseline lists using random numbers. Do not attempt to resurvey at the same grid references on more than one survey – instead choose a new random sample each time the site is surveyed.
- Display all of the random locations to be surveyed with their reference numbers on a GIS aerial photo of the site. Print this out for use in the field.
- Download these random grid refs with their reference numbers into a GPS.
- Many of the sites involved are remote, so if surveyors are to work alone make sure there is an adequate lone working procedure in place.
- In particular, surveyors should expect to have no mobile phone coverage and plan accordingly.
- Make sure all surveyors can navigate using a map and compass.
- Inform the Forestry Commission, the RAF and other landowners of when and where you plan to survey if it involves their land.
- It is likely that most of the surveyors will need some ID training before they do a survey. In particular, they may be unable to recognise bushy *Cladonia* lichens, common cottongrass, rushes or ‘red or chunky’ *Sphagnum*. They may also be unable to recognise plants like marsh thistle, bog asphodel, foxglove or rosebay willowherb vegetatively. Some generalist surveyors will struggle to recognise the different dwarf shrub species.

You will need the following in the field:

- 6 bamboo canes, each 1m long, with one cane clearly marked (e.g. with alternating different coloured paint) at 10cm intervals;
- GPS, with random survey locations downloaded into the memory;
- Hand lens;
- Identification guides/books;
- Plastic bags and paper packets for collecting plant specimens for identifying difficult species;
- Adequate clothing and footwear for surveying in the uplands in poor weather;
- Lunch and drinks;
- Survival bag, personal first aid kit and whistle;
- OS map, compass and torch;
- Spare batteries;
- Clipboard and pens/pencils;
- Recording sheets (see appendix J). **NB** make sure you have the correct recording sheet as there are different versions for **wet bogs** and **blanket bogs**.
- If you are also doing the habitat structure survey, you will need a measuring tape that extends at least 10m.

In the field:

- **NB** If this is the first time the site has been surveyed and after completing a number of quadrats you find that more than two have landed at atypical vegetation for that stratum, then it is likely that the mapping used for the stratification was inadequate. If this happens it is best to stop surveying and do a proper baseline map of the site instead – otherwise you will just be wasting even more resources.

- Refer to your printed aerial of the site with the random sampling locations marked and work out a sensible route for covering the sampling points efficiently.
- Use the **Goto** function of your GPS to find the first random point to be surveyed. When you get within 20m of the location slow down and stop when you get to within 1m.
- **NB** your exact stopping position should be determined only by referring to the GPS and not by looking at what the vegetation is like (but don't forget to look where you are going if there are bog pools or blocked drains about!).
    - If before you arrive at your stopping position you can see that the quadrat will be wholly or partly within a bog pool, blocked drain full of water or on a track, you need to choose an alternative sampling point. **NB** these are the only exceptions – all other habitats should be sampled regardless of the vegetation present.
    - To choose an alternative sampling point, pick the first available random number between 1 and 4 on your recording sheet (1 = north, 2 = east, 3 = south, 4 = west).
    - Go to the edge of the pool/drain/track on the side in the direction you have chosen from the original stopping point. Walk in that direction for five normal sized paces and then stop. This is the new sampling point.
- Where the toe of your left boot has landed is the bottom-left corner of your quadrat, so place the first cane from your left toe away from you in the direction you are facing.
- Place the second cane from your left toe at right angles to the first cane towards the right.
- Complete the 1m square with the other two canes.
- If you are in heathery vegetation, you may need to thread the canes through the heather rather than laying them on top.
- Fill in the boxes at the top of the recording sheet: 'Site', 'Stratum', 'Surveyor' and 'Date'.
- Write in the quadrat reference number at the top of the first available column on the sheet (the quadrats will probably not be surveyed in numerical order).
- In this column tick each of the species from the list that is at least partly inside the quadrat. It does not have to rooted inside the quadrat.
- Do not include any species that are not listed on the recording sheet.
- If a species is found which cannot be identified with certainty in the field and you think it may be one of the species on the list;
    - Collect a specimen and put it in a plastic bag (vascular plants), or paper packet (bryophytes and lichens).
    - Label the packet with the quadrat reference number and label it with the appropriate species reference, such as 'common cottongrass?', '*Sphagnum* sp. (red/chunky)?', etc.
    - Put a question mark, instead of a tick in the appropriate box for that species in that quadrat.
- When you have finished surveying the quadrat, cross through or circle the quadrat reference number on your aerial, so that you can keep track of which quadrats have been surveyed.

