16. An ecohydrological investigation of wetlands in the border counties of Ireland: a framework for a holistic understanding of wetland systems

Valerie McCarthy[1] and Alec Rolston[1]

How to cite this chapter:

McCarthy, V. and Rolston, A., 2016 'An ecohydrological investigation of wetlands in the border counties of Ireland: a framework for a holistic understanding of wetland systems' in M.E. Young (ed.), *Unearthed: impacts of the Tellus surveys of the north of Ireland*. Dublin. Royal Irish Academy.

DOI: https://doi.org/10.7486/DRI.hd775d90j

With increasing recognition of the value of wetlands, there is an increased need to acquire baseline information on their status in Ireland. Using Tellus soil geochemistry data, in conjunction with a range of other data already available from a variety of sources, we collated information on the occurrence of wetlands across the border counties of Ireland in relation to key geochemical and geological characteristics. In addition, we carried out detailed monitoring at selected case-study sites. The lessons learned during this process were used to inform the development of a framework for wetland assessment, with emphasis placed on synthesising methods from different fields of science in order to develop a more holistic understanding of wetland systems.

Introduction to wetlands

Wetlands are areas that are periodically or permanently inundated by surface water or groundwater and support vegetation adapted for life in saturated soil. Consequently, they are sensitive to changes in both of these water supply systems. Wetlands provide major ecosystem services, which are processes perceived to be beneficial to human society (Cairns, 1997). Wetlands can affect the hydrological cycle and hence the supply of water for both drinking and irrigation (Kingsford, 1999), and also have an important role in flood mitigation where floodplains, lakes and reservoirs may reduce the impact of floods. In addition, certain biogeochemical processes occurring within wetland ecosystems can play an important role in nutrient cycling and attenuation (Reddy and DeLaune, 2008), and they

[1] Dundalk Institute of Technology.

have an important function in the global carbon cycle (Mitsch *et al*., 2013). Wetlands can also provide significant cultural, aesthetic and educational benefits.

A number of studies have attempted to value wetland ecosystem services, but these estimates vary widely owing to differing analyses and data availability. In Ireland, the biodiversity value of wetlands has been estimated to be €385 million per year (DEHLG, 2008). In addition, the value of six case-study sites in County Monaghan over a 50 year period was estimated to range from €10,000 to €2.9 million, depending on the size of the wetland (Eftec, 2010).

Despite the evidence that wetlands contribute significant value to the global environment and economy, major wetland habitat loss has occurred throughout the world (Millennium Ecosystem Assessment, 2005), including in the UK and Ireland (Berry *et. al*., 2003; Morris and Camino, 2011; Lehane and O'Leary, 2012). This is due at least in part to inadequate identification and valuation of their benefits. However, with greater awareness of their value, there is an increased need to acquire information on the current status of wetlands and assess the level to which they are being affected by human activities. There are numerous national and international policies relating to the protection of wetlands, principal among which is the EU Habitats Directive (HD, 92/43/EEC). This Directive aims to protect, maintain or restore to favourable conservation status selected species and habitats of importance, and lists numerous wetland habitats and species under Annexes I and II. In addition, the main objective of the EU Water Framework Directive (WFD, 2000/60/EC) is the achievement of good ecological and chemical status for surface waters and good chemical and quantitative status for groundwater. Therefore, as a consequence of their association with other water bodies, protection of wetlands is implicit within the WFD.

Developing a holistic approach to wetland assessment

It has been recognised that there is a lack of baseline data for the full range of Irish wetlands (Foss, 2007; Kilroy *et al*., 2008; Kimberley and Coxon, 2013). The work summarised here aimed to investigate the water delivery mechanisms and water requirements (notably water levels and hydrochemistry) of different types of regional wetlands across counties on both sides of the Irish border, in order to describe and characterise the biological communities within these wetland systems. Emphasis was placed on developing an understanding of the relationships between hydrogeology, hydrochemistry and ecology. A multidisciplinary approach was therefore of fundamental importance, in which hydrologists, ecologists and geologists worked closely together in developing the monitoring programme, the subsequent analyses of data and development of conceptual models. By synthesising data and methods from different fields of science, new insights into the functioning of ecosystems can be obtained.

