BTO Research Report No. 572

An examination of reptile and amphibian populations in gardens, the factors influencing garden use and the role of a 'Citizen Science' approach for monitoring their populations within this habitat

Authors

Elizabeth Humphreys, Mike Toms, Stuart Newson, John Baker and Kathy Wormald

Report of work carried out by the British Trust for Ornithology, the Amphibian & Reptile Conservation Trust and Froglife.

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British Trust for Ornithology

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EXECUTIVE SUMMARY

Our knowledge of the changing status of the British reptiles and amphibians is far from complete and the challenge of collecting robust long-term monitoring data has been highlighted by a number of authors (*e.g.* Beebee *et al*. 2009). Monitoring schemes are in place for rare or localised species and efforts are being made to develop long-term reptile and amphibian monitoring across the wider landscape. One habitat, however, of value to amphibians, and to a lesser extent reptiles, but which is currently poorly monitored is gardens (McKinney 2008).

A national survey of amphibians and reptiles in gardens was launched in spring 2009 as a joint venture by the British Trust for Ornithology (BTO), Froglife and the Amphibian & Reptile Conservation Trust (ARC). Using a questionnaire-based approach, the survey set out to collect information on which reptile and amphibian species were present in gardens and what factors (both within and surrounding individual gardens) might influence species occurrence.

A total of 3,806 completed survey forms was returned from England (3,428), Scotland (189) and Wales (189). An additional 19 forms from Ireland (14), the Channel Islands (1) and the Scillies (1) were excluded from all analyses because of sample size considerations and their different and impoverished amphibian and reptile faunas. Some 80% of responses came from participants in the BTO Garden BirdWatch, 16% from Froglife or ARC supporters and the remainder from the wider media appeals.

Common Frog was the most commonly recorded amphibian (89% of gardens), followed by Smooth Newt (45%), Common Toad (44%) and Palmate Newt (8%). Slow-worm was the most commonly reported reptile (16% of gardens), followed by Grass Snake (13%). Records of rare or non-native species were validated through correspondence with volunteers, resulting in 17 records of ‘green’ frog, four of Midwife Toad, five of Alpine Newt, two of Sand Lizard and one of Smooth Snake. One of the ‘green’ frogs was likely to have been a European Tree Frog. The maximum number of amphibian species recorded from a single garden was six (two gardens), while the corresponding figure for reptiles was also six (one garden).

Significant relationships between the occurrence of individual reptile or amphibian species and particular features within or surrounding the garden were identified. From these, some general patterns emerge. Rates of occurrence showed a general pattern of increase with increase in garden size. The permeability of boundary features was found to be important, with abiotic features like walls, buildings and fences tending to be negatively associated, and biotic features (like hedges) positively associated.

The presence of ponds within the garden was found to be important for the occurrence of all the amphibians plus Grass Snake. At the level of individual ponds, occupancy was relatively low in the first year of existence but otherwise pond age had little effect. The presence of Goldfish appeared to exert a negative impact on the occurrence of newts, echoing the results of work elsewhere.

The presence of compost heaps, log-piles and piles of rubble were positively related to the occurrence of all amphibian and reptile species, whereas plastic compost bins were not. There was no evidence that the use of herbicides, slug pellets or other pesticides had a negative influence on the occurrence of amphibians and reptiles in gardens.

The occurrence of all reptile and amphibian species except Common Frog was negatively associated with the presence of parks, recreational areas, other gardens and habitats characteristic of an urbanised landscape. This might suggest a greater tolerance of urbanised landscapes for Common Frog. Major roads were found to negatively affect the presence of Common Toad, combined newt species and Grass Snake, suggesting they may act as a barrier.

At a wider landscape scale the current study highlights generally positive associations between reptiles/amphibians and rural landscapes, and generally negative associations with urbanised landscapes (including parks, recreation areas and other gardens). The pattern of associations identified by our study, namely between features within and surrounding individual gardens, suggest that favourable gardens (in terms of the habitats they contain and the management practices adopted) may be separated by unfavourably managed gardens or other areas of unsuitable habitat (including physical barriers to dispersal such as walls, buildings and roads). This implies that gardens have the potential to provide good amphibian/reptile habitat but that good practices (both within and beyond the garden) are needed to realise this potential.

Examination of BTO Garden BirdWatch data allowed us to model the potential for a citizen science approach to determine long-term trends in garden use by amphibian and reptile species. Two different modelling approaches, one based on 'unmatched' datasets and one on 'matched' datasets, revealed the potential of the scheme for long-term monitoring.

These analyses provide evidence that the BTO Garden BirdWatch scheme would allow the annual monitoring of changes in garden use by Common Frog, Common Toad, Grass Snake and Slow-worm at the national level (the four species considered), to which Smooth Newt could be added, with an ability to detect changes in the order of 5-25% between two periods of time.

1. INTRODUCTION

Some 13 terrestrial reptile and amphibian species are currently recognised as being post-glacial natives of Britain (Table 1.1), with all but four of these considered widespread across the region (Beebee *et al*. 2009). Declines in amphibian populations globally have been identified over the past two decades (Wake 1991, Stuart *et al*. 2004, Beebee & Griffiths 2005), prompting efforts to determine the patterns of such declines and to identify their underlying causes (Collins & Storfer 2003). Although early work in this area suggested that amphibian populations were exhibiting greater levels of decline than seen in other taxonomic groups (Stuart *et al*. 2004), more recent work (Beebee *et al*. 2009) suggests that, at least for Britain, reptile populations show similar levels of decline to those seen in amphibians, but with both showing more pronounced declines than those seen in birds or mammals. Recent work on snakes (Reading *et al*. 2010) also reveals sharp declines in some populations and highlights the possibility of underlying causes that may, perhaps, be operating on a global scale. Consequently, many post-glacial native amphibians and reptiles are listed as UK Biodiversity Action Plan species (see Table 1.1).

Table 1.1: Status of British Reptile and Amphibian species.

Species	Distribution	Status	UK BAP priority listed
Common Frog *Rana temporaria*	Widespread	Common. Documented decline up to 1970s, since when appears to have stabilized.	-
Pool Frog *Pelophylax lessonae*	Localised, East Anglia	Recent reintroduction to a single site. Also exists as some introduced populations from other sources.	England
Common Toad *Bufo bufo*	Widespread	Common, but long-term declines	England, Scotland and Wales
Natterjack Toad *Bufo calamita*	Localised.	Stable after period of decline	England, Scotland and Wales
Smooth Newt *Lissotriton vulgaris*	Widespread	Common; thought to have suffered a general decline in rural areas, though may have been offset somewhat by colonisation of new garden ponds.	-
Palmate Newt *Lissotriton helveticus*	Widespread, though patchily distributed. More common in Wales and Scotland; rare in East of England.	General decline	-
Great Crested Newt *Triturus cristatus*	Lowland species, widespread across most of England but rare or absent in north and west of UK.	General decline	England, Scotland and Wales
Common Lizard *Zootoca vivipara*	Widespread, but patchy	General decline	England, Scotland and Wales
Sand Lizard *Lacerta agilis*	Localised	Documented decline	England, Scotland and Wales
Slow-worm *Anguis fragilis*	Widespread	General decline	England, Scotland and Wales
Grass Snake *Natrix natrix*	Widespread in England and Wales. Almost absent from Scotland except for introductions.	General decline but current trends unknown	England, Scotland and Wales
Adder *Vipera berus*	Widespread, but restricted by habitat preferences	Declines in some areas	England, Scotland and Wales
Smooth Snake *Coronella austriaca*	Localised, Dorset, Surrey and Hampshire heaths	Decline, but current trends largely unknown	England

A number of non-native species have established breeding populations, with the following species considered in this report: Marsh Frog, Edible Frog, Alpine Newt, Midwife Toad and Wall Lizard.

Our knowledge of the changing status of the British reptiles and amphibians is far from complete and the challenge of collecting robust long-term monitoring data has been highlighted by a number of authors (*e.g.* Storfer 2003, Gleed-Own *et* al. 2005, Beebee *et al*. 2009). Even allowing for some uncertainty over changes in status (and distribution), it is clear that many of our reptile and amphibian populations have undergone quite serious declines (Cooke & Arnold 1982, Cooke & Scorgie 1983, Hilton-Brown & Oldham 1991, Carrier & Beebee 2003). These have been linked to changes in land management (notably the intensification of agriculture, extensive land drainage and the loss of lowland heath to agriculture and urbanisation). The substantial loss of rural waterbodies, associated with the main period of agricultural intensification and sometimes linked to the decline of several amphibian species within Britain, now appears to have halted; the latest figures show a 1.4% per annum increase in pond numbers nationally between 1998 and 2007, reversing the losses seen in the 1980s of around 1% per annum (Beebee 1997, Williams *et al*. 2010).

Within the UK, gardens form a potentially important resource for wildlife, collectively covering an area in excess of 400,000 ha. (an area larger than the county of Suffolk – Davies *et al*. 2009). Garden ponds often provide breeding sites for Common Frog *Rana temporaria*, Common Toad *Bufo bufo* and Smooth Newt *Lissotriton vulgaris* (Cooke 1975, Beebee 1979, Banks & Laverick 1986, Latham 1995). The value of gardens for reptiles, and indeed the wider value of gardens for amphibians (beyond any ponds they may contain), has yet to be determined. Similarly, while the value of the wider urbanized landscape has been evaluated for certain taxonomic groups (notably birds, Chamberlain *et al*. 2004, 2009), information remains sketchy for reptiles and amphibians (Ansell *et al*. 2001, McKinney 2008, Simon *et al*. 2009).

This report considers the factors that might influence garden use by reptile and amphibian species, before going on to make recommendations for management options within individual gardens. Data from the '*Reptiles and Amphibians in your Garden Survey*' (RAGS) are used to examine those factors influencing garden use, including those present within individual gardens as well as in the wider landscape which surrounds them (Chapter 2). This report also examines the potential value of data collected through the BTO Garden BirdWatch for monitoring long-term trends in garden use by reptile and amphibian species (Chapter 3).

2. GARDEN REPTILE AND AMPHIBIAN POPULATIONS: ASSOCIATIONS WITH LOCAL AND LANDSCAPE LEVEL HABITAT FEATURES

Elizabeth Humphreys, Mike Toms, John Baker and Kathy Wormald

Information on the role of specific habitat features (operating at varying spatial scales) in determining the occurrence of reptile and amphibian species within gardens, was investigated through the '*Reptiles and Amphibians in your Garden Survey*' (RAGS), a joint venture between the British Trust for Ornithology (BTO), Froglife and the Amphibian and Reptile Conservation Trust (ARC). The survey, launched in spring 2009, utilised a questionnaire approach to collect records of reptiles and amphibians from gardens located across England, Wales and Scotland, together with information on habitat features present within and around these gardens. Additional information for records of amphibians within ponds, together with characteristics associated with these ponds, were also gathered. Data derived from gardens located in Ireland were not analysed because of the small sample size available for this region and the impoverished herpetofauna present there. Similarly, data from the Channel Islands and the Isles of Scilly were also excluded. An additional component of the study collected information on amphibian mortality events noted in participating gardens.

