CRANFIELD UNIVERSITY

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MANAGING WOODLANDS FOR CONSERVATION AND BIODIVERSITY ON PRIVATE LAND

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Abstract

The concept of sustainable development has become a central and fundamental aim of governments, and increasingly corporate strategy. Conservation and biodiversity are fundamental to this agenda. Although research has assessed the conflicts between sustainable development and biodiversity conservation at global, regional and landscape levels, few authors have focused on the local scale. Where privately owned land has significant ecological value, and future site re-development is a consideration to realise full economic potential, a number of issues and potential tradeoffs arise. Indeed sustainability involves not just environmental aspects but social and economic goals. This paper draws on evidence gathered from a privately owned woodland in Hertfordshire, UK which is known to contain a population of the protected great crested newt (*Triturus cristatus*). A vegetation survey was carried out and geo-referenced data incorporated into a Geographical Information System (GIS). A management plan has been designed to protect and enhance the *T. cristatus* population and the inherent biodiversity of the woodland, as well as to contribute to social and economic sustainability. The implications of different management options and nearby development on the site are discussed and potential tradeoffs identified. This study has shown the usefulness of GIS in the display and analysis of ecological survey findings and the presentation of management options. The research has demonstrated that with the implementation of a management plan landowners can contribute to environmental, social and economic sustainability as well as creating corporate benefits. The study has highlighted a number of knowledge and research gaps that need attention, in particular the investigation of tradeoffs and issues that arise at the local scale between conservation, development and other landowner objectives.

Key words: habitat management; great crested newt (*Triturus cristatus*); sustainable development; biodiversity; conservation; tradeoffs

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Abbreviations

BAP	Biodiversity Action Plan
DEFRA	Department for Environment, Food, and Rural Affairs
GIS	Geographical Information System
IUCN	International Union for the Conservation of Nature
LPA	Local Planning Authority
SAP	Species Action Plan

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1. Introduction

1.1. Research Background

With sustainability aspirations in mind, an increasingly common attribute of successful companies, proactive management of privately owned land is becoming more necessary (Collins *et al.* 2007). Moreover, ecological issues are concerns that many companies now articulate (Starkey and Welford 2001). And furthermore, where privately owned land contains components of potentially significant ecological value, and future site re-development is a consideration to realize full economic value, a number of issues and potential tradeoffs arise. Indeed government guidance 'Planning Policy Statement 9' advises that if a site has "*significant biodiversity or geological interest of recognised local importance*" then the developers should "*aim to retain this interest or incorporate it into any development of the site*" (DCLG 2005b).

The presence of protected species is often perceived as a hurdle in the development process. Although the great crested newt (*Triturus cristatus*) population has suffered considerable decline within its natural range over the last century, it is common on suitable development land (Stuart *et al*. 2004). In Britain it is protected under the Conservation (Natural Habitats &c) Regulations 1994 where Regulation 39 strictly protects both individual newts and their habitat. Where such protected species are present on private land legal compliance is paramount but there is also an opportunity for enhancement. In order for any such protection and conservation activities to proceed, detailed ecological survey needs to be undertaken to characterize available habitat which forms a backdrop for the formulation of management options.

This thesis draws on evidence gathered from a privately owned woodland in Hertfordshire, United Kingdom which is known to contain a population of the protected great crested newt (*Triturus cristatus*) (Herbert 2001, 2003, 2004), and which may be impacted by nearby site re-developments.

To contribute further to sustainability, woodlands, including those with protected species presence can be managed to incorporate human use. In this way, land owners can increase the wellbeing of their staff. This case study considers the possibility of creating trails within the woodland for staff to enjoy at lunch times, thus enhancing their working environment. Indeed, local authorities have a duty to educate the public on nature conservation issues under Section 25 of the Wildlife and Countryside Act 1981 (HEF 2006) and the inclusion of such facilities may be looked at favourably. In addition, the erection of education boards within the woodland is considered.

1.2. Research Aims and Objectives

1.2.1. Aims

- To produce management options for a woodland area containing a population of the protected great crested newt (*Triturus cristatus*).

- To investigate the compatibility of environmental sustainability aspirations i.e. managing private woodland for conservation and biodiversity, alongside other social and economic sustainability goals.

1.2.2. Objectives

- To carry out a detailed ecological survey and to display findings in a geographical information system (GIS)

- To develop a management plan for the site, which will be incorporated into the GIS. This will incorporate:

    a) practical options available to conserve and enhance the *T. cristatus* population and the biodiversity of the woodland area

    b) considerations of other land owner goals

2. Literature Review

2.1. Environmental protection and development

2.1.1. *S*ustainability and business

The Brundtland Report *Our Common Future* defined sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED 1987). This statement recognises that sustainability is about rights to welfare for both present and future generations (Asheim *et al.* 2000; Turner 2006). Welfare includes environmental, social and economic factors, which are all affected by the impacts of business and development (Bansal 2002). It can therefore be said that business has an important role to play in meeting the goals of sustainability and Hart (1997) argued that sustainability goals will not be reached without business actively engaging with its principles.

The literature indicates an awareness of the benefits that sustainable practice can have for the competitiveness and profitability of business (Collins *et al.* 2007), indeed the World Business Council for Sustainable Development recognises that sustainable development makes business sense (Schmidheiny 1992). In addition, in the context of a company's aspirations to carry out site redevelopments, incorporating biodiversity enhancement and species protection, may be looked favourably upon as a contribution to sustainable development, as opposed to impinging the proposed plans on a Greenfield site.

2.1.2. Development and the protection of biodiversity

Biodiversity is the "*variety of life on Earth and the natural patterns it forms*" and maintaining it is central to sustainable development (CBD 2008). It provides a number of elements that we cannot live without – food, water and oxygen - as well as enriching our quality of life by providing relaxation and health (HEF 2006). However, there is a large body of evidence that suggests a global decline in biodiversity, largely as a result of development and agricultural activity (Henle *et al.* 2008; Young *et al.* 2005; JNCC 2008). ('Development' is used here to encompass the main forms of land use change for example the construction of housing developments and industrial parks or raw material extraction). Accordingly in 1992 at the Rio de Janeiro 'Earth Summit' over 150 countries, including the UK signed the 'Convention on Biological Diversity' which, under Article 6a obliged them to "*develop national policies, plans and programmes for the conservation and sustainable use of biological diversity'*.

Subsequently European legislation on the conservation of biodiversity has been formulated to ensure that economic growth and development do not compromise with these long-term aims (Etienne *et al.* 2003). The Directive on the Conservation of Natural Habitats of Wild fauna and Flora [92/43/EEC], or the so-called 'Habitats Directive' binds European Union members to maintain natural habitats and species of wild flora and fauna "at favourable conservation status" (McLean *et al.* 1999). This is transposed into UK law as the Conservation (Natural Habitats, & c.) Regulations 1994 (as amended), which under Schedule 2, lists those protected European species.

To implement the aims of the Habitat Directive and to comply with the obligations attached to the signing of the Rio Convention, a UK Biodiversity Action Plan (BAP) was published in 1994 with the aim to '*conserve and enhance biological diversity within the UK"*. In addition, Local Biodiversity Action Plans were formulated so that targets are realised on the ground (HEF 2006). Within the UK BAP there are also Species Action Plan (SAP) largely for those species listed under Schedule 2 of the 1994 Regulations. Their primary aim is to maintain the named species' population status and existing range. Within the SAP the potentially negative impact that development can have on the species is identified and local authorities are encouraged to contribute to their conservation through promoting favourable management (English Nature 2001; Langton *et al*. 2001).

An understanding of planning policy and process is essential in order to understand provisions for biodiversity and protected species in the development process. Additionally, an awareness of government guidance on biodiversity conservation and species protection is important. Local Planning Authorities (LPAs) play a central role in development control and when assessing proposals, sustainable development (including all environmental, social and economic aspects) is their primary guide (English Nature 2001). Indeed with biodiversity as a key aspect of environmental sustainability, the Biodiversity Duty which is set out in Section 40 of the Natural Environment and Rural Communities Act (NERC) 2006 obliges local authorities to "*have regard, so far as is consistent with the proper exercise of those functions, to the purpose of conserving biodiversity*".

Planning Policy Statement 1 sets out how planning policy will contribute to sustainable development and states its aim to take account of "*the conservation and enhancement of wildlife species and habitats and the promotion of biodiversity…*" (DCLG 2005a). In addition government 'Planning Policy Statement 9' outlines how biodiversity is to be considered fully as part of planning applications and advises that if a site has "*significant biodiversity or geological interest of recognised local importance*" then the developers should "*aim to retain this interest or incorporate it into any development of the site*" (DCLG 2005b). Associated guidance for LPAs, Planning Policy Guidance note 9: Nature Conservation (PPG9) [England], details the government's objectives regarding conservation and ensures that biodiversity protection and enhancement are taken into account in planning decisions (Oxford *et al.* 2007; Froglife 1998). This guidance highlights how protected species are regarded as a material consideration in planning applications and that LPAs have a responsibility to prevent developments occurring if any listed population may be disturbed leading to a compromise of its conservation status. LPAs are encouraged to impose conditions to safeguard their interests including mitigation measures (see section 2.3.2) (Froglife 1998).

Balancing biodiversity conservation with sustained economic development is a difficult task (Semlitsch 2000). Private landowners account for the majority of UK land cover and therefore are in a prime position to, and must, make a positive impact on the biodiversity agenda (HEF 2006). Indeed the government's Biodiversity Strategy for England "Working with the grain" not only aims for minimal impacts on biodiversity as a result of planning, construction, and regeneration, but aims to enhance biodiversity by making it an integral consideration in policies and decisions made in the development process (DEFRA 2002). It also states "*we want to see companies automatically* *engaging in the management of and reporting on biodiversity as an integral part of their business operations and processes*" (DEFRA 2002). The strategy also emphasises the opportunity for increasing the chance for green spaces to be valued by people, recognising the important contribution they can make to wellbeing through providing recreational benefits which add to people's quality of life (DEFRA 2002).

2.2. Ecology of the great crested newt (Triturus cristatus)

2.2.1. Distribution and legal status

The great crested newt (*Triturus cristatus*) is one for four European newt species. Although widespread across most of North West Europe (Figure 1) like many other amphibian species, its population has suffered considerable decline within its natural range over the last century (Pechmann *et al.* 1991; Semlitsch 2000; Stuart *et al*. 2004). Indeed in Hertfordshire, UK, although there is a wide distribution of the species, a widespread decline has been observed; since 1990 only 18 ponds have been observed to have a positive presence of newts (HEF 2006).

These declines are thought to be a result of a combination of factors including pollution, global climate change and poor management, but largely due to habitat destruction and modification and the resultant fragmentation and isolation of populations (Collins and Storfer 2003; Edgar *et al.* 2005; McLean *et al.* 1999). As a result, *T. cristatus* is protected under both European and UK legislation. Under European law it is listed in Annexes II and IV of the EC 'Habitats and Species Directive' (Council Directive 92/43/EEC (a) on the Conservation of Natural Habitats and of Wild Fauna and Flora). Annex IV specifies that it be provided strict protection. This is implemented through national legislation of member states and in Britain this is the Conservation (Natural Habitats &c) Regulations 1994. Regulation 39 strictly protects both individual newts and their habitat and consequently the species is one of 400 priority species which has been afforded specific Species Action Plans (SAP) (McLean *et al*.1999).

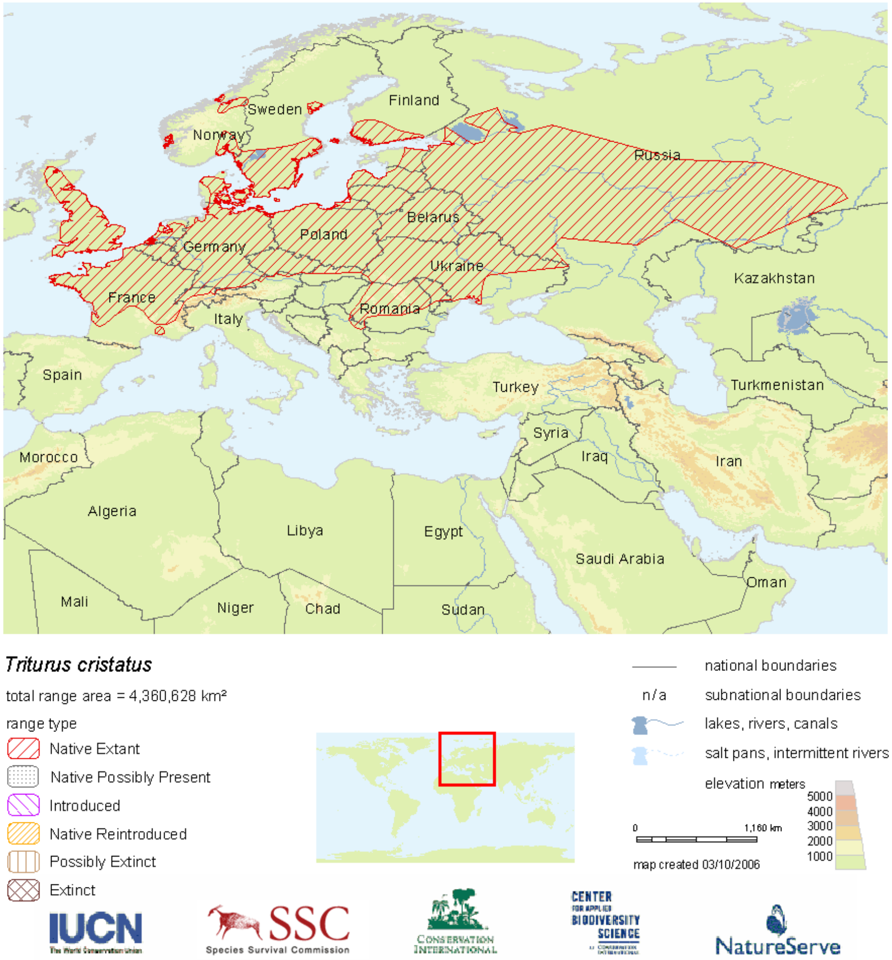

Figure 1 Distribution of the great crested newt (*Triturus cristatus*)

(Source: IUCN 2008)

2.2.2. Life history

Research efforts to understand best ways to conserve amphibians have increased significantly in recent years due to global declines, range constrictions and extinctions (Blaustein *et al*. 1994; Wake 1998). This research has shown how important an understanding of amphibian population biology is in efforts to conserve pond environments (Griffiths 1997). If populations of *T. cristatus* are to be effectively managed and conserved, especially in the light of potential negative impacts from development, it is crucial that there is an in-depth understanding of the species' ecology including its life history, habitat requirements and behaviour, both at the population and metapopulation level (English Nature 2001; Semlitish 2008). Griffiths (1997) has shown how conservation of amphibian species can be significantly improved with an understanding of both the life history and population biology of species, these understandings are reviewed below.

Amphibians have complex life cycles at three levels of influence, namely the aquatic habitat, their terrestrial landscape and their metapopulation structure (Cushman 2006; Griffiths 1997). Indeed, *T. cristatus* has a biphasic lifecycle, using both land and water habitats throughout it's lifecycle. This adaptation means that they can be successful when their breeding ponds are temporary (Griffiths 1997). As a result of this and the fact that they have a sensitive skin they are also often considered to be bio-indicators of the general health of an ecosystem (Collins and Storfer 2003).