A two-phase approach was undertaken. The first phase involved a desk-based review of wetland systems, which included the development of a baseline report on the occurrence of wetlands across the border counties of Ireland. This involved a combined approach using digital spatial data sets and published and unpublished survey data held by local authorities and other institutions, with simple walkovers and more detailed monitoring where needed. The Tellus and Tellus Border geochemical data sets were an additional source of data for the implementation of this desk-based approach, providing important regional information on geochemical and geological features likely to influence wetland occurrence. These data were then used as a basis to shortlist wetland sites for further assessment. The shortlisted case-study sites were monitored intensively over a 14 month period for a range of hydrochemical, hydrological and ecological parameters. This allowed the development of a working hypothesis describing key environmental processes including an understanding of the mechanisms of water delivery and the identification of major pressures acting on the site and ecosystem processes. The details of the work done at the case-study sites were presented by McCarthy and Rolston (2013).

Wetland occurrence in the border counties of Ireland

In order to improve wetland management it is necessary to acquire information on the occurrence and distribution of wetlands. The type of wetland that develops in a particular landscape setting can be determined by a range of factors, including underlying geological and geochemical conditions. As a first step in the development of a full inventory of wetland sites for both the Republic of Ireland and Northern Ireland, information was collated on the occurrence of wetlands in relation to a range of geological and geochemical characteristics in the border counties using the Tellus and Tellus Border geochemical data sets, in conjunction with a range of digital data sets already available from a variety of sources (e.g. soil and subsoil data from Teagasc and the Agri-food and Bioscience Institute (AFBI), and bedrock geology data from GSI and GSNI).

Data on the occurrence of wetlands with designated protection was collated including information on Special Protected Areas (SPAs), Special Areas of Conservation (SACs), Areas of Special Scientific Interest (ASSIs) and National Heritage Areas (NHAs). In addition, sites that had previously been monitored or surveyed but did not necessarily have designated status were included and were identified following consultation with local authority representatives and other stakeholder groups. Consequently, information was gathered for over 2000 known wetland habitats and the key geochemical and geological parameters occurring within a 1.5 km radius of the wetland were then assessed.

The use of the Tellus data sets was beneficial in allowing observations to be made regarding the occurrence of wetland habitats within the border counties, which were found over a range of different geological and geochemical environmental conditions. As an example, loss on ignition (LOI) data (measured as a proxy for carbon content) obtained from the Tellus Border data set showed, as expected, that the highest LOI values in the Republic of Ireland border counties were associated with bogland habitats, such as blanket bogs and raised bogs, and with peatland environments (such as poor fen, dystrophic lakes