Soon after the fieldwork:

- A filing system should be set up to store the paper recording forms for easy retrieval.
- Ideally, each completed paper form should be photocopied immediately after each survey, so that there are at least two sets of the original forms, each kept at separate locations.
- Under no circumstance should the original paper field forms ever be discarded. Errors inevitably creep into all databases and the paper forms will be the only way of checking many of these errors in future.
- As soon as possible after the field survey any unidentified specimens should be identified.
- As each specimen is identified, the question marks on the field recording form should be changed to ticks if it was the right species or, deleted if it turned out to be something different.
- **NB** In order to minimise errors, it is vital that this identification stage is completed before the data entry stage.

Data entry

- **NB** It is vital that the data storage system for the **minimal** survey data is fully compatible with the data from the **full** survey. Ideally the **minimal** survey data should be a subset of the **full** database.
- Before entering any data, decide on a data entry system. E.g. will the data be stored on spreadsheets, or will a relational database be used? Databases are more flexible and more efficient, but not everyone has the relevant experience to manage databases.
- Set up a clear protocol for managing the data, covering issues including: data structure; unique record identifiers; checks prior to data entry; checks during data entry; protocol for recording missing values; checks after data entry; training of users of the database; back-up procedures.
- For advice on good practises for data management see publications on 'Help on data management' and 'Guides on using Excel for statistics' by Reading University's Statistical Services Centre at http://www.reading.ac.uk/ssc/n/publicat.htm#c.
- Make sure that every user of the database is fully informed of the protocols and is competent to use the system.
- As the species data for the minimal survey are from a short, standard list of species, by far the best and quickest method for data entry will be by using a database form set up with tickboxes for each of the species.

Calculating derived values

- Only one derived value can be calculated using the minimal method – the **minimal bog quality index**.
- This index is calculated by adding the quality weightings of all the species present in the quadrat.
- These calculations can be done automatically very easily in Excel or Access.

Appendix H: Instructions for habitat structure field survey methodology

Before the fieldwork:

- The habitat structure survey can be carried out at the same time as the vegetation survey, either with the **full** survey or with the **minimal** survey.
- Follow the instructions for what to do before the vegetation survey and what equipment to bring for either the **full** or **minimal** vegetation survey as appropriate.
- **NB** make sure you have at least one cane with markings for every 10cm.
- **NB** you will also need a measuring tape that extends to at least 10m.

In the field:

- Follow the instructions for finding random quadrat locations in the instructions for field survey.
- Complete either the **full** or **minimal** vegetation survey in the 1m x 1m quadrat as appropriate.
- After you have completed the vegetation quadrat, stick a cane in the middle of the quadrat. The canes marking the 1m x1m quadrat are now no longer needed.
- Measure out 10m north from this cane using a compass and measuring tape. Stick a cane in at the 10m mark.
- Measure out and stick canes in at 10m south, east and west from the central cane.
- You now have a large circle of 10m radius with four quarters. Decide which of the quarters gets each of the numbers from 1 to 4.
- The first time you use a particular sheet, fill in the five boxes at the top: ‘Site’, ‘Stratum’, ‘Surveyor’, ‘Date’ and ‘Type’ (circle **wet** or **blanket** as appropriate).
- On each sheet there is space for completing the survey at four different quadrats.
- In the first available quadrat space on the sheet, fill in the **quadrat reference number**.
- In each of the four quarters in turn, tick all of the positive and negative features that are present. Refer to the **feature definitions** on the back of the recording sheet if you are unsure.
- When you have completed the survey for each of the four quarters, count how many quarters you found each feature in and put these figures in the **TOT** column.
- Add all of the figures from the **TOT** column for the positive features and put this total in the **Total positive** box.
- Add all of the figures from the **TOT** column for the negative features and put this total in the **Total negative** box.
- Subtract the **Total negative** value from the **Total positive** value and put the result in the **Habitat structure index** box.
- If you have not already done so, cross through or circle the quadrat reference number on your aerial, so that you can keep track of which quadrats have been surveyed.

