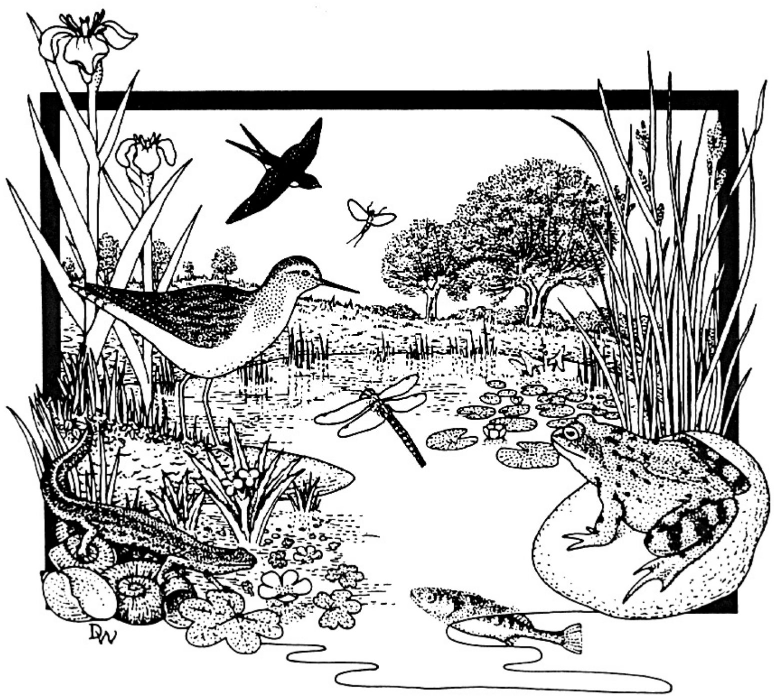
Pond Action & The Ponds Conservation Trust

Proceedings of the

Ponds Conference 1998

10 - 12th December 1998
Denman College, Abingdon, Oxon.



Pond Action
c/o Oxford Brookes University
Gipsy Lane Headington
Oxford OX3 0BP
Tel: 01865 483249; Fax: 01865 483282
www.brookes.ac.uk/pondaction

Proceedings of the
Ponds Conference 1998

This document should be cited as:

Pond Action (2000). *Proceedings of the Ponds Conference 1998*. Pond Action, Oxford.

Published by Pond Action, Oxford, October 2000.

ISBN: 0-9537971-1-2.

Acknowledgements

Pond Action would like to thank the National Federation of Women's Institutes for hosting the 1998 Ponds Conference. We are also very grateful to all who gave papers and those that chaired sessions and workshops.

Pond Action
c/o Oxford Brookes University
Gipsy Lane Headington
Oxford OX3 0BP
Tel: 01865 483249; Fax: 01865 483282
www.brookes.ac.uk/pondaction

Contents[1]

[1] Note: in multi-author papers, the first author gave the conference presentation

Biographical notes of conference speakers

Dr Pedro Beja is Assistant Professor of Habitat Management and Coastal Zone Management at the University of Algarve. He has a wide range of interests in the ecology and conservation of freshwater ecosystems and following the completion of his PhD in 1996 for work on the ecology of otters, he has been responsible for the initiation of a programme of work on the conservation biology and management of threatened vertebrate aquatic species including otters, endemic freshwater fish (*Cottus* spp.) and endemic amphibians. He has also worked on the amphibian and aquatic invertebrate assemblages of temporary ponds and has a special interest in the impact of agricultural intensification on the ecology of temporary ponds.

Dr Jeremy Biggs is a founder member and Manager of Pond Action. He specialises in conservation policy, ecological assessment and invertebrate ecology.

Dr Mervyn Bramley is Head of R & D at the Environment Agency. He is a civil engineer by profession and worked for 15 years in the management of water resources in various parts of the world before turning to research. His interests at the interface between research and practice led him to become Water Research Manager with Construction Industry Research and Information Association (CIRIA) where one of the initiatives he took forward was the CIRIA Guide on Design of Flood Storage Reservoirs (Storage Ponds). He is involved with many bodies outside of the Agency including the UK Foresight Panel on Natural Resources and the Environment.

Dr Steve Brooks is a member of the British Dragonfly Society and works as a research entomologist at the Natural History Museum**.**

Dr Jane Bunting is currently a lecturer in the Department of Geography at the University of Hull. She is an environmental archaeologist and palaeoecologist, whose main research interests are the evolution of cultural landscapes over the last 10,000 years. She obtained her PhD from the University of Cambridge, and worked at the Universities of Waterloo (Ontario), Sheffield and Stirling before moving to Hull.

Dr David Keen is a lecturer in the Centre for Quaternary Science, at the University of Coventry. He specialises in the palaeoecology of the Mollusca and using palaeolecology in environmental reconstruction.

Tom Langton is the founder and Director of Herpetofauna Consultants International and a leading UK amphibian ecologist. He specialises in protection schemes for the great crested newt.

Steve Maund is Group Leader for Aquatics and Non-target Plants at Zeneca Agrochemicals. He manages a pesticide ecotoxicological-testing programme working with the regulators to improve the safety of pesticides.

Mericia Whitfield is a member of the Pond Action team and specialises in the ecology of aquatic invertebrates.

Pascale Nicolet joined the Pond Action team at the end of 1998. She has an MSc in Environmental Technology from Imperial College, University of London.

Dr Martin Perrow is founder of ECON Environmental Consultancy at the University of East Anglia and specialises in fisheries ecology and biomanipulation for conservation and restoration of lakes.

Dr Simon Pickering is Conservation Advisor to the Wildfowl & Wetlands Trust and Biodiversity and Conservation Officer for the Cotswold Water Park Society. He is the Chairman of the UK Pond Conservation Group and Gloucestershire Hydro Power committee. He is also a member of the DETR Coastal Forum; DETR UK SPA/RAMSAR working group; Gwent Levels Wetlands Reserve steering group; and co-ordinator of Gloucestershire's 'Vision 21' Transport Working Group. He gained an honours degree in Applied Biology at Hatfield Polytechnic in 1979 and his PhD at the University of Durham in 1983.

Dr Tim Rich is a leading field botanist who project managed the field surveys teams for the DETR Lowland Pond Survey and the Cardiff Pond Surveys of 1997 and 1998. He is now Head of Vascular Plants at the National Museum of Wales and has particular experience of surveys, monitoring and assessing the value of vegetation in a range of habitats.

Martin Spray is the Director of the Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust, with responsibility for all aspects of strategic development and management. He has experience of working with volunteer and community groups and managing environmental education and biodiversity programmes. He is a trustee of the Trust for Oxfordshires Environment, member of the Country Landowners Association Oxfordshire Committee and former Area Manager in London and the South East for WWF-UK. He is active in the Oxfordshire Nature Conservation Forum and takes on national responsibilities for the Wildlife Trust Partnership. He obtained an Honours degree in Zoology at the University of Wales, Swansea in 1973.

Dr Mary Swan runs the Amphibian Habitat Advisory Services and was the co-organiser of the National Amphibian Survey with Professor Rob Oldham.

Penny Williams is a member of the Pond Action team and specialises in the design, ecology and management of pond ecosystems. She is a highly experienced field botanist.

The palaeoecology of ponds: evidence from the Pleistocene record

David Keen

Centre for Quaternary Science, Coventry University, Prior Street, Coventry, CV1 5FB.

Introduction

For ponds to develop, basins capable of being flooded are required. In the case of extant ponds it is easy to see small water bodies formed in a large variety of hollows. In the geological record ponds are only identifiable by their sedimentary infill and its contained biota. Small sediment bodies are rarely preserved, so the record of very small ponds is poor. Larger ponds and their infills are better known, and overwhelmingly are formed from flooded basins due either to glaciation or to floodplain processes such as meander cut-off. Much more rarely pond basins may be formed by landslides or karstic subsidence, but overwhelmingly the evidence for ponds of Pleistocene age is found associated with glaciation or fluvial action.

Glacially-formed ponds in Britain only occur north of the ice limit. The maximum extent of the ice was during the Anglian Glacial Stage around 450,000 years ago. At this time the ice reached a line from north Essex and north London, west to Bristol and along the north coast of the South West Peninsula (Jones & Keen, 1993). Although lake basin infills from this stage are known in East Anglia (West, 1956; Turner, 1970), later erosion and weathering has destroyed all evidence of the existence of smaller water bodies. The only major glaciation after the Anglian which is agreed on by all authorities is the Devensian (Jones & Keen, 1993) which ended around 10,000 years ago. This stage had ice limits from the north Norfolk coast to Wolverhampton, south Wales and the south of Ireland. Many of the basins excavated by the Devensian ice still have ponds in them, especially in hard rock districts of the west and north, but most are already infilled with muddy sediments and peat.

By contrast with glacially formed ponds, floodplain ponds occur wherever rivers have developed and then abandoned part of their channels. Such pond basins can occur anywhere in Britain, and are best found in the context of the interglacial stages evidence for which can be found at least back to 650,000 years ago.

Size and ephemeral nature of ponds

In glacial areas flooded basins may range in size from a few metres in diameter to Lake Windermere. Large lakes persist in the landscape, but most genuine ponds are short lived. If basins are connected to streams sedimentation on newly de-glaciated terrain will be rapid and most ponds will be infilled in 2-3,000 years. Even closed ponds infill rapidly, at first with blown sand and silt in newly de-glaciated terrain, then with overland sheet wash. Most important in pond infill is the contribution of organic material. The lake chalk or marl so characteristic of pond infills in the area of Devensian glaciation in northern Britain (Keen *et al.* 1988) is principally composed of debris from *Chara* spp. Up to 3 m of such sediment accumulated in many ponds in the first 2-3,000 years after the retreat of Devensian ice in Yorkshire and Northumberland, so that the original basins became reduced in depth enough for colonisation by shallow water macrophytes which soon completed the infill of the basins with fen peat.

Floodplain ponds, mostly formed as sections of channel abandoned by processes such as meander cut-off, may be equally short-lived. These ponds are still in contact with the river at times of flood, so that they are infilled by fluvial sediments as well as by organic materials of all kinds. Most floodplain pond infills seem to indicate deposition over the same sorts of time spans as those of glacial basins. The majority of such basins examined (Green *et al.* 1996; Keen *et al.* 1999) exhibit pollen from only part of the theoretical interglacial pollen sequence of Turner & West (1968). As the full sequence of interglacial pollen development seems to take about 10,000 years to accomplish (Jones & Keen, 1993) ponds with pollen spectra representing only part of this time must indicate a time span of less than 10,000 years. In the Ipswichian Interglacial (128-118, 000 years before present) most pollen records from floodplain ponds represent around a quarter of the stage and so were developed and infilled in between 2-3,000 years (Keen *et al.* 1999). That these estimates are realistic are confirmed by the time taken for floodplain ponds to infill in the present interglacial where radiocarbon dating allows accurate age estimates of time from establishment to infill of basins. At Enfield Lock, Middlesex a floodplain pond was initiated during the transition of the River Lea to a meandering form at 9,500 years ago, and finally infilled by 6,500 before present, after the development of *Chara* marl and then deposition of peat and silt. The final infill of this pond (Chambers, Mighall & Keen, 1997) was aided by the soil erosion caused by the advent of Neolithic farming in the area, but the pond was already very shallow and close to complete infill by this time.

Environmental evidence from ponds

Evidence available from pond sediments can give a baseline of pond environments before the action of human cultures made all such modern environments artificial. Palaeontological work on the biota from pond sediments can show what the conditions were like in a "natural" pond. However, the controls of fossilisation and taphonomy (the changes that occur in a natural association of living organisms from death to final burial in sediment) may remove much of the biota of a living assemblage before it can be fossilised. For example no soft-bodied invertebrates are fossilised, removing a considerable part of the potential environmental evidence as compared to a living assemblage. Palaeontological work has centred around particular fossil groups which are abundant and well preserved. Some of these give good information on local environmental conditions, others on regional conditions.

a) Plant fossils

Plant fossils are represented by pollen, but also plant macrofossils (leaves, seeds, fruits etc). Most pollen can only be identified to genus or family, although some taxa can be identified to specific level. Pollen can be blown long distances on the wind or washed along in rivers, so may give a regional climatic signal. Pollen of aquatic plants is often very abundant in pond sediments such that it dominates all of the pollen spectrum and thus may make it difficult to interpret. Where a reasonable number of identifications to specific level can be made pollen can indicate water depth, degree of water movement and water pH. The techniques of pollen analysis are well established and there are a large number of workers in Britain.

Plant macrofossils can almost always be identified to species, so environmental reconstructions can be more accurate than those from pollen alone. Most pond floras are locally derived and so consist of aquatic and waterside plants, but these can give valuable information about water conditions, depth and substrate. The identification of plant macro-remains is difficult because they are mostly degraded and broken. Although identification by comparison with modern material can be done given time, the number of workers active in this field is low.

b) Vertebrate fossils

Vertebrate assemblages are common in pond sediments of temperate origin. Mammals which live in ponds may range in size from hippopotamus found in many Ipswichian Interglacial sites (Stuart, 1982), to water voles and shrews. Most of the small mammals currently live in western European so their habitats are well known and can easily be used to interpret the past. There is a long history of investigation of fossil mammals and considerable expertise is available for their identification and analysis.

The main pond-dwelling vertebrate groups are fish, and amphibian and reptiles. Both of these groups are difficult to identify from their skeletal remains which mostly occur as isolate bones, not whole skeletons. Problems of identification have tended to mean that they have been neglected in the past. However, the recognition that the reptile and amphibian record particularly allows good reconstruction of water conditions and temperature, as well as regional climate, has prompted a recent interest in this group (Gleed-Owen, 1998) and good palaeoenvironmental results have been obtained from their analysis.

Fish are still neglected and there are no experts specialising in Pleistocene fossil fish alone.

c) Invertebrate fossils

The major invertebrate environmental indicators which have been examined are Mollusca, Coleoptera and Ostracoda, although some work has also been done on Trichoptera.

Mollusca are common in pond sediments. Faunas include both gastropods and bivalves. The entire fauna is composed of modern species at least back to the early Middle Pleistocene at 750,000 years ago, so interpretation is easy. In closed basins faunas may include 20 species, in floodplain ponds up to 50 species. Mollusca can give good information about water depth, temperature, flow conditions and substrate. Because of their history of investigation extending back into the 19th century, good museum collections exist and a tradition of molluscan work is well developed. Despite this only three or four experts have been active at any one time in the last fifty years in Britain.

Coleoptera provide very large faunal lists so have high potential to give very detailed information about conditions in the water body and in the area around. Many, principally land, taxa are temperature sensitive and can be used for exact thermal climate reconstructions (Atkinson, Briffa & Coope, 1987). Aquatic Coleoptera and especially Trichoptera give valuable data on water temperature, flow and substrate, the presence of host plants and predator/prey relationships. The huge faunas which have been recovered from some sites (Horton *et al.* 1992; Keen *et al.* 1999) with 2-300 taxa identified present problems of their own for interpretation as considerable levels of expertise are needed to identify the often fragmented and warped exoskeletons. Thus only a few workers are active, all associated with the Birmingham-based team of G.Russell Coope.

Ostracods are entirely aquatic in habitat. Pond faunas contain up to 30 species in a good ostracod environment. They are sensitive indicators of water temperature, salinity, depth and substrate. There are problems with their identification however, because of the lack of morphological differences in the carapaces of most taxa. Thus their study is restricted to one or two experts only.

The best palaeoenvironmental results are obtained by combining all lines of evidence to attempt as complete a reconstruction of the former pond environment as can be obtained. Such work is now done routinely by a number of teams working in Britain, but because of the nature of fossilisation, environmental reconstructions are partial at best. None-the-less much detail can be obtained and the last section of this paper contains two examples of such reconstructions, one from a glacial basin pond, Bingley Bog, West Yorkshire (Keen *et al.* 1988) and one from a floodplain pond infill of Ipswichian Interglacial age at Deeping St James, Linconshire (Keen *et al.* 1999).

Bingley Bog, West Yorkshire

The basin was formed as a kettle, from the melting of a block of buried glacial ice which was emplaced about 2 km from the terminal moraine of the Aire Valley Glacier. This ice limit was occupied at about 15,000 years ago. The pond basin was about 300 m in diameter and 7 m deep at the beginning of sedimentation. The initial infill of the pond was by the formation of *Chara* marl, but because of the recent retreat of the ice, the biota was restricted to a few macrophytes, *Potamogeton* spp. and *Typha*, and a fauna of ten pioneer mollusc and eleven ostracod species. As the basin was not connected to any stream system, these immigrants must have reached the pond as "passengers" on wildfowl, or by other indirect means of dispersal. After about 3,000 years of pond history, a regression to a short phase of glacial climate, the Younger Dryas stadial between 11,000 and 10,000 years before present, caused complete extinction of fauna in the pond and also great reduction of vegetation. Inwash of debris from the basin sides replaced *Chara* marl with muds and this rapid sedimentation caused the near complete infill of the basin. For a short time after the climate warmed again into the present interglacial, *Chara* marl dominated deposition, but the now shallow pond was soon filled with reed swamp and a fen bog was in place by about 8,000 years before present.

Deeping St James, Lincolnshire

This former pond lies close to the channel of the modern River Welland (Keen *et al*, 1999) but was formed as an abandoned channel of a predecessor of the river in the Ipswichian Interglacial. Dates obtained by luminescence methods suggest that deposition was going on around 120,000 years before present and pollen evidence shows that the site was active as a pond during subzone IIb of the interglacial, and thus had a duration of infill of about 3,000 years. The basin was about 2m deep, 50m wide and the preserved portion revealed by gravel quarrying can be seen to be 750 m long. Pollen of aquatic plants shows that the pond was vegetated by the water lilies *Nuphar* and *Nymphaea* as well as sedges and horsetails. Plant macrofossils include the seeds of seven species of *Potamogeton* and *Ranunculus* which occur in Britain today, but also seeds of *Salvinia natans* and *Najas minor* which at present have continental distributions in southern and eastern Europe. The pond infill yielded 31 species of aquatic molluscs including the gastropod *Belgrandia marginata* which is currently distributed in Catalonia and southern France. The insect fauna contains 215 species of Coleoptera, although about 50% of these are from land habitats. A number of these beetles have modern distributions in France, Spain, Italy and the Balkans, all indicating a more temperate and continental climate than occurs in Britain today. The total biota from Deeping St James thus indicates a pond environment with elements of both modern British and south European affinities.

Conclusions

The geological record of ponds of the last few hundred thousand years is a rich one in Britain, with many examples of pond sediments yielding varied evidence for environmental reconstruction. The problems of fossilisation and taphonomy make <u>total</u> reconstruction of former environments very difficult, if not impossible. The example of sites such as Deeping St James indicates that there may be no direct modern analogue for many of the pond sediments which occur in the geological record and underlines the complexity of defining a baseline from which ponds may be conserved. The geological record also shows clearly that ponds are not static elements of the landscape. Over timespans longer than a few centuries the fate of all pond basins is infill and evolution into fen and dry land. Most pond basins have a maximum life expectancy of around 2-3,000 years, with many lasting much less than this, so that conservation needs to be thought of in terms of the ephemeral and developing nature of ponds.

References

Atkinson, T.C., Briffa, K.R. & Coope, G.R. 1987 Seasonal temperatures in Britain during the last 22,000 years, reconstructed using beetle remains. *Nature* **325**, 587-592.

Chambers, F.M., Mighall, T.M. & Keen, D.H. 1996 Early Holocene pollen and molluscan records from Enfield Lock, Middlesex, UK. *Proceedings of the Geologists' Association*, **107(1)**, 1-14.

Gleed-Owen, C.P. 1998 *Quaternary herpetofaunas of the British Isles: taxonomic descriptions, palaeoenvironmental reconstructions, and biostratigraphic implications*. PhD thesis Coventry University, 547pp.

Green, C.P., Coope, G.R., Jones, R.L., Keen, D.H., Bowen, D.Q., Currant, A.P., Holyoak, D.T., Ivanovich, M.,Robinson, J.E., Rogerson, R.J. & Young, R.C. 1996 Pleistocene deposits at Stoke Goldington, in the valley of the Great Ouse, UK. *Journal of Quaternary Science*, **11(1)**, 59-87.

Horton, A., Keen, D.H., Field, M.H., Robinson, J.E., Coope, G.R., Currant, A.P., Graham, D.K., Green, C.P. & Phillips, L.M. 1992 The Hoxnian Interglacial deposits at Woodston, Peterborough. *Philosophical Transactions of the Royal Society of London* **B338**, 131-164.

Jones, R.L. & Keen, D.H. 1993 *Pleistocene Environments in the British Isles.* London, Chapman & Hall, 346 pp.

Keen, D.H., Jones, R.L., Evans, R.E. & Robinson, J.E. 1988 Faunal and floral assemblages from Bingley Bog, West Yorkshire and their significance for Late Devensian and early

Flandrian environmental changes. *Proceedings of the Yorkshire Geological Society* **47**, 125-138.

Keen, D.H., Bateman, M.D., Coope, G.R., Field, M.H., Langford, H.E., Merry, J.S. & Mighall, T.M. 1999 Sedimentology, palaeoecology and geochronology of Last Interglacial deposits from Deeping St James, Lincolnshire, England. *Journal of Quaternary Science*, **14**, 411-436.

Stuart, A.J. 1982 *Pleistocene vertebrates in the British Isles.* London, Longmans.

Turner, C. 1970 The Middle Pleistocene deposits at Marks Tey, Essex. *Philosophical Transactions of the Royal Society of London* **B257**, 373-440.

Turner, C. & West, R.G. 1968 The subdivision and zonation of interglacial periods. *Eiszeitalter und Gegenwart*, **19**, 87-93.

West, R.G. 1956 The Quaternary deposits at Hoxne, Suffolk. *Philosophical Transactions of the Royal Society of London* **B239**, 265-356.

Ancient ponds and modern landscapes

Penny Williams, Jeremy Biggs, Mericia Whitfield, Gill Fox and Pascale Nicolet

Pond Action, c/o Oxford Brookes University, Gipsy Lane, Headington, Oxford OX3 0BP.

Why study natural ponds?

Studies of modern and ancient natural ponds provide many clues about how ponds function, and about the best ways to conserve and protect them. In this paper the aim has been:

(i) to piece together available evidence about pre-historic ponds in order to describe the distribution of ponds in Britain prior to major drainage.

(ii) to discuss how man has changed the natural distribution of ponds to create the modern pond landscape.

(iii) to suggest how this information can inform modern techniques of pond management.

Are ponds man made or natural habitats?

Today, ponds are often thought of as quintessentially artificial habitats. This is hardly surprising: very few modern lowland ponds, probably less than 1% - 2%, appear to have been created by natural processes. Most have been either deliberately or accidentally created by man.

The obvious and very commonly drawn conclusion from this is that ponds are *not a natural habitat type*. However, this is demonstrably false.

There is abundant evidence from the geological record that ponds have existed very commonly in Britain for many millions of years (see Keen, this volume), and that freshwater plants and animals have become well adapted to the conditions that they provide. It is certain too that, even without man's pervasive influence on the landscape, natural ponds would be a common habitat in Britain to this day.

It has been estimated that before our ancestors started draining Britain 2000 to 3000 years ago, about a quarter of the British Isles would have been some kind of wetland (Rackham 1985), and even in the remaining drier areas, much of the land would have been water-logged in winter.

Today, just a few remnants of undrained semi-natural land remain to provide landscape evidence about Britain in the past. Over the last 10 years members of the Pond Action team have spent much time observing the natural ponds of these remaining semi-natural areas in Britain (e.g. the Cambridgeshire fens, the New Forest, Breckland, the uplands of Wales and Scotland) and in Europe (e.g. France, Spain, Poland and Russia) investigating where and how natural ponds are formed.

The New Forest: natural ponds in a dry landscape

The New Forest is the largest area of lowland semi-natural vegetation in Western Europe and it provides one of the best UK analogues for many of the rather drier areas of Britain before drainage and intensification. The Forest has mixed sand and clay geology and many parts of it are naturally very well drained and dominated by dry heath. It is, therefore, surprising how common natural ponds still are in some places (Tubbs, 1986)

Across the Forest as a whole, there are a number of different types of *permanent* pool, most of which are found in association with rivers, floodplains or flushes. They include:

Cut-off channels. Ponds formed in cut-off channels are common in the Forest, but the classic oxbow type is not frequent. Instead most cut-offs are created by isolated sections of braided channel. Such multi-thread channels occur extensively where valley slopes flatten out and numerous channel cut-off pools occur within them, forming behind sediment bars and banks.

Flush pools. A whole series of tiny pools in the New Forest form wherever flushes are disturbed, often by animals or fallen wood. Such pools are common and can be anything from a few centimetres to many metres across. Some are 30 cm deep or more.

Tree throw pools. Tree throw pools are an abundant feature in many of the wetter parts of the New Forest, particularly in wooded valley bottoms where the water table is high. Trees are less stable and more shallow-rooted in wet soils than they are in dry, so trees tend to fall over relatively frequently in valley woodlands. It is possible to see 20 or more tree fall pools in a 100 metre belt of woodland along some New Forest river valleys, and across the New Forest as a whole there must be many thousands of such tree pools.

Bog pools. Today mires are no longer common in lowland Britain, and it is surprising how extensive the mire systems still are in the New Forest. Associated with them are a wide variety of bog pools of various sizes and depths, forming in their surface.

By far the majority of these permanent ponds are small and shallow, but despite this, most are still species-rich systems. For example, a tiny $2m^2$ tree-fall pool in Matley Bog, which was surveyed for the National Pond Survey, supported nearly 40 freshwater invertebrate species including the Red Data Book Mud Snail (*Lymnaea glabra*) (see Table 1).

Temporary ponds in the New Forest

In winter and spring, when relatively few people visit the New Forest, a completely new set of ponds appear. After periods of rain, pools of water collect in local depressions, and these often persist for many months through winter and into April and May. Across the New Forest as a whole these *seasonal pools* are an exceptionally common habitat.

In the last 4 years we have ground-truthed areas of the Forest in spring, taking random $200m^2$ survey squares and calculating the areas of each type of wetland in those squares. The results show that in spring, seasonal ponds are the most abundant of all the waterbody types in the Forest, with an average of over100 discrete seasonal pools per 1 km^2.

One of the reasons that seasonal pools are so common is that they can form in a great variety of ways. One of the commonest places is at the base of slopes where surfacewater runs down from the hillside and collects at the bottom. But in fact any natural depression can become a seasonal pond: old meanders which have almost filled in, or just surface irregularities.

Temporary pools and puddles often look uninteresting. Most people splash through them without a second glance, but sweep a pond net through them and their value becomes clear. Seasonal ponds support very distinctive freshwater communities, including many of the rarest freshwater species found in the New Forest including animals such as the tadpole shrimp *Triops cancriformis* and the fairy shrimp *Chirochephalus diaphanus* and plants such as Slender Marsh Bedstraw (*Galium constrictum*).

Extrapolating from the New Forest

Taking the sorts of natural ponds and pools that are found in the New Forest, and extrapolating these findings to the rest of the naturally *drier* parts of lowland Britain suggests that, before extensive land drainage occurred, the majority of ponds in these areas would have been small and shallow. Very few of the New Forest ponds are large by the standards of today's man-made ponds – indeed, most are no more than 10 - 20 m^2 in area.

Data from the New Forest also suggest that, in drier areas, there would have been a natural difference in the distribution of permanent and temporary ponds. In the Forest today, permanent ponds are concentrated into discrete areas, particularly associated with wetland corridors such as river valleys, springs, or areas of mire. *Within* these corridors permanent pools are often a common habitat; outside of them they are rare.

In contrast it is likely that *seasonal ponds* would once have been a much more widespread freshwater habitat in lowland Britain than they are today. Not only would temporary ponds have occurred more frequently than permanent ponds, they would also have been more widely dispersed, occurring almost everywhere, even in the apparently driest, free-draining areas.

Table 1. Aquatic invertebrates recorded in the 2 m^2 Matley Bog tree-throw pool, New Forest in 1992

	Spring	Summer	Autumn
Polycelis nigra	1	-	-
Lymnaea glabra	3	3	-
Lymnaea palustris	3	8	-
Lymnaea truncatula	-	4	-
Glossiphonia complanata	-	-	4
Asellus meridianus	47	53	27
Crangonyx pseudogracilis	308	46	1050
Niphargus aquilex	-	-	1
Leptophlebia marginata	34	-	-
Nemoura cinerea	56	-	-
Calopteryx splendens	-	-	2
Velia caprai	-	2	-
Plea leachi	-	-	1
Hesperocorixa sahlbergi	-	1	1
Hydroporus memnonius	5	3	2
Hydroporus palustris	7	10	33
Hydroporus pubescens	-	5	-
Hydroporus striola	1	-	-
Hydroporus tesselatus	-	1	-
Agabus bipustulatus	4	11	3
Agabus melanocornis	-	1	-
Ilybius fuliginosus	-	11	1
Anacaena globulus	-	-	1
Anacaena limbata	2	-	-
Hydrochus angustatus	-	6	4
Helophorus flavipes	-	-	2
Helophorus obscurus	-	1	1
Hydraena riparia	1	-	23
Hydraena testacea	3	1	62
Limnebius nitidus	-	-	26
Limnebius truncatellus	7	4	97
Sialis lutaria	-	2	-
Trichostegia minor	2	-	-
Glyphotaelius pellucidus	29	-	5
Limnephilus auricula	19	-	-
Limnephilus rhombicus	2	-	-

Bialowieza Forest Poland: a European analogue

A few months after the 1998 Pond Conference, two of the authors (PW,JB) made a visit to Bialowieza Forest in eastern Poland to look at pond formation in the largest remaining area of pristine native woodland in Europe. The findings confirmed observations made in the New Forest and also added some new twists. Bialowieza has a geology similar to the New Forest, in that it is dominated by sands and clays. With its low undulating topography it also typifies many of the vegetation types and ecological processes which would dominate Central Europe in the absence of man's alteration of the landscape.

A preliminary survey of the types of waterbodies which predominate in the forest in spring showed that in all forest stand types the most abundant kind of waterbody was temporary standing water. These temporary pools varied from small seasonal ponds on higher ground, often created by tree fall and enlarged by foraging wild boar, to much more extensive seasonal waterbodies of up to a hectare in area, located amongst alder woodland in areas of lower topography. Surprisingly, there appeared to be little running water in the forest: small streams were almost non-existent. Larger streams and rivers occupied a relatively small area. Permanent pools were an even more uncommon habitat, largely restricted to channel cut-off ponds in the floodplain of the larger rivers.

These findings confirmed that although permanent ponds in "dry" landscapes are often relatively restricted in occurrence, temporary ponds are often ubiquitous. The data suggested further that, in upper catchments, even stream channels were replaced by extensive terraced sets of seasonal pools. Only where there was localised man-made drainage were these seasonal waterbodies replaced by narrow stream channels.

Wetter areas of lowland Britain

Reconstructing the ancient wetlands areas of Britain is much more difficult than analogising the drier areas. Today a few reasonably extensive lowland acid mires still exist (e.g. on the Surrey or Dorset Heaths) but no neutral marshes or large undrained river valleys and fens remain in anything like their original pristine state.

Yet in the past extensive wetlands were probably commonplace. For example, today, the River Thames at Abingdon in Oxfordshire, is a single deep channel bordered by intensive grassland and arable lands. However, archaeological evidence from the floodplain gravels shows that until at least the Iron Age, the R. Thames was a multi-thread river, with multiple channels that spread out over a mile across the floodplain (Benson, 1974). Between the channels were extensive areas of marsh and reed beds through which raised trackways were built by Iron Age man to reach settlements located on gravel islands in the floodplain. It is unclear how common ponds were in these marshy areas, but it is known that they were present because the complete remains of a beaver skeleton, its lodge and evidence from a pond formed behind the dam have recently been excavated from these floodplain gravels (Bob Eeles, *pers. comm.*)

In other wet areas, like the once extensive fens and coastal marshes, archaeological evidence suggests that these areas were most likely to have been a complex of standing water pools and other wetland habitats, such as reedbeds, wet grassland, bog myrtle, and wet woodlands (Rackham, 1986; Coope and Angus, 1974; Keen *et al.*, 1999).

Although such undisturbed habitats are now lost from Britain, there are still probable analogues in some parts of Europe. In Central and Eastern Europe, for example, the River Biebza (Poland) and the Morava River (Czech Republic) still have natural meandering river valleys with channels that are often highly complex, ponded-up and which merge into a complex of pools and marsh habitats. Such valleys are full of large channel cut-off ponds, and together these occupy an area vastly greater than the river channel itself (Eiseltova and Biggs, 1995).

Extrapolating from these findings it seems likely that many of Britain's wet lowlands were probably once complex wetland mosaics which included numerous pools. Many of these would have been larger and more permanent than the ponds and pools that were common in drier landscape areas such as the New Forest.

Natural ponds in upland areas

The uplands of northern and western Britain today retain a similar range of natural pond types to the lowlands but perhaps support a greater number of *permanent* waterbodies.

Glaciation, has left deep hollows gouged out by the ice across much of the uplands, and many of these hollows are still left as moorland lakes and pools which are slowly filling with sediment.

The steeper slopes associated with the uplands also produce very active *high energy braided and meandering gravel rivers* which frequently change their course to leave cut-off channels.

In addition, high rainfall in the uplands is essential to the maintenance of extensive *peat bog* systems, and undoubtedly much more common in the past, would have been many*woodland pools*, like those that can be seen in the native pinewoods of Abernethy in Scotland today - a mixture of tree-fall pools, *Sphagnum*-filled hollows and seasonal pools.

There has been little ground truthing of the upland areas of Britain to estimate numbers of natural ponds, but initial evidence suggests that, as in the lowlands, *small, shallow and seasonal pools* are surprisingly common in many upland areas.

Temporal persistence of ponds

An alternative to looking at natural ponds in terms of their spatial abundance and distribution, is to consider their 'temporal persistence'.

Viewed this way, ponds appear to group into three broad categories, all of which have been partially discussed above. These are (i) permanent ponds (ii) bog pools, and (iii) seasonal ponds.

Typically, ponds that are formed by very active processes, such as river ablation or tree-fall, are themselves temporally dynamic, in that they fill-in relatively quickly. So, for example, we have observed small tree-fall pools filling-in completely over a period of 6 or 7 years to become seasonal hollows. Historic and archaeological evidence suggests that deeper ponds, such as large meander cut-offs, can take anything from 30 years to 100,000 years or more, to fill in - the difference being largely dependent on how deep the pond is and how much sediment the water body receives. Such timescales are, geologically at least, very short.

In addition, although individual permanent ponds of this kind are transitory, such ponds often occur together in distinct areas where water is abundant or near to the surface (in river valleys and areas with springs, flushes, fens, bogs or wet woodland). Thus the habitat type is being constantly created. So even when a pond fills in, there is always likely to be another pool created somewhere nearby.

Bog pools have rather different temporal characteristics. The more recent work of paleoecologists has shown that they are usually highly persistent as individual features in the landscape, often maintaining their position and approximate water depth for thousands of years. They do this by a remarkable congruity between the rate at which underwater sediment builds up at the pool bottom, and the rate of growth of *Sphagnum* at the bog surface. Thus many pools persist, unchanged, for very long periods.

The third type of pond, seasonal ponds, are a particularly interesting waterbody type because, although they dry up each year and appear to be highly transitory, they have the potential to be one of the most persistent of all standing waterbody types with individual life-spans that can sometimes exceed even large lakes (Gray, 1988).

The reason for the longevity of some seasonal ponds is that they tend not to accumulate organic sediments. This is because, in their dry phase, organic matter which has accumulated is rapidly oxidised. Thus, as long as the pool is not receiving inorganic matter (e.g. river sands or silts), a temporary depression can persist almost indefinitely as a hollow which just holds water in winter and spring.

Summary of the natural distribution of ponds in Britain

Summarising the information above, it seems likely that across Britain as a whole, in the absence of human intervention, natural ponds would not only be rather unevenly distributed across the landscape, but are also changing on rather different time scales. Thus there are:

Seasonal pools which would naturally be a very common waterbody type in Britain, widely distributed across the countryside, and often very long lived as individual features, but not holding water all year round.

Bog pools which can be permanent in all senses of the word: both very stable and long-lived, but less widely distributed than temporary pools, and concentrated into discrete areas associated with their parent mires.

'Permanent ponds' which are in many respects the least permanent of all pond types, in that they are constantly created and filled-in. However, although such ponds are neither temporally nor spatially permanent as individual waterbodies, collectively, the permanent pond habitat remains constantly available as new permanent ponds are created nearby.

Man's influence - the damage

Through the centuries, man has fundamentally altered both the abundance and types of ponds that occur in Britain. From Roman times up to the present day, there have been successive waves of drainage in Britain, which have reduced the once huge swathes of marshes, fens and bogs to a fraction of their former extent (Rackham 1986). Land intensification has also had profound effects. For example, the multiple channels of the Thames at Abingdon, discussed above, were lost not because of recent channelisation, but because they silted up when land clearance in the upper catchment from Neolithic times onwards began to release huge amounts of silt into rivers downstream.