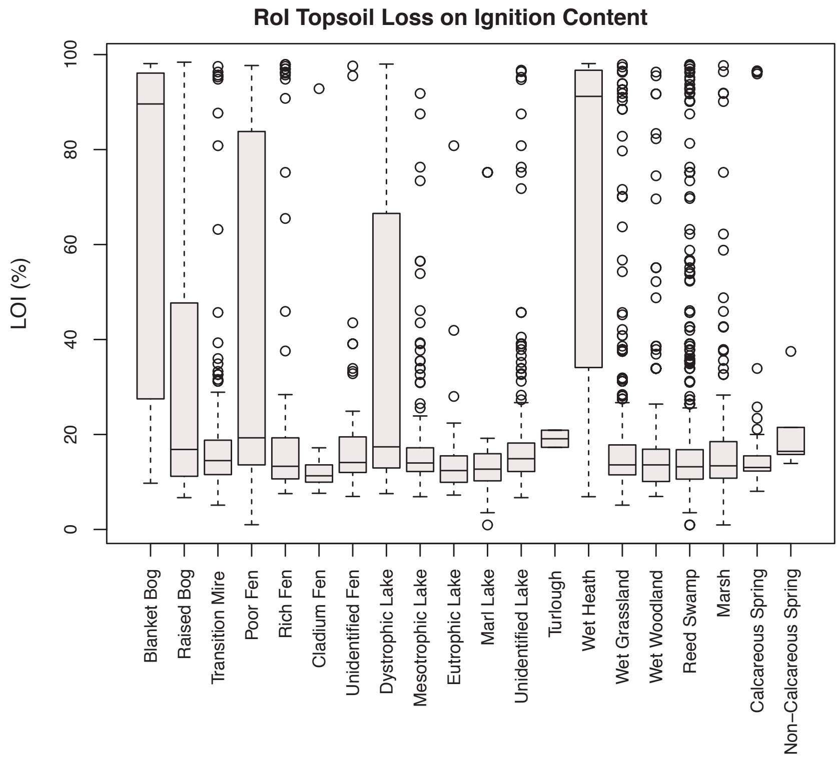

Figure 16.1. Comparison of topsoil loss on ignition (LOI) across wetland habitat types in the Republic of Ireland border counties using the Tellus Border geochemical data set. The boxplots show the median, 75th percentile and 25th percentile, whiskers delineate the data value less than or equal to 1.5 times the inter-quartile range outside the quartile, o = outlier data value ≤3 times and >1.5 times the inter-quartile range outside the quartile.

and wet heath) (Fig. 16.1). Nevertheless, blanket bog and raised bog differed significantly in the LOI content of their topsoils, with raised bogs occurring in areas with lower LOI content but higher values of pH, aluminium (Al), manganese (Mn) and phosphorus (P) than blanket bogs, despite the fact that both are acidic bogland habitats. Further exploration of these data is required and has the potential to further understanding of the key hydrochemical conditions required for specific wetland types.

Developing a framework for wetland assessment

As described above, five case-study sites with a range of habitat types were shortlisted for intensive monitoring based on data collected during the initial desk-based phase, which also included preliminary scoping visits, site inspections and spot sampling where necessary. The intensive monitoring was carried out once a month between June 2012 and August 2013 (Table 16.1; Fig. 16.2) using hydrological, geochemical, hydrochemical and ecological methods. Samples of both surface water and groundwater were taken and analysed for physico-chemical characteristics indicative of water quality at each site. Data on various hydrological parameters such as water level and flow were also taken using a variety of techniques including the installation of piezometers, water level, temperature and pressure groundwater data loggers, flow meters and gauge boards. Biological data on macroinvertebrates, plankton and vegetation were also recorded. The number, location and

Table 16.1. Intensive monitoring data.

Site name	County	Coordinates	Site area (ha)	Wetland habitat type	Surface/GW dependency
Kilroosky Lough	Fermanagh/ Monaghan	249563, 327375	23.53	Marl lough, *Cladium* fen, large reed and sedge swamp, wet woodland, drainage ditches	Predominantly surface water and some inflow from springs
Greenan Lough	Down	311846, 323301	18.24	Mesotrophic lough, reedbed swamp, fen	Likely groundwater inflow
Loughaveely	Armagh	295467, 314157	4.73	Poor fen, swamp, open water, wet grassland	Predominantly groundwater
Windy Gap	Louth	313096, 313382	5.48	Cutover blanket bog, bog pools, poor fen, wet grassland	Surface water
Rockmarshall	Louth	311627, 308207	23.00	Transition mire and fen, reed and large sedge swamp, wet grassland, drainage ditches	Groundwater

type of monitoring points within each site varied depending on the hydrological features of the site. The data collected through the monitoring programme were used to develop conceptual diagrams for shortlisted sites, which summarise the current understanding of the mechanisms of water delivery and ecosystem function of each site, and the pressures acting upon and within the site.

Overview of five-stage framework for wetland assessment

The experience of setting up the monitoring protocol as described above, and the lessons learned throughout this process, led to the development of a framework for the assessment of wetland habitats, which is aimed to be applicable to the objectives of both the Habitats Directive and the Water Framework Directive. Wetland assessment is essential in order to understand threats, risks and likelihood of change to the hydrological and ecological character of wetland habitats, factors that depend on the system's resistance or its ability to withstand change and resilience. Human-induced environmental impacts can affect wetlands' ecosystem stability, resilience or resistance and will consequently affect their ability to provide ecosystem services.

