DARWIN PLUS 116

FALKLANDS WETLANDS AND AQUATIC HABITATS: BASELINES FOR MONITORING FUTURE CHANGE

INDICATOR MONITORING REPORT

S. Carter, C. D. Evans, R. J. Flower, D. A. Stroud, J. R. Thompson

2022

Citation: Carter, S., Evans, C. D., Flower, R. J., Stroud, D. A., Thompson, J. R.(2022) *Falklands wetlands and aquatic habitats: baselines for monitoring future change – indicator Monitoring Report*. Report under Darwin Plus Project 116 by South Atlantic Environmental Research Institute. 11 pp.

DARWIN PLUS 116 WETLANDS PROJECT

INDICATOR MONITORING REPORT – MARCH 2022

1. BACKGROUND

The Wetlands Project is funded by the Darwin Initiative through UK Government and is supported by Falkland Islands Government's Environmental Studies Budget, the Ernest Kleinwort Charitable Trust, the John Cheek Trust, and through in-kind contributions by Swansea University.

The term 'wetlands' for this project was defined at the outset and differs from the internationally adopted Ramsar definition of wetland[1] as it concentrates on selected inland wetland types. The following Ramsar wetland types[2] are included within the scope of the project but the primary focus is the first five categories:

- Rivers, streams and creeks (permanent and seasonal)
- Freshwater lakes, over 8 ha (permanent and seasonal)
- Saline and brackish lakes, over 8 ha (permanent and seasonal)
- Saline and brackish marshes, pools and ponds, under 8 ha (permanent and seasonal)
- Freshwater marshes, pools and ponds, under 8 ha (permanent and seasonal)
- Water storage areas (reservoirs)
- Excavations (quarry lakes)

The Falkland Islands (FI), a UK overseas territory in the South Atlantic, are a biodiversity hotspot. Wetland habitats are generally not well understood, but are known to be important as biodiverse sites supporting rare species and regionally distinctive ecosystems. The FI historically lacked herbivorous mammals and the introduction of grazing animals with human settlement has led to vegetation changes and soil erosion. The impact of these changes on wetland ecosystems within the FI are not clear. In addition, human induced climate change will both directly and indirectly impact wetland ecosystems through a predicted increase in temperature and storm incidence /magnitude as well as potential changes in precipitation totals and distribution through the year. Such meteorological changes can be expected to – at least - modify evaporation rates and catchment-wide hydrological processes with implications for the supplies of water to wetlands, their water levels and water quality. These landscape and climate changes threaten wetland ecosystems and accordingly baseline data as well as long-term monitoring data are urgently required to understand threats, track changes into the future and mitigate threats through appropriate management.

This report provides a framework for on-going and future long-term monitoring of these wetlands. It can be picked up by relevant government departments or research and conservation organisations, who wish to streamline and expand environmental monitoring across the FI. The report first provides an overview of selected indicators of change through which wetland condition can be assessed and monitored. Section 3 outlines what the current monitoring set-up includes. In the next section different monitoring scenarios are presented. The fourth scenario would be the ideal scenario as it includes all selected indicators across a large geographical range. However, future monitoring efforts are likely to be dependent on available funding; therefore different scenarios are proposed with the first one including the very basic coverage only. A table with estimated costings is included. The final section provides a broad overview of monitoring protocols for each of the indicators.

---

[1] Article 1(1). "...wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres."

[2] Appendix B of Ramsar's Strategic Framework and guidelines for the future development of the List of Wetlands of International Importance of the Convention on Wetlands

2. INDICATOR SELECTION

Indicators for monitoring were selected based on their roles in these wetland ecosystems and their ability to highlight short-term and long-term environmental change. Their role and justification for selection are described below.

2.1 Water Level

Water levels within wetlands exerts critical controls upon plant and animal communities and, in turn, the ecosystem services that these ecosystems provide (e.g. Baker et al., 2009; Wheeler et al. 2004). The complete range of water levels experienced over time exert different ecological controls so that information on the magnitude of the highest and lowest water levels, their duration and the rate of change between these extremes is just as critical compared to relatively simple measures of mean water levels. In the long-term, climate change could have differential impacts on low, mean and high water levels (e.g. Thompson et al., 2017) inducing a range of ecosystem responses. Wetland water levels also integrate the hydroclimatic process operating within their catchments providing a means of establishing wider changes, including those associated with a change in climate.

