Natural England Commissioned Report NECR080

Assessing population status of the great crested newt in Great Britain

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

The great crested newt is strictly protected under EU and domestic legislation. The government is required to undertake surveillance to assess the status of the species, in terms of population, range and habitat. Recent attempts at assessing population status have been hampered by problems with survey data, in terms of coverage, age, resolution and the fact that most survey data are not collected in an effort-related manner. Problems have also arisen with determining which units (or "metrics") to use to describe population status.

The current UK Species Action Plan lists country and GB baselines and targets for (i) number of occupied 10km squares, (ii) occupied vice counties, (iii) number of occupied ponds and (iv) number of ponds with Habitat Suitability Index (HSI) score >0.7. These were set out in 2006, based on the best available information at the time. The intention was that they would be amended as information and methods improved, hence the current project.

Here, the contractors sought to review existing information and develop new approaches to data analysis. The project focused on trialling modelling approaches, given that only a very small proportion of ponds has been reliably surveyed for great crested newts. Such a strategy was thought worthwhile as developing predictive methods could overcome the problems associated with patchy coverage.

This report:

- Reviews and evaluates past attempts at assessing population status of great crested newts
- Proposes new approaches to population status assessment
- Discusses metrics that have been used, or could be used, to assess population status
- Presents the methods and results of models used to predict population status
- Makes recommendations for how population status could be assessed in future reporting rounds.

This report will be used by Natural England and others for a range of activities including:

- Assisting with reporting on the status of great crested newts
- Assisting with developing future surveillance projects
- Assisting with setting goals for conservation action for great crested newts
- Informing how to deploy interventions such as agri-environment schemes, or regulation such as land use planning controls.

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Further information
This report can be downloaded from the Natural England website: **www.naturalengland.org.uk**. For information on Natural England publications contact the Natural England Enquiry Service on 0845 600 3078 or e-mail **enquiries@naturalengland.org.uk**.

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1. INTRODUCTION

1.1 Background

The great crested newt (*Triturus cristatus*) is afforded strict protection through a combination of the Wildlife and Countryside Act 1981 (as amended) and the Conservation of Habitats and Species Regulations 2010. It is also listed as a species of principal importance for the conservation of biodiversity in both England and Wales under Sections 41 and 42 (respectively) of the Natural Environment and Rural Communities (NERC) Act 2006.

The Conservation of Habitats and Species Regulations 2010 implements the European Union's 'Habitats Directive' (Council Directive 92/43/EEC (a) on the Conservation of Natural Habitats and of Wild Fauna and Flora) in Great Britain; the great crested newt is listed on Annexes II and IV of the Directive. As a consequence of this strict protection, the United Kingdom has legal obligations to report on the conservation status of the great crested newt every six years, with the specific reporting requirements set out in Article 17. Moreover, article 11 of the Habitats Directive states that good knowledge of a species (range/distribution, occurrence, biology, ecology, threats and sensitivity, conservation needs, etc.) and regular surveillance of its conservation status over time are essential preconditions for any meaningful conservation strategy.

Much conservation action for the great crested newt is coordinated through the great crested newt Species Action Plan (SAP), which is part of the UK Biodiversity Action Plan. The original plan for this species was written in 1995 (Tranche 1 Action Plan) and formed the framework for conservation work for over a decade. In 2005-6, the first full review of the UK BAP was undertaken and involved setting SMART (Specific, Measurable, Achievable, Relevant and Time-bound) targets. This process was instigated, to some extent, to bring a consistency across the species groups, as a range of methods had been used to derive the published targets. It also allowed for new information to be used to reflect the changing knowledge base for species and, importantly, to reflect the shift of responsibility for biodiversity conservation to devolved administrations, with country-level targets being required. The SAP steering groups were asked to define baseline values (i.e. current status, estimated if necessary) and allocate targets for species *population size, range* and *viability*.