2.1 Methodology

Approaches were made to already-established networks of volunteers (*e.g.* BTO Garden BirdWatchers and local Amphibian and Reptile Groups – ARGS) and to other audiences, the latter targeted through a national media campaign. Paper recording forms were mailed to *c.*15,000 BTO Garden BirdWatchers as part of their standard quarterly mailing, while a further *c.*4,000 recording forms were circulated to Froglife and ARC supporters and 1,273 to members of the public who expressed an interest in helping with the survey. These survey forms were specifically designed to allow data capture through optical mark recognition, with respondents placing simple marks in the appropriate boxes, which were then interpreted by a special scanning machine.

Participants were asked to provide presence/absence information for various reptile and amphibian species from within their gardens over the period 1st January 2008 to 30th June 2009. All of the native species were explicitly named on the questionnaire except for Pool Frog *Pelophylax lessonae*, for which there is a discrete reintroduced population at a single site in Norfolk and a number of introduced populations of captive origin elsewhere (Lever 2009). In addition, several recently established non-native species were explicitly named, with the option to record any other non-native reptile or amphibian also available on the form (Appendix I). All participants were provided with a colour identification guide (Appendix II) in case they were not familiar with the species that they might encounter.

For Common Frog and Common Toad, the stage of the life cycle encountered was also recorded (categorised as 'Adult', 'Spawn' and 'Tadpole'). Edible Frog *Pelophylax esculentus*, Marsh Frog *P. ridibundus* and Pool Frog were recorded under the collective term 'green frog' as they can be difficult to separate in the field (Wycherley 2003). Observers were, however, encouraged to name the species of 'green frog' encountered by using a box on the recording form. These boxes were also used to record any non-native species not named on the form (*e.g.* Wall Lizard *Podarcis muralis* and Midwife Toad *Alytes obstetricans*).

Participants were then asked to provide information on specific habitat features within and around their garden (Table 2.1). As well as details of the aquatic and terrestrial habitats available, information was also sought on those features (*e.g.* walls, buildings and hedgerows) that might determine boundary permeability. Information was also collected on those features providing potential terrestrial refuges (*e.g.* log piles and compost heaps). Participants were additionally asked to record their use of herbicides, slug pellets and other pesticides and the presence of cats within the garden. Cats are generalist obligate predators, known to take reptiles and amphibians in not insubstantial numbers (Woods *et al*. 2003, Baker *et al*. 2005), and it is possible that the high densities of cats found in many urbanised areas may limit herptile abundance in a similar manner to that seen in small mammals (Baker *et al*. 2003). Since ponds may have a particular bearing on amphibian occurrence within gardens, at least during the breeding phase of the lifecycle, more detailed information was collected on the nature of any ponds present and their management (Table 2.2), along with records of amphibians actually sighted within these ponds.

Table 2.1: Garden habitat/character variables and landscape habitat variables recorded in the survey by the surveyors and the binomial rankings used in the analyses (where appropriate).

Variable	Definition	Ranking presented to surveyors	Binomial ranking
Garden habitat/character variables			
Garden Size	Size of garden	Small (<2m^2), Medium (2-6m^2), Large (>6m^2)	
Garden Age	Years old	1(0-4), 2 (5-10), 3 (11-19), 4 (20-49), 5 (50+)	
Lawn	% garden covered	1(0), 2(1-25), 3 (26-50), 4 (51-75), 5 (76-100)	1=0, 2-5=1
Flowerbeds	% garden covered	1(0), 2(1-25), 3 (26-50), 4 (51-75), 5 (76-100)	1=0, 2-5=1
Shrubberies	% garden covered	1(0), 2(1-25), 3 (26-50), 4 (51-75), 5 (76-100)	1=0, 2-5=1
Vegetables	% garden covered	1(0), 2(1-25), 3 (26-50), 4 (51-75), 5 (76-100)	1=0, 2-5=1
Wild	% garden covered	1(0), 2(1-25), 3 (26-50), 4 (51-75), 5 (76-100)	1=0, 2-5=1
Bare ground	% garden covered	1(0), 2(1-25), 3 (26-50), 4 (51-75), 5 (76-100)	1=0, 2-5=1
Water	% garden covered	1(0), 2(1-25), 3 (26-50), 4 (51-75), 5 (76-100)	1=0, 2-5=1
Ponds	Presence in gardens	Presence/Absence for up to five ponds	0,1
Fence	% of garden boundary	1(0), 2(1-25), 3 (26-50), 4 (51-75), 5 (76-100)	1=0, 2-5=1
Wall	% of garden boundary	1(0), 2(1-25), 3 (26-50), 4 (51-75), 5 (76-100)	1=0, 2-5=1
Buildings	% of garden boundary	1(0), 2(1-25), 3 (26-50), 4 (51-75), 5 (76-100)	1=0, 2-5=1
Evergreen hedge	% of garden boundary	1(0), 2(1-25), 3 (26-50), 4 (51-75), 5 (76-100)	1=0, 2-5=1
Deciduous hedge	% of garden boundary	1(0), 2(1-25), 3 (26-50), 4 (51-75), 5 (76-100)	1=0, 2-5=1
Other	% of garden boundary	1(0), 2(1-25), 3 (26-50), 4 (51-75), 5 (76-100)	1=0, 2-5=1
Log pile	Presence in garden	Presence/Absence	0, 1
Rubble pile	Presence in garden	Presence/Absence	0, 1
Compost heap	Presence in garden	Presence/Absence	0, 1
Compost bin	Presence in garden	Presence/Absence	0, 1
Herbicides	Use in garden	Presence/Absence	0, 1
Slug pellets	Use in garden	Presence/Absence	0, 1
Other pesticides	Use in garden	Presence/Absence	0, 1
Cats use garden	Presence in garden	Presence/Absence	0, 1
Cat ownership	Ownership	Presence/Absence	0, 1
Landscape habitat variables			
Mixed woodland	Occurrence within 100 m	Presence/Absence	0, 1
Deciduous woodland	Occurrence within 100 m	Presence/Absence	0, 1
Coniferous woodland	Occurrence within 100 m	Presence/Absence	0, 1
Scrubland	Occurrence within 100 m	Presence/Absence	0, 1
Semi-natural grassland	Occurrence within 100 m	Presence/Absence	0, 1
Marsh	Occurrence within 100 m	Presence/Absence	0, 1
Moor	Occurrence within 100 m	Presence/Absence	0, 1
Lowland heathland	Occurrence within 100 m	Presence/Absence	0, 1
Major road	Occurrence within 100 m	Presence/Absence	0, 1
Ploughed farmland	Occurrence within 100 m	Presence/Absence	0, 1
Farmed grassland	Occurrence within 100 m	Presence/Absence	0, 1
Other grassland	Occurrence within 100 m	Presence/Absence	0, 1
Gardens	Occurrence within 100 m	Presence/Absence	0, 1
Parks/recreation areas	Occurrence within 100 m	Presence/Absence	0, 1
Allotments	Occurrence within 100 m	Presence/Absence	0, 1
Waste ground	Occurrence within 100 m	Presence/Absence	0, 1
Railway	Occurrence within 100 m	Presence/Absence	0, 1
Refuse tip	Occurrence within 100 m	Presence/Absence	0, 1
Small water body	Occurrence within 100 m	Presence/Absence	0, 1
Large water body	Occurrence within 100 m	Presence/Absence	0, 1
Stream	Occurrence within 100 m	Presence/Absence	0, 1
River	Occurrence within 100 m	Presence/Absence	0, 1
Canal	Occurrence within 100 m	Presence/Absence	0, 1
Seashore	Occurrence within 100 m	Presence/Absence	0, 1

Table 2.2: Pond variables (for up to five individual ponds within any one garden) as used by surveyors, together with the reduced binomial definitions used in the analyses.

Variable	Definition	Ranking presented to surveyors	Binomial ranking
Pond size	Size of pond	Small (<$2m^2$), Medium ($2-6m^2$), Large (>$6m^2$)	
Pond age	Years old	1 (<1 yr), 2 (1-5 yr), 3 (6-10 yr), 4 (> 10 yr)	
Weed removed annually	Yes or no	0 or 1	0, 1
Wildlife pond	Yes or no	0 or 1	0, 1
Chemical treatments	Yes or no	0 or 1	0, 1
Pond surround	Yes or no	0 or 1	0, 1
No fish	Presence/absence	0 or 1	Na
Goldfish	Presence/absence	0 or 1	0, 1
Other fish	Presence/absence	0 or 1	0, 1
Adult frog	Use of pond	0 or 1	0, 1
Frog spawn or tadpoles	Use of pond	0 or 1	0, 1
Toad	Use of pond	0 or 1	0, 1
Smooth newt	Use of pond	0 or 1	0, 1
Palmate newt	Use of pond	0 or 1	0, 1
Great crested newt	Use of pond	0 or 1	0, 1
Unknown newt	Use of pond	0 or 1	0, 1
Frogspawn introduced	Yes or no	0 or 1	0, 1

The opportunity was also taken to collect information on amphibian mortality, this time extending the survey period back to January 2006 and thus including the very hot summer of 2006 (Table 2.3). It was felt that observers would be able to recall any unusual mortality events witnessed over this extended period and the opportunity to include summer 2006 was taken as it has been suggested that specific temperature conditions may contribute to some mass mortality events (Berger *et al*. 2004). Observers were asked to report on any mass mortality event involving frogs, with a mass mortality event defined as involving at least five animals. They were also instructed to record the time of year when the incident occurred and life stage involved.

Table 2.3: Mass mortality event variables recorded in the survey.

Variable	Definition	Ranking presented to surveyors
Mass mortality	Recorded in garden	Yes, No, Don't know
Season	Quarter of year	1 (spring), 2 (summer), 3 (autumn), 4 (winter)
Life cycle stage	Stage affected	1 (adult frogs), 2 (baby frogs), 3 (not sure)

All survey returns were geocoded to allow regional reporting and the mapping of presence/absence records emerging from this survey in Arcview GIS 3.3.

Records were taken at face value and no attempt was made to validate records of common species or of the habitat data supplied. Records of rare species and non-natives were extracted for separate validation; those from BTO Garden BirdWatch volunteers were approached by the BTO and those from other sources were approached by John Wilkinson (JW) on behalf of ARC/Froglife. An initial examination of the records by JW suggested that only a few such records had a high probability of validity based on their location within or near existing records for these species. A series of standard questions was therefore agreed and used as the basis for validating these records in a systematic manner. Where it proved impossible to secure a response from a volunteer the record was treated as unvalidated and excluded.

2.2 Analytical Approaches Adopted

Treatment of variables: All landscape scale habitat variables were recorded as a binomial response (*e.g.* present/absence) whereas garden habitat/character variables were recorded either as a categorical (*e.g.* A=0%, B=1-25%, C=26-50%, D=51-75% and E=71-100%) or binomial (*e.g.* present/absent) response (see Table 2.1). Categorical data were analysed in two ways, depending on the number of returns received for each of the available categories. Where the number of responses was small across adjoining categories then the data were either reclassified to bring together certain categories (*e.g.* D+E). Conversion of categorical data, wherever possible, to a binomial response (*e.g.* A=0, B+C+D+E=1) was also performed to bring the variable in question into the same format as other variables that were already binomial in nature (see Table 2.1).