Water levels can be monitored by in-situ automatic data logging but also across large geographic areas as 'water area' through satellite imagery. Many ponds and lakes dry out in the Falkland Islands regularly but recently observed trends suggest that more waterbodies are drying out now compared to historic trends. Whilst differences in mean, low and high water levels are crucial for the hydrological functioning of a wetland, the actual presence of water is the most important requirement. Water level monitoring should therefore also include monitoring of water areas across the Falklands.

2.2 Temperature, Precipitation (and evapotranspiration)

A major driver of the hydrological conditions of wetlands and their catchments is regional climate (Baker et al. 2009). The nature of precipitation falling within a catchment (including total depth and its seasonal distribution through the year) determines potential water supplies to associated wetlands. These are moderated by evapotranspiration, which in turn is controlled by meteorological conditions (temperature in particular as well as other factors such as wind speed and humidity and their temporal variability). The variability in water supplies to wetlands through the year, as well as any between year variability, is strongly controlled by the balance between precipitation and evapotranspiration (Thompson et al. 2009). Seasonal differences in precipitation and evapotranspiration exert a dominant influence on how wetland water levels vary throughout and between years.

2.3 Light level

Light levels closely determine aquatic primary productivity (Goldsborough & Kemp, 1988) and macrophyte morphology (Barko & Smart, 1981), thus making light an important indicator for aquatic productivity. Light levels are affected by a range of factors including water depth, water colour (largely determined by the concentration of dissolved organic matter) and turbidity (linked to sediment concentrations).

2.4 pH

Short-term changes in pH can indicate changes in plant growth through the depletion of carbon dioxide as well as imbalances in respiration rates; whereas long-term decreases in pH indicate acidification (Sykes & Lane, 1996). pH directly influences the bioavailability and potential toxicity of elements and sediments in the water. Different aquatic species also have different pH optima; long-term changes in pH therefore also have direct knock-on effects the community assemblage of aquatic biota.

2.5 Electrical Conductivity

Conductivity is a measure of water's capability to pass electrical current, which is directly related to the concentration of mineral ions (i.e. dissolved salts) in the water. Conductivity therefore provides a good estimate of the concentration of major ions within the water. Any short-term or long-term variability in ionic concentration are early indicators of change in the water system.

2.6 Absorbance of organic matter

Absorbance of light by organic matter is a measurement directly related to the concentrations of dissolved organic carbon (DOC). Changes in DOC indicate larger changes in the ecosystem and its surroundings. In the UK, for instance, DOC increased as rivers and lakes recovered from the acidification initiated during the Industrial Revolution (e.g. Evans et al., 2012). Increased DOC reduces light availability by absorbing more incoming solar radiation (Thrane et al., 2014) and reduces bioavailability of toxic metals (Evans et al., 2005). High DOC levels can impede water treatment processes such as chlorination levels and cause production of carcinogenic organo-chlorine compounds (Evans et al., 2005). Because of its importance as an indicator of change, absorbance of organic matter was added to the UK Environmental Change Network in 2005.

2.7 Chlorophyll for primary productivity

Chlorophyll levels are incorporated into monitoring programmes because they are an indicator for primary productivity and nutrient status (Carlsson, 1977). Changes in chlorophyll can affect other variables, such as oxygen concentration and pH (Sykes & Lane, 1996).

2.8 Diatoms

Diatoms are ubiquitous and species diverse group of microalgae found in fresh and marine waters as phytoplankton[3] and phytobenthos[4]. They are important for several reasons; they are responsible for c. 20% of global primary productivity, they have intrinsic relevance to biological diversity and, notably for freshwaters species, their sensitivity to water quality makes them excellent organisms for biomonitoring environmental change. They have a long-standing history in freshwater biomonitoring for indicating change trends in water acidity, conductivity (saltiness) and dissolved nutrients. Monitoring of diatoms additionally to water quality parameters provides additional insight into the combined long-term effects of changing water quality exerting ecological controls, which might be missed by spot measurements for water quality at a given temporal frequency.