A number of approaches to this work were discussed and trialled, involving considerable input from a number of groups including statutory agencies and non-governmental organisations, mainly through the great crested newt Species Action Plan steering group. The recorded distribution (e.g. as shown on the NBN Gateway, the single most complete record) is widely acknowledged to be a substantial under-estimate of the number of actual newt locations. Hence, a re-evaluation was required. The starting point involved consideration of previous estimates, with two figures often being cited, that of 17,800 populations from the Nature Conservancy Council National Amphibian Survey contract published in 1989 (Swan and Oldham, 1989), and 18,300 populations originating from the JNCC commissioned review in 1993 (Langton *et al.*, 1993).

By the mid-2000s, two areas of understanding critical to the derivation of these earlier population estimates had changed substantially. Recent survey work in key areas had revealed high great crested newt occupancy rates, suggesting that the earlier national great crested newt population figures were considerable under-estimates. In addition to this, re-assessment of pond numbers nationally (Biggs *et al.*, 2005), suggested a significant increase to the earlier pond estimates. This was particularly important to the target review work, as the calculations used to determine the national great crested newt figures in 1989 and 1993 had used considerably lower estimates of pond numbers. The great crested newt SAP steering group concluded that it would be useful to recalculate the national assessment for great crested newt populations, based on the new information.

Work to amend the population estimates and devise new targets was reliant upon sourcing new great crested newt occurrence data, including blanket surveys. However, the data available from the National Biodiversity Network (NBN) Gateway were limited; the coverage of the UK was poor, and much of the data were old or not at an appropriate resolution for the group's purposes.

A data request was sent to recorders and Local Records Centres in the UK to collate newt occupancy data and information on pond quality, to facilitate our assessments. It was clear from the results received that a significant amount of survey work had been undertaken for the species. Nevertheless, the data were of variable quality (for the objectives of the targets review). Much of the survey effort tended to be directed to areas where newts were likely to occur in high numbers and the sample was unrepresentative.

It became apparent from this data collation exercise that the evidence base was insufficient to make suitably precise and accurate assessments for the great crested newt. Wright and Foster (2009) give a full account of the work undertaken in the targets review for the great crested newt. The SAP steering group decided to set broad targets to reflect the inadequacies of the available information, and to make it clear that future refinement of the targets would be necessary.

1.2 Baseline population measures and SAP targets

The metric used to represent *population size* was *occupied ponds.* Although the great crested newt SAP steering group had difficulties in obtaining a representative dataset, it was evident from the information gathered that earlier estimates needed to be revised. Using all the information available, notably blanket survey results (which enabled local great crested newt occupancy rates to be determined), the steering group concluded that the number of occupied ponds was likely to be between 50,000 and 100,000. The upper limit was chosen for the published SAP targets review, with a clear caveat outlining the significant limitations, and the plan to revise the target values in the future.

It was decided to have two *range* targets, namely, occupied *10 km squares* and *occupied vice counties*. The first of these figures measures the 'spread' of populations at a coarse level, with the aim to change this metric to 1km resolution in future, once data quality allowed. The second range target uses *vice counties* as the metric; quantifying the overall distribution of the species; reflecting the desire to retain the species throughout all parts of its natural range. Both of these targets were calculated using post-1970 records from the NBN Gateway, with the addition of new records from the data collation exercise outlined earlier, and will be amended when new data become available.

The *viability* target uses the great crested newt Habitat Suitability Index, developed by Oldham *et al.* (2000), to define ponds of suitable quality to maintain viable meta-populations. The value used for this metric was set using a proportion of the number of *occupied ponds* (target 3), based on the Habitat Suitability Index work, which suggested that approximately 60% of occupied ponds have an HSI value of >0.7. The sample size for these deliberations was small, and originated from work undertaken in two counties (Leicestershire and Gloucestershire), and therefore may not represent the true nature of pond quality across the UK. It is likely that further research and survey work will refine the proportion of occupied ponds with an HSI value of >0.7, and therefore the target values at the next revision.