Additional information at the level of the landscape was taken from the 1-km summary information from the Countryside Survey 2000, a survey of the entire UK based on a combination of remote sensing and ground truthing (Fuller *et al.* 2002). This survey produced a landcover map that estimated the percentage cover of 27 different habitat types, which are termed sub classes, in every 1-km square in the UK. These sub classes have, in turn, been grouped accordingly to produce a total of 12 aggregate classes. For the purposes of this study, the sub classes of interest were 'continuous urban development' and 'suburban/rural development' which, when summed, created the recognised LCM2000 aggregate class of 'Built-up areas and gardens'. For all three, classes were reclassified into binomial data. Moreover an additional classification based on the aggregate class of 'Built-up areas and gardens' was also generated: <25%=rural, 25-75%=suburban and >75%=urban.

A new variable, termed 'Total Pond Area', was also created for the analyses of gardens containing multiple ponds. First, the mid-point size value from each of the ponds present within the garden was summed and then transformed into one of three 'Total Pond Area' classes (A=1 m^2, B=2-5 m^2 and C=>5 m^2). In order to look at factors that may influence the likelihood of mass mortality events, information on individual pond characteristics were summed across all ponds within a garden since evidence of mass mortality was recorded at the level of the garden rather than at the level of individual ponds.

Statistical analysis: The influence of garden habitat/character variables and wider landscape habitat features on the presence of individual amphibian and reptile species within individual gardens was explored using Generalised Linear Models (GLMs), with a logit link function and a binomial error distribution (PROC GENMOD in SAS 9.2.). A similar approach was adopted when analysing the likelihood of mass mortality events in gardens. A slightly different modelling approach was adopted for examining the influence of pond characteristics on the presence of amphibians within individual ponds by including garden identity as a repeated measure (within the PROC GENMOD options). This allowed correlations between presence/absence records within gardens to be accounted for and for different gardens to be treated as being independent of one another.

Due to the large number of possible explanatory terms that were of interest in this study, each was run individually as a series of univariate analysis. In order to control for any errors that might arise from the application of multiple tests, the level of statistical significance was increased from <0.05 to <0.01. This is acknowledged as a means of delivering more conservative tests without resorting to the application of a Bonferroni correction. While helpful when used correctly, concerns have been expressed about possible misuse and misunderstanding of the Bonferroni correction and, in particular, about the balance achieved between controlling the probability of a Type 1 error and the cost of increasing the probability of a Type 2 error.

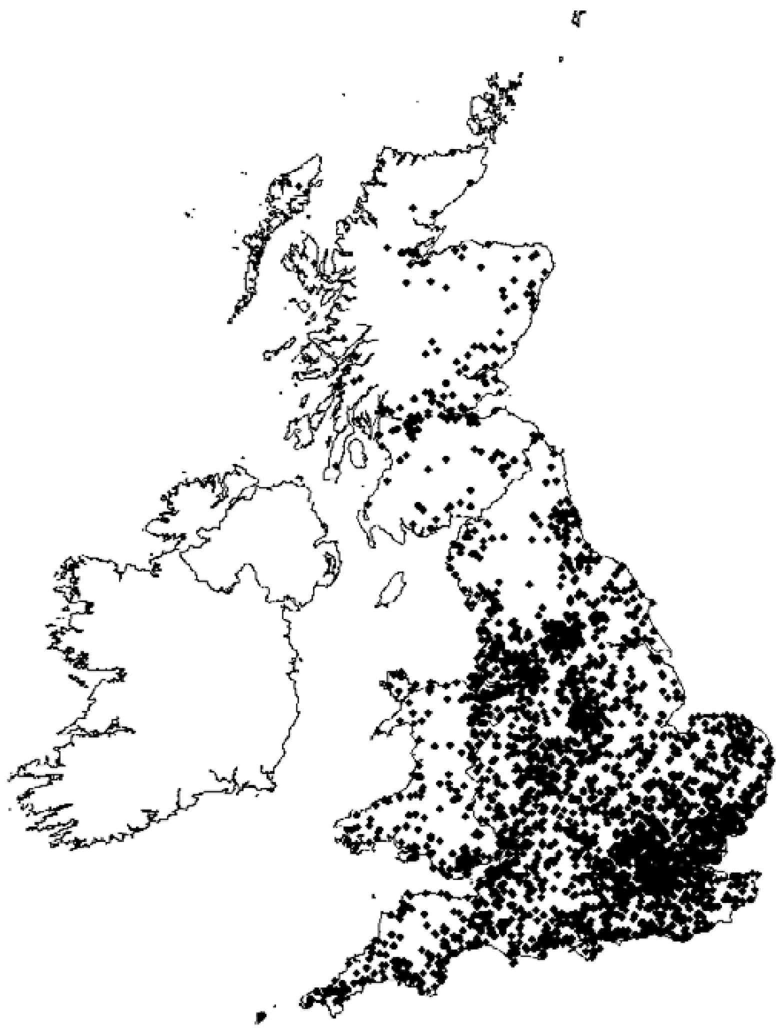
Chamberlain *et al*. (2004), looking for associations of birds with garden and landscape features, used a different method to that adopted here. The ordination approach they adopted is designed to control for intercorrelations between possible explanatory variables, essentially by grouping them together, but such an approach does not lend itself to the identification of relationships between the individual explanatory and response variables - the latter being a key aim of this study.

Another possible approach would have been to follow that adopted by Marnell (1998), who used Discriminant Analysis to determine which habitat factors influenced breeding site selection of Smooth Newt and Common Frog. This approach compared sites where the species was recorded with those where it was found to be absent. Such an approach is best suited to the systematic recording of sites with intensive fieldworker effort, such that negative records for a species are genuine and not 'false negatives' where the species was present but not recorded (Tabachnick & Fidell 2006). The latter are more likely to occur where casual records are submitted and it was felt that the nature of the current survey makes it more likely that observers might miss some species that were actually present. For example, the presence of newts is more likely to be determined at a site by using a torchlight survey at night and very few of the participants are likely to have adopted this approach.

2.3 Results

A total of 3,806 completed survey forms was returned from England (3,428), Scotland (189) and Wales (189). An additional 19 forms from Ireland (14), the Channel Islands (1) and the Scillies (1) were excluded from all analyses because of the small sample size available for these regions and because of their different and impoverished herpetofaunas (O'Neill *et al.* 2004). Some 80% of returns came from BTO Garden BirdWatch participants, 16% came from Froglife or ARC supporters and the remainder came from the media appeal. The distribution of gardens from which data were received and used in the analyses is shown in Figure 2.1

Figure 2.1. Distribution of gardens from which data were received and which were included in the subsequent analyses.



2.3.1 Distribution of amphibians and reptiles at the garden level

Common Frog was the most commonly recorded amphibian, occurring in 89% of gardens (Table 2.4) and with a distribution map (Figure 2.2) reflecting its widespread occurrence across the region. Smooth Newt was the next most abundant amphibian species, being reported from 45% of the returns (Figure 2.3), followed by Common Toad at 44% of gardens (Figure 2.4). Slow-worm was the most commonly reported reptile, being reported in 16% of gardens and showing a strongly southerly bias to its distribution (Figure 2.5). Grass Snake also showed a southerly bias to the distribution, being reported from 13% of gardens (Figure 2.6). All other species of amphibian and reptile were reported from fewer than 10% of gardens.

Table 2.4: Records of the core reptiles and amphibians recorded within individual gardens during the survey.

Species	Number of records	% of gardens with records
Common Frog	3,388	89
Common Toad	1,684	44
Smooth Newt	1,705	45
Palmate Newt	285	8
Great Crested Newt	171	5
Unknown newt sp.	133	4
Slow-worm	607	16
Common Lizard	215	6
Grass Snake	503	13
Adder	52	1

Table 2.5: Records of the core reptiles and amphibians recorded for all ponds within gardens during the survey.

Species	Number of records	% of ponds with records
Frogs	3,552	86
Frog spawn or tadpoles	2,870	70
Toads	1,026	25
Smooth Newt	1,933	47
Palmate Newt	357	9
Great Crested Newt	192	5

2.3.2 Records of rare or introduced reptiles and amphibians

Records of rare or introduced reptiles and amphibians from 96 sites were validated through correspondence with the survey participant, with 43 approached by BTO and 53 approached by ARC (Table 2.6).

Table 2.6: Validation of reptiles and amphibians recorded during the survey.

	BTO			ARC		
Species	**Valid**	**Invalid**	**Unknown**	**Valid**	**Invalid**	**Unknown**
Green Frog	5*	21	7	12	1	26
Midwife Toad	4	3	1	0	1	1
Natterjack Toad	0	0	0	0	0	1
Alpine Newt	0	0	0	5	0	2
Smooth Snake	0	2	0	1	0	1
Sand Lizard	0	1	0	2	0	3
Wall Lizard	0	2	0	0	0	0

* One of the 'Green Frogs' was European Tree Frog - see below.

Details of the validated records reported through BTO were as follows:

Green Frog:

TM0117: Hugh Owen, Tawnies, Hall Lane, Langenhoe, Colchester, Essex. Marsh Frog known to be present in good numbers on Fingringhoe Ranges (Langenhoe Marsh). They have been seen in an adjacent farm pond - 400m from marsh. Hugh lives 100m from the farm and his frogs first appeared in 2008. Validated by BTO on basis of photograph supplied.

TQ2049: Mrs Higgins, Mill High Lane, Brockham, Bethworth, Surrey. Has had green frogs since 2005 and also provided detail on green frogs at Newdigate Brick Works. Confirmed by BTO by photographs and thought to be Marsh Frog.

TQ3040: Mr Robin Tomlin, 1 Glebe Cottages, Antlands Lane East, Shipley Bridge, Horley, Surrey. A local distributor imported Hungarian green frogs (thought to be Marsh Frogs) into a neighbouring garden some years ago and they have now spread to his garden. Also noted frogs were introduced to two ponds in a property on Tupwood Lane, Caterham, Surrey.

TQ7916: Mrs Lynch, 2 Spraysbridge Cottage, Sprays Lane, Sedlescombe, Battle, East Sussex. Has both Common Frog and green Frog in her ponds. Photographs supplied. Validated by BTO on basis of photographs and locality.

European Tree Frog:

SX9494: Mrs Millini, 29 Elaine Close, Beacon Heath, Exeter, Devon. Description examined by ARC and thought likely to be this species. '*It was a vivid green, the sort of green you usually see in a parrot's feather. It climbs bushes. Skinny legs. Different snout/nose. The only reference book photograph that looks like it is a European Tree Frog. I wonder if it was a lost pet. No sight of it since the big freeze. I only saw it during the mild, rainy year.*' Call: '*I think it was the very soft call I heard in spring but I never managed to see it calling.*'

Midwife Toad:

SK5584: Sheila Newsome, 2 Brandsmere Drive, Woodsetts, Worksop. Well-known colony present in village and photograph supplied. Validated by BTO on basis of photograph supplied.

TL0451: Yvonne Anderson, 64 Eagle Gardens, Bedford. Validated by BTO on basis of locality.