An understanding of the life history of *T. cristatus* is fundamental when making conservation decisions since its elements determine the species' habitat requirements (Griffiths 1997). Adults move into ponds around March each year, by the end of March males begin to perform a 'dance' to females in open water areas; males, release a packet of sperm which the females then pick up and fertilize. Females then deposit around 250 eggs individually on aquatic vegetation throughout the breeding pond between March and May (Arntzen and Teunis 1993; Edgar and Bird 2006; Griffiths 1997). Eggs are deposited singly on submerged marginal plants such as *Nasturtium officinale* which is broad leaved and flexible so that after deposition the female can fold it over thus hiding the egg from predators (Langdon *et al.* 2004; Edgar and Bird 2006). Larvae hatch after 10-20 days; their survival dependant on a number of factors including predation, pond desiccation, competition and temperature (Griffiths 1997; Semlitsch 2000).

The time spent in breeding ponds varies among individuals between 1-7 months (Langton *et al.* 2001). But it has been found that the majority of adults migrate from the breeding ponds between May and July, and usually after periods of rain. Once on land *T. cristatus* travels mainly at night and prefers to over-winter in woodland, which provides protection from exposure and freezing (Langton *et al.* 2001).

2.2.3. Habitat requirements

The habitat requirements of *T. cristatus* are a lot more specialised than other palaearctic newt species (Arntzen and Teunis 1993). As already established, they require both aquatic and terrestrial habitats throughout their lifecycle. The main requirements, preferences and dislikes of *T. cristatus* are summarised in Table 1.

T. cristatus breeds in ponds, where the presence of suitable aquatic vegetation is critical as it provides both shelter against predation and somewhere to deposit their eggs (Denoel and Lehmann 2006). There should also be some open water in order for females to observe males carrying out breeding displays.

Networks or clusters of ponds linked by suitable habitat are also essential features for the maintenance of long-term healthy newt populations, especially if any of the ponds are susceptible to desiccation (Edgar and Bird 2006; Griffiths 1997). Concurrently, the literature suggests that such density independent factors such as pond longevity play an overriding role in amphibian population size compared to density dependent factors such as competition (Griffiths 1997). Because of the metapopulation structure of newt populations it is essential that ponds exist in groups so that both sources and sinks are provided, allowing natural extinctions and re-colonisations to occur (Griffiths 1997).

Although ponds that dry out completely before eggs have hatched are lethal to larvae (Denoel and Lehmann 2006), *T. cristatus* has evolved means by which to cope with changes in pond quality as well as desiccation. In fact their lifecycle is well suited to the drying up of temporary ponds and it may be to their advantage to breed in such ponds due to the effect of desiccation on predators such as waterfowl and fish (Griffiths 1997; HEF 2006). Petranka and Holbrook (2006) also emphasise the importance of having a diversity of ponds in an area which have variable hydroperiods. They suggest that this kind of variability creates spatio-temporal variability in predation risk and therefore increases the probability that juveniles will be recruited to the adult population (Petranka and Holbrook 2006).

Table 1 Key habitat requirements, preferences and dislikes of *T. cristatus*

	Key Point	Main Reference(s)
Aquatic Habitat	**Must have…**	
	• Suitable aquatic vegetation for shelter and egg laying	Denoel and Lehmann (2006)
	• Some open water for breeding displays	Griffiths (1997)
	• Networks of clusters of ponds linked by suitable habitat	Edgar and Bird (2006)
	Prefer…	
	• Still, mid succession ponds with surfaces up to 25-50% emergent vegetation and 50-75% submerged vegetation	Oldham (1994)
	• No shading on southern margins	Forestry Commission (2007)
	• Broadleaved plants such as *Alisma plantago-aquatica*, *Myosotis scorpioides*, *Mentha aquatica* and *Veronica beccabunga*	
	• Small-medium size ponds (50-250m^2) over 50cm in depth	HEF (2006)
	• A diversity of ponds in the area with different hydroperiods	Petranka and Holbrook (2006)
	Dislike/ cannot tolerate…	
	• Presence of *Crassula helmsii* – reduces breeding success	Langdon *et al*. (2004)
	• Presence of fish and waterfowl	Griffiths (1997)
	• The silting up of ponds	Oldham (1994)
Terrestrial Habitat	**Must have…**	
	• Suitable foraging, resting and shelter habitat such as well developed litter layers, dense shrub layers and glades, dead wood, rocks and logs	Forestry Commission (2007) Latham *et al.* (1996);
	• Connectivity between aquatic habitats for dispersal	Edgar & Bird 2006
	• At least 0.4ha of suitable habitat within 500m of breeding pond	Arntzen and Teuniiss (1993) Oldham (1994)
	Prefer…	
	• Unanimously thought to prefer open deciduous woodland – providing diverse understories	Forestry Commission (2007)
	• Availability of ditches and hedge banks due to the microclimate they provide	Langton *et al.* (2001)
	Dislike/ cannot tolerate…	
	• Steep banks	Lan and Verboom (1990)
	• Open fields and pastures	

Terrestrial habitat surrounding the breeding pond is essential for the health and persistence of populations as it is central in determining *T. cristatus's* dispersal ability in the environment (Langton *et al*. 2001). *T. cristatus* uses its terrestrial environment to forage for invertebrate prey, to disperse and to rest; it is unanimous throughout the literature that deciduous woodland is the favoured habitat of the crested newt (e.g.

Latham *et al.* 1996; Oldham et al. 2000; Swan and Oldham 1993). Open woodlands are preferred as they have more diverse understories and provide greater opportunities for foraging (Forestry Commission 2007). Latham *et al.* (1996) highlight the importance of dead wood on woodland floors by finding a positive correlation between the amount of dead wood and population density. This may be linked to the availability of invertebrates, which gather under logs and other debris and provide food for *T. cristatus* (Edgar and Bird 2006; Langton *et al*. 2001).

Connectivity is another important factor for the survival of the great crested newt. Woodland provides this connectivity for migration as well as providing shelter from bad weather and refuge from desiccation (Griffiths 1997; Langton *et al*. 2001). Within well connected landscapes small numbers of individuals have been found to disperse as colonisers up to 1000m from their breeding pond (Arntzen and Wallis 1991) and Arntzen and Teuniis (1993) found that they travel up to 800m from their breeding ponds. Despite newts being observed to travel these distances, it is thought that adults usually spend the majority of their lives within just 200-250m of the breeding pond, with densities of newts naturally decreasing with distance from ponds (HEF 2006; Langton *et al.* 2001). Indeed Semlitsch and Bodie (2003) found that adult newts mainly travel between 142m to 289m from the edge of breeding ponds. Moreover, in Jehle (2000)'s study, it was found that 95% of refuges for 30 radio tagged crested newts lay within 63m of breeding ponds and 50% of these were found within 15m of the waters edge.

Oldham (1994) estimated that at least 0.4 ha of suitable breeding habitat is necessary within 500m of breeding ponds, to sustain viable populations of *T. cristatus*. So, although type and quality of terrestrial habitat is important, *area* is also an issue to be considered when the aim is the maintenance of a long term and healthy population. As a result of these findings Natural England recommends that newt habitat be considered to extend up to 500m from a breeding pond (English Nature 1996). Unfortunately fragmentation has become increasingly prevalent due to deforestation and associated developments, leading to smaller and more isolated populations, often with less habitat area available than this. This makes populations much more vulnerable to extinction as it creates barriers to natural dispersal patterns (Denoel and Lehmann 2006).

2.2.4. Population dynamics and metapopulation structure

Population dynamics, especially metapopulation structure and dispersal of *T. cristatus* is crucial to the understanding of the species and any effective management plan to conserve it (Semlitsch 2000; 2008). A metapopulation can be defined as *"a collection of partially isolated breeding habitat patches, connected by occasionally dispersing individuals whereby each patch exists with a substantial extinction probabilit*y" (Smith and Green 2005). In light of this, we can understand that populations cannot be considered in isolation, but as part of source-sink dynamics. Metapopulation theory highlights the dependence on other nearby populations for the persistence of a species, which leads to the conclusion that higher pond densities will support higher numbers of individuals in a population.

Conversely, other authors such as Petranka and Holbrook (2006) suggest an alternative to metapopulation structures, at least at the local scale. They suggest that amphibians function in patchy populations surrounding ponds, and move rapidly between local ponds. This concurs with Smith and Green (2005) who suggest that when pond populations are less than 10km apart, metapopulation organisation is less prevalent. If this is the case then it has implications for local pond restoration projects where ponds are close together. Petranka and Holbrook (2006) go on to suggest that where ponds are in close proximity (<500m) restoration projects should consider populations to be patchy and create ponds accordingly. Pentranka and Holbrook (2006) go on to stress the importance of understanding population dynamics at the local scale so that individual restoration projects can be tailored to the specific needs of populations. In agreement, Arntzen and Teunis (1993), in a review of population data from a number of locations, concluded that population processes vary between sites.

2.3. Management of the great crested newt (Triturus cristatus)

2.3.1. Development and *T. cristatus*

Because *T. cristatus*'s habitat preferences often coincide with land suitable for development (English Nature 2001), there is frequent conflict with conservation interests. In these situations land managers and owners need to pay careful attention to the legislation (see section 2.2.1) (Edgar *et al*. 2005; English Nature 2001). As previously mentioned because of the protected status of *T. cristatus*, LPAs regard their presence as a material consideration in development proposals. Therefore, wherever a population resides and land use change or development is planned, LPAs will require additional information such as site-specific impact assessments and mitigation proposals before planning permission can be considered (English Nature 2001). Planning applications may then be refused on the basis of harmful predicted impacts on newt populations. It should also be noted that reckless as well as intended impacts on newts are regarded as offences under the Countryside and Rights Of Way Act (CROW) (Langton *et al.* 2001). If the proposal is agreed then mitigation measures are a legal requirement if the proposed development may interfere with a newt population.

The growing amount of conservation legislation is promising as it ensures the serious consideration of implications of developments on the species, aiding LPAs to make informed decisions (Langton *et al.* 2001; McLean *et al.* 1999). Despite this, the effectiveness of European legislation to protect such endangered species has been debated. It is largely thought to have been successful at preventing direct exploitation and persecution, however it is arguable whether it fully deals with issues related to land use change such as threats from forestry, transport and developments for housing (Edgar *et al*. 2005; McLean *et al*.1999). This is largely because the legislation simply prohibits certain actions with regard to newts, rather than specifying mitigation methods or placing any duty to be proactive towards conservation (English Nature 2001; Langton *et al.* 2001). Indeed McLean *et al.* (1999) propose that endangered species legislation cannot by itself tackle all threats posed to those species. They instead advocate the need for more proactive conservation involving local communities and a more positive response to endangered species than simply adhering to legal prohibitions (McLean *et* *al*. 1999). Additionally, ever more stringent laws protecting threatened species, such as *T. cristatus*, often conflict with government targets to enhance biodiversity (Harrop *et al.* 1999) and can be confusing when considering the most sustainable options when planning for redevelopment of sites. Section 74 of the CROW Act 2000 goes someway to rectifying this by placing a duty on government departments in England and Wales to advance biodiversity conservation (Langton *et al.* 2001).

Because metapopulation structures may be important in maintaining viable populations of crested newts and their ability to travel up to 1km from their breeding ponds (see section 2.2.4) any loss of terrestrial habitat, especially that closest to ponds, can have harmful effects (English Nature 2001; Griffiths and Williams 2000). Newts disperse to forage and thus buildings and roads, as parts of proposed development plans, may act as barriers to dispersal, fragmenting habitat and splitting newts into small isolated populations. These effects will be detrimental to newt populations creating risk of genetic impoverishment and extinction (Froglife 1998; Griffiths and Williams 2000). Simple changes to habitat for aesthetic reasons, increased public access, and changes in habitat management may also cause negative impacts (Froglife 1998). Indirect changes such as movements of the water table, changes in shade and siltation may also have impacts on newt populations (Semlitsch 2000).

2.3.2. Mitigatory measures and *T. cristatus*

The Polluter Pays Principle states that '*environmental costs should fall on those that impose them*' (DCLG 2005a). Accordingly, increasingly as part of development proposals, mitigatory plans are formulated to reduce potential negative impacts on great crest newts. This is a difficult task and often the lack of, or deficient, knowledge can prevent the full prediction of ecological impacts (Etienne *et al.* 2003). Mitigation can be defined as "*measures envisaged in order to avoid, reduce and if possible remedy significant adverse effects*" (Glasson *et al.* 1999). It thus involves the planning for ways to reduce any predicted impacts on the newt population and will often involve habitat enhancement, habitat creation and also translocation (Edgar *et al.* 2005). This may in fact be a legal requirement depending on the nature of the proposed project and the predicted impacts (Edgar *et al.* 2005). The translocation of newts and destruction of their natural habitat should only be considered a last resort and only as a part of a wider programme that aims to conserve the population (English Nature 2001). Such translocation programmes must also be executed under strict protocols and with a licence from Natural England.

In a study carried out by Edgar *et al.* (2005), they found that development, since 1990 has resulted in a 72% loss in aquatic habitats. And although there has been a remarkable growth in the number of mitigation projects in England, the associated programmes have been inadequate in terms of the provision of number and surface area of new aquatic habitats created as part of translocation programmes. In terms of impacted terrestrial habitat their study also concluded that as a result of developments, although habitat enhancement normally occurred, roughly 27% of newt terrestrial habitat was destroyed and it is unknown how effective the mitigation programmes have been, especially considering the resultant smaller habitat patches which often result (Edgar *et al.* 2005). The great crested newt mitigation guidelines published in 2001 however have gone some way to rectifying this by specifying that there should be no net loss in *T. cristatus* sites and stipulating that post-development monitoring is carried out (English Nature 2001). Indeed Regulation 44 (3) b of the Consercation Natural Habitats, & c.) Regulations 1994 (as amended) states that any action authorised as part of a conservation licence "*will not be detrimental to the maintenance of the population of the species concerned at a favourable conservation status in their natural range*".

2.3.3. Importance of woodlands and ponds for biodiversity

Woodland is the natural vegetation cover over the majority of the UK and is important for most wildlife groups (HEF 2006). Ancient woodland is particularly valuable and LPAs are given guidance, through Planning Policy Statement 9 not to grant planning permission to developments that will cause a loss or deterioration in its status, unless "*the development in that location outweighs the loss of the woodland habitat*" (DCLG 2005b). Woodlands are an important reservoir of biodiversity and the UK BAP is adverse to any conversion of broadleaved woodlands to other uses but aims to conserve the woodland extent and restore ancient woodland sites (Haines-Young *et al.* 2000).

Ponds are known to contribute significantly to the UK's biodiversity, being able to support such a rich flora and fauna that they can achieve a higher diversity of species compared to an equal area of differing terrestrial habitat (Drake 1995; Duigan and Jones 1997). Ponds support more species than any other freshwater habitat including more rare species (Cereghino *et al*. 2008). In fact, an estimated one eighth of British flora is found in and around ponds and they can often represent biodiversity 'hot spots' (Cereghino *et al.* 2008; Drake 1995). Indeed Scheffer *et al.* (2006) show that small isolated ponds often contribute disproportionately to biodiversity. Sadly however, 150 of the 280 wetland invertebrates listed in the International Union for Conservation of Nature Red list are found in ponds (Drake 1995). This is significant considering the small surface area that ponds cover in the UK and emphasises the importance of pond conservation.

2.3.4. Conservation and management of *T. cristatus* in woodland ponds

Woodland management and conservation is not a static subject; when implemented it has aims to enhance both flora and fauna but the core principles used in formulating plans cannot be described as absolute (Saunders 1993). In fact because woodland is the natural climax community in much of Britain it should not require too much attention, however due to fragmentation they are now vulnerable to outside influences and lack the genetic diversity to be self-sustaining (Saunders 1993).