Data entry

- Once again, a database will be the best way of managing these data. It would also possible to use spreadsheets, but the data entry process would be more complicated and more prone to error.
- The codes used for site name, stratum, site type, quadrats reference number and recorder should be fully compatible between the **full** and **minimal** vegetation data and the **habitat structure** data.

- For each quadrat, the key pieces of data that need to be entered include the data from the five boxes on the top of the page, the quadrat reference number and the number of quarters that each feature was found in (from 0 to 4).
- The database can be set up to calculate the **Total positive**, **Total negative** and **Habitat structure index** automatically.
- The database can also automatically calculate average scores for each individual positive and negative habitat feature from all of the quadrats for the whole stratum.

Appendix I: JNCCs CSM Guidance for bogs (taken from JNCC (2004) and JNCC (2009))

Interest feature: Lowland raised bog and lowland blanket bog
Where a lagg fen exists it should be considered a component part of the habitat, unless it is a notified feature in its own right
Note: Attributes and targets concerning lagg fen relate mainly to lowland raised bog only.
Frequency classes for species should be as follows: 1-20% rare, 21-40% occasional, 41-60% frequent, >60% constant. Frequency is defined as the chance of finding a species at a point positioned at random in a stand. Cover is dealt with separately.
All attributes are mandatory except where indicated *

Attribute	**Targets**	**Method of assessment**	**Comments**
Habitat extent	There should be no reduction in the total extent (area) of bog, including any associated pools and lagg fen, in relation to the established baseline.	A baseline map, showing the boundary of the bog and any associated lagg fen, should be used to assess any changes in extent. Aerial photographs can offer a convenient means of rapidly assessing extent.	'Bog' is taken here to be the peat deposit together with typical bog vegetation, irrespective of the precise nature and condition of that vegetation. 'Lagg fen' comprises both peat deposit and vegetation, irrespective of nature and condition.
Habitat composition	Targets should be set for specific components of the wetland (mire expanse, lagg fen, bog pools) where relevant and appropriate (see sect. 7.1).	A baseline map, showing the boundary of the bog and any associated lagg fen, should be used to assess any changes in extent. Aerial photographs can offer a convenient means of rapidly assessing extent.	'Bog' is taken here to be the peat deposit together with typical bog vegetation, irrespective of the precise nature and condition of that vegetation. 'Lagg fen' comprises both peat deposit and vegetation, irrespective of nature and condition.
Habitat structure	There should be no obvious modification to structural features (e.g. vegetation cover, surface patterning and natural drainage), in relation to the established baseline. See Sect. 7.1.1.6. Targets should be set to register too much or too little exposed substrate (see comments). As a generic standard, total extent across the	Aerial photographs can offer a convenient means of rapidly assessing these. It may also be necessary to make a visual assessment using a structured walk or transects.	Active raised bogs in particular show varying degrees of structural variation and surface patterning reflecting hydrological gradations. These can be disrupted by activities such as drainage, burning, grazing, vehicular access and peat digging. A high frequency and cover of exposed substrate will usually be undesirable and may

	area assessed should be no more than 10%.		indicate, *inter alia*, over-grazing, and water scour.
Vegetation composition: positive indicators - vascular plants	Targets for the **mire expanse only**: (1) At least 3 of *Calluna vulgaris*, *Erica tetralix*, *Eriophorum angustifolium*, *E. vaginatum* & T*richophorum cespitosum* constant, with a combined cover not exceeding 80%; (2) no single species > 50% cover; (3) At least one of *Andromeda polifolia, Drosera rotundifolia, Empetrum nigrum, Narthecium ossifragum* and *Vaccinium oxycoccos* at least frequent	Visual assessment of cover and frequency, using structured walk or transects and recording quadrats	The vegetation of the mire expanse should comprise an inter-mix of bryophytes (predominantly *Sphagnum* spp), graminoids and dwarf shrubs, with no one group dominating at the expense of others on 'active' sites, although *Sphagnum* may predominate on hyper-oceanic sites. *Molinia* may be abundant on the bog margin (rand) of active sites and more widely on degraded sites. Where lagg fen is an important element, refer to guidance for Lowland fen for appropriate positive indicator species targets.
Vegetation composition: positive indicators - bryophytes	Targets for the **mire expanse only**: (1) At least 2 of the following spp. constant, with a combined cover > 20%: *Sphagnum capillifolium, S. magellanicum, S. papillosum, S. tenellum* (2) *Sphagnum cuspidatum* and/or *S. pulchrum* at least occasional	Visual assessment of cover, using structured walk or transects and recording quadrats	Expectations for Sphagnum **cover** vary widely across the country, but **some** *Sphagnum* should be scattered across all sites. *S.cuspidatum* cover is a surrogate indicator for year-round high water table position. *Sphagnum cuspidatum* present in at least 10% of quadrats, or at least occasional indicates 'unfavourable recovering' condition, where the other targets are not achieved (particularly important for degraded bogs).
Vegetation composition: indicators of negative	(1) No more than 1% cover of the following on the bog surface (subject to exceptions	Visual assessment of cover, using structured walk or transects and	This target applies to the whole bog, not just the mire expanse. The plants listed are