Examples of their use include the UK Upland Waters Network to track acid rain impacts since 1988 (Battarbee et al. 2014) and more recently the EU Water Framework Directive to indicate ecological states (e.g. Masouras et al. 2021). Diatom phytobenthos communities are well developed in the near pristine inland waters of the Falkland Islands; these waters are acid to circum-neutral (often influenced by dissolved humic matter) and dissolved sea salts range from fresh to saline (Flower et al. 2012). Given such variation, long-term monitoring of diatom communities is well suited to tracking likely trends in climate change effects on inland waters. It is noteworthy to say that DNA sequencing

[3] Photosynthetic organisms that live suspended in water.

[4] Photosynthetic organisms that live on bottom surfaces.

techniques show promise for expediting diatom biomonitoring but are not yet sufficiently developed to replace microscopy (Masouras et al. 2021).

2.9 Macro-invertebrates

Macro-invertebrates are a diverse group of organisms and different taxa respond to environmental change differently, which means that changes in species composition can highlight changes in the underlying aquatic conditions. Changes in macro-invertebrates are usually assessed at a community-level response because it incorporates a broader picture, which is more informative than changes of individual species (Hodkinson & Jackson, 2005). Additionally, monitoring of macro-invertebrates alongside environmental variables has proven more effective in indicating prevailing environmental conditions than monitoring abiotic variables alone (Bonada et al., 2006). The effective use of freshwater macro-invertebrates in monitoring environmental change has a long-standing history with well-developed protocols (e.g. Cairns & Pratt, 1993) and applications include the UK Environmental Change Network (UK ECN, 2022).

3. CURRENT MONITORING

There are currently six water logger stations deployed across the Falkland Islands set up to monitor some of the basic indicators listed under Section 2 (Figure 1). The parameters logged by each station are outlined in Table 1. The five stations that only cover the most basic parameters have the potential to be upgraded to include pH and conductivity monitoring, should such loggers be acquired in the future.

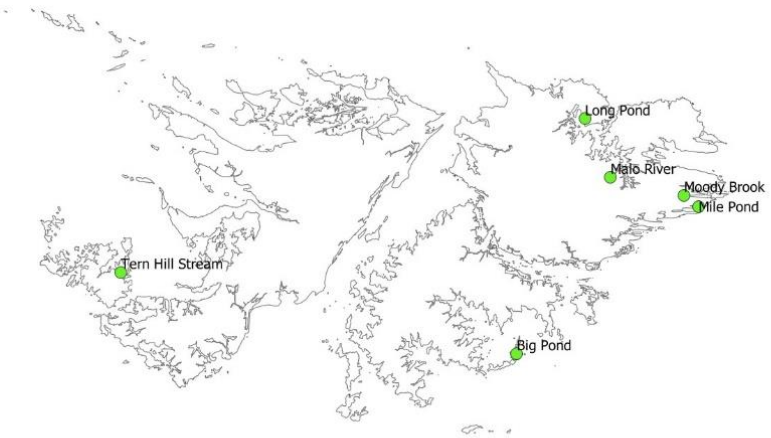

Figure 1: Location of the six logger stations.

Table 1: List of the six water bodies with monitoring stations, their locations and indicators monitored at each station.

Water Body Name	Farm	Location	Indicators covered
Moody Brook	Stanley Common	-51.6845, -57.94413	Water table, water temperature and light level, pH and conductivity
Mile Pond	Stanley Common	-51.72266, -57.868259	Water table, water temperature and light level
Malo River	Riverview	-51.62186, -58.32878	Water table, water temperature and light level
Long Pond	Salvador	-51.42869, -58.45709	Water table, water temperature and light level
Big Pond	Bleaker Island	-52.192205, -58.845182	Water table, water temperature and light level
Tern Hill Stream	Weddell Island	-51.874509, -60.924816	Water table, water temperature and light level

4. INDICATOR MONITORING OPTIONS

The following options provide a range of options for the monitoring programme for wetlands in the FI. These range from maintaining the current monitoring sites with some additional coverage provided through remote sensing to an expansion in the number of monitoring sites to provide better spatial coverage and increasing the number of indicators monitored at all sites to provide a more comprehensive picture of environmental conditions within the wetlands of the FI. Table 2 provides an overview of the estimated costs and staff time that would be required for each scenario. Section 5 highlights the individual work processes and protocols required for each indicator.