Ponds can be defined as "*Water bodies between 1m^2 and 2ha in area which may be permanent or seasonal, including both man-made and natural water bodies*" (Biggs *et al*. 2005). Between 1880 and 1993 there was an estimated 75% decline in the number of ponds in Britain from 1.3 million to 375,000. In Hertfordshire during roughly the same period the number of ponds halved from 7,007 to 3,595 (HEF 2006). However, according to the Hertfordshire Habitat survey 1994-1996 only 2608 ponds now exist. Neglect of ponds and surrounding habitat, one of the main causes of pond loss, can cause them to become silted and over-shaded, both of which lead to ponds being less suitable breeding sites (English Nature 2001; Langton *et al.* 2001). Ponds in their late successional stages are of little value to *T. cristatus*, though they will provide value to other species, in particular invertebrates (Langton *et al.* 2001).

Not only has the number of ponds declined but their quality has also suffered. In 1986 a pond condition survey in Hertfordshire revealed that, from a sample of 730 ponds, 80% were defined as ‘poor’. It is also worrying that a revisit to the 50 highest quality ponds in 1993 revealed that only two ponds were adequately managed and 5 of them no longer existed (HEF 2006). This loss of ponds increases the likelihood of local extinctions occurring (HEF 2006), emphasising the importance of their active management.

Unfortunately there is a general lack of knowledge on the ecology and management of ponds (Biggs *et al.* 1995; Gee *et al.* 1997; Oertli *et al.* 2002). This is due to the lack of any rigorous scientific research (Williams *et al.* 1999). However Biggs *et al*. (1994) have outlined four main principles on the management of woodland ponds:

- make the most of existing habitats
- avoid making ponds that look the same - in any area retain examples of all stages of succession and a variety of depths
- do not suddenly change the management regime of a pond or its surrounds
- maintain buffer zones to support natural hydrological regimes

These principles should be integrated with the primary habitat requirements of *T. cristatus* for the completion of their life history; namely breeding ponds, terrestrial refugia and foraging habitat (Forestry Commission 2007; Semlitsch 2008). It must also be considered how a management plan for a ‘Flagship Species’ such as *T. cristatus* might lead to a trade-off for the needs of other species and biodiversity as a whole (Semlitsch 2000). Management should support a range of different vegetation types and ideally a full range pond successional stages allowing a variety of species with differing habitat requirements to inhabit the area at any one time (Angelibert *et al*. 2004).

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Managing woodlands for conservation and biodiversity on private land

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Abstract

The concept of sustainable development has become a central and fundamental aim of governments, and increasingly corporate strategy. Conservation and biodiversity are fundamental to this agenda. Although research has assessed the conflicts between sustainable development and biodiversity conservation at global, regional and landscape levels, few authors have focused on the local scale. Where privately owned land has significant ecological value, and future site re-development is a consideration to realise full economic potential, a number of issues and potential tradeoffs arise. Indeed sustainability involves not just environmental aspects but social and economic goals. This paper draws on evidence gathered from a privately owned woodland in Hertfordshire, UK which is known to contain a population of the protected great crested newt (*Triturus cristatus*). A vegetation survey was carried out and geo-referenced data incorporated into a Geographical Information System (GIS). A management plan has been designed to protect and enhance the *T. cristatus* population and the inherent biodiversity of the woodland, as well as to contribute to social and economic sustainability. The implications of different management options and nearby development on the site are discussed and potential tradeoffs identified. This study has shown the usefulness of GIS in the display and analysis of ecological survey findings and the presentation of management options. The research has demonstrated that with the implementation of a management plan landowners can contribute to environmental, social and economic sustainability as well as creating corporate benefits. The study has highlighted a number of knowledge and research gaps that need attention, in particular the investigation of tradeoffs and issues that arise at the local scale between conservation, development and other landowner objectives.

Keywords: habitat management; great crested newt (*Triturus cristatus*); sustainable development; biodiversity; conservation; tradeoffs

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Managing woodlands for conservation and biodiversity on private land

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Abstract:

The concept of sustainable development has become a central and fundamental aim of governments, and increasingly corporate strategy. Conservation and biodiversity are fundamental to this agenda. Although research has assessed the conflicts between sustainable development and biodiversity conservation at global, regional and landscape levels, few authors have focused on the local scale. Where privately owned land has significant ecological value, and future site re-development is a consideration to realise full economic potential, a number of issues and potential tradeoffs arise. Indeed sustainability involves not just environmental aspects but social and economic goals. This paper draws on evidence gathered from a privately owned woodland in Hertfordshire, UK which is known to contain a population of the protected great crested newt (*Triturus cristatus*). A vegetation survey was carried out and geo-referenced data incorporated into a Geographical Information System (GIS). A management plan has been designed to protect and enhance the *T. cristatus* population and the inherent biodiversity of the woodland, as well as to contribute to social and economic sustainability. The implications of different management options and nearby development on the site are discussed and potential tradeoffs identified. This study has shown the usefulness of GIS in the display and analysis of ecological survey findings and the presentation of management options. The research has demonstrated that with the implementation of a management plan landowners can contribute to environmental, social and economic sustainability as well as creating corporate benefits. The study has highlighted a number of knowledge and research gaps that need attention, in particular the investigation of tradeoffs and issues that arise at the local scale between conservation, development and other landowner objectives.

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1 Introduction

Sustainable Development has been broadly defined as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED 1987). This involves environmental, social and economic aspects (Bansal 2002). With the wide recognition that sustainability is of vital importance to our planet's future, the concept has become one of the central and fundamental aims of government, and increasingly corporate, strategy (e.g. Aigner *et al.* 2003). Hart (1997) has stated that sustainability goals will not be reached without business actively engaging in its principles and it has been suggested that in fact sustainable practice can increase the competitiveness and profitability of business (Collins *et al.* 2007; Lo and Sheu 2007).

Biodiversity, “*the variety of life on Earth and the natural patterns it forms*” (CBD 2008), and the protection of endangered species are central components of sustainability. Global declines of biodiversity and the increasing loss and extinction of species has largely been associated with development and agriculture (Dirzo and Rven 2003; Milder *et al.* 2008). (‘Development’ is used here to encompass the main forms of land use change i.e. the construction of housing developments and industrial parks or raw material extraction). Although research has assessed the conflicts between biodiversity conservation and sustainable development at global (e.g. Swanson 1999), regional (e.g. Henle *et al.* 2008) and landscape levels (e.g. Leita and Ahern 2003), little has been studied on the tradeoffs between biodiversity conservation and the protection of species against development aspirations at the local scale. Neither has research focused on how strong international commitments to protect biodiversity and endangered species can practically be applied at the local management scale (Thompson and Starzomski 2007). Indeed where significant ecological value exists on private land but where future site redevelopment is a consideration to reach full economic potential, a number of issues and potential tradeoffs arise. Guidance to local authorities in the UK states that if a site has “*significant biodiversity or geological interest of recognised local importance*” then the developers should “*aim to retain this interest or incorporate it into any development of the site*” (DCLG 2005b). How this is worked out in practice however has not been the subject of a significant discussion in the literature.

Triturus cristatus (great crested newt) is one of four European newt species, and although it is widespread across most of northwest Europe, like many other amphibian species it has suffered significant decline within its natural range over the last century (e.g. Blaustein *et al.* 1994; Pechmann *et al.* 1991; Stuart *et al.* 2004). *T. cristatus* is the most strictly protected amphibian in Britain (Langton *et al.* 2001) and the Conservation (Natural Habitats & c.) Regulations 1994 (as amended) command that no compromise to their conservation status occurs as a result of development activity. The habitat preferences of *T. cristatus* often coincide with land suitable for development; this causes frequent conflicts with conservation interests (Oldham and Humphries 2000; English Nature 2001). Indeed the decline of the species is thought to be largely associated with habitat destruction, modification and resultant fragmentation and isolation of populations (e.g. Collins and Storfer 2003; Edgar *et al.* 2005).

Understanding the life history, habitat requirements and local population dynamics of *T. cristatus* is essential in conservation efforts and in the production of effective management plans (Griffiths 1997; Petranka and Holbrook 2006; Semlitsch 2000; 2008). *T. cristatus* has a biphasic lifecycle requiring both aquatic and terrestrial habitats and its main habitat requirements, preferences and dislikes are summarised in Table 1 (view in literature review). Time spent in breeding ponds varies between individuals from 1-7 months but generally adults leave the pond between May and July after periods of rain (Langton *et al.* 2001). Woodland is the preferred terrestrial habitat as it provides optimal foraging, dispersal, sheltering and resting habitat (Griffiths 1997; Latham *et al.* 1996; Oldham *et al*. 2000). Core terrestrial habitat is considered to lie within 500m of breeding ponds, where at least 0.4 ha of suitable habitat is necessary (Oldham 1994), however *T. cristatus* has been observed to disperse up to 1000m (Arntzen and Teuniis 1993; Arntzen and Wallis 1991).

Metapopulation structures may be important in maintaining viable populations of crested newts, therefore any loss of terrestrial habitat, especially that closest to ponds, can have harmful effects (English Nature 2001; Griffiths and Williams 2000). Newts disperse to forage and thus buildings and roads, as part of proposed development plans, may act as barriers to dispersal, fragmenting habitats and splitting newts into small isolated populations. These effects will be detrimental to newt populations creating risk of genetic impoverishment and extinction (Griffiths and Williams 2000). Simple changes to habitat for aesthetic reasons, increased public access, and changes in habitat management may also have negative impacts (Froglife 1998). Indirect changes such as movements of the water table and changes in shade and siltation may also have impacts on newt populations (Semlitsch 2000).

Ponds can be defined as "*Water bodies between 1 m^2 and 2 ha in area which may be permanent or seasonal, including both man-made and natural water bodies*" (Biggs *et al.* 2005). Unfortunately there is a general lack of knowledge on the ecology and management of ponds due to the lack of any rigorous scientific research (Biggs *et al.* 1995; Gee *et al*. 1997; Oertli *et al.* 2002; Williams *et al.* 1999). Between 1880 and 1993 there was an estimated 75% decline in the number of ponds in Britain from 1.3 million to 375,000 (HEF 2006). Neglect of ponds and their surrounding habitat is one of the main causes of pond loss because this can cause them to become silted and over-shaded, both of which lead to ponds being less suitable breeding sites (English Nature 2001; Langton *et al.* 2001). Ponds in their late successional stages are of little value to *T. cristatus*, however they provide much value to other species, in particular invertebrates (Langton *et al.* 2001). Not only has the number of ponds declined but their quality has also suffered. In 1986 a pond condition survey in Hertfordshire revealed that, from a sample of 730 ponds, 80% were defined as ‘poor’. It is additionally worrying that a revisit to the 50 highest quality ponds in 1993 revealed that only two of these ponds were adequately managed and 5 of them no longer existed (HEF 2006). This loss of ponds increases the likelihood of local extinctions occurring, emphasising the importance of their active management.

Woodlands are an important reservoir of biodiversity in the UK (Haines-Young *et al.* 2000) and the UK Biodiversity Action Plan (BAP) is adverse to any conversion of broadleaved woodlands to other uses. Ponds are also known to contribute significantly to the UK’s biodiversity, being able to support such a rich flora and fauna that they can achieve a higher diversity of species compared to an equal area of differing terrestrial habitat (Drake 1995; Duigan and Jones 1997). Additionally, an estimated one eighth of British flora is found in and around ponds and they can often represent biodiversity ‘hot spots’ (Cereghino *et al.* 2008; Drake 1995). So together, woodlands and ponds make up a significant contribution to the biodiversity of the UK.

This study aims to present practical options for a privately owned woodland site, in Hertfordshire UK, which contains locally important biodiversity and a population of the protected great crested newt (*Triturus cristatus*). Results of an ecological survey have been displayed in a geographical information system (GIS). From these results a management plan has been formulated which considers the practical options available to conserve and enhance the *T. cristatus* population and the biodiversity of the woodland area. The case study identifies that there are tradeoffs between opportunities for protection and enhancement with other corporate aims such as the potential re-development of the land to maximise its economic value. The case study shows how environmental, social and economic aspects of sustainability can be integrated into management plans and how these can provide benefits to landowners

2 Study Site

The case study site is composed of a woodland containing a number of ponds, adjacent to a Site of Special Scientific Interest (SSSI) in Hertfordshire, England. Although the SSSI is not considered a rare habitat type, it is significant within Hertfordshire and has been classified as a key Biodiversity Area in the county's BAP (HEF 2006). The currently unmanaged woodland area within the case study site covers approximately 5.2 hectares of private land where a series of ponds can be found. Newt surveys were carried out in 2000, 2002, 2003 and 2004 by consultants and three ponds were found to be inhabited by the great crested newt (*Triturus cristatus*), along with populations of the Palmate newt (*Triturus helveticus*), the Smooth newt (*Triturus vulgaris*), the Common toad (*Bufo bufo*) and Common frog (*Rana temporara)* (Herbert 2001, 2003, 2004). The surrounding habitat was at the time described as optimal for *T. cristatus*, though no detailed vegetation survey was undertaken.

Ordnance survey maps from 1883, 1896, 1925 and 1960 confirm the origin of the ponds. Ponds 1, 2 and 3 are obvious infillings of three major pits of a brick works, which appears active in the 1883 and 1896 maps. By 1925 the works have ceased and the pits seem to have become ponds. The ponds remain through to 1960 however Pond 2 (See Figure 2) appears to have decreased in size compared to present day maps.

3. Materials and Methods

Knowledge of the ecology of an area is essential when planning for sustainability (Leita and Ahern 2003). It is essential that core terrestrial habitat is geographically referenced to inform the conservation and management of local breeding populations of protected species such as *T. cristatus* and of general biodiversity (Biggs *et al.* 1995; Blackburn and Milton 1997; Semlitsch and Bodie 2003). This is vital in order to understand how *T. cristatus* will be affected by any action taken, and for monitoring purposes (English Nature 1996; Wyatt 1991). Additionally, data on the vegetation present at a site and the condition that it is in provides information about the environment as a whole. Because vegetation diversity plays a direct role in driving faunal diversity it is also a good overall indicator of biodiversity (JNCC 1993; Oertli *et al*. 2002).

A vegetation survey was conducted on eight days between 3rd and 20th of June 2008. Features were captured using a handheld GeoXT Geographical Positioning System (GPS) (Trimble GeoXT) and exported to ArcGIS 9.1. All vegetation species within 97 10m^2 random sample areas were recorded in separate layers: ground layer, mid canopy and upper canopy. General pond characteristics were recorded, but no formal pond survey was carried out. ArcGIS has been used to create a geographical information system (GIS), which displays survey data, additional findings and presents management options. Figure 2 shows the woodland area, its ponds and sample locations.

