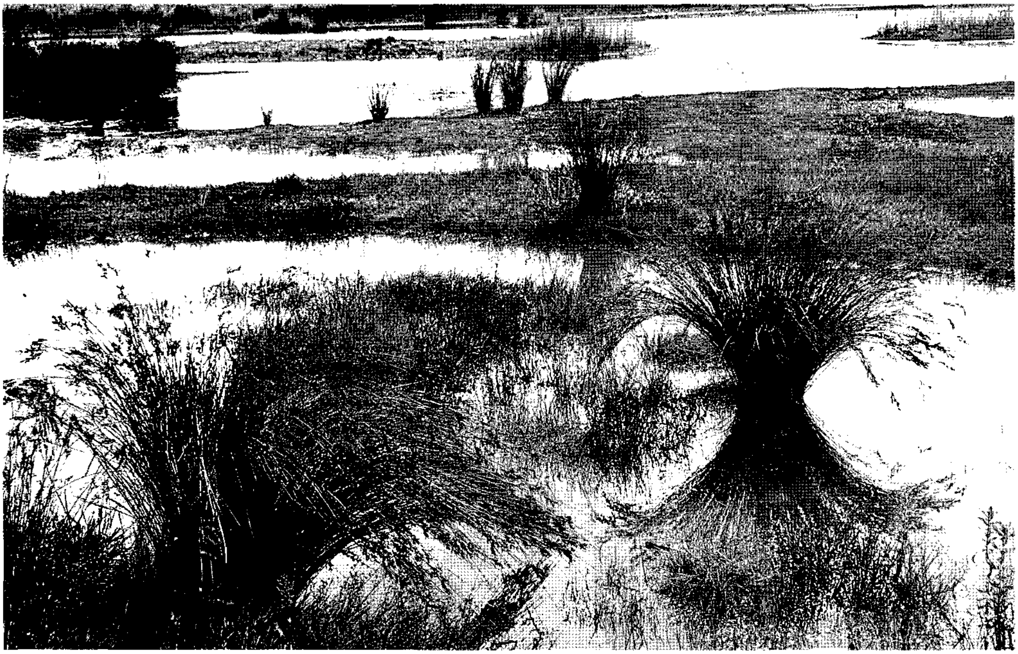
Designing New Ponds for Wildlife

Neil G Morrison/WWF-UK



Penny Williams, Jeremy Biggs, Antony Corfield, Gill Fox, Dave Walker and Mericia Whitfield

A pond 3-4 years after creation, showing shallow undulating waterbody margins.

Ponds can be one of the easiest and most rewarding semi-natural habitats to re-create and, by applying simple principles to their design and location, most ponds can quickly develop into useful wildlife habitats.

Important principles for pond creation are:

i Locate new ponds in areas where they are at least risk from pollution.

ii Where possible, key new ponds into existing wetland areas (streams, fens, ditches, etc.).

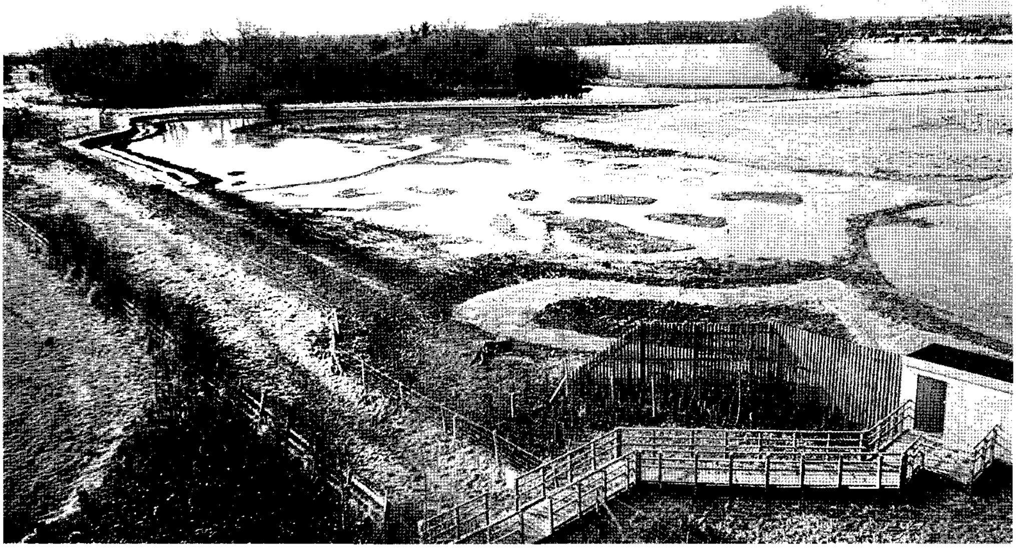
iii Above all, design ponds with natural wetlands in mind: create pond mosaics and wetland complexes rather than single isolated waterbodies.

iv To maximise species diversity, vary the main factors influencing community type at any pond site (e.g. depth, permanence, size).

v Expect development to take time – pond creation is often best considered as at least a two-phase process.

vi Ensure that some effort is allotted to pond management during early colonising stages.

Adhering to these principles should enable rich communities to develop quite rapidly at new sites and, where carefully planned and located, these ponds can often make a significant contribution to maintaining or enhancing aquatic communities in an area. In the mosaic of new pools created on a 2ha riverside site in Oxfordshire, for example, we recorded 20% of all Britain's wetland plants and larger macro-invertebrates (water beetles, snails, dragonflies, etc.) within five years of excavation, and in the largest of the ponds (0.2ha) species richness was as great as that recorded from any other pond in Oxfordshire (Biggs *et al.* 1995).



This complex of 40 ponds and pools at Pinkhill Meadow was created in 1990/91 using the principles outlined in this article. Within five years of its creation, 20% of Britain's wetland plants and 22% of freshwater macro-invertebrates were recorded from the ponds.

Why create ponds for wildlife?

There is now abundant evidence that small waterbodies play an important role in protecting freshwater biodiversity in the UK. Ponds support populations of at least two-thirds of all wetland plants and animals found in Britain. Many species, particularly of invertebrates and amphibians, are largely restricted to ponds, which are also home to some of our rarest freshwater plants and animals, such as Starfruit, *Damasonium alisma*, and the tadpole shrimp, *Triops cancriformis*. Ponds, therefore, represent an important freshwater resource, and it is important that they are adequately maintained and protected.