The assessment can be undertaken in a number of ways, from initial low-cost, desk-based data and literature gathering through to large scale, multi-stakeholder, multi-year, high-investment research and monitoring projects. However, wetland assessment is typically resource-limited in terms of budgets, time and personnel. In order to achieve the key tasks of this project, a combination of desk-based data collation and intensive seasonal field monitoring was undertaken. Desk-based data collection was carried out in order to acquire information on the occurrence of wetlands in the border counties and as part of

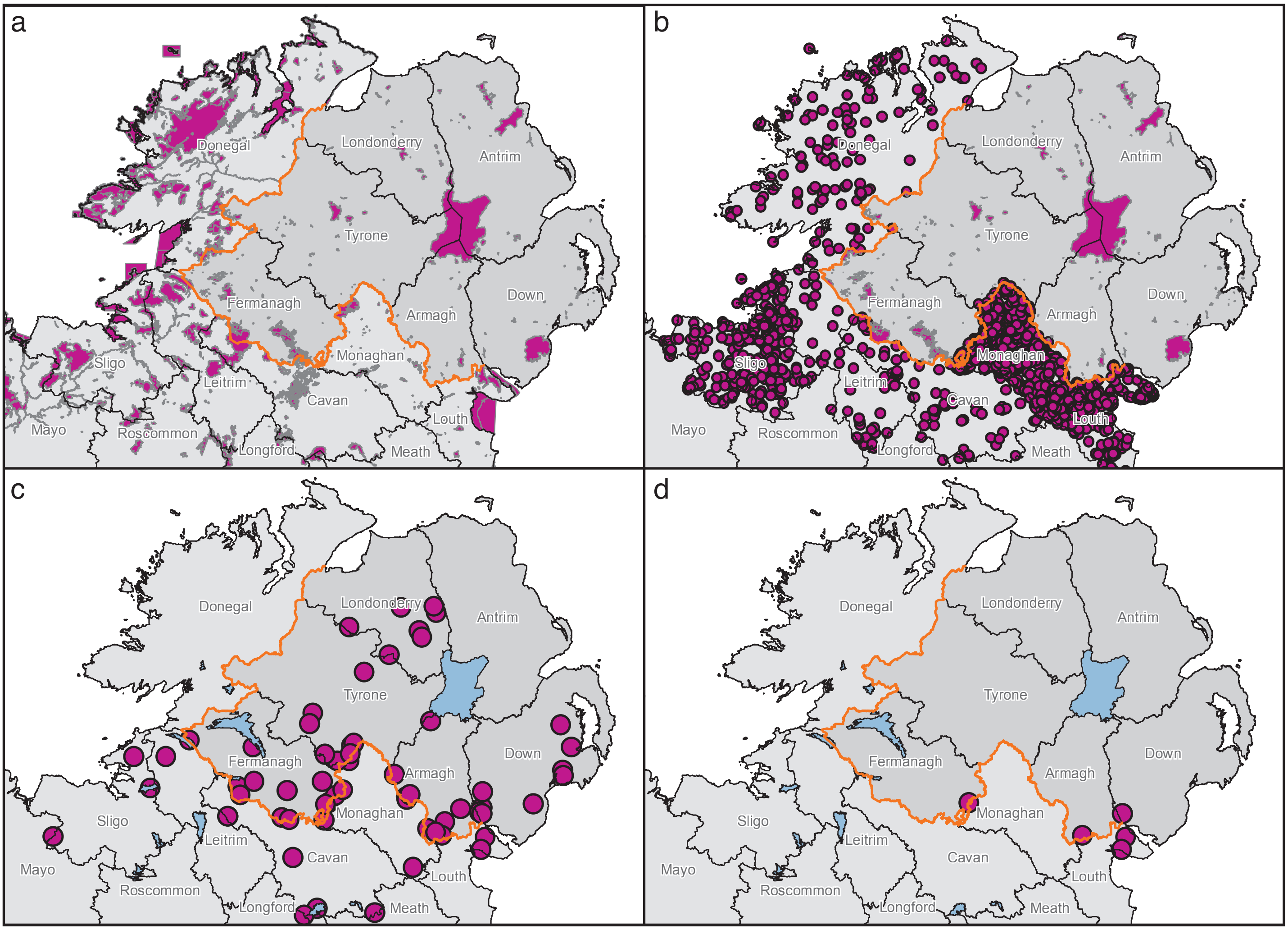

Figure 16.2. (a) All protected areas in the Tellus and Tellus Border survey areas. (b) ASSI sites in NI containing wetland habitats and all known/surveyed wetland habitats in the RoI border counties. (c) 60 sites selected for potential further investigation. (d) Locations of five sites chosen for further investigation.

the site shortlisting process. This also allowed an initial wetland characterisation of the shortlisted sites which identified key knowledge gaps and helped to define the wetland monitoring activities over the course of the project.