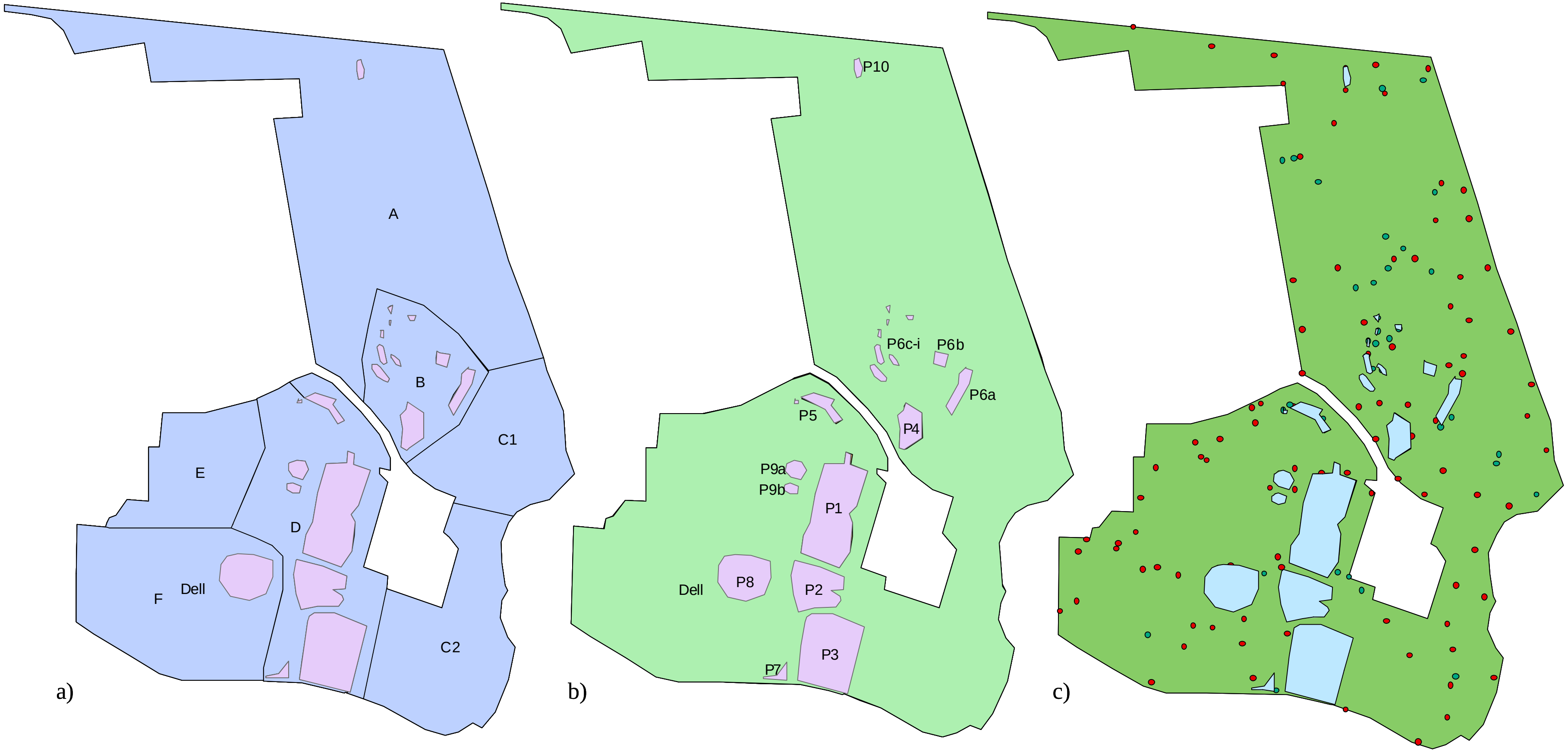

Figure 2 Maps of site created in GIS

a) Designated woodland areas
b) Observed ponds
c) Sample locations, Red = vegetation survey location, Green = point interest location

4. Results and Discussion

4.1. Survey Results

4.1.1. Woodland

The woodland area can be described as broadleaved deciduous woodland as it is composed of 10% or less conifer in the canopy (JNCC 1993). For ease of description and to represent the main habitat transitions, the woodland has been divided into segments A-F (see Figure 2a) (following Langton *et al.* 2004). The main vegetation findings are summarised below. Table 2 gives a more detailed overview and Appendix 1 gives a complete species list including abbreviations used in the GIS.

The Northern part of the woodland (A) is largely relict *Corylus avellana* coppice with Quercus standards though there is also significant cover of *Betula pendula* which has reached climax. The mid-storey is characterised by *Ilex aquifolium*, and the ground is largely bare with some areas of ancient woodland herbs, and where sunlight penetrates at the edges a rich ground flora has developed. Area B is characterised by a number of temporary and permanent ponds in various stages of succession with wetland species of ferns, sedges and grasses forming the ground flora. The canopy is dominated by fallen and dead *Betula pendula*. C1 has a species poor ground flora and is mainly bare ground. C2 is more biodiverse with a high total number of species present. Area D contains eight ponds of varying sizes and conditions. Vegetation surrounding ponds 2 and 3 is particularly overgrown (see Figure 4), the latter is described as carr rather than a pond due to the extensive *Salix cinerea* which is growing within and across it. The western end of Area E has a low diversity ground flora, but as it drops into the wetland area to the south (not marked on Figure 2 due to the inaccessibility for mapping the

Table 2 Summary of vegetation survey results

	Under-storey/ Ground flora	Mid-canopy	Upper-canopy
A	Predominantly bare ground covered in dead leaves and twigs, little sunlight penetration. Some patches of moss and frequent occurrence of *Rubus fruticosus, Pteridium, Lonicera periclymenum. Ilex aquifolium* and young *Fraxinus excelsior.*	Overhanging large *Quercus robur* on Northern boundary in poor condition. Sparse mid-canopy and low species richness. Mainly *Corylus avellana* and *Crataegus monogyna*. Some *Fraxinus excelsior, Fagus sylvatica, Carpinus betula.*	Dominated by *Quercus robur* and *Fraxinus excelsior*. Scattered *Betula pendula* and a large *Aesculus hippocastanum* attracting a seemingly large jay population.
B	A series of ditches and channels mostly full of water but silted up to varying extents. A good biodiversity is immediately apparent here with various species of ferns, sedges and grasses. Young *Fraxiuns excelsior* and *Lonicera periclymenum* are also prevalent.	Dominated by fallen dead *Betula pendula* amongst rooted *Prunus spinosa, Ilex aquifolium*, *Fraxinus excelsior*, *Crataegus monogyna* and *Corylus avellana.*	No real upper-canopy growing within this series of ditches and channels. However around edges both *Quercus* and *Fraxinus excelsior* are present.
C1	On the SW edge of this area there is a rich diversity where sunlight penetrates the edge of the wood allowing a rich ground flora to develop. The interior ground cover however is largely bare with some occurrence of *Prunus spinosa, Mercurialis perennis* and *Fraxinus excelsior.*	Most of the canopy on the Eastern margin comes from trees rooted in the SSSI. Low diversity of mid-canopy species with *Corylus avellana* and *Crataegus monogyna* dominating and some occurrence *of Ilex aquifolium.*	Dense in the central region of this area dominated by both *Quercus robur*, *Quercus petraea* and *Fraxinus excelsior*. Also present in some abundance are *Betula pubescens* and *Carpinus betulus.*
C2	A rich ground flora with evidence of animal tracks. *Urtica dioica*, *Rumex sanguineus* and *Myosotis caespitose* almost ubiquitous. *Prunus spinosa*, *Cornus sanguinea*, *Fraxinus excelsior* and *Galium aparine* very common.	Dominated by *Fraxinus excelsior* and *Crataegus monogyna.* Also presence of *Rosa arvensis*, *Rosa canina*, *Lonicera periclymenum, Cornus sanguinea* and *Acer campestre.*	Dominated by *Quercus robur* and *Fraxinus excelsior*
D	Most common species include *Urtica dioica, Symphoricarpos albus* (appears invasive), *Junus effuses, Junus inflexus*, young *Fraxinus excelsior*, *Crataegus monogyna and Brachypodium sylvaticum.*	Mainly low diversity. *Salix cinerea* is common around the ponds, especially ponds 2 and 3. Fraxinus excelsior is also dominant along with *Crataegus monogyna* and *Corylus avellana*	No real upper-canopy over ponds 2 and 3. Tress sounding ponds are mainly *Fraxinus excelsior* with some occasional *Quercus robur* and *Quercus petraea*
E	To north of area, a good diversity of species has developed. Dominant species include *Urtica dioica, Rumex obtusifolius, Rubus fruticosus, Pteridium, Lonicera periclymenum, Brachypodium sylvaticum, Crataegus monogyna*, young *Fraxinus excelsior* and *Ilex aquifolium.* Rubbish including paint tins, glass, mirror, detergent bottles are present.	Sparse mid-canopy of a combination of *Corylus avellana, Lonicera periclymenum, Ilex aquifolium* and *Fagus sylvatica.*	*Quercus robur* and *Fraxinus excelsior.*
F	Very varying topography. Southern boundary receiving plenty of sunlight and exhibiting high biodiversity. *Urtica dioica* present at almost every sample site. Some localised presence of *Fallopia japonica.* Common presence of *Rumex obtusifolius, Brachypodium sylvaticum, Mercurialis perennis, Fraxinus excelsior* and *Populus tremula.*	Where in the centre of area there is a swampy area, with probable seasonal pond presence, there are many fallen and dead *Betula pendula* and *Populus tremula* individuals. The mid-canopy is thick with main species including *Lonicera periclymenum, Fraxinus excelsior, Corylus avellana, Crataegus monogyna.* There is also presence of *Prunus avium, Prunus spinosa* and *Populus tremula.*	*Fraxinus excelsioris* present across this whole area. *Populus tremula* is also dominant. Species not present else whereon the site include *Prunus avium, Tilia platyphyllos* and *Acer platanoides.*

area), a number of wetland species are present. Area F contains two 10m deep clay pits. The western pit is dry and is thriving with *Urtica dioica* in particular. The Eastern pit is full of water that has probably drained from Pond 1 to the southwest, some water may also have drained south from the ditch which runs through area D. To the west of Area F *Populus tremula* is the dominant tree species as well as *Pteridium* on the ground. The Southern boundary of F gets plenty of sunlight and there is a large patch of *Digitalis purpurea*. Previously, orchids have been known to grow here (HMWT 1984).

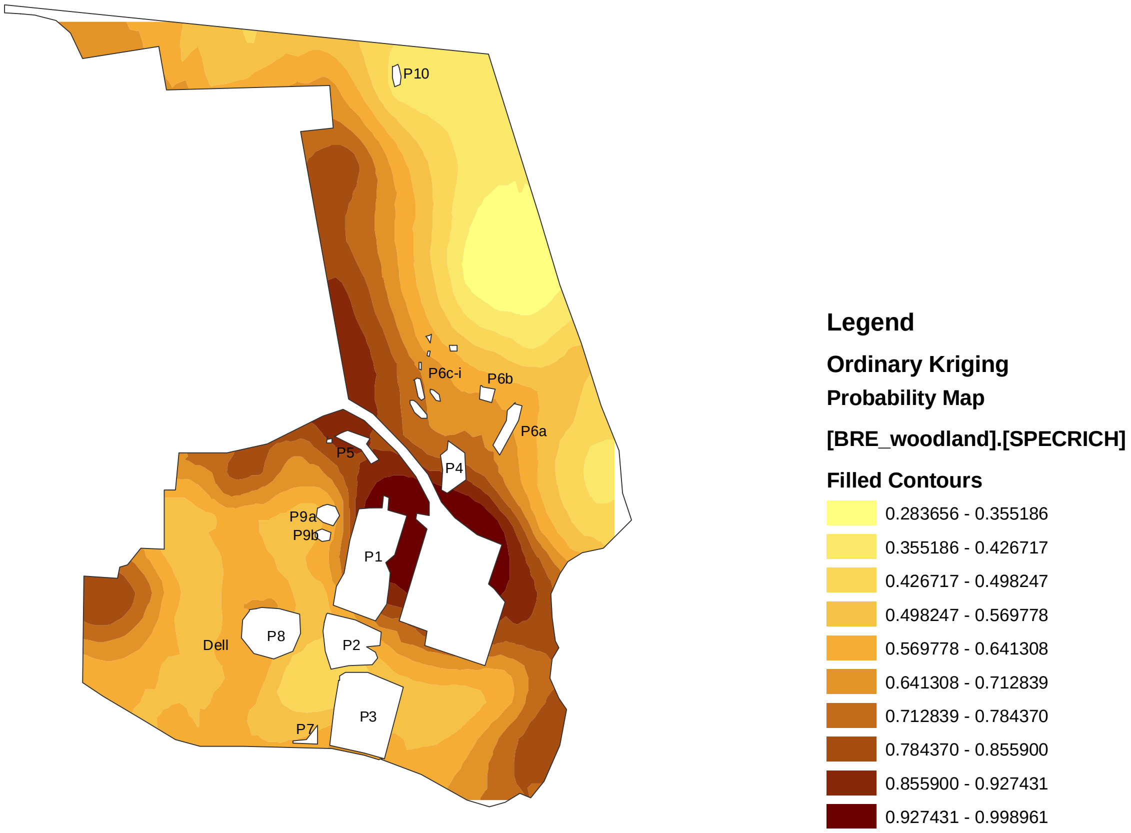

Figure 3 Species diversity map

(created in GIS using all data)

A total of 112 vegetation species were recorded at 97 point locations. Using the GIS, species diversity was mapped and results show that diversity largely depended on the ground flora diversity, and that, as would be expected, more vegetation diversity existed where more sunlight reached the ground (Figure 3).

No formal fauna survey was carried out, however, during the flora survey the following species were identified; Muntjac deer (*Muntiacus reevesi*), Fox (species unknowns), Common Blue damselfly (*Enallagma cyathigerum),* Large Red damselfly (*Pyrrhosoma nymphula),* Speckled Wood butterfly (*Pararge aegeria),* European Peacock butterfly *(Inachis io*), Great tit *(Parus major),* Common Moorhen (*Gallinula chloropus),* European Robin *(Erithacus rubecula),* squirrels, Tree-creepers and jays. There is also evidence of badgers and there are likely to be a number of bat species roosting in the woodland.

4.1.2. Ponds

Langton *et al.* (2001) suggest that for management of the great crested newt local ‘pondscapes’ should be created showing where all ponds and suitable habitats are located within 1.2km of breeding ponds. The research presented here has achieved this. At the time of survey, twenty ponds both permanent and temporary and with varying quality and size were identified (Figure 2 and 4). The core ponds (Ponds 1-5) are remnants of old brick works, and are characteristically angular in shape (Abington 1982). Ponds 1-3 and 5 are fed from surface runoff from nearby car parks and from direct precipitation. All other ponds are thought to depend upon direct precipitation apart from pond 8, thought to be a new pond formed through drainage from Pond 1. In addition to these distinct water bodies, numerous other wetland/swampy areas were found, for example in area E.

Figure 4 Photographs of ponds a) Pond 1 looking south **b)** Pond 2 looking west **c)** Pond 3 looking north **d)** Pond 4 looking northwest **e)** Pond 5 looking east **f)** Pond 6a looking north **g)** Pond 8 looking north **h)** Ponds 9a and b looking northwest

Figure 4 shows photographs of the main wetland areas of the woodland and Table 3 gives a summary of the main observations made in and around the ponds including an estimated area of each water body.