change - non-woody vascular plant species	in comments column): *Phragmites australis, Phalaris arundinacea, Glyceria maxima, Epilobium hirsutum, Urtica dioica, Pteridium aquilinum, Rubus fruticosus, Juncus effusus, Deschampsia cespitosa, Cirsium* spp. (2) Invasive non-native plant species should be absent or no more than rare (if present at baseline)	recording quadrats	indicators of enrichment, or of drying out of the bog. *Phragmite*s is acceptable around upwellings or their equivalent on ditched bogs.
Vegetation composition: indicators of negative change - bryophytes	*Polytrichum* spp. Other than *P. alpestre* no more than occasional	Visual assessment of cover, using structured walk or transects and recording quadrats	
Vegetation composition: indicators of negative change – undesirable woody species	On the mire expanse, trees and shrubs (*Betula, Salix, Rhododendron, Pinus s*pecies, other gymnosperms no more than rare and < 5% cover. On the bog margin (rand) woody species < 10% cover	Visual assessment of cover of the whole feature, using structured walk or transects. Aerial photography may be a useful aid though not for seedlings.	Invasion by woody species and their development to healthy maturity may indicate drying out and/or enrichment. Trees and shrubs will exacerbate drying out. *Salix* spp. and *Myrica gale* can occur on raised bogs, but scrub generally constrains itself to areas where it receives a source of nutrients (e.g. near water that has passed through or over a mineral soil). As a result, it often is found close to or on the 'rand' of the raised bog, where it is more acceptable.
Indicators of local distinctiveness – micro-topography*	No reduction in extent of microtopographic features (e.g. bog pools).	% length of transects intersecting bog pools or other microtopographic features.	The quality of microtopographic features may also be assessed by providing a definition of target composition – for example, for a bog pool to count as such it could be defined as having little cover of living dwarf

			shrubs or *Eriophorum vaginatum*; a complete or extensive cover of sphagna with *S. pulchrum* and/or *S. cuspidatum* predominant. Some open water or bare peat may be present.
Indicators of local distinctiveness* *e.g.rare/scarce spp*	There are no generic targets for this attribute. Local targets should be set to ensure: - existing populations of rare/scarce species are maintained - community and habitat transitions are maintained at current levels and in current locations Additional targets may be set for other attributes as appropriate.	Visual assessment of frequency/cover of rare/scarce/local species in sample points chosen to represent their known distribution. Aerial photographs may offer a convenient means of rapidly assessing these.	This attribute is intended to cover any site specific aspects of this habitat feature (forming part of the reason for notification) which are not covered adequately by the previous attributes, or by separate guidance (e.g. for notified species features). Targets to be determined locally.

Blanket bog and valley bog (upland)

Where blanket bog communities are being replaced by either degraded mire communities (M15, M16, M25), drier heath communities (H8, H12) or grassland type U6, and where restoration back to blanket bog is considered to be feasible, then the degraded communities should be assessed using the attributes and targets ascribed to blanket bog.

• Rhynchosporion: given the intimate relationship between blanket bog and the Rhynchosporion, with the latter typically occurring as a minor component of the former, no specific guidance has been developed for Rhynchosporion in a blanket bog setting. It should be assumed to reflect the condition of the surrounding blanket bog. Guidance for the assessment of Rhynchosporion in a lowland setting is given in the Lowland Wetland Guidance.