The framework developed (Fig. 16.3) adopts a five-stage approach to wetland assessment, with a number of tasks identified within each phase. The level of expertise required to complete each phase is identified as basic, moderate or expert. The five phases of the framework are as follows.

Phase I, the initial phase. A desk-based data-gathering exercise that can be undertaken by personnel at the lower (basic) expertise level, with the aim of collating all known information available on the wetland habitat or site. This phase is divided into three distinct tasks:

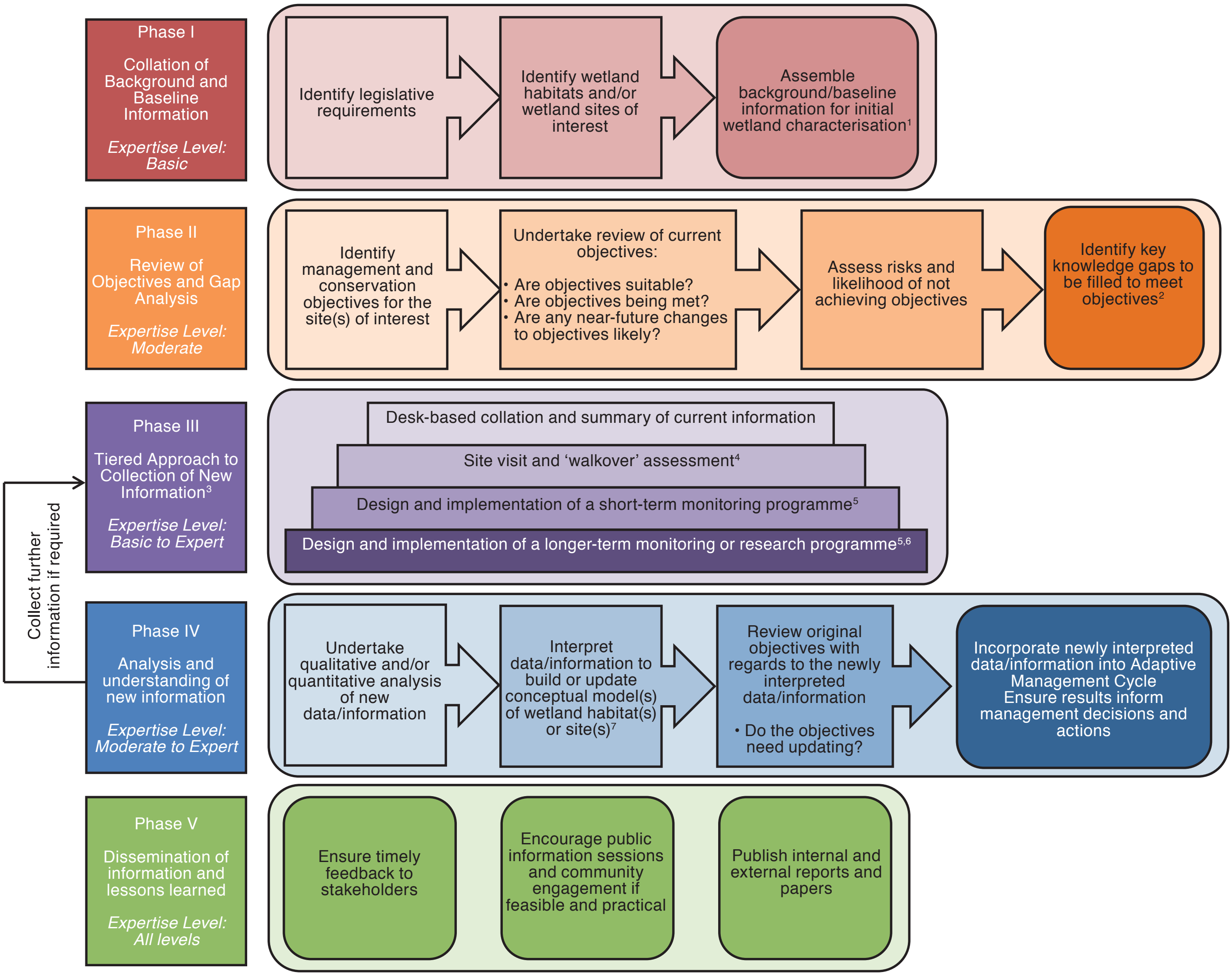

Figure 16.3. Framework for the assessment of wetland habitats and sites.
[1]Background/Baseline information should include, but not be restricted to: (1) underlying geology; (2) soils; (3) subsoils; (4) aquifer classification and groundwater vulnerability; (5) delineation of catchment area(s); (6) CORINE data; (7) hydrological data for both surface waters and groundwaters; (8) ecological data (e.g. vegetation, macroinvertebrate and bird surveys); (9) hydrochemical data.
[2]Methods for filling knowledge gaps include (1) desk-based studies and literature reviews; (2) field-based surveys; and (3) networking with external bodies and agencies (national and international).
[3]This four-tiered approach is resource limited in terms of budget, time and personnel.
[4]A site walkover assessment should be undertaken by a suitably qualified ecologist and hydrologist in order to confirm: (1) hydraulic connectivity and interactions to, from and within the site and (2) key aspects of the ecology and any potential indicators of a change of ecological character from that for which the site is protected or described (if no conservation designation).
[5]Monitoring programmes should be designed to achieve SMART objectives, answer key questions and be aligned (if feasible) with any current legislative objectives and monitoring programmes.
[6]Additional funding and research collaborators are likely necessary to implement longer term (>1 year) monitoring and research programmes. National and International funding bodies and programmes will be important, in addition to the leveraging of additional funding from industry, academia and in-kind contributions from governmental bodies, NGOs and community groups and other stakeholders.
[7]Conceptual model building for wetland habitats should aim to follow the processes outlined by Wilkinson *et al.* (2007a, 2007b).

Task 1 is the identification of any legislative requirements that are driving the assessment;
Task 2 is the identification of wetland habitats and/or wetland sites that are of interest;
