2017 Broads Authority Report

Development of Fen Monitoring, Research and Management

Report 1 Recommended Vegetation and Hydrological monitoring in Broadland Fens

Broads Authority

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SUMMARY

This report proposes a methodology for surveillance monitoring of fen vegetation in the Broads. The objective of surveillance monitoring is defined as:

"To identify long-term change in fen vegetation, however it may be caused."

Hence it is distinguished from Research Monitoring, which may be long term but is designed to answer a specific question, and is then stopped. Surveillance monitoring is ongoing, and aims to provide a check on the health and changing conditions of fen vegetation.

Current monitoring effort in the Broads has been collated elsewhere. This shows a relatively modest range of active monitoring.

A wide range of fen monitoring methodologies are reviewed. Repeat of NVC-style surveys can be effective but large numbers of samples are required over quite large areas. Only then can the data overcome the impossibility of relocating samples from one recording episode to another. Large data sets are also required to control for variation caused by management and changing physical conditions across a compartment. It is concluded that the only reliable method for surveillance monitoring is permanent plots, which can be accurately relocated and are large enough to accommodate minor boundary errors.

The need to record other variables in order to reliably interpret vegetation data is emphasised. The range of physical information that could be collected is wide and will be different between sites. The two variables universally required are site management and hydrology.

An effective surveillance monitoring network requires pooling of resources by land management organisations. It also requires coordination by one organisation and long term commitment. A Collaboration Agreement is suggested.

The objectives and characteristics of the surveillance monitoring network are detailed.

A detailed methodology is proposed. It is based on 10 x 10m permanent plots paired with a dipwell. The plots are linked along transects, which can be across environmental gradients or designed to link a series of vegetation types of particular interest. The WetMecs approach for assessing eco-hydrological characteristics of fens is recommended as the basis for selecting sites and positions of transects. Sample layouts of the transects are provided for illustration. Protocols for recording vegetation, hydrology, and management are given, along with suggested storage and analysis of data.

1. REVIEW OF CURRENT PRACTISE

1.1 Current Monitoring

Under Item A of this contract, existing and dormant fen vegetation monitoring schemes are documented. The spreadsheet shows:

- Relatively few schemes are live, although there has been a small increase since the last review (Harding 2005).
- Some schemes that were started in earnest have now gone dormant or have been abandoned altogether.
- The purpose and methodologies of the schemes vary greatly and lack comparability.
- Few if any have identified the method of analysis, the timeframe for analysis and the resources for so doing. They appear to be characterised by open-ended data collection without firm plans for application of the results. Analysis is often ad hoc.

While the schemes will be useful for their original purpose (assuming the data is analysed and applied), they do not amount to a Broads surveillance monitoring scheme and cannot be made to be so because of their differing approaches.

Few schemes undertake any hydrological monitoring. They depend on wider site or even regional hydrological instrumentation to benchmark hydrology against vegetation change. The exception is the monitoring of catch dyke restoration where vegetation plots are paired with dipwells (OHES 2016a, b).

Natural England's Site Condition Monitoring

Natural England's site condition monitoring programme (JNCC 2004) is an excellent scheme because it has a straightforward methodology which is closely focussed on meeting a clear objective– assessing the condition of fen vegetation (Figure 1) within the

Figure 1 : Species-rich fen vegetation at Mrs Myhills Marsh

favourable/unfavourable condition framework. It is intended to assess whether the protected site series is meeting the Government's primary nature conservation objectives for key habitat types. The data is collected in a relatively consistent way (subject to variance due to differing surveyors, resources applied per site and return frequency), it is analysed (albeit the statistical treatment is modest) and it is applied in setting and managing site conservation objectives. Coverage at least on SSSI and Natura 2000 sites is thought to be good.

However, the survey frequency is likely to be reduced in future, and may only respond to issues raised for a site rather than be routine. In addition, its focus on condition monitoring means that it does not answer many other questions that may be of interest to conservation strategists and site managers. Not all plant taxa are recorded. Most important of all, the monitoring plots are not permanent, so that individual fixed stands are not revisited each monitoring round. The scheme does not therefore provide information on change. It measures condition, and only for that point in time. The system assumes that if condition as determined by the data collected is different in subsequent monitoring rounds, it is because the condition of the site as a whole has changed. This assumption is validated by the number of samples taken on the site, which is assumed to override any natural variability in the fen vegetation.

The maps of plant communities in the Fen Ecological Survey (ELP 2010b) and subsequent attempts to analyse change by comparing broad brush NVC style survey repeats (e.g. ELP

Figure 2 : Mire Communities Requiring Long-term "Surveillance" Monitoring

2010a, OHES 2015), shows clearly that the assumption made by condition assessment monitoring is indeed unreliable and inconclusive, unless vegetation change is very marked and significant (which would for instance push condition from favourable to unfavourable). In such cases, the technique can be useful in providing objective evidence which documents a site managers observations (e.g. ELP 2005, OHES 2013). When reviewing monitoring approaches, Wheeler et al (1999) came to similar conclusions. When developing their own fen monitoring protocol, they started with an approach very similar to site condition monitoring but abandoned it for similar reasons:

> "The approach which has been developed here is one that was originally inspired by the 'butterfly transect' monitoring procedure (Hall, 1981) in which a set route is identified across a site, and records made within separate sections of this. A similar method has already been used with some success in monitoring vegetation at Woodwalton Fen (Alan Bowley, pers. comm.). However, during the discussion and development process, we were forced to conclude that following this type of approach would not provide a sufficiently robust indicator of change, and thus the method described here is based on recording from fixed quadrats, but with a reduced species data set."

In conclusion, while NE's SCM method provides a broad indication of site condition for the time visited, it does not provide a detailed and statistically robust indication of ecological change. Hence Parmenter (2014) stated it was not applicable when monitoring vegetation change at Catfield Fen in response to eco-hydrological change. Condition Monitoring is highly sensitive to variability within a site and is not a reliable tracker of change over time. It does not provide reliable evidence of subtle or long term change.

Wetland Monitoring Methodology by Wheeler et al (1999)

In the late 1990's there was increasing concern about the impacts of groundwater abstraction on wetlands in East Anglia. As part of a monitoring effort by the Environment Agency, Wheeler et al (1999) produce a methodology for monitoring wetland vegetation (Figure 3). It was intended to be resource-light, recording only key wetland indicators (listed in Appendix 1) that might show early indication of dehydration and change. It was not intended to be dependent on taxonomically difficult plants, omitting bryophytes for example, but the list still required significant survey experience. Like Site Condition Monitoring, it is an excellent monitoring

Figure 3: Monitoring Mire Communities Using Wheeler's Methodology

method for a specific objective and with a specific set of resources available. However, for broadly-based surveillance monitoring, the omission of species will inevitably result in loss of potentially important information.

Wheeler et al tested the potential loss of information by comparing a full data set and the reduced indicator species list on real monitoring data from 1959, 1991 and 1997 recorded on Redgrave and Lopham Fen. They concluded the reduced data set did adequately represent environmental change on that site. However, the site had experienced very significant environmental change, which was easily detectable by simply comparing NVC surveys. This comparison was made in Harding (1995). Hence it was not an especially arduous test to pass. A similar comparison on sites with more subtle change would better test the subtlety of the protocol.

Their method requires establishment of 0.5m x 2m permanent plots, the dimensions chosen so that the plot can be recorded without disturbing the vegetation. Note that this is a much smaller area than even the smallest NVC quadrat, and may not be representative of grosser-structured fen vegetation.

Plant abundance is recorded using the Braun-Blanquet scale, a simpler system to the Domin scale but otherwise very similar.