• When assessing frequency or cover within the vegetation, exclude all bare rock and recently burned ground from the assessment. Recently burned areas can be recognised by the presence of loose charcoal on partially burnt stems that easily produces black marks on fingers and clothes (it takes two to three years for charcoal to be weathered from stems).

Mandatory attributes	**Targets**	**Method of assessment / Comments**
Feature extent (see Section 7 for further guidance).	(1) There should be no measurable decline in the area of the feature.	Field comparison with baseline map of feature, or occurrence of feature at points on a systematic sample grid, or recording of location and number of individual patches if the feature is fragmented into very small patches (the last may be all that is practical for Rhynchosporion hollows).
Vegetation composition — frequency of indicator species.	(1) At least 6 indicator species should be present (Table 1). **Qualifiers:** In blanket bog, *Sphagnum fallax (S. recurvum* p.p.) scores one if other species of *Sphagnum* are present, but scores zero if it is the only species of *Sphagnum* present. In valley bog it scores as one.	Target (1) assessed against visual estimate at 4 m2 scale. Score each *Sphagnum* sp separately.
Vegetation composition — cover of indicator species.	(1) At least 50% of vegetation cover should consist of at least 3 indicator species (Table 1). (2) *Sphagnum* cover should not consist only of *Sphagnum fallax (S. recurvum* p.p.). (3) Any one of *Eriophorum vaginatum*, Ericaceous species collectively, or *Trichophorum* should not individually exceed 75% of the vegetation cover.	Targets (1-3) assessed against visual estimate at 4 m2 scale.
Vegetation composition — cover of other species	(1) Less than 1% of vegetation cover should be made up of non-native species. (2) Less than 10% of	Targets (1 and 2) assessed against visual estimate for as much of the feature as is visible while standing at a sample location. Target (3)

	vegetation cover should be made up of scattered native trees and scrub. **Qualifiers**: For target (2) exclude *Betula nana* and *Myrica gale*. Refer to Woodland guidance for Bog Woodland. (3) Less than 1% of vegetation cover should consist of, collectively, *Agrostis capillaris, Holcus lanatus, Phragmites australis, Pteridium aquilinum, Ranunculus repens*.	assessed at two scales and should be met at both scales: (a) against visual estimate at 4 m2 scale; and (b) against visual estimate for as much of the feature as is visible while standing at a sample location.
Vegetation structure —indicators of browsing.	(1) Less than 33% of the last complete growing season's shoots of dwarf-shrub species (collectively but excluding *Betula nana* and *Myrica gale*) should shows signs of browsing. (2) In pioneer stage regrowth, or where there is *Betula nana* or *Myrica gale* (at any stage of regrowth), less than 66% of the last complete growing season's shoots of the dwarf-shrubs, (collectively) should show signs of browsing.	Targets (1 and 2) assessed against visual estimate at 4 m2 scale. Assessment is best done in late winter through spring.
Vegetation structure —disturbance	(1) There should be no observable signs of burning into the moss, liverwort or lichen layer or exposure of peat surface due to burning. (2) There should be no signs of burning or other disturbance (e.g. mowing) in the **sensitive areas** defined in Table 2.	Targets (1 and 2) assessed against visual estimate for as much of the feature as is visible while standing at a sample location. For target (2) if a feature is viewed at a distance, and there is uncertainty about whether or not a burn has actually entered the feature, then use a rough guide of 25 m (ie. if the burn is further than 25 m inside the feature, it is considered damaging). There is a general policy in Wales and Northern Ireland of no burning on blanket bog. Burning of the dwarf shrub layer may result in bleaching of the bryophyte layer. This should not be confused with burning **into** the bryophyte layer and does not constitute failure to achieve Target (1).