Table 3 Pond attributes observed

Pond No°	Vegetation observed in pond	Vegetation observed around pond	Size (calculated in GIS) m^2	*T. cristatus* breeding pond in 2004?
1	*Potamogeton natans*, *Elodea Canadensis*, and *Nymphaea alba*.	Pond edge is surrounded by a good diversity of plant species including *Junus inflexus* and *Junus effuses*, *Iris pseudacorus*, *Typha latifolia*, *Salix cinerea* and *Carex pendula*	1240	✓
2	No macrophytes present.	*Salix cinera*, *Corylus avellana*, *Fraxinus excelsior*, *Crataegus monogyna* and *Quercus robur*. Very shady southern margin.	565	
3	'carr': *Salix cinerea* dominated around, across and within the water body.	*Symphoricarpos albus* - present in abundance	1122	
4	*Lemna minor* – in abundance	*Iris pseudacorus* and *Corylus avellana*	229	✓
5	No vegetation observed	*Corylus avellana*, *Carex pendula*, *Junus inflexus*, *Junus effuses*, *Iris pseudacorus*, *Carex sylvatica*, *Rhododendron ponticum* and *Rubus Fruticosus*	116	✓
6a-i	No vegetation observed	Various species of ferns, sedges and grasses. Young *Fraxiuns excelsior* and *Lonicera periclymenum* are also prevalent.	280	
7	No vegetation observed	*Populus tremula* in abundance	41	
8	*Populus tremula*, *Quercus rubur* and *Cornus sanguinea*	*Urtica dioica*, *Corylus avellana* and *Quercus robur*	581	
9	No vegetation observed	*Junus effuses*, *Solanum dulcamara*, *Rumex sanguineus*, *Lazula campestris* and *Brachypodium sylvaticum*	113	
10	No vegetation observed	*Corylus avellana* and *Ilex. Aquifolium*	34	

4.2. Consequences of 'do nothing', 'protect' or 'enhance'

There seem to be three main options for managing woodlands and ponds with significant ecological value. These are to *do nothing,* to *protect the site* in its most basic form, or to *enhance* the area for conservation purposes. Each of these options has a number of implications for the future ecology of an area as well as for the landowner. The site featured here has a number of options available, and the one chosen will depend on the level of commitment the landowner is willing to provide. For this case study, the main options, and the level of commitment required for each are shown in Table 4.

Table 4 Options and level of commitment.

(L) Low= Virtually no time, effort or resources needed, **(M) Medium**= Will require time to plan, implement and monitor. Will require a commitment and an element of priority to the interests of biodiversity and species protection, **(H) High**= Will require significant time, effort and resources

		Commitment		
	Description	**L**	**M**	**H**
Do Nothing	Leaving the woodland and pond areas as they are with no habitat management.	✓		
Protect	Provide suitable quality and quantity of habitat. Provide protection from threats such as future development and disturbance.		✓	
Enhance	Enhancement: there are a number of options (see management plan). The management plan suggests a medium to high commitment option where sustainability is an aspiration.		✓	
Incorporate human use	The addition of paths within the woodland and wetland areas for staff to enjoy in breaks and for sharing with site visitors		✓	

If the *do nothing* option is chosen for this site it is likely that the *T. cristatus* population will disappear in the medium term due to the loss of the ponds as a result of succession. This decline is part of a natural process of ecological succession and is not covered by any legislation i.e. there are no requirements by law to carry out active management.

However, pursuing this option does not contribute to sustainability aims to conserve and enhance species and biodiversity. If any proposed development is likely to impact the great crested newt population, this option will not be acceptable under law and a detailed newt survey and a mitigation plan will be necessary (English Nature 2001).

If conservation and biodiversity are primary concerns then this requires the safeguarding of both aquatic and terrestrial newt habitat from any future site re-developments. Terrestrial newt habitat is considered to extend 500m from breeding ponds and therefore any development planned within such a radius will require a rigorous newt survey and an associated mitigation plan for this area (English Nature 2001). Protection means the prevention of damage to, or destruction of, breeding sites or resting places as well as ensuring that all life stages including eggs are protected against deliberate capture, killing, injury, and disturbance. This includes impacts from any activity outside of their habitat that might kill, injure or disturb them such as changes to the water table (Conservation (Natural Habitats, &c.) Regulations (1994)).

The literature survey and ecological findings confirm the case study area is optimal newt habitat and can be classified as semi-natural ancient woodland. The implementation of a management plan, where the goal is to both protect and enhance the biodiversity and presence of protected species, is the optimal solution. In order for management plans to be effective, they need to be based on ecological evidence (as presented here). The suggested management plan is outlined in the next section.

4.3. Management Plan

In concurrence with the aims of this research the main considerations that underpin the proposed management prescriptions include:

- Protection, conservation and enhancement of *Triturus cristatus*
- Enhancement of biodiversity
- Realistic time and effort that might be available
- Potential for incorporation of human use
- Potential for economic gain

Using these aims and the survey data an optimal management plan for both the woodland and ponds has been formulated that will enhance the current biodiversity and habitat for *Triturus cristatus,* while considering the social and economic goals of this privately owned woodland. The use of GIS was valuable to display the large dataset collated from the ecological survey, to analyse results, and to present the management plan. Table 7 at the end of the section summaries the ecological advantages and disadvantages of the options discussed.

4.3.1. Outline of woodland management plan

Primarily the woodland (indeed any woodland with the presence of protected species) needs to be managed without committing an offence under the Habitats Regulations. A risk assessment must therefore always be carried out prior to any work to ensure that no damage or destruction of a breeding pond or terrestrial resting place occurs (Forestry Commission 2007). There is no one set way in which woodland should be managed and it must be recognised at the outset that management of landscape features is inherently subjective (Bell and McGillivray 2007). Different management options will result in different species assemblages – ultimately the decision-makers chose how they want the wood to be (Saunders 1993). In this case the *T. cristatus* population is of primary importance but so is the maintenance of biodiversity. The following sections outline and discuss the options for the woodland area and Table 5 outlines a proposed management timetable.

Table 5 Proposed woodland management timetable

	2008	2009	2011	2013	2015	2017
A	Winter – remove waste	Winter – restore coppice A1	Winter - restore coppice A2	Winter - restore coppice A3	Winter - restore coppice A4	Winter - coppice A1 (8 year crop)
B	-	-	Summer- footpath clearance if sufficient evidence	-	-	-
C1	Winter – Remove waste	-	(As above)	-	-	-
C2	(As above)	-	(As above)	-	-	-
D	(As above)	Spring - insert benches	(As above)	-	-	-
E	(As above)	-	-	-	-	-
F	-	Summer - clear scrub in SE and N bank of western dell	-	-	-	-

- = no action required

4.3.1.1. Coppicing in area A

Coppicing is valuable to wildlife as it maintains a variable age structure attracting a range of different bird species that prefer different canopy densities, under the same management practice at any one time (Saunders 1993). It is a chosen option for this area of the woodland since in the first few years after coppicing the opening up of the canopy, and thus the increase in light levels at the woodland floor, will increase structural and species diversity by encouraging the colonisation of woodland edge/

glade species namely spring flowers and butterflies (Saunders 1993). Once a rich understorey of shrubs, herbs and ground flora has developed this provides optimal dispersal and foraging territory for *T. cristatus*, which is particularly valuable within 50-250m from breeding ponds (Forestry Commmission 2007). Coppice *rotation* should minimise any impact on the *T. cristatus* population by removing any sudden change in the environment (disturbance).

Other benefits of coppicing include potential revenue generation and also potential demonstration of how to sustainably manage woodland, with possible feedbacks into the construction industry.

It is suggested that an eight year rotation is put in place, based on four coupes in area A (A1-A4) (see Figure 5). The first harvest should be used for firewood and for newt refuge habitat. The next harvest (8 years from one cut) would be suitable for thatching spars and hurdles for example (Evans 1992). A barrier of brushwood should be placed over the stumps to prevent deer browsing. The wood from the coppice should remain in the woodland and be left in piles. This will provide foraging habitat and refuge habitat for over-wintering newts.

Woodland Improvement Grants (WIG) may be available from the Forestry Commissions Woodland Grant Scheme (WGS), to fund the coppicing, where up to 50% of the agreed costs may be available. It is recommended that if this is a favourable option then further research should be undertaken into the practicalities and the potential economic value it might create.

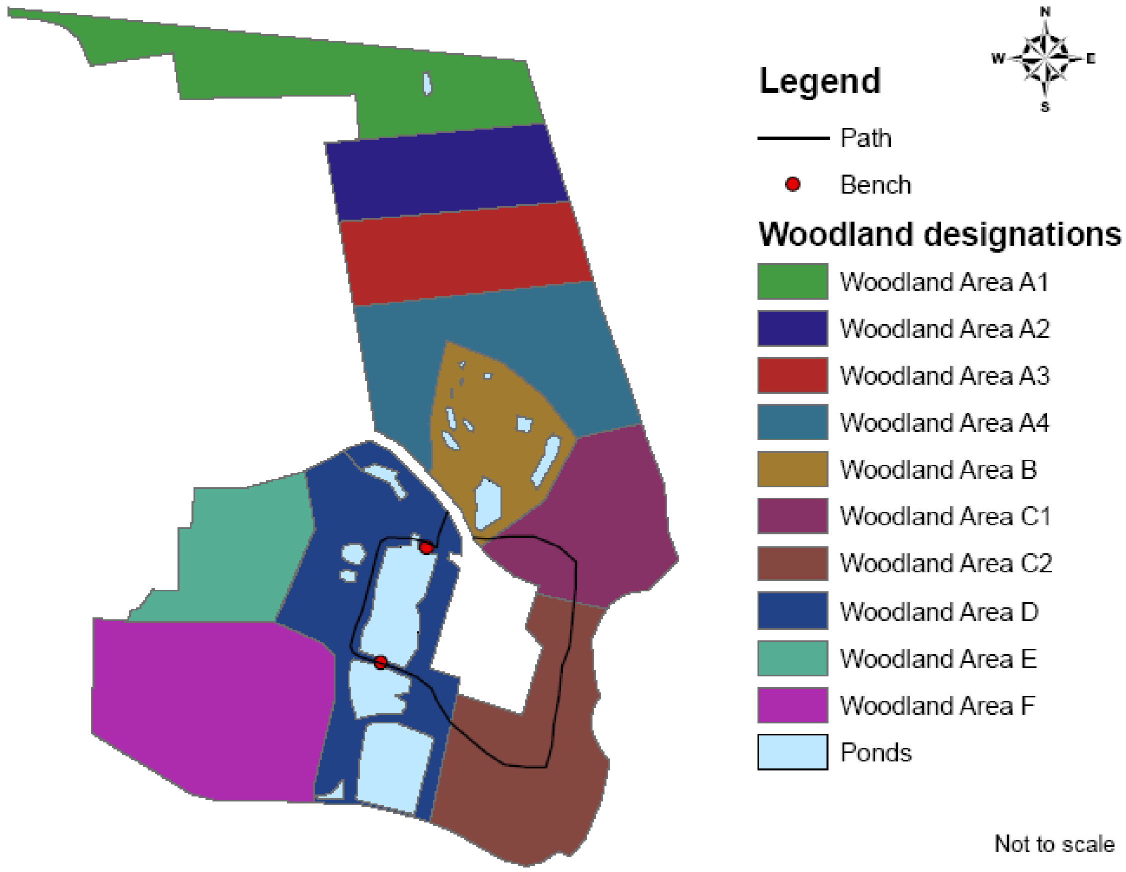

Figure 5 Woodland designations, path and bench locations

4.3.1.2. Glade creation

Glades increase biodiversity (Smith *et al.* 2007). It is suggested that glades are created on the south-facing bank of the dells in area D due to the low diversity currently present. Here nettles will need to be controlled so that other species can colonise. To the southeast of area F, near the boundary, orchids are known to have previously been present, if scrub was removed and glades created then orchids may re-appear along with other ground flora, this is therefore recommended (HMWT 1998). Some dense areas of woodland cover such as that found in areas C1 and C2 should be kept as this provides cover for a number of animal species including foxes, muntjac deer, insects and woodland birds, such as jays and tree creepers.

4.3.1.3. Path creation

It is recommended that small scale clearance takes place to the west of Pond 1, leading around the south of Pond 1/north of Pond 2, through management area C1/2 and terminating to the south of Pond 4 (See Figure 5). Such a path will enable the enjoyment of the rich biodiversity of Pond 1 and the woodland area to the east of the site, adjacent to the SSSI. Signs should warn those walking along the path of areas of deep water. It is also proposed that two benches are purchased; one could be placed at the entrance to area D, north of Pond 1 and the other between Ponds 1 and 2, where both ponds can be enjoyed. The insertion of the latter bench will require significant clearance and maintenance of *Symphoricarpos albus*. It is recommended that further research be carried out on the potential impacts of paths/ human disturbance on *T. cristatus* and its habitat before the paths are created.

It is recommended that in association path creation education boards be erected nearby. This would be acting in accordance with government guidance on biodiversity education as a part of the Biodiversity Duty (DEFRA 2007).

4.3.1.4. Clean up of waste disposal

The GIS highlights areas where waste has been found, namely areas E and C2. Objects should be carefully removed, taking caution due to the potential presence of newts.

4.3.2. Outline of pond management plan

With regards to the ponds in the woodland area there are three main priorities 1) to conserve and enhance the *T. cristatus* population, 2) to conserve and enhance their biodiversity, and 3) to make the woodland and ponds accessible for enjoyment by staff. Table 6 outlines the management prescriptions designed after analysis of survey results. It is important to note that before any pond restoration/ management is implemented a detailed pond survey should be carried out. This should include a *T. cristatus* survey and a pond vegetation survey by an appropriately qualified individual (English Nature 2001; 1996b).

Table 6 Proposed pond management timetable

	Winter 2008	Winter 2009	Winter 2010	Winter 2011	Winter 2012
1*	- Re-coppice/pollarding of some overhanging *Corylus avellana* and *Salix cinerea* -only 25% of margin in one year, start at southern edge. - Clear *Symphoricarpos albus* on southern margin between ponds 1 and 2 - Transfer vegetation cuttings to Ponds 2, 4, 5	Monitor effect of increased sunlight on vegetation	Assess if need more coppicing	-	Re-coppice if necessary to maintain sunlight on pond surface
2	- Coppice 1 or 2 *Corylus avellana* trees on northern bank. - Transfer vegetation in from Pond 1 - Coppice of trees on southern margin (decrease shading and reduce silting) and other fallen trees, but leave some.	Monitor effect of increased sunlight on vegetation	Assess if need more coppicing	-	Re-coppice if necessary to maintain sunlight on pond surface
3	-	-	-	-	-
4*	Rake out *Lemna minor*. Transfer vegetation from Pond 1	Rake out excessive re-appearance of *Lemna minor*	Monitor vegetation abundance	Monitor vegetation abundance	-
5*	Transfer vegetation from Pond 1	-	-	-	-
6a – i	-	-	-	-	-
7	-	-	-	-	-
8*	Investigate origin and plan restoration of habitat	Action depends on results of findings	Action depends on results of findings	Action depends on results of findings	Action depends on results of findings
9a & b	-	-	-	-	-
10	-	-	-	-	-

* = Prioritise these ponds (known *T.cristatus* breeding ponds)

\- = No action required but monitoring recommended. i.e. size, depth, condition

4.3.2.1. Vegetation in and around ponds

Each pond in the woodland is in a slightly different successional stage. However, they all have an above optimum level of shading. It is known that woodland ponds that are heavily shaded and overgrown have reduced species diversity of aquatic plants and invertebrates (Biggs *et al.* 1995). Less than 20% cover is thought to be optimal as it is important that sunlight reaches ponds particularly at their southern margins (Cooke *et al.* 1994). More than 20% cover may be detrimental to breeding newt populations, though if concentred on the northern edge of ponds, it may be tolerated (Cooke *et al.* 1994). This is because too much shade can reduce water quality due to excessive leaf fall and consequent silting, however it should also be noted that no shade cover is also detrimental (Oldham 1994). It is therefore proposed that Ponds 1 and 2 are maintained as open by careful coppicing of trees.