TL0649: Carol Scrase, 69 Greenshields Road, Bedford. Electronic sounding call heard from May to end of August. Validated by BTO on basis of description of call and locality.

TL0823: Ms J Taylor, 48 Culverhouse Road, Luton, Bedfordshire. Has dozens that 'peep' from dusk to dawn. Has witnessed and photographed males with eggs wrapped in legs and very large tadpoles. Would like to get rid of them! Validated by BTO on basis that Beds Amphibian Reptile Recorder has confirmed identification; by call and by locality.

Figure 2.2. Map showing the distribution of Common Frog records received from England, Wales and Scotland from the survey. Solid dots show sites at which the species was recorded as present; hollow dots show sites at which the species was recorded as absent.

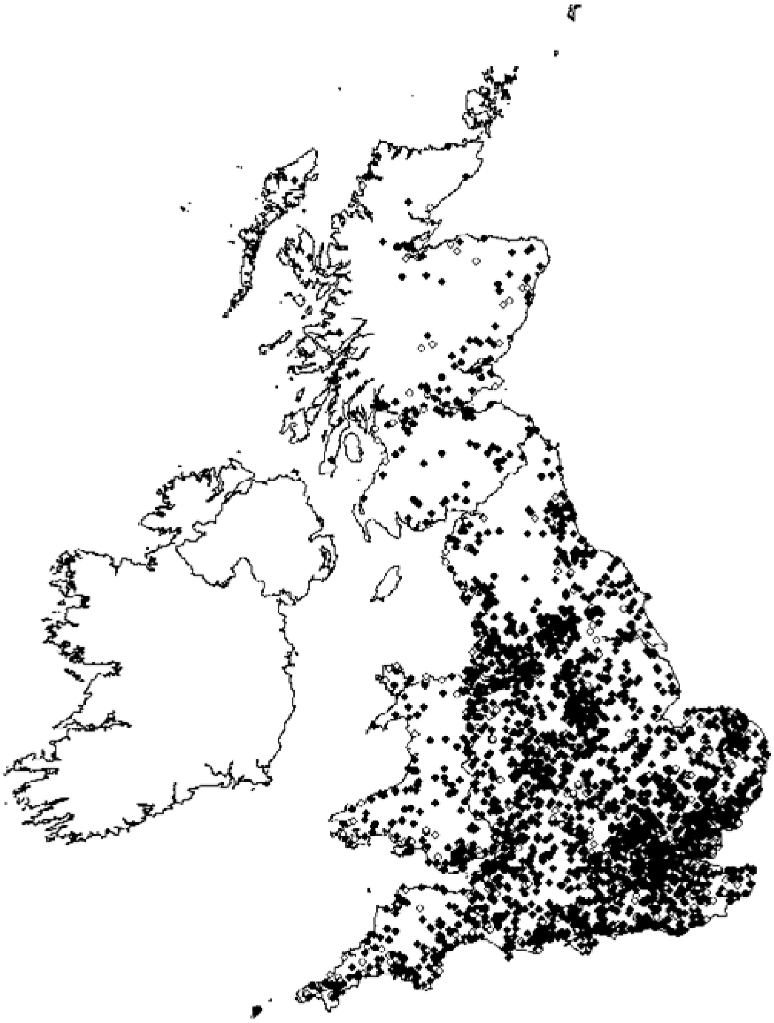


Figure 2.3. Map showing the distribution of Smooth Newt records received from England, Wales and Scotland from the survey. Solid dots show sites at which the species was recorded as present; hollow dots show sites at which the species was recorded as absent.

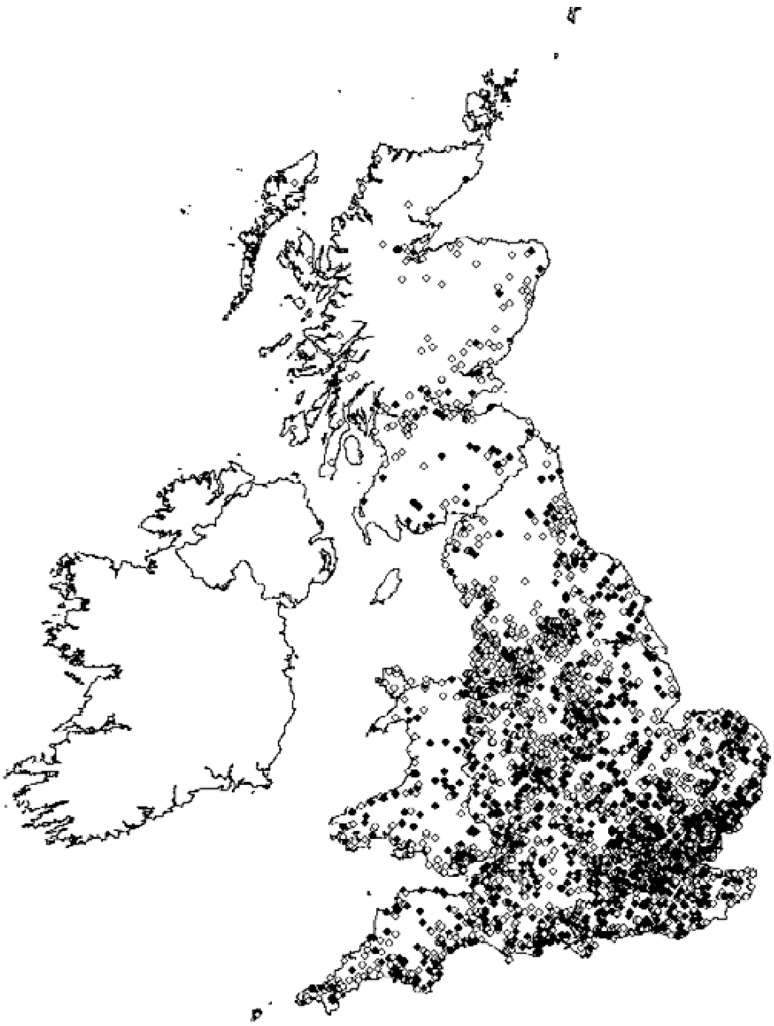


Figure 2.4. Map showing the distribution of Common Toad records received from England, Wales and Scotland from the survey. Solid dots show sites at which the species was recorded as present; hollow dots show sites at which the species was recorded as absent.

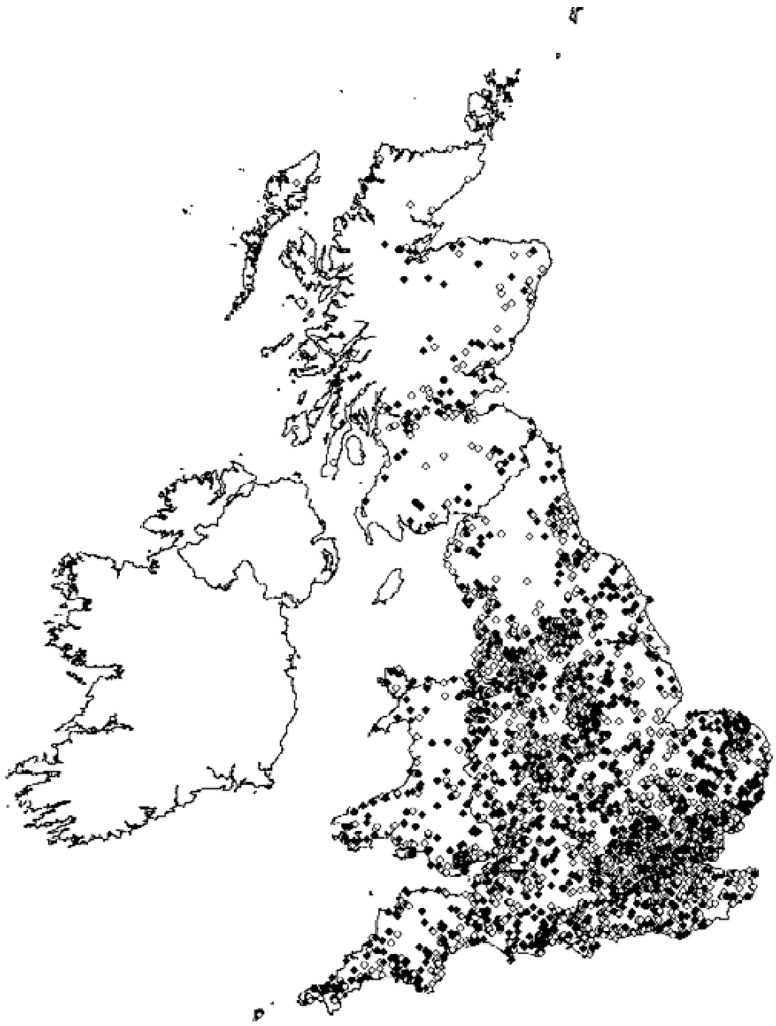


Figure 2.5. Map showing the distribution of Slow-worm records received from England, Wales and Scotland from the survey. Solid dots show sites at which the species was recorded as present; hollow dots show sites at which the species was recorded as absent.