Scenario 1

Scenario 1 continues with indicator monitoring through the existing set-up, which includes six stations; all of which monitor water level, water temperature and light levels, and one station also monitors pH and conductivity. This scenario also includes monitoring of lake water areas through satellite imagery. The following is required:

a) Continue maintaining the six current logger stations set up.

b) Assess surface water area in lakes and ponds across the Falkland Islands twice per year (at the end of summer and at the end of winter) using satellite remote sensing imagery.

Scenario 2

Scenario 2 continues with indicator monitoring through the existing set-up but expands the capacity of five logger stations by equipping them with a pH and a conductivity logger. The meteorological monitoring is also expanded to Lafonia and West Falkland. This scenario also includes monitoring of lake water areas through satellite imagery. The following is required:

a) Continue maintaining the six current logger stations set up.

b) Assess surface water area in lakes and ponds across the Falkland Islands twice per year (at the end of summer and at the end of winter) using satellite remote sensing imagery.

c) Add pH and conductivity loggers to all existing stations

d) Add at least two automatic weather stations to the monitoring network to cover Lafonia and West Falkland

Scenario 3

Scenario 3 continues with indicator monitoring through the existing set-up but expands the capacity of five logger stations by equipping them with a pH and a conductivity logger. The meteorological monitoring is also expanded to Lafonia and West Falkland. This scenario also includes monitoring of lake water areas through satellite imagery. Additionally, it expands the range of indicators monitored by adding biota and two further water quality indicators. The following is required:

a) Continue maintaining the six current logger stations set up.

b) Assess surface water area in lakes and ponds across the Falkland Islands twice per year (at the end of summer and at the end of winter) using satellite remote sensing imagery.

c) Add pH and conductivity loggers to all existing stations

d) Add at least two automatic weather stations to the monitoring network to cover Lafonia and West Falkland

e) Add monitoring of diatoms, invertebrates, organic matter absorbance and chlorophyll to each of the six sites.

Scenario 4

Scenario 4 expands the geographic coverage of the current monitoring set-up by adding three further stations. All current and new stations would be equipped with loggers for monitoring water level, water temperature, light levels, pH and conductivity. The meteorological monitoring is also expanded to Lafonia and West Falkland. This scenario also includes monitoring of lake water areas through satellite imagery and monitors biota and two further water quality indicators. The following is required:

a) Continue maintaining the six current logger stations set up.

b) Assess surface water area in lakes and ponds across the Falkland Islands twice per year (at the end of summer and at the end of winter) using satellite remote sensing imagery.

c) Add pH and conductivity loggers to all existing stations

d) Add at least two automatic weather stations to the monitoring network to cover Lafonia and West Falkland

e) Add monitoring of diatoms, invertebrates, organic matter absorbance and chlorophyll to each of the six site

f) Expand geographic coverage of water logging stations to include at least one station in Lafonia and two stations on West Falkland

Table 2: Estimated costs and staff time for the individual elements of the different scenarios based on costs occurred during the DPLUS 116 Wetlands Project. Actual costs might differ and it is recommended to obtain quotes before commitment to specific work packages.

COSTS	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Equipment Costs (one-off)	£0	£9,000[1] (data loggers) £4,000 (automated weather stations x2)	£9,000[1] (data loggers) £4,000 (automated weather stations x2)	£17,000[2] (data loggers) £4,000 (automated weather stations x2)
Maintenance Costs (per year)	£1,000	£1,750	£1,750	£2,500
Travel Costs (per year)	£1,000	£1,500	£1,500	£2,000
Consultancy[3] Costs (per year)	£0	£0	£1,200	£1,800
Number of Staff Days[4] (days x staff numbers) (per year)	Logger stations: 8 x 2 Remote sensing: 4 x 1 Data processing and analysis: 20 x 1	Logger stations:16 x 2 Remote sensing: 4 x 1 Weather stations: 6 x 2 Data processing and analysis: 30 x 1	Logger stations:16 x 2 Remote sensing: 4 x 1 Weather stations: 6 x 2 Lab work[5]: 4 x 2 Data processing and analysis: 35 x 1	Logger stations:28x 2 Remote sensing: 4 x 1 Weather stations: 6 x 2 Lab work[5]: 4 x 2 Data processing and analysis: 50 x 1