Physical structure — peat erosion.	(1) The extent of eroding peat should be less than the extent of stable re-deposited peat and new growth of bog vegetation within the feature.	Target (1) assessed against an aggregate of visual estimates of as much of the feature as is visible while standing at sample locations. The assessment should include any eroded peat within gullies between haggs if peat is being redeposited there. Do not include peat that cannot be directly observed, such as peat that might be inferred to have once filled the gullies but which is now gone. Stable areas can be recognised because the peat surface is solid; if it is soft, then it should be very wet. Actively eroding peat will have a loose, often puffy, surface that is usually relatively dry other than during, and immediately after, rainfall. Stable areas usually only become established on very shallow gradients, and often consist of peat sediment that is backed-up behind a boulder dam, a displaced solid peat block, a developing Sphagnum dam, or a patch of recolonising vascular plants (e.g. Eriophorum angustifolium) that slows down water flow and traps any transported peat sediment. If an area of re-deposited material is densely revegetated, so that bare peat between the individual plants amounts to less than 50% ground cover, then it should be assumed to be stable.

Physical structure — indicators of active drainage and/or ground disturbance due to herbivore and human activity.	(1) Less than 10% of the total feature area, should be disturbed bare ground* and/or show signs of active† drainage, resulting from ditches or heavy trampling or tracking. **Qualifiers**: Failure of this target should also be recorded if any evidence of this is found while walking between sample locations. (2) Less than 10% of the Sphagnum cover should be crushed, broken, and/or pulled-up.	Target (1) assessed in the following two ways: (a) for diffuse/scattered disturbance of the ground, not on clearly defined drains, paths or tracks, by visual estimate at 4 m2 scale; and (b) for distinct and clearly defined drains, paths and tracks (exclude constructed tracks) by visual estimate for as much of the feature as is visible while standing at a sample location.

Table 1. Indicator Species		
Andromeda polifolia	*Empetrum nigrum*	*Racomitrium lanuginosum*
Arctostaphylos spp	*Eriophorum angustifolium*	*Rubus chamaemorus*
Betula nana	*Eriophorum vaginatum*	*Rhynchospora alba*
Carex bigelowii	*Menyanthes trifoliata*	*Sphagnum* spp.
Calluna vulgaris	*Myrica gale*	*Trichophorum cespitosum*
Cornus suecica	*Narthecium ossifragum*	*Vaccinium* spp.
Drosera spp.	Non-crustose lichens	
Erica spp.	Pleurocarpous mosses	

Table 2. Areas very sensitive to disturbance
(a) Slopes greater than 1 in 3 (18°), and all the sides of gullies. (b) Ground with abundant and/or an almost continuous carpet of *Sphagnum*, other mosses, liverworts and/or lichens. (c) Areas with noticeably uneven structure, at a spatial scale of around 1 m2 or less. The unevenness should be the result of *Sphagnum* hummocks, lawns and hollows, or mixtures of well-developed cotton-grass tussocks and spreading bushes of dwarf-shrubs. The surface of the vegetation canopy, including moss dominated areas will not be uniform and some parts should be at least 20 cm higher than other parts. (d) Pools, wet hollows, haggs and erosion gullies, and within 5 – 10 metres of the edge of watercourses.

Appendix J: Field recording sheets

The following recording sheets are presented on the next few pages:

- Vegetation recording sheet for the **full** method;
- Vegetation recording sheet for the **minimal** method for **wet bog** sites;
- Vegetation recording sheet for the **minimal** method for **blanket bog** sites;
- **Habitat structure** recording sheet (with habitat features definitions on second page).

Border Mires monitoring: vegetation recording sheet (full method)

Site								**Stratum**						**Q.ref.**			
Surveyor					**Date**						**Type:** wet bog / blanket bog						
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**TOT**
Andromeda polifolia																	
Aulacomnium palustre																	
Calluna vulgaris																	
Campylopus flexuosus																	
Cladonia portentosa																	
Deschampsia flexuosa																	
Dicranum scoparium																	
Erica tetralix																	
Eriophorum angustifolium																	
Eriophorum vaginatum																	
Hypnum jutlandicum																	
Juncus effusus																	
Molinia caerulea																	
Narthecium ossifragum																	
Odontoschisma sphagni																	
Plagiothecium undulatum																	
Pleurozium schreberi																	
Polytrichum commune																	
Polytrichum strictum																	
Rhytidiadelphus loreus																	
Rhytidiadelphus squarrosus																	
Sphagnum cap. ssp. *cap*																	
Sphagnum cap. ssp. *rub.*																	
Sphagnum cuspidatum																	
Sphagnum fallax																	
Sphagnum magellanicum																	
Sphagnum papillosum																	
Sphagnum tenellum																	
Trichophorum germanicum																	
Vaccinium myrtillus																	
Vaccinium oxycoccos																	
1 = N, 2 = E, 3 = S, 4 = W	2	3	2	2	3	4	1	3	1	1	3	3	1	1	3	4	1