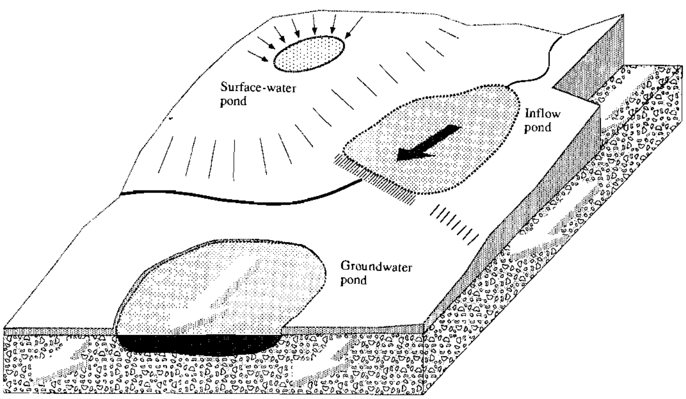
New pond creation is the most natural, and arguably the most ecologically valid, of all methods that can be used to maintain pond communities. As we discussed in a companion article (Biggs *et al.* 1994), man's creation of new ponds mimics the age-old processes of natural pond formation, creating new sites which pass through a range of successional stages, all of which are exploited by freshwater life.

Now that there are so few opportunities for ponds to form naturally in our drained and intensively managed landscapes, human activity provides an essential replacement for natural pond-creation processes. Where well planned and executed, the creation of new ponds can make an important contribution to the conservation of wetland wildlife.

Ensuring good water quality

The best start to give any new pond is to ensure that it has good water quality. Unpolluted ponds have, on average, significantly more uncommon species than polluted ponds, they have richer aquatic plant communities and they have fewer problems with nuisance levels of plants such as duckweeds and algae, or aliens such as Water Fern, *Azolla filiculoides* (Pond Action 1994a, b). Water pollution is now probably the most important and widespread cause of pond management problems in the UK, and a great advantage of creating new ponds is that their location can be chosen specifically to minimise future pollution inputs.

Water sources for ponds Apart from rainwater, there are three main sources of water for ponds: surface run-off, groundwater and inflows (Fig. 1). Individual ponds may be fed by one or more of these water types and the importance of each may vary during the year.



Pond Action

Figure 1 Water Sources for ponds
Ground water is essentially water which lies below the water table. It is the typical source of water for ponds dug into layers of gravel, sand and some peats. All groundwaters move, and in open gravels flow rates may be as much as 10cm per second. Clays, in comparison, may have through-flow rates in the order of 1cm per day.
Surface water is often the main water source for ponds dug into clay substrates, or ponds that are artificially lined and have no inflow. However, most ponds have some surface or near-surface inflows from adjacent lands, particularly land rising above the pond. The amount of water entering ponds through surface run-off is routinely under-estimated. Because surface water-fed ponds typically have relatively impermeable bases and low throughflow rates, pollutants can accumulate relatively quickly.
Inflows (e.g. streams, ditches and springs) are commonly used as temporary or permanent sources for ponds, either as a main water source or to top-up ponds fed by other means. All running water carries sediment so ponds with inflows, even those fed by tiny trickles, usually fill-in much more quickly than non-inflow fed ponds.

Understanding the water sources available for a new pond helps with all aspects of its design, from avoiding, or minimising, pollution inputs to maximising hydrological diversity (by, for example, combining seasonal surface-water pools and permanent groundwater pools at a site). A brief resume of the main characteristics of the three water sources is given below.

Surface water Surface run-off can provide some of the best, and some of the worst, quality water for new ponds, depending largely on the naturalness of the pond's catchment. In agricultural and urban areas, surface waters are often severely degraded, with high levels of soluble pollutants (nitrate, soluble phosphorus, biocides, etc.), together with metals, organics and other sediment-bound toxins which are washed in with soil particles. Because surrounding land-use exerts such a strong influence on the quality of run-off, surface-water ponds are usually least impacted by pollutants when located in semi-natural landscapes. In areas of intensive land-use, the aim should be to minimise pollution sources in the drainage area around the pond, by, for example, installing semi-natural buffer zones to intercept pollutants.

Groundwater In intensively managed landscapes, groundwater ponds are often less polluted than their surface-water counterparts. Groundwaters have inevitably been partly filtered before reaching a pond but, in addition, since all groundwaters move (albeit slowly), soluble pollutants entering a pond from surface run-off or inflows are continually diluted and carried away. For these reasons, groundwater ponds may sometimes support high-quality plant and animal communities even where their surroundings are degraded.

Inflows and drains Creating ponds that are linked to a temporary or permanent inflow always needs careful consideration. The quality of water in stream- or ditch-fed ponds will reflect the quality of the inflow's catchment, and where a watercourse partly drains intensive agricultural land or urban areas it can bring in many soluble pollutants and deposit polluted sediments. In the Oxfordshire Pond Survey, for example, ponds with inflows had both elevated pollutant levels and significantly fewer uncommon invertebrate species than non-inflow ponds (Pond Action 1994a). Overall, where a suspect inflow would only top-up a new permanent or seasonal pool, it would be better to do without it. For similar reasons, urban and road run-off drains should be avoided.

Buffer zones Although buffer zones will not cure all pond water-quality problems, there is evidence that they may help to limit pollutant inputs into some pond types.

Semi-natural buffers seem likely to be most effective around surface-fed waterbodies, where it is certain that most flows to the pond will be intercepted. In groundwater-fed ponds the situation is more complex, because sub-surface flow may effectively by-pass the buffer zone. Buffer zones remain valuable even for groundwater-fed ponds, however, because, as these ponds age and accumulate sediments, their subsurface flows may reduce and the immediate surroundings become more important in determining water quality.

Around inflow-fed ponds buffer zones are likely to have relatively little impact, since it is the watercourses draining into the pond which primarily determine its quality. Sediment traps and reedbed filters may help to remove some pollutants from inflow streams but, ultimately, pollution-prevention measures throughout the upstream catchment (using buffer zones and point-source controls) are likely to be needed to protect water quality in the long term.

General prescriptions for the ideal type and size of buffer zones will always be difficult to give, although it is clear that the bigger the buffer zone area the better. Maximum widths currently recommended range from 30m (EA 1996) to 50m or more. More specifically, recent evidence suggests that:

i 20m-wide strips may be a minimum for avoiding the effects of spray drift (Marrs *et al.* 1993).

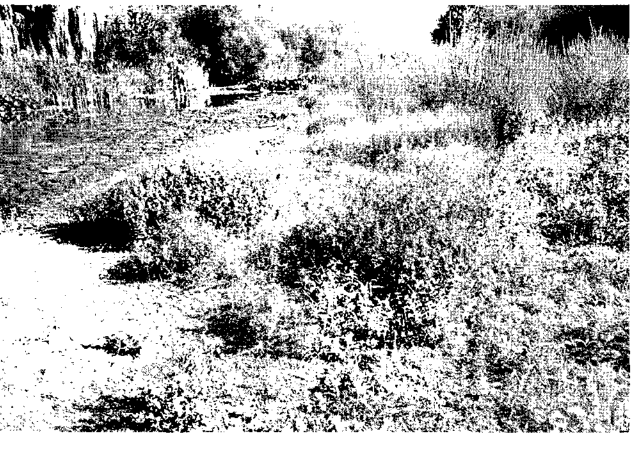
ii Ponds with muddy edges and a high proportion of annual plants (i.e. many new ponds) need particular protection from spray drift, since seedlings are especially vulnerable to damage (Marrs *et al.* 1993).

iii Buffer zones which aim to intercept water-borne and sediment-borne pollutants should be wider on the side of hillslopes from which most water and sediments will be derived.

iv Where tile drainage or surface runnels cut through a buffer they significantly compromise its effectiveness and should be removed or broken.