Task 3 involves the assemblage of all available background and baseline information on the wetland habitat and/or site(s), to develop an initial characterisation of the wetland.

Phase II, review of objectives and gap analysis. Before any specific investigations are undertaken, a clear understanding of the management and conservation objectives of the habitat and/or site is required. A moderate skill level is required for this stage. Four tasks are outlined in Phase II:
Task 1 involves identification of the management and conservation objectives for the site(s) of interest;
Task 2 requires a review of current management and conservation objectives for the site and assessment as to whether these objectives are currently being met;
Task 3 requires assessment of the risks and likelihood of not achieving the objectives;
Task 4 acknowledges that if the objectives are not being met, there will be key knowledge gaps that need to be filled in order to move towards achieving the objectives.

Phase III, tiered approach to the collection of new information. The level of investigation that is required can be determined following the identification of key knowledge gaps and also an examination of resources. Budgets, personnel and time are the limiting factors associated with the collection of new information and a four-tiered approach has been developed that reflects these limitations:
Tier 1 is a desk-based collation and summary of current information;
Tier 2 requires a site visit and walkover site investigations;
Tier 3 involves the design and implementation of a short-term monitoring programme;
Tier 4 involves the design and implementation of a longer-term monitoring or research programme.

Phase IV, analysis and understanding of new information. The information collected in Phase III must be analysed and interpreted. This generally requires an expertise level of medium to expert. Four tasks are outlined in Phase IV:
Task 1 requires qualitative or quantitative analysis of new data or information to be undertaken;
Task 2 requires any updating of the conceptual understanding of the wetland habitat or site;
Task 3 involves a review of the original management and conservation objectives in light of the newly refined conceptualisation of the wetland habitat. Assessment of what is required to fully address any outstanding knowledge gaps should be addressed, which may lead to the collection of further information if necessary;

Task 4 requires that all newly interpreted information and data must be incorporated into an adaptive management cycle to ensure that management decisions and actions are informed by the most up-to-date information available. Communication of the data and information is therefore vital.