Border Mires monitoring: vegetation recording sheet (minimal method for wet bogs)

Site						**Stratum**				
Surveyor						**Date**				
Insert Q. Ref. No. -->										
Bog asphodel										
Bog rosemary										
Bracken										
Bramble										
Cladonia sp. (bushy lichen)										
Cloudberry										
Common cottongrass										
Conifer (any species)										
Cowberry										
Cranberry										
Cross-leaved heath										
Crowberry										
Foxglove										
Heather										
Lesser twayblade										
Marsh thistle										
Rosebay willowherb										
Round-leaved sundew										
Rush sp. (large rush)										
Sphagnum sp. (red/chunky)										
Tick each species you find										

Insert Q. Ref. No. -->										
Bog asphodel										
Bog rosemary										
Bracken										
Bramble										
Cladonia sp. (bushy lichen)										
Cloudberry										
Common cottongrass										
Conifer (any species)										
Cowberry										
Cranberry										
Cross-leaved heath										
Crowberry										
Foxglove										
Heather										
Lesser twayblade										
Marsh thistle										
Rosebay willowherb										
Round-leaved sundew										
Rush sp. (large rush)										
Sphagnum sp. (red/chunky)										
Tick each species you find										

1 = N, 2 = E, 3 = S, 4 = W	2	2	3	4	1	3	1	1	3	3

Border Mires monitoring: vegetation recording sheet (minimal method for blanket bogs)

Site						**Stratum**				
Surveyor						**Date**				
Insert Q. Ref. No. -->										
Bog rosemary										
Bracken										
Bramble										
Cladonia sp. (bushy lichen)										
Cloudberry										
Conifer (any species)										
Cowberry										
Cranberry										
Cross-leaved heath										
Crowberry										
Foxglove										
Lesser twayblade										
Marsh thistle										
Rosebay willowherb										
Round-leaved sundew										
Rush sp. (large rush)										
Sphagnum sp. (red/chunky)										
Insert Q. Ref. No. -->										
Bog rosemary										
Bracken										
Bramble										
Cladonia sp. (bushy lichen)										
Cloudberry										
Conifer (any species)										
Cowberry										
Cranberry										
Cross-leaved heath										
Crowberry										
Foxglove										
Lesser twayblade										
Marsh thistle										
Rosebay willowherb										
Round-leaved sundew										
Rush sp. (large rush)										
Sphagnum sp. (red/chunky)										
Insert Q. Ref. No. -->										
Bog rosemary										
Bracken										
Bramble										
Cladonia sp. (bushy lichen)										
Cloudberry										
Conifer (any species)										
Cowberry										
Cranberry										
Cross-leaved heath										
Crowberry										
Foxglove										
Lesser twayblade										
Marsh thistle										
Rosebay willowherb										
Round-leaved sundew										
Rush sp. (large rush)										
Sphagnum sp. (red/chunky)										
1 = N, 2 = E, 3 = S, 4 = W	2	2	3	4	1	3	1	1	3	3

Border Mires monitoring: habitat structure recording sheet

Site		Stratum
Surveyor	Date	**Type:** wet / blanket

Quadrat ref. number						Quadrat ref. number					
Positive features	1	2	3	4	TOT	Positive features	1	2	3	4	TOT
Sphagnum hummock						*Sphagnum* hummock					
Spongy *Sphagnum*						Spongy *Sphagnum*					
Pool/*Sphagnum* hollow						Pool/*Sphagnum* hollow					
Variable veg. height						Variable veg. height					
Natural flush/lagg						Natural flush/lagg					
Total moss cover						Total moss cover					
2 high value indicators						2 high value indicators					
Total positive						Total positive					
Negative features	1	2	3	4	TOT	Negative features	1	2	3	4	TOT
Unblocked drains						Unblocked drains					
Track						Track					
Recent burning						Recent burning					
Conifer						Conifer					
Overgrazing						Overgrazing					
Erosion						Erosion					
Grass						Grass					
Stump/brash/log						Stump/brash/log					
Dominant plant						Dominant plant					
Total negative						Total negative					
Habitat structure index						Habitat structure index					