As well as establishing buffer zones around the pond, the structure of the pond itself may give some protection from pollution. The development of extensive macrophyte stands (emergent, submerged, floating) may be valuable because plants can help to intercept airborne pollutants, soak up excess nutrients and, in larger ponds, slow the spread of contaminants through the waterbody. On balance, although the interactions between plants and pollutants are complex, it seems possible that wetland vegetation may mitigate some of the effects of pollution.

Where ponds are receiving polluted water, it may often be beneficial to focus attention on creation of shallow water areas and the drawdown zone. In this semi-urban pond in Reading, Berkshire, the centre of the pond was virtually devoid of life. In contrast, the drawdown zone (foreground) and marshy margins supported a rich plant and invertebrate community, including uncommon species.



Pond Action

Working with polluted water Where polluted water inputs are unavoidable, it may be best to concentrate space and effort on creating shallow, rather than deep, ponds, including good drawdown zones and marshy margins. In polluted waters, submerged aquatic plants rarely thrive: as such, areas of deep water are typically species-poor, serving mainly to accumulate polluted sediments. In the shallows, at least some marginal-emergent plant species will survive under most water-quality conditions and provide a habitat for aquatic and semi-terrestrial invertebrates, as well as birds and mammals. We have, for example, surveyed polluted urban ponds where the open water in the centre has been almost devoid of life but very extensive marshy margins have still supported a diverse plant and invertebrate community, including local fen beetles such as *Peltodytes ceasus*.

Strategic locations for ponds

Most people creating a new pond have some leeway with its siting, and some (nature-reserve managers, landowners) may have considerable flexibility.

On a large scale, evidence from the National Pond Survey and Oxfordshire Pond Survey data-sets and other studies suggests that land-use has a strong influence on the development of pond community type (Pond Action 1994a, b and unpublished data; Gee *et al.* 1994). Where planning pond conservation strategies on the broadest scale, it therefore makes sense to extend the distribution of new ponds across different landscape types (woodland, meadows, heath, marsh, moorland) to protect the spectrum of community types and species.

Pond Action

In semi-natural landscapes, such as the New Forest, small topographic undulations often give rise to shallow pools which support a wide range of characteristic freshwater plant and invertebrate species. With careful design it is possible to mimic these features during pond creation schemes.

Linking ponds and other wetlands On a local scale, several lines of evidence suggest that there may be particular advantages in siting new ponds near to existing wetlands.

In natural and semi-natural landscapes ponds rarely occur in isolation: typically they form part of a wetland complex, in close proximity to other wet habitats such as streams and their floodplains, wet woodlands, springs, seepages, mires or other ponds and pools. Frequently, waterbodies may also be seasonally linked by high winter water levels or floods. Simulating this natural connectedness has benefits both for a new pond and for the adjacent wetlands.

For a new pond, close association with existing wetlands facilitates rapid colonisation because, not surprisingly, plants and animals are more likely to colonise a nearby site than a distant one. 'Donor' waterbodies do not need to be ponds; many freshwater plants and animals are 'generalists' able to occupy a range of waterbody types. Thus, pond margins may be as easily colonised by species from the edges of nearby rivers, ditches or lakes.

In rare-species projects, creating new sites near to existing populations is a common method for facilitating natural colonisation and spread. It is also a strategy which is more widely applicable. In wetland habitats, plant and animal populations often fluctuate widely, and in some waterbody types extinctions may be relatively common, exacerbated by changes such as succession, natural 'catastrophes' like drought, or episodic pollution incidents (Nürnberger 1996; Moore 1990). If complexes of other waterbody types are available nearby to provide refuges or sources of propagules for recolonisation, the chances of maintaining the species pool will be considerably improved.

Poor locations for ponds Although there is sometimes concern about how appropriate it is to dig new ponds in naturally dry landscapes, pond creation is often more problematic in wet habitats. Given a damp patch in a dull field, it can be tempting to dig the new pond in the wettest spot. But small-scale wetland habitats, such as seasonal pools, springs and flushes, are notoriously undervalued and easily damaged. It is a point often, but well, made that, when choosing the location for a new pond, it is essential to undertake sufficient survey work to ensure that the new pond does not replace a more valuable habitat, wet or dry. Equally, care needs to be taken to ensure that the new pond does not alter the hydrology of an existing site by, for example, increasing evapotranspiration or, where groundwater is under hydrostatic pressure, by flooding adjacent areas.

Pond mosaics – creating new wetland complexes

By looking at semi-natural wetlands and considering the preferred habitats of pond species it is possible to improve many standard features of pond design. But perhaps the single most important recommendation is that, instead of digging individual and isolated ponds, we should begin to focus on the creation of wetland complexes.

Pond depth and permanence (and probably waterbody size) are major influences on pond community types. Varying these factors at a site, to create habitat mosaics with a mixture of permanent, semi-permanent and seasonal pools, provides habitats for a far greater variety of plants, invertebrates, amphibians, birds and mammals than could be accommodated in a single waterbody. In most cases, creating some form of mosaic is usually possible in all but the smallest of pond-creation schemes.

At Pinkhill Meadow, Oxfordshire, a pond mosaic approach was taken in a 1990/91 experimental pond-creation scheme. Subsequent NRA/EA-funded monitoring showed that this wetland developed an exceptionally diverse and complex wetland flora and fauna and it was clear that the range of water regimes on the site contributed significantly to its diversity (Biggs *et al.* 1995 and unpublished data; Critchley 1995).

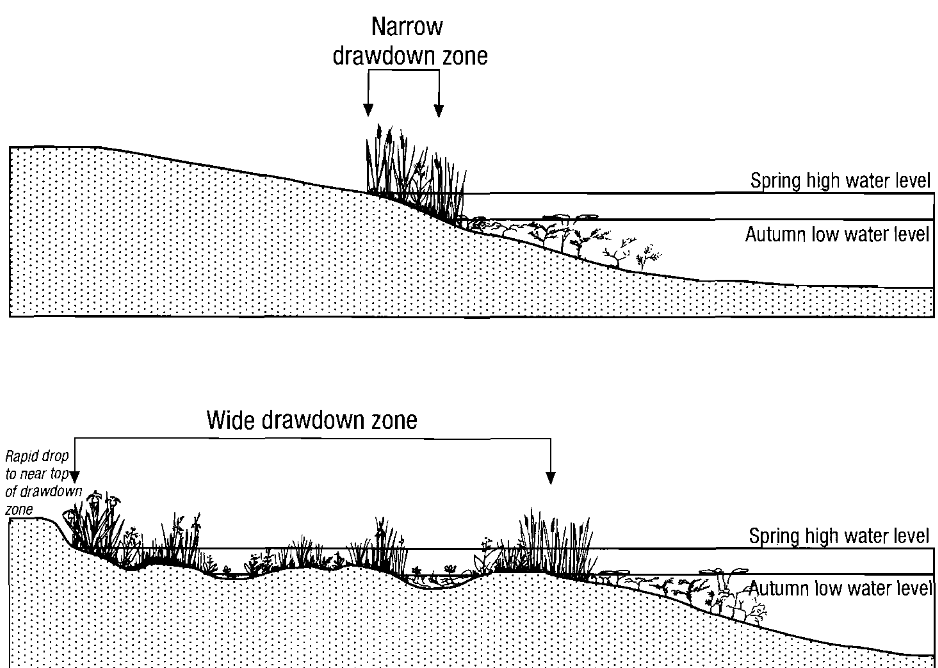
Shallow water, microtopography and the drawdown zone