In addition, most rivers and streams are nowadays controlled by man in some way. Many lowland rivers have been straightened, and most rivers have been widened and over-deepened (often by one or two metres or more), usually to allow drainage of floodplains for agricultural use. Overall, more than 80% of lowland river channels have been modified for land drainage or flood control (Raven *et al.* 1998).

The net result has been that almost all of the wet areas around Britain's rivers have now been lost, and with this most of the places and dynamic processes in which permanent ponds can be naturally created. This includes not only the actively meandering and braided river channels and their cut off pools, but rather more damaging for natural pond formation, the many thousands of square kilometres of adjacent floodplain, where both permanent and seasonal pools would have been abundant.

Drainage has not, of course, just been restricted to floodplains. Almost all the seasonally wet soils, like those still covering much of the New Forest, have now been drained to a greater or lesser extent. So most of the seasonal pools which must once have been a remarkably common feature across lowland Britain, have largely been lost. It does not take much drainage to destroy them: a 10 cm - 20 cm drop in spring water levels and the small undulations become just dry hollows; a little ploughing and no remnant is left at all.

Man's influence - the gain

Concomitant with the negative side of man's increasing dominance and control of the landscape, has come a positive side in pond creation.

Ponds have been deliberately created by man for a multitude of purposes through the last two millennia: moats, village ponds, fish ponds, retting pools, hammer ponds, field ponds, ornamental ponds in gardens and parkland, and more recently, conservation ponds, balancing ponds and golf-course water hazards.

An equally wide variety of ponds have been accidentally formed, particularly after quarrying or mineral workings, from the ancient coprolite pools of Kent to the many thousands of marl pits that cover Cheshire and the gravel pits still created today.

The net difference

If man has removed much of the potential for *natural* pond creation in Britain, but many new ponds have also been created in their place. What is the net difference likely to be?

Three main differences are obvious. First, most man-made ponds are rather larger and deeper than many natural pools would be. Most-man made ponds today resemble large the ‘meander cut-off’ ponds of river valleys, rather than the small shallow pools that would probably have been the most frequent natural pond types in the past.

Second, ponds in the past would have been much more abundant than they are today, with the numbers, particularly of seasonal pools, greater by many orders of magnitude.

Third, most of today’s man-made ponds are likely to be rather more isolated than natural ponds would probably have been in the past: usually today a single pond is present in a field. In the past, ponds would almost certainly been clustered together in groups and often very closely associated with other wetlands like marshes or streams.

This said, however, man-made or natural, ponds are essentially the same habitat type. Thus when pond plant and animal communities from man-made and natural ponds are statistically classified together, the analyses show no discernible differences in their community types. It is environmental factors such as water depth and geology that influence the biological communities of ponds, not how the waterbody was made.

Overall then, although there is no doubt that human kind has radically changed the countryside, reduced the number of ponds in Britain and probably altered the pond types which occur, the essential habitat has remained for freshwater plants and animals to utilise.

Implications

Beginning to understand the different types of natural ponds, and how man has changed these over the centuries, has considerable implications for our understanding of ponds and how to manage them.

First, understanding natural ponds helps to explain many aspects of pond ecology. If ponds are essentially natural waterbodies, it becomes clear why they are such rich wildlife habitats (see Biggs *et al.* this volume). It also helps to explain why so many species, including all our native amphibians, are more or less dependent on ponds as a habitat. Once ponds are recognised as ancient freshwater habitats that have been around commonly and continually for many millions of years, it becomes clear why so many plants and animals have become particularly well adapted to living in them.

Linked with this, it has often been noted that many freshwater plants and invertebrates are unusually mobile, and move very effectively between waterbodies. Charles Darwin first recognised this, noting in the ‘Origin of Species’ that many freshwater plants and animals are far better at moving between sites than the species of terrestrial habitats like woodland animals which tend to be more sedentary (Darwin 1872). The likely reason, which Darwin also suggested, is that their mobility is a specific adaptation to moving between small isolated waterbodies as conditions in those waterbodies change.

The implication is that many pond plants and animals are well adapted to the cycle of ponds being created, filling-in and being created elsewhere. This can provide a strong rationale for developing pond management practices that take account of this. For example, *pond creation* programmes which mimic natural pond creation processes (see Williams *et al.* this volume).

Recognising the naturalness of ponds also has implications for *pond management*. In particular it indicates why it is important to try and protect examples of all types of ponds in all stages of succession, from new pools to, well-vegetated and mature silty ponds, and from seasonal ponds too deep-water pools. All of these variations in depth and successional stage are natural and predictable in ponds, and have occurred widely and repeatedly throughout geological time. It should not, therefore, be surprising to find that all of these different sets of conditions are fully exploited by plant and animals, with species specialising in all ages and successional stages of ponds. Protection of differing stages will ensure the protection of a full range of pond biota.

The naturalness of ponds also has implications for *pond protection.* There are still many eminent freshwater biologists who believe that the protection of ponds is not important, and certainly not such a high priority as the protection of rivers or lakes or fens. The main reason given, is usually that, unlike these other wetlands, most ponds are recently created artificial waterbodies - not a natural freshwater habitat type.

What is not widely enough appreciated is that ponds are, in fact, a highly unusual freshwater system. The pond habitat as a whole is an ancient one, but many types of individual ponds are naturally short lived and constantly re-created. Thus man-made ponds are recreations of the natural habitat type.

The danger is that, if ponds are thought of as just artificial waterbodies with no history or particular ecological significance for freshwater life, then it is very easy to undervalue them. Once we begin to think about ponds as essentially ancient natural wetlands, which man has destroyed by the thousand but can also successfully recreate, it is easy to see why we need to protect the broad spectrum of ponds that we have in Britain, and the important freshwater communities that they support.

References

Aalto, M.M., Coope, G.R. and Gibbard, P.L. (1984). Late Devensian river deposits beneath the floodplain terrace of the River Thames at Abingdon, Berkshire, England. *Proceedings of the Geological Association*, 95. 1. 65-79.

Benson, D. (1974). The Upper Thames Valley : an archaeological survey of the river gravels. Oxfordshire Archaeological Unit Survey, No. 2. Oxfordshire Archaeological Unit, Oxford.

Coope, G.R. and Angus, R.B. (1975). An ecological study of a temperate interlude in the middle of the last glaciation, based on fossil Coleoptera from Isleworth, Middlesex. *Journal of Animal Ecology*, 44, 365-391.

Darwin, C. (1872). *The origin of species by means of natural selection : or, the preservation of favoured races in the struggle for life*. 6th Edition. John Murray, London.

Eiseltova, M. and Biggs, J. (eds.) (1995). *Restoration of stream ecosystems. An integrated catchment approach*. IWRB Publication No. 35, International Waterfowl and Wetlands Research Bureau, Slimbridge.

Foster, D.R. and Wright, H.E. (1990). Role of ecosystem development and climate change in bog formation in central Sweden. *Ecology*, 71, 450-463.

Gray, J. (1988). Evolution of the Freshwater Ecosystem: The Fossil Record. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 62: 1-214.

Keen, D.H., Bateman, M.D., Coope, G.R., Field, M.H., Langford, H.E., Merry, J.S. & Mighall, T.M. 1999 Sedimentology, palaeoecology and geochronology of Last Interglacial deposits from Deeping St James, Lincolnshire, England. *Journal of Quaternary Science*, 14, 411-436.

Rackham, O. (1986). *The history of the countryside*. J.M. Dent and Sons Ltd, London.

Raven, P.J., Holmes, N.T.H., Dawson, F.H., Fox, P.J.A., Everard, M., Fozzard, I.R. and Rouen, K.J. (1998). *River habitat quality*. River Habitat Survey Report No. 2. Environment Agency, Bristol.

Tubbs, C.R. (1986). *The New Forest*. Collins, London.

The ecological quality of ponds in Britain - the results of the DETR Lowland Pond Survey

Jeremy Biggs¶, Penny Williams¶, Colin Barr§, Clive Cummins§, Morna Gillespie§, Tim Rich¶, Alison Baker¶, Judith Baker¶, Justin Beesley¶, Antony Corfield¶, Diane Dobson¶, Adrian Culling§, Gill Fox¶, David Howard§, Karen Luursema¶, Matt Rich¶, David Samson¶, Andy Scott§, Rosie White¶ and Mericia Whitfield¶.

¶Pond Action, c/o Oxford Brookes University, Gipsy Lane, Headington, Oxford OX3 0BP. §Institute of Terrestrial Ecology, Merlewood Research Station, Grange-over-Sands, Cumbria LA11 6JU.

1. Introduction

The aim of this paper is to summarise some of the main results from the DETR Lowland Pond Survey, a study which has provided one of the first assessments of the ecological quality of ponds in lowland Britain. The full results are given in Williams *et al.* (1998).

2. Background

Lowland Pond Survey 1996 (LPS96) was carried out by Pond Action and the Institute of Terrestrial Ecology (ITE) as part of the Countryside Survey initative.

The Countryside Survey is a major programme funded by the DETR which has now been running for approximately 15 years. Its main aim is to describe changes in the land-use, landscape features and habitats of the British countryside. To date, the Countryside Survey has involved three main projects:

- 1984 Survey of Rural Britain
- 1990 Countryside Survey
- Countryside Survey 2000 (which was undertaken in 1998 so the results can be reported in 2000).

These surveys were concerned with many different kinds of landscape features, including information about the number of ponds and their size. They did not, however, consider the ecological quality of ponds.

The Lowland Pond Survey 1996, was a 'thematic' survey within the larger Countryside Survey programme aimed at gathering more specialised survey information about ponds, particularly relating to aspects of their physical condition, ecological and amenity value.

The survey dealt with the lowland landscape (63% of the total land area). It did not include upland Britain or urban areas. The 'lowlands' were defined using ITE's Land Classification system which divides the whole of the landscape into 32 Land Classes. Of these 32 Land Classes, 19 are regarded as lowland.

From these Land Classes ITE selected a stratified random sample of 150 1 km squares spread throughout lowland England, Wales and Scotland to form the basis of the survey.

Fieldwork for the survey was undertaken over a short period between July and September 1996 and involved systematic searches of each 1 km square to locate and describe the ponds that were present. Each pond was described in terms of its physico-chemical, biological and amenity characteristics. The biological quality of the ponds was evaluated using characteristics of the ponds' plant communities. Plants were, therefore, used as an indicator of the ecological value of the ponds as a whole. Where ponds had disappeared, data were also collected to describe the type of landuse in which the lost pond had occurred together with any evidence of reasons for loss.

Data gathered from the LPS96 ponds were also extrapolated to give estimates of numbers and quality of ponds across Britain as a whole. Additional analyses were undertaken to investigate how the quality of LPS96 ponds from the wider countryside compared with similarly collected data from Pond Action's existing databases of high quality National Pond Survey sites.

3. Results

3.1 Pond numbers

In the 1990 Countryside Survey it was estimated that there were about 177,000 ponds in lowland Britain. The 1996 Lowland Pond Survey recorded an additional 50,000 ponds. This was, however, due to methodological changes rather than to any real increase in pond numbers. In 1996 there was a much more precise definition of a pond than was used in earlier surveys. Using this definition (a pond is: 'a waterbody between 25 m^2 and 2ha which holds water for more than four months of the year') meant that temporary ponds were recorded much more consistently than previously. In fact, about 40% of all LPS ponds recorded in 1996 were seasonal, whereas in previous surveys many of these had been treated as lost or had been overlooked.

In terms of true gains and losses, the data showed that ponds are still being filled-in at a rapid rate. National estimates suggest that about 17,000 ponds were filled in between 1990 and 1996 - a figure which represents about 1% pond loss each year. Balanced against this, however, a similar number of ponds were created: about 15,000 in total over that same period.

Table 1 Estimates of change in lowland pond numbers between 1990 and 1996

Number of ponds lost	*Number of new ponds*	*Net change 1990-1996*
17,000	15,000	-2,100
(SE±3,900)	(SE±6,400)	(SE±7,500)

SE = Standard error.

It should be emphasised that the sample size for LPS96 was fairly small. With only 150 1 km squares, the loss and gain figures inevitably have high standard errors (see Table 1). Thus, although the gains and losses approximately balance it is not possible to be more precise than to state that the results show that there could have been either a small increase or a small decrease in numbers during the survey period. Fortunately, the CS2000 survey which has just been completed, uses over 500 sample 1 km squares, and should give more precise data in the near future.

What is clear, however, is that there is currently a very high rate of turnover of ponds in Britain with in the order of 1% of ponds being lost and replaced annually.

3.2 Physical condition of ponds

One of the most striking results of the survey is how many ponds were very shallow. As noted above, approximately 40% of ponds were seasonal. In addition, however, a further 22% had average water depths less than 25 cm in summer. Altogether, therefore, over 60% of all lowland countryside ponds were either very shallow or dry in the summer of 1996.

The survey showed that most ponds were relatively unshaded by trees. Nearly half were less than 25% overhung by trees, and only 20% would probably be called heavily shaded, with more than 75% tree cover.

In terms of wetland vegetation abundance, the survey showed that most ponds were comparatively poorly vegetated with less than 25% cover of any major vegetation type (i.e. submerged, floating-leaved or emergent plants). Similarly, relatively few ponds (18%) were more than three quarters filled by any type of pond vegetation.

3.3 Ecological quality of ponds

An important result from the survey was that lowland ponds were an important biodiversity resource. Collectively, ponds supported a very wide range of wetland plant species including a variety of nationally uncommon species.

In total the survey recorded 177 vascular wetland plant species in 377 ponds. This represents about 55% of all Britain's wetland plant species. A number of ponds supported nationally rare and uncommon species, such as the RDB2 Fox Sedge (*Carex vulpina*), Frogbit (*Hydrocharis morsus-ranae*), Least Duckweed (*Wolffia arrhiza*), Soft Hornwort (*Ceratophyllum submersum*), Fat Duckweed (*Lemna gibba*) and Fine-leaved Water-dropwort (*Oenanthe aquatica*).

Extrapolating these data to provide national estimates of the occurrence of rare and scarce plants suggests that some 2% (c. 5000) ponds in lowland Britain probably support Red Data Book or Nationally Scarce plants. Many thousands more support plants of regional importance. That such a high proportion of Britain's wetland plants was recorded is perhaps surprising particularly since the survey was restricted to lowlands and therefore excluded acid upland habitats and their distinctive assemblages.

Of some concern, however, were survey results which indicated how extensively non-native plants have entered Britain's semi-natural wetland flora. Exotic plants are now very widespread in the lowland pond flora: 14% of all ponds had one or more exotic species, and one in six of all records for submerged plants was of a non-native species. Of these species, the most widespread was *Elodea canadensis* (Canadian Pondweed) which occurred in over 5% of all ponds. *Crassula helmsii* (New Zealand Pigmyweed) and *Myriophyllum aquaticum* (Parrot's-feather), two species which are often highly aggressive and currently causing some concern in Britain, were recorded in 1.6% and 0.8% of ponds respectively.

3.4 Evidence of pond degradation

Perhaps the single most important result from LPS96 was the evidence of the extent to which many ponds in Britain are degraded below their potential, and the range of evidence linking this to intensive landuse.

To investigate the quality of the LPS96 ponds, this data set was compared with the plant assemblages of the National Pond Survey (NPS) sites. The NPS is Pond Action's database of high quality ponds located in areas of non-intensive landuse where they are as little exposed to human impacts from pollution, drainage and physical disturbance as is possible in Britain. Plant assemblages from the two sets of ponds were compared in terms of both species richness and species rarity. The results showed that the NPS ponds from high quality, non-intensive landscapes had much richer assemblages than the ponds in the ordinary countryside which had, on average, only half the number of wetland plant species you would expect (see Table 2).

Table 2 Comparison of plant richness in National Pond Survey and LPS96 ponds

	Average number of plant species recorded	
	LPS96	*Expected (NPS)*
Aquatic plant	1.6	4.8
Marginal plants	8.0	17.7

These biotic data provide evidence of widespread degradation in many countryside ponds. Additional analyses suggested that this degradation was linked with aspects of landuse. Thus the survey showed that:

- the greater the proportion of unimproved grassland immediately around the pond, the more plant species were present,
- the higher the proportion of arable land around the ponds, the lower the number of emergent and total plant species,
- comparing ponds in the pastural landscapes with those in the arable landscape, species richness and rarity were significantly higher.

It is not clear from the current data which aspects of intensive landuse are causing degradation but likely candidates are nutrient pollution, biocides, road runoff, farm wastes and probably also the increasing isolation of countryside waterbodies.

3.5 Temporary ponds and new ponds

The DETR LPS96 findings provide additional evidence which confirms and supports other recent data about the value of temporary ponds and new ponds.

In terms of temporary ponds, LPS96 showed that although temporary ponds had lower numbers of wetland plant species than permanent waters, they supported the rarest species found in the study, the RDB2 Fox Sedge (*Carex vulpina*), which was recorded in a small temporary pond in Kent. These findings coincide with the results of other Pond Action work in the Oxfordshire Pond Survey and National Pond Survey, both of which recorded Red Data Book species in temporary ponds.

New ponds in the DETR survey were, perhaps surprisingly, significantly richer than more mature ponds ($P<0.01$). They also had significantly more uncommon species ($P<0.05$). These conclusions are tentative however, because only about 5% of the LPS96 ponds were new, giving small sample numbers. These data again, however, tie in with the results of the Oxfordshire Pond Survey, as well as with data from the Pinkhill wetland creation scheme (see Williams *et al.*, this volume), which indicate how quickly new sites can colonise.

4. Implications and recommendations for pond conservation

The LPS96 findings suggest the need for a number of actions to increase the protection of pond biodiversity in the countryside. Specifically:

1. The need to promote the much wider use of buffer zones around ponds, in order to protect them from the effects of intensive landuse.

The LPS and the large body of information associated with the NPS, very strongly suggests that the protection of ponds from pollution and other stresses is one the key factors in maintaining their ecological quality.

Buffer zones are not, of course, a panacea and the ideal is to de-intensify the whole pond catchment. In some areas this might not be as hard as it seems because many ponds have comparatively tiny catchments of a hectare or two (or even less). In many situations it is possible that areas of this size could be completely deintensified - in ESAs for example. In contrast, complete catchment de-intensification is all but impossible for large lakes and rivers, which may have catchments of 10s or 100s of square kilometres.

What this means is that because of the small catchments of ponds it is quite conceivable that large numbers could be thoroughly protected from one of the main factors damaging them - intensive landuse.

2. The need for high quality pond creation schemes

LPS96 results made clear the need to be vigilant about pond loss. Losses may currently be approximately balanced by gains - but there is no doubt that without the continued creation of ponds, numbers would go down rapidly. The survey also confirms other data about new ponds and taken together this suggests that well-located and designed new ponds are potentially very valuable and an important part of our overall pond conservation strategy.

3. The need for increased survey and protection

It is clear that there are many ponds which are supporting rare and threatened species. The LPS96 estimates suggest that about 2% of lowland ponds had rare or scarce plants. Since other surveys Pond Action have undertaken suggest that for every pond with a rare plant there are further eight with rare invertebrate species, and more still with protected amphibians (especially Great Crested Newts), the number of exceptionally high value ponds is likely to be considerable - perhaps 50,000 or more. Unfortunately, however, at present the possibilities for monitoring or protecting these sites are negligible. If ponds are to feed into Biodiversity Action Plans, the Agenda 21 process or Environment Agency LEAPs, or to be considered for designation as SSSIs, we need to know and map the location of high quality sites.

References

Williams, P.J., Biggs, J., Barr, C.J., Cummins, C.P., Gillespie, M.K., Rich, T.C.G., Baker, A., Baker, J., Beesley, J., Corfield, A., Dobson, D., Culling, A.S., Fox, G., Howard, D.C., Luursema, K., Rich, M., Samson, D., Scott, W.A., White, R. and Whitfield, M. (1998). *Lowland Pond Survey 1996*. Department of the Environment, Transport and the Regions, London.

A comparison of the ponds in the County of Cardiff with the national statistics from the Lowlands Ponds Survey 1996

Tim Rich

Department of Biodiversity and Systematic Biology, National Museum and Gallery of Wales, Cathays Park, Cardiff CF1 3NP.

Abstract

Ponds in the County of Cardiff were surveyed in 1997 and 1998 using the Lowland Pond Survey 1996 method to allow direct comparison with the national data. There are about 150 ponds in the County of Cardiff (c. 140 km^2). Historical map studies showed an 80% decline in the numbers of ponds in the City area since the 1880s, but a 54% increase in County overall since the 1950s. Compared to the statistics from the Lowland Pond Survey 1996, Cardiff ponds were very rich in plant species, had a higher conservation, and were of high amenity value. They are a valuable biodiversity resource.

Introduction

The Lowland Pond Survey 1996 (LPS96) (Williams *et al.* 1998) provided national statistics on the number, quality and amenity value of ponds in the lowland countryside of Britain. One advantage of such statistics is that they allow ponds within small areas such as a county to be placed in the wider national context.

In 1997, about 190 freshwater bodies of varying size were known within the County of Cardiff, but little was known about the quality of their wildlife or their public amenity value. The Cardiff Pond Survey 1997-1998 (CPS97-98) was therefore set up to:

- Survey all the ponds in the County of Cardiff using the same survey methods as for the LPS96.
- Compile a database for planning and environmental activities.
- Identify ponds to be surveyed in more detail for invertebrates.
- List ponds with potential for restoration.
- Compare the Cardiff ponds against the national statistics from the LPS96.

The project was jointly funded by the National Museum & Gallery Cardiff, Cardiff County Council (CCC) and the Environment Agency. In this paper, the emphasis is placed on the comparison of Cardiff ponds with the national statistics; for full details of the CPS97-98, see Carey *et al.* (1999).

Methods

The definition of a pond was taken from the LPS96 to allow direct comparison of the data:

> 'A body of standing water 25m^2 (0.0025 ha) to 2.0 ha in area which usually holds water for at least four months of the year'.

In addition ponds within curtilage (i.e. within a garden) were excluded.

The survey was carried out in 1997 and 1998. An initial list of 180 ponds held in the CCC Geographical Information System (GIS) was prepared and access permission obtained by letter, telephone or most successfully by knocking on doors. In 1997 the field survey was carried out by Rosie White and Matthew Rich, both of whom had taken part in the LPS96, and in 1998 by John Alder and Matthew Rich. A quality assurance exercise was carried out in 1998, but the small sample size (n=6) placed significant constraints on the statistical analysis.

The methods used followed the LPS96 exactly (Williams *et al*. 1998) to allow direct comparison of the data with three exceptions:

1. For the LPS96, stock and change were assessed by comparison against 1990 Countryside Survey data. For the CPS97-98 there was no previous baseline survey, so a comparison was made against historical maps held at the Museum, though old maps are notoriously difficult to interpret.

2. For the LPS96, 1-km squares were searched for all ponds meeting the definition. For the CPS97-98 all ponds on the CCC GIS database were surveyed even if they did not meet the definition, but only ones that did were included in the comparison. Also, no deliberate search was made for new or unknown ponds, although 21 additional ponds were found and surveyed. Potentially this could give significant differences between the surveys as small, temporary, species-poor ponds could have been overlooked for the CPS97-98. However, this type of pond does seem to be genuinely uncommon within the Cardiff area, and whilst some have undoubtedly been overlooked, the discrepancy should not be too significant overall.

3. For the CPS97-98, additional data on wetland trees and crude abundances of water snails, dragonflies, water beetles and pond skaters were collected, and the surveyors judged which ponds should be surveyed in more detail for invertebrates. There are no comparable data for the LPS96.

Results

Number of ponds present in 1997 and 1998, County of Cardiff

A historical study of ponds in the County of Cardiff was carried out by comparing ponds on the CCC GIS database with old maps (Atkin & Rich 1997).

The first study was of old 25 inches to the mile maps centred on what is now the urban part of the City of Cardiff. In 1880-1886 there were 135 ponds, but by 1997 there were only 27 ponds in the same area (80% decrease). Of the 135 ponds in 1880-1886, 125 have been lost and only 10 were still present, but there were 17 new ponds since 1880-1886. The decline is due to the rapid growth of the City within the last century.

The second study covered the whole of the present County of Cardiff and was based on 2.5 inches to the mile maps from the 1950s. Between 1951-1961 there were 120 ponds, but surprisingly in 1997 there were 185 ponds (54% increase). Of the 120 ponds in the 1950s, 64 have been lost and only 56 were still present, and there were 117 new ponds. This increase is partly due to new ponds being created for leisure activities such as fishing and golf courses, but may also be due to the 1950s maps being significantly incomplete.

During the 1997-1998 surveys, information was collected on a total of 200 ponds, with another 10 unsurveyed mainly due to lack of ownership information (access was only refused to one pond) (Table 1). During the course of the work an additional 21 ponds to the list in the CCC GIS database were found: these were either not in database, or two ponds were present instead of one. The GIS information is based on relatively recent Ordnance Survey data, which shows a 17.5% loss of ponds from when the GIS data were surveyed (date unknown) thus indicating the importance of checking such data in the field. In general the GIS data gave a good indication of the sizes of ponds. There were thus at least 146 (possibly 156) known ponds which fit the survey definition in Cardiff in 1997-1998.

The 1997-1998 survey established a detailed baseline which can be used to measure future changes, but gives no indication of current numerical trends.

Table 1. Summary of ponds surveyed in Cardiff 1997-1998

Survey	Number of ponds (%)
Ponds surveyed in detail	146 (69%)
Ponds outside LPS96/CPS97-98 definition	16 (8%)
Ponds drained, dried out, filled in or gone	35 (17%)
Ponds absent (probably erroneous GIS data)	4 (2%)
Not surveyed	10 (5%)

Comparison with Lowland Ponds Survey 1996

The comparison is based on 377 ponds in the LPS96 and 146 ponds in the CPS97-98. Table 2 shows selected differences between the two surveys. Figures are national averages for all pond types unless otherwise stated. No statistical tests for significance have been carried out.

Physical characteristics

The pond density in the CPS97-98 area was 1.04 ponds/km^2 (c. 150 ponds in c. 140 km^2), compared to the LPS96 average for lowland Wales of 1.4 ponds/km^2 (Table 2). However, the CPS97-98 area includes the large urban area of the City of Cardiff with an average density of c. 0.5 ponds/km^2 which has expanded into areas previously rich in ponds (e.g. the Vale and Lisvane areas which have averages of 3.5 ponds/km^2).

The size distribution of ponds from the LPS96 and the CPS97-98 are shown in Table 3. Compared to the LPS96 data, the ponds in Cardiff were generally larger (mean size 0.11 ha). This may partly reflect the sampling method for the CPS97-98 where small seasonal ponds may have been over-looked (cf. above).

The LPS96 found 36% of ponds nationally were seasonally-dry, compared to an average of 8% in CPS97-98 (Table 2). Although 1996 was a very dry, hot year, the LPS96 average for seasonally-dry ponds in Wales was higher (41% $\pm$ 15%) than the national average, suggesting that the relatively wet Welsh climate plays little part in determining whether ponds retained water. The LPS96 found that 77% of the seasonal ponds were in the smallest size category, compared with 100% in the CPS97-98. The differences are probably real (i.e. Cardiff has relatively few seasonal ponds), but could again include some effects of the different sampling.

Table 2. Comparative means or % of selected features for the Lowland Ponds Survey 1996 and the Cardiff Pond Survey

Feature	Variable Measured	Lowland Pond Survey (N= 377)	Cardiff (N= 146)
Pond density	-	1.5 ponds/km^2	c. 1.04 ponds/ km^2
Physical features	Water depth	44 cm	45 cm
	Drawdown	33 cm	20 cm
	Sediment depth	43 cm	32 cm
	Total depth	120 cm	97 cm
	% water cover	52 %	68 %
	% seasonally dry	36%	8%
Water chemistry	pH	7.8	7.5
	Calcium	86 mg/l	68 mg/l
	Conductivity	808 µS/cm	444 µS/cm
	Alkalinity (H+)	N/A	1.9 m/mol
Vegetation	% pond covered with vegetation	43%	67%
	% cover by emergent species	27%	36%
	% cover by floating species	8%	17%
	% cover by submerged species	8%	14%
	% pond shaded by trees	37%	25%
Botanical diversity	Total no. species	183	143
	Average no. species/pond	9.6 (range 0-35)	16.1 (range 0-54)
	'Local' species/pond scores	2.0 (range 0-32)	2.7 (range 0-14)
	% ponds with aliens	14%	34%
Trophic ranking score	Aquatic species only	8.2 (range 2.5-9.7)	8.82 (range 0-10)
	All species	8.7 (range 4.7-10)	8.07 (range 0-10)
Botanical conservation value	Very high	2 %	1.3%
	High	18%	37%
	Moderate	30 %	46 %
	Low	50 %	16 %
Ponds with management (all types)	-	14%	39%
Pollution	All types (shopping trolleys included!)	35%	40%
	Serious pollution	5%	8.3%
All forms of amenity	-	c. 40%	70%

Table 3. Comparison of pond sizes between the Lowland Ponds Survey 1996 and the Cardiff Pond Survey 1997-1998.

Size category	LPS96	CPS97-98
0.0025-0.04 ha	60%	51%
0.04-0.2 ha	31%	48%
0.2-1.0 ha	7%	0.7%
1.0-2.0 ha	2%	0.7%

In general, the CPS97-98 pond depths match the national picture well (Table 2), though they have slightly more water and a lower drawdown (these two factors are related), and apparently less sediment. If there really has been a 54% increase in the number of ponds since the 1950s, the smaller sediment depths may be related to a generally younger set of ponds than the national average (Williams *et al*. 1998 suggest that an average rate of 2.5-3 cm of sediment is accumulated each year, hence young ponds will have less sediment).

The chemistry of pond water from the LPS96 and the CPS97-98 was generally similar, though the Cardiff ponds have a slightly lower pH, calcium and conductivity (Table 2). If this is related to water source, it suggests that the higher rain input (especially during the wet summers of 1997 and 1998) and lower ground water input may be influencing the water chemistry.

Rubbish was observed in 35% of the LPS96 ponds, although it was usually present in small quantities, and 5% of the ponds had significant amounts of rubbish (often partly used to in-fill the ponds). In the CPS97-98, 41% of the ponds had rubbish of one form or another - the vast majority of these were in the City - but instances of severe pollution were still rare (8%) despite the urban/industrial context (Table 2).

The LPS96 found that 14% of ponds had had some sort of management, though this figure represents a minimum. In the CPS97-98, 39% of the ponds had been managed; this appears much higher than the national average (Table 2).

Ecological quality

During the LPS96, 183 vascular plant wetland species and six charophytes were recorded, c. 54% of the total wetland plants in Britain (Table 2). During the CPS97-98, 139 vascular plants and 2 charophytes were recorded, c. 43% of the wetland flora of Britain, and 25% of the species only occurred in one or two ponds. This difference in overall numbers is partly due to the sample sizes (377 ponds for the LPS96, 146 ponds for the CPS97-98), and to the fact that Cardiff is generally considered rich in wetland plants.

What was surprising was the high species-richness of the individual CPS97-98 ponds compared to the LPS96 ponds (Table 2). The number of species was on average 67% higher per pond than the national average. Also two of the Cardiff ponds with 53 and 45 species were significantly richer than any of the ponds recorded in the LPS96 (maximum 35 species).

The CPS97-98 ponds also on average contained more 'rare' species, though in essence for Cardiff this should read 'local' rather than rare as only one nationally scarce and no rare species were found (in contrast to the LPS96). This confirms the general impression from the species richness above that the CPS97-98 ponds were richer.

The abundances of vegetation in ponds from the LPS96 and the CPS97-98 are shown in Table 2. There appear to be significantly larger proportions of ponds with vegetation in all categories in Cardiff than the national average. The abundance of vegetation correlates with the higher species richness.

The LPS96 found that 14% of the ponds supported one or more exotic plant species, with many more records of submerged exotic species than expected (15% of all records of submerged species). The most commonly recorded exotic plant was Canadian pondweed in 5.3% of the sites nationally with New Zealand pigmyweed and Parrot's-feather, both currently considered significant threats to the native flora, found in 1.6% and 0.8% of sites nationally. The CPS97-98 found 32% of the ponds with one or more alien species, much higher than the LPS96. The high proportion of aliens was almost certainly the result of the largely urban location of the ponds and reflects the tendency of people to dispose of garden pond plants in the nearest 'natural' pond. Canadian pondweed occurred in 5.5% of the CPS97-98 ponds, New Zealand pigmyweed in 1.4% and Parrot's-feather in 1.4% of the ponds.

The mean trophic ranking scores (cf. Palmer, Bell & Butterfield 1992) show generally similar results in both the LPS96 and CPS97-98, but the CPS97-98 had a higher proportion of eutrophic ponds (cf. Tables 2 and 4 below). The smaller range in the trophic ranking scores may be the smaller sample sizes, but also there are unlikely to be any oligotrophic ponds in Cardiff.

Table 4. Comparison of % of ponds in different nutrient status categories in the Lowland Ponds Survey 1996 and the Cardiff Pond Survey 1997-1998.

Pond nutrient status	**LPS96 All species**	**CPS97-98 All species**
Eutrophic	33%	74%
Mesotrophic	66%	26%
Oligotrophic	0.5%	0%
Dystrophic	0%	0%

The conservation values of the LPS96 and the CPS97-98 ponds are shown in Table 2. Cardiff had significantly more ponds of high conservation value than the national average.

Amenity value

Ponds in Cardiff were generally more visible than the national average, and more were in areas of public access as might be expected due to the urban location (19% of ponds compare to 12% nationally). Surprisingly, fewer ponds have formal amenity use in Cardiff than elsewhere, though the percentage of pond dipping/nature reserve was slightly higher. There was no evidence of any shooting, and fishing was oddly low. One explanation of these unexpected results in light of the higher public access may be that the Cardiff ponds were more widely used for informal activities (such as throwing sticks into ponds for dogs) which would not have been recorded. When all uses were combined, 70% of the Cardiff ponds had some amenity use.

Discussion

The Cardiff Pond Survey 1997-1998 met its aims with data collected on a total of 200 ponds, and detailed survey information on 146 ponds. A database has been compiled for the CCC Planning Department and lists of 48 ponds to be surveyed in more detail for invertebrates and 23 ponds with potential for restoration (i.e. those with low conservation value) have been compiled.

The comparison of the Cardiff ponds against the national statistics was particularly enlightening. This showed that Cardiff ponds were larger, had less shade, were more diverse and were generally of high conservation quality, with species-rich vegetation and many locally distributed species. Collectively 139 wetland vascular plants were recorded, c. 43% of the wetland species in Britain. The best pond had 54 species recorded and was described by the surveyors as the 'perfect pond'. It is clear that the Cardiff ponds are an important biodiversity resource which should be valued highly. The largely urban context also gives them a high amenity value.

The richness of the Cardiff ponds may be due to the close proximity of the rich wetlands of the Gwent Levels, the original high densities of ponds, the clay surface geology (which often results in good ponds) and the diversity of management and situations. The richness, coupled with the known reliance of wetland plants and animals on metapopulation dynamics, suggests that all the ponds together are important for maintaining local diversity. Additionally, the urban context may be important where ponds are not subject to the degradation linked to intensive use of the surrounding land (cf. Williams et al. 1998). It would be interesting to compare the urban ponds in the City in more detail with the ponds in the surrounding countryside.

There is plenty of potential for further work. Statistical analysis should be carried out to look at correlations between variables which can be used to predict the conservation value of Cardiff ponds. The data will also be cross-correlated with those obtained from the Cardiff Amphibian Survey which was carried out independently in 1998/1999.

Acknowledgements

The CPS97-98 was carried out as a jointly funded project between the National Museum & Gallery, Cardiff, Cardiff County Council and the Environment Agency. Cardiff County Council would like to acknowledge support from the Countryside Council for Wales.

I would like to thank the field surveyors Rosie White, Matthew Rich and John Alder, Bob Wardell and Linda Moore of Cardiff County Council and Teg Jones of the Environment Agency, Jessica Carey and other staff for assistance at the Museum, and all the land owners for access permission.

References

Carey, J. L., Alder, J., Moore, L., Rich, M. D. B., Wardell, R., White, R. & Rich, T. C. G. (1999). *Cardiff Pond Survey 1997-1998*. National Museum and Gallery, Cardiff.

Atkin, R. & Rich, T, C. G. (1997). *Changes in the number of ponds in the Cardiff area between 1880-1886, 1951-1961 and 1997*. Unpublished report, National Museum and Gallery, Cardiff.

Palmer, M. A., Bell, S. L. & Butterfield, I. (1992). A botanical classification of standing waters in Britain: applications for conservation and management. Aquatic Conservation: Marine and Freshwater Ecosystems, 2:125-143.

Williams, P. J., Biggs, J., Barr, C. J., Cummins, C. P. Gillespie, M. K., Rich, T. C. G., Baker, A., Baker, J., Beesley, J., Corfield, A., Dobson, D., Culling, A. S., Fox, G., Howard, D. C., Luursema, K., Rich, M. D. B., Samson, D., Scott, W. A., White, R. & Whitfield, M. (1998). *Lowland Pond Survey 1996*. DETR, London.

The Heritage Ponds Project: approaches and potential

Martin Spray

Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust, The Lodge, 1, Armstrong Road, Littlemore, Oxford OX4 4XT.