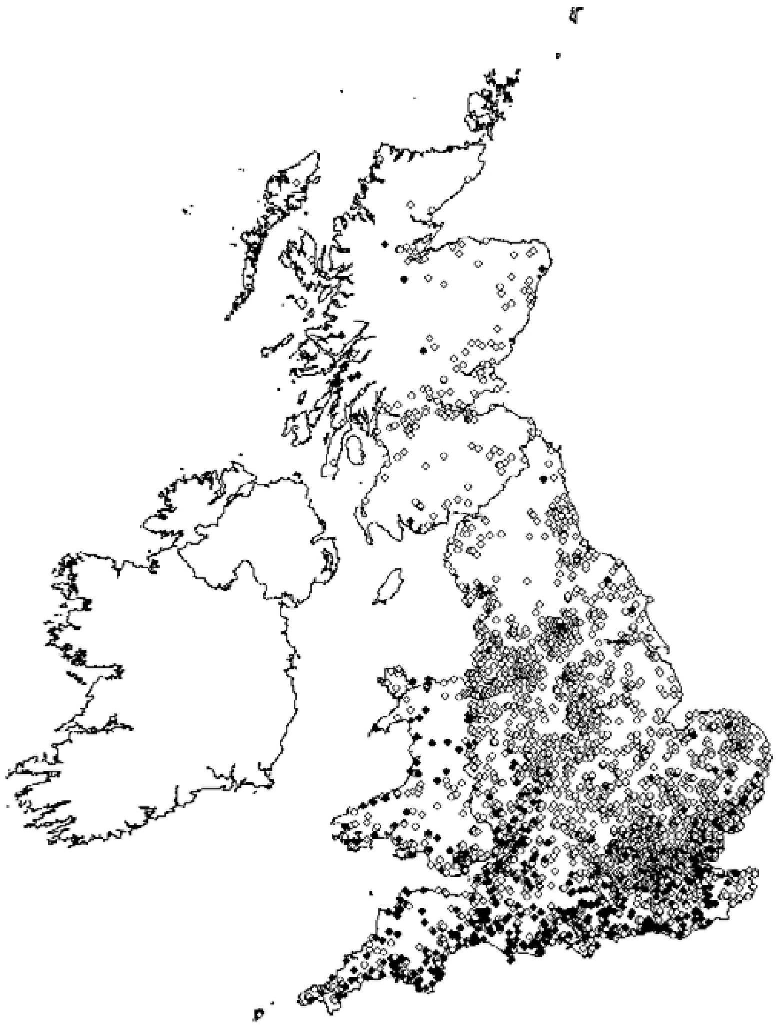
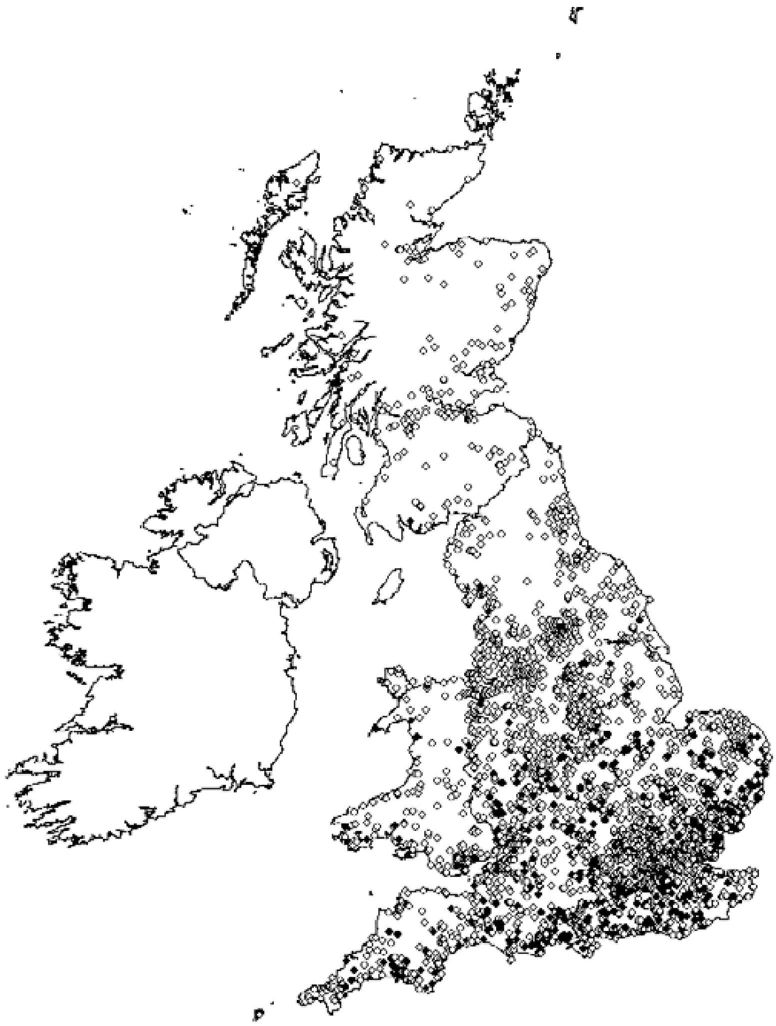


Figure 2.6. Map showing the distribution of Grass Snake records received from England, Wales and Scotland from the survey. Solid dots show sites at which the species was recorded as present; hollow dots show sites at which the species was recorded as absent.



2.3.3. The presence/absence of reptiles and amphibians in relation to garden habitat/character variables and landscape habitat features

The influence of garden habitat/character variables and landscape habitat features on the presence of particular reptiles and amphibians was examined individually for each of those species found to occur in at least 10% of the gardens surveyed (see Table 2.4). In order to look such influences more widely across the three newt species, and to bring in the data for Palmate Newt and Great Crested Newt, data from the three species were combined to create a generic ‘newt’ group. Data from all sites within England, Wales and Scotland were used in these analyses with two exceptions: 1) only English and Welsh sites were used in the analyses for Grass Snake (although there were two Scottish records); and 2) only gardens with ponds (approximately 80% of all records) were included when analysing the importance of pond-related features at the garden level (*e.g.* presence of fish and Total Pond Area).

Significant explanatory terms for the models are presented in descending order of their Chi-square value, within the different groupings of Garden habitats, Garden characteristics, Landscape habitats and the presence of Other species; thereby giving an indication of the factors most likely to be important.

2.3.3.1 Common Frog

Medium sized gardens were significantly more likely to have records of Common Frogs compared to both small and large gardens (see Table 2.7). ***Garden habitats***: the likelihood of Common Frog occurring was positively related to the presence of ponds (and water), wild areas, shrubberies, fences and flowerbeds. ***Garden characteristics***: The occurrence of Common Frogs was positively related to the presence of the following garden characteristics: log piles, piles of rubble, compost heaps and compost bin. ***Landscape habitats:*** the presence of Common Frog was positively influenced by the garden being adjacent to other gardens but showed a negative relationship to the presence of ploughed farmland and canals nearby. **Other species:** Common Frog was also positively associated with the presence of Smooth Newt, Common Toad and Palmate Newt but was negatively associated with the presence of Slow-worm.

2.3.3.2 Common Toad

Size of garden was an important factor for Common Toad, with large gardens having a higher occurrence rate compared to medium sized gardens, which in turn had higher rates than that found for small gardens. ***Garden habitats:*** the likelihood of the Common Toad occurring was positively related to the presence of wild areas, boundary deciduous hedges, boundary evergreen hedges, vegetable plots, flowerbeds and shrubberies but was negatively correlated with the presence of boundary fences and boundary buildings. ***Garden characteristics:*** the presence of Common Toad was positively related to the presence of compost heaps, Total Pond Area, piles of rubble, log piles, herbicide use and cat ownership. These last two factors were rather surprising, however, as negative relationships might have been predicted. Interestingly, Common Toad presence was negatively related to cat activity in the garden. ***Landscape features:*** the presence of Common Toad was positively related to the presence of the following habitat types within 100 m of the garden: farmed grassland, small water body, ploughed farmland, stream, dry semi-natural grassland, other farmland, marsh, deciduous woodland, mixed woodland, river, coniferous woodland, scrubland, large water body and moor. Negative associations were found with suburban/rural development, built-up areas and gardens, other gardens, parks/recreation areas, major roads and refuse tips. **Other species:** Common Toad was positively associated with the presence of Smooth Newt, Grass Snake, Slow-worm, Common Lizard, Great Crested Newt, Palmate Newt, other fish *(i.e.* not Goldfish) and Common Frog.

2.3.3.3 Smooth Newt

The occurrence rates of Smooth Newt increased with the size of the garden. ***Garden habitats:*** the occurrence rates of the Smooth Newt were positively correlated with the presence of ponds (and water), wild areas, boundary deciduous hedge, vegetable plots, boundary evergreen hedges, shrubberies and lawn. ***Garden characteristics:*** the presence of Smooth Newt was positively related to the Total Pond Area, log pile, compost heap and pile of rubble. As found for other amphibian species, e.g. Common Toad, there was also a positive association with the use of herbicides and the ownership of cats, which again was counter-intuitive. The presence of Smooth Newt was negatively associated with the presence of boundary walls and boundary buildings. ***Landscape features:*** there were positive associations between the occurrence of Smooth Newt and ploughed farmland, other farmland, farmed grassland and deciduous woodland. There were negative associations with the presence of parks/recreation areas, major roads, continuous urban development and railways. ***Other species:*** The Smooth Newt was positively associated with the presence of Great Crested Newt, Common Frog, Grass Snake, Common Toad, Slow-worm, Common Lizard and Palmate Newt.

2.3.3.4 All newt species

The likelihood of newt species occurring increased with the size of garden. ***Garden habitats***: the occurrence of newt species was positively related to the presence of ponds (and water), wild areas, deciduous boundary hedges, vegetable plots, evergreen boundary hedges, shrubberies and lawns. Newt species presence was negatively related to the presence of boundary walls and boundary buildings. ***Garden characteristics:*** The occurrence rates of newt species was positively associated with Total Pond Area, log pile, compost heap, pile of rubble, cat ownership and herbicide use. ***Landscape features***: the occurrence of newt species was positively related to the presence of farmed grassland, other farmland, deciduous woodland, ploughed farmland, marsh, mixed woodland, stream, dry semi-natural grassland and small water body. Conversely, newt species occurrence was negatively associated with the presence of parks/recreation areas, continuous urban development, major roads and suburban/urban development. ***Other species***: Newt species were positively associated with the presence of Common Toad, Common Frog, Grass Snake, Slow-worm and Common Lizard.

2.3.3.5 Slow-worm

As the size of the garden increased so did the occurrence of Slow-worm. ***Garden habitats***: the frequency of Slow-worm occurrence was found to be positively associated with wild areas, deciduous boundary hedges, vegetable plots and evergreen boundary fences. Slow-worm occurrence was negatively associated with the presence of boundary buildings and boundary fences. ***Garden characteristics:*** Positive associations were found for Slow-worm records with compost heap, pile of rubble, log pile, Total Pond Area and the use of slug pellets. ***Landscape features***: Slow-worm presence was positively associated with the presence of mixed woodland, farmed grassland, deciduous woodland, stream, small waterbody, scrubland, coniferous woodland, lowland heathland, dry semi-natural grassland and river. Slow-worm occurrence was negatively associated with the presence of parks/recreational areas, continuous urban development and other gardens. ***Other species:*** presence of Slow-worm was also positively associated with the presence of Grass Snake, Common Lizard, Common Toad, Smooth Newt and Palmate Newt but negatively with Common Frog.

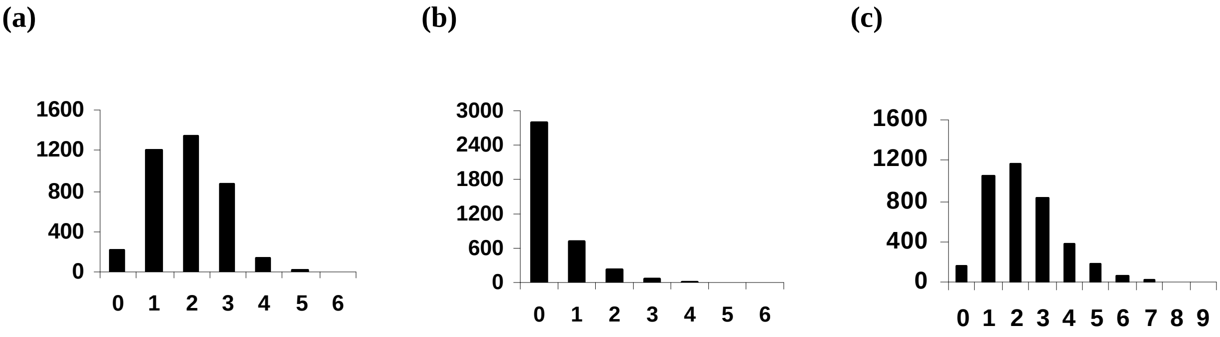
2.3.3.6 Grass Snake

Size of garden was shown to be positively associated with the occurrence of Grass Snakes. ***Garden habitats***: The occurrence rate of Grass Snake was shown to be positively associated with deciduous boundary hedges, wild areas, vegetable plots, water, ponds, lawn and evergreen boundary hedges but was negatively associated with boundary buildings, boundary walls and boundary fences. ***Garden characteristics:*** the presence of Grass Snake was also positively associated with presence of compost heap, Total Pond Area, log pile, pile of rubble and the use of herbicides. Negative associations were found with cat activity. ***Landscape features***: factors which were positively associated with the occurrence of Grass Snakes were farmed grassland, mixed woodland, scrubland, ploughed farmland, refuse tip, deciduous woodland, dry semi-natural grassland, marsh, small water body and coniferous woodland. Landscape features that were negatively associated with Grass Snake occurrence were continuous urban development, parks/recreational area, major roads and other gardens. ***Other species***: Grass Snake was positively associated with Slow-worm, Common Lizard, Great Crested Newt, Smooth Newt and Common Toad.