Note that their methodology did not provide guidance on how many samples should be located for reliability. They suggest use of Decorana ordination analysis (based on that used at Redgrave and Lopham fen in Harding 1990 and Fojt and Harding 1995) would be a starting point for analysis.

Despite these concerns, their methodology represents one of the best existing protocols available.

Broads Authority (Kennison's) Fen Monitoring Plots

In 1983, Gary Kennison set up a series of permanent plots in fens such as Reedham Marshes (Figure 4) on behalf of the Broads Authority (Kennison 1986 *et seq*). The plots were 12 x 12m

Figure 4 : Fen at Reedham Marshes in the Ant Valley, one of Kennison's sites

in length, marked on site by a single post which provided the origin of the plot. The first side of the 12m square went due north with the second side due east. The 12m sides were divided into 24, 0.5m graduations providing x- and y-axes. The plot was sub-sampled with 25 1m quadrats located by means of 25 pairs of random numbers locating the 1 x 1m quadrat on the axes of the 12m plot. The 1 x 1m quadrat was sub-divided into four 0.5m x 0.5m sub-quadrats. At the locations determined by random numbers, the occurrence of each species in the four 0.5m sub-divisions was noted giving a frequency for the quadrat of 1 to 4. Using twenty five such 1m quadrats gave 100 mini 0.5m quadrats, providing a maximum frequency of 100. Abundance was not recorded for each 0.5m sample, just presence/absence. Bryophytes were not recorded and some plants were not recorded to specie level on some occasions.

The sub-sampling and randomisation (within the plot) allowed statistical analyses such as comparison of frequency between sampling, using for instance Chi-squared procedures.

The fact that the plot was sub-sampled means that small mis-registrations are likely to have minimal impact on the resultant data. The considerable robustness of the method is further enhanced by the possibility of full statistical analysis. No other data were recorded other than vegetation. The penalty was the intensity of sampling providing significant trampling and the time involved in recording 100 samples per plot, including location by random numbers. Kennison (1984) notes that if time is short the number of sampling points can be reduced to 10 (rather than 25) and the results multiplied by 2.5 to restore 100% frequency but he notes the impact of the procedure on accuracy. There appears to have been plant identification issues and the absence of bryophyte recording would be an issue in some communities.

The method used is very similar to that used by Bellamy and Rose (1961) to characterise valley fen community types, and subsequently re-used by Fojt and Harding 1995 and Harding 1993 to describe change in the Ouse-Waveney Valley fens where Bellamy's plots were relocated after 35 years. The difference here was that Bellamy and Rose (1961) used a 10 x 10m plot, recording 30 sub-samples of 0.5m individually located by random numbers. They also used a Braun-Blanquet abundance rating similar to Wheeler et al (1999). The 0.5m size sampling plot is reasonable for the short sedge and moss mires they sampled but must be almost impossible in tall, dense sedge and reed communities of floodplain fens.

When assessing change at Reedham Marshes, one of Kennison's sites, OHES (2015) found it very difficult to make assessments of change over time using his and NVC data because of the difficulty of relocating plots and the difference in sample sizes.

Monitoring Through Relocation of NVC-style Samples at Catfield and Sutton Fens

In 2013 and 2015, Jo Parmenter revisited quadrat locations recorded originally in 1991 to assess vegetation change in association with the assessment of impacts of a nearby abstraction (Parmenter 2016). However, these were not permanent plots. Their location was established by six figure grid reference in 1991, and re-found by GPS in 2013, with likely significant error. Richard Mason of RSPB also presented time series change data for plant communities and also species at Catfield based on similar NVC repeat and mapping exercises (OHES 2013). Convincing though the data is, they are not derived from permanent plots and both his and Parmenter's methods are only appropriate when demonstrating gross change such as that experienced by the examined areas of Catfield Fen (Figure 5).

Figure 5: Acid mire vegetation (BS5 *Sphagnum-Dryopteris cristatus* community) at Catfield Fen.

Wheeler et al (1999) reviewed repeat NVC surveys and concluded:

> "We would contend that, while this [*repeat of broadscale NVC survey]* might be helpful in identifying gross change, the results are too general to produce information which could be used in the current context."

At Sutton Fen, OHES (2015) compared the 2007 data in the Fen Ecological Survey with a partial repeat undertaken by RSPB in 2012. Both adopted NVC-style sampling, but there was selection in 2012 of key samples and areas of the fen. The work allowed some comparison and analysis of change. However, variation in placement of samples made robust conclusions difficult. Variations in wetness (2007 being a very wet year) may have been one of the most significant reasons for change. Variation in management regime was also a key variable. When OHES compared vegetation change within the same management regime, firm conclusions were confounded by natural site variability, modest sample sizes per management type and variability in placement of samples between surveys. OHES concluded:

> "….in order to assess the impact of management, repeat vegetation sampling either needs to be of sufficient density to have several samples per management type per community, or preferably needs to use permanent monitoring plots (with marker posts) so that actual loss or gain of species can be detected." (OHES 2015 p13).

Repeated broad scale surveys provide time series data on change only at the much larger scale, where large numbers of samples can be aggregated and change is not required to be described at specific point locations. Hence when RSPB undertook a comprehensive resurvey of the site in 2016[1], recording 574 samples, more meaningful comparisons were possible, identifying changes in the vegetation, both positive and negative. The resources required for this were significant and the site is very large.

The Ecological Change Network: Woodbastwick Vegetation Monitoring

The monitoring scheme set up by the Ecological Change Network (ECN, a part of CEH) at Woodbastwick includes fen plots. It is part of a wider national network whose aim is to detect and understand the impact of environmental change on vegetation types. The protocol is based on permanent plots and their approach is summarised:

> "It has been concluded therefore that it is better to use an objective method which records presence and absence of plant species rather than to attempt difficult and subjective assessment, such as cover estimation. Further, it has been thought more efficient statistically to use a relatively large number of small plots rather than a small number of larger plots." Rodwell et al 1996.

The plots recorded are aggregated nationally. All species in the plots are recorded. There are two scales of recording: The ***coarse-grained plots*** are intended to capture broadscale changes in a site's vegetation. They are recorded every 9 years, with sample areas of 2 x 2m. These plots are subdivided into 25 40 x 40cm sub-plots and presence absence data for each recorded, providing an overall frequency for the 2 x 2 plot. The **fine grained plots** are intended to record change to recognisable communities and be relatable to the NVC. They are recorded every three years, with 10 x 10m plots sub-divided into 40cm cells with presence/absence recorded for ten of the cells located using random numbers.

The practicality of recording 40x40xm cells in grossly structured fen vegetation such as *Cladium,* especially poorly managed stands with *Myrica* and *Rubus,* would be challenging. However, the method combines permanent plots with recording of all species and some degree of randomisation and sub-sampling to provide meaningful statistical analysis. It is also a national scheme, useful for benchmarking local change.

Monitoring at Ebb and Flow and at Decoy Marshes Acle

These monitoring schemes were set up to record change in response to restoration of catch dykes. The capital works would see the drainage effects of catch dykes neutralised (OHES 2016a,b) with the restoration of groundwater discharge to the floodplain from the permeable upland margin. The eco-hydrological change would vary with distance up and downslope of the catch dyke. Hence transects of permanent monitoring plots were laid out perpendicular to the axis of the catch dyke. Permanent plots were more closely spaced near to the catch dyke and more distantly spaced deep into the fen compartments where distance-decay was expected to dampen the effect. Each permanent plot was 10m x 10m, with all species recorded and their abundance rated according to the Domin scale. It is expected that the results will be analysed using Decorana ordination type analysis, with other statistical tests which compare vegetation similarity also applied.