Phase V, dissemination of information and lessons learned. Incorporating new information into an adaptive management cycle critically relies on the clear communication of that information. Communication will be important across a number of levels from senior management through to the engagement of community groups and can be undertaken in different ways, both orally and written, through published reports, papers and presentations, formally through official management and funding reporting structures and informally through casual meetings and conversations.

Conclusion

In order to meet our obligations fully under EU legislation such as the Habitats Directive and the Water Framework Directive, there is a need to develop our understanding of the relationship between hydrogeological and ecological characteristics of wetland systems, particularly those that are dependent on groundwater. In this way it will be possible to gain a more complete understanding of how these systems function in terms of hydrological services such as flood mitigation, supply of freshwater and groundwater recharge (Mitsch and Gosselink, 2000). Improved strategies for managing wetlands require knowledge relating to the ecological character of wetlands, the extent of wetland loss, the implementation of management strategies and an evaluation of their success following implementation. In turn, this baseline information should be linked directly to the principal legislative and policy drivers in order to facilitate meeting Ireland's obligations in this regard, and to guarantee successful integration with management processes. This will provide the basis for maintaining the ecological functioning of a wetland and will ensure the sustainable use of resources.

The data collated as part of this project have provided baseline information on the response of wetland systems to hydrological and hydrochemical variations and on the principal threats to wetland habitats in the border counties of Ireland. This has been achieved as a consequence of a two-phase approach which included a desk-based study in combination with site visits and walkover investigations followed up by intensive monitoring programmes at a set of case-study sites, which proved highly effective. During this process, the Tellus and Tellus Border geochemical data sets provided an effective source of data on geochemical and geological characteristics which may influence wetland occurrence.

The project benefited greatly from the multidisciplinary approach taken. Co-operation between hydrogeologists and ecologists is vital so as to ensure that scarce resources are not needlessly exhausted through repetitive sampling, which often fails to integrate conceptual understanding from the full range of hydrogeological, hydrochemical, geochemical and biotic factors affecting ecosystem function. It is also important when planning monitoring programmes that hydrologists and ecologists operate within the same scale (e.g. catchment, wetland site, within wetland site) so that ecological effects can be measured. By taking this multidisciplinary approach it will also be possible to improve understanding of the links between groundwater and ecological communities, particularly in groundwater-dependent terrestrial ecosystems (GWDTEs), thereby allowing a more holistic approach to water resource management (Hancock *et al*., 2009).

The methodologies used throughout this project can provide a framework for similar multidisciplinary studies to be conducted over a wider range of wetland habitat types, so as to provide an integrated approach to data collection and consequentially improved understanding of integrated ecosystem processes. Monitoring programmes that aim to address the requirements of both the HD and the WFD should be encouraged, to ensure a more cost-effective use of limited resources. Although the scope of the two directives differs, it is possible to integrate monitoring programmes by including biological quality elements, which are needed for both directives, or by including elements required for both directives in the same programme, allowing an assessment to be made based on a common data set.

The importance of long-term monitoring sets must also be considered as they allow assessments of ecosystem change to be monitored, providing evidence of the impact of land-use change or other management decisions on ecosystem processes over time. This is particularly significant as implementation of both the HD and the WFD requires the identification of threshold hydrochemical and hydrological conditions. These thresholds can be difficult to define in complex systems, particularly as they may vary over time, and this variability may be necessary to maintain system stability or resilience. There is, however, a lack of long-term data sets. Research must be carried out in conjunction with more widespread surveys of wetland condition in relationship to potential impacts, to ensure that ecohydrological dynamics are fully understood. Cross-jurisdiction co-operation is also necessary in order to ensure coherent interpretations of data collected and effective management, particularly in cases where sites span the border.

References

Berry, P.M., Dawson, T.P., Harrison, P.A., Pearson, R. and Butt, N., 2003 'The sensitivity and vulnerability of terrestrial habitats and species in Britain and Ireland to climate change', *Journal for Nature Conservation*, 11, 15–23.

Cairns J., Jr, 1997 'Protecting the delivery of ecosystem services', *Ecosystem Health*, 3, 185–94.

DEHLG, 2008 *The Economic and Social Aspects of Biodiversity: Benefits and Costs of Biodiversity in Ireland*. Dublin. Department of the Environment, Heritage and Local Government.