2.4 Amphibian and Reptile Communities in Survey Gardens

The maximum number of amphibian species recorded from a single garden was six (two gardens - one on the outskirts of Brighton and the other to the south of Tunbridge Wells). A single garden was reported to hold six reptile species (located near Christchurch, Bournemouth) and a single garden had nine herptile species (the garden south of Tunbridge Wells). The number of species per garden is shown in Figure 2.7(a-c).

Figure 2.7 Frequency plots of the number of species per garden: (a) amphibians; (b) reptiles and (c) combined herpetofauna.



2.5 The Presence/Absence Of Amphibians In Relation To Pond Character Variables

Some 79.6% of the gardens from which returns were received had one or more ponds present, with 26.9% of those gardens with ponds having two or more present. There were 33 sites where all five of the individual pond boxes were used, so conceivably there may have been some sites with 6 or more ponds present.

Frogs: Medium-sized ponds were more likely to be associated with reports of frogs compared to small ponds. Larger ponds did not, in turn, produce more records than medium-sized ponds and were not significantly different from small ponds either. The frequency of frog records increased with pond age, although there were no further significant increases seen across the pond age classes ‘6-10 years’ and ‘more than 10 years’. Pond features: the occurrence of frogs within ponds was positively related to the annual removal of weeds and whether the pond was managed for wildlife.

Frogspawn and tadpoles: Medium and large-sized ponds had higher occurrence rates for frogspawn when compared with small ponds. In addition, the age of the pond was found to be positively related to the frequency of records of frogspawn, although the increase in records was less notable beyond a pond age of five years. Pond features: numbers of records of frogspawn were positively related to the annual removal of weeds, whether the pond was managed as a wildlife pond, whether spawn was added to the pond and the presence of Goldfish (though the latter relationship was weak when compared to the others). Frogspawn was recorded as having been introduced to 32.5% of all individual ponds reported during the survey.

Toads: The occurrence rate of toads was found to increase with the size of the pond. Moreover, all ponds older than one year of age were found to have significantly higher frequencies of toads compared to those that had only been created within the last year. Pond features: the occurrence rate of toads within ponds was positively related to the presence of fish (for both Goldfish and other species) and the annual removal of weed.

Smooth Newt: Medium and large sized ponds had a higher occurrence rate for the Smooth Newt compared to small ponds. Moreover, the incidence rate of Smooth Newt was higher for all pond greater than one year of age when compared to those ponds created recently. Pond features: the occurrence rate of Smooth Newt was positively related to whether the pond was managed for wildlife, whether weeds were removed and if frog spawn had been introduced. There was a negative relationship between the frequency of Smooth Newt records and the presence of Goldfish.

Palmate Newt: The frequency of records of the Palmate Newt was shown to increase with pond size (although pond age was not shown to be a significant factor). Pond features: the likelihood of Palmate Newt records was shown to be positively related to whether the pond was managed for wildlife. A negative relationship between the frequency of Palmate Newt records and the presence of Goldfish was found.

Great Crested Newt: Records of Great Crested Newt were shown to increase with pond size (although pond age was not shown to be a significant factor). Pond features: the occurrence rate of Great Crested Newt was positively related to whether the pond was managed for wildlife. There was a negative relationship with the presence of Goldfish.

2.6 Mass Mortality Events

Mass mortality events of frogs within those gardens which also had ponds were reported from 293 gardens (7.4%) for the period Spring 2006 to Summer 2009 inclusive. Some 2,622 observers stated that there had been no mass mortality event in their garden during this period. Records from a further 12 sites lacked any seasonal information. Although most reports related to a single season only (see Table 2.7), there were a small number of gardens in which mass mortality events had occurred in more than one season. These events were most commonly reported in the spring and summer and the majority (across all seasons) involved the adult stage alone (n=265). Some 16 cases involved only young frogs leaving the pond, four cases were reported for which the stage affected was flagged as unknown and a further eight cases involved both adult and young frogs. For the purposes of further analyses, no attempt was made to distinguish between the sub-groups of season or life stage affected due to the small sample sizes involved. A number of pond-related features were examined (see Table 2.2), including the introduction of frogspawn and the addition of chemical treatments, none of which were found to predict mass mortality.

Table 2.7: Seasonality of Common Frog mass mortality events, Spring 2006 to Summer 2009 inclusive.

	Spring	**Summer**	**Autumn**	**Winter**
Spring	***102***	22	2	3
Summer		***93***	6	0
Autumn			***14***	0
Winter				***37***

Those sites where an event occurred in just a single season are shown in bold and italics. Those sites where events occurred over two seasons are shown in combination (*e.g.* there were 22 sites in which the events occurred in both spring and summer). In addition to the above, there was a single site for which incidents were noted in spring, summer and autumn.

2.7 Discussion

The results presented in the previous section are tabulated here to highlight a number of consistent patterns seen across species, or groups of species, and operating at particular spatial scales.

Table 2.8: Summary cross-tabulation of significant relationships between species occurrence and garden/habitat characteristics and landscape habitats features. *** p<0.0001, ** p<0.001 and * p< 0.01. (Bold indicates a positive relationship and *Italic* indicates a negative relationship).

	Species					
Habitat	**Common Frog**	**Common Toad**	**Smooth newt**	**Combined newts**	**Slow-worm**	**Grass Snake**
Garden Habitat						
Garden Size	M>S=L***	S=M>L**	S<M<L***	S<M<L***	S<M<L	S<M<L***
Garden Age	-	-	-	-	-	-
Lawn	-	-	+ve*	+ve*	-	+ve***
Flowerbeds	+ve*	+ve*	-	-	-	-
Shrubberies	+ve*	+ve*	+ve*	+ve*	-	-
Vegetable plots	-	+ve**	+ve**	+ve***	+ve**	+ve***
Wild	+ve***	+ve***	+ve***	+ve***	+ve***	+ve***
Bare ground	-	-	-	-	-	-
Water	+ve***	-	+ve***	+ve***	-	+ve***
Ponds	+ve***	-	+ve***	+ve***	-	+ve***
Fence	+ve**	-ve**	-	-	-ve**	-ve**
Wall	-	-	-ve*	-ve***	-	-ve***
Buildings	-	-ve**	-ve*	-ve**	-ve**	-ve***
Evergreen hedge	-	+ve**	+ve**	+ve**	+ve***	+ve**
Deciduous hedge	-	+ve**	+ve**	+ve**	+ve***	+ve***
Garden characteristics						
Log pile	+ve***	+ve***	+ve***	+ve***	+ve***	+ve***
Pile of rubble	+ve**	+ve***	+ve***	+ve***	+ve***	+ve**
Compost heap	+ve*	+ve***	+ve***	+ve***	+ve***	+ve***
Compost bin	+ve*	-	-	-	-	-
Herbicides	-	+ve***	+ve**	+ve***	-	+ve**
Slug pellets	-	-	-	-	+ve***	-
Other pesticides	-	-	-	-	-	-
Cats active in garden	-	-ve**	-	-	-	-ve**
Own cat	-	+ve**	+ve**	+ve**	-	-
Pond volume	-	S<M<L***	S<M<L***	S<M<L***	S=M<L**	S=M<L***

Continued overleaf

Habitat	Species					
	Common Frog	Common Toad	Smooth newt	Combined newts	Slow-worm	Grass Snake
Other species						
Common Frog		+ve***	+ve***	+ve***	-ve***	-
Common Toad	+ve***		+ve***	+ve***	+ve***	+ve***
Smooth Newt	+ve***	+ve***			+ve***	+ve**
Palmate Newt	+ve**	+ve***	+ve**		+ve***	-
Great Crested Newt	-	+ve***	+ve**		-	+ve***
All newts (combined)	+ve***	+ve***			+ve***	+ve***
Slow-worm	-ve***	+ve***	+ve***	+ve***		+ve***
Common Lizard	-	+ve***	+ve***	+ve***	+ve***	+ve***
Grass Snake	-	+ve***	+ve***	+ve***	+ve***	
Goldfish	-	-	-	-	-	-
Other fish	-	+ve***	-	-	-	-
All fish	-	+ve***	-	-	-	+ve**
Landscape habitats						
Mixed Woodland	-	+ve**	-	+ve*	+ve***	+ve***
Scrubland	-	+ve**	-	-	+ve***	+ve***
Moor	-	+ve**	-	-	-	-
Ploughed farmland	-ve*	+ve***	+ve**	+ve***	-	+ve***
Gardens	+ve**	-ve***	-	-	-ve**	-ve***
Waste ground	-	-	-	-	-	-
Small water body	-	+ve***	-	+ve*	+ve**	+ve***
River	-	+ve**	-	-	+ve*	-
Deciduous woodland	-	+ve**	+ve**	+ve***	+ve***	+ve***
Dry semi-natural grassland	-	+ve**	-	+ve*	+ve*	+ve***
Lowland heathland	-	-	-	-	+ve**	-
Farmed grassland	-	+ve**	+ve**	+ve***	+ve***	+ve***
Parks/recreation areas	-	-ve**	-ve**	-ve***	-ve***	-ve***
Railway	-	-	-ve*	-	-	-
Large water body	-	+ve*	-	-	-	-
Canal	-ve**	-	-	-	-	-
Coniferous woodland	-	+ve*	-	-	+ve***	+ve*
Marsh	-	+ve**	-	+ve**	-	+ve*
Major road	-	-ve**	-ve**	-ve***	-	-ve***
Other farmland	-	+ve**	+ve**	+ve***	-	-
Allotments	-	-	-	-	-	-
Refuse tip	-	-ve*	-	-	-	+ve**
Stream	-	+ve**	-	+ve*	+ve***	-
Seashore	-	-	-	-	-	-
Continuous urban	-	-ve***	-ve**	-ve**	-ve**	-ve**
Suburban/rural development	-	-ve***	-	-ve**	-	-
Built-up areas and gardens	-	-ve***	-	-	-	-

Table 2.9. Summary cross-tabulation of significant relationships between species occurrence at the level of the pond and features associated with the ponds. *** p<0.0001, ** p<0.001 and * p< 0.01. (Bold indicates a positive relationship and *Italic* indicates a negative relationship).