The plots were laid along a line strung between permanent posts. The position of the plots was marked on the line with gaffer tape and on subsequent monitoring rounds the same line was used for the same transect line. The plots were always recorded on the same side of the

[1] Information taken from a briefing note from RSPB to the Broads Biodiversity Partnership meeting, November 2016.

line to avoid ambiguity. The location of the plots was selected on the basis of distance from the catch dyke, not on the basis of a target community – although at Decoy Carr, it was ensured that the last plot on one transect reached the *Cladium* bed as this was a documented SAC feature. Two transects per site were used. The plots were recorded in 2016 to provide the baseline before restoration. Each permanent plot was paired with a dipwell recording water table level. For the first year the level was recorded fortnightly to provide a water table profile. Dipwells located in grazed areas required fencing against cattle.

1.2 Conclusion

There is no single, agreed monitoring methodology. Even the more generic methods such as Common Standards Monitoring and Wheeler et al (1999) have a particular focus. The catch dyke monitoring is in part “research monitoring”, although the technique could be applied to surveillance monitoring. Broads Authority (Kennison’s) and the Ecological Change Network’s plots are both true surveillance monitoring but with quite different plot sizes and sampling strategies.

The majority have one main characteristic in common – use of permanent plots. Workers seem to agree that this is the only effective method for identifying long term change with certainty.

2. LINKING VEGETATION MONITORING WITH CAUSAL FACTORS

Assuming ecological change can be identified and quantified reliably, interpretation of change requires evidence of change in other environmental variables.

The number of factors which can influence the composition and quality of fen vegetation are many, and they are often interrelated in complex ways. It is simply not feasible to monitor all of the factors for each vegetation plot, or even each site, desirable though that may be.

Some, such as climate (including rainfall) can be ascertained through other monitoring networks. EA maintain some site monitoring of salinity and groundwater, although coverage is patchy and recording intensity variable.

Other factors are extremely complex to monitor and/or their precise relationship to species composition poorly understood. Primary among these is nutrient levels. Site fertility is known to strongly affect fen vegetation, but measuring it has only reliably been undertaken through phytometric methods (Wheeler et al 1991). These are not feasible on the scale and frequency required for surveillance monitoring. Quick and easy surrogate measurements have not been identified. Measuring free nutrients does not seem to be meaningful.

Two variables of relative importance and ease of measurement can be recorded:

- Water table level in the shallow deposits, via a dipwell near to the permanent plot.
- Recording of site management. Recording mowing regimes for the plots is straightforward, less so for grazing. Because of the free-ranging nature of the grazers it is perfectly possible for a permanent plot within a grazed area to receive a different level of grazing to the "average" (as recorded by LU/ha/week for instance) or even no grazing at all. The issue is less problematic on fen types that are more evenly grazed (e.g. fen meadow), but becomes vexatious on dense and tall vegetation which is lightly grazed. Monitoring infrastructure such as posts can affect the behaviour and therefore impact of stock on the plots. As grazed fens are an important component of Broadland fens they cannot be omitted from the scheme. Best efforts must be made to record level of grazing in the plots at the end of each season, and analysis of data should control for management type.

3. OBJECTIVES AND CHARACTERISTICS OF SURVEILLANCE MONITORING

3.1 Surveillance Monitoring Objective

The objective set for fen monitoring described in this section is:

To identify long-term change in fen vegetation, however it may be caused.

It is therefore ***surveillance monitoring,*** rather than research monitoring which looks at a particular issue or process. Because it is not measuring change in relation to any particular environmental variable, the method needs to be sensitive to all forms of potential environmental change, including (and perhaps most importantly) internal or autogenic change, i.e. changes brought about by the plant community upon itself. Autogenic changes include effects of inter-specific competition, succession, dehydration of sites through peat accumulation and or the evolution of poor-fen. To understand the complexity of change that fens undergo, it is necessary to record the full set of species.

Figure 6: Surveillance monitoring aims to document long term change in fen vegetation. British White cattle introduced at Crostwick Marshes

Surveillance Monitoring is not intended to answer very specific questions, e.g. “what happens to the fen if we change from no management to cutting or grazing”. Such questions are accommodated under Research Monitoring. Neither does Surveillance Monitoring determine trends in rare species. The method discussed here does not include monitoring of fauna.

Such monitoring cannot examine the whole of sites, and any network cannot examine *all* fen sites. Plot selection needs to be fully representative of the Broads fens, but be realistic in terms of resources.

3.2 Characteristics of Surveillance Monitoring

- The data set needs to be able to control key variables in order to tease out the cause of change. Consequently, monitoring needs to include a range of sites across the Broads, in different river valleys, under different hydrologies and management regimes. Highland margin-to-floodplain provides a useful transect line for much valley wetland variability. A network is required representative of the diversity of Broads fens.
- The range of plant taxa recorded needs to be comprehensive (Figure 7) in order to detect the full scope of potential change. Selective indicators may be useful for focussed research monitoring, but will be limiting for surveillance monitoring.

Figure 7 : Accurate identification is critical to reliability of the results.

- The plots should be located so that they provide useful information to particular site managers, as well as contributing to the Broads-wide network.
- The resulting data needs to be collated and stored reliably, in both a central location and with site managers. The data needs to be analysed periodically and the results disseminated.
- The data needs to be of sufficient quality in terms of accuracy of botanical identification and recording, and of sufficient quantity in terms of numbers of plots to allow statistical robustness and reliable conclusions. The more subtle the expected changes, or the more contentious or important the interpretation of the results, the more robust should be the statistical analysis of the results.

- Accurate recording of the species is essential and requires experienced workers.
- Baseline hydrological data should be included with the plots.
- The plots need to be marked in such a way that they can be *reliably refound.* Even then, the method must ensure that small variations in plot boundaries do not impair reliability of results, and that any site infrastructure does not unduly impact on site management or affect the monitoring plots by changing grazing patterns.
- The methodology needs to accommodate differing vegetation architecture, from short fen meadows to robust sedge- and reed beds. Comparability needs to be ensured via a consistent sizing of plots and quadrats.

4. RESOURCES

Resources are a significant constraint, and are variable in time and between organisations. The scheme needs to be efficient and best value. However, the objectives need to be met and not compromised by the need to reduce resources. Otherwise what is spent could be wasted, or the results be impossible to interpret or be misleading.

Key to effective surveillance monitoring is sustaining the scheme in the long term. There is no point in setting up a scheme for it to be abandoned due to resources.

Maintaining the integrity of the scheme therefore requires significant resources and long-term commitment from the partners.

The network of conservation sites in the Broads is such that if all sites were monitored by site managers, much of the network would be achieved. However, the Partners will need to commit to the project.

A Collaboration Agreement will be essential to provide long-term commitment and coordination between partners.