Introduction

This paper describes the Heritage Ponds Project[2], which was initiated by the Ponds Conservation Group (PCG). The project is a lottery funded pond restoration scheme which is now six months into an eighteen month pilot phase. This paper describes the background to the project, the approaches being taking and the outcomes to date.

The Heritage Ponds Project is an initiative to enable community groups to restore or recreate ponds for the benefit of wildlife and archaeology. The project will raise awareness of the importance of ponds not only for wildlife but also as repositories for archaeological artefacts, and as important landscape features. To do this the project will distribute small grants and support local community groups in their work.

In particular, he pilot phase of the Heritage Ponds Project is designed to demonstrate how wildlife conservation and archaeological expertise can be made available to coordinated groups of local people in order to achieve high quality improvements in their ponds.

Who we are?

The Heritage Ponds Project is run by a consortium of 22 member organisations[3], representatives of which now meet every six months. The consortium is in the process of setting up a registered charity[4] to run the Heritage Ponds Project and all members of the consortium have been invited to put forward trustees for the Board of the new charity. The statutory agencies, and individuals who do not wish to take on the legal responsibilities of trustees, will be invited to attend Board meetings as Observers. While the Board is legally responsible for the project, the direction of the project is delegated to a Management Committee supported by a full time Project Officer (Alison Fowler).

For the Heritage Ponds Pilot Project the country has been divided into ten regions, each with a Regional Co-ordinator to support the volunteers and community groups who are carrying out the practical work on-site. The Regional Co-ordinators are employed part-time by the project - their full-time employees are the members of the consortium.

The consortium has brought together ecologists, archaeologists, community groups, statutory bodies and NGOs and because of this is much more powerful than any one group could be on its own.

Why we want to do it

As the papers in the Conference Proceedings show, ponds are biologically important yet threatened habitats. They are also important landscape features and, because they often preserve human artefacts and paleo-environmental material (e.g. pollen,

---

[2]In 1999 the Heritage Ponds Project became the Ponds for People Project run by the Ponds Conservation Trust.

[3]British Dragonfly Society, British Herpetological Society, British Trust for Conservation Volunteers, British Waterfowl Association, De Montfort University, English Nature, Environment Agency, The Association of Local Government Archaeologists, Farming and Wildlife Advisory Group, Freshwater Biological Association, Froglife, Ian Benton Ponds, Institute of Terrestrial Ecology, National Federation of Women's Institutes, Oxfordshire Nature Conservation Forum, Pond Action, Pond Life Project Liverpool John Moores University, Surrey Amphibian and Reptile Group., The Wildlife Trusts, University of Bournemouth, University of Sussex, Wildfowl & Wetlands Trust, WWF UK.

[4] The Ponds Conservation Trust

ostracods, diatoms and plant microfossils), can be an important repository of information about the past.

Despite the importance of ponds 'restoration' work carried out on them has often been, at best, neutral in its effects, and at worst, positively damaging. Much of the ecological management of ponds been based on a series of myths and misconceptions about pond ecology, and the archaeological value of ponds has rarely been considered. As a consequence of this, management of ponds in the past has almost certainly resulted in damage to biological communities and the loss of important archaeological material.

As well as being valuable habitats and features, ponds are also very popular habitats and one of the easiest places for community groups to begin to make a difference. People, especially children, like ponds and tend to associate pond loss and neglect with a more general neglect of the environment. In a survey carried out in 1996 by the PCG over 75% of the community groups questioned expressed an interest in carrying out pond restoration or creation.

As a result of the growing interest in ponds, the last 10 years has seen an enormous increase in understanding of their ecology. However, it was clear to the members of the Pond Conservation Group that, although a relatively small number of specialists were well-aware of the new approaches that were now available for the management and protection of ponds, this information was simply not reaching people working out on the ground. The recognition that there was an enormous need to disseminate high quality technical information to practical conservationists, especially community groups, led to the PCG, with the support of WWF, initiating the present project.

The project

The Heritage Ponds Project began life as an initiative of the Ponds Conservation Group, to provide community groups with advice and practical support in pond conservation. In 1996 the group applied for funding from the Millennium Commission, in a project entitled 'Ponds For People'. This application was unsuccessful but discussions quickly began for its submission to the Heritage Lottery Fund. In due course the HLF gave the go-ahead for the present £200,000 pilot project, as the precursor to the full-scale project at the end of the 18 month trial period.

The project is concerned with a wide variety of ponds which have recognised cultural or natural heritage value. To be included in the Heritage Ponds Project ponds must be:

- Of known historic or archaeological significance
- In public ownership and with free access - the lottery fund is for the public benefit and can't be used for projects which give purely private benefit;
- Valuable wildlife sites, where practical work will protect or improve the wildlife interest.

In addition, for the pilot project, it was agreed that it would be advantageous if there was an existing community group to undertake the work as the time constraints of the pilot meant that it would be impractical for groups to organise themselves and start work in less than eighteen months.

For the pilot project a representative range of ponds were selected, exemplifying the range of management objectives and practical problems likely to be met in the main project.

The ten pilot ponds

The pilot project is working on 10 representative ponds in England, Wales, Scotland and Northern Ireland and is providing grants of about £2.5k to community groups to buy materials and hire contractors where necessary. This size of grants, and the criteria used to select the ponds, has allowed the project to take on a wide range of ponds and management objectives.

Ponds in the pilot project include:

- Mayford Green Pond in Woking (Surrey). The original village green pond was filled-in by 1920 (it can be seen on the 1870 1st Edition Ordnance Survey map) and the project will recreate this pond close to the original site.
- Stadwell Pond, Nettlebed Common (Oxfordshire). This pond was created as a result of clay extraction but has been infilled over the years by rubbish. The project will re-excavate the pond to its former extent and remove rubbish.
- The Dell, Fairwater, Cardiff. This pond is a high quality wildlife site requiring only minimal maintenance; the pond will have habitat creation enhancements (new small pools in the drawdown zone) and rubbish removal.
- Ashton Court Estate Ponds, Bristol. At Ashton Court three stone-lined dew-ponds, believed to have been built between 1790 and 1820 for watering deer, will be renovated. The ponds have been damaged by vandals and the project is paying for the community group to be trained to repair and maintain the stone linings.

More information is available about these sites in the archaeological and ecological survey reports for the sites (Van de Noort, 1997a,b,c,d; Pond Action, unpublished survey data from the pilot ponds).

To support the work of the community groups the project is taking on Regional Co-ordinators, who are employed part-time by the project to support the community groups. Regional Co-ordinators act as the first port of call for the community group and also help to develop the groups' ideas for their sites. The Regional Co-ordinators attended a two day training course at the beginning of the project and the full-scale project will develop an extensive training programme for Regional Co-ordinators. The main objective of the training courses is to ensure that the latest ideas about pond ecology and management are available to the community groups.

Surveys

To help the groups draw up their objectives, and to help ensure the work is of real benefit, each site will be surveyed before any management takes place. The surveys will be for both archaeological artefacts and ecological value and the restoration objectives for the site should be guided by the results.

Even with the limited scope of the pilot the importance of good survey data is already evident. This is perhaps best exemplified by The Dell, in Cardiff.

This pond is on the edge of a housing estate and suffers from fly tipping. It was locally assumed to be 'in a bit of a state' and in need of management work. However, survey work quickly showed it to be a lovely pond, with a rich plant and animal community including three species of amphibians and a Red Data Book water beetle. The water beetle was found in temporary pools in the ponds drawdown zone (Pond Action, unpublished data).

The original management proposals for the site, prior to any survey work, focussed on deepening (i.e. eliminating) the drawdown zone which was one of th richest parts of the pond. In the light of survey data being available it was possible for the community group to develop a plan which focussed more on maintaining the existing high value of the site with non-invasive management, (e.g. litter removal), habitat creation and very limited vegetation management.

It should not be forgotten that however good the surveys are or however active the Regional Co-ordinator is, the physical restoration will be carried out by the community groups. To help then, an information pack covering all areas of the work is been drafted by the Project Team and will be published for the main project.

The information packs are intended not only for those groups that secure funding, but for all groups applying for funding, even if unsuccessful. By disseminating this information as widely as possible the project will help to raise the profile of the ponds, improve understanding of their archaeology and ecology, and go some way to improve the management and design of ponds outside of this project. We hope that this will allow the project to influence pond management and creation generally, not just the ponds that are directly funded as part of the project.

Lessons learnt

Even in its first 6 months the project has learnt many valuable lessons and the consortium's views on how best to run the project have changed dramatically since the original project proposals were formulated.

Three areas are of special interest:

1. Before the project started there was some concern that there would be a conflict between archaeology and wildlife conservation - archaeologists perceived that nature conservation organisations were mainly concerned with dredging sediments and pulling out plants, both activities extremely damaging to archaeological artefacts.

   In reality, new approaches to pond management for wildlife, which emphasise much more gentle and less destructive management, prove to be closely compatible with maintaining archaeological interest. This has been an important development within the project.

2. The importance of good survey work has already been mentioned, but the project has shown just how important this is to enable community groups and land managers to make the right decisions for their sites.

   The project is now investigating ways of ensuring that all the ponds in the full-scale project are surveyed to a consistent and high standard. Although good quality surveys often seem costly, the benefits they provide are considerable; indeed, in many instances they may reduce the need to spend money on practical work. An important objective of the main project, therefore, will be to maintain the same high standard of survey and assessment as that adopted for the pilot project.

   In addition, people respond well to information - we all like to know that our local pond contains a particularly rare species and even if it doesn't the information still stimulates interest.

3. The grants being distributed by the project are quite small, but combined with the efforts of the community group and the technical support of the project, a large amount of work can be done. In addition, the money can also free up other grants and even within the pilot project it has been obvious that the project can create considerable leverage for funds from other organisations.

The future

So what next? The project is only at the start of the pilot phase, despite having been around since 1995 in the guise of the Ponds For People Project.

The physical work will be starting in the next few weeks and, while it is certainly a very important milestone, for the project team it really only marks the start of a fairly hectic period of work.

The results of the pilot project need to be reported on and written up for the Heritage Lottery Fund, along with the proposals for the full-scale project, which will be submitted early in the spring of 1999.

The project consortium is obviously hopeful that the application to the HLF for the main project will be successful. If it is the project will be on target for a smooth transition from the pilot project to the full-scale programme in August 1999, when the full restoration programme will begin. It is currently anticipated that grant-aid will be provided to about 50 ponds in the first full year of the project, building up to about 200 a year by the end of the project.

References

Van de Noort, R. (1997a). Heritage Ponds Pilot Project archaeological assessment: Ashton Court Estate Ponds, Bristol, South West Region. Centre for Wetland Archaeology, Hull.

Van de Noort, R. (1997b). Heritage Ponds Pilot Project archaeological assessment: The Dell at Fairwater, Cardiff, Wales. Centre for Wetland Archaeology, Hull.

Van de Noort, R. (1997a). Heritage Ponds Pilot Project archaeological assessment: Stadwell Pond, Nettlebed Common, Southern Region. Centre for Wetland Archaeology, Hull.

Van de Noort, R. (1997a). Heritage Ponds Pilot Project archaeological assessment: Mayford Village Pond, Woking, Southern Region. Centre for Wetland Archaeology, Hull.

Editors Note

The Heritage Lottery Fund was unable to fund the main pond management project described in this paper.

Renamed 'Ponds for People', the work described here is now being taken forward by the Ponds Conservation Trust who have initiated projects in the North East of England and Wales. It is anticipated that work will begin in North West England and the Midlands in 2001. For more information about the Ponds for People Project contact: Richard Snow, Ponds Conservation Trust, Oxford Brookes University, Gipsy Lane, Headington, Oxford, OX3 0NP. Tel: 01865 483199; Fax: 01865 483282; e-mail: rsnow@brookes.ac.uk.

Factors affecting the nature conservation value of ponds: results of the National Pond Survey

Jeremy Biggs, Mericia Whitfield, Penny Williams, Gill Fox and Pascale Nicolet. Pond Action, c/o Oxford Brookes University, Gipsy Lane, Headington, Oxford, OX3 0BP.

1. Introduction

Managing ponds to improve their conservation value is a popular nature conservation activity, but the ecological literature contains very little information about the factors that are actually affecting the conservation value of ponds. With this in mind, back in 1989, Pond Action began the National Pond Survey, one of the first of what subsequently became a series of projects, all aimed at collecting basic ecological data about ponds.

2. About the National Pond Survey

The National Pond Survey (NPS) was initiated, with support from WWF, to create a core reference database containing information from about 200 ponds throughout Britain. NPS ponds are located in high quality landscapes, representative of the geological and land-use variation across Britain. The ponds are as little exposed as possible to the damaging effects of pollution, intensive landuse and land drainage. They are, therefore, in as near to pristine condition as it is possible to get in Britain.

Data from the NPS ponds have been collected using standard methods, summarised in the NPS methods booklet (Pond Action 1998). The biotic data from each pond includes (i) a three-minutes hand net macroinvertebrate sample taken in each of threes seasons (spring, summer, autumn), with the animals identified at species level (ii) a wetland plant list with abundances (iii) information on the occurrence of amphibians. A wide range of physical and chemical data are also collected including data on geology, water sources, water chemistry, shade, depth, area and surrounding land-use.

In addition to the NPS data set, funding from Natural Environment Research Council (the Governments research funding body, NERC), has enabled Pond Action to extend the survey to include a second 200-site database - this one focussing on more degraded ponds from the wider countryside, collectively exposed to a wide range of impacts including pesticides, nutrients, road runoff, farm wastes etc. With the Environment Agency, Pond Action has also been looking at a small number of high quality lakes (up to 5ha in area), such as Hatchet Pond in the New Forest and Upton Broad in Norfolk. The benefit of this is that, gradually, large databases of compatible information are being built-up which are available for re-analysis.

Overall, therefore, the NPS now provides a generic dataset with a wide range of uses. To date this has included:

- a point a reference against which the DETR Lowland Pond Survey 1996 data could be compared to assess the quality of ponds in lowland Britain (see Biggs et al. this volume),
- a basis for the new PSYM technique for assessing the ecological quality of ponds (see Biggs et al., this volume),
- extensive information on the ecological preferences of freshwater plants and animals,
- information about the factors affecting the conservation value of ponds and the practical implications of this for pond management in terms of pond design and management.

Aspects of this last point, information about the factors affecting the conservation value of ponds, are the main focus of the remainder of this paper.

3. Classification of ponds

The ability to identify different pond community types is of obvious importance in conservation management. It helps to provide fundamental information about the environmental factors which are influencing community structure and enables recognition of different community types, both essential to enable adequate protection of the full range of biodiversity in ponds.

Figure 1 shows a TWINSPAN classification of National Pond Survey macroinvertebrate data. This uses multivariate statistics to group ponds according to how similar their invertebrate communities are. Each of the end-groups therefore represents a set of ponds with similar invertebrate communities. To produce Figure 1, the invertebrate communities have been correlated with environmental variables to show which physical and chemical factors show statistically significant relationships with the invertebrate end-groups.

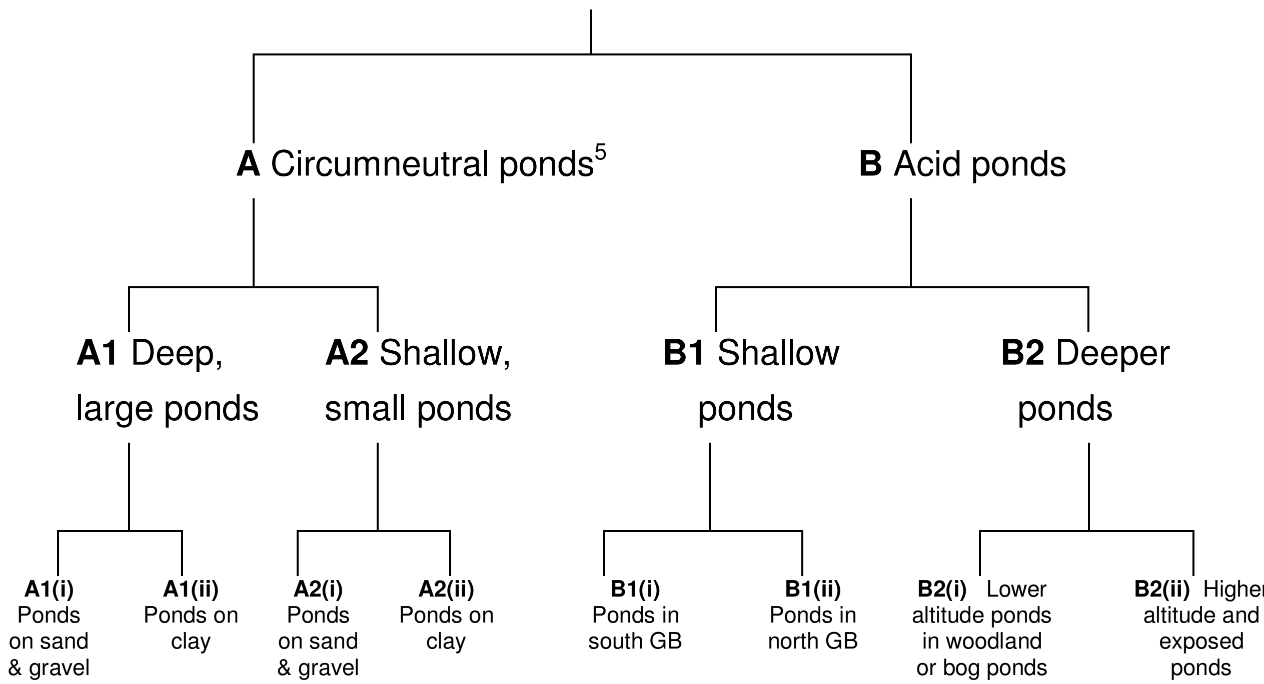


Figure 1. TWINSPAN classification of ponds in Britain based on aquatic macroinvertebrate data

The analysis shows that the main pond types defined using invertebrate data can be characterised in terms of four major environmental variables: pH, depth/permanence, substrate/hydrology and location. The over-riding influence on communities at a national level is pH; thus the first TWINSPAN division splits ponds broadly into those with invertebrate communities typical of circumneutral ponds and those with communities typical of acid ponds. This is a pattern seen in all national freshwater datasets including those from rivers, lakes and mires - with acid and more-or-less neutral sites always broadly distinguished.

The second most important factor in the classification is pond depth and permanence, with both circumneutral and acid sites split into deeper and shallower or seasonal sites. At TWINSPAN division 3 the circumneutral ponds further divide in terms of substrate

[5] Ponds with a pH of about 7.

(which is intimately linked to hydrology), whilst the acid sites divide in terms of geographic location and altitude.

The implication of such an analysis is that, at its most basic level, protection of the full range of biodiversity in Britain's ponds depends on regional protection of both alkaline and acid site, both deep, shallow and seasonal ponds, and ponds from a range of substrates and altitudes.

3. Factors affecting the conservation value of ponds

Factors affecting the conservation value of ponds were investigated using two data sets. The NPS dataset of minimally impaired ponds was used to investigate which *natural* factors affected the species richness and rarity of high quality ponds in natural landscapes. The NPS and ROPA data sets were then used together to investigate the effect of man's influence (i.e. *anthropogenic factors*) on the conservation value of ponds.

In both analyses, pond conservation value was assessed using two biotic communities: macroinvertebrates and wetland plants. The plant community was also separated into two groups - aquatic plants and emergent plants since they tend to respond to rather different environmental factors (aquatic plants being more responsive to water quality, and emergents to bank sediments and structure).

3.1 Factors affecting pond conservation value in semi-natural areas

The results of correlations between these biotic groups and physico-chemical environmental variables are interesting in that a comparatively small number of 30 or so main environmental variables relate to either the number of species or the occurrence of rarities. This may be because the study ponds are all relatively unimpaired, with the differences between them simply reflecting natural differences that exist between ponds. Since pond plants and animals might be expected to be good at exploiting the range of *natural* physical and chemical conditions in ponds, the occurrence of high quality assemblages in these ponds is perhaps not unexpected.

Thus, trees are generally thought of as undesirable around ponds and much effort is spent cutting them back. However, in the high quality NPS ponds, shade has only very slight detrimental effects: in high quality landscapes shaded ponds were as rich as unshaded ponds, and just as likely to support uncommon species, with only emergent plants showing a slight depression in species richness as shade increased. Similarly the data showed no detrimental effects from silt accumulation, which begs questions about what is being achieved by conservation dredging of ponds.

The main factors which did show correlations with number of species and the occurrence of rarities in ponds were: area, isolation, pH (and the related chemical measures alkalinity, calcium, conductivity) and abundance of vegetation (see Table 1).

Area. Not surprisingly, the NPS data showed a relationship between species richness and area, with bigger ponds supporting more species. There were, however, no relationships between size and species rarity. Thus small ponds were just as likely to support uncommon species as large ponds when they occur in high quality semi-natural landscapes.

Table 1 Factors affecting the conservation value of ponds

The table shows *p* values for Spearman's coefficient of rank correlation for the relationship between the environmental variable and the measure of conservation value. Correaltions are positive unless otherwise stated.

Shade	**Species richness**	**Species rarity**
Emergent plants	0.05 (-ve)	ns
Aquatic plants	ns	ns
Macroinvertebrates	ns	ns
Silt depth	**Species richness**	**Species rarity**
Emergent plants	ns	ns
Aquatic plants	ns	ns
Macroinvertebrates	0.05	ns
Area	**Species richness**	**Species rarity**
Emergent plants	0.001	ns
Aquatic plants	0.001	ns
Macroinvertebrates	0.001	ns
Isolation	**Species richness**	**Species rarity**
Emergent plants	0.001 (-ve)	0.05 (-ve)
Aquatic plants	0.01 (-ve)	0.001 (-ve)
Macroinvertebrates	0.01 (-ve)	ns
Chemistry: pH	**Species richness**	**Species rarity**
Emergent plants	ns	ns
Aquatic plants	ns	0.001
Macroinvertebrates	0.001	ns
Chemistry: alkalinity	**Species richness**	**Species rarity**
Emergent plants	ns	ns
Aquatic plants	ns	ns
Macroinvertebrates	0.05	ns
%cover vegetation	**Species richness**	**Species rarity**
Emergent plants	0.01	ns
Aquatic plants	0.001	0.05
Macroinvertebrates	ns	ns

Isolation. Isolation was measured in the NPS by assessing the number of other wetlands in the area. This included streams, river valleys and wetlands, as well as other ponds. The relationship between such factors and pond species richness and rarity was clear from the NPS data, and also shown in the DETR study (Biggs et al. this volume). One implication from this is that it is important to maintain the density of ponds and other wetlands in the countryside in order to maintain metapopulations of wetland species. Another implication is that an excellent location to create new ponds is near to existing wetland areas from which they can derive propagules to encourage a rapid establishment.

Chemistry. Within the NPS dataset there were comparatively few relationships between water chemistry and species richness and rarity. The strongest relationship was between pH and invertebrate species-richness, with fewer invertebrate species in more acid ponds, a fairly well-known relationship. Invertebrate rarity was not related to pH however, suggesting that there are just as likely to be uncommon specialised invertebrates in acid water as in base-rich water. Aquatic plant species richness was not affected by pH but more alkaline ponds were more likely to have uncommon species. This may be a reflection of how few high quality alkaline ponds are now present in the British countryside rather than a characteristic inherent to these communities. Perhaps not surprisingly,emergent plants did not seem to be strongly affected by water chemistry. Probably, as noted earlier, because they predominantly take nutrients from the soil and not directly from the water.

Vegetation abundance. The cover of vegetation in a pond had a significant relationship with both emergent and aquatic plants, with greater vegetation cover associated with more species. For aquatic plants there was also a hint that the more vegetation, the more potential for uncommon species. Some of the implications of these findings are discussed in Williams et al. (this volume).

3.2 Man's influence on pond conservation value

To investigate the effect of anthropogenic impacts on ponds, the NPS and ROPA data sets were combined to give a data set of variably degraded ponds. This included both ponds which were minimally exposed to pollutants, and ponds in more intensively managed areas where they were exposed to biocides, high concentrations of nutrients, urban runoff etc. The results told a rather different story to the analyses of minimally impaired ponds alone.

The extent of anthropogenic impacts on these ponds was assessed in a variety of ways. This included direct measures, looking at water chemistry (pH, nutrients, metals etc) and a number of indirect measures. Indirect measures were employed because of the difficulty of measuring all potential impacts. For example, there are 450 different pesticides alone being used in the countryside, and many degrade rapidly, making it difficult to measure them without a highly intensive water sampling programme.

Indirect measures included:

(i) The extent of intensive land use types around the pond.

(ii) 'Overall Pollution Index', which was a catch-all assessment made on-site to rank each pond according to how exposed it was to agricultural runoff, urban runoff, piped inputs, farm wastes, road runoff etc.

(iii) An index of pesticide and fertiliser application rates, calculated from MAFF data and other sources.

The results of these analyses provided evidence of widespread degradation of ponds in Britain.

Table 2 Anthropogenic factors influencing pond conservation value

The table shows *p* value of Spearman's coefficient of rank correlation for the relationship between the environmental variable and the measure of conservation value. All correlations are negative.

Aquatic plants	**Species Richness**	**Species Rarity**
Indirect		
Pollution Risk Index, landuse intensity	0.001	0.001
Pesticide, fertiliser application rate	0.001	0.05
Direct		
Phosphorus, potassium, suspended solids	0.01	0.01
Emergent plants	**Species Richness**	**Species Rarity**
Indirect		
Pollution Risk Index, landuse intensity	0.001	0.001
Pesticide application rate	0.001	0.01
Fertiliser application rate	0.01	0.01
Direct		
None		
Aquatic invertebrates	**Species Richness**	**Species Rarity**
Indirect		
Pollution Risk Index, landuse intensity	0.001	0.001
Direct		
Ammoniacal nitrogen	0.001	0.001
Total Oxidised Nitrogen	0.001	0.001

Relationships between anthropogenic impacts and aquatic plants showed a strong and consistent negative relationship between the aquatic plant assemblage value and both Overall Pollution Index and occurrence of intensive landuse around a pond. So ponds with a high risk of exposure to pollutants had fewer species and fewer rarities. Similar relationships were shown for emergent plants in terms of Overall Pollution Index and land use intensity. However, emergents did not show relationships with water chemistry, again perhaps because they are growing at the edge of ponds and are less affected by water quality. The richness of pond invertebrate assemblages also showed consistent negative correlations between exposure risk, landuse intensity and nutrients and the numbers of species.

Overall, these data provide consistent evidence that pond quality is degraded in areas where there is considerable anthropogenic stresses from factors such as nutrients, biocides, runoff from urban areas and roads, organic wastes from farms, sediments - all the things that differ between intensively managed areas and semi-natural habitats.

Ponds biodiversity compared to other freshwaters

Finally, the NPS data has provided, for the first time, a means of comparing ponds with other freshwater systems - and, therefore, more objective ways of assessing the contribution that this waterbody type makes to the conservation of freshwater biodiversity.

When the NPS methods were devised, an effort was made to maximise compatibility with other freshwater surveys. This now enables NPS invertebrate data to be directly compared with the Institute of Freshwater Ecology's RIVPACS data set (Wright *et al*. 1996), and the pond plant data to be compared with English Nature's lake dataset, collected in the 1970s and 1980s by Margaret Palmer and colleagues (Palmer *et al*. 1992).

Table 3 Pond and river invertebrate species richness and rarity comparison

§

	Ponds **200 sites**	**Rivers** **600 sites**
Number of species	431	377
Nationally Scarce species (occurring in 15-100 10-km squares)	78	41
Red Data Book species	26	13

Table 4 Pond and lake aquatic plant species richness and rarity comparison

	Lakes 1100 sites	Ponds 200 sites
Number of species	89	72
Nationally Scarce species (occurring in 15-100 10-km squares)	8	7
Red Data Book species	5	5

The pond/river analysis compares the invertebrate species from 600 minimally impaired RIVPACS sites with 200 minimally impaired pond sites. The results (Table 3) show that despite their being three times as many sites in the IFE river database, there are approximately 10% more species recorded from the ponds, and roughly double the number of Nationally Scarce and Red Data Book species.

The pond/lake analysis compares the numbers of species of aquatic macrophytes in 200 NPS ponds with the 1100 site English Nature lake dataset. The results showed that, although the EN survey included over five times as many sites, many of which were very large, the ponds still supported 80% of the species found in the lakes (Table 4).

The obvious conclusion from these comparisons is that ponds, collectively, provide a rich biodiversity resource which it is important to protect.

The reasons that they are so rich, particularly in comparison to rivers, are not known for sure, but may be at least partly linked to their catchments. Many ponds have small catchments, particularly compared to large waterbodies such as rivers and lakes. As waterbodies that tend to be a sink for pollutants, ponds are highly responsive to the character of their catchments, and since these are often small, they typically reflect very local natural variations in geology, hydrology, climate, vegetation, tree-shade, etc. This means that ponds are probably more varied physically and chemically than larger waterbodies which, with their larger catchments, tend to 'average out' variations in environmental conditions.

A strong link between ponds and their small catchment is both a blessing and a curse. At its worst ponds, with their small volumes, are highly vulnerable to degradation from their surrounds. Unlike lakes and rivers, there is little possibility of diluting or buffering pollutants inputs, so that poor quality ponds are often degraded to an extreme rarely seen in larger waters. Set against this, however, because of their small catchments ponds can be exceptionally rich - and often completely protected from land-based pollutants - something which is very rare in rivers and lakes which, with their much bigger catchments, are almost always exposed to a wide range of pollutants and other degrading influences. And this may also be a factor which helps to explain the relative richness of these small waterbodies, which can sometimes be kept pristine, within landscapes that are widely damaged by man.

Acknowledgements

We would like to gratefully acknowledge funding from WWF UK who supported the National Pond Survey, and NERC who funded data gathering and analysis of the degraded pond data set via the ROPA (Realising Our Potential Award) scheme.

References

Palmer, M.A., Bell, S.L. and Butterfield, I. (1992). A botanical classification of standing water in Britain: applications for conservation and monitoring. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **2**, 125-143.

Pond Action (1998). *A guide to the methods of the National Pond Survey*. Pond Action, Oxford.

Wright, J.F., Blackburn, J.H., Gunn, R.J.M., Furse, M.T., Armitage, P.D., Winder, J.M. and Symes, K.L. (1996). Macroinvertebrate frequency data for the RIVPACS III sites in Great Britain and their use for conservation evaluation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **6**, 141-167.

The archaeological and palaeoecological value of ponds

Robert Van der Noort[§] and Jane Bunting[¶]

[§]Centre for Wetland Archaeology, University of Hull, Cottingham Road, Hull, HU6 7RX.

[¶]Department of Geography, University of Hull, Cottingham Road, Hull, HU6 7RX

Introduction

The archaeological and historical importance of ponds arises from their usefulness for a wide variety of human activities. Ponds are a source of water for people, their livestock, and their industries. They contain some food resources, like fish, and attract others, e.g. ducks and deer. They can even provide power (e.g. mill-ponds). Ponds can also have recreational and aesthetic value, and have an important contemporary role in nature conservation and landscape biodiversity. Therefore ponds tend to become a focus for human activity within a wider cultural landscape.

Archaeology, which investigates the past largely by looking at physical remains and relic features of previous human activities within the modern landscape, and history, which studies the past mostly via the documentary evidence left behind by previous generations, approach the study of ponds from different angles, but both disciplines highlight the central role of the pond in many cultural landscapes. In this paper, we focus on the physical features of ponds which yield information of value to both archaeologist and historian. We examine some of the ways in which these different uses have affected the location and structure of ponds, and the sorts of clues to past use which are available to us. We then consider the importance of pond ‘contents’, of the sediments that accumulate within the pond, for investigating past landscapes and environments.

The archaeological/historical importance of ponds

The archaeological and historical value of ponds is two-fold. Firstly, ponds are valuable as built or modified features of the cultural landscape. The pond’s location within a landscape is closely correlated with its function, as is its physical appearance and shape. These basic attributes can hold useful information on social and economic aspects of past societies. Examples include the role of fish ponds in medieval monastic societies (Aston 1988, Gilchrist & Lythum 1989), the importance of millponds in the early Industrial revolution (Crossley 1990), the central role of the village pond, and the use of quasi-ornamental dew-ponds on country estates, which were made for drinking water for deer as well as aesthetic additions to the landscape (Rackham 1986).

Ponds are also a repository of archaeological and palaeoenvironmental source material. They are valuable not just for being a pond per se, but for being a permanently waterlogged sedimentary system located within a cultural landscape. As sediments accumulate, they preserve a wide variety of objects such as pollen, fish bones, seeds, fishing weights, charcoal, coal dust and other airborne pollutants, which offer a wide variety of information about human activities and the environment around the pond (e.g. Currie 1991).

A brief history of ponds

Ponds are highly variable entities, in terms of their current status, origin, use, and ecology. Many ponds came into being by processes other than direct human action, but once in existence were exploited in various ways, and modified to better fit them for human activity, whether this involved major alteration of pond structure and function (e.g. deepening work from damming outflows, building up the edges or dredging out the sediments), or minor additions in its general environment (e.g. benches, shoring up the edges).

Ponds are known to have been created or modified since later prehistory, with examples from the late Bronze Age in the Upper Thames region (Bradley et al. 1980), and the Iron

Age hillfort of Breiddin in the Welsh Marches (Musson et al. 1991), where excavation of a pond produced both palaeoenvironmental information and a collection of wooden artefacts. A larger number of sites are known from the Roman period (Zeepvat 1988), including both fishponds and ornamental ponds, recorded at sites like Fishbourne Roman Palace (Cunliffe 1968) (Figure 1).

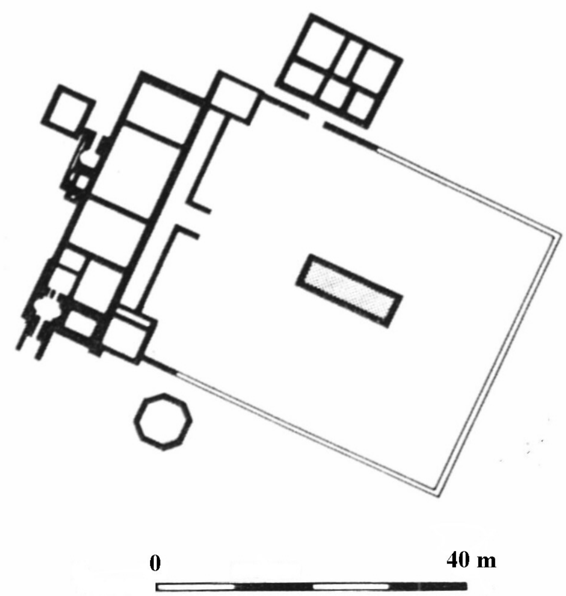


Figure 1. Plan of Roman villa with ornamental pond, Bancroft, Buckinhamshire (cf. Zeepvat 1988). North is at the top of the figure.

The main phase of pond-building was in the Medieval period (e.g. Aston 1988). The best documented and excavated examples are often strongly associated with monastic communities. These ponds were not the ornamental features associated with later great houses, but functioning landscape components, generally either fish ponds or mill ponds. The role of the fish pond in the monastic economy was probably as a local supply of fresh food for the frequent meat-free 'fast days', rather than larger-scale commercial fish production (Steane 1988, Currie 1989). Medieval millponds are also commonly found on monastic estates, since the ability to process grain and collect the associated taxes was an important prerogative for medieval landowners. In the late and post medieval period, mill ponds also became common throughout the secular landscape.

During the post-medieval period, many dew ponds were built in deer parks and elsewhere for watering livestock (e.g. Hayfield & Brough 1987). As larger landowners began to create purely ornamental and idealised landscapes, water features became ever more elaborate, often including ponds, ranging from highly geometric, elaborately shaped structures to the Romantic grotto pond that aimed to be more natural than the real thing (e.g. Currie 1990).

The shape of ponds reflects their past or present function. Ponds used for wildfowling (decoys) have a central pool and elongated arms, curling ponds are rectangular and ornamental ponds often have elaborate geometric outlines, whilst the size and shape of mill ponds is controlled primarily by the capacity of the water wheel they were built for.

The importance of water as a resource often affects the built features associated with ponds, for example, paved areas aid access for drinking animals or people and prevent water fouling (e.g. dew ponds on Ashton Court Estate, Bristol [Van de Noort 1998a]), channels taking water to and from holding ponds near foundries and iron-works (e.g. at

Carron Iron Works, Stenhousemuir [Van de Noort] 1998b), or the mill house, wheel, weir and race associated with mill ponds. Thus the various human activities in and around the pond affect the archaeological/architectural aspects of ponds, and also contribute to the archaeological finds within ponds. These finds include both the obvious built features such as landing stages and human-made objects accidentally or deliberately dropped into the pond (e.g. fishing hooks and weights).

Archaeological evidence from pond sediments

The nature of the pond habitat (e.g. depth, amount of vegetation cover) is also important, whether as a home for fish, an attraction for wildfowl, increasing local biodiversity, landscape aesthetics or recreational amenity. Present-day conditions can provide clues to what were often very different past habitats, but the main clues to changing pond environments come from the muds building up within the ponds themselves. These sediments have considerable value for the archaeologist, because they contain the remains of a wide variety of plants and animals (see Keen, this volume). As the sediments accumulate, each successive layer includes and preserves the remains of the living organisms in and around the pond at the time that layer was deposited. By taking cores of pond sediments, we can go back in time.