[1] Covering 5 x pH loggers and 5 x conductivity loggers.
[2] Covering 8 x pH loggers and 8 x conductivity loggers, 3 x pressure based water level loggers, 3 x atmospheric pressure loggers, 3 x light level loggers.
[3] To identify and count diatoms and invertebrates in collected samples based on £100 per sample.
[4] Staff time is required for field visits, lab work data analysis to complete the specified work. For health and safety purposes, fieldwork assumes two members of staff working together; for work efficiency purposes, lab work also assumes two members of staff working together although this is not a requirement.
[5] Lab work is required to analyse samples in the lab for absorbance of organic matter and chlorophyll

5. MONITORING PROTOCOLS

Indicator	Methodology	Actions required	Frequency
Water Level	Data logging with pressure based water level recorder	Downloading data	Once per year
		Changing batteries	Once per year
		Processing and analysis of data and uploading to data portal	Once per year
	Remote sensing of water levels	Downloading and analyses of satellite imagery	Twice per year (with March and September satellite imagery)

Indicator	Methodology	Actions required	Frequency
Water Temperature	Data logging with temperature logger.	Downloading data	Once per year
		Changing batteries	Once per year
		Processing and analysis of data and uploading to data portal	Once per year

Indicator	Methodology	Actions required	Frequency
Light Level	Data logging with light level logger	Downloading data	Once per year
		Changing batteries	Once per year
		Cleaning sensor surface	Four times a year
		Processing and analysis of data and uploading to data portal	Once per year

Indicator	Methodology	Actions required	Frequency
pH	Data logging with pH logger	Downloading data	Once per year
		Changing batteries	Once per year
		Calibration	Four times a year
		Processing and analysis of data and uploading to data portal	Once per year

Indicator	Methodology	Actions required	Frequency
Electrical Conductivity	Data logging with conductivity logger	Downloading data	Once per year
		Changing batteries	Once per year
		Calibration	Four times a year
		Processing and analysis of data and uploading to data portal	Once per year

Indicator	Methodology	Actions required	Frequency
Meteorological Variables (including temperature, precipitation, wind, solar radiation)	Data logging with automated weather station	Downloading data (This is the requirement for the current station, additional stations may have the ability to send data remotely)	Once per month
		Processing and analysis of data and uploading to data portal	Once per month

Indicator	Methodology	Actions required	Frequency
Absorbance of organic matter	1. Collect 250 ml of water 15 cm from below the surface 2. Filter with a 0.45 µm cellulose nitrate membrane filters 3. Run filtered sample through the Cary 60 spectrophotometer according to protocol	Collection of water sample in the field; filtering of water sample and running water sample through the spectrophotometer in the laboratory	Four times a year (at the same time of year)
		Analysis of data and uploading to data portal	Once per year

Indicator	Methodology	Actions required	Frequency
Chlorophyll for primary productivity	1. Collect 250 ml of water 15 cm from below the surface 2. Filter with a 0.7 glass microfiber filter (e.g. Whatman Grade GF/F) 3. Run filtered sample through the Cary 60 spectrophotometer according to protocol	Collection of water sample in the field; filtering of water sample and running water sample through the spectrophotometer in the laboratory	Once per year (at the same time of year, e.g. December or January, peak of biological activity)
		Analysis of data and uploading to data portal	Once per year

Indicator	Methodology	Actions required	Frequency
Diatoms	1. Collect diatom samples according to protocol either for epilithon (diatoms growing on rocks) or epipelon (diatoms growing on sediment) and fix in 100% ethanol 2. Send sample off for analyses to consultant	Collection of samples in the field, preservation of samples and shipping of samples to consultant	Once per year (at the same time of year, e.g. December or January, peak of biological activity)
		Analysis of data and uploading to data portal	Once per year

Indicator	Methodology	Actions required	Frequency
Invertebrates	1. Collect invertebrates either through kick sampling (in streams) or sweep netting (in lakes) according to protocol and preserve in 70% ethanol and 5% glycerine 2. 2. Send sample off for analyses to consultant	Collection of samples in the field, preservation of samples and shipping of samples to consultant	(at the same time of year, e.g. December or January, peak of biological activity)
		Analysis of data and uploading to data portal	Once per year

6. REFERENCES

Baker, C., Thompson, J.R., Simpson, M. (2009) Hydrological dynamics I: Surface waters, flood and sediment dynamics. In: Maltby, E.B., Barker, T. (eds.) *The Wetlands Handbook*. Chichester: Wiley-Blackwells, 120-168.