In most ponds water rises and falls between winter and summer, creating a drawdown zone of variable wetness and high biological diversity. In traditional pond designs this drawdown area is rarely considered in detail and, by default, is typically restricted to a narrow strip at the water's edge. Extending the area of the drawdown zone to give extensive summer marsh and mud habitats can considerably improve a pond's wildlife potential, particularly for marginal, shallow-water and semi-terrestrial plants and invertebrates.

Drawdown zones do not need to slope evenly down to deeper water. Anyone who has walked across a wet meadow in spring will be aware that subtle, centimetre-scale irregularities in the ground surface can cause considerable differences in waterlogging and major variations in plant-community type.

In new pond designs we have an opportunity to simulate such small-scale topographic variability through careful physical shaping of the

The drawdown zone is often a particularly valuable part of any pond. Traditional pond designs often have very narrow drawdown zones, but with careful design it is easy to extend this rich area.



Pond Action

drawdown zone and shallow-water areas. The result is a patchwork of hummocks and pools with varying water regimes which will ultimately create a rich mosaic of small-scale habitats for plants and animals.

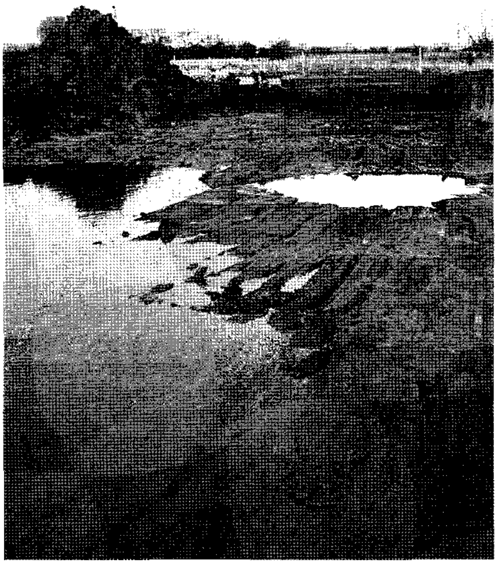
Key design points for pond wetland complexes and drawdown zones are:

i Vary the size of waterbodies as much as possible – the smallest that can easily be created with most mechanical diggers is about 0.5m diameter.
ii Include very shallow water pools, near water level; even pools with a depth of 5cm or so will be valuable.
iii Ensure that at least some shallow and deep pools are not directly linked except at very high water levels.
iv Drawdown-zone slopes should often be very shallow; if necessary, dig down relatively steeply along some edges to reach the high winter water level, then flatten out to give a broad drawdown zone.
v Create 'hummocks and hollows' in the drawdown zone together with flat areas that will retain seasonal inundation.
vi Tailor the topography to fit with post-creation management: where drawdown zones are lightly grazed, rather subtle topographic variations will result in plant-community differences. In unmanaged ponds, where tall emergents will eventually dominate, a larger scale of topographic variation will often be more useful.
vii Consider mixing hydrological regimes, perhaps by combining shallow or temporary surface-water pools with deeper groundwater or inflow-fed ponds.

Deeper water

In many parts of Britain very deep water (1m-2m+) will always have been a relatively uncommon habitat compared with shallow permanent and temporary pools, and there is no imperative to include deep water in all pond-creation schemes. In specific cases, however, deep water can be useful. Fish and many wetland birds generally benefit from both deeper and larger sites. More rarely, where new sites are located in areas with clear unpolluted water, deep waterbodies can be particularly valuable, providing habitats for a diverse range of submerged plant species (and associated habitats for invertebrates), including some of the rarer charophytes (Stewart 1996) and pondweeds.

Pond Action



Creating shallow undulating margins and small pools in practice.

Islands

It is a cliché of pond-design manuals that every pond should have an island. In practice, for plants and macro-invertebrates, islands are most likely to be of value where the margin of the pond is shaded, grazed or trampled and islands provide a different set of habitats. For wetland birds, however, islands are a preferred habitat providing safe areas for feeding, loafing and nesting. Thus, in larger ponds where wader or waterfowl conservation is an aim, islands are particularly valuable. Specific advice on island design for birds is given by Andrews & Kinsman (1990); a few more general points are:

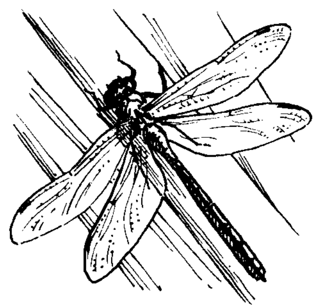
i Height above water level will determine vegetation type: if islands are low, they can also provide a wetland habitat.
ii Gentle slopes near water level, and low flat islands that are submerged in spring, will give mud banks that can be valuable for both wetland plants and birds.

Table 1 Pond-design features for specific plant and animal groups

Plants

Aquatic plants Good water quality, although floating-leaved species are often tolerant of natural turbidity (e.g. ponds in clay catchments). Some submerged species prefer deeper water (>0.5m). For most uncommon plants (e.g. Frogbit, *Hydrocharis morsus-ranae*, bladderworts, *Utricularia*, some pondweeds, *Potamogeton*) proximity to existing populations likely to be important.

Emergent/marginal plants Extensive drawdown zone, mosaic of pools with differing degrees of permanence waterlogging. Water quality less important than for aquatics, although substrates with relatively low nutrient status promote diversity. Some scarce emergent plants strongly associated with ancient wetland habitats, so proximity essential (e.g. Saw-sedge, *Cladium mariscus*). **Literature** Grime *et al.* (1988); Red Data Books. For Common Reed, *Phragmites australis*, management see Hawke & José (1996).