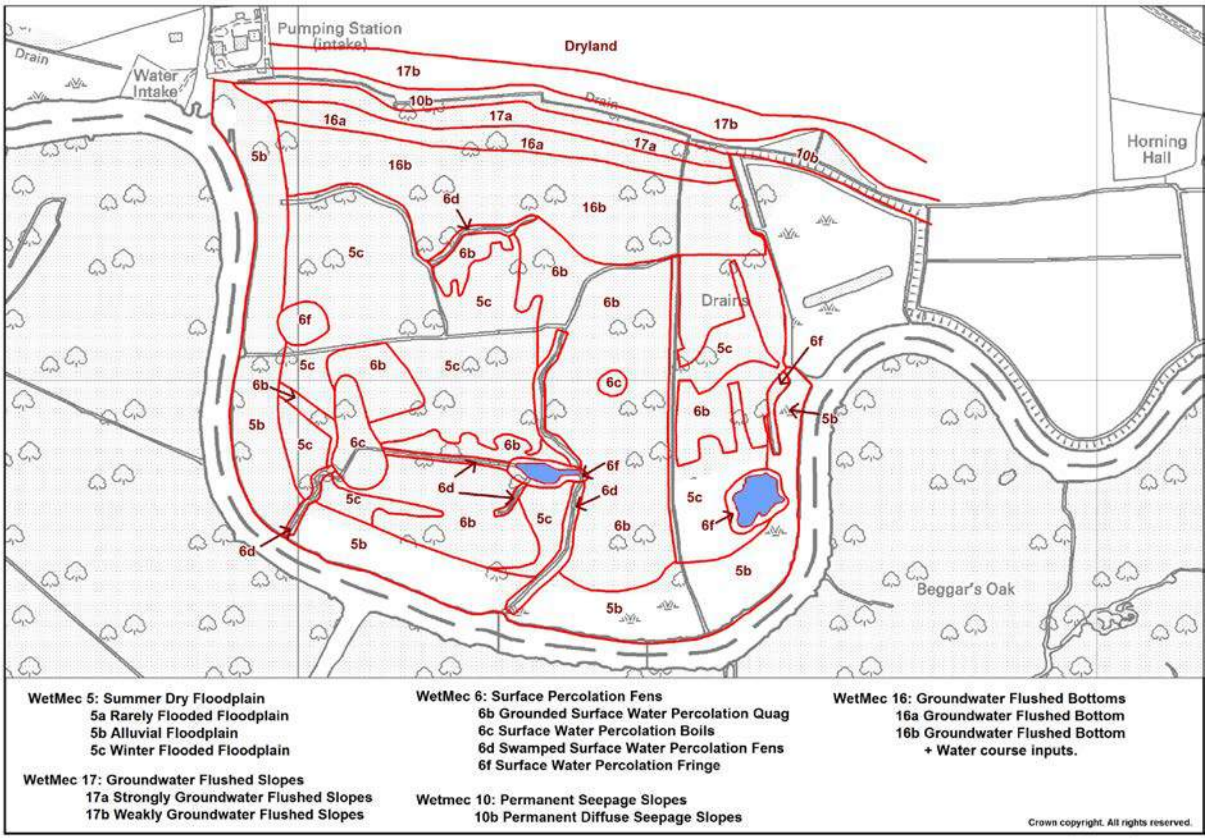
5. PROPOSED METHODOLOGY

Having reviewed existing monitoring schemes and the objectives and criteria described above, the following provides the recommended methodology. To ensure comparability between sites and in time, site managers are urged not to make substantive changes to this methodology.

5.1 Using WetMecs To Plan Monitoring

An assessment of WetMecs (short for Wetland Mechanism, Wheeler et al 2009) and their arrangement on the site is an important preliminary step of the following method. WetMecs have been used successfully in characterising wetland hydrology and ecological functioning in several studies (OHES 2013, OHES 2016a, b in the Broads, and Harding 2015 in a valley mire). Figure 8 provides an example from a Broadland site. Particular hydrologies are usually associated with a particular fen community. Hence a change in WetMec type at a particular location, through for instance altered groundwater flow, can be expected to result in changed plant communities. A good understanding of the pattern of WetMecs on a site should inform the layout and recording of hydrology and vegetation plots. Surveillance monitoring should include permanent plots through the principal WetMecs found on a site.

Figure 8: WetMec Map at Ebb and Flow Marshes, River Bure, if the Catch Dyke is Restored.
From OHES (2016b)



5.2 Vegetation Monitoring

The method utilises **permanent plots** that are returned to for each monitoring round.

In order to accommodate more grossly structured vegetation, plot size should be **10m x 10m.** This also provides some robustness against minor mis-registration when re-siting plots. It is close to the size used by Kennison (1984) and the same as Bellamy and Rose (1961) and Fojt and Harding (1995). It is also the plot size used by Wheeler (1980a,b) in his primary characterisation of UK fens.

5.3 Hydrological Monitoring

Water Table Level

A single dipwell (Figure 9) should be inserted at each plot. This should be located about 5m away from the further edge of the vegetation plot to prevent interference between plots and dipwells, with 3m being the minimum

Figure 9: Dipwell in a fenced enclosure on a cattle-grazed fen meadow.

The depth of dipwell below ground should reflect the likely range of water levels through seasons, including droughts. The minimum depth should be 1m, 2m seems unnecessary in good quality fen, so 1.5m below ground seems a good working guide. The bottom section of the dipwell tube should be slotted or drilled and enclosed within a silt sock. There should be at least 1m projecting above ground to aid relocation, and tubes should be capped. In grazed areas fencing may be required (Figure 9). A triangular arrangement suffices, tight enough to allow reaching in to record the dipwell.

Once inserted the topographic level of the top edge of the dipwell (**cap off**) and the "average" ground level next to the dipwell, should be measured accurately to ordnance datum. This allows water levels in a given dipwell to be related to all of the other dipwells and to other water level monitoring equipment.

The water level in any dykes or turfponds adjacent to the plot lines should be measured using a gaugeboard, also calibrated to OD. Comparison of water level in a ditch and the dipwells may give an indication of the relationship between dyke level and the water table in the peat body. Tying the monitoring programme in with other research or monitoring projects – such as EA's groundwater monitoring network (Figure 10) – can assist interpreting monitoring data and obtain better value from the monitoring effort.

Figure 10: EA Dipwells in an SAC Fen.

Other Hydrological Variables

Recording other hydrological factors may be helpful where resources allow. Salinity is a significant concern at some sites. Regular measurements of salinity in the dykes is useful especially when associated with storm surges or extensive flooding. More difficult is measuring salinity within the plant communities, requiring expression of peat soil water.

Nutrient levels are difficult to measure meaningfully, but long term recording of phosphate, nitrate and potassium in water expressed from peat or in dipwells could provide a long-term trend which could be correlated with changes to vegetation.