For many species, including *T. cristatus*, plants are a vital part of their life cycle (Biggs *et al.* 1995). Emergent plants in particular are important as they provide a habitat for both aquatic and semi-aquatic species (Biggs *et al.* 1995). Indeed most aquatic animal species live in the more complex and vegetated parts of ponds as open-water is exposed and potentially dangerous (Biggs *et al.* 1995). The National Pond Survey concluded that the larger the vegetated area of a pond, the greater the total number of different plant species (Pond Action 1994a in Biggs *et al.* 1995). The more diverse this aquatic vegetation is, and the more variations in densities there are, the more likely that a higher diversity of animals will also be present (Biggs *et al.* 1995). Such diversity should therefore be created or maintained.

Some ponds in the woodland contain little or no vegetation at all, for example Pond 5. It is therefore recommended that small cuttings of vegetation are taken from Pond 1 which is well vegetated, and placed in ponds 2, 4 and 5 (this can be done by simply pushing the vegetation into the sediment) (Williams *et al.* 1999). Biggs *et al.* (1995) suggest that it is most favourable to remove wedges of vegetation from shallow to deep. Given enough sunlight, these transferred cuttings will colonise and create additional breeding habitat in the recipient ponds. Transfer of vegetation should be strictly limited to the winter months (November to January) so that breeding adults and larvae are not disturbed (this would be a breach of *T. cristatus'* protection under the Conservation (Natural Habitats &c) Regulations 1994 (as amended). Other plant species that could be introduced, which newts would benefit from, include *Alisma plantago-aquatica*, *Sagittaria sagittifolia*, *Ceratophyllum demersum* and *Stratiotes aloides* (in increasing order of suitable depth).

4.3.2.2. Temporary ponds

There are a number of temporary ponds within the woodland. It is normal that shallow ponds of less than 1m depth should dry out regularly or even annually; these ponds will naturally have lower species diversity. Biggs *et al.* (1995) suggest that deepening such ponds is unnecessary and can even be damaging since the rotting leaves present may be an important food source for some groups. It is therefore unnecessary to take any action with these ponds. Likewise, some of the ponds have a lot of wood matter in them which provides an excellent egg laying substrate for invertebrates and should therefore be left undisturbed.

4.3.2.3. Creation of ponds

Latham *et al.* (1996) suggest that the creation of ponds up to 500m from core breeding ponds are likely to be colonised and thus will enhance populations. Indeed the Forestry Commission (2007) also advise that creating new ponds within 500m of existing breeding ponds will help to enhance populations. This is therefore to be recommended after all other restoration has been completed in existing ponds.

The main ecological advantages and disadvantages of the above options for managing the woodland alongside the *T. cristatus* population are summarised in Table 7.

Table 7 Ecological advantages and disadvantages of management options

Management Option	Advantages	Disadvantages	Main reference(s)
Coppice Rotation	- Maintains variable age structure – therefore will attract a range of bird species - Encourages the colonisation of woodland edge and glade species i.e. spring flowers and butterflies (biodiversity enhancement) - Increases foraging and dispersal habitat for *T. cristatus* - Rotation minimises effects as a result of sudden change - Chopped coppice wood provides foraging habitat and refugia for over-wintering newts	- In first 4 years increased *T. cristatus* juvenile mortality due to increased predation, desiccation or freezing - Reduces shade for lichens, fungi and mosses	Saunders (1993); Forestry Commission (2007); Latham *et al.* (1996)
Glade creation	Increases ground flora biodiversity	Dense woodland is good for foxes, muntjac deer, insects and woodland birds e.g. jays and tree creepers	Smith *et al.* (2007)
Clearance/ coppicing of trees on southern margins (max 25% affected)	- Reduced shade and leaf litter and therefore increased water quality and decreased siltation - Advantageous for *T. cristatus*	If over 50yrs old will have developed a specialised fauna and should not be disturbed	English Nature (1996b); Cooke *et al.* (1994); Biggs *et al.* (1995)
Transfer of vegetation from high to low vegetated ponds	Colonisation of vegetation to recipient ponds will create additional breeding habitat for *T. cristatus*	May disturb over-wintering larvae	Biggs *et al.* (1995)
Creation of new ponds	Creation of new ponds 500m from core breeding ponds will likely be colonised, enhancing the current population	This may be an expensive option for a land owner	Latham *et al.* (1996); Forestry Commission (2007)
Creation of paths	Benefit to landowner and staff	Disturbance to foxes, muntjac deer and other wildlife	No literature found

4.4. Potential tradeoffs between conservation and other objectives at local scale

There are strong international commitments to protect biodiversity and endangered species. Despite this there has been a significant lack of research on how to implement these aims at the local management scale (Thompson and Starzomski 2007). Woodlands and ponds make a significant contribution to the biodiversity of the UK and management plans such as the one designed here, aim to protect and enhance such habitats. However through conversations with the landowner at the case study site, it is clear that where land is privately owned conservation interests cannot be considered in isolation but must be applied in the context of business interests and other sustainability goals. Sustainability does not only consider environmental aspects, such as the material consideration of *T. cristatus*, but incorporates economic and social goals – both factors that must also be considered in the planning process (DCLG 2005a). Indeed, in the case study used here, nearby development may not be the optimal choice for the newt population or biodiversity, but it may be optimal to meet economic and social aims, locally or even regionally. For the purposes of this discussion ‘development’ should be considered mainly on the scales of construction of business parks, housing and small scale modifications/refurbishments of buildings. On whichever level development occurs it is clear that trade-offs are required (Faith and Walker 2002).

Although research on the tradeoffs between development and achieving environmental, social and economic sustainability has been undertaken at the large scale (e.g. Swanson 1999), little research has been dedicated to these tradeoffs at the local scale, where they most commonly exist. This case study has identified a number of trade-offs that arise between conservation and other landowner objectives and vice-versa. They mainly consist of the costs of protecting the woodland habitat and *T. cristatus* population instead of developing without regard for sustainability *versus t*he benefits of protection and enhancement with no impacts from development. The initial tradeoffs that have been identified are summarised in Table 8. The tradeoffs assume that either conservation or development occurs. In reality it is likely that a compromise is reached, how the tradeoffs then interact needs further investigation.

Table 8 Initial tradeoffs identified between conservation and development from scoping at case study site

Costs of implementing conservation	Benefits of implementing conservation
Reduced revenue that could be generated from full development of land	Enhanced reputation of landowner. Enhanced productivity and wellbeing of employees as a result of recreational opportunities
Loss of opportunity to create local employment (construction and/or functional phases) and enhance the local economy	Social benefits: educational and recreational
Cost of environmental consultancy	Work will ensure no compromise to conservation status of woodland or protected species occurs
	No changes to the water table or siltation which may impact on newt populations
	No new barriers to newt dispersal which would fragment habitat and split species such as *T. cristatus* into small isolated populations

It is difficult to evaluate the relative importance of these tradeoffs without further research (i.e. questionnaires and interviews to landowners). However as shown in Table 9, there can be a clear combination of environmental, social and economic benefits if management plans, like the one outlined in this paper consider the context in which the conservation work is being carried out.

Table 9 Environmental, social and economic benefits of options (to landowner)

	Environmental benefit	Social benefit	Economic benefit
Coppicing	✓		✓*
Restoration of ponds	✓	✓	
Creation of 'footpath'		✓	
Re-development/ refurbishment of nearby buildings		✓**	✓
Development on woodland area		✓**	✓

* needs further investigation

** potential benefit – difficult to predict without knowledge of specific plans

4.5. Conservation: constraint or opportunity for landowners?

The tradeoffs at this site do not exist in isolation. Across all European landscapes there are conflicts between conservation objectives and human activity, often related to stakeholder livelihoods (Young *et al.* 2005). These conflicts, largely related to development/land use change, need to be managed in order to prevent the further loss of biodiversity. It is therefore argued here that these perceived conflicts/trade-offs at the local scale are not necessarily negative but can be used as tools to advance sustainability - creating opportunities to enhance the natural environment, business reputation, and the wellbeing of those with access to the land e.g. employees. DEFRA in their 'Guidance for local authorities on implementing the Biodiversity Duty' suggest that there can be both positive and negative effects of development on biodiversity. Positive effects include:

- Creative master planning to integrate improvements to biodiversity features and encourage sensitive management'
- Habitat creation
- Increasing people's access to and awareness of wildlife

It is often the case that the negative effects are focused on more heavily, they include;

- The implications of direct loss of land
- The fragmentation of habitats
- The disturbance and pollution from increased transportation

(DEFRA 2007)

These negative effects are both real and important however, development is a necessary component of sustainability and therefore better use must be made of the potential benefits that it can contribute to biodiversity and conservation and vice versa. Indeed guidance to local authorities in the UK states that if a site has "*significant biodiversity or geological interest of recognised local importance*" then the developers should "*aim to retain this interest or incorporate it into any development of the site*" (DCLG 2005b). Additionally they are advised to create opportunities for biodiversity enhancement to further sustainable development (DEFRA 2007). They are encouraged to integrate these goals with "*other policy objectives and other land uses, for example housing and economic development, health, education and social inclusion*" (DEFRA 2007). This should be more highly emphasised to landowners, as an opportunity rather than as a burden. For example the implementation of the management plan outlined here, alongside plans for site re-developments could form part of a master plan that is likely to be looked upon favourably by local planning authorities in the planning process.

The management plan for the case study site demonstrates how with minimal expenditure and effort woodlands can be maintained at a desirable conservation status. It also shows that human use can be incorporated into plans, creating environmental and social benefits. With the suggestion of the re-introduction of coppicing in area A, there is also a potential long-term economic benefit. With the management plan in place the perceived constraints imposed by protected species and biodiversity can be looked at more positively.

4.5.1. Benefits of conservation to landowners/businesses

A number of drivers, for example from market forces, legislation and client demand, mean that sustainability has become an important element which forms part of the reputation of a company. Biodiversity, as a core aspect of sustainability must therefore be integral to the decisions companies make, or it might threaten reputation and potentially access to licences and capital. In essence, biodiversity protection generally equates to good business practice (Earthwatch Institute 2008).

Enhancing woodlands creates opportunities for amenity and educational use of the land for either staff and/or visitors. Indeed, the woodland and wetland area at the case study site has potential amenity value as an area to be enjoyed by staff and clients. This would contribute to social sustainability, arguably increasing the welfare of employees. (Note: caution should be applied here since no research has been carried out as part of this research, or been found in the literature, to investigate the impacts of footpaths through areas where *T. cristatus* populations reside. Also equal opportunities i.e. wheelchair access and potential wildlife value decline from disturbance in the form of noise and litter, for example, should also be considered). Although a path has been suggested, before any implementation, there should be a detailed study of the advantages and disadvantages of this proposal.

Local authorities have a responsibility to educate the public on nature conservation issues under Section 25 of the Wildlife and Countryside Act 1981 (HEF 2006). The erection of education boards within woodland areas, as proposed in the management plan would concur with these aims. By doing this landowners can demonstrate coherence with wider conservation aims for example with local BAPs and SAPs. Also, if management plans are largely carried out by staff members this creates good internal communication as well as loyalty and a sense of purpose. Such actions can also be highlighted in marketing material and contribute to Corporate Social Responsibility thereby enhancing the company/ landowner image (Earthwatch Institute 2008).

It is the LPAs responsibility to regulate development activity and they have a duty to make sure that development does not affect a BAP or SAP. Implementing management plans that aim to conserve and enhance environments may therefore act to mitigate negative impacts that might occur in association with development elsewhere on a site. In addition, there may be cost savings from planning ahead for biodiversity, including adding value to any nearby site re-developments especially if housing is a consideration (Earthwatch Institute 2008). In the long term, for the management plan outlined in this study, the re-introduction of coppice in section A of the woodland may bring in a supplementary income for the landowner, though site specific research needs to be undertaken.

One clear constraint is the time and cost that is involved in designing and implementing management plans. The literature has shown the importance of site-specific population data to inform management plans (e.g. Griffiths 1997; Petranka and Holbrook 2006;

Semlitsch 2000; 2008). This, and the sensitive nature and detailed legislation on biodiversity and protected species, means that ecological consultants are likely to have to play a part and clearly this will incur a cost. In some cases this cost could prohibit pro-active management. Further research on this subject is recommended and should include investigation of the availability of advice and grants to landowners.

5. Conclusions and recommendations

This study has highlighted a number of knowledge and research gaps that need rapid attention. Firstly, it is clear that there is a lack of understanding of the ecology and management of ponds. There is also a lack of consideration of the tradeoffs between conservation and development at the local scale. Further research should investigate how landowners/ business feel they can contribute to conservation and biodiversity on their site as well as what tradeoffs they identify between development and conservation, especially with regards to protected species. With this information, constraints and opportunities of biodiversity on private land can be resolved and enhanced.

This study has shown the usefulness of Geographical Information Systems in the display and analysis ecological survey findings and the presentation of management plan options. The study has indicated that where woodlands exist with significant biodiversity, including the presence of protected species, and the aim is to act sustainably in all aspects, then some form of management should take place.

It has been indicated, through scoping at the case study site, that with the implementation of a management plan landowners can help to contribute to environmental, social and economic sustainability and create benefits for themselves including:

- Enhanced reputation through a demonstration of a commitment to sustainability; biodiversity being a key component
- Amenity and recreation value – contributing to staff sense of wellbeing
- The potential mitigation of negative impacts associated with development elsewhere on site
- Economic benefits i.e. from enhanced reputation or revenue from coppicing

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7. References

Abington, C, 1982. A souvenir of Bricket Wood. Bricket Wood Society

Aigner, D. J., Hopkins, J. and Johansson, R., 2003. Beyond compliance: Sustainable business practices and the bottom line. *American Journal of Agricultural Economics* **85** (5), 1126–1139

Arntzen, J. W. and Teunis, S. F. M., 1993. A six year study of the population dynamics of the Crested Newt (*Triturus cristatus*) following the colonization of a newly created pond. *Herpetological Journal* **3**, 99-110

Arntzen, J. W. and Wallis, G. P., 1991. Restricted gene flow in a moving hybrid zone of the newts *Triturus cristatus* and *T. marmoratus* in western France. *Evolution* **45**, 805-826

Bansal, P., 2002). The corporate challenges of sustainable development. *Academy of management executive* **16**(2), 122-131

Bell, S. and McGillivray, S. (2006). Environmental Law. Oxford University Press, New York

Biggs, J., Corfield, A., Walker, D., Whitfield, M. and Williams, P., 1995. *New approaches to managing woodland ponds*, in Woodland Pond Management. Corporation of London, London.

Biggs, J., Williams, P., Whitefield, M., Nicolet, P. and Weatherby A., 2005. 15 years of pond assessment in Britain: results and lessons learned from the work of Pond Conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems* **15,** 693–714

Blackburn, G. A. and Milton, E. J., 1997. An ecological survey of deciduous woodlands using airborne remote sensing and geographical information systems (GIS). *International Journal of Remote Sensing* **18** (9), 1919-1935

Blaustein, A. R., Wake, D. B. and Sousa, W. P., 1994. Amphibian Declines: Judging Stability, Persistence, and Susceptibility of Populations to Local and Global Extinctions. *Conservation Biology* **8,** 60-71

Céréghino, R., Biggs, J., Oertli, B. and Declerck, S., 2008. The ecology of European ponds: defining the characteristics of a neglected freshwater habitat. *Hydrobiologia* **597,** 1–6

Collins, J. P. and Storfer, A., 2003. Global amphibian declines: sorting the hypotheses. *Diversity and Distributions* **9**, 89-98

Collins, E., Lawrence, S., Pavlovich, K. and Ryan, C., 2007,). Business networks and the uptake of sustainability practices: the case of New Zealand. *Journal of Cleaner Production* **15,** 729-740

Convention on Biological Diversity (2008). http://www.cbd.int/ Accessed 29/05/2008

Cooke, S. D., Cooke, A. S., Sparks, T. H., 1994. *Effects of scrub cover of ponds on great crested newts' breeding performance*. In: Conservation and Management of the Great Crested Newt: Proceedings of symposium held at Kew Gardens. English Nature Report No. 20 Edited by Gent, A. and Bray, R.