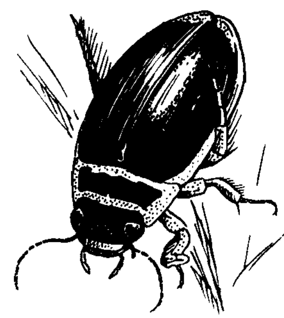


Invertebrates

All species Mosaic of pools and wet habitats. All sizes of waterbody useful, including very small (e.g. 1m^2, 5cm-deep temporary pools). Complex underwater plant structure, varied substrates and marginal habitats. Good water quality. **Literature** Kirby (1992), Biggs *et al.* (1994). Insect and Non-Insect Red Data Books. For individual groups, Freshwater Biological Association identification guides often provide a useful starting point.

Examples of invertebrate groups

Dragonflies Permanent ponds for maximum diversity, but many common species are found in semi-permanent ponds and some are associated with temporary water. Key features include: a good range of aquatic, floating and emergent plants for egg-laying, habitat and emergence, a variety of substrates, sheltered edges for emergence. Most uncommon species have more specialised habitat requirements (e.g. acid heath, bog pools). Specific designs are beginning to be possible for individual species. **Literature** Merritt *et al.* (1996).



Water beetles Maximum species richness in fish-free marginal/shallow-water habitats. Low-growing grasses in centimetre-deep water and mosses (especially *Sphagnum*) are favourite habitats. Many common species highly mobile, but for non-mobile fen/bog species habitat-creation schemes near existing high-quality wetlands are probably essential. **Literature** No single literature source available, but Kirby (1992) gives general guidance.

Caddis flies Large (permanent) ponds for maximum species richness. Some species are characteristic of the smallest seasonal pools. **Literature** Habitats of individual species briefly summarised by Wallace (1991).

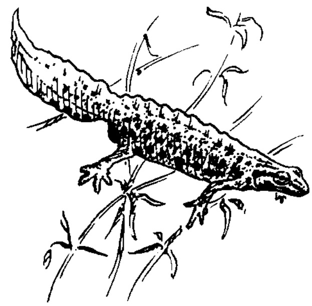
Molluscs Common species found in wide range of habitats; greatest numbers of species in calcium-rich sites close to (or part of) long-established wetlands (such as river valleys, old fens). Rarest species (e.g. Shiny Ramshorn Snail, *Segmentina nitida*) likely to colonise new ponds only close to existing habitats. Rarer species generally associated with good water quality. Some temporary-water specialists (e.g. Mud Snail, *Lymnaea glabra*, Moss Bladder Snail, *Aplexa hypnorum*). **Literature** Introduction to biology of common species in Thorpe & Covich (1991). Bratton (1991) for introduction to rare species.

Semi-aquatic invertebrates (e.g. flies, ground beetles). Wet marshy ground and extensive drawdown zones providing mud and organic matter; areas of dense vegetation, including scrub, are also valuable. **Literature** Kirby (1992) provides good introduction for all groups. General information on Diptera in Stubbs & Chandler (1978) and specific information on hoverfly species in Stubbs & Falk (1983).

Amphibians

All species Surroundings should include less intensively managed land, ideally with woodland/scrub.

Common Frog, *Rana temporaria* Catholic in choice of ponds, breeding in a wide range of sizes and successional stages, but likely to be most successful in fish-free ponds with warm shallows. Preferred conditions perhaps commonest in smaller ponds (e.g. 1-500m^2) but these features can be designed into larger sites.

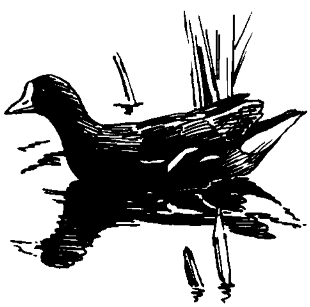


Newts (Smooth, Palmate, Great Crested) Similar habitat requirements to Common Frog, but also need leafy plants in shallow water for egg-laying. Great Crested Newts have more specific habitat requirements (e.g. ideal pond size 25-750m²). For information on habitats see EN (1994) and Swan & Oldham (1993).

Common Toad, *Bufo bufo* Co-exists well with fish and usually found in larger (>500m²) ponds.

Natterjack Toad, *Bufo calamita* Requires temporary ponds and heathland/dune terrestrial habitat. Detailed information about pond design is given in Beebee & Denton (1996).

Birds

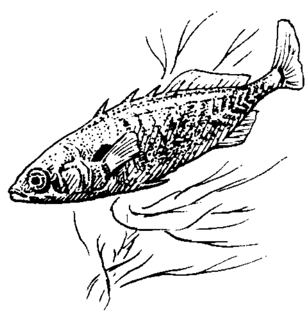


Many species will use ponds if they form part of larger wetland complexes with mosaics of waterbody types and cover, including permanent and seasonal wetland habitats (e.g. in reedbeds, wet grasslands). New ponds may provide breeding sites in extensive semi-natural habitats, but isolated small ponds are used by only a very few wetland birds (e.g. Moorhen, Mallard, common wetland passerines).

Waders Shallow water and mud, combining drawdown zones with standing water during the breeding season.

Waterfowl Depths and vegetation cover vary for different species; refer to standard sources such as Andrews & Kinsman (1990) and *Birds of the Western Palearctic* (9 vols, 1977 onwards). See also RSPB *Conservation Review* and specialist literature.

Fish



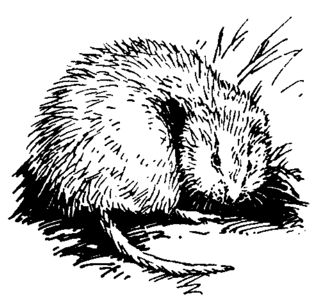
General Deep permanent ponds with shallow, warm, well-vegetated water for fry development. Dense vegetation stands and good water quality will probably encourage maximum species richness. **Literature** Maitland & Campbell (1992) give good introduction to individual species and provide entry point to the very extensive literature on fish ecology and management.

Mammals

Water Vole, *Arvicola terrestris* Large, deep ponds with abundant vegetation for food, which suggests that extensive drawdown zones may be useful. Deep-water access to steep banks (for burrows) valuable. **Literature** Introduction in Corbet & Harris (1992).

Bats Recent evidence shows ponds amongst most preferred bat feeding habitats (with broad-leaved woodland) (Walsh & Harris 1996). New pond-creation projects may be generally beneficial for bats.

Otter, *Lutra lutra* May use ponds as food supply, especially in breeding season (for fish, and amphibians in spring). In larger ponds, islands provide safe lying-up areas. Link ponds to other wetland corridors with dense cover. **Literature** NRA (1993) gives introduction to Otter habitat management.