By looking at the remains of organisms that lived in the water (e.g. fish scales, midges and algae) we can reconstruct the changing nature of the pond itself, for example, eutrophication, or changing surface water temperature (in response to climate change). We can also reconstruct the changing landscape around the pond, using the remains of plants, particularly pollen grains. These tiny plant propagules (c.0.1-0.01 mm) are produced in their millions every spring and summer, and widely dispersed in the atmosphere as any hayfever sufferer will know. Ponds, which are generally small in size, mostly collect pollen produced by plants growing within a few hundred metres of the banks (Jacobson & Bradshaw 1981), and therefore can give a fascinating record of land use and vegetation change in the local area, at a human spatial scale.

Medieval ponds often contain several metres of sediment, all of which has been deposited since they were built, so that a continuous record of landscape change during this millennium is preserved with an unusually good potential time resolution. For comparison, many ‘natural’ lakes have accumulated less than 5 m of sediment in the last 10 000 years, about 50 cm a millennium.

A particular example of the way the remains trapped in these sediments can inform the archaeologist comes from a ‘fishpond’ at St Mary’s Priory, a Gilbertine monastery founded before 1212AD by William Fitz-Peter at Ellerton, on the east bank of the River Derwent in East Yorkshire (Figure 2). The owners, a conservation trust, want to increase the biodiversity of their land, and in keeping with the historical landscape would like to reinstate the pond. Because it forms part of a protected archaeological monument, the owners commissioned a coring survey of the pond. Pollen analysis of sediments from this pond showed a massive peak in Cannabis pollen during the Medieval period (Lillie & Gearey 1999). This probably reflects the processing of hemp plants for their fibre, probably post-dating the use of the pond for fish. Hemp is again becoming fashionable for clothing, but is also an important resource for more mundane fibre uses like rope-making, which used to be very important in the English economy. The fibres are most easily extracted by rotting the rest of the plant away, in a process called retting. The plants are allowed to flower, then deposited in the ponds, hence the high pollen counts. Many existing ponds were used for this process, which was part of an important local industry in the period, and some were even dug out specially for the purpose. This case study illustrates the changing role but continuing importance of the pond in the cultural landscape, in this case from food source to fibre processing site to wildlife habitat and heritage feature.

Figure 2. Aerial photograph of Ellerton Priory, East Yorkshire. The 'fishpond' is indicated by the arrow (RCHME – Crown Copyright reserved). North is at the top of the figure.

Sediments in ponds don't just contain the remains of living organisms. Dust particles and all kinds of fine inorganic matter also falls into the pond from the atmosphere, or are washed out in rain, and are also 'locked into place' within the sediment archive. These particles include soot and heavy metals from industry, lead from petrol fumes, and charcoal from fires, and there is considerable potential to use these kinds of indicators to look at changes in the historic period, for example, the spread of industrialisation and its impact on the environment (e.g. Battarbee et al. 1985).

Summary

Ponds are an important feature of the cultural landscape, being valuable to human communities in a variety of ways, as a source of water, food, and motive power, as well as for industrial and recreational uses. Since they have been important to people through the ages, they are of considerable importance to archaeologists. The shape and location of the pond itself, the structures built into and around it, and the sediments contained within it, can all provide fascinating insights into the past.

References

Aston, M. (Ed.) 1988. Medieval Fish, Fisheries and Fishponds in England. British Archaeological Reports British Series 182.

Battarbee, R.W., Flower, R.J., Stevenson, A.C. & Rippey, B. (1985) Lake acidification in Galloway: a palaeoecological test of competing hypotheses. Nature 314 350-352.

Bradely, R., Lobb, S., Richards, J. & Robinson, M. 1980. Two late Bronze Age settlements on the Kennett Gravels: excavations at Aldermaston Wharf and Knight's Fram, Burghfield, Berkshire. Proceedings of the Prehistoric Society 46, 217-295.

Crossley, D. 1990. Post-medieval archaeology in Britain. Leicester University Press, Leicester.

Cunliffe, B.W. 1968. Excavations at Fishbourne 1967; 7th and final interim report. Antiquarian Journal 48, 32-40.

Currie, C.K. 1989. The role of fishponds in the monastic society. In: Gilchrist, R. & Mythum, H. (eds) The archaeology of rural monasteries. British Archaeological Reports British Series 203.

Currie, C.K. 1990. Excavations of an early eighteenth century garden pond: the west pond, Castle Bromwich Hall, west Midlands. Post-medieval Archaeology 24, 93-123.

Currie, C.K. 1991. Southwick Priory fishponds: excavations 1987. Proceedings of the Hampshire Field Club Archaeological Society 46, 53-72.

Gilchrist, R. & Mythum, H. (eds) The archaeology of rural monasteries. British Archaeological Reports British Series 203.

Hayfield, C. & Brough, M. 1987. Dewponds and pondmakers of the Yorkshire Wolds. Folk Life 25, 74-91.

Jacobson, G.L. Jr & Bradshaw, R.H.W. 1981. The selection of sites for paleovegetational studies. Quaternary Research 16, 80-96.

Lillie, M. & Gearey, B. 1999. The palaeoenvironmental survey of the Rivers Aire, Ouse, Wharf and Derwent. In: van de Noort, R. & Ellis, S. (eds) Wetland Heritage of the Vale of York: an archaeological survey. Humber Wetlands Project, University of Hull, Hull.

Musson, C.R., Britnell, W.J. & Smith, A.G. 1991. The Breiddin hillfort: a later prehistoric settlement in the Welsh Marches. Council for British Archaeology Report 76, London.

Rackham, O. 1986. The History of the Countryside. Dent, London.

Steane, J.M. 1988. The Royal fishponds of medieval England. In: Aston, M. (Ed.) 1988. Medieval Fish, Fisheries and Fishponds in England. British Archaeological Reports British Series 182. 39-68.

Van de Noort, R. (1997a). Heritage Ponds Pilot Project archaeological assessment: Ashton Court Estate Ponds, Bristol, South West Region. Centre for Wetland Archaeology, Hull.

Van de Noort, R. (1997b). Heritage Ponds Pilot Project archaeological assessment: Carron Dams, Stenhousemuir, Scotland. Centre for Wetland Archaeology, Hull.

Zeepvat, R.J. 1988. Fishponds in Roman Britain. In: Aston, M. (Ed.) 1988. Medieval Fish, Fisheries and Fishponds in England. British Archaeological Reports British Series 182. 17-26.

25 years of change in the plant communities and conservation value of some Cheshire ponds

Pascale Nicolet

Pond Action, c/o Oxford Brookes University, Gipsy Lane, Headington, Oxford, OX3 0BP.

1. Introduction

The importance of ponds for biodiversity and amenity has been recently shown by a number of studies (eg Biggs et al, 1993; Williams et al, 1998). However, little pond monitoring has been carried out and this was the first time that a survey of a group of ponds was repeated after 25 years. The study had two main aims:

- To identify changes in the conservation value and plant communities of ponds in the parish of Christleton between 1973 and 1998.
- To assess whether the changes were due to natural or anthropogenic causes.

2. Study location: Christleton parish

The study took place in Christleton ecclesiastical parish, in Cheshire, which consists of five clerical parishes: Christleton, Cotton Abbotts, Cotton Edmunds, Littleton and Rowton. The parish covers an area of about 13 km^2 and has a high pond density. The landuse in the parish is typical of lowland dairy farming.

About 8% of ponds in lowland England and Wales are found in Cheshire (Boothby, 1997; Williams et al, 1998). The large numbers of ponds in the county are mainly due to the practice of marling where marl (a calcium rich clay) used to be dug out and spread on fields to improve fertility. Most fields in Christleton still have one or more water-filled marl pits and this is a significant wetland resource.

3. Surveys Methods

3.1 1973 Christleton Pond Survey

From 1971 to 1973 a botanical survey of all ponds in Christleton was carried out as part of a general survey of the natural history of the parish. The survey was one of the first comprehensive pond surveys in Britain, and the results were published by *Watsonia*, the journal of the Botanical Society of the British Isles (Brian et al, 1987). A total of 181 ponds were found in the parish (a density of about 14 ponds/km^2) and the results showed that the ponds and their immediate surroundings were the richest area for wildlife in the parish. This reflected the fact that there are few areas of woodland or other semi-natural habitat in Christleton.

For the purpose of the present study, the 1970s data were re-analysed from the original recording sheets supplied by Barbara Redwood, one of the 1970s study co-ordinators. The data sheets included a plant list and limited environmental data.

3.2 1998 Christleton Pond Survey

In 1998 a complete survey of all ponds in the parish, including new ponds, could not be carried out due to time constraints. For this survey, therefore, a stratified random sub-sample of ponds was selected for re-survey. The sample was stratified according to plant species richness and rarity to ensure that a full range of ponds was selected, including both good and poor quality ponds.

A total of 88 ponds were surveyed, which represents about half the number of ponds surveyed in 1973. The National Pond Survey method was used to allow comparison with national datasets, such as the DETR Lowland Pond Survey and Pond Action's National Pond Survey (Pond Action, 1998).

4. Comparison between the results of the 1973 and 1998 Christleton Pond Surveys

4.1 Pond losses

The number of ponds in Christleton decreased by a quarter from 1973 to 1998. Out of the 88 ponds surveyed, 21 ponds had been lost. The rate of loss of about 1% per annum is similar to the national average found in the DETR Lowland Pond Survey (Williams et al, 1998). Inspection of the 1970s data indicated that ponds with both high and low plant species richness were lost over the 25 years. Although new ponds were not specifically searched for it seems likely that pond creation did not compensate for these losses. No new ponds were seen at any time during the survey, and no landowners (from whom permission was sought to visit ponds) indicated that they had created any new ponds.

The main causes of pond loss were similar to those in other parts of the country: deliberate infilling, drainage or succession and development (e.g. Oldham and Swan, 1997). Filling in ponds to facilitate modern farming practices seems to be the main reason for pond loss. In this survey, more than half the ponds lost were on arable land, and 80% had been filled in. Drainage (or natural succession), and development only accounted for 20% of ponds lost.

4.2 Species turnover

One of the most interesting findings of this study was the turnover of species within ponds (i.e. the gains and losses of plant species in individual ponds over 25 years). From 1973 to 1998, the species turnover was low for the parish as a whole, but high for individual ponds. More than half the ponds had similarity coefficients between 40% and 60%, which means that for any one pond only about half the species present in 1973 were found again in 1998. In contrast 90% of the species found in the parish as a whole in 1973 were also present in 1998. A total of 69 species were found in 1970s, and 75 species in 1998.

These results indicate that extinction and colonisation from surrounding ponds are important processes in the parish, and that the Christleton pond cluster functions as a whole system. This implies that a decrease in pond density would make recolonisation more difficult for some plant species.

4.3 Exotic plants

Another interesting result was the change in the number of non-native species, which increased from 2 to 6 species (Table 1). In 1973, only Canadian Pondweed and the water fern *Azolla filiculoides* were present. The additional species found in 1998 were Curly Waterweed, Least Duckweed, Monkeyflower and New Zealand Pigmyweed. Most exotic species were present in only a few ponds, apart from Least Duckweed, which was found in about half the ponds.

Table 1 Exotic plants in Christleton parish, 1973 and 1998

Common name (*Latin name*)	**1973**	**1998**
Canadian Pondweed (*Elodea canadensis*)	9	5
Water fern (*Azolla filliculoides*)	2	3
Curly Waterweed (*Lagorosiphon major*)	0	1
Least Duckweed (*Lemna minuta*)	0	46
Monkeyflower (*Mimulus guttatus*)	0	1
New Zealand Pigmyweed (*Crassula helmsii*)	0	1

At present there is no evidence that exotic species have had a negative impact on the plant communities of the Christleton ponds. However, Least Duckweed and New Zealand Pigmyweed are both invasive species and are considered a threat to native pond plant communities (Preston and Croft, 1997).

4.4 Changes in conservation value from 1973 to 1998

In this study, the criteria used to assess the conservation value of the ponds were the species richness (the total number of species present in the pond) and the rare species score for each pond. The latter is calculated by giving rare species a score depending on their national distribution and adding together all the scores for the species in a pond (Pond Action, 1997).

4.5 Species richness, 1973 and 1998

The mean number of species recorded per pond in Christleton was greater in 1998 than 1973. In addition, the proportion of ponds with relatively low species richness (1-10 species) decreased, whilst ponds with high plant species richness (11-20 and 21-30 species) increased (Figure 1). It was notable, however, that generally ponds with high species richness in 1973 also had high species richness in 1998.

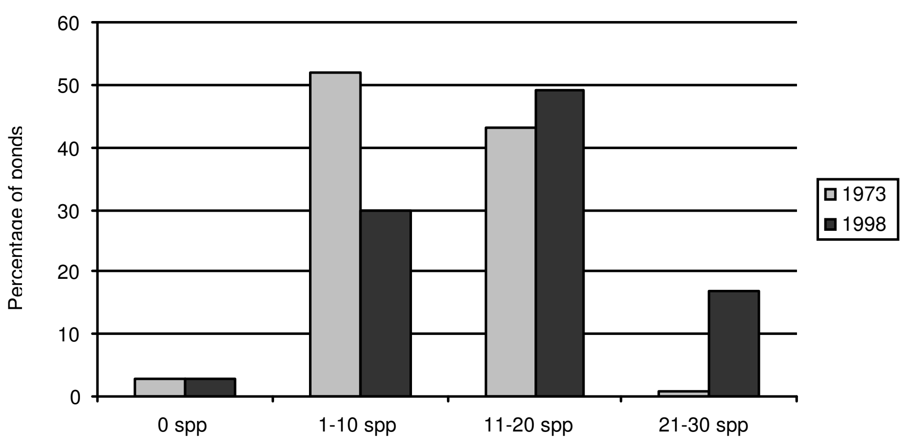


Figure 1. Species Richness in Christleton Ponds, 1973 and 1998

There is evidence that the increase in species richness seen between 1973 and 1998 was due to a methodological difference between the two surveys, rather than a real change in plant richness. In particular, in the 1998 survey chest waders were used (allowing better access to the water) whereas in the 1970s the survey was carried out by workers wearing only Wellington boots, which restricted them to shallow water. This methodological difference might, in particular, explain the increase in the number of ponds with aquatic plants seen between the two surveys.

4.6 Rare Species Score (RSS) and rare species

Even though the species richness increased, many rare species showed a decline, with the mean SRS decreasing from 3.5 to 3 ($P<0.01$) from 1973 to 1998. The proportion of ponds with no rare species increased, the proportion of ponds with low and medium scores decreased, and there was a small (5%) increase in ponds with high scores (Figure 2).

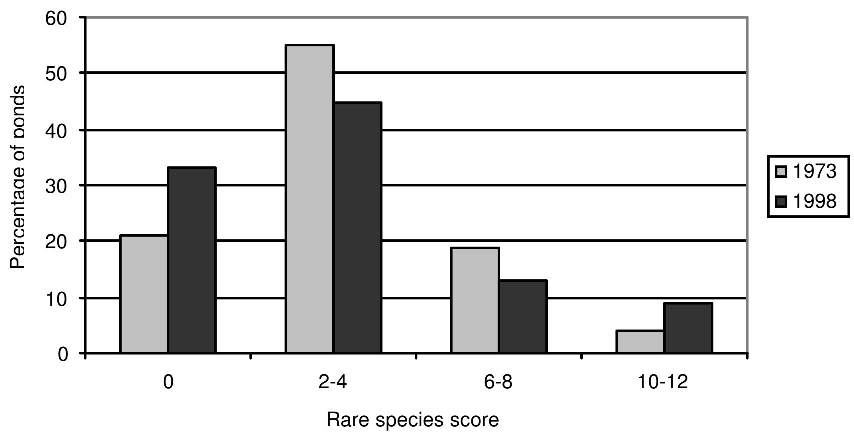


Figure 2. Rare Species Score, 1973 and 1998

This decline in the Rare Species Score reflected changes in the frequency of rare species from 1973 to 1998 (Table 3). There was a decline in the frequency of the Nationally Scarce Cowbane from 3 ponds in 1970s to 2 ponds in 1998. Many of the 18 local species found in the survey also had declined over the past 25 years. To note in particular is the decline of Frogbit by 83%. Other local species also showed a large decline, such as Bur-marigold (-35%), Lesser Waterparsnip (-30%), and Tubular Water-dropwort (-30%). The only notable increase was Common Water-crowfoot (63%).

Table 2. Rare species frequency, 1973 and 1998				
Status	**English name (Latin name)**	**1973**	**1998**	**% decrease (-) or increase (+)**
Nationally Scarce	Cowbane (*Cicuta virosa*)	3	2	-33
Local	Frogbit (*Hydrocharis morsus-ranae*)	12	2	-83
Local	Bur-marigold (*Bidens* spp)	26	17	-35
Local	Lesser Waterparsnip (*Berula erecta*)	23	16	-30
Local	Tubular Water-dropwort (*Oenanthe fistulosa*)	20	14	-30
Local	Common Water-crowfoot (*Ranunculus aquatilis*)	4	11	+63

4.7 Changes in the plant community from 1973 to 1998

The classification of the selected ponds according to their plant community, using TWINSPAN, also showed a high level of change at the pond level (Figure 3). Most ponds were classified into different end-groups in 1973 and 1998, supporting the species turnover results discussed earlier (Section 4.2).

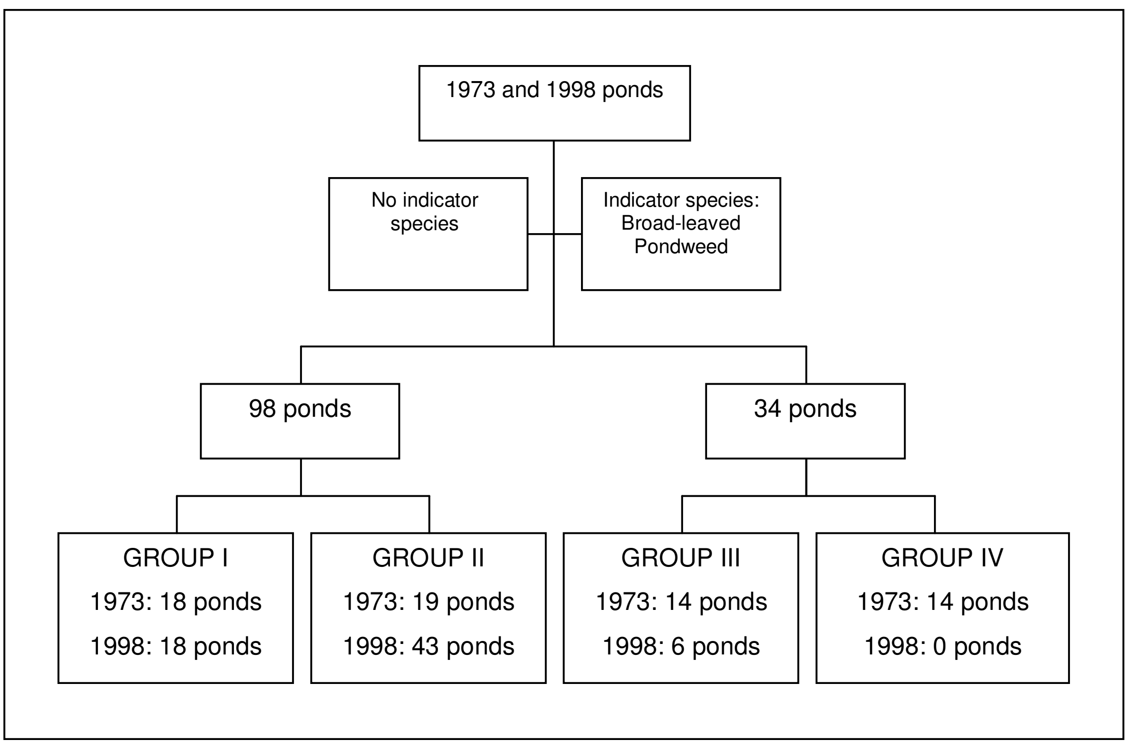


Figure 3 Plant community TWINSPAN classification, 1973 and 1998 ponds

The main point highlighted by the plant community classification was the decrease in two community types characterised by the aquatic species Broad-leaved Pondweed, Frogbit and Canadian Waterweed in Groups III and IV (Figure 3). The ponds in these groups tended to have a high aquatic species richness and total species richness. Most of the ponds in those two groups in 1973 moved to other less well-defined groups in 1998. Only four ponds had their plant community classified in Group III both in 1973 and 1998 and the Group decreased from 14 to 6 sites over the past 25 years. Group IV decreased from 14 to no ponds from 1973 to 1998.

It is generally recognised that aquatic plants, and in particular submerged species, are good indicators of environmental degradation. The frequency of all three characteristic aquatic species (Frogbit, Broad-leaved Pondweed and Canadian Pondweed) declined from 1973 to 1998:

- Frogbit, a local species, declined by 83%, the greatest decline of all species. Frogbit is a floating-leaved species, typical of relatively unpolluted waters and of shallow grazed margins. It appears to be very sensitive to nutrient enrichment (P. Williams, pers. comm.) and can be replaced by species characteristic of eutrophic sites, such as some duckweed species.
- Broad-leaved Pondweed, a common species, decreased by about 50%. This floating-leaved species has a broad habitat tolerance and is widespread nationally, but has recently been declining. Possible reasons for this decline are the loss and eutrophication of aquatic habitats, and the conversion of grazing land to arable.
- Canadian Pondweed, a naturalised submerged species, decreased by approximately 50%. This species is typical of meso- to eutrophic waters, and it can be suppressed by floating carpets of duckweeds.

4.8 Causes of change in the conservation value of the Christleton ponds between 1973 and 1998

Between 1973 and 1998 there was a decline of wetland plant species noted for their sensitivity to nutrient enrichment or to changes in farming practice. Although other factors, such as succession and pond management, did affect individual ponds, changes in land-use, with creeping intensification, seems to be the most likely cause of the changes observed in Christleton ponds between 1973 and 1998. Three lines of evidence, in particular, suggest that changes in landuse had an impact on the conservation value of the Christleton ponds:

- Decline of grazed grassland: a comparison of the 1970s survey and the present landuse showed that there was widespread conversion of grazing land to arable. Added to this, more of the remaining grassland is now used intensively for silage production (rather than for pasturing animals), and is cultivated almost as intensively as arable land.
- Decline of species tolerant of grazing: a number of species intolerant of grazing (e.g. Bulrush), which prefer uncut and ungrazed wetlands, have increased from 1973 to 1998.
- Decline of species sensitive to nutrient enrichment: as shown earlier, species such as Broad-leaved Pondweed and Frogbit have declined. Although no information was available on changes in nutrient input for the parish, it is recognised that the use of fertilisers generally increased from the 1970s.

5. Summary and Conclusion

The main results of this project were that, over the past 25 years:

- Approximately a quarter of ponds were lost on the Christleton parish, with no compensatory pond creation. This has increased pond isolation and is likely to have reduced inter-pond connectivity.
- The species composition of the ponds was highly variable at individual pond level but relatively stable at parish level. This emphasises the importance of groups of ponds in maintaining plant metapopulations, as species come and go from individual ponds.
- There was an increase in exotic species which may result in further changes in the plant community of some ponds.
- There was a loss of rare species and of Pondweed and Frogbit communities.
- Change in landuse was identified as the main cause of pond losses, and of loss of sensitive species and communities.

Acknowledgements

Thank you to everyone at Pond Action, with species thanks to Penny Williams for field and plant identification training. Also special thanks to Eric Kenyon, from the Christleton Pit Group, for local support. Thanks also to my supervisors Jeremy Biggs of Pond Action and Alan Morton of Imperial College for their comments, advice and encouragement. This project was carried out as part of an MSc in Ecological Management, and was jointly supervised by Pond Action and Imperial College.

References

Biggs J, Corfield A, Walker D, Whitfield M and P Williams (1993), *The Importance of Ponds for Wildlife*, Pond Action.

Brian A D, Price P S, Redwood B C and E Wheeler (1987), *The Flora of the Marl-pits (Ponds) in One Cheshire Parish*, Watsonia 16:417-426.

Boothby, J. (1997), Ponds and other small water-bodies in North-West England: an audit. In Boothby, J. (ed.) (1997). *British Pond Landscape. Action for protection and enhancement*. Pond Life Project, Liverpool.

Oldham R S and M J S Swan (1997), *Pond Loss and Amphibians: Historical Perspectives*, in British Pond Landscape: Proceedings of the UK Conference of the Pond Life Project 7-9 September 1997.

Pond Action (1998), *A guide to the methods of the National Pond Survey,* Pond Action, Oxford.

Pond Action (1997), *Conservation Assessment of Wetland Plants and Aquatic Macroinvertebrates*, Pond Action.

Pond Action (1994), *The Oxfordshire Pond Survey Vol 1*, Pond Action.

Preston C D and J M Croft (1997), *Aquatic Plants in Britain and Ireland*, Harley Books.

Williams P J, Biggs J, Barr C J, Cummins C P, Gillespie M K, Rich T C G, Baker A, Baker J, Beesley J, Corfield A, Dobson D, Culling A S, Fox G, Howard D C, Luursema K, Rich M, Samson D, Scott W A, White R and M Whitfield (1998), *Lowland* Pond Survey 1996. Department of the Environment, Transport and the Regions (DETR), London.

The ecological basis for pond management: a synthesis and update of pond management myths

Penny Williams, Jeremy Biggs, Mericia Whitfield, Gill Fox and Pascale Nicolet

Pond Action, c/o Oxford Brookes University, Gipsy Lane, Headington, Oxford OX3 0BP.

1. Introduction

In 1994 Pond Action published an article in British Wildlife which attempted to summarise some of the research information gathered about ponds in the previous five years (Biggs *et al.*, 1994). In particular, the paper identified a series of pond management myths which were commonly perpetuated in books and leaflets, but which did not fit with the ecological survey data.

The aim of the current paper is to review some of the original myths, and to bring them up to date with new information that has been gathered in the intervening years.

2. Water depth and permanence

Amongst the key myths addressed in the 1994 paper were a series of common misconceptions relating to water depth and permanence. In particular, that (i) ponds must have areas of very deep water - at least 2m deep - if they are going to support good wildlife communities, and that (ii) drying out is a complete disaster for ponds. In the myths paper we used a number of case studies to show that neither of these statements was inevitably true. Since that time, more evidence has been gathered about the effects of seasonality on ponds to support and extend this view.

2.1 Temporary ponds support distinct communities

In 1995 we published a survey that compared the invertebrate animal communities of permanent, semi-permanent and seasonal ponds in Oxfordshire (Collinson *et al.*, 1995). These data were analysed using multivariate statistics (TWINSPAN and DECORANA) to give a computer-based classification of the biological communities. The results showed that pond invertebrate communities grouped strongly according to how permanent their ponds were, with water permanence by far the most significant environmental variable correlated with community type (Figure 1).

The implication from this is that water permanence strongly influences pond community types. Thus, in practical terms, to protect the freshwater communities and species in any area, it is important to protect ponds that span a range of depths and permanences. If semi permanent or seasonal ponds are destroyed, this will inevitably reduce freshwater biodiversity in an area, because the community types associated with these ponds will be lost.

2.2 Drying-up is not disastrous

To investigate the affect of drying-out on ponds, data from the Oxfordshire study and from Pond Action's National Pond Survey were used to compare the biota of permanent ponds with that of semi-permanent ponds i.e. ponds which usually hold water, but occasionally dry up, perhaps just in drought years. The results (Table 1) showed that, on average, both types of pond held similar numbers species.

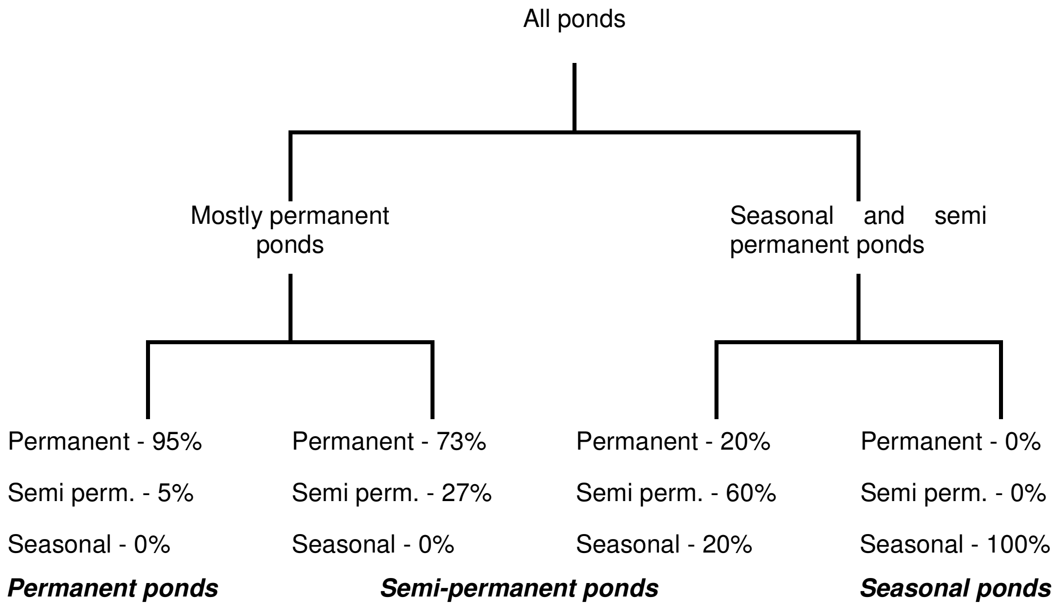


Figure 1. TWINSPAN dendrogram of the invertebrate assemblages from Oxfordshire Ponds

Table 1. Comparison of permanent and semi-permanent ponds

Oxfordshire Pond Survey results[1]:	**Permanent ponds**	**Semi-permanent ponds**
Mean number of invertebrate species[2]	35	37
National Pond Survey results	**Permanent ponds**	**Semi-permanent ponds**
Mean number of invertebrate species[2,3]	36	32
Mean number of plant species	23	23

Notes:

1. Data from Collinson *et al.*, 1995
2. All invertebrate samples were collected as 3 minute hand-net samples, and processed in the laboratory.
3. To avoid a species/area bias, the ponds used for this comparison were objectively selected to have a similar average area and range of areas.

These studies, therefore, provide a much greater body of data confirming that occasional periods of drying up appear not to be severely damaging to pond community richness in ponds which are usually already quite shallow.

The data also back up the common observation that many pond plant and animal species are tolerant of, and some benefit from, occasional droughts. For example, some water crowfoot and stonewort species appear to grow much more extensively the year after a pond has dried out, perhaps because of their germination requirements. Similarly many animal species, including amphibians like the Great Crested Newt, thrive best in ponds which dry out occasionally. Their populations may suffer for that season, but in the long term they gain usually, it is believed, because drying up is a natural way of removing larger predators, particularly fish.

2.3 Implications

A number of conclusions and implications can be drawn from the new data.

1. If a pond is already rather shallow and begins to dry-up from time to time this is unlikely to be causing significant harm: the pond community may change a little, but its richness is unlikely to decline. So, in particular, there is no need for urgent deep dredging of the pond, since this has the potential to do far more harm than good.

2. The most recent data emphasise the need to pay more attention to seasonal ponds. Current evidence suggests that seasonal ponds support distinctive plant and animal communities, including a range of very rare species (see also Biggs *et al*., this volume). It is important, therefore:

- not to damage high quality seasonal ponds by drainage or bad management, particularly over deepening, but to focus conservation effort on protecting the quality and reliability of their water source.
- to consider seasonal ponds in planning conservation strategies for an area and in creating new wildlife sites.
- to raise the profile of seasonal sites amongst both the public and conservationists who may not be aware of their potential value.

3. Tree shade

Another myth discussed in the 1994 paper was the common idea that tree shade was damaging to ponds.

Thus pond management guides often quoted so-called ‘rules’ which said things like: ‘to stay healthy, a pond must get at least 4 hrs full sunlight a day’, that ‘trees should be felled on the south side of ponds’ and that ‘fallen tree branches should be removed from the water’.

In the 1994 article we noted that, although heavily shaded ponds may sometimes look uninviting, and they do cast leaves and branches into ponds, the effect is not necessarily damaging to wildlife and having trees around ponds can often be beneficial.

There are, for example, many wetland plants particularly associated with shaded ponds including water violet (*Hottonia palustris*), Yellow Iris (*Iris pseudacorus*) and Pendulous Sedge (*Carex pendula*). Similarly, a wide range of animals exploit tree associated habitats. This includes tree roots which, when they are submerged, provide an excellent complex habitat for many invertebrates and amphibians. Fallen and floating tree branches when they begin to rot, provide a favoured egg laying substrate for some invertebrates, particularly the hawker dragonflies and submerged wood and leaf debris provide food for many pond detritivores.

Using the data available when we wrote the myths article, we originally made a number of recommendations, including:

- if there are very few shaded ponds in an area, then try to retain the existing examples so that their associated communities are maintained in the landscape.

- the case for tree management is sounder where either (i) overgrown and shaded ponds are a common feature in an area, or (ii) the tree growth is of recent origin (i.e. less than 10 years). In such cases, shade-removal can enable the development of more extensive plant stands, and that may be beneficial to aquatic and terrestrial invertebrates.
- even where the case for management is good, avoid drastic changes at all costs: do not clear-fell a ring of trees around the pond and ensure that there is always good cover available for amphibians and birds to approach the water.
- do not drag out or dredge all the wood and leaf litter so that there are still habitats for the existing pond community which may depend on them.

With the benefit of more recent data, it is now possible to add three further recommendations.

The first recommendation is tentative because it is as yet unquantified. Comparing plant data from ponds in the National Pond Survey ponds (located in semi-natural areas) with ponds from the wider countryside, the data suggest that heavily shaded pools (>70% overhung by trees) suffer particularly if they are surrounded by intensively managed land. Thus, in the lowlands, shaded ponds in semi-natural areas frequently support a range of local and uncommon plants associated with mesotrophic waters such as Lesser Marshwort (*Apium inundatum*), Fine-leaved Water-dropwort (*Oenanthe aquatica*), Water-violet (*Hottonia palustris*), Fen Pondweed (*Potamogeton coloratus*) and the floating liverwort *Riccia fluitans*. In contrast, shaded ponds located in arable or urban areas tend to be species-poor and dominated by robust and ubiquitous species such as Bittersweet (*Solanum dulcamara*), Yellow Flag (*Iris pseudacorus*) and Creeping Bent (*Agrostis stolonifera*).

The explanation for this may be that semi-natural wooded ponds are often naturally rather nutrient poor, and frequently slightly acidic as a result of leaf decomposition. Perhaps, therefore, these nutrient poor conditions represent the natural habitat to which many shade-tolerant pond plants have adapted, making them particularly *intolerant* of eutrophication. If so, the implication is that controlling nutrient pollution in shaded ponds may be particularly important for retaining or restoring high quality plant communities.

The second point that can now be added to the original management recommendations for shaded ponds is the importance of monitoring. Pond Action's practical experiences of tree management work over the last few years has shown us how hard it is to accurately predict the effects of trees removal from a site.

The difficulty is that individual ponds vary considerably in their seed banks and their sediment quality. In some cases the effects of removing some trees from around ponds can be beneficial (e.g. Starfruit *Damasonium alisma*, management [Wheeler, 2000]).

In other cases, tree removal is potentially damaging. Clearly, shade will inhibit plant growth at a site. Sometimes increasing light levels allows domination by unwanted species. In ponds with deep sediment, for example, a thick covering of duckweed will often develop across the pond after shade is removed, usually with little benefit to either pond wildlife or aesthetics. More worryingly, removing shade can allow more vigorous species to suppress the less competitive. At a nature reserve in Kent, for example, a pond which originally supported a high quality flora, including regionally uncommon plants like Fine-leaved Water-dropwort (*Oenanthe aquatica*) and the floating liverwort *Riccia fluitans* was gradually opened up to light by tree felling. The result was initially beneficial, allowing greater spread of the local species. However, progressively greater clearance allowed other emergent plants to colonise and spread. This included Bulrush (*Typha latifolia*) which took over the pond during the succeeding five years, turning a valuable shaded pool into a sunlit Bulrush marsh with few other species.

The implication is that we should go rather carefully with management of shaded ponds, monitoring whenever we can, and taking time to look carefully at the effects of tree removal as we go.

The third point reflects the to think carefully before removing willows from ponds. Willows are unusual trees in that they root freely into water. So, for example, overhanging boughs touching the water surface will send out tangled root bundles into the water column. The submerged portion of willow trunks will do the same. In a pond, these “mangrove swamp” areas where trees and branches grow in, rather than over, the water provide an excellent underwater habitat, used both by newts and by many aquatic invertebrates, including uncommon taxa. Where such habitats exist, maintain and treasure them. Where they do not, consider promoting them, perhaps at the expense of more ‘terrestrial’ trees which simply line the bank.

4. Plant management

The last myth relates to plants and plant management and particularly to the misconception that ponds must be periodically dredged so that they don’t become choked with vegetation.