Department for Communities and Local Government, 2005a. Planning Policy Statement 1: Delivering Sustainable Development. Office of the Deputy Prime Minister

Department for Communities and Local Government, 2005b. Planning Policy Statement 9: Biodiversity and Geological Conservation. Office of the Deputy Prime Minister

DEFRA, 2007. Guidance for Local Authorities on Implementing the Biodiversity Duty. Department for Environment, Food and Rural Affairs.

Dirzo, R. and Raven, P.H., 2003. Global state of biodiversity loss. *Annual Review of Environment and Resources* **28,** 137-167

Duigan, C. A. and Jones. A. T., 1997. Pond Conservation Symposium: Introduction A meeting organized by the Countryside Council for Wales, the Environment Agency and the British Ecological Society (Aquatic Ecology Group), Caersws, Powys, Wales, 5 September 1996. Aquatic Conservation: *Marine and Freshwater Ecosystems* **7**, 87-89

Drake, M., 1995. Ponds as a habitat for organisms. In: *Woodland Pond Management*. Corporation for London; London

Earthwatch Institute, 2008. Business and Biodiversity Resource Centre. http://www.businessandbiodiversity.org/index.html Accessed 5/08/08

Edgar, P. W., Griffiths, R. A., and Foster, P. J., 2005. Evaluation of translocation as a tool for mitigating development threats to Great Crested Newts (*Triturus cristatus*) in England, 1990-2001. *Biological Conservation* **122**, 45-52

English Nature, 2001. Great crested newt mitigation guidelines, Peterborough

Evans, 1992. 'Coppice Forestry – an overview'. *In Ecology and Management of Coppice Woodlands* Ed Buckley, G. P. Chapman and Hall; London

Faith, D. P. and Walker, P. A., 2002. The role of trade-offs in biodiversity conservation planning: linking local management, regional planning and global conservation efforts. *Journal of Bioscience* **27** (4): 393-407

Forestry Commission, 2007. Guidance on managing woodlands with great crested newts in England: Interim Guidance Version 2 (September 2007). Available at http://www.forestry.gov.uk/pdf/england-protectedspecies-newt.pdf/$FILE/england-protectedspecies-newt.pdf Accessed 7/06/08

Froglife, 1998. The Planning System and Site Defence: How to protect reptile and amphibian habitats. Froglife Advice Sheet 9. Froglife, Peterborough

Gee, J. H. R., Smith, B. D., Lee, K. M. and Griffiths, S. W., 1997. The ecological basis of freshwater pond management for biodiversity. *Aquatic Conservation: Marine and Freshwater Ecosystems* **7**, 91-104

Griffiths, R. A., 1997. Temporary ponds as amphibian habitats. *Aquatic conservation: marine and freshwater ecosystems* **7,** 119-126

Griffiths, R. A., and Williams C., 2000. Modelling population dynamics of great crested newts (*Triturus cristatus*): a population viability analysis. *Herpetological Journal* **10**, 157-163

Haines-Young, R.H., Barr, C.J., Black, H.I.J., Briggs, D.J., Bunce, R.G.H., Clarke, R.T., Cooper, A., Dawson, F.H., Firbank, L.G., Fuller, R.M., Furse, M.T., Gillespie, M.K., Hill, R., Hornung, M., Howard, D.C., McCann, T., Morecroft, M.D., Petit, S., Sier, A.R.J., Smart, S.M., Smith, G.M., Stott, A.P., Stuart, R.C. and Watkins, J.W., 2000. Accounting for nature: assessing habitats in the UK countryside, November 2000. Department of the Environment, Transport and the Regions: London

Hart, S. L., 1997. Beyond greening: strategies for a sustainable world. *Harvard Business Review* **75** (1), 66-76

Henle, K., Alard, D., Clitherow, J., Cobb, P., Firbank, L., Kull, T., McCracken, D., Moritz, R. F. A., Niemela¨, J., Rebane, M., Wascher, D., Watt, A., Young, J., 2008. Identifying and managing the conflicts between agriculture and biodiversity conservation in Europe–A review. *Agriculture, Ecosystems and Environment* **124**, 60–71

Herbert, C., 2001, 2003, 2004. Great Crested Newt Survey and Habitat Assessment: Original Survey; Monitoring programme - Year 2 Update; Monitoring programme - Year 3 Final Report. Amphibian, Reptile and Mammal Conservation Limited

Herts and Middlesex Wildlife Trust, 1998. An Ecological Assessment prepared by Herts and Middlesex Wildlife Trust for the Building Research Establishment woodland adjacent to Bricket Wood (Common), January 1984, updated 1998

Hertfordshire Environmental Forum, 2006. A 50 Year Vision for the Wildlife and Natural Habitats of Hertfordshire: A Biodiversity Action Plan for Hertfordshire.

Joint Nature Conservation Committee, 1993. Handbook for Phase 1 habitat survey – A technique for environmental audit

Langton, T. E. S., Beckett, C. I., and Foster, J. P., 2001. Great Crested Newt Conservation Handbook, Froglife, Halesworth

Langdon, S. J., Marrs, R. H., Hosie, C. A., McAllister, H. A., Norris, K. M. and Potter, J. A., 2004. *Crassula helmsii* in U.K. Ponds: Effects on Plant Biodiversity and Implications for Newt Conservation. *Weed Technology* **18,** 1349-1352

Latham, D. M., Oldham, R. S., Stevenson, M. J., Duff, R., Franklin, P. and Head, S., 1996. Woodland management and the conservation of the great crested newt (*Triturus cristatus*). *Aspects of Applied Biology* **44,** 451-459

Leita, A. B. and Ahern, J., 2003. Applying landscape ecological concepts and metrics in sustainable landscape planning. *Landscape and Urban Planning* **59**, 65-93

Lo, S. and Sheu, H., 2007. Corporate Sustainability a Value-Increasing Strategy for Business? *Corporate Governance: An international Review* **15** (2), 345-358

Milder, J. C., Lassoie, J. P. and Bedford, B. L., 2008. Conserving Biodiversity and Ecosystem Function through Limited Development: an Empirical Evaluation. C*onservation Biology* **22** (1), 70–79

Oldham, R. S., 1994. *Habitat assessment and population ecology*. In: Conservation and Management of the Great Crested Newt: Proceedings of symposium held at Kew Gardens. English Nature Report No. 20 Edited by Gent, A. and Bray, R.

Oldham, R. S. and Humphries, R. N., 2000. Evaluating the success of great crested newt (*Triturus cristatus*) translocation. *Herpetological Journal* **10**, 183-190

Oldham, R. S., Keeble, J., Swan, M. J. S., Jeffcote, M., 2000. Evaluating the suitability of habitat for the great crested newt (*Triturus cristatus*). *Herpetological Journal* **10,** 143-155

Oertli, B. Joye, D. A., Raphae, E., Juge, I., Cambin, D. and Lachavanne, J., 2002. Does size matter? The relationship between pond area and biodiversity. *Biological Conservation* **104,** 59–70

Pechmann, J. H. K., Scott, D. E., Semlitsch, R. D., Caldwell, J. P., Vitt, L. J. and Gibbons, J. W., 1991. Declining amphibian populations – the problem of separating human impacts from natural fluctuations. *Science* **253**, 892-895

Petranka, J. W. and Holbrook, C. T., 2006. Wetland Restoration for Amphibians: Should Local Sites Be Designed to Support Metapopulations or Patchy Populations? *Restoration Ecology* **14** (3), 404-411

Saunders, G., 1993. Woodland Conservation in Britain. In: *Conservation in Progress* Edited by Goldsmith, F. B. and Warren, A. John Wiley and Sons, Chichester

Semlitsch, R. D., 2000. Principles for Management of Aquatic-breeding Amphibians. *Journal of Wildlife Management* **64** (3), 615-631

Semlitsch, R. D., 2008. Differentiating Migration and Dispersal Processes fro Pond-Breeding Amphibians. *The Journal of Wildlife Management* **72** (1), 260-267

Semlitsch, R. D. and Bodie, J. R., 2003. Biological Criteria for Buffer Zones around Wetlands and Riparian Habitats for Amphibians and Reptiles. *Conservation Biology* **17** (5), 1219-1228

Smith, G. F., Iremonger, S., Kelly, D. L., O'Donoghue, S., Mitchell, F. J. G., 2007. Enhancing vegetation diversity in glades, rides and roads in plantation forests. *Biological Conservation* **136**, 283-294

Stuart, S. N., Chanson, J. S., Cox, N. A., Young, B. E., Rodrigues, A. S. L., Fischman, D. L. and Waller, R. W., 2004. Status and Trends of Amphibian Declines and Extinctions Worldwide. *Science* **306,** 1783-1786

Swanson, T., 1999. Conserving global biological diversity by encouraging alternative development paths: can development coexist with diversity? *Biodiversity and Conservation* **8,** 29-44.

Thompson, R. and Starzomski, B. M., 2007. What does biodiversity actually do? A review for managers and policy makers. *Biodiversity and Conservation* **16,** 1359–1378

WCED, 1987. Our common *future.* Oxford: Oxford University Press, 43.

Williams, P., Biggs, J., Whitfield, M., Thorne, A., Bryant, S., Fox, G. and Nicolet, P., 1999. *The Pond Book: a guide to the management and creation of ponds*. Ponds Conservation Trust, Oxford

World Commission on Environment and Development, 1987. Our Common Future. Oxford University Press, Oxford.

Wyatt, G., 1991. A review of Phase 1 habitat survey in England. England Field Unit: Nature Conservatory Council

Young, J., Watt, A., Nowicki, P., Alard, D., Clitherow, J., Henle, K., Johnson, R., Laczko, E., McCracken, D., Matouch, S., Niemela, J. and Richards, C., 2005. Towards sustainable land use: identifying and managing the conflicts between human activities and biodiversity conservation in Europe. *Biodiversity and Conservation* **14,** 1641–1661

8. Introduction and Literature Review references

Angelibert, S., Marty P., Cereghino, R.E. and Giani, N., 2004. Seasonal variations in the physical and chemical characteristics of ponds: implications for biodiversity conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems* **14**: 439–456

Arntzen, J. W. and Teunis, S. F. M., 1993. A six year study of the population dynamics of the Crested Newt (*Triturus cristatus*) following the colonization of a newly created pond. *Herpetological Journal* **3**: 99-110

Arntzen, J. W. and Wallis, G. P., 1991. Restricted gene flow in a moving hybrid zone of the newts *Triturus cristatus* and *T. marmoratus* in western France. *Evolution* **45**, 805-826

Asheim, G. B., Buchholz, W. and Tungodden, B., 2001. Justifying Sustainability. *Environmental Economics and Management* **41**, 252-268 check date

Bansal, P., 2002). The corporate challenges of sustainable development. *Academy of management executive* **16**(2), 122-131

Biggs, J., Corfield, A., Walker, D., Whitfield, M. and Williams, P., 1995. *New approaches to managing woodland ponds*, in Woodland Pond Management. Corporation of London, London.

Biggs, J., Williams, P., Whitefield, M., Nicolet, P. and Weatherby A., 2005. 15 years of pond assessment in Britain: results and lessons learned from the work of Pond Conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems* **15**: 693–714

Blaustein, A. R., Wake, D. B. and Sousa, W. P., 1994. Amphibian Declines: Judging Stability, Persistence, and Susceptibility of Populations to Local and Global Extinctions. *Conservation Biology* **8**: 60-71

Céréghino, R., Biggs, J., Oertli, B. and Declerck, S., 2008. The ecology of European ponds: defining the characteristics of a neglected freshwater habitat. *Hydrobiologia* **597**:1–6

Collins, J. P. and Storfer, A., 2003. Global amphibian declines: sorting the hypotheses. *Diversity and Distributions* **9**: 89-98

Collins, E., Lawrence, S., Pavlovich, K. and Ryan, C., 2007. Business networks and the uptake of sustainability practices: the case of New Zealand. *Journal of Cleaner Production* **15**: 729-740

Convention on Biological Diversity (2008). http://www.cbd.int/ Accessed 29/05/2008

Cushman, S. A., 2006. Effects of habitat loss and fragmentation on amphibians: A review and prospectus. *Biological Conservation* **128**: 231-240

Department for Environment, Food and Rural Affairs, 2002. Working with the Grain of nature: A biodiversity strategy for England. London

Department for Communities and Local Government, 2005a. Planning Policy Statement 1: Delivering Sustainable Development. Office of the Deputy Prime Minister

Department for Communities and Local Government, 2005b. Planning Policy Statement 9: Biodiversity and Geological Conservation. Office of the Deputy Prime Minister

Denoél, M. and Lehmann, 2006. Multi-scale effect of landscape processes and habitat quality on newt abundance: Implications for conservation. *Biological Conservation* **130**: 495-504

Duigan, C. A. and Jones. A. T., 1997. Pond Conservation Symposium: Introduction A meeting organized by the Countryside Council for Wales, the Environment Agency and the British Ecological Society (Aquatic Ecology Group), Caersws, Powys, Wales, 5 September 1996. Aquatic Conservation: Marine and Freshwater Ecosystems 7: 87-89

Drake, M., 1995. Ponds as a habitat for organisms. In: *Woodland Pond Management*. Corporation for London; London

Edgar, P. and Bird, D. R., 2006. Action Plan for the Conservation of the Crested Newt *Triturus cristatus* Species Complex in Europe. Convention on the Conservation of European Wildlife and Natural Habitats, Standing Committee 26th meeting Strasbourg 27-20 November 2006

Edgar, P. W., Griffiths, R. A., and Foster, P. J., 2005. Evaluation of translocation as a tool for mitigating development threats to Great Crested Newts (*Triturus cristatus*) in England, 1990-2001. *Biological Conservation* **122**: 45-52

English Nature, 1996. Great Crested Newts – Guidelines for developers, Peterborough

English Nature, 2001. Great crested newt mitigation guidelines, Peterborough
Etienne, R.S., Vos, C. C. and Jansen, M. J. W., 2003. Ecological Impact Assessment in Data-Poor Systems: A Case Study on Metapopulation Persistence. *Environmental Management* **32** (6), 760-777

Etienne, R. S., Vos, C. C. and Jansen, M. J. W., 2003. Ecological Impact Assessment in Data-Poor Systems: A Case Study on Metapopulation Persistence. *Environmental Management* **32**, (6), 760-777

Forestry Commission, 2007. Guidance on managing woodlands with great crested newts in England: Interim Guidance Version 2 (September 2007). Available at http://www.forestry.gov.uk/pdf/england-protectedspecies-newt.pdf/$FILE/england-protectedspecies-newt.pdf Accessed 7/06/08

Froglife, 1998. The Planning System and Site Defence: How to protect reptile and amphibian habitats. Froglife Adivce Sheet 9. Froglife, Peterborough

Gee, J. H. R., Smith, B.D., Lee, K. M. and Griffiths, S. W., 1997. The ecological basis of freshwater pond management for biodiversity. *Aquatic Conservation: Marine and Freshwater Ecosystems* **7**: 91-104

Glasson, J., Therivel, R., Chadwick, A., 1999. Introduction to Environmental Impact Assessment. London: UCL Press Ltd

Griffiths, R. A., 1997. Temporary ponds as amphibian habitats. *Aquatic conservation: marine and freshwater ecosystems* **7**: 119-126

Griffiths, R. A., and Williams C., 2000. Modelling population dynamics of great crested newts (*Triturus cristatus*): a population viability analysis. *Herpetological Journal* **10**: 157-163

Haines-Young, R.H., Barr, C.J., Black, H.I.J., Briggs, D.J., Bunce, R.G.H., Clarke, R.T., Cooper, A., Dawson, F.H., Firbank, L.G., Fuller, R.M., Furse, M.T., Gillespie, M.K., Hill, R., Hornung, M., Howard, D.C., McCann, T., Morecroft, M.D., Petit, S., Sier, A.R.J., Smart, S.M., Smith, G.M., Stott, A.P., Stuart, R.C. and Watkins, J.W., 2000. Accounting for nature: assessing habitats in the UK countryside, November 2000.Department of the Environment, Transport and the Regions: London

Harrop, S. R., 1999. Conservation regulation: a backward step for biodiversity? *Biodiversity and Conservation* **8**: 679- 707

Hart, S. L., 1997. Beyond greening: strategies for a sustainable world. *Harvard Business Review* **75** (1): 66-76.