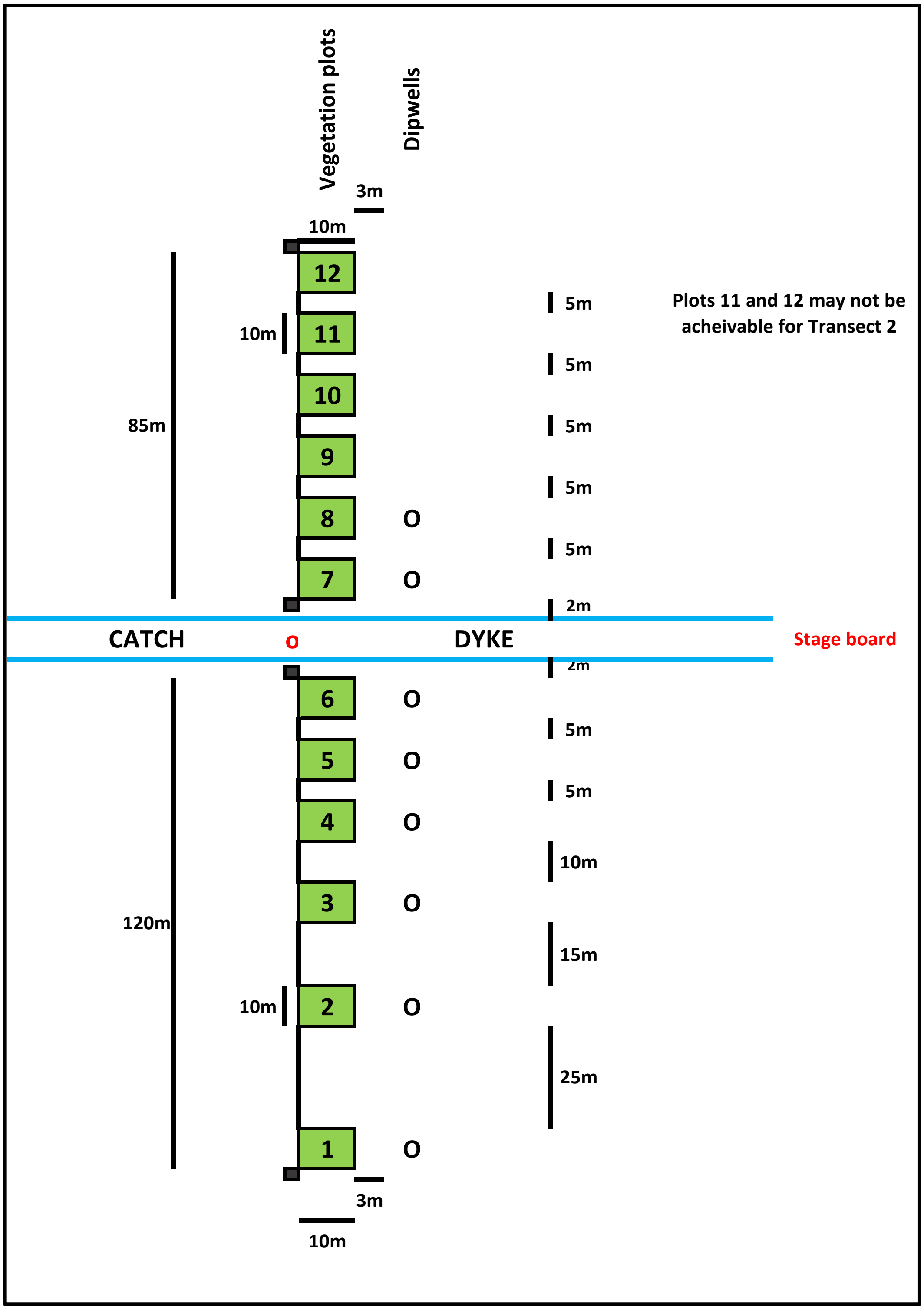
The work of Mason (2016) has shown the value of measuring pH in interstitial peat waters when interpreting vegetation change. It is easy to measure and produces reliable results.

Other hydrological and water quality measures may suggest themselves from a full WetMecs analysis. If so these should be added to the methodology, but these would be site-specific.

5.4 Setting Out the Vegetation and Hydrological Monitoring Plot Lines

The broad method used in OHES (2016a, b) will be adopted (Figure 11) as it provides the most reliable way of relocating plots especially in soft peats and dense vegetation. Surface or buried markers such as Feno markers are very difficult to relocate and can be pushed into peat by stock or management operations.

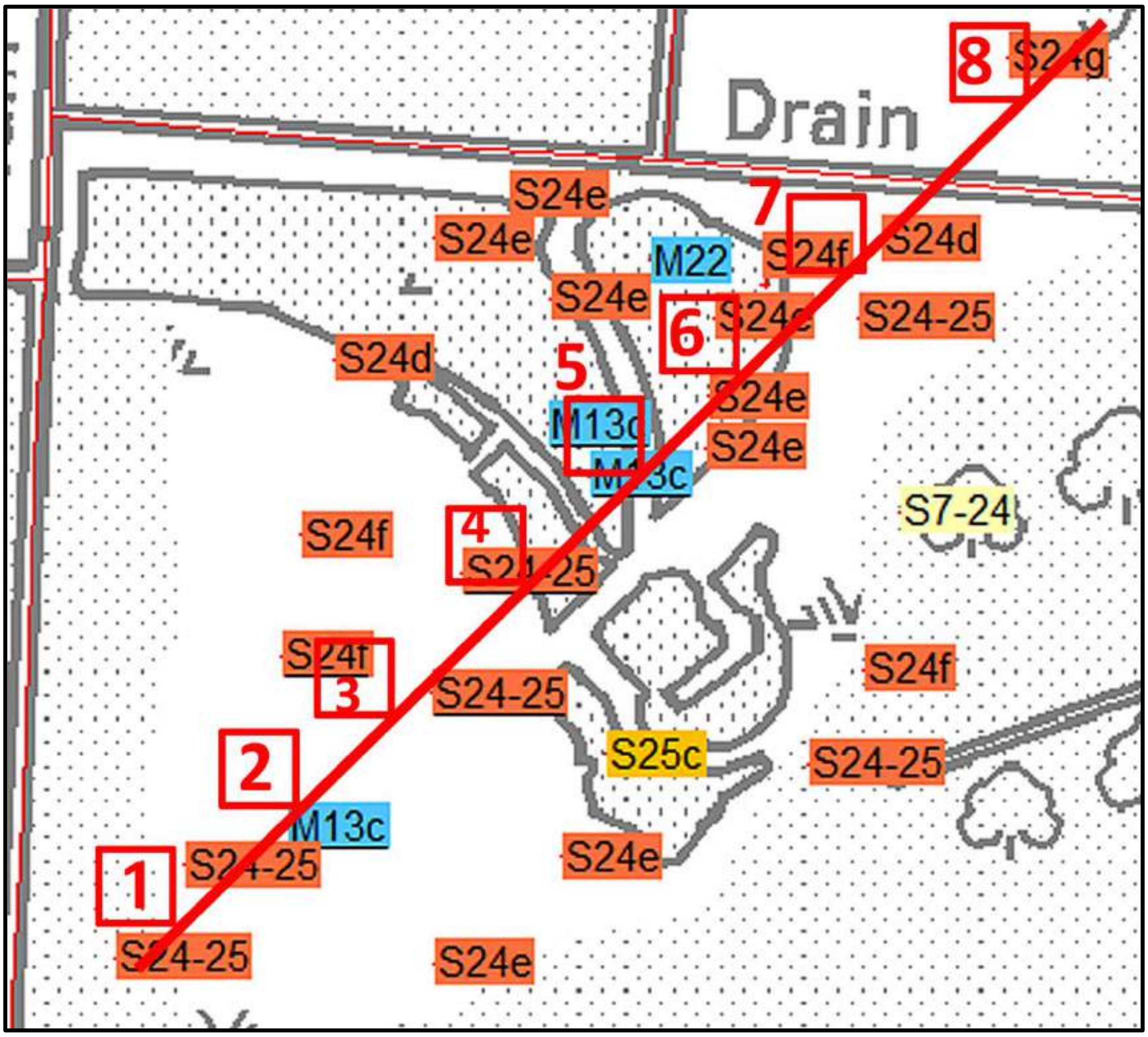
Figure 11. Layout of Vegetation Plots and Dipwells at Decoy Carr, Acle (OHES 2016a)



The arrangement shown in Figure 11 is a transect, from the dry margin to the fen interior, crossing a catch dyke. It is designed to record change along a strong environmental gradient – the groundwater table.

Plot lines are still appropriate for extensive fen interiors. Here, the location of 10 x 10m plots are selected in order to cover the range of plant communities, using the Fen Resource Survey (ELP 2010) and maps of WetMecs to identify plot lines. Figure 12 shows a theoretical example from Broad Fen, Dilham. The plots are arranged to monitor key vegetation communities using the maps in ELP (2010) as a guide. Only two permanent posts are required for this plot line.

Figure 12: Example plot line through the principal plant communities at Broad Fen, Dilham. Plots (red squares) record: 1 - S24/4; 2 – M13c; 3 – S24f; 4 – S24/5; 5 – M13c; 6 – S24e; 7 – S24f; 8 – S24g



Posts marking the corners of each plot would provide unequivocal relocation but are unpopular with site managers and encourage interference from wild and domestic stock. They are not recommended. Some permanent marking is however needed.