Quadrat ref. number						Quadrat ref. number					
Positive features	1	2	3	4	TOT	Positive features	1	2	3	4	TOT
Sphagnum hummock						*Sphagnum* hummock					
Spongy *Sphagnum*						Spongy *Sphagnum*					
Pool/*Sphagnum* hollow						Pool/*Sphagnum* hollow					
Variable veg. height						Variable veg. height					
Natural flush/lagg						Natural flush/lagg					
Total moss cover						Total moss cover					
2 high value indicators						2 high value indicators					
Total positive						Total positive					
Negative features	1	2	3	4	TOT	Negative features	1	2	3	4	TOT
Unblocked drains						Unblocked drains					
Track						Track					
Recent burning						Recent burning					
Conifer						Conifer					
Overgrazing						Overgrazing					
Erosion						Erosion					
Grass						Grass					
Stump/brash/log						Stump/brash/log					
Dominant plant						Dominant plant					
Total negative						Total negative					
Habitat structure index						Habitat structure index					

Definitions for positive and negative habitat features

Positive features	
Sphagnum hummock	Hummock surface at least **20cm** above surrounding ground layer vegetation (ignore dwarf shrub canopy) and at least **1m** in diameter
Spongy *Sphagnum*	Continuous patch at least **2m** in diameter. It counts as spongy if your feet sink by **10cm** or more when you step on it. If hummocks you counted above are the only bits of spongy *Sphagnum*, **do not** count them again here.
Pool/*Sphagnum* hollow	Hollows with surface water, **or** complete cover of green *Sphagnum* without other plants. Must be at least **2m** in diameter to count, **or else 3 or more** hollows/pools of at least **1m** diameter. Pools formed behind dams along blocked drains **can** be included here.
Variable veg. height	Consider 3 heights of vascular plant vegetation: **High** (> 40cms); **Medium** (10-40cms) and; **Low** (< 10cms). If less than two-thirds (67%) of the area is dominated by **one** of these, then it counts as variable vegetation height (i.e. it only **does not** get a tick if it is mostly all the same height).
Natural flush/lagg	Sloppy, green *Sphagnum* vegetation with sedges or rushes above. At least **50cm** wide x **2m** long. Drains (blocked or unblocked) do not count here.
Moss cover > 50%	Ignore vascular plants to assess this. You may have to poke about to see what is under the heather. Include **all** mosses including *Sphagnums*.
2 high value indicators	**Two** of the following present (**one** individual is enough to count as ‘present’): bog rosemary, cranberry, round-leaved sundew or *Sphagnum magellanicum* (the only *Sphagnum* which is **both** red and chunky)

Negative features	
Unblocked drains	Water level or *Sphagnum* surface in drain is **15cm** or more below the adjacent bog surface.
Track	Include any visible tracks caused by animals or vehicles.
Recent burning	Charred dwarf shrub stems, blanched moss layer, charred bare peat, etc. **all** count here. If the area has obviously been burnt in the past, but has re-vegetated and none of the signs of recent burning are still visible, then it **does not** get a tick here.
Conifer	A **single** seedling (or more) counts here.
Overgrazing	Vegetation mostly short & grassy/sedgy, **or**; Dwarf shrubs severely munched (topiary or drumstick forms), **or**; Cottongrass with hardy any flowers/seedheads visible (spring to autumn only). Any **one** of these count here.
Erosion	Bare peat on side of drains or haggs, at least **50cm** deep by **2m** wide.
Grass	**3 or more** separate plants or tufts of **any** grass species (but not cottongrass, which is a sedge).
Stump/brash/log	Record this if **any** one of these are still visible. If the area was obviously part of a plantation in the past but all of the stumps, brash or logs have disintegrated or been vegetated over, then don’t record it.
Dominant plant	If any **one** of (i.e. don’t add them all together) heather, hare’s-tail cottongrass **or** deergrass cover more than **three-quarters** (75%) of the area, it gets a tick.