	Species					
Pond features	Frogs	Frogspawn	Toads	Smooth Newt	Palmate Newt	Great Crested Newt
Pond size	S<M, M=L and L=S**	S<M=L***	S<M<L***	S<M=L***	S<M=L***	S<M<L***
Pond age	A<B<C=D***	A<B=C=D and B<D***	A<B=C=D* **	A<B=C and C=D and B<D***	-	-
Weeds removed annually	+ve***	+ve	+ve**	+ve***	-	-
Wildlife pond	+ve***	+ve	-	+ve***	+ve***	+ve***
Nature of pond surroundings	-	-	-	-	-	-
Goldfish present	-	+ve*	+ve**	-ve**	-ve**	-ve**
Other fish present	-	-	+ve***	-	-	-
Frogspawn introduced	-	+ve***	-	+ve***	-	-

2.8 Gardens Characteristics Influencing the Presence of Reptiles and Amphibians

Rates of occurrence for the amphibian and reptile species considered showed a general pattern of increase with increasing size of garden. Larger gardens may be more likely to support a greater range of habitat features favourable to amphibians and reptiles than smaller gardens simply because they are bigger. However, Chamberlain *et al.* (2004) found that larger gardens were more likely to occur in rural habitats and, therefore, were more likely to be associated with wider countryside habitats favourable to amphibians and reptiles. In contrast, smaller gardens tend to be urban or suburban in nature and it is interesting to note that, with the exception of Common Frog, the other amphibian and reptile species examined showed a negative association with those landscape features associated with urbanisation (*e.g.* others gardens, continuous urban). Possible interactions between landscape type (*e.g.* rural, suburban and urban) and garden size were tested in a separate set of analyses by including both terms in the models, along with an interaction term for each of the herptile species. There was no evidence that there was any form of interaction for any of the species, as trends in occurrence rates with increasing garden size were the same across each of the three landscape types.

Boundary features also appear to be of importance to both amphibians and reptiles. The presence of abiotic features such as walls, buildings and fences, was negatively associated with occurrence rates, while the presence of biotic boundary features (*e.g.* deciduous and evergreen hedges) tended to be positively associated. This might indicate that abiotic features are less permeable to the movement of reptiles and amphibians or that they provided limited use either as a refuge or as a potential source of invertebrate prey.

The importance of ponds for both the amphibians and Grass Snake is perhaps unsurprising, mirroring the findings of Banks & Laverick (1986), Latham *et al*. (1994) and Gledhill *et al*. (2008).

It is worth noting that some potentially important variables were not examined in this study. For example, water chemistry affects pond occupancy by newts. Palmate Newts prefer soft water and can be found in more acidic ponds, whereas both Smooth and Great Crested Newts tend to be found in areas of hard water and are less tolerant of acidic breeding ponds (Beebee & Griffiths 2000).

The results reveal a potential negative impact of the presence of goldfish on newt occurrence (when analysed at the level of the individual pond), supporting findings elsewhere that fish are recognised as a notable predator of their larvae (Latham *et al*. 1994). The positive association between fish (both goldfish and other fish) and Common Toad may stem from similar habitat 'preferences', for example toads generally prefer larger breeding ponds, and larger garden ponds may be more likely to be stocked with fish. Additionally, Common Toad tadpoles are distasteful to fish, so toads are less susceptible to fish predation than other amphibians. The presence of fish may even be beneficial to toads, possibly by reducing the numbers of invertebrate predators of toad tadpoles. The results of the current work also suggest that there may be some differential impacts of goldfish versus ‘other fish’ on newts. Table 2.9. highlights the significant negative relationship between the presence of goldfish and that of the three newt species, a relationship not evident with ‘other fish’. This is something that would warrant further and more detailed investigation. The association between Grass Snake occurrence and fish (non-goldfish) presence may be due to Grass Snakes visiting ponds specifically to feed on fish.

2.9 Garden Practices Influencing the Presence of Reptiles and Amphibians

The presence of compost heaps, log piles and piles of rubble were positively related to the occurrence of all amphibian and reptile species examined in this study. The association between compost bins and herpetofauna was much less evident, being positively associated only with Common Frog. It is unclear why compost bins should be less favourable than compost heaps but the difference may be due to ease of access and is certainly worthy of further investigation.

There was no evidence that the use of herbicides, slug pellets or other pesticides had a negative influence on the occurrence of amphibians and reptiles in gardens. This could indicate that the intensity of use of such chemicals, within the sample of gardens studied, is at such low levels as to have a negligible impact. The volunteers contributing to this survey were self-selecting and it could be that they are not representative of all gardens in Britain. Interestingly, the use of herbicides was found to be associated with an increase in the occurrence rate of Common Frog, combined newt species and Grass Snake, something that might warrant further investigation.

2.10 Landscape Scale Features and the Presence of Reptiles and Amphibians

The presence of parks/recreational areas and other gardens were both found to be negatively associated with all the species examined apart from Common Frog, for which a positive association with other gardens was found. Parks and recreation areas may be dominated by areas of mown grass or hard-based sports surfaces, which are of limited use for wildlife. The presence of urban development, either as continuous urban or as suburban/rural development, was found to negatively influence the occurrence rates of all species studied apart from Common Frog. The positive association of Common Frog with the presence of other gardens locally, and the lack of any negative association with urban development, may suggest a greater tolerance of the urban environment in this species. However, work by Hitchings & Beebee (1997, 1998) has shown that urban development hinders gene flow in Common Frog and Common Toad populations, implying that urbanised landscapes may inhibit dispersal opportunities, leaving a fragmented patchwork varying in habitat suitability.

However, as Banks & Laverick (1986) note, the spread of Common Frogs to new ponds within urban areas may be facilitated through the deliberate introduction of spawn by householders. In the current study there was little evidence that the occurrence rate of frogs was influenced by the introduction of spawn at the level of the individual pond, even though the occurrence rate of frogspawn was (Table 2.9). This might suggest that frogspawn is often introduced into ponds (and/or garden locations) that are ultimately unsuitable and unable to sustain a population of frogs.

Other landscape features within the urbanized landscape may have an influence on the occurrence of various amphibian and reptile species. Simon *et al*. (2009) found that landscape features, present at distances of up to 1,000m from storm-water management ponds, influenced amphibian species richness in ponds - both directly by the provisioning of source habitat and indirectly through influences on within pond habitat quality. While Simon *et al*. (2009) found road density to be only weakly related to species richness or the occurrence of individual species, our results are suggestive of a stronger relationship. We found the presence of major roads to negatively affect the presence of Common Toad, combined newt species and Grass Snake, which may suggest that they are effective as a barrier to dispersal and subsequent colonisation of ponds. An additional influence, not considered here, could be pollutant run-off, although this is likely to be less of an issue for garden ponds compared with the storm-water ponds studied by Simon *et al.* (2009).

At a wider landscape scale the current study highlights generally positive associations between reptiles/amphibians and rural landscapes, and generally negative associations with urbanised landscapes (including parks, recreation areas and other gardens). The pattern of associations identified by our study, namely between features within and surrounding individual gardens, suggests that favourable gardens (in terms of the habitats they contain and the management practices adopted) may be separated by unfavourably managed gardens or other areas of unsuitable habitat (including physical barriers to dispersal such as walls, buildings and roads). This implies that gardens have the potential to provide good amphibian/reptile habitat but that good practices (both within and beyond the garden) are needed to realise this potential.

2.11 Species Interactions and Common Influences on Occurrence Rates of Reptiles and Amphibians

The positive or negative interactions between particular species are likely to reflect some degree of commonality in their relationships with specific habitat or management variables. Some of these may relate to a shared dependency at a point during their life cycle. For example, while Common Frog, Common Toad and the combined newt species were all found to display positive predictive relationships with one another, they all rely on water for spawning and the tadpole stage of the lifecycle. However, the effects of inter-specific competition and/or predation should also be considered.

The association between Grass Snake and water within the garden is likely to reflect the snake’s favoured prey spectrum of frogs, toads and newts. Since these prey are associated with garden waterbodies, the Grass Snake is likely to target these features because of the species associated with them.

The negative interaction between Slow-worm and Common Frog is of particular note, given that the Slow-worm was found to be positively associated with the presence of Common Toad and combined newt species. This may be an artefact of geographical range differences, with Common Frog the one species to be found in a significant number of Scottish gardens, beyond the core range of the other species.

2.12 Summary of Factors Influencing Reptile and Amphibian Occurrence in Gardens and Recommendations for Appropriate Management Practices

In general, it has been demonstrated that larger gardens have higher occurrence rates across a range of reptile and amphibian species. The current trend for new-build housing to be developed at high density and with smaller gardens may reduce opportunities for reptiles and amphibians within new housing developments.

Recommendations for individual homeowners to provide better opportunities for reptiles and amphibians to make use of their gardens are as follows:

A) Create habitat diversity:

Allow part of the garden to become wild.

Use hedges as barriers, in preference to fences or walls.

B) Create habitat features:

Make a log pile.

Make a compost heap (rather than a compost bin).

C) Dig a pond:

Minimum size should be no less than $2m^2$.
Remove excess weed from ponds on an annual basis.
Manage for wildlife.
To encourage newt species, refrain from adding ornamental goldfish to a pond.

3. GARDEN REPTILE AND AMPHIBIAN POPULATIONS: MONITORING CHANGE IN THE USE OF GARDENS

Mike Toms and Stuart Newson

3.1 Introduction

The willingness of volunteers to record simple presence/absence data on reptiles and amphibians in gardens may allow monitoring of reptile and amphibian populations within this habitat, since changes in population size and occurrence can be inferred from a change in the number of sites at which the species is detected (Strayer 1999, Toms & Newson 2006).

3.2 Methods

Reptile and amphibian data collected as part of the optional 'Other Wildlife' component of the BTO Garden BirdWatch scheme were examined to determine their potential for use in the long-term monitoring of trends in garden use. Data used in these analyses were derived from a pilot study, carried out in 2003, in which participants recorded the presence/absence of two amphibian and two reptile species (plus 24 mammal species and 14 butterfly species). The four herptile species (Common Frog *Rana temporaria*, Common Toad *Bufo bufo*, Grass Snake *Natrix natrix* and Slow-worm *Anguis fragilis*) were selected on the basis of being likely to utilise the garden environment and because they could be readily identified.

Observers were asked to record the presence/absence of the four reptile and amphibian species within their defined garden recording area on a monthly basis over the summer of 2003. Data were collected on specially prepared optically-mark-readable forms, similar to those used in the main component of the BTO Garden BirdWatch. Survey returns were received from 4,530 participants, of which 97% (4,403) recorded the presence of one or more of the species listed on the form. It was assumed that those participants returning blank 'Other Wildlife' forms had chosen not to record non-avian taxa. This assumption was made on the basis that it was considered extremely unlikely that a participant would not have encountered at least one of the species listed on the form over the survey period. In order to examine the potential for these data to be used at the regional level the dataset was divided (for the relevant analyses) using the nine English Government Office regions and for Scotland (divided into Southern and Northern Scotland), Wales and Northern Ireland.

3.3 Analytical approach

While participants were asked to record species presence/absence on a monthly basis, here we examine the power to detect change in presence (recorded in one or more months) between years, *i.e*. examining the potential for these data to be used to determine change in garden use over time. Two approaches were adopted to examine the relationship between the power to detect a specified level of decline (we use the term 'decline' as it is decline that is of most interest to conservation practitioners, although it could equally well refer to 'increase'), the starting proportion of occupied gardens and the number of participants, the latter being a measure of sample size.