Plots should be laid along a **plot line**, with the square plots always on the same side of the line.

A large “strainer” post should be set solidly at each end of the plot line, and a non-elastic string or wire set **as taught as possible** between them, creating the plot line. Baler twine has proven effective for this, as it is cheap, strong, light and non-elastic. The 10 x 10m plots are then laid out along the plot line at the required distances **always on the same side of the line.** The start and finish of each 10 x 10m plot is marked **on the string** permanently with gaffer tape, preferably silver for visibility. The plot number is marked on both pieces of gaffer tape with permanent markers. The plot is completed at the time of recording by running strings out perpendicular to the line to make a 10m square. Care must be taken to ensure the plot is square to minimise mis-registration.

GPS readings of the strainers and of the two marker tapes for each plots are taken, to aid relocation if the plot lines are lost.

After recording, the plot line should be re-wound onto a stick starting from the end of the plot. When the plot line is set up next time, the free end of the plot line with be the loop which goes around the start strainer of the plot line. The plot line is then unrolled and should be relocated almost exactly along the original line, with the 10 x 10m markers (silver gaffer tape) in the right place.

For the system to work, it is essential that (a) the knot used to tie the plot line to the strainers forms a **permanent loop** and is not a sliding knot or is not undone each time – otherwise the line length will vary as will the registration of the 10 x 10m plot; (b) the plot line is wound in and unfurled **in the right order** otherwise the plots will be in reverse order and (c) critically, each plot line is **kept on its stick, is labelled permanently and unequivocally** e.g. “Woodbastwick Compartment 3 Transect 2”, and is **stored safely** in a place unlikely to be disturbed, forgotten or cleared out.

On very soft substrates, or hover, straining posts may not be sufficient to provide permanence or line tension. An alternative is steel rod whose sections can be connected as it is progressively driven in until hard strata are reached. Even then, a bracing rod may be needed. On some sites, some ingenuity may be required to provide permanent fixings.

5.5 Recording the Data – Vegetation

Standard Baseline Vegetation Monitoring

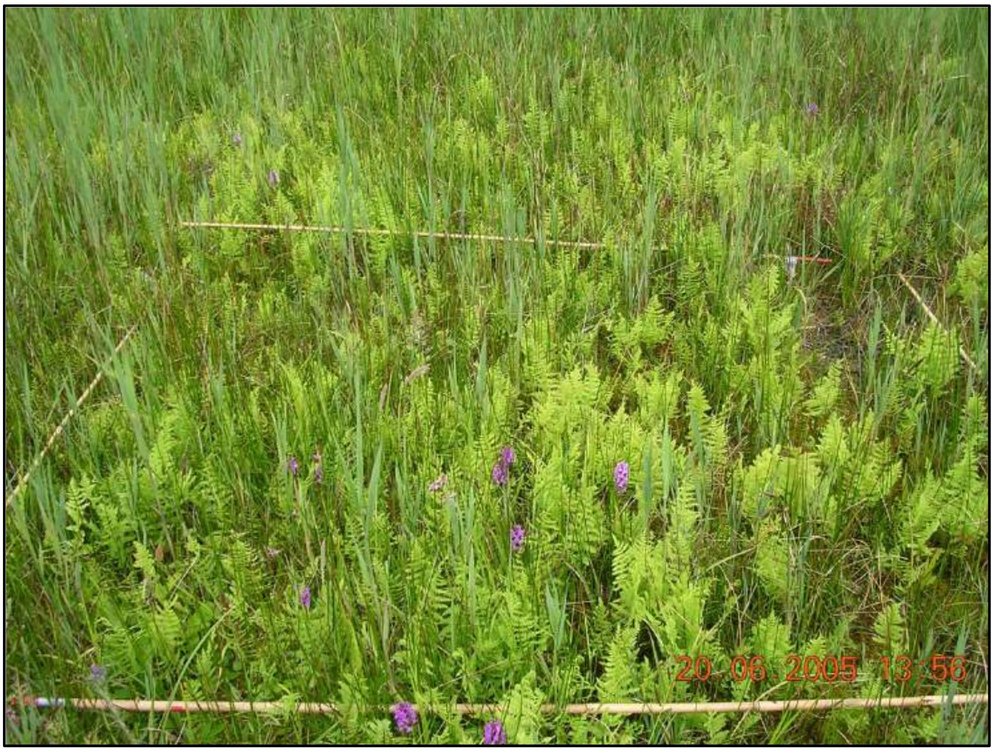
For each recording event, the following should be recorded:

- All plant species including mosses to species level. Accurate identification is required.
- The abundance should be rated according to the Domin scale.
- The amount of litter, bare ground, open water, total cover of bryophytes, total cover of herbs and total cover of scrub should be recorded for the whole plot as a %. Depth of water and depth of litter in cm.
- A photograph should be taken and the image file labelled with site, transect number, plot number and date.
- A GPS reading for the centre of the plot should be taken.
- Notes on visual condition, patterning in the vegetation, damage to the plot or any other information relevant to the interpretation of the data should be concisely recorded.
- Management for the year preceding recording should be recorded.

Sub-sampling and Data Enrichment

In some circumstances, there may be more intense interest in the change within a particular plot. If the vegetation is considered especially sensitive to change, is of unique or exceptional conservation value, or its state and direction of change is contentious or the subject of debate, sub-sampling which allows detailed statistical analysis may be required. (Figure 13).

Figure 13 : Species-rich mire vegetation at Upton Fen. Communities such as this may justify more intense sampling effort.



In such circumstances it is recommended that 30 sub-samples are recorded with 0.5 x 0.5m quadrats relocated by random numbers and rating abundance with the Braun-Blanquet scale is utilised. This is the same approached used in Bellamy and Rose (1961) and subsequently Harding (1993) and Fojt and Harding (1995). The data was then used as evidence for some difficult water resources case work.

The protocol requires significant resources for field recording and analysis. It could have a significant impact on vegetation type by trampling and requires careful consideration for the most sensitive bryophyte mats or unstable fen surfaces.

The standard baseline and sub-sampled plots could be combined on a single plot line, the latter being applied to exceptional locations which meet the above criteria.

Frequency of Recording

This is difficult to pre-determine for all sites, but there are some guidelines:

- The minimum frequency for all plots should be every 5 years.
- Where there are issues or a site is subject to major shocks or to an environment known to be fluctuating, more frequent monitoring will be needed. Annual provides the best characterisation especially in very dynamic sites, but is very resource-intensive,

generates a lot of data and if the vegetation is sensitive to mechanical damage (e.g. *Cladium*), can significantly affect the results. A judgement thus needs to be made by site managers as to the right frequency for each plot line, as long as the minimum is adhered to.

It is possible to change frequency, i.e. start with annual or 2-yearly to characterise the range of variability and after preliminary analysis – say 3-5 recording rounds – reset a more appropriate frequency if required.

Surveillance Monitoring and NEs Condition Monitoring

While Section 1.1 makes clear that Condition Monitoring cannot replace the surveillance monitoring described here, surveillance monitoring could either supplement or replace condition monitoring on a particular site. Best value could be obtained by consulting with NE when identifying plot locations to ensure that all the key site features are covered so that additional CM visits are not needed.

5.6 Recording the Data – Hydrology

What to Record

Using a dipwell recorder, the depth of the water table below the rim of the dipwell should be recorded (Figure 14).

Figure 14 : A dipwell at Ebb and Flow Marshes

The water table height below ground level and the absolute water table level to ordnance datum can then be calculated. These are the two measures that will be used to interpret vegetation change.

Frequency of Recording

To profile variation in water levels and to buffer against short term fluctuation in water table height, the greater the frequency of recording the better. It is **not sufficient just to record water levels when the vegetation monitoring is undertaken,** as vegetation composition is characterised by the annual water regime.