In the myths article we spent much time extolling the virtues of plant habitats in ponds. Subsequent work has not diminished this view, but the results from three pieces of new work do add to it.

4.1 Protecting plant communities

A considerable amount of data emphasise that, when managing ponds for conservation, it is important not just to think about plants as invertebrate habitats but as an important and biodiverse group in their own right.

All three major national pond surveys with which Pond Action has been involved have consistently shown a strong relationship between plant cover and plant richness, with well vegetated ponds supporting more plant species than ponds with just a thin fringe of vegetation (Williams *et al*., 1998).

The corollary to this, however, is that if plant stands are extensively removed from ponds as part of plant management, this is likely to remove plant species altogether. Regional and local pond studies have shown that wetland plant species often only occur in a single pond in many areas. So it is easy to see that by careless pond management there is the potential for creeping, but progressive, loss of biodiversity from individual ponds, and potentially from an area. The implication from this is that plant management in ponds needs to be undertaken carefully, and with a good knowledge of the existing flora.

4.2 Effect of dredging on ponds

The second piece of research also relates to the effects of dredging out plants from ponds. Considering how frequently ponds are dug-out it is surprising just how little research there has been into management effects. There appear, for example, to be no published studies of dredging effects.

The best data we currently have, is from Central Pond, a small field pond (c.400 m^2) on Otmoor SSSI, Oxfordshire (see Figure 2). Pond Action have monitored this pond for 10 years now with seven of those years covering a period after the pond was dredged at the end of the 1980’s.

Figure 2. Central Pond, Otmoor SSSI, Oxfordshire.

Central Pond is not, perhaps, a typical countryside pond: it is located in one of the largest areas of semi-natural grassland in Oxfordshire, and the pond has always been very high quality: supporting plants like Frogbit (*Hydrocharis mosus-ranae*) and a population of the Red Data Book water beetle *Enochrus isotae*.

Central Pond was one of the first ponds surveyed by Pond Action, and we had sampled it twice when by chance, in 1989, a local farmer undertook an unauthorised dredging to provide water for cattle in a drought year when the pond looked as if was beginning to dry up. During the dredging the farmer removed approximately 0.5 m depth of silt from across the bottom of the pond together with most of the vegetation from the pond. The management was, therefore, both highly invasive and extensive. After that dredging, we surveyed the pond again three times, the last time in 1996.

The macroinvertebrate survey results showed that, after the dredging, there was little change in the number of invertebrate species recorded from the site: the average number of species recorded in samples before dredging was 52, with an average of 50 species after dredging, a difference that was not statistically significant. There were, however, significant declines in the abundance of many of the uncommon invertebrates present. Thus, although only one locally uncommon species increased after dredging, populations declined in six species of uncommon invertebrates (a third of all the uncommon taxa recorded from the pond). This included the RDB water beetle, *Enochrus isotae* (Table 2).

The plant community in Central Pond showed two main post-dredging changes. In the year immediately after dredging, the alien species Canadian Pondweed (*Elodea canadensis*), appeared to take advantage of the disturbance caused by the dredging. It colonised the pond for the first time and rapidly developed into an extensive stand which dominated the open water area of the pond. In subsequent years, the species has declined in abundance, but it still occurs in many parts of the pond.

Table 2. The effect of dredging Central Pond (Otmoor SSSI) on the abundance of uncommon invertebrates[1]

Species that increased in abundance after dredging

Helophorus granularis (Local)

Species that declined in abundance after dredging

Enochrus isotae (RDB3)

Limnebius papposus (Nationally Notable)

Enochrus testaceus ((Local)

Erpobdella testacea (Local)

Copelatus haemorrhoidalis (Local)

Cymbiodyta marginella (Local)

1. Based on the results of 24 three-minute hand net samples, 13 samples taken before dredging (1987-89) 11 taken after (1989-1996)

The second main post-dredging change was the temporary loss of the most uncommon plant in the pond: Frogbit (*Hydrocharis mosus-ranae*). For five years, from 1989 - 1995 this species was not seen at the site. In 1996 it was recorded again, and a population has been maintained since then. It is not clear, however, where these plants came from, whether they germinated from the sediment seed bank or recolonised from adjacent habitats, in particular a ditch about a 100 m away from Central Pond, which is one of the few other places to support Frogbit in Oxfordshire.

The net result, then, from this dredging were rather mixed. Overall, there do not seem to have been any significant benefits from the work, even seven years after the work was undertaken. This is an important finding, because wildlife benefits are still a commonly proposed as reasons for dredging out ponds. On the other hand, the effects of dredging were not catastrophic. Reassuringly, most of the plant and invertebrate species recorded from the pond before the dredging continued to occur afterwards.

Balanced against this though, were a number of potentially worrying effects on pond quality. Firstly the populations of several uncommon invertebrate species declined. None of these populations appeared to have recovered even seven years after dredging. They are, therefore, potentially more vulnerable to extinction than before the dredging. Second, there was a suggestion that disturbance provided an opportunity for a non-native plant species to invade a site for the first time. Given the high proportion of invasive alien aquatic plants in our pond flora (see Biggs *et al.*, this volume) this was rather a worrying consequence of the dredging.

Finally it is important to recognise that Central pond is not a typical pond. It is located in close proximity to high quality ditches, and the surrounding grassland often floods in winter linking the pond to many of the waterbodies across Otmoor SSSI. This pond has, therefore, and unusually high potential to recover by re-colonisation from the surrounding area, and in this respect its recovery may well have been much better than would be expected in an isolated pond in a more intensively managed area.

In the face of worries about possible damaging effects from dredging, is there any way of dredging ponds without doing damage. The most obvious advice is probably the best here: if dredging is essential, then gather as much biological information as possible to identify which species are likely to be particularly sensitive to damage. It needs to be recognised, however, that such advice is not always easy to follow. It can be difficult and expensive to gather such data. Where this is true, then the best advice is to ensure that some part of every habitat that looks different in the pond is maintained after plant or sediment removal. This includes: different types of plant stands, differing densities of plants, grasses, areas of bare ground, submerged tree roots, shaded areas. In other words, rather than working by prescription i.e. “dredge out half the pond at a time” - think of ponds individually, and aim with management to avoid destroying any habitat completely, so that there is a good chance that species which rely on one or more of those habitats will survive somewhere in the pond.

4.3 The importance of underwater plant architecture

The last piece of new information about plant management comes from some unexpected research results in a study of experimental ponds at Pinkhill Meadow in Oxfordshire, funded by the Environment Agency.

In the early 1990s Pond Action was involved in the design of a new pond complex at Pinkhill Meadow. The design included a series of 4 experimental ponds (each c.8 m x 12 m), which were used in an experiment to investigate whether the number of plant species in a pond affected the number of invertebrate species to colonise a pond.

Two of the experimental ponds were planted-up with one species of tall emergent plant (*Glyceria maxima*) and two ponds with five species (*Glyceria maxima*, *Carex riparia*, *Schoenoplectus lacustris*, *Phragmites australis*, *Sparganium erectum*). The ponds were then monitored for a period of 2 years.

The expected result was that the plant-rich ponds would develop richer invertebrate communities. What the results actually showed was that in the first year after planting all the ponds had very similar numbers of invertebrates. In year 2, however, a difference developed (Table 3). Three of the ponds (both 5-plant species ponds and one of the 1-plant species ponds) had rich faunas, with an average of 40 - 42 species recorded per sample. However, Pond 4 (one of the ponds with only one plant species), was unusually rich with approximately 20% more invertebrate species and over 50% more individuals than the other ponds. Statistically, the difference between this pond and the other three was highly significant.

Table 3. Pinkhill Meadow Experimental ponds: does the number of plant species affect the number of invertebrate species?

Pond	Number of emergent plant species	Average number of invertebrate species
Pond 1	5	40
Pond 2	5	41
Pond 3	1	42
Pond 4	1	52

Methods: aquatic macroinvertebrate surveys in each pond were carried out on 11th November 1992; 30th March and 10th November 1993; and 14th April and 22nd November 1994. Each pond was divided into four quadrats. The corners of these quadrats (5 metres by 3 metres) were sampled with a pond net, duplicate samples (22.5 seconds each, adding up to a total of three minutes per pond) being taken from each quadrat. The resulting samples (32 in all on each occasion) were returned to the laboratory, where they were sorted exhaustively. Identification was, as far as possible, to species level. (Biggs *et al,* 1995).

The probable reason for this difference arose from a mistake. When the ponds were originally planted-up, Pond 4 was planted last, and although it was planted at the same density as the other ponds, many of the individual plants used were small and poorly developed. In year 2, when the plants were growing up, it was clear that whereas the plants in the other three ponds were now tall and strong with good aerial growth, most plants in Pond 4 were still straggly, and most of the leaves remained underwater or floating. Thus, although the plants in the other ponds grew lushly above the surface, their underwater habitat was relatively uniform. In Pond 4, however, the plants developed a complex and varied underwater mosaic.

The results of this study emphasise that it is the underwater architecture of a pond that is important to aquatic animals. This is a fundamental factor which it is always easy to forget. Considering it - and focusing much more on looking at ponds from an animal or a plant's eye view - is likely to improve all our future efforts to manage ponds for wildlife.

References

Biggs, J., Corfield, A., Walker, D., Whitfield, M. and Williams, P. (1994). New approaches to the management of ponds. *British Wildlife*, 5, 273-287.

Biggs, J., Corfield, A., Walker, D., Whitfield, M. and Williams, P. (1995). *Experimental management of wetland habitats at Pinkhill Meadow*. NRA Project Record 383/I/T. National Rivers Authority, Bristol.

Collinson, N.F., J. Biggs, A. Corfield, M.J. Hodson, D. Walker, M. Whitfield and P.J. Williams (1994). Temporary and permanent ponds: an assessment of the effects of drying out on the conservation value of aquatic macroinvertebrate communities. *Biological Conservation*, 74, 125-133.

Wheeler, B.R, (2000). *Starfruit (Damasonium alisma). Progress report on the 1999 project*. Plantlife Report No. 146. Plantlife, London.

Williams P J, Biggs J, Barr C J, Cummins C P, Gillespie M K, Rich T C G, Baker A, Baker J, Beesley J, Corfield A, Dobson D, Culling A S, Fox G, Howard D C, Luursema K, Rich M, Samson D, Scott W A, White R and M Whitfield (1998), *Lowland Pond Survey 1996*. Department of the Environment, Transport and the Regions (DETR), London.

Use of rotenone as a narcotic in the removal of predatory carnivorous fish from small waterbodies

Tom Langton

Herpetological Consultants International, Triton House, Halesworth, Suffolk, IP19 9AE.

Abstract

Complete removal from waterbodies of predatory carnivorous fish (pcfs) may be required following their accidental or natural colonisation. A large multi-pond system within a 120 hectare partly flooded clay pit at Orton Brickworks in Peterborough, Cambridgeshire has been subject to controlled experimental fisheries management in close consultation with the Environment Agency since 1996. Work has been conducted in order to minimise the influence of pcfs on the amphibian and aquatic invertebrate populations. These groups comprise a large proportion of the Speacial Scientific Interest for which the site was designated an SSSI by English Nature in 1995. Additional interest in deciding appropriate management methodology at the site includes the occurrence of eight species of charophytes, and notably *Chara canescens* (bearded stonewort) for which this is the only known site in Britain.

Long term management for water levels, aquatic vegetation and fish populations at Orton Brickpits is dicussed within the context of a sustainable approach to maintaining species diversity at multi-pond sites.

Implications of the Lowland Pond Survey for the conservation of British amphibians

Mary Swan¶ and Rob Oldham§

¶Amphibian Habitat Advisory Services, 19 St Judith's Lane, Sawtry, Huntingdon, Cambridgeshire, PE17 5XE.

§Dept of Biological Sciences, De Montfort University, Leicester, LE7 9SU.

Summary

We describe the range of habitats associated with three of the widespread amphibian species in Britain, the common frog *Rana temporaria*, common toad *Bufo bufo* and the great crested newt *Triturus cristatus*, and assess the extent to which the habitat requirements are being satisfied, using data recorded in the recent national Lowland Pond Survey. The trends suggested by the survey are not encouraging. Over half the ponds in the survey were either ephemeral or too shallow to support species other than the common frog. Aquatic vegetation cover, and associated plant productivity was correspondingly low. Pond densities high enough to support amphibians were recorded only in woodland habitats, and probably not even here if shallow and heavily shaded sites are excluded. Furthermore, although the survey revealed a relatively small net loss of ponds, pond loss being nearly balanced by gain, many of the newly created sites are unlikely to be suitable for most amphibian species.

Introduction

The Department of the Environment, Transport and the Regions Lowland Pond Survey (LPS), carried out by Pond Action and the Institute of Terrestrial Ecology (ITE), was a survey of all ponds in a stratified random sample of 150 1km squares in ITE arable and pastural land classes, as defined by Bunce et al (1983). It is reported in Williams et al (1997). It provides valuable data on the recent status of British ponds, but excludes information on fauna. The current paper attempts to assess the implications of the survey's findings for one group, the Amphibia, in the light of their known habitat requirements. Amphibian habitat requirements in Britain can be assessed from the National Amphibian Survey (NAS; Swan & Oldham, 1993). This was coordinated from De Montfort University on behalf of English Nature, between 1983 and 1992, and was carried out by a network of volunteer recorders surveying ponds in areas of their own choosing. Over 11,000 pond records were received of which 49% included detailed site descriptions.

The habitats of three species of amphibian widespread in Britain are described: viz. the common frog, *Rana temporaria*, ubiquitous throughout Britain, occupying a wide range of water-body types, the common toad, *Bufo bufo*, geographically as widespread as the frog but breeding in a narrower range of pond types and the great crested newt *Triturus cristatus*, the most restricted of the three species both geographically and in terms of breeding habitat. The great crested newt and its habitats are fully protected under the Wildlife and Countryside Act (1981).

Table 1. Characteristics of ponds normally associated with each of three amphibian species in Britain, (excluding garden ponds) (From Swan and Oldham, 1993).

Pond characteristic	Common frog	Common toad	Great crested newt
Surface area (m^2)	Ponds of any size with shallow vegetated margins	500 m^2+	25 m^2 - 750m^2
Depth (m)	Shallow margins	0.5 m+	0.5 m - 2.0 m with vegetated margins
% surface shading by trees	Less than 25%	1 - 75%	1 - 75%
% cover by emergent vegetation	0 - 100%	1 - 50%	1 - 75%
% cover by submerged vegetation	0 - 100%	1 - 100%	50 - 75%
Fish present	Can coexist	Fish ponds suitable	Can cause extinction
Desiccation	Late summer drying only	Negative effect	Tolerated if occasional

Amphibians usually breed in still water and the three species discussed here are found in a wide range of water-body types, ranging from dune slacks to quarries. Table 1 indicates water-body characteristics associated with each of the three species, as recorded in the NAS. Although categories of water-body type are not directly comparable between the two surveys, approximately 50% of the ponds in each sample were on farmland. Woodland ponds, however, comprise 20% of the LPS sample but only 11% of NAS sites.

Pond area

Ninety-two percent of the water-bodies described in the NAS were less than 1 ha in area and 71% were smaller then 1000 m^2. Of the ponds identified as amphibian breeding sites, 69% were under 1000 m^2 indicating small water-bodies to be important breeding habitat for amphibians in Britain. Ponds reported in the LPS were mainly within a size range suitable for most amphibian species in Britain; 62% were between 25 m^2 and 400 m^2 and 98% were smaller than 1 ha.

Pond permanence

Frogs and great crested newts have been shown to tolerate pond desiccation to some degree (NAS). Frog populations can persist in ponds which dry up annually, in late summer, i.e. after the tadpoles have completed metamorphosis. Great crested newts, which metamorphose later in the season, can tolerate only very late or infrequent drying up, i.e. only in exceptionally dry years. Occasional desiccation is thought to be beneficial to amphibians in preventing the establishment of fish, which can cause extinction of great crested newt populations, and in limiting numbers of aquatic predators generally. Toads are associated with large, permanent ponds and can coexist with fish. Many LPS ponds were probably too ephemeral to support breeding populations of any amphibians. Thirty-seven percent of all ponds in the LPS sample and 45% of those under 400 m^2 dried out in summer. In the summer of 1996, 63% of all ponds were either dry or had a water depth of less than 25 cm, which is probably not deep enough to sustain toads or great crested newts. In each of the main land-use categories ponds were significantly prone to summer desiccation; 40% of ponds in arable land, 35% in grassland, and 30% of woodland ponds. The ephemeral nature of so many ponds could be halving the number of potential amphibian breeding sites in lowland Britain.

Aquatic vegetation

In the NAS records, ample submerged vegetation (up to 100% substrate coverage) was associated with each of the three species but emergent vegetation cover exceeding 75% of the water surface was apparently inimical to all but the frog. Relatively low levels of vegetation cover were recorded for most LPS ponds, the average emergent cover being 27%, submerged 8% and floating also 8%. NAS data suggest that higher levels of submerged vegetation coverage would probably benefit all three species in many sites.

Surface shading

According to the NAS data, toads and great crested newts can breed successfully in ponds with up to 75% surface shading even though vegetation growth can be severely limited. Frog ponds, however, tend to be more open. Well shaded ponds (51 - 75%) accounted for 18% of the LPS sample, which is not necessarily inimical in otherwise suitable ponds but a further 20% were over 75% shaded, which could limit amphibian success.

Land use

Surprisingly few of the pond characteristics measured in the NAS differed significantly between land-use types. Woodland ponds were significantly more likely to be heavily shaded but less prone to desiccation than those in other habitats and improved grassland ponds were more prone to desiccation. In the LPS sample, however, there were more ponds in the larger size classes (> 2000 m^2) in woodland than in pasture or arable land. The LPS also reports that more seasonal, unshaded ponds were recorded in improved grassland than arable land where ponds were more likely to be overhung by trees. The range of pond characteristics associated with each species in the NAS also did not vary significantly between terrestrial land-use types. Amphibians were thus occupying a similar range of ponds in different habitats across Britain. The frequency of occurrence of each species did, however, vary between land-use types (Table 2). Frogs and great crested newts were least common in the arable pond sample and the latter were also uncommon in improved grassland and woodland. Toads were recorded less frequently in ponds in improved grassland, which may be related to the increased tendency of grassland ponds to dry up. Differences in the abundance of each species could be due to variation either in numbers of ponds or in the suitability of the terrestrial habitat, or both.

Table 2. Percentage of ponds occupied by each species in different land-use types throughout Britain, recorded in the NAS (from Swan and Oldham, 1993).

Land-use predominant within 500m of pond

Species	All land-use	Improved grassland	Unimproved grassland	Arable	Woodland
Frog	58	52	58	39	61
Toad	28	13	29	27	32
Great crested newt	13	10	14	8	11

Pond density

Pond density is probably an important determinant of species presence. However, in the NAS an expected positive effect of high pond density was counteracted by negative effects of low pond quality in many areas. For example, the percentage frequency of frog populations decreased significantly with increasing pond density, the negative relationship being due to the species' high frequency of occurrence in sparse upland ponds. Although generally at lower density than lowland ponds, the upland water-bodies recorded were often situated in natural or semi-natural terrestrial habitat, ideal for frogs. In the lowlands, high density was often associated with excessive vegetation encroachment in ponds and low water-body quality in general. Great crested newt populations, which were seldom found in upland areas, occurred more frequently in landscapes where pond density exceeded 0.7 ponds per km^2, but the relationship was weak because the species was rare or absent from many areas of high pond density. Within areas of relatively high pond density, the actual density of suitable sites may, in fact, be low and the intervening land inhospitable for amphibians.

Halley et al (1996) suggest that the effects of population density vary between species. Their demographic model predicts that a population of great crested newts in a pond with a small newt carrying capacity has a low probability of extinction over a given time period if situated within 0.5 km of another population. At just over 1 km from its nearest neighbouring population, however, the extinction probability rises to 50%. The NAS data indicate that most great crested newt ponds in Britain support low numbers of animals and are frequently part of a larger pond cluster. For the common toad, however, Halley et al (1996) maintain that the major predictive factor for population survival is the carrying capacity of a breeding pond and that the degree of pond isolation is less important for this species. Baker & Halliday (1999) in their study of the colonisation of new farm ponds by amphibians report that frogs and toads colonised ponds up to 950 m from a neighbouring population whereas newt colonisations were always within 400 m of a potential source. They recommend that, for newts, new ponds are sited within 400 m of existing populations. As a blanket prescription for all amphibians, we recommend at least two suitable ponds per 1 km^2 across most landscapes, with higher densities where the intervening land supports little permanent cover. In the light of this, estimates of pond density from the LPS data reveal pond densities high enough for amphibians only in the woodland habitats (3.6 ponds per km^2). Pond densities recorded in grassland (1.3 per km^2) and, particularly, in arable land (0.5 per km^2) are unlikely to sustain amphibian populations in the medium to long term.

Determinants of amphibian presence

Combining NAS terrestrial and aquatic habitat parameters, factors associated with the presence or absence of each of the three species have been identified using discriminant analysis (Swan & Oldham 1994). For the frog, which breeds in the widest range of pond types of all three species, the main determining factor was the presence of arable land: ponds where this land-use occurred within 500 metres were significantly less likely to support frog populations. For toads, on the other hand, which are the most discriminating of the three species regarding choice of breeding site, aquatic factors, such as pond size and permanence were the most important. For the great crested newt landscape descriptors embodying both terrestrial and aquatic elements were identified as species determinants - e.g. the presence of mineral extraction sites within 500 metres, possibly indicative of high pond density and low intensity agriculture, was strongly positive. Submerged vegetation and pond depth over 0.5 m were also positive factors whereas important negative parameters were the presence of flowing water within 500 m (suggestive perhaps of flood risk and fish), and the recorded presence of fish. For each of the species, however, the relative importance of terrestrial over aquatic factors increased with decreasing diversity of the landscape, i.e. permanent landscape features increased in significance as determinants of the presence of amphibians in intensively farmed land (Swan & Oldham 1994).

Pond management

LPS data reveal low levels of pond management. Approximately 1% of ponds were managed every year, management mostly taking the form of dredging. Ponds most likely to have been managed recently were large, with amenity uses, close to human settlements. However, according to the NAS these types of ponds are not ideal amphibian habitat and tend often to support waterfowl and fish. The many small and relatively inaccessible field ponds which probably support most of Britain's amphibians, are, apparently, deteriorating and being lost, unnoticed. Increased levels of pond management are needed in most areas, with clusters of ponds out of sight of human settlement in need of particular attention. By their nature and location, these are the sites least likely to appeal to local human communities, so voluntary effort is unlikely to improve the situation significantly. The mechanism for the conservation of small farm ponds will probably have to be through farming and countryside policy, offering incentives solely for wildlife habitat creation or restoration.

Pond numbers

The LPS reports that nearly as many ponds were created during the six years prior to the 1996 survey (15,000) as were lost in the same period (17,000). Oldham and Swan (1998) report similar findings in a review of published data on changes in pond densities. The LPS found new ponds to have a wider range of aquatic macrophytes than old ponds but the pond fauna were not surveyed. At present, many new ponds are being created for aesthetic and conservation reasons as well as for commercial purposes. Unfortunately, many are also subsequently stocked with fish and waterfowl, inimical to amphibians (Baker & Halliday, 1999), are of a size and structure also unsuited to amphibians and are often isolated from other older pond clusters. Although it is encouraging that the net loss of water-bodies is being offset significantly by pond creation, unless the ecological aspects of structure, management and siting are better considered, any increase in amphibian habitat nationally will be limited and could still fail to compensate for the loss and integrity of older habitats.

References

Baker, J.M.R. & Halliday, T.R. (1999) Amphibian colonisation of new farm ponds in an agricultural landscape. The Herpetological Journal. 9 (2): 55 - 63.

Bunce, R.G.H., Barr, C.J., & Whittaker, H.A. (1983) A stratification system for ecological sampling. In: Ecological mapping from ground, air and space, edited by Fuller, R.M., 39 - 46 (ITE Symposium no. 10) ITE Cambridge.

Halley, J.M., Oldham, R.S. & Arntzen, J.W. (1996). Predicting the persistence of amphibian populations with the help of a spatial model. J. of Applied Ecology. 33: 455-470.

Oldham R.S. & Swan M.J.S. (1998) Pond loss, historical perspective. In: Boothby, J. (ed) British Pond Landscapes – Action for protection and enhancement. Proceedings of the UK Conference of the Pond Life Project. Liverpool.

Swan, M.J.S. & Oldham, R.S. (1993) Herptile Sites, Volume (i), National Amphibian Survey. English Nature Research Report No 38. Contract Number F72-15-04. Peterborough.

Swan, M.J.S. & Oldham, R.S. (1994) Amphibians and landscape composition in Dover, J.W. (ed) Fragmentation in agricultural landscapes: Proceedings of the Third IALE(UK) Conference, Preston.

Williams, P.J., Biggs, J., Barr, C.J., Cummins, C.P., Gillespie, M.K., Rich, T.C.G., Baker, A., Baker, J., Beesley, J., Corfield, A., Dobson, D., Culling, A.S., Fox, G., Howard, D.C., Luursema, K., Rich, M., Samson, D., Scott, W.A., White, R., Whitfield, A.M. (1998). *Lowland Pond Survey 1996*. Department of the Environment, Transport and the Regions, London.

Acknowledgements

We should like to thank English Nature and Pond Action for the use of the survey data. We also thank Dr Clive Cummins for his assistance in the preparation of the manuscript.

Pond management for dragonflies (Odonata)

Steve Brooks

Department of Entomology, Natural History Museum, Cromwell Road,London, SW7 5BD.

Abstract

Dragonflies are a high-profile group of insects that have attracted considerable public interest. People want dragonflies to visit and breed in their ponds, be they situated in gardens, parks or nature reserves. Because the life history of all dragonflies encompasses an aquatic larval stage and an aerial adult, habitat management considerations have to be given to both terrestrial and aquatic environments. The larvae of most species will not tolerate poor water quality, so the pond should be isolated from potential sources of pollution. Within the water, dense growths of submerged aquatic macrophytes provide cover for dragonfly larvae from which to hide from predators and ambush their prey. Over-stocking of fish, especially carp, or waterfowl will result in reduction of submerged macrophytes, increased predation pressure on larvae and potential problems of nutrient enrichment and reduced dissolved oxygen. Adult dragonflies require oviposition sites and places to rendezvous with mates, and these can be provided by patches of floating-leafed vegetation and emergent plants. Adults also require foraging and roosting sites, which can be provided by blocks of woodland or rough herbage near breeding localities. Trees and scrub close to the pond also provide shelter from the wind, but dense bank-side growths will shade the water and make it less attractive to dragonflies. Dragonfly species each have subtly different habitat requirements so, to increase the diversity of dragonflies using a pond by appropriate habitat management, the autecology of target species should be understood.

Introduction

Compared with many other kinds of animals and plants in Britain, dragonflies are a relatively minor group. Only 38 species have resident populations in this country and the majority of these species are confined to the southern half of Britain (Merritt et al., 1996). So why should we be concerned about managing ponds for dragonflies?

Dragonflies should be conserved because people care about them. The large size, bright colours and prodigious aerobatic skills of dragonflies, coupled with their habit of flying on warm summer's days close to water, mean that people notice them but also miss them if they are not there. Dragonflies are a popular group of insects: the British Dragonfly Society is one of the largest insect societies in the UK with over 1200 members. But many more people enjoy watching dragonflies and they have become more popular with advances in macro-photography since they make superb and dramatic subjects to photograph. They can be important predators of nuisance insects such as midges and mosquitoes. In Myanmar (Burma) they have been used successfully to control mosquitoes in villages (Sebastian et al., 1990). Dragonflies have also been used widely as biodiversity and conservation indicators (Corbet, 1993; Brooks, 1996; Samways, et al., 1996).

The availability of good quality ponds is important for dragonflies. About 80% of British dragonflies breed in ponds and for most of these species ponds are the primary breeding habitat. For this reason good pond management practice goes a long way towards the general conservation of dragonflies in Britain. This is especially important for species such as *Leucorrhinia dubia* (White-faced Darter) and *Lestes dryas* (Scarce Emerald Damselfly) which breed exclusively in small ponds but which are declining in England at present. Dragonfly faunas in certain regions of Britain have suffered significant declines due to recent changes in land use and so conservation and sensitive management of ponds in these areas are particularly important. Examples of areas that have suffered large scale faunistic losses include East Anglia, due to agricultural intensification, the Somerset Levels and Yorkshire Moors, from industrial-scale peat extraction, and upland regions of Scotland following drainage and afforestation. In the wider countryside, it is estimated that 70% of ponds have been lost in the last century (Pond Conservation Group, 1993) and this has resulted in declines and fragmentation of populations of even common and widespread species.

Much of the information about pond creation and management for dragonflies contained in this article has been drawn from two British Dragonfly Society publications (British Dragonfly Society, 1992; 1993) and these booklets should be referred to for further details on the practical aspects of dragonfly conservation in ponds.

Typical pond species

Dragonflies occur in a wide variety of pond-types. With the decline in farm ponds, garden ponds have become increasingly important as refuges for many of the common, widespread species such as *Sympetrum striolatum* (Common Darter), *Libelulla depressa* (Broad-bodied Chaser), *Anax imperator* (Emperor Dragonfly) and *Coenagrion puella* (Azure Damselfly). Where suitable ponds are available these species will readily colonise even to the heart of urban conurbations (Brooks, 1989; Honey et al., 1998). Larger ponds, lakes and gravel pits are important for species preferring expanses of open water like *Orthetrum cancellatum* (Black-tailed Skimmer), *Aeshna grandis* (Brown Hawker), *Aeshna mixta* (Migrant Hawker), and *Enallagma cyathigerum* (Common Blue Damselfly). Woodland ponds are important for *Cordulia aenea* (Downy Emerald), *Somatochlora metallica* (Brilliant Emerald) and *Aeshna cyanea* (Southern Hawker), while fens and dykes on grazing marshes also support a few specialist species including *Coenagrion pulchellum* (Variable Damselfly), *Brachytron pratense* (Hairy Dragonfly) and *Aeshna isosceles* (Norfolk Hawker). Acid pools on bogs and wet heathland probably support a greater number of dragonfly species than any other biotope in Britain and many of the characteristic bog species have restricted distributions in this country (Brooks, 1997). Typical species include *Sympetrum danae* (Black Darter), *Orthetrum coerulescens* (Keeled Skimmer), *Ceriagrion tenellum* (Small Red Damselfly), *Leucorrhinia dubia* (White-faced Darter), *Aeshna caerulea* (Azure Hawker) and *Somtochlora arctica* (Northern Emerald). Finally, temporary ponds with profuse emergent vegetation are important for *Lestes dryas* (Scarce Emerald Damselfly) and *Lestes sponsa* (Emerald Damselfly).

Management protocols

Pond managers should be aware of possible conflicting interests that may arise when a management plan for dragonfly conservation is being considered. Most dragonfly species do best in early to mid-successional stages of pond development. These ponds hold water all year, have little shade from tall trees and are not crowded with emergent vegetation, although submerged vegetation is luxuriant. It so happens that such ponds coincide with what most human observers consider to be ideal, so there is a possibility that many managed sites tend to conform to this standard. While this may be good for dragonflies, other groups of organisms, that prefer more heavily shaded ponds, or reed beds, or shallow seasonal pools, may suffer as a result. It is therefore essential that a wetland site is thoroughly surveyed before any management activities are started, to establish the existing wildlife interest. Anything of conservation significance should be taken into account fully before habitat management work is begun.

General habitat requirements of dragonflies

Before discussing the habitat requirements of particular dragonfly species it is useful to consider dragonfly biology and to understand the general requirements that are essential for all species. Dragonfly larvae are aquatic and the adults are aerial, so good dragonfly ponds are more than just areas of standing water: they must include a suitable terrestrial hinterland which may extend for at least 1-2 ha around the site. For most species larval development takes at least one year, so permanent water is essential. The water should be free from pollutants and high in dissolved oxygen. There should be an abundance of submerged and emergent vegetation to provide perches for plant-dwelling larvae, help conceal the larvae from fish and other predators, and act as emergence supports when larval development is complete. The nature of the substrate on the bottom of the pond will also influence the distribution of species since some larvae favour organic debris, while others prefer silt or gravel.

Adult dragonflies require feeding and roosting sites, and these can be provided by rough grassland, scrub and woodland blocks close to the pond. The environs of the pond should also be warm, so a sunny site exposed to the south and sheltered from prevailing winds is ideal. Submerged, floating-leaved and emergent aquatic vegetation serve as oviposition sites and territorial perches.

Creating a dragonfly pond

Because dragonflies are adept at widespread dispersion they will rapidly colonise new sites. Suitably positioned and managed garden ponds in urban areas of southern England may support eight or more species within a year or two of creation. Dragonfly larvae live in the warm shallow pond margins, so the length and area of the margins should be maximised, especially in the south- and west-facing ends, and the banks should not be steeply shelving. This will also encourage the growth of aquatic vegetation. Several small ponds will support a greater abundance of dragonflies than a single large one of the same surface area. The pond should also include a deeper part, of at least 1 m, so that there is a cool refuge in summer and the water column will not completely freeze during the winter. Even ponds with a surface area as small as 4 m^2 will support dragonflies, but the bigger the pond the better. Bank-side trees and shrubs or a raised bank created from the pond spoil are an important part of a dragonfly pond since they provide shelter from the prevailing wind. However, a small pond should be sited away from over-hanging trees which may shade the pond or produce an over-supply of leaf-litter. The pond should be planted with a wide variety of native submerged, floating-leaved and emergent plants to give a mosaic of plant architecture. This may increase the numbers of species that can coexist together since adult males of different species adopt different perching heights (Sternberg, 1994). Care should be taken that the pond does not receive run-off containing salt from roads or fertilisers, insecticides and herbicides from agricultural land that will pollute the water.

Pond management

Small ponds are easily encroached by terrestrial and aquatic vegetation so they must be periodically managed to maintain their dragonfly interest. Vigorous marginal plants such as reed mace (*Typha* spp.) and rush (*Phragmites australis*) should be removed since they will reduce the availability of marginal water. The woody stems of these plants are also unsuitable as oviposition sites and dense stands will deter adult dragonflies. Over-shading trees should also be removed. A heavily shaded pond will not attract dragonflies and excessive leaf fall will fill up the pond rapidly leading to oxygen depletion. However, it should be noted that patchy bankside vegetation is actually beneficial to many odonates. If possible, the pond should not be topped up with tap water since it often contains high concentrations of phosphates which can encourage nuisance blooms of algae and duckweeds (*Lemna* spp.). Fluctuating water levels during the summer should not cause any long-term problems, as long as the pond is big enough to avoid complete desiccation. Usually the winter rains are sufficient to completely fill the pond. Certain non-native aquatic plants, especially *Myriophyllum aquaticum* (Parrot's Feather), *Crassula helmsii* (New Zealand Stonecrop) and *Azolla* spp. (Water Fern), will rapidly invade a pond and so should not be introduced. It is good practice only to introduce native aquatic plants and so reduce the risk of non-natives escaping into the countryside. While submerged aquatic plants are an important habitat for dragonflies it may be necessary to thin out invasive plants. This should be carried out during the autumn. Trampling by people or stock will increase turbidity, leading to reduced plant growth so it may be necessary to restrict access to certain areas by fencing. However, some bare banks (especially those facing south) are attractive for species like *Orthetrum cancellatum* (Black-tailed Skimmer) and *Libellula depressa* (Broad-bodied Chaser).

Domestic ducks or geese will ruin a small pond. Their droppings will lead to eutrophication, and they will uproot and eat aquatic plants resulting in turbid water. Large populations of sparrows, for example near farm buildings, will exert high predation pressures on dragonflies populations, especially on emerging dragonflies. The pond should not be stocked with goldfish, carp or other fish that will uproot and eat aquatic plants. Large numbers of fish may also impoverish the dragonfly population by competing with the larvae for food or by preying on them directly (Crowder & Cooper, 1982; Morin, 1984; Giles, 1992).

Examples of specific habitat requirements of some pond species

The general pond management criteria discussed above will make any pond suitable for dragonflies. However, most species have particular requirements and specific management may be necessary to provide optimum conditions. To illustrate this point a few of the specific habitat requirements of some typical pond species are briefly discussed below. Further autecological details on these and other species are summarised in Brooks & Lewington (1997). Before any management work is carried out, it is essential for a pond manager to conduct a dragonfly survey and establish which species are already using the pond. Protocols for dragonfly surveys are discussed by Moore & Corbet (1990) and Brooks (1993). The manager should also be aware of the dragonfly species that already breed in the surrounding region and which may therefore be expected to colonise the pond.

Cordulia aenea (Downy Emerald) and *Somatochlora metallica* (Brilliant Emerald) are usually confined to woodland ponds. The larvae occur on the pond bottom amongst large fragments of leaf-litter and avoid fine detritus, and exposed silty or gravely substrates. Adult males patrol the banks of the pond defending sunlit territories, delimited by bankside trees. They avoid flying into dense tree-shade. Females usually oviposit amongst tree roots or at the base of sparse stands of emergent vegetation. Mating occurs in the tree-tops, feeding in sunny woodland glades. The adults are poor at dispersing and only reluctantly leave the tree canopy. Both species may be eliminated from a site after excessive clearance of bank-side trees or dredging operations that remove organic detritus.