Sources

Andrews, J, & Kinsman, D 1990 *Gravel pit restoration for wildlife.* RSPB

Beebee, T, & Denton J 1996 *The Natterjack Toad conservation handbook.* English Nature

Biggs, J, Corfield, A, Walker, D, Whitfield, M, & Williams, P 1994 New approaches to pond management. *British Wildlife* 5:273-287

Bratton, J H 1991 *British Red Data Books: 3. Invertebrates other than insects.* JNCC

Corbet, G B, & Harris, S (eds) 1991 *The Handbook of British Mammals* Blackwell

EN 1994 *Facts about Great Crested Newts.* English Nature

Grime, J P, Hodgson, J G, & Hunt, R 1988 *Comparative plant ecology.* Unwin Hyman, London

Hawke, C J, & José, P V 1996 *Reedbed management for commercial and wildlife interest.* RSPB

Kirby, P 1992 *Habitat management for invertebrates: a practical handbook.* RSPB, Sandy

Maitland, P S, & Campbell, R N 1992 *Freshwater fishes of the British Isles.* HarperCollins, London

Merritt, R, Moore, N W, & Eversham, B C 1996 *Atlas of the dragonflies of Britain and Ireland.* ITE Research Publication 9. HMSO, London

NRA 1993 *Otters and river habitat management. Conservation Technical Handbook, 3.* National Rivers Authority, Bristol

Stubbs, A E, & Chandler P 1978 *A Dipterist's Handbook. The Amateur Entomologist 15* AES

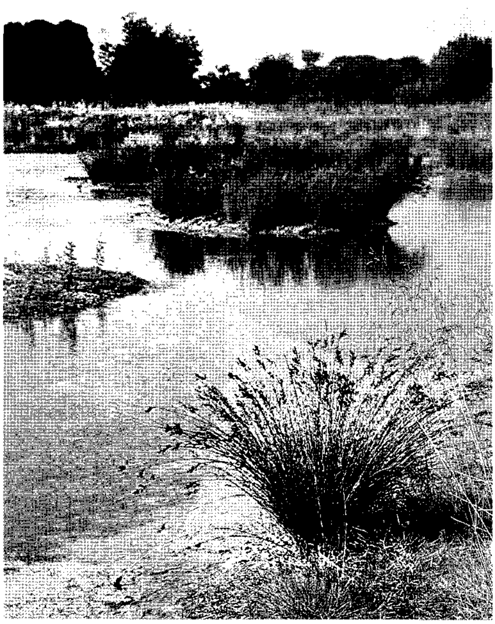
Stubbs, A E, & Falk, S J 1983 *British Hoverflies.* BENHS

Swan, M J S, & Oldham, R S 1993 *Herptile sites. Volume 1: National Amphibian Survey. English Nature Research Report, 38.* English Nature, Peterborough

Thorpe, J A, & Covich, A P 1991 *Ecology and classification of North American freshwater invertebrates.* Academic Press, San Diego

Wallace, I D 1991 *A review of the Trichoptera of Great Britain. Research and survey in nature conservation, 32.* NCC, Peterborough

Walsh A L, & Harris, S 1996 Foraging habitat preferences of vespertilionid bats in Britain. *Journal of Applied Ecology* 33, 508-518



Neil G Morrison/WWF-UK

Islands can be valuable nesting and roosting areas for birds. Areas which remain above waterlevel will eventually scrub-up and this should be borne in mind.

iii Ensure that if islands need to be managed or monitored they are easy to reach. Access on foot (using waders) can be much more convenient than use of a boat. However, water should be deep enough to ensure that islands are isolated from predators such as Foxes, *Vulpes vulpes*.

iv island areas which are permanently above water level will usually develop tall weedy vegetation, and eventually scrub or woodland. Careful thought should be given to the implications of this for management.

Retaining bare mud

Bare pond edges are especially valuable for many annual wetland plant species, a range of aquatic and semi-terrestrial invertebrates and wading birds. There are, therefore, times when muddy areas need to be created and, more problematical, to be retained. Grazing or trampling (by stock, wetland birds or man) are often the most successful means of constantly creating muddy zones. But where this is not possible, design can help to encourage the retention of bare open ground. Monitoring at Pinkhill Meadow suggests that muddy areas remain bare for longest in areas of very low topography which lie at and *below* water early in the growing season (spring/early summer). This inhibits germination and increases the water stress and disturbance caused by fluctuating water levels. In these areas even very low undulations, which allow plants to gain a foothold and spread out, should be avoided.

Special designs for wildlife

Traditionally pond design has been 'all-purpose', with the aim of encouraging general diversity. However, there is now sufficient information about some freshwater plants and animals to begin designing new ponds with particular groups or species in mind. Table 1 gives a brief summary of some of the main features that can be used to encourage particular groups, together with references for more detailed information sources.

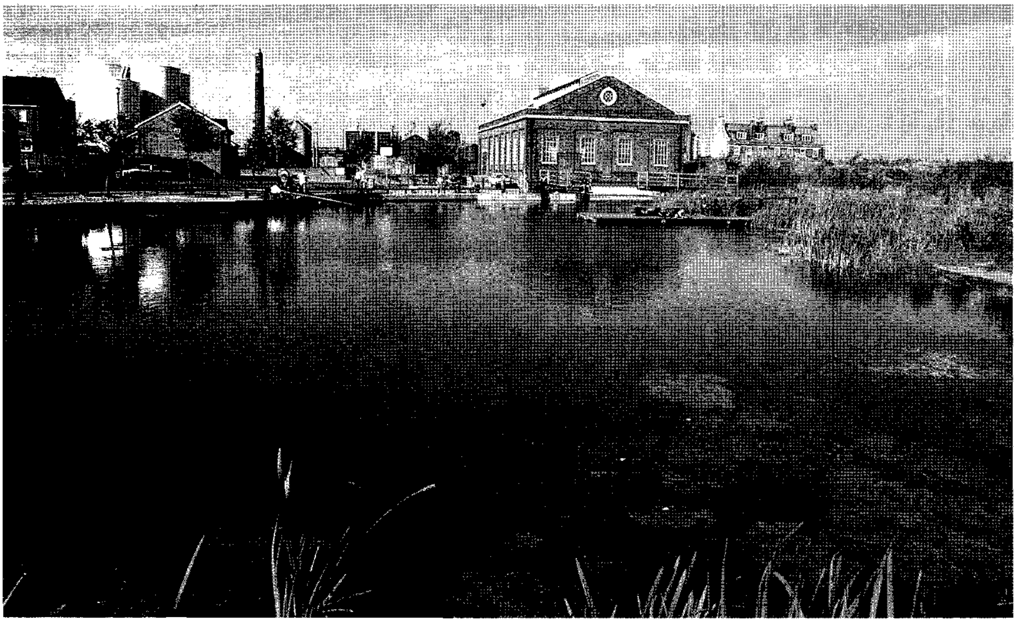
Designs for people

Most ponds are created for purposes other than just wildlife, and, where appropriate, relatively minor modifications can sometimes be made to these ponds to improve their conservation potential.

The potential to combine conservation with other pond uses largely depends on the intensity of that use. Where new pond ecosystems will be put under severe stress (e.g. heavily polluted balancing ponds, village ponds with large numbers of ducks), we may need to accept that the valid social or economic functions of such ponds are essentially incompatible with the development of rich pond communities. In such cases, it will usually be more worthwhile putting conservation effort into creating other, perhaps adjacent, waterbodies with a more specifically wildlife-based objective.