The ideal would be weekly water level recordings, the minimum monthly.

5.7 Recording Site Management

Understanding how the site has been managed will be critical to interpreting monitoring data. Most organisations and individuals will record management in a slightly different way and in general the more detail the better. No-one collects data for the whole of the Broads. Natural England collate data for Stewardship schemes but this may be patchy.

Figure 15: Recording patterns and intensity of grazing helps interpret monitoring data.

The Broads Authority collect management data for their own sites or those they have management agreements over. The following is a summary (Sue Stephenson, BA):

> "….we are in the process of amending the system so that planned work and work achieved are both GIS-based with the ability to confirm works on site with a tablet GPS… This way of recording fen management events has been in place since the 1990s." (email 14/12/16).
>
> - Management works are assigned to either staff or contractors with spec and work area detailed in method statement
> - Once works complete, Environment Officer records boundary coordinates of the area using handheld GPS and a sketch map is made to record shape (coordinates are recorded in main 'corners')
> - These coordinates are then transferred onto GIS (point data) and polygons drawn to recreate the work area as recorded on the ground
> - The attribute data relating to each polygon is recorded within an MS Access database using Countryside Management project codes

- A unique identifying number is assigned to each database record and its related polygon within the GIS so that database table and polygon can be joined
- The GIS and/or the database can then be queried for management events based on year, site, management type etc.

5.8 Data Collation and Storage

All field recording sheets should be stored safely with the site manager and ideally scanned into pdf for greater security and shared with the coordinating partner.

Data should be entered into Excel using a standard template, stored by site managers and shared with the coordinating partner.

The coordinating partner will collate all plot data and management records across the Broads and will be responsible for central storage and provide a back-up facility.

5.9 Data Analysis

Vegetation

Comparison of plots over time can be achieved by ordinating data and seeing how the plots track across the ordination diagram. This approach was used effectively in Harding (1993) and Fojt and Harding (1995) to track change in fen vegetation, and by Wheeler et al (1999) to test data during development of their methodology.

Statistical procedures can also be used to compare indices such as fen species richness or Ellenberg indicator values between years (see for instance Mason 2016, Parmenter 2016 and OHES 2015). Statistical tests can also be used to assess changes in abundance or frequency of critical species between years. These can either be species of particular conservation concern or indicators of environmental change.

The best yield of information will be obtained by consistent analysis of data across all plots in the Broads, but of course individual sites may wish to undertake specific interrogation of their data where they have specific concerns.

Only non-parametric statistics would be appropriate for this kind of vegetation data.

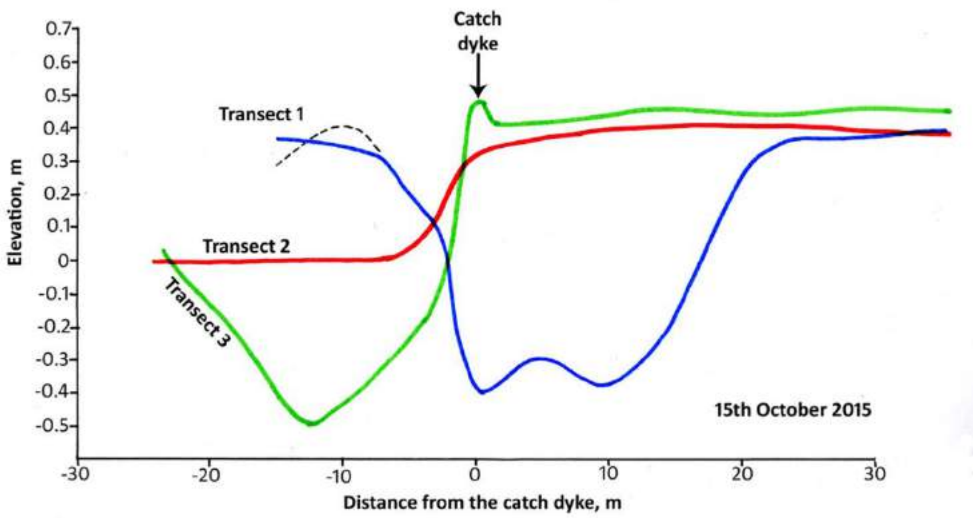
Hydrology

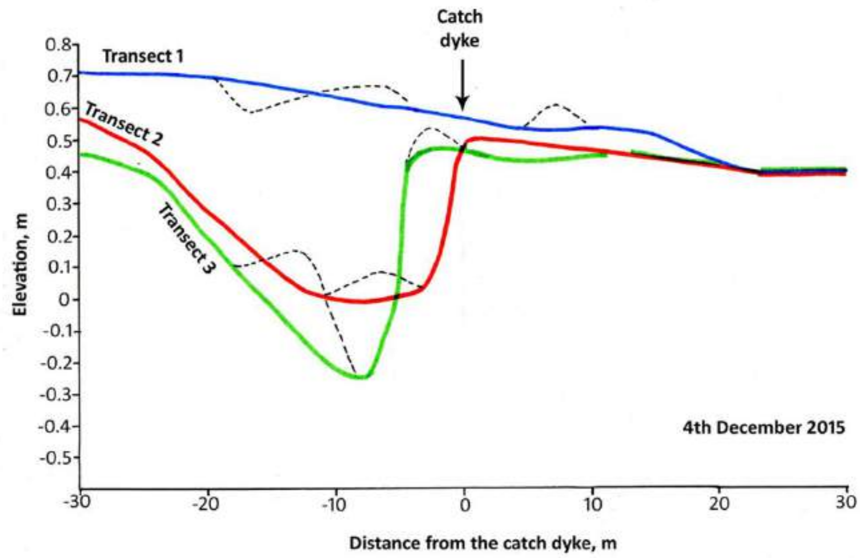
The annual water level profile for each dipwell should be plotted to determine the annual water level regime for each vegetation plot.

The annual profile can also be plotted for all dipwells on a single graph so the hydrologies of all plots can be compared.

The hydrological profiles for individual plots should be presented for each monitoring round on one graph to identify temporal change. Figure 16 provides an example of comparing water table profiles along transects between seasons.

Figure 16 : Water table profiles autumn and winter across the catch dyke at Ebb and Flow Marshes.





Long term hydrological monitoring data held by the Environment Agency should be incorporated into periodic analyses. As well as dipwells and boreholes, EA's river level, regional borehole, water quality and salinity data should be integrated into the analysis to provide context.

In terms of plots across the Broads, it would not be helpful to lump hydrological data of all plots. However, it may be of interest to plot all hydrographs for one community type to ascertain range, to determine a mean hydrograph for a given community each year and to plot a series year by year to ascertain temporal change.

When plotting water tables within a monitoring plot line, water level to ordnance datum should be used to illustrate relative water tables (as in Figure 16), especially on a plot line that aims to investigate topographical gradients. Where plots are compared that are not topographically related (i.e. not on the same sites or in a different hydrological unit), depth of water table below ground is the only meaningful metric.

6. REFERENCES

Bellamy, D.J. & Rose, F. (1961) The Waveney-Ouse valley fens of the Suffolk-Norfolk border. *Transactions of the Suffolk Naturalists' Society*, 11, 368-385.

ELP (2005) *Redgrave and Lopham Fens: NVC Phase II Re-survey June – Oct 2004*. Unpublished report to Suffolk Wildlife Trust.

ELP (2010a) *Vegetation Responses to Management at 5 Broadland Fen Sites: a pilot study.* Unpublished Report to the Broads Authority.

ELP (2010b, 2014) *Fen Plant Communities Of Broadland Results Of A Comprehensive Survey 2005-2009*. Report to Broads Authority, Norwich. Minor amendments in 2014.