Battarbee, R.W., Shilland, E.M., Kernan, M., Monteith, D.T. and Curtis, C.J. (2014) Recovery of acidified surface waters from acidification in the United Kingdom after twenty years of chemical and biological monitoring (1988–2008). *Ecological Indicators*, 37: 267-273.

Bonada, N., Prat, N., Resh, V. H., & Statzner, B. (2006) Developments in aquatic insect biomonitoring: a comparative analysis of recent approaches. *Annual Review of Entomology*, 51: 495-523.

Cairns, J., Pratt, J. R. (1993) A history of biological monitoring using benthic macroinvertebrates. In: Rosenberg, D.M., Resh, V. R. (eds.) *Freshwater biomonitoring and benthic macroinvertebrates*. Chapman & Hall, New York, 10-27.

Carlson, R. E. (1977) A trophic state index for lakes. *Limnology and oceanography*, 22(2): 361-369.

Evans, C. D., Monteith, D. T. & Cooper, D. M. (2005) Long-term increases in surface water dissolved organic carbon: Observations, possible causes and environmental impacts. *Environmental Pollution*, 137: 55-71.

Evans, C. D., Jones, T. G., Burden, A., Ostle, N., Zielinski, P., Cooper, M. D. A., Peacock, M., Clark, J. M., Oulehle, F., Cooper, D. & Freeman, C. (2012) Acidity controls on dissolved organic carbon mobility in organic soils. *Global Change Biology*, 18: 3317-3331.

Flower, R.J., Kernan, M., Noon, P.E. and Jones, V.J., (2012) On the factors affecting distributions of freshwater diatom species in a remote South Atlantic archipelago. *European Journal of Phycology*, 47(3): 291-309.

Goldsborough, W. J., & Kemp, W. M. (1988) Light responses of a submersed macrophyte: implications for survival in turbid tidal waters. *Ecology*, 69(6): 1775-1786.

Hodkinson, I. D., & Jackson, J. K. (2005) Terrestrial and aquatic invertebrates as bioindicators for environmental monitoring, with particular reference to mountain ecosystems. *Environmental Management*, 35(5): 649-666.

Masouras, A., Karaouzas, I., Dimitriou, E., Tsirtsis, G. and Smeti, E., (2021) Benthic Diatoms in River Biomonitoring—Present and Future Perspectives within the Water Framework Directive. *Water*, 13(4): 478.

Ritson, J. P., Bell, M., Graham, N. J. D., Templeton, M. R., Brazier, R. E., Verhoef, A., Freeman, C. & Clark, J. M. (2014) Simulated climate change impact on summer dissolved organic carbon release from peat and surface vegetation: Implications for drinking water treatment. *Water Research*, 67: 66-76.

Sykes, J. M., & Lane, A. M. J. (1996) *The United Kingdom Environmental Change Network: protocols for standard measurements at terrestrial sites*. Centre for Ecology and Hydrology. http://nora.nerc.ac.uk/id/eprint/16518/

Thompson, J.R., Gavin, H., Refsgaard, A., Refstrup Sørenson, H., Gowing, D.J. (2009) Modelling the hydrological impacts of climate change on UK lowland wet grassland. *Wetlands Ecology and Management* 17: 503-523

Thompson, J.R., Iravani, H., Clilverd, H.M., Sayer, C.D., Heppell, C.M., Axmacher, J.C. (2017) Simulation of the hydrological impacts of climate change on a restored floodplain. *Hydrological Sciences Journal* 62(15): 2482–2510.

Thrane, J. E., Hessen, D. O. & Andersen, T. (2014) The Absorption of Light in Lakes: Negative Impact of Dissolved Organic Carbon on Primary Productivity. *Ecosystems*, 17: 1040-1052.

UK ECN (2022). *UK Environmental Change Network*. https://ecn.ac.uk/

Wheeler, B.D., Gowing, D.J.G., Shaw, S.C, Mountford, J. O., Money, R. P. (2004) Ecohydrological Guidelines for Lowland Wetland Plant Communities (Eds. Brooks, A. W., Jose, P.V., Whiteman, M. I.) Environment Agency (Anglian Region). https://www.floodplainmeadows.org.uk/sites/www.floodplainmeadows.org.uk/files/files/Eco%20Hydrological%20Guidelines%20(1).pdf