Orthetrum cancellatum (Black-tailed Skimmer) and *Libellula depressa* (Broad-bodied Chaser) typically colonise ponds in the early stages of succession. Male *O. cancellatum* adopt sun-warmed patches of bare earth, gravel or rocks around the pond edge as territorial perches. *L. depressa* males usually use tall stems over-looking the water as perches, but open water with sparse submerged aquatic plants are the favoured oviposition sites. As the pond is colonised by increasingly dense terrestrial and aquatic vegetation, both species become less abundant. Larvae of *L. depressa* are able to tolerate short periods of desiccation, and the advantages of semi-permanent ponds for this species are that they maintain themselves at an early successional stage.

Another species that requires sites in the early stages of succession is *I. pumilio* (Scarce Blue-tailed Damselfly). Breeding sites are typically seepages in bogs and chalk pits. The species appears tolerant of a wide range of pH but warm, shallow, slow-flowing water, with little vegetation seems to be an essential requirement (Cham, 1997). The species has a distribution centred on the Mediterranean and is at the north-western edge of its range in southern England and Wales. Mineral extraction pits that are frequently disturbed by vehicular activity appear to offer ideal conditions (Cham, 1996). Such biotopes are susceptible to desiccation but the adults are well adapted to dispersal and fly high into the air to be carried on air currents to colonise new sites.

Enallagma cyathigerum (Common Blue Damselfly) is usually most abundant at large ponds and lakes. Males are typically seen skimming low over the surface of open water or perched on the leaves of floating plants. The species often occurs at sites which support large populations of fish but because the larvae hide amongst submerged plants and are relatively inactive they may escape detection (Miller, 1997). The species is less plentiful in small ponds or those choked with vegetation. Conversely, *Coenagrion puella* (Azure Damselfly) is most numerous in small ponds or amongst dense bank-side vegetation at larger sites.

Erythromma najas (Red-eyed Damselfly) usually occurs at large sites with floating-leaved macrophytes. Males are rarely seen near the water's edge but perch on the leaves of water-lilies and pond weeds a metre or so off-shore. However, the presence of these plants does not appear to be a pre-requisite for successful colonisation since sometimes the species may be present at sites at which there are no floating-leafed plants.

In England *Lestes dryas* (Scarce Emerald Damselfly) is a rare species, confined to the Thames marshes of Essex and north Kent and a few sites in Norfolk. In Ireland it is more widespread but still local in occurrence (Merritt et al., 1996). During the 1970s it was thought to have become extinct in England but was subsequently rediscovered in 1983 (Benton & Payne, 1983). The species breeds in shallow ditches and pools, choked with emergent vegetation, and which frequently dry-out in late summer (Drake, 1990; 1991). Adults are on the wing during July and settle amongst dense emergent vegetation at the breeding sites (Nelson, 1997). The drought resistant eggs are the over-wintering stage. Larval development begins in the spring and is rapid in the warm, shallow pools, being completed in just a few months. The larvae are unable to survive prolonged desiccation, so development must be completed before the pools dry out. The larvae are large and active daytime predators and this exposes them to predation by fish, so the species thrives best in fish-free sites like temporary pools. However, this biotope is easily destroyed by lowering of the water table following drainage of agricultural land (Moore, 1980).

In England, *Aeshna isosceles* (Norfolk Hawker) is one of the few dragonflies that shows a close association with a particular species of plant. Work by Leyshon and Moore (1993) has confirmed observations that breeding populations of A. isosceles are confined to ditches on grazing marshes in Norfolk and Suffolk that contain *Stratiotes aloides* (Water Soldier). However, those authors were not able to establish precisely the nature of the relationship although noted that *S. aloides* does not survive in highly eutrophic waters polluted by field run-off. The association between *A. isosceles* and *S. aloides* has not been observed in continental Europe where the dragonfly is widespread but local in a wide range of biotopes which often do not support *S. aloides*.

Sympetrum sanguineum (Ruddy Darter) oviposits in the shallow margins of ponds which support extensive stands of tall emergent vegetation, especially *Equisetum* spp. (horsetails) and reed mace (*Typha* spp.) (McGeeney, 1997). Eggs are laid in late summer often in damp mud or in dry depressions by the pond margin which will be inundated during the winter. Deepening and excessive removal of reed beds will have a negative impact on populations of this dragonfly.

Leucorrhinia dubia (White-faced Darter) is a species of acid bog pools. Larvae live amongst clumps of floating or submerged *Sphagnum* moss in pools of varying depth. The larval habit of clinging to the underside of floating rafts of moss has made them vulnerable to the activities of moss-collectors for the hanging basket trade (Kemp, 1997). The small pools favoured by *L. dubia* tend to become overgrown by *Sphagnum* after a few years (Bailey, 1992). However, pools can be maintained by dredging, although care must be taken to leave the spoil on site since it is likely to contain larvae, or created by winching trees from the bog. The larval habit of being active during the day also makes them susceptible to predation by fish and the species is absent from pools that contain fish. Adults frequently perch on pale surfaces which radiate heat such as fallen tree trunks, rocks and patches of dead, dry *Sphagnum* (Schiemenz, 1954).

Both *Aeshna cyanea* (Southern Hawker) and *A. grandis* (Brown Hawker) often oviposit in damp, rotting wood lying at the edge of ponds or partially submerged. While *A. cyanea* will breed in a fairly wide variety of pond habitats it is a common resident of shady woodland ponds that are avoided by most other odonate species.

Brachytron pratense (Hairy Dragonfly) is typically a species of ditches and dykes with luxuriant growths of subaquatic and emergent vegetation in fenlands and grazing marshes. One important habitat requirement appears to be the availability of floating mats of dead reeds and rushes into which the females oviposit.

Conclusions

During the last 30-40 years dragonflies have declined in many parts of Britain because intensification of agriculture, forestry and urbanisation have resulted in the widespread loss of wetland biotopes. However, dragonflies will respond positively and quickly to the provision of ponds and other aquatic habitats that are managed appropriately. The ecological requirements of the actual and potential dragonfly faunas of a site should be carefully considered prior to any management activities, since inappropriate management can lead to impoverishment of the existing dragonfly fauna. In order to maximise dragonfly biodiversity at a site, a mosaic of aquatic and terrestrial biotopes should be available. This will cater for those species which have precise habitat requirements as well as encouraging the colonisation of generalist species (Samways, et al., 1996). However, it is unlikely that all species that could potentially occupy a site could be catered for at one site because of conflicting habitat requirements.

References

Bailey, M.P. (1992) The white-faced dragonfly *Leucorrhinia dubia* (Vander Linden) at Chartley Moss National Nature Reserve, Staffordshire. Journal of the British Dragonfly Society 8: 1-3.

Benton, E. & Payne, R.G. (1983) On the rediscovery of *Lestes dryas* Kirby in Britain. Journal of the British Dragonfly Society 1: 28-30.

British Dragonfly Society (1992) Dig a pond for dragonflies. British Dragonfly Society, Purley.

British Dragonfly Society (1993) Managing habitats for dragonflies. British Dragonfly Society, Purley.

Brooks, S.J. (1989) The dragonflies (Odonata) of London: the current status. The London Naturalist 68: 109-131.

Brooks, S.J. (1993) Review of a method to monitor adult dragonfly populations. Journal of the British Dragonfly Society 9 (1): 1-4.

Brooks, S.J. (1996) Monitoring and surveying dragonflies (Odonata) for use as indicators of wetland site quality. In: Eyre, M.D. [ed.] Environmental monitoring, surveillance and conservation using invertebrates. EMS Publications, Newcastle upon Tyne.

Brooks, S.J. (1997) Peatland dragonflies (Odonata) in Britain: a review of their distribution, status and ecology. pp. 112-117. In: Parkyn, L., Stoneman, R.E. & Ingram, H.A.P. Conserving peatlands. CAB International, Wallingford.

Brooks, S.J. & Lewington, R. (1997) Field Guide to the dragonflies and damselflies of Great Britain and Ireland. British Wildlife Publishing, Hook.

Cham, S. (1996) The Scarce Blue-tailed Damselfly - the conservation of a wandering opportunist. British Wildlife 7: 22-225.

Cham, S. (1997) Scarce Blue-tailed Damsefly *Ischnura pumilio* (Charpentier). pp. 90-91. In: Brooks, S.J. & Lewington, R. Field Guide to the dragonflies and damselflies of Great Britain and Ireland. British Wildlife Publishing, Hook.

Corbet, P.S. (1993) Are Odonata useful as bioindicators? Libellula 12: 91-102.

Crowder, L.B. & Cooper, W.E. (1982) Habitat structural complexity and the interaction between Bluegills and their prey. Ecology 63: 1802-1813.

Drake, C.M. (1990) Records of larval *Lestes dryas* Kirby in Essex during 1987. Journal of the British Dragonfly Society 6: 34-41.

Drake, C.M. (1991) The condition of *Lestes dryas* Kirby larval populations in some Essex grazxing marshes in May 1990. Journal of the British Dragonfly Society 7: 10-17.

Giles, N. (1992) Wildlife after gravel. Game Conservancy, Fordingbridge.

Honey, M.R., Leigh, C. & Brooks, S.J. (1998) The flora and fauna of the newly created Wildlife Garden in the grounds of the Natural History Museum, London The London Naturalist 77: 17-47.

Kemp, R.G. (1997) White-faced Darter *Leucorrhinia dubia* (Vander Linden). pp.156-157. In: Brooks, S.J. & Lewington, R. Field Guide to the dragonflies and damselflies of Great Britain and Ireland. British Wildlife Publishing, Hook.

Leyshon, O.J. & Moore, N.W. (1993) A note on the British Dragonfly Society's survey of *Anaciaeschna isosceles* at Castle Marshes, Barnby, Suffolk, 1991-1992. Journal of the British Dragonfly Society 9: 5-9.

McGeeney, A. (1997) Ruddy Darter *Sympetrum sanguineum* (Müller). pp. 146-147. In: Brooks, S.J. & Lewington, R. Field Guide to the dragonflies and damselflies of Great Britain and Ireland. British Wildlife Publishing, Hook.

Merritt, R., Moore, N.W. & Eversham, B.C. (1996) Atlas of the dragonflies of Britain and Ireland, London: HMSO.

Miller, P.L. (1997) Common Blue Damselfly *Enallagma cyathigerum* (Charpentier). pp. 87-89. In: Brooks, S.J. & Lewington, R. Field Guide to the dragonflies and damselflies of Great Britain and Ireland. British Wildlife Publishing, Hook.

Moore, N.W. (1980) *Lestes dryas* Kirby - a declining species of dragonfly (Odonata) in need of conservation: note on its status and habitat in England and Ireland. Biological Conservation 17: 143-148.

Moore, N.W. & Corbet, P.S. (1990) Guidelines for monitoring dragonfly populations. Journal of the British Dragonfly Society 6: 21-23.

Morin, P.J. (1984) The impact of fish exclusion on the abundance and species composition of larval odonates: results of a short-term experiment in a North Carolina pond. Ecology 65: 53-60.

Nelson, B. (1997) Scarce Emerald Damselfly *Lestes dryas* Kirby. pp. 66-67. In: Brooks, S.J. & Lewington, R. Field Guide to the dragonflies and damselflies of Great Britain and Ireland. British Wildlife Publishing, Hook.

Pond Conservation Group (1993) 'A future for Britain's ponds. An agenda for action', Oxford: Pond Conservation Group.

Samways, M.J., Caldwell, P.M. & Osborn, R. (1996) Spatial patterns of dragonflies (Odonata) as indicators for design of a conservation pond. Odonatologica 25: 109-220.

Sebastian, A., Sein, M.M., Thu, M.M. & Corbet, P.S. (1990) Suppression of *Aedes aegypti* (Diptera: Culicidae) using augmentative release of dragonfly larvae (Odonata: Libellulidae) with community participation in Yangon, Myanmar. Bulletin of Entomological Research 80: 223-232.

Schiemenz, H. (1954) Über die angebliche Bindung der Libelle *Leucorrhinia dubia* v.d.L an das Hochmoor. Zoologische Jahrbücher (Systematik) 82: 473-480.

Sternberg, K. (1994) Niche specialization in dragonflies. Advances in Odonatology 6: 177-198.

Microcosms and mesocosms: masochism or mysticism? Ponds and the Regulation of pesticides

Steve Maund

Zeneca Agrochemicals, Jealotts Hill Research Station, Bracknell, Berkshire, RG42 6ET.

Abstract

Aquatic risk assessment for pesticides is based on comparisons of exposure and effect concentrations at a variety of levels (tiers). At lower tiers, a conservative approach is used in which large safety factors are applied to laboratory toxicity data. As the tiers are ascended, the effects and exposure data become increasingly complex, but more environmentally realistic. At these higher tiers, aquatic effects data are sometimes generated under field conditions using ponds. Ponds have historically been used as a

"worst case" aquatic ecosystem for pesticide risk assessment because of both their low levels of dilution and perceived isolation in the landscape compared to streams and rivers.

Agrochemical companies originally carried out studies in single natural or semi-natural ponds, and effects were monitored before and after pesticide treatment. The problems with these studies were that:

- it was difficult to determine a "representative" exposure scenario (what concentration do you use?)
- the results of the studies were often equivocal (e.g. how do you differentiate between seasonal and pesticide-related declines in abundance?)

As a result of these difficulties, in the 1980s, replicated experiment ponds ("mesocosms") began to be used to examine a range of treatments in relation to a control. In the USA, mesocosm studies were conducted in ponds of at least 400 m^3. Unfortunately, due to regulatory requirements to add breeding fish to the ponds and the generally large variation between ponds (probably due to spatial gradients), the results did not provide much "bang for Buck". In Europe, similar studies were conducted, but on a more modest scale in ponds of 20-50 m^3. Results were generally better because fish were not usually included, but there were still problems with variability and experimental power. Recently, smaller test systems ("microcosms", typically between 1 and 10 m^3) have found favour, probably because they offer the best compromise realism and experimental control.

One of the remaining problems with microcosm and mesocosm studies is interpretation of data. Frequently asked questions are:

- how should one separate statistically significant "differences" from ecologically significant effects?
- how representative are the experimental systems of the real world?
- how can results from these studies be extrapolated to different situations?

Since 1995, Zeneca has been supporting research to evaluate the potential of ecological information, theory and models to assist with these questions. Our experience has been that there is much synergy to be gained from bringing together the ecological and ecotoxicological aspects of pond research. However, the project has also highlighted some gaps in our fundamental knowledge of pond ecology which need to be filled before more significant progress is possible.

Ecology and conservation of Portuguese temporary ponds

Pedro Beja

Universidade do Algarve, Unidade de Ciências e Tecnologias dos Recursos Aquáticos, Campus de Gambelas, 8000 Faro, Portugal.

Introduction

Portugal is a wildlife rich country, with large natural areas holding many species that are rare or absent elsewhere. Portugal still has wolves, lynx, vultures, bustards and storks, as well as many other large and appealing creatures. There are huge estuaries, such as the Tagus, holding tens of thousands of waders and wildfowl. There are many species of freshwater fish, primarily cyprinids, and almost all of these are endemic to the Iberian Peninsula. Because of this richness, it is hardly surprising that such inconspicuous and relatively dull looking habitats such as temporary ponds and their associated biological communities have merited little attention by Portuguese ecologists, conservationists and wildlife managers.

Conservation of Portuguese temporary ponds

Even a thorough search of the Portuguese scientific literature would hardly reveal anything more on temporary ponds than a few and generally old references to the incidental collection of invertebrates or vascular plants. For instance, when a team from the University of Algarve first detected the presence of the tadpole shrimp, *Triops cancriformis*, and the clam shrimp, *Cyzicus grubei*, in temporary ponds in Southwest Portugal, they realised with surprise that these were the first records of the species since the early 1950s. For other taxonomic groups the situation is the same or even worse: thus, at present, the biodiversity inventory of Portuguese temporary ponds should be considered to be in its very early infancy. Not surprisingly, information on the structure and dynamics of biological communities inhabiting temporary ponds is almost entirely absent from the Portuguese scientific literature.

In spite of this lack of basic information about temporary ponds, there seems to be at present in Portugal a growing awareness of the conservation value of these habitats. The reasons for this are manifold, but one of the most relevant is the classification of “Mediterranean temporary ponds” as a priority habitat under the European Directive 92/43/EEC. This Directive is, at present, the most important nature conservation instrument at the level of the European Union and obliges member states of the Union to assure the conservation of the habitats classified under this Directive, with particular emphasis on those considered conservation priorities. In addition, member states must designate sites for promoting the conservation of each of these habitats, each country then submitting such sites to the European Commission who will decide in due course which of the sites will be integrated into the so-called Natura 2000 network.

In Portugal, the application of this Directive prompted a major survey of the country for inventorying and mapping the distribution of the areas most representative of each habitat listed in the Directive. Mediterranean temporary ponds have also been inventoried during these surveys, and indeed this habitat is represented in 17 (55%) out of 31 sites submitted by Portuguese authorities to the European Commission for incorporation in the Natura 2000 network. These 17 sites cover an area of about 850,000ha and span the whole country, from north to south, and from east to west.

For the first time in Portugal, temporary ponds were given relevance in terms of conservation value, and they were considered alongside habitats normally considered of greater importance, such as dunes, salt marshes and coastal lagoons.

The conservation priority given to Mediterranean temporary ponds by the European Directive 92/43/EEC was also one of the main reasons behind the beginning of present authors interest in this type of habitats. In 1996 Pedro Beja started working at a Natural Park in Southwest Portugal (Parque Natural do Sudoeste Alentejano e Costa Vicentina), where temporary ponds are prominent features in the landscape. There, the conservation value of temporary ponds had been suspected since the early 1990s, when it was discovered that they provide important feeding grounds for white storks and breeding sites for many species of amphibians. In consequence, an effort had been made to map the distribution of these freshwater bodies in the Natural Park, revealing the presence of over 100 temporary ponds. However, no studies had been carried out to characterise these habitats in any detail, and there were no indications on how to manage these ponds for wildlife. Also, there was a general feeling that these habitats were rapidly being lost or degraded because of farming activities.

As a consequence, it was proposed that further work should be carried out on the ecology and conservation of temporary ponds in Southwest Portugal. The proposal was accepted, and studies went ahead (although with limited funding), this being the first time in Portugal that a conservation management project was directed specifically at temporary ponds.

In the autumn of 1996 an extensive pond survey was carried out by the authors. Our first problems then were related to the very definition of temporary ponds. On the one hand to ensure that we gave some conservation significance to the term “temporary ponds”, it was important not to call every puddle of rainwater a temporary pond. On the other hand, however, we felt that the definition of “Mediterranean temporary ponds” available in the EU Directive 92/43/EEC was too restrictive, leaving out many temporary freshwater bodies with outstanding conservation value. Because of this we tried to reach a compromise, adopting a rough definition to which we hoped to give ecological meaning later on: we called a “temporary pond” any natural depression in the soil that fills up in winter, except in the most dry years, drying out every summer except in the most rainy years, usually presenting a characteristic hydrophilic vegetation composed chiefly of rushes and sedges.

With this definition we inventoried and mapped 237 temporary ponds, ranging from about 0.08 ha to 4.2 ha in area and from 0.15 m to over 2 m in maximum depth. Ponds varied considerably in terms of general physiognomy, natural vegetation cover, and human activities. It was apparent that there was a north-south gradient in pond character, with ponds in the north of the Natural Park showing features characteristic of an Atlantic environment, whereas those in the south were typically Mediterranean in character. Pristine Atlantic ponds were surrounded by a belt of wet heathland dominated by *Erica ciliaris*, *Erica erigena* and *Ulex minor*, whereas in the South this same belt was composed chiefly of *Erica scoparia* and *Myrtus communis*, like ponds in Corsica and elsewhere in the Mediterranean. This same gradient seems likely to be apparent for other taxonomic groups but at present we have little data to support this contention.

Other important data obtained at this time included a general overview of the human impacts upon these ponds. It quickly became clear that all the ponds were under agricultural influence, including in its lightest forms some kind of extensive cattle grazing (about 25% of the ponds). Most ponds, however, were under a much stronger farming regime: about 25% of ponds had been ploughed a little time before the survey, for improving the pastures to cattle, and another 40% showed signs of recent cultivation with cereals or other crops. A small percentage (about 5%), had been deepened and transformed into permanent water reservoirs. Also, a small but not quantified number of ponds showed signs of nutrient enrichment, revealed by the proliferation of reedmace (*Typha* species).

Following this survey, it was decided to analyse in more detail the potential impacts of farming regime on the biological value of these temporary ponds. Constrained by the available taxonomic expertise, we decided to focus our work on the communities of breeding amphibians. Ponds under different farming regimes were then sampled, and the relative abundance of amphibian larvae was estimated, along with data on water chemistry, geomorphology, and human activities. Sampling at 57 ponds yielded eight species of breeding amphibians, the most common being the western spadefoot, *Pelobates cultripes*, the sharp-ribbed salamander, *Pleurodeles waltl*, and the stripeless tree frog *Hyla meridionalis*.

This study indicated clearly that once a pond becomes permanent it looses much of its value for breeding amphibians: permanent ponds had fewer amphibian species, and also lower abundance of most species. In Southwest Portugal this is probably because permanent ponds have populations of non-native predators, such as the American crayfish, *Procambarus clarkii* and small-mouth bass, *Micropterus salmoides*, that predate on the eggs and larvae of most amphibians.

Surprisingly it was not possible to find any negative relationships between the amphibian community and the ploughing of the pond during the dry season. Indeed, some of the amphibians, such as the spadefoot toad, seemed to benefit from ploughing, though this was by no means the rule for every species.

The data collected in the amphibian study is currently being analysed in great detail and prepared for publication.

Branchipod crustaceans in Southwest Portugal

Another, line of research that has been pursued in Southwest Portugal is concerned with the non-cladoceran Branchiopod crustaceans. Following the discovery of *Triops cancriformis mauritanicus* and *Cyzicus grubei* in some temporary ponds, a team from the University of Algarve decided to carry out a more intensive survey for the presence of these and other non-cladoceran Branchiop crustaceans. This survey proved very fruitful, yielding three more species that had not been reported previously from Portugal: two anostracans, *Branchipus cortezi* and *Chirocephalus diaphanus*, and one spinicaudatan *Maghrebestheria maroccana*.

This survey also showed that the Branchiopod crustaceans are relatively rare inhabitants of temporary ponds: they were only detected in 16 out of 83 temporary ponds sampled. *Maghrebestheria maroccana* and *Cyzicus grubei* each occurred in only two ponds, *Chirocephalus diaphanus* in three ponds*, Branchipus cortezi* in seven ponds and *Triops cancriformis mauritanicus* in eight ponds. The reasons behind the distribution observed for these species are still little understood; however, it was found once again that ponds ploughed and even cultivated during the dry season were sometimes of very high conservation value. Indeed, the rarest species found, the clam shrimp, *Maghrebestheria maroccana*, only occurred in two very disturbed ponds. From this study it also become clear that most species of non-Cladoceran crustaceans are extremely rare, and a few may be facing extinction in the short term, at least at the regional level. Further information about this work can be found in Machado et al. (1999).

Besides these large scale studies on the ponds of Southwest Portugal, it soon became clear that to further our comprehension of the structure and functioning of these ponds it would be necessary to select a smaller number for more detailed analysis. Two groups of comparatively pristine ponds were selected, one group in the northern part of the Natural Park (Malhão-Aivados) and the other in the south (Sagres). These groups represent the two extremes of the gradient between the Atlantic and the Mediterranean ponds available in the Park.

These studies are currently underway and only limited data are available for analysis at present. The research includes investigations of the hydrology of the ponds, chemical characterisation, biodiversity inventory, temporal succession of invertebrate communities and biology and ecology of *Triops cancriformis*. The taxonomic groups that are being investigated in most detail are the aquatic beetles. In two years of work about 40 species of aquatic beetles have been identified in the two groups of ponds, including species that seem to be of special conservation concern. This includes the very threatened dytiscid *Acilius duvergeri*.

Also of interest are the preliminary results describing the structure of invertebrate communities in ponds holding *Triops cancriformis*. *Triops* are voracious predators, so in the ponds where they are abundant the populations of aquatic insects, including chironomid larvae, are very small, and the ponds seem to be dominated by crustaceans during almost the entire aquatic phase. Only a little time before the pond dries out, when the populations of *Triops* are extremely reduced, do the aquatic insect populations seem to be allowed to build up.

Although this work is being done by a small team with limited funding, it is already enhancing out knowledge of these valuable ecosystems and it is anticipated that a much better understanding of the functioning of the ponds will be fairly quickly developed. In addition, by analysing ponds in a relatively pristine condition, we expect to obtain the necessary background information to assess and monitor the quality and degradation of these habitats.

Conclusions

From these first few years dealing with temporary ponds in Southwest Portugal, we have gathered a range of data that allow some hypothesis to be put forward concerning the structure, functioning, management and conservation of these habitats. Some of these hypotheses are relatively well supported by data, but many others are only a little bit more than educated guesses.

Outlined below are some of the key hypotheses and concepts that we have developed in the light of data gathered on Southwest Portugal temporary ponds.

Conservation value of temporary ponds. Our studies, though certainly incomplete, have shown beyond doubt that temporary ponds have a high conservation value, being inhabited by a number of species that find there their optimum or exclusive habitat. Of particular importance are some non-cladoceran crustaceans which are so closely associated with temporary ponds that they are at risk of regional extinction from the ongoing destruction of this habitat;

Conservation management of temporary ponds. The management of temporary ponds is very complex owing to their extreme variability and variety of ecological requirements of the species inhabiting them. The only undisputed guideline concerning the management of these habitats is that once the freshwater body gets permanent it looses much of its conservation value. No other firm rule could be found. Management prescriptions should thus be dependent on the target species that one wants to benefit. Even ponds ploughed during the dry season have their conservation value, and it is not unlikely that strong disturbance is a key requirement of valuable biological communities.

Conservation of temporary ponds in the landscape. Physical and chemical conditions in temporary ponds are extremely variable, nearby ponds being frequently very different from each other, and each pond suffering major transformations both within and between years. Hence, temporary ponds are islands in space and time, the species present in a given pond at a given time being only a small subset of the species pool available in the region. The dynamics of these biological communities may thus be strongly influenced by phenomena of colonisation-extinction. As a consequence, the regional biodiversity of organisms inhabiting temporary ponds can probably only be maintained provided the variety of conditions available if the ensemble of ponds is preserved. This leads the conservation of temporary ponds to the realm of landscape planning.

Temporary ponds under EU Directive 92/43/EEC. EU Directive 92/43/EEC, by classifying “Mediterranean temporary ponds” as a priority habitat, has given more visibility to the problem of conserving temporary ponds. However, the definition adopted for Mediterranean temporary ponds it is too restrictive, leaving unprotected many threatened types of temporary ponds of outstanding conservation value. It should be urged that this definition is reviewed to accommodate these types or ponds, or that an alternative set of habitat categories should be created under the Directive, so that they adequately account for and protect the different types of threatened temporary ponds. As a first suggestion, I believe that temporary freshwater bodies holding populations of non-cladoceran branchiopod crustaceans should be considered a priority habitat under EU Directive 92/43/EEC, eventually with some exceptions that should be analysed case by case.

Research and temporary ponds. Temporary ponds provide many opportunities for research, both from the theoretical and the applied points of view. If there was anyone unsure about this, the 1995 Robert MacArthur award lecture of the Ecological Society of America, by Henry Wilbur (Wilbur, 1997), should have dissipated any remaining doubt.

Indeed, Henry Wilbur has demonstrated that temporary ponds are relatively simple and workable ecosystems, where many ecological processes may be resolved in detail. Temporary ponds thus merit much more research, and this is critical for better management of these systems. Also, as temporary ponds are small water bodies that seem to react very quickly to many environmental constraints, it will probably be worth considering their usefulness for various aspects of environmental monitoring.

As a concluding remark, it should be noted that temporary ponds are extremely interesting habitats, that have been systematically undervalued in the past. However, all over Europe there seems to be growing awareness of their conservation relevance, making this the right moment for joining the information and experience of workers dealing with this theme. Therefore, I leave here a call for the urgent organisation of an European Conference on the Ecology and Conservation of Temporary Ponds and Marshes, that will be most useful for the continued study and conservation of these threatened habitats.

References

Machado, M., Cristo, M. and Da Fonseca L.C. (1999). Non-cladoceran branchiopod crustaceans from southwest Portugal. I. Occurrence notes *Crustaceana*, 72: 591-602.

Wilbur, H.M. (1997). Experimental ecology of food webs: Complex systems in temporary ponds - The Robert H. MacArthur. *Ecology*, 78, 2279-2302.

Acknowledgements

We would like to thank Pond Action for providing the opportunity to present information on the ecology and conservation problems of temporary ponds in Portugal.

The role of fish in pond community structure and function

Martin R. Perrow & Mark L. Tomlinson

ECON Ecological Consultancy, Biological Sciences, University of East Anglia, Norwich, NR4 7TJ.

Introduction

To many people, ponds and fish are synonymous. This perhaps stems from the historical practice of stocking ponds with fish for use as food (e.g. carp *Cyprinus carpio* culture in medieval times). Indeed many ponds, particularly those associated with our historic houses, were designed and built for holding and harvesting fish. This practice has been superseded with the stocking of visually attractive species such as goldfish (*Carassius auratus*) or koi carp (a variant of *C. carpio*). In the wider community, ponds created to water livestock and people (e.g. in village green and farm situations), as well as more natural ponds, perhaps associated with river floodplains, also often hold fish. Many young anglers start their careers in such locations, catching 'tiddlers' with nets before moving on to larger quarry. Today, many ponds contain those larger individuals and species as the demand for intensive commercial stillwater recreational fisheries grows. As a result of such intensive management, there are likely to be conflicts with the conservation and aesthetic value of ponds, however. In this paper, we outline what species of fish may be encountered in ponds and discuss the likely role of fish in determining pond community structure and function. We then discuss the way forward in managing fish stocks, with an example from a pond in Suffolk; and discuss future research needs, in order that we may maintain or even enhance our pond heritage.

What is expected of pond fish communities?

There are currently around 54 species of freshwater fish in the UK (Maitland & Campbell 1992), although the number continually changes as a result of introduction of large or powerful exotic species that appeal to anglers. Several of these have originated from garden centres as 'garden pond' fish (e.g. sterlet *Acipenser rutheneus*). New legislation by the Environment Agency & CEFAS has sought to curb such illegal introduction by making the suppliers liable to prosecution should they sell certain non-native species to anyone without a MAFF/Welsh Office licence (Bowman 1998).

Reviewing the distribution of the British freshwater fish fauna, Wheeler (1977) concluded that dispersal by humans was of primary importance in the spread of many species. This is of particular relevance to ponds, as it is probable that the majority are isolated from other waterbodies containing fish. Without human intervention, many ponds would naturally be fish-free: the only other tenable mechanism for dispersal being the 'birds-foot' hypothesis. Whilst it is plausible that the sticky eggs of many species may accidentally attach to the feet, beaks or plumage of birds, they are susceptible to physical damage and drying out. Even if eggs manage to stay viable and hatch out, the establishment of a viable population of fish may take many such instances. In contrast, fish may readily access ponds with direct connection to rivers or drainage systems, especially in times of flood. Even water of a few centimetres deep may be utilised. Eels (*Anguilla anguilla*) are also capable of crossing short stretches of dry land, albeit in cool, damp conditions. Even so, there are ecological constraints to fish producing self-sustaining populations. This includes the presence of potential competitors and predators and the nature of the prevailing conditions, for example, the abundance of submerged macrophytes (Perrow *et al.* 1999a). Thus, even connected ponds may retain different communities, in keeping with the ecological conditions within them (Figure 1).

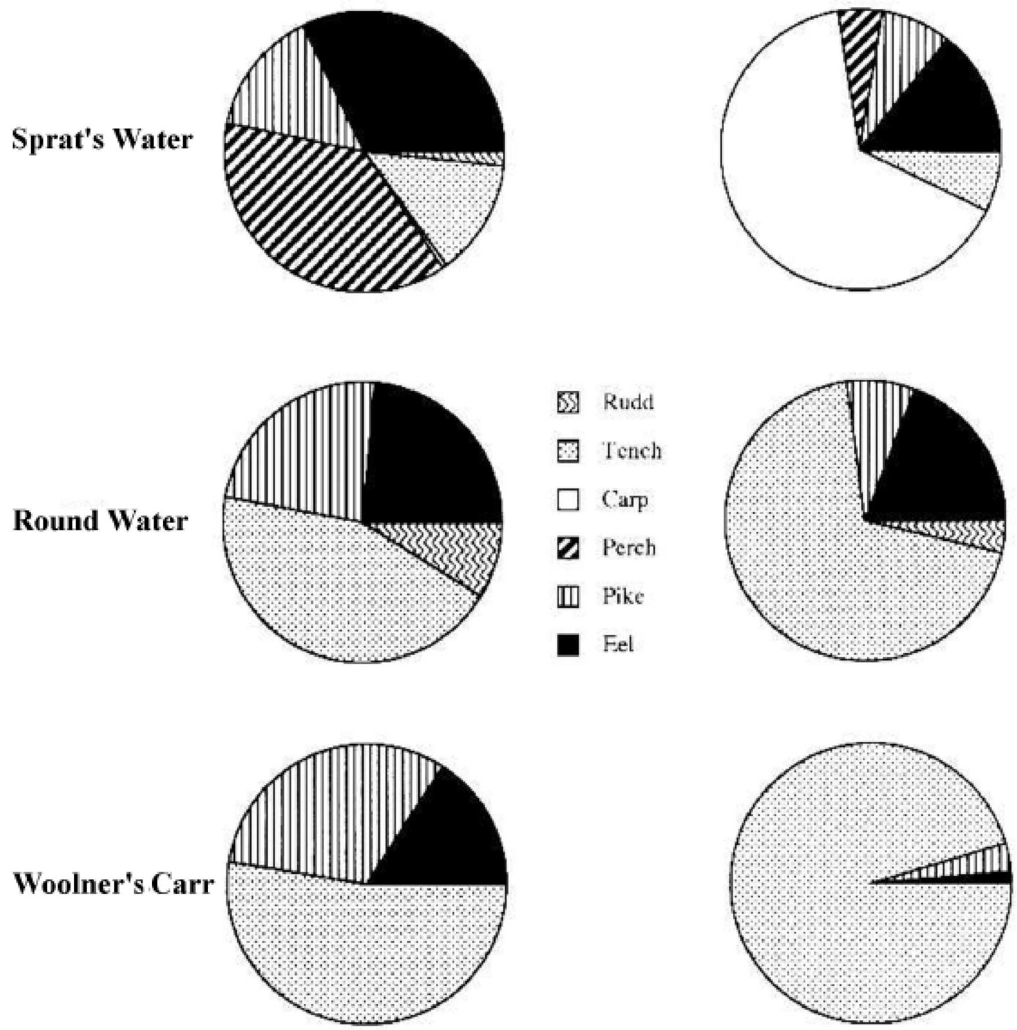


Figure 1. **Proportional abundance and biomass of different fish species captured in the three pools at Carlton Marshes Nature Reserve, Suffolk.**

A combination of the means of access of the different fish species able to survive in ponds and the prevailing conditions within them (Table 1), may produce a number of typical fish communities (Table 2). The fact that ponds are, by nature, small (we consider a stillwater < 1 ha to be a pond), means that the range of habitats found within larger water bodies is somewhat restricted. For example, ponds have a large edge : surface area ratio and may thus be viewed as largely 'littoral' (edge) biomes. That is, they do not have a true pelagic (open water) zone. This is of consequence when considering the influence of fish (see below) and also means that more pelagic species or age classes of particular species are unlikely to do well in ponds (e.g. bream-Table 1). Restriction in the range of habitats may restrict the range of exploitable niches. In the absence of management, ponds may tend to support simple fish communities, comprised of just a few species, particularly those with physiological adaptations to pond life (e.g. tolerance to low oxygen or high ammonia concentrations) (Fig. 1). Examples of this group include tench and Crucian carp *Carassius carassius*, which may survive under anaerobic conditions for short periods. Furthermore, although the British fauna contains no species specifically adapted to drying out (like the South American *Cynolebias* spp. killifish, which are adapted to temporary pools with their drought tolerant eggs); species such as tench, Crucian carp and eels may survive for short periods in damp mud, in a manner akin to lungfish (e.g. *Protopterus* spp).

The impact of fish

There is a wealth of literature of the impact of fish upon lake trophic structure and function, both through pelagic (Carpenter & Kitchell 1993) and benthic (Threlkeld 1994) food web interactions. There is far less information on ponds specifically, although it can be safely assumed that much information can be directly applied. Furthermore, the lack of separation between the pelagic and littoral zones may mean that the intensity of some interactions is not spatially buffered. In other words, whereas in larger lakes zooplankton may seek refuge from pelagic fish in the littoral or littoral fish in the pelagic: in small ponds, fish may easily swim between zones in a matter of moments, reducing the chances of zooplankton finding a refuge. The impact of fish is best considered according to their foraging modes: zooplanktivory, benthivory and piscivory.