Fojt, W and Harding, MJ (1995) Thirty years of change in the vegetation communities of three valley mires in Suffolk, England. *J. Appl. Ecol*, v 32 561-577.

Harding, MJ (1993) Redgrave and Lopham Fens, East Anglia, England. A case study of change in the flora and fauna due to groundwater abstraction. *Biological Conservation*, v 66 35-45.

Harding, MJ (2005) *Review Of Monitoring, Survey And Research Relating To Management Of Fens In Broadland.* Unpublished report to the Broads Authority Norwich.

Harding, MJ (2015) *Nacton Meadows SSSI. Ecohydrology and Site Management.* Report to Natural England.

JNCC (2004). *Common Standards Monitoring Guidance for Lowland Wetland Habitats* . Joint Nature Conservation Council, Peterborough.

Kennison, G.C.B. (1984). *A permanent quadrat monitoring programme for fen management purposes*. Broads Authority report.

Kennison, G.C.B. (1986). *A permanent quadrat monitoring programme for fen management purposes; 1983 to 86*. Broads Authority report. Subsequent reports: 1987, 1991.

Kent, M (2012) *Vegetation Description and Data Analysis. 2nd Edition.* Wiley Blackwell.

OHES (2011) *Analysis of salinity data from 2003-2008*. Report to Broads Authority, Norwich.

OHES (2013). *Analysis of Vegetation Change at Sutton and Catfield fens between 2007 and 2012*. RSPB and Broads Authority report.

OHES (2015) *Scoping report for the repeat of the Broadland Fen Ecological Survey.* Unpublished report to the Broads Authority.

OHES (2016a) *Remedial Works for the Catch Dykes at Decoy Carr, Acle*. Report to Natural England, Norwich.

OHES (2016b) *Remedial Works for the Catch Dykes at Ebb and Flow Marshes*. Report to Natural England, Norwich.

Parmenter, JM (2016) *Proof Of Evidence (Including Summary Proof Of Evidence) Of Dr Joanne Marie Parmenter.* Landscape Partnership report submitted as evidence to Andrew Alston Appeal, APP/WAT/15/316 & APP/WAT/15/317

Parmenter, JM (2014) *Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3.* Note of evidence submitted to Andrew Alston Appeal, APP/WAT/15/316 & APP/WAT/15/317

Rodwell, JS, Sykes, JM, and Helps JB (1996) *The UK Environmental Change Network Protocols for Standard Measurements at Terrestrial Sites*. Natural Environmental Research Council.

Wheeler, BD (1980a) Plant communities of rich fen systems in England and Wales. I Introduction. Tall sedge and reed communities. *Journal of Ecology*. v. 68, 365-395

Wheeler, BD (1980b) Plant communities of rich fen systems in England and Wales. II Communities of calcareous mires. *Journal of Ecology*. v. 68, 405-20

Wheeler, BD, Shaw, SC and Hodgson, JG (1999) *A Monitoring Methodology For Wetlands* Report to the Environment Agency. Available from http://www.environmentdata.org/archive/ealit:2090/OBJ/20003000.pdf
Wheeler, BD, Shaw, SC and Cook, RED (1991) Phytometric assessment of the fertility of undrained rich-fen soils. *Journal of Applied Ecology,* v. 29, 466-475

Appendix 1: List of species used in the methodology of Wheeler et al (1999)

DOMINANTS	*FEN SPECIES & TARGET SPECIES*	*INVADERS*
Acer pseudoplatanus	*Achillea ptarmica*	*Achillea millefolium*
Alnus glutinosa	*Alisma plantago-aquatica*	*Anthriscus sylvestris*
Betula pendula/pubescens	*Anagallis tenella*	*Arctium minus/lappa*
Calamagrostis canescens	*Apium nodiflorum/Berula erecta*	*Atriplex patula*
Calamagrostis epigejos	*Bidens cernua/tripartita*	*Atriplex prostrata*
Catex acutiformis/riparia	*Calluna vulgaris*	*Brassica rapa*
Carex elata	*Caltha palustris*	*Carduus crispus*
Carex paniculata	*Calystegia sepium*	*Chenopodium album*
Chamerion angustifolium	*Carex flacca/panicea*	*Chenopodium rubrum*
Crataegus monogyna	*Carex pseudocyperus*	*Cirsium arvense*
Deschampsia cespitosa	*Cirsium dissectum*	*Cirsium vulgare*
Epilobium hirsutum	*Cirsium palustre*	*Conium maculatum*
Frangula alnus	*Cladium mariscus*	*Crassula helmsii*
Fraxinus excelsior	*Dactylorchid* spp.	*Galeopsis tetrahit agg.*
Glechoma hederacea	*Drosera intermedia/longifolia*	*Galium aparine*
Glyceria maxima	*Drosera rotundifolia*	*Heracleum mantegazzianum*
Humulus lupulus	*Epipactis palustris*	*Heracleum sphondylium*
Juncus acutiflorus/ articulatus/ subnodulosus	*Equisetum arvense*	*Lamium purpureum*
Juncus conglomeratus/effusus	*Equisetum fluviatile*	*Matricaria discoidea*
Juncus infiexus	*Equisetum palustie*	*Matricaria recutita/ Tripleurospermum /Anthemis*
Phalaris arundinacea	*Erica tetralix*	*Persicaria amphibia*
Phragmites australis	*Eupatorium cannabinum*	*Persicaria hydropiper/maculosa/ lapathifolia*
Populus spp	*Filipendula ulmaria*	*Potentilla anserina*
Pteridium aquilinum	*Galium palustre*	*Potentilla reptans*
Quercus robur/petraea	*Galium uliginosum*	*Ranunculus acris/repens*
Rosa spp	*Glyceria f/uitans agg.*	*Ranunculus sceleratus*
Rubus fruticosus agg.	*Hydrocotyle vulgaris*	*Rumex crispus/obtusifolius*
Salix aurita/caprea/cinerea	*Hypericum elodes*	*Senecio jacobaea*
Sambucus nigra	*Hypericum tetrapterum*	*Senecio sylvaticus/vulgaris*
Sparganium emersum/erectum	*Iris pseudacorus*	*Sinapis arvensis*
Typha angustifolia/latifolia	*Lathyrus palustris*	*Sisymbrium officinale*
Urtica dioica	*Lemna minor*	*Sonchus arvensis*
Viburnum opulus	*Lemna trisulca*	*Sonchus asper*
	Lotus pedunculatus	*Sonchus oleraceus*
	Lychnis flos-cuculi	*Stellaria media*
	Lycopus europaeus	*Taraxacum agg*
	Lysimachia nummularia	*Trifolium repens/pratense/fragiferum*
	Lysimachia vulgaris	
	Lythrum salicaria	
	Mentha aquatica/arvensis	
	Menyanthes trifoliata	
	Molinia caerulea	
	Myrica gale	
	Osmunda regalis	
	Pamassia palustris	
	Pedicularis palustris	

	Pedicularis sylvatica *Pinguicula vulgaris* *Potamogeton coloratus/polygonifolius* *Potentilla erecta* *Potentilla palustris* *Pulicaria dysenterica* *Ranunculus flammula* *Ranunculus lingua* *Rorippa nasturtium-aquaticum agg* *Rumex hydrolapathum* *Schoenus nigricans* *Scrophularia auriculata* *Senecio erucifoiius* *Sium latifolium* *Solanum dulcamara* *Sonchus palustris* *Succisa pratensis* *Thalictrum flavum* *Thelypteris palustris* *Utricuiaria spp* *Valeriana dioica* *Valeriana officinalis* *Veronica beccabunga* *Viola palustris*	