Where ponds are less disturbed (especially by pollution), it is usually possible either to minimise the effects of the main stress factors in some part of the pond or to accentuate the positive aspects of the pond's use. Deep, steep-sided irrigation ponds may, for example, support good aquatic-plant communities if they can be kept pollution-free. In heavily stocked fish ponds, very dense marginal vegetation and temporary or isolated sub-basins can provide protection from fish for invertebrates and

David Woodfall/Woodfall Wild Images



A pond with good access for people at one end, but with areas with emergent plants providing cover for birds and other animals.

amphibians. Watering ponds, which are still occasionally created for grazing animals, can give good poached margins and diverse vegetation swards where the stocking intensity is moderate or the pond is partially fenced.

In practice, by far the most common multifunctional requirement of new ponds is that they should be attractive to people as well as valuable for wildlife. It is often possible to reach a good compromise between visual amenity and conservation, and some of the main points to consider are listed below.

i The perception of what makes 'an attractive pond' varies considerably among people and places. However, regardless of place, almost all of us seem to enjoy clear views across water and this needs to form the basis of most designs for people.

ii A key to combining high wildlife value and visual amenity is that people will usually accept quite well-vegetated and semi-natural ponds, so long as from their own vantage point they can see water easily, preferably at close quarters.

iii Amenity pond designs, therefore, need to ensure that plants are kept low or absent in front of the main public viewing places (footpaths, access points, etc.). Conservation features can then be designed into many other parts of the pond.

iv Without grazing, most shallow pond areas (<0.8m deep in summer) will eventually develop a tall emergent plant cover, so consider the implications of these areas visually and in terms of their management requirements.

v Tall emergent plants do not germinate well underwater, so, to minimise the work needed to keep views open, create short lengths of low vertical bank at key viewpoints and ensure that the base of the bank is always covered by water in summer.

vi Steep slopes into deep water (more than about 1m) can prevent encroachment of marginal plants (except as vegetation rafts). Note, however, that when they fill up with sediment, deep areas are difficult and expensive to dredge.

vii Large islands which block long views of the far pond bank should be avoided.

viii People trampling at the edges of a pond can be locally beneficial, giving bare muddy or grassy areas as an alternative habitat type. Where necessary, heavy trampling of the entire pond perimeter can be avoided by creating short wet or dry barriers (e.g. scrub belts, banks, ditches).

Finally, in areas to which there is good public access, think carefully about safety. Low, flat-topped, vertical banks at the pond edge can be safer than steep slopes because they provide a clear edge. Ideally, water depths below any accessible edge should be very shallow and slope away gently, to provide an easy exit for people and animals. Below water level avoid sudden drops into deep water.

The need to phase design and creation

It is difficult to dig a new pond to a detailed design specification without good knowledge of pond water levels. Creating waterbodies with mud banks and a good drawdown zone, or with shallow and temporary pools, usually requires estimates of seasonal water-level variations accurate to at least 10-15cm. If the likely water levels for a new pond are not known, it is not intrinsically difficult to collect such information. Monthly or fortnightly records should be made over a fair length of time, usually at least a year, to be sure of seasonal water-level variations. However, it will take only a few minutes at each visit to the site to make the necessary observations.

To provide information about potential pond water levels a number of options are possible:

i Observe levels in adjacent waterbodies likely to have the same or similar water sources. This is particularly effective if there are nearby groundwater-fed ponds.
ii Excavate a trial hole to the maximum expected depth of the future pond, and monitor it for at least a year.
iii Create the pond in at least two phases, and extend the excavation after a year or so.

Advantages of two-phase pond construction If a waterbody is not lined, and it is likely to hold water for all or part of the year, then creating a new pond in a number of phases has the big advantage of providing both information and flexibility to the pond-design process.

A strategy we use where possible is to dig out part of the deepest area of the pond in Phase 1 (so that seasonal water levels can be monitored), and roughly to shape some potential areas for shallow pools, mud flats and islands, etc. Ensure, however, that any parts of the pond that might require modifying (islands, steep banks, etc.) remain accessible to people and/or machinery.

Phase 2 is used to incorporate design changes that have become desirable following an observation year, and to undertake delicate shaping of margins and shallows where knowledge of water levels is critical.

The main benefits of this approach are four-fold.

i Water levels can be monitored in a way that relates to the waterbody itself rather than to a trial hole or to an unconnected waterbody.
ii It is possible to experiment with ideas and concepts without commitment, and to correct mistakes inadvertently made.
iii Initial use of the new pond by people and wildlife can be observed. This is particularly valuable because it enables the final design to be tailored and fine-tuned to its objectives.
iv Finally, on a practical basis, working with a pond already filled with water in Phase 2 makes sculpting the pond edges and shallows much easier. It is surprisingly difficult to see or to create subtle variations of height in uniform stretches of bare mud; with a full pond, it is possible for an excavator or digging party to work out from the pond (taking the water along, too), shaping delicate undulations rapidly and effectively.

Planting-up versus natural colonisation

An unexpected consensus from recent pond surveys is that new ponds can become species-rich very quickly. Animals and plants migrate rapidly into new ponds. Most insect families (i.e. mayflies, caddis flies, water beetles, dragonflies) and some annual water plants usually become established within the first summer, even in isolated pools. Leeches, flatworms, snails, fish and both aquatic and marginal plants will usually arrive within a few years, if there are other waterbodies nearby (Moller & Rordam 1985; Wicks 1996; Gee *et al.* 1994; Gee & Smith 1995; Biggs *et al.* 1995).

The implication is that, from a wildlife perspective, planting-up or adding animals to a new pond is rarely a necessity. Indeed, as noted in our companion article on pond management (Biggs *et al.* 1994), new waterbodies often support distinctive communities and sometimes uncommon species during their early stages. Cutting this phase short may therefore work against conservation objectives.

There are exceptions of course. In specific cases, artificially maturing sites may help to hasten the natural spread of uncommon species characteristic of later successional stages. There may also be a case for artificially introducing species or community types in cases where natural spread is no longer possible. In US prairie pond restorations, for example, it was found that wet-prairie plant communities often needed to be introduced by an active re-vegetation programme. If they were not established early in a restoration, undesirable plants such as Bulrush, *Typha latifolia*, and Reed Canary-grass, *Phalaris arundinacea*, colonised and made it difficult for them to become established later (Galatowitsch & van der Valk 1994).

Commonly, there are also non-conservation reasons for rapidly maturing ponds, particularly in 'amenity' locations where it is important that a pond looks 'finished' or 'cared-for' quickly.

There are a number of options for helping to vegetate ponds, of which the most common are seeding, adding plants or addition of topsoil. Whilst such schemes are often at least moderately successful, some caution is necessary. For example, wherever possible, do not purchase plants from garden centres or suppliers, particularly if they deal in non-native stock: even if the provenance of introduced native species is known, alien species such as New Zealand Pygmyweed, *Crassula helmsii*, are quite frequently present as seeds or small plants in purchased pots.