Zooplanktivory

Size-selection predation of visually-feeding fish upon zooplankton has been studied in detail since the seminal work of Brooks & Dodson (1965). In simple terms, small individuals of species such as roach may eliminate large-bodied grazing Cladocera such as *Daphnia* spp. The grazing pressure on phytoplankton is reduced as a result and where sufficient nutrient is available (which is more or less anywhere in lowland UK), green turbid water results. Even relatively low densities of fish (>0.2 m^{-2}) may induce this response (Perrow *et al.* 1999b) (Fig. 2). Turbid water disfavours submerged macrophytes, culminating in an impoverished flora and fauna. This trophic cascade (Carpenter & Kitchell 1993) response has been exploited by the management/restoration tool of biomanipulation, whereby removal of zooplanktivorous fish promotes clear water and the chances of domination by submerged macrophytes and greater biodiversity (Perrow *et al.* 1999b).

Where submerged macrophytes are already present, grazing zooplankton may utilise them as refuges from predation from many, though not all, fish species.

Such is the strength of refuging, that grazing Cladocera may persist at much higher fish densities in the presence of macrophytes than in their absence (perhaps >1 m^{-2} –Perrow *et al.*1999b, Fig. 2). Schriver *et al.* (1995) suggest even a PVI (per cent volume of water column infested with macrophytes) of 15-20% may offer a refuge. Stansfield *et al.* (1997) however, suggested that 75% or more is more effective. In the face of intense fish predation, *Daphnia* spp., which have to move into open water to forage effectively, are still likely to be reduced over the course of the season. However, their role as efficient grazers may be taken over by other macrophyte-associated species such as *Simocephalus* spp. (Perrow *et al.* 1999b).

Table 1. The status of the fish species likely to occur in ponds in the UK.

Species	Origin in U.K	Ornamental	Stocked by anglers	Native & suited to ponds
Brown trout *Salmo trutta*	native		occasionally	
Rainbow trout *Oncorhynchus mykiss*	introduced		occasionally	
Pike *Esox lucius*	native		occasionally	*
Common carp *Cyprinus carpio*†	introduced	*	routinely	
Grass carp *Ctenopharyngodon idella*	introduced	*		
Crucian carp *Carassius carassius*	introduced		occasionally	*
Goldfish *Carassius auratus*	introduced	*		
Barbel *Barbus barbus*	native		rarely	
Gudgeon *Gobio gobio*	native			
Tench *Tinca tinca*	native	*††	frequently	*
Common bream *Abramis brama*	native		occasionally	
Bitterling *Rhodeus sericeus*	introduced			
Rudd *Scardinius erythrophthalmus*	native	*††	frequently	*
Roach *Rutilus rutilus*	native		frequently	*
Chub *Leuciscus cephalus*	native		rarely	
Orfe *Leuciscus idus*	introduced	*††		
Wels catfish *Silurus glanis*	introduced		occasionally	
Eel *Anguilla anguilla*	native			*
Three-spined stickleback *Gasterosteus aculeatus*	native			*
Ten-spined stickleback *Pungitius pungitius*	native			*
Pumpkinseed *Lepomis gibbosus*	introduced	*		
Perch *Perca fluviatilis*	native		occasionally	*
Ruffe *Gymnocephalus cernuus*	native			

†includes mirror, leather and koi †† in golden form

Table 2. Likely composition of native pond fish communities in relation to macrophyte status.

Principal species	Supplementary species	Macrophyte status
Tench and pike	Crucian carp, eel	dense
Crucian carp	Ten-spined stickleback, eel	dense
Rudd and perch	Roach, tench, pike,eel	sparse
Perch	Pike, eel	sparse
Three and ten-spined sticklebacks	Pike, eel	sparse
Roach	Pike, eel	none

Benthivory

During foraging, bottom-feeding fish such as carp or bream, disturb and resuspend sediments (Breukelaar *et al.*1994), promote nutrient (especially phosphorus) release (Tatrai & Istvanovics 1986) and uproot macrophytes (Ten Winkel & Meulemans 1984). Green or brown turbid water results from dense algal populations or high levels of suspended solids. As in much of experimental ecology, cause and effect within the interactions may be hard to demonstrate. For example, whilst Zambrano *et al*. (1999), working in sub-tropical ponds in Mexico, clearly demonstrated that submerged macrophytes declined in increasing densities of introduced carp, the mechanism for this loss was debateable (Fig. 3). It was also unclear whether the decline in macroinvertebrates was a result of the loss of macrophytes, direct predation or a combination of both (Fig. 4). A further important result of this study was that the impact of carp was dependent on density, for example macrophytes were only lost at high stocking densities.

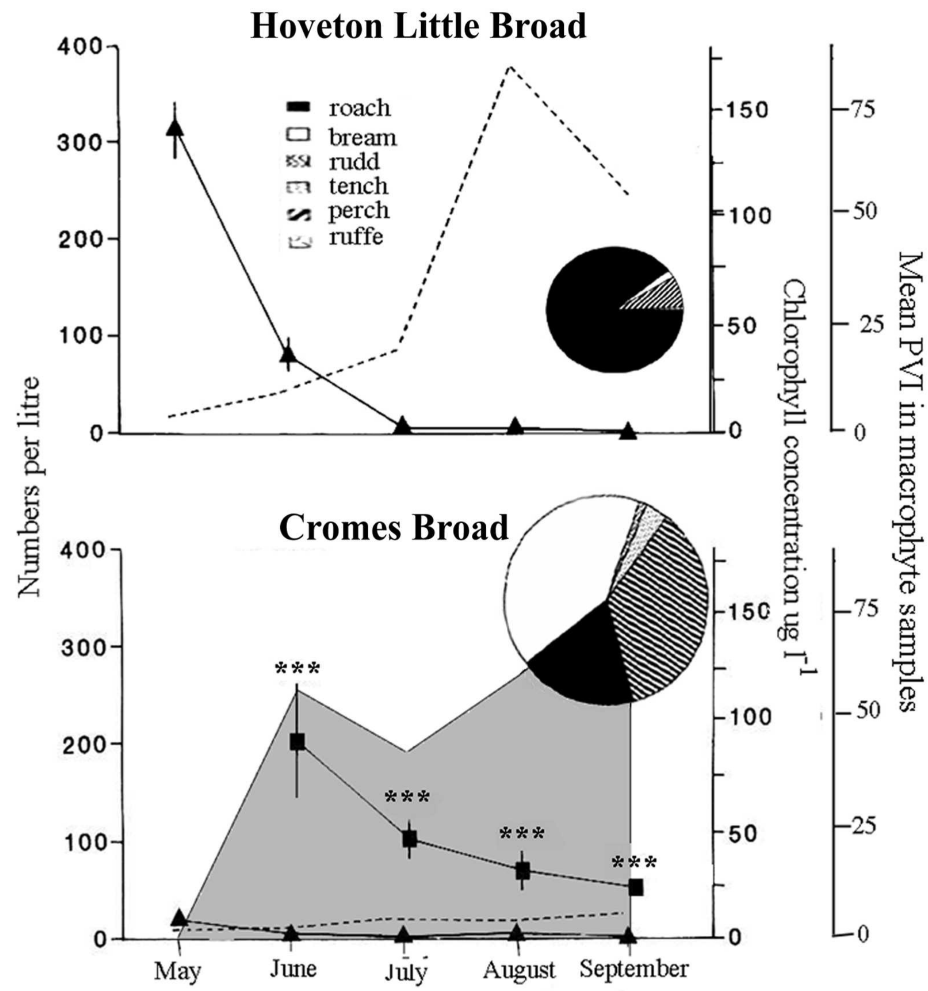


Figure 2. **Relationships between i) abundance of grazing Cladocera (numbers l^{-1}) in macrophytes (squares) and open water (triangles): significant differences in abundance between habitats are shown ii) chlorophyll a concentration ($\mu g\ l^{-1}$) (dotted line) iii) relative abundance (size of pies) and composition of the 0+ fish assemblage and iv) mean PVI in macrophyte samples (shaded area): in the phytoplankton-dominated Hoveton Little (top) and macrophyte-dominated Cromes Broads (bottom). Modified from Stansfield *et al.* (1997).**

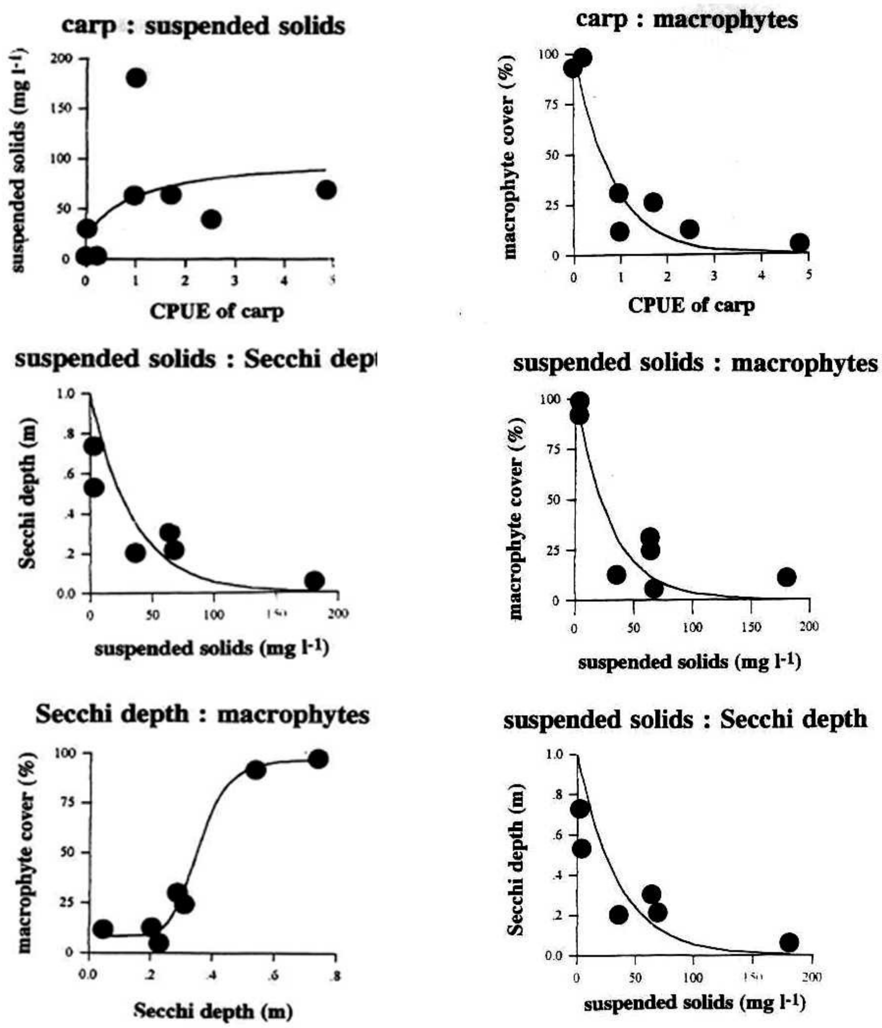


Figure 3. **Potential cascading effects (top to bottom) of foraging carp resuspending bottom sediments (left column) or uprooting macrophytes (right column). In either case, macrophytes are lost from the system at high carp densities (expressed as CPUE). Modfied from Zambrano *et al.* (1999).**

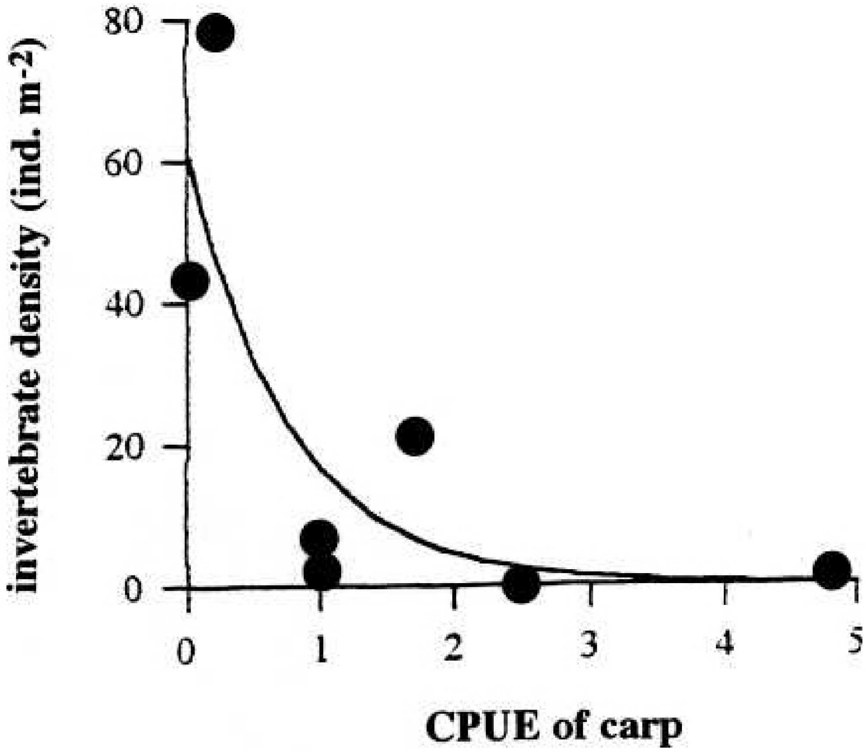


Figure 4. Relationship between the density of introduced carp (expressed as CPUE) and invertebrate density (ind. m^{-2}) in ponds in the Lerma Valley, central Mexico. After Zambrano *et al.* (1999).

Tatrai *et al*. (1994) also demonstrated that the impact of benthivorous bream in experimental ponds was dependent on the size of the bream concerned. Large bream (35–50 cm) had a greater impact, per unit biomass, than smaller (25–35 cm). This may have been linked to the ability of larger fish to penetrate deeper into the sediments and generate greater suction pressure with their larger mouths. Incidentally, large (40-50 cm) carp had around twice the impact as bream. The same study also showed that whilst high biomasses (300-500 kg ha^{-1}) of large bream or carp resulted in a low diversity and abundance of benthic organisms, some fish (c. 150 kg ha^{-1}) was better than no fish. The authors speculated that some disturbance increased the heterogeneity of the substrate and some predation reduced the abundance of dominant groups, resulting in a more diverse benthic fauna.

Piscivory

Predation by piscivorous fish may also change the nature of prey fish populations. For example, Bronmark *et al.* (1995) using data from many Scandinavian lakes and ponds, showed that populations of Crucian carp and tench subject to perch predation, were composed of large, old individuals at low density. In contrast, in the absence of significant predation, populations were dominated by small individuals at high density. Predation may then knock-on throughout the food web. A compelling example of this comes from the work of Spencer & King (1984) in experimental ponds in the US. Here, where Largemouth bass (*Micropterus salmoides*) were present, densities of Fathead minnows (*Pimephales promelas*) and Brook sticklebacks (*Culaea inconstans*) were extremely low, large zooplankton were abundant and submerged macrophytes dominated. Macrophytes were exploited by grazing waterfowl and muskrat (*Ondatra* *zibethica*). In the absence of bass; minnows and sticklebacks occurred at high density, zooplankton numbers were low and phytoplankton dominated. Small fish were exploited by piscivorous birds including kingfishers, herons and egrets. Bass thus exerted natural, effective, top-down control: as mimicked by biomanipulation (see above).

Whether or not piscivores are typically a controlling factor is debated, as there are many constraints on piscivores being effective (Perrow *et al.* 1999a). Not least, gape size limits the size of prey that can be taken. The size of the predator also needs to be matched to the size of the prey. For example, for species such as pike, the principal facultative piscivore in the UK, which tends to handle prey one at a time, the metabolic demands of large pike are unlikely to be met with very small prey. Moreover, small pike, those best suited to take small prey, are highly vulnerable to cannabalism from larger conspecifics. This restricts them to the cover of submerged and emergent vegetation, more prevalent in the littoral zone. In the absence of suitable habitat, the age structure of pike populations is biased to large, old fish, with little potential to control the recruitment of young-of-the-year cyprinids. As ponds are largely littoral habitats (see above), perhaps pike populations within ponds are more likely to have the necessary attributes (a high density of young fish) for piscivore control, than in larger lakes?

Management implications

As demonstrated by Scheffer *et al.* (1993) shallow (<3 m) still waters may exist in two alternative stable states at equivalent nutrient concentration: one dominated by planktonic algae and the other dominated by submerged macrophytes. At low nutrient concentrations (< 0.1 mg l^{-1} total phosphorus) it is likely that submerged macrophytes will dominate. In such structurally diverse conditions, appropriate fish species and communities (Tables 1 & 2) may form stable configurations with other trophic levels and actually promote biodiversity.

The upper range of nutrient concentrations at which algae is likely to dominate is debated and may be dependent on a number of other factors, notably the presence of fish. Suffice it to say, many ponds will fall within the range in which either state is possible. As intensive zooplanktivory or benthivory will promote the dominance of algae and reduce biodiversity, the management of fish populations becomes a key issue in pond conservation. Typically, high densities of especially non-native or inappropriate fish (Table 1), where they have been stocked by anglers or for ornamental purposes, will need to be reduced, either manually and/or through the introduction of appropriate predators.

Furthermore, where present, fish virtually always operate as top predators and if other predators such as some birds or especially dragonflies are the target, then these best favoured by the absence of fish. There is thus a clear need to define the likely appropriate natural state of the pond and set appropriate targets for the composition, density and biomass of the fish stock, in accordance with nutrient levels and its uses (e.g. as visual amenity, water supply, fishery, conservation site).

Surveys of the different trophic levels: fish, macroinvertebrates and zooplankton, macrophytes, algae and nutrients (Table 3); can allow a working food web and the likely nature and strength of interactions within it, to be determined.

Case study: The Grimmer

The centrepiece of the village of Wickham Skeith in Suffolk is the Grimmer, a small (0.3 ha) pond formed by harvesting clay for building materials. Remembered as clear with abundant life by the residents, by 1990, the pond had become turbid with blue-green algae and had suffered significant sedimentation. A Grimmer action group was formed to return the pond to its former glory. Over £4000 was raised from voluntary contributions and awards from various organisations. Management focused on sediment removal. Prior to draining the pond, the abundant small fish (>5000 roach) along with a few eels, pike and tench were netted and removed. Over 2000 tons of sediment was then removed with a hymac digger. The original form of the Grimmer as two waterbodies (Grimmer and Little Grimmer) was incorporated into the design as two basins with maximum depths around their original values (3.3 m and 2.8 m respectively). The pond was then re-filled with groundwater, topped up by precipitation. The pond stayed clear and within a short time supported a variety of macrophytes, macroinvertebrates and breeding frogs and toads. The success of the restoration of the Grimmer led to a 'Caring for the Environment Award' and several appearances on local television. A local resident then introduced around 40 carp and a few golden orfe. By 1993, the Grimmer became turbid again and the diversity of aquatic life declined. This led to control of >100 waterfowl, a ban on artificial feeding and introduction of more submerged plants from a local high quality pond. The introduction failed and attention turned to removal of the carp, which by now, had reached considerable size (reputedly to 9 kg). This led to unwanted attention from visiting anglers, many of which stayed for days on end, leading to considerable disturbance of local residents.

In 1995, a contractor employed to remove the carp by the Parish council was turned away from by a number of pro-fish residents. The community became divided on the issue of the carp and a long political process ensued. In 1997, ECON were commissioned to assess the state of the pond and recommend management. A site visit including liaison with local residents and basic survey of pond characteristics was conducted on 29th August 1997. Water clarity was poor (Secchi depth of 30 cm), limited primarily by the high concentration (60 mg l^{-1}) of suspended solids (fine clay particles). In contrast, algal populations seemed limited to some benthic blue-green algal colonies. Nutrient levels were relatively low (e.g. 50 $\mu g\ l^{-1}$ orthophosphate) providing scope for submerged macrophytes rather than phytoplankton to dominate. However, submerged macrophytes (*Ceratophyllum demersum* <5%, *Elodea canadensis* <1%, *Potamogeton crispus* <1%) and filamentous macroalgae (<10%) were scarce, apparently limited by the lack of light in a relatively deep water column. The littoral margin was relatively diverse (6 emergent and 2 floating-leaved species), but limited in extent by the lack of shallow water around the margins. Incredibly, no macroinvertebrates were captured in a series of open water Ekman grab samples and no zooplankton were captured in a series of tube samples.

Following a quantitative fish survey that October, there seemed little doubt that the high biomass of carp (41 $\pm$ 24 g m^{-2}) was responsible for re-suspending the fine clay sediment, resulting in light limitation of the macrophytes. Predation by carp and a lack of habitat meant that macroinvertebrate populations outside the emergent zone were poor. However, the density of other fish species, primarily rudd, was high (>2 m^{-2}) and it was likely that predation by rudd was limiting the development of grazing zooplankton. Thus, even if carp were removed, it was plausible that the lack of zooplankton would allow phytoplankton, rather than macrophytes, to develop in the improved light climate. The safe option was thus to remove a substantial (40%) part of the rudd stock.

Three options for the pond were put forward: 1) retain a high density and biomass fishery; 2) establish a more appropriate fish community, with a controlling piscivorous fish stock in balance with a moderately diverse flora and fauna; and 3) remove all fish to maximise the conservation value of the pond. The council overwhelmingly selected Option 2. In 1998, the Environment Agency removed a 'large' number of rudd, but, unfortunately, only captured 1 carp. ECON were then commissioned to remove the carp and in March 1999, 15 individuals (compared to the 18 originally surveyed) to 620 mm and 6.75 kg, along with 1 golden orfe and 1 large bream were removed by seine netting. These were stocked into a nearby moat with the necessary permission from the Environment Agency. The removal also confirmed that a large proportion of the original rudd stock had been removed (the resulting density of 0.08 ind. m^{-2} suggested a 96% reduction).

Water clarity increased considerably following fish removal (*pers obs*), which, in accordance with the management plan, allowed the planting of selected macrophyte species (e.g. yellow water lily *Nuphar lutea*). However, the management plan had also included further adjustment of the fish community: 1) modification of the existing pike population by removal of the few large individuals and stocking with small (<25 cm) fish at 15 kg h^{-1}; 2) stocking of piscivorous (>15 cm) perch at 20 kg ha^{-1} and eels (>1kg) at 10 kg ha^{-1}) and; 3) stocking native Crucian carp (20 kg ha^{-1}): in order to achieve a self-sustaining stable state. Without this final step, relapse into a turbid state seems inevitable.

Table 3. Relevant population parameters of pond trophic levels and their recommended means of sampling, required for management planning.

Trophic level	Type	Parameter	Sample method
Secondary consumer	Fish	Species composition Abundance (ind. m^{-2}) Biomass (g m^{-2})	Seine netting where macrophytes are absent and the fish are large, otherwise, point-abundance sampling by electrofishing (Perrow *et al.* 1996)
Primary consumer	Zooplankton	Species composition Abundance (ind. l^{-1})	Tube samples (n>5) preferably sorted separately, otherwise pooled
	Macro-invertebrates	Community composition Rank abundance	Timed pond net sample divided proportionately between different habitats
Primary producer	Macrophytes	% cover or preferably PVI	Visual mapping of entire pond or recorded in a series of quadrats
	Algae	Species composition Chlorophyll *a* concentration	Pooled water sample
Plant nutrient	Phosphorus	Total (TP) and soluble reactive phosphorus (SRP)	
	Nitrogen	Nitrate - nitrogen	

Other chemical parameters that set the boundaries of ecological interactions and even whether particular components of the food web can be supported, include pH, dissolved oxygen, ammonia concentration (measured through likely ammonium:ammonia ratios at specific pH and temperature) and concentration of suspended solids. Secchi depth, an expression of water transparency, is also a particularly useful measure. A series of samples taken at regular intervals over one or more seasons provides a range for any particular variable and increases confidence in the development of any management plan. As a general rule, the frequency of sampling needs to increase with decreasing generation time (i.e. fish may be adequately sampled once at the end of the growing season, whereas nutrients are best sampled fortnightly). However, where resources are limited and/or a specific hypothesis is being tested, even a few specific measures taken by specific means on just one occasion in a critical period, may be sufficient to develop a plan of action.

However, it should be noted that the structure and function of pond communities and the precise role of fish within them, are far from fully understood. Moreover, there are few detailed, well-documented examples of management and its impact. Consequently, predictions on the direction and rate of change as a consequence of management may be prone to error.

Conclusions

Fish are likely to have a critical role in determining pond community structure and function. Management of fish populations is thus a key issue in pond conservation. However, relationships between species composition, abundance and biomass of fish and other trophic levels, in ponds, are poorly understood. In particular, we have little idea of the composition of self-sustaining stable communities and how these relate to chemical parameters such as nutrient levels. Whilst a number of management options are likely to exist for many ponds, the principles of management require further rigorous testing.

Acknowledgements

We are grateful to Pond Action for inviting us to participate in the Ponds Conference 1998 and Luis Zambrano for permission to re-draw figures from his PhD thesis investigating the impact of introduced carp on ponds in Central Mexico.

References

Bolton, P.J., Wheeler, A. & Wellby, I.N. (1998). The future of the crucian carp. In: *Current issues in Fisheries* (eds R.H.K. Mann, A. Wheeler & I.N. Wellby), Proceedings of the Institute of Fisheries Management 29th Annual Study Course, Homerton College, Cambridge, 117-120.

Bowman, R.W. (1998). New measures to protect native flora and fauna in England & Wales. In: *Current issues in Fisheries* (eds R.H.K. Mann, A. Wheeler & I.N. Wellby), Proceedings of the Institute of Fisheries Management 29th Annual Study Course, Homerton College, Cambridge, 110-111.

Breukelaar, A.W., Lammens, E.H.R.R., Klein Breteler, J.G.P. & Tatrai, I. (1994). Effects of benthivorous beam (*Abramis brama* L.) and carp (*Cyprinus carpio* L.) on sediment resuspension and concentrations of nutrients and chlorophyll *a*. *Freshwater Biology*, 32, 113-121.

Bronmark, C., Paszkowski, C.A., Tonn, W.M. & Hargeby, A. (1995). Predation as a determinant of size structure in populations of crucian carp (*Carassius carassius*) and tench (*Tinca tinca*). Ecology of Freshwater Fish, 4, 85-92.

Brooks, J.L. & Dodson, S.I. (1965). Predation, body size, and composition of plankton. *Science*, 150, 28-35.

Carpenter, S.R. & Kitchell, J.F. (1993). *The Trophic Cascade in Lakes*. Cambridge Studies in Ecology, Cambridge University Press, 385 pp.

Maitland, P.S & Campbell, R.N. (1992*). The New Naturalist Freshwater Fishes of the British Isles*. HarperCollins Publishers, London, 368pp.

Perrow, M.R., Jowitt, A.J.D. & Zambrano González, L. (1996). Sampling fish communities in shallow lowland lakes: point-sample electric fishing vs electric fishing within stop-nets. *Fisheries Management and Ecology*, 3, 303-313.

Perrow, M.R., Jowitt, A.J.D., Leigh, S.A.C. Hindes, A.M. & Rhodes, J.D. (1999a). The stability of fish communities in shallow lakes undergoing restoration: expectations and

experiences from the Norfolk Broads (UK). *Hydrobiologia*, 408/409, 85-100.

Perrow, M.R., Jowitt A.J.D., Stansfield, J.H., Phillips, G.L. (1999b). The importance of the interactions between fish, zooplankton and macrophytes in the restoration of shallow lakes. *Hydrobiologia*, 395/396, 199-210.

Scheffer. M., Hosper, S.H., Meijer, M-L., Moss, B. & Jeppesen, E. (1993). Alternative equilibria in shallow lakes. *Trends in Ecology & Evolution*, 8, 275-279.

Schriver, P., Bøgestrand, J., Jeppesen, E. & Søndergaard, M. (1995). Impact of submerged macrophytes on fish-zooplankton-phytoplankton interactions: large-scale enclosure experiments in a shallow lake. *Freshwater Biology*, 33, 255-270.

Spencer, C.N. & King, D.L.(1984). Role of fish in regulation of plant and animal communities in eutrophic ponds. *Canadian Journal of Fisheries & Aquatic Sciences*, 41, 1851-1855.

Stansfield, J.H., Perrow, M.R., Tench, L.D., Jowitt A.J.D. & Taylor, A.A.L. (1997). Submerged macrophytes as refuges for grazing Cladocera against fish predation: observations on seasonal changes in relation to macrophyte cover and predation pressure.

Hydrobiologia, 342/343, 229-240.

Tatrai, I. & Istvánovics, V. (1986). The role of fish in the regulation of nutrient cycling in lake Balaton, Hungary. *Freshwater Biology*, 16, 417-424.

Tatrai, I., Lammens, E.H.R.R., Breukelaar, A.W., & Klein Breteler, J.G.P. (1994). The impact of mature cyprinid fish on the composition and biomass of benthic macroinvertebrates. *Archive für Hydrobiologie*, 131, 309-320.

Ten Winkel, T.E.H. & Meulemans, J.T. (1984). Effects of fish upon submerged vegetation. *Hydrological Bulletin*, 18, 157-158.

Threlkeld, S.T. (1994). Benthic-pelagic interactions in shallow water columns: an experimentalist's perspective. *Hydrobiologia*, 275/276, 293-300.

Wheeler, A. (1977). The origin and distribution of the freshwater fishes of the British Isles. *Journal of Biogeography*, 4, 1-24.

Zambrano, L., Perrow, M.R., Macías-García, C. & Aguirre-Hidalgo, V. (1999). Impact of introduced carp (*Cyprinus carpio*) in subtropical shallow ponds in Central Mexico. *Journal of Aquatic Ecosystem Stress and Recovery*, 6, 281-288.

Ponds within the wider context of environmental management

Mervyn Bramley

Environment Agency, Rivers House, Waterside Park, Aztec west, Almondsbury
Bristol BS12 4UD.

Introduction

This paper considers the scientific basis for looking at the pond environment and for managing ponds within the broader context of environmental management. The paper then goes on to describe the Environment Agency's views on the key environmental management issues that it is facing, and its vision for the future environment of England and Wales. The paper aims to give some indication as to how ponds fit into this.

Management of ponds

Do we all see ponds from the same viewpoint? Probably not. Most of us would agree that they generally form an important landscape feature, and have a distinct ecosystem. However to others, their societal role is important and they have a historical perspective, they may form the focus for a local community, and can provide an important resource for education or recreation. And for some, they provide a water resource for their livelihood.

So we see different functions of ponds from different viewpoints. However, if we are to have a rational understanding of ponds and their management, we must first have a scientific understanding of the state of the pond environment and this provides the starting point for effective pond management. For ponds, as for other parts of the environment, management requires the logical consideration of a series of issues. In the Environment Agency, these issues are referred to as a "Management Cycle" and it is a cycle as one ends up reconsidering the state-of-the-environment in the light of the success the management measures.

A management cycle for ponds is given below:

- Understand the state of the pond environment - hydrology, ecology etc.
- Consider within any relevant wider environmental issues and e.g. groundwater regime
- Identify the different pressures on the pond environment e.g. over-fishing
- Consider the different options for dealing with the pressures, and the related benefits
- Remember that implementing management action involves people and have the ìpeopleî issues really been addressed?
- Take management action
- Monitor the state of the pond environment to see how it is responding

It is important to take a scientific approach to understanding the underlying processes otherwise it is difficult to predict the effect of management action. And it is necessary to have a rational vision of what type of environment one wants.

The Environment Agency approach to environmental management

What has been described for ponds applies in many respects to what the Environment Agency is seeking to do with environment as a whole, although, of course, the latter is far more complex.

The Environment Agency was formed in 1996 when the various environmental management tasks of the National Rivers Authority, Her Majesty's Inspectorate of

Pollution, the Waste Regulation Authorities, and parts of the former Department of the Environment were drawn together. The Agency has an overall duty to deliver integrated environmental management: in other words, to ensure that all these disparate duties and powers add up to a consistent whole.

The Agency also has other overarching duties: to enhance biodiversity, to have regard to the costs and benefits of its actions, and to contribute to achieving Sustainable Development. These are no small duties and the Agency has therefore developed an Environmental Strategy[6] to focus on achieving this better environment for the nation and its future generations.

So how have we gone about this? The Agency's Strategy is based on (a) forming an opinion on the state of the environment, (b) assessing the pressures, (c) considering the options for response where the Agency can make a positive contribution, and (d) taking action in response. We seek to promote this rational environmental management cycle within the principles of Sustainable Development which have been drawn together. In particular, the Agency aims to work with others, to establish a vision of the environment which we all want, and to then achieve clear environmental outcomes at different levels and local, regional and national. We shall be publishing these for consultation later in 1999 and look forward to a response from Pond Action to help to set down a shared vision for ponds.

Our joint "2020 Vision"

The Agency has a "2020 vision" which is "joint" because we regard all of the organisations and indivduals involved in pond conservation as our partners in the management of ponds.

What are the key pressures on ponds which we might need to manage? Looking at six the viewpoints which the Agency uses it is posible to suggest the following:

- natural forces - stresses on the ecosystem and its use due to climate change;
- societal influences and stresses due to transport and the built environment;
- abstractions and/or removals from the environment and excessive water use by man;
- discharges and/or releases to the environment and poor use of fertilisers and herbicides;
- waste disposals - groundwater pollution;
- unauthorised actions by man and accidental release of contaminants, and illegal dumping of pollutants.

These are all complex pressures. The Agency sees the work of the many organisation involved in pond conservation, and particularly that of Pond Action, as essential to achieving appropriate local actions based on a sound scientific understanding. We look to the enthusiasm and support of everyone involved in pond conservation in continuing to monitor the state of the pond environment, in influencing and taking action, and in ensuring that a rational vision for the pond environment is both set and achieved.

A new predictive technique for assessing the ecological quality of ponds: the PSYM method

J. Biggs, P.J. Williams, M. Whitfield, G. Fox and P. Nicolet

[6]The Environment Agency's Environmental Strategy will be published for consultation early Spring 2000. Further information on the Environment Agency is available on its website at http://www.environment-agency.gov.uk.

Pond Action, c/o Oxford Brookes University, Gipsy Lane, Headington, Oxford, OX3 0BP.

Introduction

Historically, environmental organisations in the United Kingdom have undertaken relatively little monitoring of permanent and temporary ponds. In part this has reflected the fact that, until recently, small water bodies were not generally regarded as being of sufficient importance to warrant regular monitoring. But almost as important an obstacle to the implementation of pond monitoring programmes has been the absence of standardised assessment methodologies.

The absence of a standard pond monitoring methodology has led Pond Action and the Environment Agency to develop a new standard technique for monitoring ponds, the PSYM method. PSYM, the Predictive SYstem for Multimetrics (pronounced 'sim'), has been developed by Pond Action and the Environment Agency to provide a method for assessing the biological quality of all still waters (temporary and permanent ponds, lakes, ditch systems, canals). To date, the method has been most fully developed for ponds and small lakes (up to 5 ha) and canals. This paper describes the development of Pond PSYM but does not consider Canal PSYM.

The PSYM method uses a number of aquatic plant and invertebrate measures (metrics), which are combined together to give a single value which represents the waterbody's overall quality status.

Using the method involves the following steps:

1. Simple environmental data are gathered for each waterbody from map or field evidence (area, grid reference, geology etc.).
2. Biological surveys of the plant and animal communities are undertaken and net samples are processed.
3. The biological and environmental data are entered into the PSYM computer programme which:
   (i) uses the environmental data to predict which plants and animals should be present in the waterbody if it is undegraded,
   (ii) takes the real plant and animal lists and calculates a number of metrics[7].

Finally, the programme compares the predicted plant and animal metrics with the real survey metrics to see how similar they are (i.e. how near the waterbody currently is to its ideal/undegraded state).

The metric scores are then combined to provide a single value which summarises the overall ecological quality of the waterbody.

This paper summarise the current development of PSYM as it relates to ponds, including both the results of the Phase 1 Scoping Study where the underlying rationale for the method was developed, and the Phase 2 method evaluation and testing where the first practical trials of the assessment method were undertaken. Detailed information about the project is available in three reports (Biggs et al. 2000)

Development of the rationale

The first step in developing the method was to look at what would be required from a monitoring method. To do this we reviewed strategy documents, looked at EU legislation, and talked to regional Environment Agency staff. The results indicated that the method needed:

- to be applicable to all types of still waters (lakes, ponds, temporary pools, canals, ditches, and brackish waters), giving a uniform approach to assessment,

[7] Metrics are biological measures of environmental degradation.

- to be able to describe the overall quality of a waterbody to establish its degree of degradation,
- where possible, the method should also allow the cause(s) of degradation to be diagnosed.

Overall assessment vs diagnosis

In trying to identify the features of a method that could both establish the quality of an ecosystem as a whole and diagnose the causes of any degradation it became clear that it is more-or-less impossible to design a single biotic method that can achieve both at the same time. This is because monitoring and diagnosis require very different biological approaches.

For assessing total waterbody quality, the need is for a method that will represent and summarise the overall state of the waterbody, integrating the effect of all the possible stresses into a single measure. In contrast, diagnostic methods aim to single out causes rather than integrate - so ideal techniques are more likely to be based on a small range of indicator species or attributes which have a strong and discriminatory relationship with a particular stress. Because of the wide range of potential impacts and the required specificity of indicators, it follows that it is not possible to get a diagnosic indicator that will be applicable in all situations.