The first approach adopted estimates the power to detect a difference between two proportions, with a specified starting proportion, level of population change and sample size (Zar 1999). This essentially allows us to model the level of change that can be detected over a chosen period, the two proportions effectively being the proportion of gardens occupied by the species under consideration in year one and a subsequent year. This approach assumes that the gardens are 'unmatched', i.e. independent of one another between survey years. These analyses use the starting proportions for each of the four reptile and amphibian species recorded in 2003 at the national level, and for each region, to estimate the power to detect a population decline simulated in 5% increments and with an appropriate sample size of the sites surveyed.

The second approach, which assumes that the gardens are 'matched' – i.e. that the same gardens are surveyed each year, randomly generates artificial presence/absence data with a defined starting proportion of occupied gardens (0.90, 0.70, 0.50, 0.30, 0.10 and 0.05), covering the range of starting proportions of the different species (across taxa) recorded in this survey at the national level, a sample size of 4,430 gardens and a linear decline over a 10-year period. Because the distribution of simulated presence/absence data is randomly generated *de novo* for each time slice, there is an explicit assumption of temporal independence within the simulated data. However, the probability of a particular reptile or amphibian species being recorded as ‘present’ in a garden in a given year is likely to be strongly influenced by its presence or absence in a previous year. Consequently, in reality, a local extinction event is likely to appear as a series of presences followed by a series of absences. Given the difficulties in including a realistic and, hence, statistically valid measure of temporal dependence within the simulated data set, the approach adopted here is likely to be a conservative one. The approach also assumes spatial independence of the sampling sites.

A simple Generalized Linear Model, with a linear time trend, was fitted to these simulated data and the entire process repeated 100 times to generate 100 data sets based on the chosen scenario (McCullagh & Nedler 1989). The power to detect a predetermined level of decline under the defined scenario was then determined by testing the significance of the linear time trend of each replicate and then examining the proportion of the 100 replicates in which there was a significant decline at the 5% level, which is then used as a measure of statistical power. This ‘matched’ approach is very computer-intensive, which limits the number of simulations possible. Although reptile and amphibian species may show pronounced regional differences in rates of change, the power to detect change was only carried out at the national level. Regional analyses of the data were not carried out because these pilot year data do not provide any knowledge of the variations in trends between regions and because regional coverage was limited within some regions.

The ‘matched’ approach is the one likely to be closest in design to the BTO Garden BirdWatch, in which a relatively large proportion of the sites will be resurveyed each year. Because there will be some turnover in gardens surveyed between years, the true power will fall somewhere between the two approaches adopted here. In both analyses, a power of 80% is used as a cut-off point, this being a figure that will provide an acceptable power to detect a specified level of decline (Toms & Newson 2006).

3.4 Results

The number and percentage of gardens from which each of the four reptile and amphibian species was recorded, at both the national and regional levels, is shown in Table 3.1.

Table 3.1 Number and percentage (in parentheses) of participants reporting the presence of each reptile and amphibian species nationally, and for Government Office Regions, based on sites from which one or more amphibian or reptile species was recorded.

Species	**UK**	**NW**	**NE**	**YH**	**EM**	**EE**	**WM**	**SE**	**SW**	**LO**	**NS**	**SS**	**WA**	**NI**
Common Frog *Rana temporaria*	3009 (90.2)	247 (97)	75 (93)	173 (91)	266 (96)	569 (91)	276 (92)	667 (90)	360 (85)	153 (82)	29 (91)	75 (81)	109 (85)	10 (91)
Common Toad *Bufo bufo*	1312 (39.3)	73 (29)	24 (30)	75 (39)	114 (41)	271 (43)	110 (37)	262 (35)	188 (44)	67 (40)	17 (53)	46 (50)	65 (51)	0 (0)
Grass Snake *Natrix natrix*	236 (7.1)	4 (2)	0 (0)	1 (1)	15 (5)	57 (9)	19 (6)	92 (13)	37 (9)	1 (1)	0 (0)	1 (1)	9 (7)	0 (0)
Slow-worm *Anguis fragilis*	321 (9.6)	6 (2)	1 (1)	0 (0)	2 (1)	30 (5)	15 (5)	125 (16)	104 (24)	5 (3)	3 (9)	4 (4)	26 (20)	0 (0)

Note: These figures are the raw, unvalidated data as taken from the paper recording forms used for the pilot study. The percentage is calculated based on the 3,336 forms on which one or more reptile or amphibian species were recorded (out of 4,430 that contained one or more other taxa records).

Regions: NW North West England, NE North East England, YH Yorkshire & the Humber, EM East Midlands, EE East of England, WM West Midlands, SE South East England, SW South West England, LO London, NS Northern Scotland, SS Southern Scotland, WA Wales, NI Northern Ireland.

The results from the first simulations, assuming an 'unmatched' survey design, are shown in Table 3.2. This table reveals the approximate level of decline that could be detected between two survey years for the four species considered.

Table 3.2: Percentage decline in presence detectable at a national and regional level with a power of 80% or more assuming an 'unmatched' approach.

Species	UK	NW	NE	YH	EM	EE	WM	SE	SW	LO	NS	SS	WA	NI
Common Frog	5	15	30	20	15	10	15	10	15	20		35	25	
Common Toad	10	40		40	30	20	35	20	25	40		50	40	
Grass Snake	25					45		40						
Slow-worm	25							35	35					

Note: Results are not presented where a change in presence of more than 50% would have to be detected before the change was detected. Regions: NW North West England, NE North East England, YH Yorkshire & the Humber, EM East Midlands, EE East of England, WM West Midlands, SE South East England, SW South West England, LO London, NS Northern Scotland, SS Southern Scotland, WA Wales, NI Northern Ireland.

These results demonstrate that the BTO Garden BirdWatch 'Other Wildlife' component has adequate power to detect a decline in presence of between 5% and 25% at the national level for all four of the species considered here. Of particular interest is the potential for the scheme to pick up even small scale changes in the use of gardens by Common Frog and Common Toad. Examination of the data at the Government Office Region or country level suggests that the sample size of 4,430 sites is insufficient to provide an adequate power for monitoring three of the four species at this level. Only for Common Frog does the scheme provide an adequate level of power across the majority of regions to allow successful monitoring. The results for Common Toad suggest that an increased sample size would be required to achieve adequate power for monitoring. Given the low level occurrence of Grass Snake and Slow-worm in gardens, it is unlikely that the scheme could allow regional monitoring of these two species without a substantial increase in sample size.

Results from the second approach, which assumes a 'matched' survey design and only looks at the power to detect presence at the national level, produces results that are very similar to the 'unmatched' design when one compares like with like (Table 3.). This means that it should be possible to gain some idea of power at the regional/country level from these data. The results of the national 'matched' simulations demonstrate that it should be possible to detect at least a 10% decline at the national level over a 10 year period for species recorded in 30% or more of participant's gardens. Include line here about which of the species could therefore be monitored by using the matched approach.

Table 3.3. Results of a simulation-based study to examine the power of simple Generalized Linear Models to detect different rates of decline in the presence of a species in 4,403 BTO Garden BirdWatch gardens.

Number of years	% squares detected Start	End	Overall decline (%)	Power (%)
10	90	45	50	100
10	90	68	25	100
10	90	81	10	100
10	70	35	50	100
10	70	53	25	100
10	70	63	10	100
10	50	25	50	100
10	50	38	25	100
10	50	45	10	100
10	30	15	50	100
10	30	23	25	100
10	30	27	10	97
10	10	05	50	100
10	10	08	25	99
10	10	09	10	32
10	5	03	50	100
10	5	04	25	82
10	5	05	10	16

Note: each set of simulations consists of 100 replicates, where the power is the percentage of replicates in which a decline was detected with a significance level of α=0.05 (likelihood-ratio test).

3.5 Discussion

These analyses provide evidence that the BTO Garden BirdWatch scheme would allow the annual monitoring of changes in garden use by Common Frog, Common Toad, Grass Snake and Slow-worm at the national level, with an ability to detect changes in the order of 5%-25% between two periods of time. Under the levels of participation seen at the time of the pilot study (insert note about current levels of herptile reporting by participants) it would also be possible to monitor changes in garden use at the regional level for Common Frog (and for some regions Common Toad). There are, however, some regions/countries for which the sample size remains insufficient to allow regional monitoring.

Continuous monitoring approaches, such as those employed by the BTO, remain the most effective and reliable means for detecting changes in population status for birds and, increasingly, other taxa (Cannon *et al*. 2005; Eaton *et al*. 2010). It is important to emphasise that changes detected in the occurrence of a particular species within the garden habitat may not necessarily result from actual population change in a wider context. They may, instead, result from changes in habitat use and/or behaviour and it is important to determine the biological significance of the results of such monitoring work, perhaps by examining such data within the context of other datasets, especially those more clearly allied to overall measures of population size. Since the objective of most monitoring schemes is the timely detection of biologically important population change, it is also important to consider the consequences of environmental stochasticity (Pechmann *et* al. 1991; Thomas & Harrison 1992; Marsh 2001). Such stochasticity may cause populations of reptiles and amphibians to fluctuate widely between years, thus masking any underlying long-term trends. Populations of amphibians, in particular, may fluctuate over several orders of magnitude and the pattern and scale of these fluctuations may differ significantly between species (Pechmann *et al*. 1991). Fortunately, the systematic annual and multi-annual approach of the BTO Garden BirdWatch means that it is possible to determine the extent of such short-term variability, revealing the important long-term trends and helping us to understand how environmental stochasticity might work on reptile and amphibian populations over the short-term.

Although the precision of the data could be improved through the application of periodic and targeted specialised studies, the BTO Garden BirdWatch scheme is a valuable tool for monitoring change in populations of our more widespread reptile and amphibian species. Specialised surveys normally require substantial resources (both in terms of time and finances) and, as a consequence, cannot be operated on an annual, or even regular, basis.

As Beebee *et al*. (2009) note, limitations in standard recording schemes operating for amphibian and reptile populations in Britain were first recognised some 40 years ago. These limitations were thought to be most pronounced for species regarded as being common or widespread, and for which declines were increasingly becoming apparent. Traditional approaches for monitoring were based on the presence/absence of species at the 10-km square level, a scale at which it can be difficult to detect declines in initially common or widespread species. New approaches were developed, many centred on the use of questionnaire surveys, in an attempt to overcome such limitations. However, such approaches may have been piecemeal, the surveys not taking place annually and adopting different methodologies, all of which makes it difficult to produce data of a quality suitable for monitoring purposes. This led Beebee *et al*. (2009) to conclude that the 'mainstream species recording schemes, despite their increasing datasets, therefore proved unreliable as an approach to assess the population trends of any British species.

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APPENDIX I: REPTILES AND AMPHIBIANS IN YOUR GARDEN SURVEY FORM AND INSTRUCTIONS.

APPENDIX II: COLOUR IDENTIFICATION MATERIALS PROVIDED TO PARTICIPANTS IN THE REPTILE AND AMPHIBIANS IN YOUR GARDEN SURVEY.