Addition of topsoil around the margins of a pond typically promotes rapid and lush growth of vegetation. It may do this either by encouraging germination and growth of naturally colonising plants, or, where the donor soil is itself rich, by directly providing seeds. However, care should be taken: the vigorous growth can be time-consuming to manage in the long run and, if the topsoil is weedy, these species will predominate in the new sward. If topsoil is used at a site, it is generally best restricted to small pockets and not spread across the whole pond. Topsoiling of extensive areas below water level should be particularly avoided in areas where added nutrients would enhance unwanted eutrophication effects.

The first years of management

For wildlife ponds, the most important and effective time for plant management is often in the first 2-5 years after creation, when the vegetation sward is still establishing. It is therefore usually worthwhile ensuring that time is set aside to observe periodically the colonisation process and take any remedial steps necessary. If wildfowl, stock or people are abundant at a site, it may be necessary to protect self-colonising or planted vegetation with fencing. More commonly, it may be useful for dominating plant species to be thinned or removed. As US studies have shown, the marginal-emergent competitor species which colonise a pond during the early phase will dominate the pond in the longer term. If the natural supply of wetland species is low, the few early colonisers may dominate a pond and inhibit the colonisation and establishment of a more varied community. Bulrush presents a particular problem: it is both common and aggressive and one of the few wetland species thought to be currently increasing in the UK (Grime *et al.* 1988). It can, therfore, be worthwhile removing new Bulrush plants early in the colonisation phase. Once other plants have established a footing, natural maintenance of a diverse sward is much more likely.

Summary

As our understanding of pond ecology has grown, it has become possible to modify some of the old principles of pond creation, and to design and locate ponds so as to increase their potential value to wildlife.

It will not be possible to incorporate all new design features into all schemes, and in many waterbodies (clay- or butyl-lined ponds, for example) physical or other constraints may mean that application of more sophisticated recommendations are not appropriate. Nevertheless, it is valuable to reiterate some of the most general principles of pond design which should be applied where possible:

i Water pollution will limit the wildlife value of almost any pond, however well designed. As such, it is worth considering carefully (a) if pollutants are likely to reach a new waterbody; and (b), if they are a potential threat, how areas around or within a pond may be designed to minimise pollutant impacts.

ii Pond mosaics will generally be far more valuable for pond wildlife than single ponds, particularly where the complex incorporates variations of waterbody permanence and size.

iii Extending these wetland complexes by creating ponds near to other existing waterbodies may help to increase landscape connectivity for wetland species, and in the long term this should help to maintain existing populations.

iv Good knowledge of pond water levels is the essential basis for any detailed shaping of shallow pond areas, and taking time to gather hydrological information is worthwhile because of the great wildlife potential of shallow and temporary water zones.

v Finally, keep an eye on new ponds in their early colonising stages, when a little management may positively benefit the long-term diversity and potential of the pond.

Acknowledgements

WWF(UK) provided core funding for Pond Action during the early 1990s when much of the ecological understanding upon which this paper is based was gained. In addition, we gratefully acknowledge the organisations and individuals responsible for pond creation projects in which we have been able to trial and monitor new pond creation concepts. We would particularly like to acknowledge Thames Water Utilities Limited (especially Mike Crafer) and the NRA (now the EA), especially Alastair Driver and Richard Hellier, for their initiation of, and involvement in, the creation of Pinkhill Meadow Wetland Nature Reserve. A particular debt is owed to Alastair Driver who was instrumental in gaining NRA/EA R&D funding for monitoring of this site over the last seven years. Finally, a number of the recommendations given in this article arose from collaborative work with White Horse Contractors Ltd of Abingdon whom we thank for many valuable pratical insights.

References

Andrews, J, & Kinsman, D 1990 *Gravel pit restoration for wildlife.* RSPB, Sandy

Biggs, J, Corfield, A, Walker, D, Whitfield, M, & Williams, P 1994 New approaches to pond management. *British Wildlife* 5:273-287

Biggs, J, Corfield, A, Walker, D, Whitfield, M, & Williams, P 1995 *Experimental management of wetland habitats at Pinkhill Meadow.* NRA R&D Project Record 383

Critchley, H 1995 *An assessment of the macroinvertebrate fauna in three pond regimes at Pinkhill Nature Reserve, Oxford.* BSc Dissertation, Oxford Brookes University

Environment Agency 1996 *Understanding buffer strips.* Environment Agency, Bristol

Galatowitsch, S M, & van der Valk, A G 1994 *Restoring prairie wetlands.* Iowa State University Press, Ames

Gee, J H R, Lee, K, & Griffiths, S W 1994 *The conservation and amenity value of farm ponds.* Contract Science Report 44, Countryside Council for Wales

Gee J H R, & Smith B D 1995 *Conservation Value of Farm Ponds: Macroinvertebrates.* Contract Science Report 127. Countryside Council for Wales

Gray, N F 1989 *Biology of wastewater treatment.* Oxford University Press, Oxford

Grime, J P, Hodgson, J G, & Hunt, R 1988 *Comparative plant ecology.* Unwin Hyman, London

Hoffman, D J, Rattner, A B, Burton, G A, & Cairns, J 1995. *Handbook of ecotoxicology.* Lewis, Boca Raton

Marrs, R H, Frost, A J, Plant, R A, & Lunnis, P 1993 Determination of buffer zones to protect seedlings of nontarget plants from the effects of glyphosate spray drift. *Ecosystems & Environment* 45: 283-293

Moller T R, & Rordam, C P 1985 Species numbers of vascular plants in relation to area, isolation and age of ponds in Denmark. *Oikos,* 45: 8-16

Moore, N W 1990 The development of dragonfly communities and the consequences of territorial behaviour: a 27 year study on small ponds at Woodwalton Fen, Cambridgeshire, *Odonatologia* 20: 203-231

Nürnberger, B 1996 Local dynamics and dispersal in a structured population of the whirligig beetle *Dineutus assimilis.* Oecologia 106: 325-336

Pond Action 1994a *The Oxfordshire Pond Survey.* 2 vols. Pond Action, Oxford.

Pond Action 1994b *The National Pond Survey. Interim Report for the World Wide Fund for Nature.* Pond Action, Oxford

Stewart, N F 1996 Stoneworts – connoisseurs of clean water. *British Wildlife* 8: 92-99

Voght, L B-M 1995 *Restoration of stream in agricultural landscapes.* In *Restoration of stream* ecosystems (eds. M Eiseltova & J Biggs). IWRB, Slimbridge

Wicks, D 1996 *Classification and conservation value of pond types in Woking, Surrey.* BSc Thesis, Kingston University

Pond Action

The authors of this paper are members of the conservation group Pond Action. This is a non-profit-making organisation which aims to promote the conservation of freshwater ecosystems. The group is the national centre for pond ecology and conservation in the UK and is independently funded from grant, contract and research income.