Trying to combine general ecosystem assessment and diagnosis into a single method is likely to compromise the effectiveness of both. So, where both general ecosystem assessment and diagnosis is required at a site, a rational approach is to consider these different processes as part of a two-stage protocol:

- Stage 1. General ecosystem assessment, which evaluates the net effect of all forms of degradation,
- Stage 2. Diagnosis, a more detailed follow-up investigation, used where damage is evident, and employing one or more of an array of complementary techniques that can be flexibly tailored to help diagnose the source(s) of degradation.

In the current project the main aim has been to develop a methodology which will achieve the first of these stages. The remainder of the Scoping Study focused on this area.

Unconstained and constrained ideals

Although, ultimately, any general quality assessment method needs to be cost effective, a useful starting approach to identify what is needed in an assessment method is to identify the 'unconstrained ideal' - the perfect assessment method, and then to cut down from this ideal to what is practically feasible.

If the aim is to look fully at a waterbody and identify how damaged it is, what would we have to look at? In practice the list is huge and includes all the factors which make up 'ecological integrity'. In other words: (i) all of the elements of biodiversity i.e the organisms that make up the system, their genes and populations (ii) the attributes which are used to measure biodiversity, such as species richness and biomass and (iii) all the processes that is going on in a system - from growth and reproduction to metapopulation dynamics.

By anybody's standards, a full assessment of the biological integrity of any freshwater ecosystem is, of course, logistically impossible within a practical monitoring method. What is needed is a more restricted set of variables that still represent the overall integrity of the system. So how do we cut down?

Fortunately it is generally agreed, even by those with a special interest in promoting biological integrity assessment, that the process components of biological integrity, such as growth, competition and population dynamics, are highly complex and time-consuming to measure, so that it is rarely practicable to include them in monitoring programmes.

That leaves us with the two main biotic descriptors:

- the elements: the organisms themselves, and
- the attributes - how we describe those organisms (whether in terms of species richness, biomass, trophic structure or other measures).

Taking the organisms first, it is clear that there are a number of features that will make organisms useful for assessing ecosystem integrity. In particular they:

- should be sensitive to a wide variety of impacts,
- should integrate impacts across trophic levels,
- should integrate impacts both spatially and temporally,
- should be well-known taxonomically, so they are relatively easy to identify.

In addition it is beneficial if groups of organisms which are rich in species can be monitored so that simply working with that group encompasses a relatively large proportion of the total biodiversity of the system.

It is clear from this list that there is no single organisms that can achieve all these aims. So for general quality assessment purposes it is likely to be necessary to use major assemblages, such as fish or diatoms for biotic monitoring.

Choosing which assemblage to use is not, however, straightforward because of the wide range of variables which need to be taken into account. It is not only a question of how well the assemblage will assess water body quality but also how cost-effective it would be to survey it, and how practical the method might be, (for example, could surveys be undertaken all year round?).

To take these variables into account, we undertook matrix analyses in order to rank the potential for each assemblage type to be useful for water quality monitoring.

The results of the matrix analysis (see Williams *et al*. 1996 for details) showed that no one assemblage is able to fully represent all the main aspects of biological integrity and integrate all potential stresses. However, with two assemblages it is possible to cover most major stresses likely to affect waterbody quality, especially if a plant and an animal assemblage are combined, since together these span a complimentary range of trophic levels, habitat niches and pollutant sensitivities.

For ponds the most effective plant assemblages were either aquatic macrophytes or diatoms. The most effective animal assemblage was macroinvertebrates.

Reducing the number of attributes used

The best way to slim down the number of attributes used to assess the quality of the system is to identify those which show a clear relationship with ecosystem degradation and which can, therefore, discriminate between sites of differing water quality. Looking at degraded systems world-wide, it is clear that a number of attributes that are consistently identified as characteristic of degraded systems (see Table 1).

Table 1 Attributes associated with ecosystem degradation

- Number of native species declines.
- Number of nationally uncommon or rare species declines.
- Percentage of exotic or introduced species or stocks increases.
- Number of generally intolerant or sensitive species declines, whilst the percentage of the assemblage comprising generally tolerant or insensitive species increases.
- Percentage of trophic and habitat specialists declines, whilst generalists increase.
- Food-chain length decreases.

- Incidence of disease and anomalies increases.
- Percentage of large, mature or old-growth individuals declines.
- Reproduction of generally sensitive species decreases.
- Number of size- and age-classes declines.
- Stability decreases, i.e. spatial or temporal fluctuations are more pronounced.

What is noticeable in this table is that many of these attributes can be generated from simple species lists. This means that they could be generated relatively cost effectively simply using the ‘go-out and collect things’ method which forms the basis of most monitoring programmes. Such lists can, however, only provide a selection of *candidate* measures. What is not known, is which of these attributes will be the most effective measures of degradation in any particular habitat or area. The way to find out is to use real data to identify which measures are strongly correlated with environmental degradation.

Choosing a baseline

A further issue which needs to be resolved in developing a still water monitoring method is what to use as a baseline against which to compare sites. It is now widely accepted by most ecologists, and by an increasing number of regulatory authorities (e.g. the EU and US EPA), that wherever possible physico-chemical and biological conditions in all waterbodies should be judged against sites which are the least affected by human impacts.

Having looked at baseline methods in some detail it is clear that present day reference sites are the only consistently practical choice for biological baselines because only from present day sites is it possible to get sufficiently detailed biological data about most biotic groups.

Interim summary

The rationale for the development of a general quality assessment method worked through from first principles is summarised below.

1. The essential requirement of a GQA method in any waterbody is that it should represent and summarise the existing biological integrity of that water body.
2. It is not possible to assess all aspects of biological integrity (measured using taxa and attributes) so the number of taxa and attributes described needs to be reduced.
3. The range of taxa selected for monitoring is reduced by matrix analysis.
4. The range of attributes used to describe these taxa is reduced by selecting only those (from a candidate list) which show a statistically demonstrable relationship with environmental degradation.
5. Baselines are established against which the quality of other sites can be compared.

Review of existing methodologies

The second stage of the Phase 1 scoping study was to look at existing methods, including both European and North American methodologies. What was immediately apparent from this review was that the method had been rationalised from first principles (described above) had essentially been in practical use in the US for the last 10 years, where it was known as multi-metric assessment.

The term ‘metric’ was coined by Jim Karr to describe measures which vary predictably with degradation. In the early 1980’s he used this concept as part of a ‘multimetric integrity index’ which combined the use of many metrics, and therefore the effect of many stresses, as part of a single assessment (Karr 1995). To create the index, each metric is assessed according to how much it differs from the minimally impaired baseline condition, and then given a ‘rating’ category (essentially a 1 to 4 scale from poor to good), so that attributes which are originally on a different scale (e.g. species richness and biomass) are converted to the same scale. The individual metrics are then simply added together to give a single score which represents the integrity of the community as a whole.

The Americans often point out that multimetric indices have a number of benefits:

- They are flexible: any environmental feature can be included in an index, provided that it is relevant and there is a technique available for establishing the baseline condition.
- New metrics can be added at any stage without undermining the entire concept.

There are, however, two main problems with this multimetric approach as used in the US:

- In the past metrics were often guessed at and it was often just assumed that, for example, diversity indices were correlated with degradation, rather than actually proving this.
- Although sites were always compared with unimpaired baselines, the baseline classifications were, until very recently, based on expert opinion, rather then statistically analysis of plant or animal assemblage composition.

The US focus on establishing degradation gradients with little attention paid to the classification methods has been almost the direct opposite of the UK approach. In Britain, the development of RIVPACS by IFE and the Environment Agency focuses on classification (Wright 1995) but has the disadvantage that analysis of degradation gradients have been more limited, typically focusing, in any water body type, on a single factor, like dissolved oxygen in rivers or nutrient status in lakes.

Put like this, it becomes obvious that by combining the UK's predictive approach to classification and US's multimetric approach to assessing degradation there is the potential to get the best of both worlds. This gives us a method which in practice would look like RIVPACS with more metrics and, therefore, has a greater potential to integrate environmental stresses.

Method development required for each waterbody type

The overall method development required for a General Quality Assessment method for ponds (or other still water bodies) can be summarised as follows:

- Establish a classification of biotic community data from minimally impacted sites using multivariate methods. This provides:

  (i) the basis for the statistical prediction of taxa using physico-chemical data to develop predictive models which in turn allow us to

  (ii) predict the fauna and flora of impaired sites.

  Essentially these are the two main steps in RIVPACS.

- Identify a wide range of possible metrics which may relate to degradation (e.g. taxon richness, biomass, proportion of trophic specialists).
- Confirm which of these trial metrics actually correlate with chosen degradation factors (i.e. which ones show clear correlations with gradients of physical or chemical degradation).
- Establish the extent of deviation of metrics from the baseline condition, and then normalise them on a 1-4 scale.
- Individual metrics are then added up to give a single score.

This is the method called PSYM - the Predictive System for Multimetrics.

Project Phase 2: Developing the method

Phase 2 of the project has been used to undertake a regional trial of the method using two waterbody types - ponds and canals. And using these waterbodies, the method has been worked right through from predictions to metric development in order to get the system to the stage where it can be applied in the field for testing and evaluation by Environment Agency staff.

So for the ponds two of the preferred assemblages were tested (macrophytes and macroinvertebrates), working with a regional data set. The region used ran from Kent to mid-Wales to encompass a wide range of geographical variation, and was based on a dataset of 140 ponds: 70 minimally impacted and 70 impaired. At each pond the plant species present were recorded, and invertebrates sampled using a three minute hand-net sampling method similar to that used for river invertebrate monitoring. A wide range of environmental data were also collected describing the physical characteristics of the pond and its surrounds.

How were the plant and invertebrate metrics chosen?

Metrics were chosen by correlating known degradation gradients (nutrient levels, heavy metal levels, presence of road runoff etc.) with a wide list of possible test metrics e.g. number of Ephemeroptera, Plecoptera, Trichoptera families, family richness, number of exotic species. The 'test' list was then narrowed-down to a list of viable metrics by looking at the significance of relationships between each potential metric and anthropogenic degradation gradients.

For invertebrate, metrics were chosen, where possible, at the highest taxonomic level i.e. family or order level rather than species-level. In practice, there were generally at least equally strong correlations between family-level macroinvertebrate metrics and degradation as there were between species-level metrics and degradation. This enables family-level macroinvertebrate data to be used for quality assessments as opposed to more time-consuming (and technically demanding) species level information.

The final choice of measures includes metrics which have been shown to respond to a wide range of degradation gradients. It is, however, also valuable to (i) include metrics which have some diagnostic potential (ii) include a small number of metrics which reinforce each other, giving confidence to the user that the degradation assessment is correct.

Analyses have shown that the most effective metrics for assessing environmental degradation in ponds are:

Invertebrates

- Average score per taxon
- Number of dragonfly and alderfly families
- Number of beetle families

Plants:

- Number of submerged and marginal plant species
- Trophic ranking score for aquatic and marginal plants
- Number of uncommon plant species

Which physical and chemical variables are used in the predictions?

In ponds the main predictors of unimpaired community type fall into eight major variable categories (Table 2). Of these, three are relatively invariant (e.g. location, base geology, isolation) which need only be assessed once. The remaining five categories of variable require on-site field measurement when each assessment is made. These are water depth, pH, shade, grazing and landuse.

Table 2 Environmental variables used to predict unimpaired pond community types

	Predictive variables	
	(a) Invertebrate assemblages	***(b) Plant assemblages***
Categories		
Location	Easting, northing, altitude	Easting, northing
Size	Pond area	-
Water chemistry	pH	pH
Inflows	Presence of an inflow (Yes/No)	-
Shade	Pond area shaded (%)	Pond area shaded (%)
Pond base geology	Proportion of:	Proportion of:
	• Clay	• Clay
	• Sand/gravel/pebbles	• Sand/gravel/pebbles
	• Rock	• Rock
	• Peat	• Peat
Vegetation	Margin grazed by livestock (%)	-
	Emergent plant cover (%)	-

How are metrics scored?

Each individual metric is calculated for the specific waterbody of interest and compared to the computer predicted score for that metric. The relationship between observed and expected is presented as a percentage of similarity, and then transformed to a 4 point scale e.g. 0, 1, 2, 3 where 0 represents poor quality and 3 represents good quality (i.e. no deviation from expected). All metric scores are then summed to give an overall quality index, which is presented as a percentage of the maximum score and, potentially, forms the basis of GQA categorisation of a site.

Diagnosis

The main objective of the PSYM method is to assess the overall condition of freshwater ecosystems. The system does not, in itself, attempt to diagnose the cause, or causes, of degradation. Indeed it is considered inappropriate for a general quality assessment method to be biased towards the evaluation of a single impact. However, there is considerable potential for data which are collected using the scheme to be re-interpreted to diagnose the causes of degradation. This may be achieved both by inspection of individual metrics which make up the total integrity score or by re-analysis of the raw data to give pollution indices, such as trophic scores or acidification indices.

Conclusions

More detailed information on the testing of PSYM, and its application, is given in Williams *et al.* (1998) and Biggs *et al.* (2000). Further refinement of the method is likely to focus on extension of the baseline datasets to improve the accuracy of prediction.

Training in the use of PSYM methods was provided for Environment Agency staff in 1999 and it is anticipated that PSYM software will be made available freely over the Internet in due course.

Acknowledgements

This work was undertaken as part of an Environment Agency research and development project. The Project Leader was Shelley Howard (Environment Agency). We would like to thank the members of the Project Board (Elaine Fisher, Dave Jowett, Julia Stansfield, Roger Sweeting, Graham Newman and Kath Ferguson) for their help and advice with the project. Collection of the minimally impaired pond dataset was funded by WWF-UK and Pond Action. The impaired dataset collection was funded by the Natural Environment Research Council (ROPA Grant GR3/R9533). We thank Professor David Beadle of Oxford Brookes University for his support of the work of Pond Action.

References

Biggs, J., Williams, P., Whitfield, M., Fox, G. and Nicolet, P. (2000). *Biological techniques of still water quality assessment 3: method development*. Environment Agency R&D Technical Report E110. Environment Agency, Bristol.

Karr, J. R. (1995). Protecting Aquatic Ecosystems: Clean Water is Not Enough. In: *Biological Assessment and Criteria* (Eds: Davis, T, P. and Simon S., W.). Lewis Publishers, Boca Raton, FL.

Williams, P., Biggs, J., Dodds, L., Whitfield, M., Corfield, A. and Fox, G. (1996). *Biological techniques of still water quality assessment: phase 1 Scoping Study*. Environment Agency R&D Technical Report E7. Environment Agency, Bristol.

Williams, P., Biggs, J., Whitfield, M., Corfield, A., Fox, G. and Adare, K. (1998). *Biological techniques of still water quality assessment 2: method development*. Environment Agency R&D Technical Report E56. Environment Agency, Bristol.

Wright J.F. (1995). Development and use of a system for predicting the macroinvertebrate fauna in flowing waters. *Australian Journal of Ecology*, 20, 181-197.

Design and construction of new ponds: principles and practices

P.J. Williams, J. Biggs, M. Whitfield, G. Fox and P. Nicolet

Pond Action, c/o Oxford Brookes University, Gipsy Lane, Headington, Oxford, OX3 0BP.

1. Introduction

The aim of this paper is to identify factors which appear to be particularly important in creating high quality new ponds for wildlife. The paper is divided into two main sections. The first section covers principles of pond creation and the second describes a case study, Pinkhill Meadow in Oxfordshire, where the main principles were applied to produce very successful results.

2. Why create new ponds?

There are both practical and ecological reasons why pond creation is such a worthwhile undertaking. Firstly, there is a strong ecological precedent for creating new ponds. Ponds are unusual as freshwater systems in that individual waterbodies are often relatively short lived, but in natural areas, ponds are continually sustained by a range of natural pond creation processes (See Williams et al., this volume). New man-made ponds therefore mimic the age-old processes of natural pond formation.

Many freshwater plant and animals are particularly well adapted to colonising new sites, so new ponds colonise up quickly with species. Studies show, for example, that within 3 or 4 years new ponds are usually at least as rich as mature sites. In addition, a range of both animal and plant species particularly thrive in the bare conditions provided by new ponds. Creating new waterbodies provides a habitat for these species, helping to maintain their populations in the countryside. This includes some of the uncommon stoneworts (charophytes) and many invertebrates including libellulid dragonflies such as the blacktailed-skimmer (*Orthetrum cancellatum*).

There are also considerable practical advantages for creating ponds. New ponds can be specifically located and designed so that they have high water quality throughout their life-times. This minimises problems of pollution, particularly eutrophication, makes pond much easier to manage and creates sites that are better for wildlife than most existing new ponds in the countryside, exposed as they often are to polluted water supplies.

3. The three most important factors for creating new ponds

Ecological information suggests that three factors have a critical influence on pond biodiversity:

- good quality water,
- a wetland location, or good (indirect) links to other wetlands,
- and a varied mosaic design.

In general, a new pond which combines any two of these factors will develop a valuable wildlife community. With all three, the pond community is likely to be outstanding.

3.1 Ensuring good water quality

Of the three factors listed above, locating ponds so that their water sources are as clean as possible is the most critical. This is because water quality not only influences pond conservation value but ultimately also the need for management. With good water quality it is possible to dig a square, vertically sided, hole in the ground, and the pond will eventually develop a high quality wildlife community. If a pond is polluted, however, it is unlikely to ever achieve its full wildlife potential. Badly polluted ponds inevitably give long-term management problems.

Ponds are accumulative systems, and materials which get into the pond basin will build-up as the pond ages. If non-degradable pollutants enter the pond (e.g. phosphates, heavy metals, some of the persistent biocides) the concentrations of these substances builds-up, giving progressively deteriorating water quality, fewer species and the beginnings of more-or-less intractable problems like nuisance levels of algae, or water fern or duckweed. Such problems, which are usually impossible to sort out without major dredging of the polluted sediments, will contiune to prevail as long as pollutants continue to enter the pond.

It follows from this that the best design feature to give any new pond is a location where its water quality will be protected in the long term. A few key points, about maintaining water quality are given below.

3.2 Water sources

Generally, most ponds are fed by one or more of three water sources (in addition to rainwater). These are: surfacewater, groundwater and a stream or ditch inflow.

3.2.1 Surfacewater

If a pond is mainly fed by surfacewater, i.e. water that runs off from the pond surrounds, the most critical factor is to ensure that the pond has a good buffer zone. This is simply because what ever is applied to land around the pond, will gradually make its way into the pond with drainage water or sediment and affect pond quality. It is sensible, therefore, to surfacewater fed ponds in the most semi-natural location available in, or adjacent to, extensive areas of semi-natural vegetation such as woodland, rough grassland or scrub and heath. Of course, the pond should not replace a habitat that is already high quality, such as a spring, wet meadow or a high quality terrestrial habitat.

In more intensively managed areas, such as arable farmland or urban areas, the aim should be to try and maximise the buffer zone in the pond's catchment, particularly areas that are uphill of the pond, so that the water that drains in through the soil and vegetation is filtered to remove as many pollutants as possible. Research into the effectiveness of buffer zones suggests that there is no optimal size for the area of non-intensive land around a pond. Clearly, however, any buffer will be better than none, and protecting all of the pond's catchment is the best option of all.

3.2.2 Groundwater

Groundwater is often not so difficult to manage as other water sources and there are many occasions where very high quality groundwater-fed ponds occur in the middle of arable fields. This is partly because groundwater is at least partly filtered through the ground, so it tends to carry lower burdens of silt-borne pollutants like phosphates and metals. In addition, groundwater is constantly moving, so some of the soluble pollutants that do get into the pond (such as nitrates), will move out of the pond with groundwater, rather than accumulating.

Even with groundwater ponds, however, it is worthwhile establishing a buffer zone of some sort around the pond. This is partly because buffer zones provide a good habitat in their own right, but also because as these ponds fill up with fine sediment, groundwater ponds gradually become sealed off from groundwater by the silts accumulating at their base. Increasingly, therefore, they come to reflect the quality of their surfacewater catchment.

3.2.3 Streams and ditches

The third major water sources for ponds should be treated with caution. Streams and ditches often have large catchments, so in most areas of the country where land use is intensive, they will be bringing sediment-borne and water-borne pollutants into the pond. This is backed-up by Pond Action data for rural Oxfordshire, which shows that ponds with inflows had significantly higher pollutant levels and fewer uncommon animals than ponds with no inflow (Pond Action, 1994).

Similarly, in urban areas, road runoff is highly polluting, burdened with oils and heavy metals (particularly lead, zinc and copper), and often with organic loads similar to untreated sewage.

3.2.4 Conclusions

In summary then, in semi-natural areas, particularly in the lowlands where acidification is not such an issue, any water source is likely to be relatively good quality. This includes even stream water, as long as the whole of the stream's catchment is protected.

In intensive rural or urban areas, we would recommend:

(i) avoiding stream or ditch inflows if at all possible. This includes temporary ditches which only run in winter, together with agricultural and urban drainage pipes.

(ii) with surface water ponds (i.e. ponds dug into clay or artificially lined), aim to maximise the buffer zone in the pond's drainage catchment.

(iii) groundwater ponds are often relatively high quality. Since these ponds are fed from below, the surface catchment area can be minimised so as to reduce the amount of polluted runoff from the surrounds.

3.3 Linking ponds and other wetlands

The second factor which helps rich wildlife communities to develop is a wetland location. Data consistently show that ponds located near to other wetlands are more biodiverse than more isolated sites. Thus, both Pond Action's data and the DETR study both show that ponds have significantly better wildlife communities (richer communities and/or more uncommon species), where they are located near to traditionally wet areas such as river valleys, wet meadows, fens or areas of high pond density (Williams *et al*., 1998).

The adjacent wetlands do not need to be still waterbodies: many freshwater plants and animals are 'generalists' in the sense that they can use more than one waterbody type, so the margins of a new pond might easily be colonised by species from the edges of rivers or fens.

Neither do the new ponds need to be directly connected to these other wetlands. Indeed, as noted above, where their water quality is suspect it is preferable for them not to be. Obviously it is also important that the new pond does not replace an existing wetland so, for example, it is better to dig a pond near to a spring head or a flush, than directly into it.

When ponds are created near to other waterbodies, then, there are likely to be multiple benefits. For the new pond the benefit will be an increased potential for the new site to develop richer plant and animal communities. From a wider perspective however, the pond will also be (i) adding to the number of local refuges for freshwater plants and animals (ii) increasing the general connectedness of the wet landscape and therefore increasing the genetic pool and the general health of freshwater populations in the area

3.4 Design features for wildlife ponds

The final feature that can be used to considerably increase the quality of any new pond is a good design.

3.4.1 Creating pond mosaics

Many new ponds today are dug as single isolated basins. But, if a new pond is to be created from scratch, there is considerable potential to do much more. Evidence from many studies shows that pond depth and permanence are major influences on pond community type. Varying these factors at a site to create habitat mosaics with a mixture of permanent, semi-permanent and seasonal pools, therefore makes it possible to create habitats which support a much greater diversity of wildlife than can be encompassed in a single waterbody.

In practice, creating these sorts of complexes is usually possible in all but the smallest pond creation schemes.

3.4.2 Shallow water, microtopography and the drawdown zone

A second feature that can significantly improve design is to create extensive varied drawdown zones. In most natural ponds water levels rise and fall fairly predictably during the year, usually by half a metre or more. This drawdown zone - the area between upper winter water levels and lower summer water levels - is a particularly valuable area for wildlife. Not only is it the richest area for marginal plant species, but when wet, it is a particularly diverse area for aquatic invertebrate species. Even when it is dry, the drawdown zone is used by semi-terrestrial invertebrates and aquatic invertebrates. Some dragonflies and caddis-fly, for example, use the damp ground of the drawdown zone as an egg laying site.

Unfortunately, the drawdown zone is often ignored during the design process for new ponds, and is usually restricted to a narrow strip at the pond edge. Including drawdown areas by creating very low slopes at the waters edge, gives a much better pond profile and ultimately a much richer edge.

Drawdown zones do not need to slope evenly down into deeper water. Anyone who has walked over a wet meadow knows that centimetre-scale height differences in the ground surface, and in waterlogging, produce major differences in plant community type. In pond construction there is considerable opportunity to recreate this small scale topographic variation, by careful physical shaping of the drawdown zone. Thus, by extending the drawdown zone to include a patchwork of hummocks and pools with differing water regimes it is possible to create a diverse mosaic structure which will encourage very rich plant and invertebrate communities to develop.

3.5 Implementation

The way in which a pond creation scheme is implemented will make a considerable difference to its ultimate value. In particular, wherever possible, there are considerable benefits from leaving a little funding for a second stage. It is always difficult to predict exactly the water levels and water level fluctuations in a new pond. So wherever possible it is useful to undertake pond creation in a number of stages. Ideally these are:

1. Auger or dig a number of trial holes to look at the geology. Leave these holes open and gather information about water sources and levels.

2. Remove the bulk of the overburden and roughly shape the site. Then leave it, preferably for at least a year, and during this time (i) look at which bits of the site colonise-up well and (ii) how the water levels vary.

3. Finally, create the more subtle shaping around the pond including the low undulating margins and tiny pools.

An advantage of having a final shaping phase is that it is much easier to create the subtle areas around a pond if it has been left to fill up with water. This is because the pond should be fully filled with water by the second year, making it quick and efficient to work back from the water’s edge, taking the water back too, and seeing the shaping effects immediatly.

If it is necessary to avoid two phases of soil disposal when using this staged approach, the pond can be slightly over excavated in the initial excavation. The spoil from the final edge modifications can then be dumped into deeper water areas of the pond (perhaps creating new islands or other shallows). This avoids the need for anything more than an excavator on site for 2-4 hours for the final critical shaping.

4. Pinkhill Meadows case study

4.1 Creating Pinkhill

The Pinkhill Meadow pond creation scheme at Farmoor Reservoir provides a case study of a new pond scheme which happens to combine all three of the important attributes in pond creation - good water quality, a wetland location and a varied mosaic design. Just as significantly the Environment Agency funded ecological monitoring of the water bodies to investigate the colonisation and conservation value of the new ponds (Pond Action, 1998).

Pinkhill Meadow is a relatively small site, about 5 ha in area. In 1990 the meadow was a grassy field on land owned by Thames Water Utilities bordering Farmoor Reservoir in Oxfordshire. The site has an excellent wetland location. The River Thames meanders around two sides of the meadow with a backwater and wet woodland beyond. In addition, Farmoor Reservoir, which lies to the east, is one of the biggest areas of open water in Oxfordshire. The site is, therefore, largely surrounded by wetlands.

In addition, water quality at the site was good. Before the project had begun, Thames Water had taken a grid of 10 soil cores from the meadow. These showed that the near surface geology of the meadow comprised a top layer of clayey alluvium of varying thickness, with water-bearing gravels below.

The geology of the meadow provided two different water sources water sources for site, both of which were of good quality. Digging into only the clays created surfacewater-fed ponds. Since the meadows surrounding the ponds were relatively unimproved, the quality of this surface run-off water was high. Similarly, digging through the clays into the gravels created groundwater-fed ponds, supplied by the natural aquifer, which was also relatively unpolluted.

The designs for the site aimed to maximise use of both water depth and the natural hydrological variation on the site. It included a mosaic of approximately 40 ponds and pools of varying size and permanence. These ranged from the largest waterbody on the site, the Main Pond, which has a diameter of approximately 60 m and a maximum depth of to 2.5 m, to a whole series of smaller ponds many of which are seasonal and stay wet for less than 6 months of the year.

Knowing the water regime, it was possible to create tiny shallow pools which are permanent because they area linked to groundwater which, at Pinkhill, fluctuates relatively little during the year. Similarly, it was possible to create large semi-permanent clay-based ponds with water levels that drop by up to 1 m, giving ponds which dry-up in drought years.

In addition to creating physical differences between the pools, the design aimed to introduce variation within individual ponds, particularly in their marginal zones.

To create the site as a whole, spoil was removed across the whole of the construction area to approximately the level at which water would stand in winter. Then pools and ponds were created within this. On the largest ponds the marginal slopes were flattened-out to give very broad low-angled drawdown zones. And this low topography was undulated to create complex mosaics of hummocks and pools near to the water's edge.

The ponds at Pinkhill were dug out by contractors in 1990 and 1991 and the site was left to colonise-up completely naturally. So, apart from *Phragmites australis* (Common Reed) which was planted partly as a screen, no plants or animals were deliberately introduced to the site.

4.2 Results

The monitoring results from the site show that the creation scheme has been very successful.

In terms of breeding birds, Pinkhill has regularly had breeding Lapwing, Tufted Duck and Reed Warbler and range of other common water birds. More significantly, by putting in specific features like gravel islands, the site attracted breeding Little Ringed Plover. /Common Tern and Redshank have also used gravel-topped islands to nest.

The colonisation of plants and aquatic invertebrates was rapid and within three years the site was already exceptionally rich.

At its last monitoring, six years after its creation, the complex as a whole supported approximately 70 species of wetland plants. This means that over 20% of all Britain's freshwater flora colonised the site naturally in just six years.

Similarly, about 140 of the larger invertebrates have been recorded at the site, again almost 20% of the British freshwater fauna in the groups identified. This included breeding records for 12 species of dragonfly, including one of the only still-water breeding records for the uncommon riverine Club-tailed Dragonfly (*Gomphus vulgatissimus*).

The overall totals for the site as a whole are matched by the numbers recorded from individual pools on Pinkhill, which are also unusually rich. Many ponds support over 50 wetland plant species, and for invertebrates, using a standard 3 minute hand net sample, totals of 50 - 60 invertebrate species are common. Such totals are as rich as any of the other ponds that Pond Action have surveyed in Oxfordshire. They are also rich at a national level. Compared to ponds in the National Pond Survey, which is a survey of the highest quality ponds across Britain (mostly located in nature reserves), then many of the ponds at Pinkhill lie within the top 10% of our richest ponds, in terms of the number of plant and animal species they support.

4.3 Conclusions

The main implications from the Pinkhill Sheme is that it is clearly possible to create very high value new pond sites even on quite small areas of land.

The DETR survey, (see Biggs *et al*., this volume) showed that there is currently a very high turnover of ponds in Britain, with about about 1% of all lowland ponds both created and destroyed and each year. The extent of pond creation provides a considerable opportunity. If all of those new ponds could be (i) carefully designed and located - put into corners of the countryside where it is convenient to keep then clean and unpolluted, and (ii) designed as mosaics to be structurally varied, there would be a real potential to increase freshwater biodiversity in the countryside.

References

Pond Action (1994). *The Oxfordshire Pond Survey. 2 vols. A report for the World Wide Fund for Nature (WWF-UK)*. Pond Action, Oxford.

Pond Action (1998). *Experimental management of wetland habitats at Pinkhill Meadow. Phase II (1995-1997).* Pond Action, Oxford.

Williams P J, Biggs J, Barr C J, Cummins C P, Gillespie M K, Rich T C G, Baker A, Baker J, Beesley J, Corfield A, Dobson D, Culling A S, Fox G, Howard D C, Luursema K, Rich M, Samson D, Scott W A, White R and M Whitfield (1998), *Lowland Pond Survey 1996*. Department of the Environment, Transport and the Regions (DETR), London.

Delegate List

Name	Organisation	Position
Angell, Alison	BTCV	Community Development Officer
Armitage, Charlotte	FRCA	
Averill, Mike	Environment Agency	Team Leader (Hydrometry)
Bailey, Christine	BBONT	Species & Habitats Officer
Bains, Claire	FRCA	Assistant ESA Project Officer
Bentley, Dave		Pond Consultant
Biggs, Jeremy	Pond Action	Manager
Blackham, Bob	Moseley Bog LNR Conservation Group	Member of Mosley Bog Management Committee
Bradshaw, Katherine	SEPA	Project Manager SEPA Habitat Enhancement Initiative
Bramley, Mervyn	Environment Agency	Head of Research & Development
Bray, Robert		Landscape Architect
Brealey, Helen	BBONT	Volunteer
Broad, Emma	BBONT	Senior Community Education Officer
Brooks, Stephen	British Dragonfly Society	Research Entomologist
Buck, Darryl	Environment Agency	Ecologist
Bunting, Jane	University of Hull	
Christensen, Dee	BTCV	County Manager
Clarkson, Melissa	Environment Agency	Conservation Officer
Conder, Allison	Cambridgeshire County Council	Countryside Officer
Cook, Anne-Marie	Cheshire Wildlife Trust	Conservation Assistant
Craxford, Stuart	Environment Agency	Conservation Officer
Curran, Anne	Pond Action	Conference Organiser
Curry, Henry	National Dragonfly Museum	Technical Director
D'ayala Rod	BBONT	Warden, Warburg Reserve
Drake, Martin	English Nature	Invertebrate Ecologist
Drewitt, Joanna	Scottish Office	Ecological Advisor
Elliot, Mark	Environment Agency	Area Conservation & Recreation Officer
Everard, Mark	The Natural Step	Director of Science
Flitter, Belinda	Wychwood Project	Project Officer
Fox, Gill	Pond Action	Freshwater Ecologist
Gillespie, Morna	Institute of Terrestrial Ecology	Higher Scientific Officer
Goddard, Don	Aqua Biota Consultants UK	Invertebrate Consultant
Hale, Peter	Industrial Research & Technology Unit	Principal Scientific Officer

Name	Organisation	Position
Hart, Neville	BTCV	Project Officer
Name	**Organisation**	**Position**
Hawes, P	Hengistbury Head Nature Reserve	Management Committee Member
Hayes, Colin	English Nature	Conservation Officer
Hearn, Katherine	The National Trust	Adviser on Nature Conservation
Hellier, Karen	Babtie	Senior Ecologist
Hellier, Richard	Environment Agency	Landscape Architect
Hilton, Jennifer	House of Lords	Member of Environment Committee
Hine, Adrian	Penny Anderson Consultants	Assistant Ecologist
Howard, Shelley	Environment Agency	Regional Biologist
Hughes, Melanie	FRCA	
Hull, Andrew	Pondlife Project	Project Manager
Jacobson, Anne	British Wildfowl Association	Council member
Jenkins, Mike	Environment Agency	
Jones, Les	WWF-UK	Acting Director
Keen, David	Coventry University	
Kenyon, Eric	Christleton Parish Council	
Kirkpatrick, Jon	Environment Agency	FER Technical Assistant
Lamble, Charlotte	FWAG	Farm Conservation Advisor
Langton, Tom	Herpetofauna Consultants International	Director
Linton, S	University of Hull	Postgraduate Student
Lutt, Nick	Thames Water	Assistant Environmental Scientist
Maund, Steve	Zeneca Agrochemicals	Aquatic Ecotoxicologist
Nicolet, Pascale	Oxford Brookes University	Research Student
Newell, Simon	Colchester City Council	
Oldfield, Sally	BBONT	Berkshire Community Conservation Officer
Perrow, Martin	ECON	Principal
Phillips, Mark	FRCA	Countryside Stewardship Project Officer
Pickering, Simon	Cotswold Water Park	
Powell, Anne	Ponds Conservation Trust	Chairman
Rowsell, Edward	FWAG	Farm Conservation Officer
Raven, Paul	Environment Agency	Head of Conservation
Rees, Mair	Environment Agency	Conservation & Recreation Officer
Reynolds, Colin	Freshwater Biological Association	Acting Director
Rich, Tim	National Museum of Wales	Head of Vascular Plants
Rouen, Karen	Environment Agency	Ecologist

Scioe, Francoise	Charnwood Wildlife Project	Ecologist
Scott, Tom	Countryside Commission	National Lottery Officer

Name	Organisation	Position
Snow, Richard	FWAG	Farm Conservation Advisor
Spray, Martin	BBONT	Director
Sproat, Lesley	Environment Agency	Conservation Officer
Stanier, Henry	National Dragonfly Museum	Course Director
Stansfield, Julia	Environment Agency	Area Biologist
Steel, John	Environment Agency	Area Ecologist
Stevenson Mark	Northmoor Trust	Head of Ecology
Stobart, John	Dorset Wildlife Trust	River & Wetland Officer
Swan, Mary	British Herpetological Society	
Sweeting, Roger	Environment Agency	FRCN Manager
Symonds, David	Surrey County Council	Landscape Officer
Taylor, Mark	DETR	
Tierney, Peter	Herefordshire FWAG	Advisor
Vagg, Nick	BTCV	Tyne & Wear and Northumberland Project Officer
Vines, Gail		Journalist
Walls, Robin		Consulting Scientist
Watson, Will	Aqua Biota Consultants UK	Project Consultant
Whetter, Heather	English Nature	ConservationOfficer
Whitehurst, Julian	Cheshire Wildlife Trust	Amphibian Consultant
Whitfield, Mericia	Pond Action	Freshwater Ecologist
Wiles, Roy		
Williams, Penny	Pond Action	Freshwater Ecologist
Woodcock, Jonathon	BTCV	Berkshire Community Project Officer
Woollacott, Raz	Norfolk County Council	Countryside Officer
Yallop, Marian	University of Bristol	Lecturer in Biological Sciences