Henle, K., Alard, D., Clitherow, J., Cobb, P., Firbank, L., Kull, T., McCracken, D., Moritz, R. F. A., Niemela¨, J., Rebane, M., Wascher, D., Watt, A., Young, J., 2008. Identifying and managing the conflicts between agriculture and biodiversity conservation in Europe–A review. *Agriculture, Ecosystems and Environment* **124**: 60–71

Herbert, C., 2001, 2003, 2004. Great Crested Newt Survey and Habitat Assessment: Original Survey; Monitoring programme - Year 2 Update; Monitoring programme - Year 3 Final Report. Amphibian, Reptile and Mammal Conservation Limited

Hertfordshire Environmental Forum, 2006. A 50 Year Vision for the Wildlife and Natural Habitats of Hertfordshire: A Biodiversity Action Plan for Hertfordshire.

International Union for Conservation of Nature, 2008. Red List: *Triturus cristatus.* http://www.iucnredlist.org/search/details.php/22212/all Accessed 15/05/08

Jehle, R., 2000. The terrestrial summer habitat of radio tracked great crested newts (*Triturus cristatus*) and marbled newts (*Triturus marmoratus*). *Herpetological Journal* **10** (4): 137-142

Joint Nature Conservation Committee, 1993. Handbook for Phase 1 habitat survey – A technique for environmental audit

Langdon, S. J., Marrs, R. H., Hosie, C. A., McAllister, H. A., Norris, K. M. and Potter, J. A., 2004. *Crassula helmsii* in U.K. Ponds: Effects on Plant Biodiversity and Implications for Newt Conservation. *Weed Technology* **18**: 1349-1352

Langton, T. E. S., Beckett, C. I., and Foster, J. P., 2001. Great Crested Newt Conservation Handbook, Froglife, Halesworth

Lann, R. and Verboom, B., 1990. Effects of Pool Size and Isolation on Amphibians Communities. *Biological Conservation* **54**: 251-262

Latham, D. M., Oldham, R. S., Stevenson, M. J., Duff, R., Franklin, P. and Head, S., 1996. Woodland management and the conservation of the great crested newt (*Triturus cristatus*). *Aspects of Applied Biology* **44**: 451-459

McLean, I. F. G., Wight, A. D. and Williams, G., 1999. The Role of legislation in Conserving Europe's Threatened Species. *Conservation Biology* **13** (5): 966-969

Oldham, R. S., 1994. *Habitat assessment and population ecology*. In: Conservation and Management of the Great Crested Newt: Proceedings of symposium held at Kew Gardens. English Nature Report No. 20 Edited by Gent, A. and Bray, R.

Oldham, R. S., Keeble, J., Swan, M. J. S., Jeffcote, M., (2000. Evaluating the suitability of habitat for the great crested newt (*Triturus cristatus*). *Herpetological Journal* **10**: 143-155

Oertli, B. Joye, D. A., Raphae, E., Juge, I., Cambin, D. and Lachavanne, J., 2002. Does size matter? The relationship between pond area and biodiversity. *Biological Conservation* **104**: 59–70

Oxford, M., Hawkins, K., Hackett, R. and Everitt, J., 2007. Local Authority Services and Biodiversity. The Wildlife Trusts

Pechmann, J. H. K., Scott, D. E., Semlitsch, R. D., Caldwell, J. P., Vitt, L. J. and Gibbons, J. W., 1991. Declining amphibian populations – the problem of separating human impacts from natural fluctuations. *Science* **253**: 892-895

Petranka, J. W. and Holbrook, C. T., 2006. Wetland Restoration for Amphibians: Should Local Sites Be Designed to Support Metapopulations or Patchy Populations? *Restoration Ecology* **14** (3): 404-411

Saunders, G., 1993. Woodland Conservation in Britain. In: *Conservation in Progress* Edited by Goldsmith, F. B. and Warren, A. John Wiley and Sons, Chichester

Scheffer. M., G. J. van Geest, K. Zimmer, E. Jeppesen, M. Søndergaard, M. G. Butler, M. A. Hanson, S. Declerck and L. De Meester, 2006. Small habitat size and isolation can promote species richness: second-order effects on biodiversity in shallow lakes and ponds. *OIKOS* **112**(1): 227-231

Schmidheiny, S., 1992. Changing Course – a global business perspective on development and the environment. MIT press

Semlitsch, R. D., 2000. Principles for Management of Aquatic-breeding Amphibians. *Journal of Wildlife Management* **64** (3): 615-631

Semlitsch, R. D., 2008. Differentiating Migration and Dispersal Processes fro Pond-Breeding Amphibians. *The Journal of Wildlife Management* **72** (1): 260-267

Semlitsch, R. D. and Bodie, J. R., 2003. Biological Criteria for Buffer Zones around Wetlands and Riparian Habitats for Amphibians and Reptiles. *Conservation Biology* **17** (5): 1219-1228

Smith, A. M. and Green, D. M., 2005. Dispersal and the metapopulation paradigm in amphibian ecology and conservation: are all amphibian populations metapopulations? *Ecography* **28**: 110-128

Starkey, R. and Welford, R., 2001. The Earthscan Reader in Business and Sustainable Development. Earthscan Publications Limited, London

Stuart, S. N., Chanson, J. S., Cox, N. A., Young, B. E., Rodrigues, A. S. L., Fischman, D. L. and Waller, R. W., 2004. Status and Trends of Amphibian Declines and Extinctions Worldwide. *Science* **306**: 1783-1786

Swan, M J. S. and Oldham, R. S., 1993. *National Amphibian Survey*. English Nature Research Report. No. 38

Turner, R.K., 2006. Sustainability auditing and assessment challenges. *Building Research and Information* **34** (3): 197-200

Wake, D. B., 1998. Action on Amphibians. *TREE* **13**: 379-380

WCED, 1987. *Our common future.* Oxford: Oxford University Press, 43.

Williams, P., Biggs, J., Whitfield, M., Thorne, A., Bryant, S., Fox, G. and Nicolet, P., 1999. *The Pond Book: a guide to the management and creation of ponds*. Ponds Conservation Trust, Oxford

Young, J., Watt, A., Nowicki, P., Alard, D., Clitherow, J., Henle, K., Johnson, R., Laczko, E., McCracken, D., Matouch, S., Niemela, J. and Richards, C., 2005. Towards sustainable land use: identifying and managing the conflicts between human activities and biodiversity conservation in Europe. *Biodiversity and Conservation* **14**: 1641–1661

Appendix 1: Vegetation inventory and abbreviations

(used in GIS database)

Common name	Latin name	GIS abbreviation
Field maple	*Acer campestre*	ACE_CAM
Norway maple	*Acer platanoides*	ACE_PLA
Sycamore	*Acer pseudoplatanus*	ACE_PSE
Red maple	*Acer rubrum*	ACE_RUB
Horse chestnut	*Aesculus hippocastanum*	AES_HIP
Velvet bent grass	*Agrostis canina* L.	AGR_CAN
Bugle	*Ajuga reptans*	AJU_REP
Common Water-plantain	*Alismaplantago-aquatica*	ALI_APL
Garlic mustard	*Alliaria petiolata*	ALL_PET
Cow parsley	*Anthriscus sylvestris*	ANT_SYL
Lesser burdock	*Arctium minus*	ARC_MIN
False oat grass	*Arrhenatherum elatius*	ARR_ELA
Daisy	*Bellis perennis*	BEL_PER
Silver birch	*Betula pendula*	BET_PEN
Downy birch	*Betula pubescens*	BET_PUB
Wood false brome	*Brachypodium sylvaticum*	BRA_SYL
Glaucous sedge	*Carex flacca*	CAR_FLA
Pendulous sedge	*Carex pendula*	CAR_PEN
Wood sedge	*Carex sylvatica*	CAR_SYL
Hornbeam	*Carpinus betulus*	CAR_BET
Sweet chestnut	*Castanea sativa*	CAS_SAT
Black knapweed	*Centaurea nigra*	CEN_NIG
Rough chervil?	*Chaerophyllum temulum* L.	CHA_TEM
Oxeye daisy	*Chrysanthemum leucanthemum*	CHR_LEU
Enchanters nightshade	*Circaea lutetiana*	CIR_LUT
Creeping thistle	*Cirsium arvense*	CIR_ARV
Old mans beard	*Clematis vitalba*	CLE_VIT
Dogwood	*Cornus sanguinea*	COR_SAN
Hazel	*Corylus avellana*	COR_AVE
Common Hawthorn	*Crataegus monogyna*	CRA_MON
Smooth hawksbeard	*Crepis capillaris*	CRE_CAP
Foxglove	*Digitalis purpurea*	DIG_PUR
Teasel	*Dipsacus Fullonum*	DIP_FUL
Broad buckler fern	*Dryopteris dilatata*	DRY_DIL
Male fern	*Dryopteris filix-mas*	DRY_FIL
Bluebells	*Endymion non-scriptus*	END_NON
Broadleaved willowherb	*Epilobium montanum*	EPI_MON
Wood horsetail	*Equisetum sylvaticum*	EQU_SYL
Beech	*Fagus sylvatica*	FAG_SYL
Japanese Knotweed	*Fallopia japonica*	FAL_JAP
Ash	*Fraxinus excelsior*	FRA_EXC
Cleavers	*Galium aparine*	GAL_APA
Cut leaved cranesbill	*Geranium dissectum*	GER_DIS

Herb-robert	*Geranium robertianum*	GER_ROB
Yorkshire fog	*Holcus lanatus* L.	HOL_LAN
St johns wort	*Hypericum perforatum*	HYP_PER
Holly	*Ilex aquifolium*	ILE_AQU
Yellow iris	*Iris pseudacorus*	IRI_PSE
Soft rush	*Junus effuses*	JUN_EFF
Hard rush	*Junus inflexus*	JUN_INF
Nipplewort	*Lapsana communis*	LAP_COM
Common Duck weed	*Lemna minor*	LEM_MIN
Honeysuckle	*Lonicera periclymenum*	LON_PER
Wood rush	*Luzula campestris*	LUZ_CAM
Heath woodrush	*Luzula multiflora*	LUZ_MUL
Gipsywort	*Lycopus europaeus*	LYC_EUR
Yellow pimpenell	*Lysimachia nemorum*	LYS_NEM
Black medic	*Medicago lupulina*	MED_LUP
Ribbed melilot	*Melilotus officinalis*	MEL_OFF
Water mint	*Mentha aquatica*	MEN_AQU
Dogs mercury	*Mercurialis perennis*	MER_PER
Tufted Forget-me-not	*Myosotis caespitosa*	MYO_CAE
White water-lily	*Nymphaea alba*	NYM_ALB
Birds foot	*Ornithopus perpusillus*	ORN_PER
Pale persicaria	*Persicaria lapathifolium*	PER_LAP
Ribwort plantain	*Plantago lanceolata* L.	PLA_LAN
Rough meadow grass	*Poa trivialis*	POA_TRI
Common polypody	*Polypodium virginianum*	POL_VIR
Aspen	*Populus tremula*	POP_TRE
Broad-leaved Pondweed	*Potamegetan natan*	POT_NAT
Creeping cinquefoil	*Potentilla reptans*	POT_REP
Selfheal	*Prunella vulgaris*	PRU_VUL
Wild cherry	*Prunus avium*	PRU_AVI
Blackthorn	*Prunus spinosa*	PRU_SPI
Bracken	*Pteridium*	PTERI
Sessile oak	*Quercus petraea*	QUE_PET
Pedunculate oak	*Quercus robur*	QUE_ROB
Meadow buttercup	*Ranunculus acris*	RAN_ACR
Bulbous Buttercup	*Ranunculus bulbosus*	RAN_BUL
Creeping buttercup	*Ranunculus repens. L.*	RAN_REP
Rhododendron	*Rhododendron ponticum*	RHO_PON
Field rose	*Rosa arvensis*	ROS_ARV
Dog Rose	*Rosa canina*	ROS_CAN
Bramble	*Rubus fruticosus*	RUB_FRU
Curled dock	*Rumex crispus*	RUM_CRI
Broad leaved dock	*Rumex obtusifolius*	RUM_OBT
Wood dock	*Rumex sanguineus*	RUM_SAN
Grey willow	*Salix cinerea*	SAL_CIN
Elder	*Sambucus nigra*	SAM_NIG
Common Figwort	*Scrophularia*	SCROP

Common Ragwort	*Senecio jacobaea*	SEN_JAC
Red campion	*Silene dioica*	SIL_DIO
Bittersweet	*Solanum dulcamara*	SOL_DUL
Rowan	*Sorbus aucuparia*	SOR_AUC
Hedge woundwort	*Stachys sylvatica*	STA_SYL
St johns wort	*Stellaria graminea*	STE_GRA
Common Snowberry	*Symphoricarpos albus*	SYM_ALB
Black bryony	*Tamus communis*	TAM_COM
Dandelion	*Taraxacum officinale*	TAR_OFF
Common yew	*Taxus baccata*	TAX_BAC
Wood sage	*Teucrium scorodonia*	TEU_SCO
Large-leaved lime	*Tilia platyphyllos*	TIL_PLA
Red clover	*Trifolium pratense*	TRI_PRA
Common Reedmace	*Typha latifolia*	TYP_LAT
Common Gorse	*Ulex europaeus*	ULE_EUR
Common Nettle	*Urtica dioica*	URT_DIO
Germander speedwell	*Veronica chamaedrys*	VER_CHA
Heath speedwell	*Veronica officinalis*	VER_OFF
Guelder rose	*Viburnum opulus*	VIB_OPU
Common vetch	Vicia sativa	VIC_SAT
Common Dog-violet	*Viola riviniana*	VIO_RIV

Appendix 2 Journal of Environmental Management: Guide to Authors

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Submission of an article to the *Journal of Environmental Management* implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, without the written consent of the Publisher. **It is essential to give a fax number and e-mail address when submitting a manuscript. Articles must be written in good English.**

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