Economics for the Environment Consultancy (Eftec), 2010 *Wetland Ecosystem Economics: Evaluating the Benefits Derived from Monaghan's Wetlands*. Final report submitted to Monaghan County Council and the Heritage Council. London.

Foss P., 2007 *Study of the Extent and Conservation Status of Springs, Fens and Flushes in Ireland 2007*. Internal Report for the National Parks and Wildlife Service. Dublin. Department of the Environment, Heritage and Local Government.

Hancock, P.J., Hunt, R.J. and Boulton, A.J., 2009 'Preface: hydrogeoecology, the interdisciplinary study of groundwater dependent ecosystems', *Hydrogeology Journal*, 17, 1–3.

Kilroy, G., Dunne, F., Ryan, J., O'Connor, Á., Daly, D., Craig, M., Coxon, C., Johnston, P. and Moe, H., 2008 *A Framework for the Assessment of Groundwater-Dependent Terrestrial Ecosystems under the Water Framework Directive*. Wexford. Environmental Protection Agency. Available at https://www.epa.ie/pubs/#.VoloT1LOHYQ.

Kimberley, S. and Coxon, C., 2013 *Evaluating the Influence of Groundwater Pressures on Groundwater-Dependent Wetlands*. Wexford. Environmental Protection Agency.

Kingsford, R.T., 1999 'Managing the water of the Border Rivers in Australia: Irrigation, government and the wetland environment', *Wetlands Ecology and Management*, 7, 25–35.

Lehane, M. and O'Leary, B., 2012 *Ireland's Environment 2012 – An Assessment*. Wexford. Environmental Protection Agency. Available at https://www.epa.ie/pubs/reports/indicators/00061_EPA_SoE_2012.pdf.

McCarthy, V. and Rolston, A., 2013 *Wetland Project: An Ecohydrological Investigation of Wetlands in the Border Region of Ireland*. Tellus Border Project Report. Available at http://www.tellusborder.eu/Research/.

Millennium Ecosystem Assessment, 2005 *Ecosystem and Human Well-Being: Wetlands and Water Synthesis*. Washington, DC. World Resources Institute.

Mitsch, W.J., Bernal, B., Nahlik, A.M., Mander, U., Zhang, L., Anderson, C.J., Jorgensen, S.E. and Brix, H., 2013 'Wetlands, carbon, and climate change', *Landscape Ecology*, 28, 583–97.

Mitsch, W.J. and Gosselink, J.G., 2000 'The value of wetlands: Importance of scale and landscape setting', *Ecological Economics*, 35, 25–33.

Morris, J. and Camino, M., 2011 *Economic Assessment of Freshwater,* Wetland and Floodplain (FWF) Ecosystem Services. Cambridge. UK National Ecosystem Assessment (UKNEA) Working Paper. Available at http://uknea.unep-wcmc.org/.

Reddy, K.R. and DeLaune, R.D., 2008 *Wetlands: Science and Applications*. Boca Raton, FL. CRC Press.

Wilkinson, J., Souter, N. and Fairweather, P., 2007a *Best Practice Framework for the Monitoring and Evaluation of Water-Dependent Ecosystems 1: Framework*, DWLBC Report 2007/12. Adelaide, Australia. Department of Water, Land and Biodiversity Conservation. Available at https://www.waterconnect.sa.gov.au/SearchCenter/results.aspx?k=Best%20Practice%20Framework.

Wilkinson, J., Souter, N. and Fairweather, P., 2007b *Best Practice Framework for the Monitoring and Evaluation of Water-Dependent Ecosystems 2: Technical Resource,* DWLBC Report 2007/13. Adelaide, Australia. Department of Water, Land and Biodiversity Conservation. Available at https://www.waterconnect.sa.gov.au/SearchCenter/results.aspx?k=Best%20Practice%20Framework.

Table of Contents:

Unearthed: impacts of the Tellus surveys of the north of Ireland
First published in 2016 by the
Royal Irish Academy
19 Dawson Street
Dublin 2
www.ria.ie

ISBN: 978-1-908996-88-6

British Library Cataloguing-in-Publication Data. A catalogue record is available from the British Library.

Design: Alex Donald, Geological Survey of Northern Ireland.
Index: Brendan O'Brien.
Printed in Poland by L&C Printing Group.