The baseline values and targets set in 2005/6 are shown in Table 1. For the revised Species Action Plan, published in 2009 (with the target figures set until 2030), see HCT (2009).

1.3 Project description

The aim of this project is to develop techniques to assess the current population status of the great crested newt. It is hoped that these techniques could also be applied to assessments for other European Protected Species (EPS). The remit of this work is therefore to gather ideas and resources from both statutory and voluntary sectors to progress a number of approaches, to address the reporting requirements for this species, and to ascertain a sound evidence base for conservation work. The template for this population status reporting is based upon the reporting categories used in the EU Habitats Directive Article 17 reports and the UK Biodiversity Action Plan three yearly Lead Partner reports. Ultimately, it is hoped that this work will inform revisions to the baseline and target values of the great crested newt Species Action Plan.

The remit of this project included an examination of the number of breeding ponds (*population* metric), the number of occupied 1km squares, the number of occupied National Character Areas (England only) and the area of the outer ‘polygon’ of all locations, excluding ‘empty’ areas (km^2) (*range* metrics). The final metrics include the area of suitable habitat (aquatic and terrestrial) (km^2) and the number of suitable ponds (whether occupied or not).

Table 1 Great crested newt targets as agreed by Government
As agreed in 2006.

1. Increase the range of the species (10km squares)

	GB	Scotland	Wales	England
Baseline	904	51	57	796
2010	926	54	59	813
2015	952	58	61	833
2020	976	62	63	851
2030	1,026	70	68	888

2. Increase the range of the species (vice counties)

	GB	Scotland	Wales	England
Baseline	88	21	9	58
2010	89	22	9	58
2015	90	23	9	58
2020	91	24	9	58
2030	93	26	9	58

3. Increase the number of occupied ponds

	GB	Scotland	Wales	England
Baseline	100,000	6,000	6,000	88,000
2010	120,000	7,200	7,200	105,600
2015	140,000	8,400	8,400	123,200
2020	160,000	9,600	9,600	140,800
2030	200,000	12,000	12,000	176,000

4. Increase the number of ponds with a Habitat Suitability Index of > 0.7

	GB	Scotland	Wales	England
Baseline	60,000	3,600	3,600	52,800
2010	72,000	4,320	4,320	63,360
2015	84,000	5,040	5,040	73,920
2020	96,000	5,760	5,760	84,480
2030	120,000	7,200	7,200	105,600

1.4 Datasets Used in this Report

The following datasets were used to generate the figures in this report:

[A] NBN Gateway records at 1km square resolution or finer for [Ai] the great crested newt alone and [Aii] all native amphibian species including the great crested newt, downloaded February 2010 (see **http://www.searchnbn.net/**).

[B] Great crested newt records from the ARC (=HCT) database additional to the above, downloaded February 2010.

[C] Great crested newt records and Habitat Suitability Index data from NARRS (National Amphibian and Reptile Recording Scheme) Widespread Amphibian Surveys 2007 – 2009.

[D – G] Great crested newt records from North Wales, sourced from CCW (Matt Ellis).

[H] Great crested newt records from Scotland, sourced from SNH (John McKinnell).

[I & K] Great crested newt Habitat Suitability Index data from surveys in Kent (Lee Brady) and Scotland (ARC-SNH great crested newt Distribution Project data; unpublished).

[J] GB Land Cover Map 2000 (LCM2000) data accessed through the Countryside Information System, downloaded February 2010 (see **http://www.cis-web.org.uk/home/**).

In addition to the above, calculations were performed using GIS-based estimates of land area and numbers of ponds by 1km square per area (Tables 2.1 and 2.2). The latter were extracted (by Stuart Ball, JNCC, under licensing agreement with NE) from OS Master Map polygons categorised as water features. Pond polygons between 50 – 750 m^2 in area (i.e. broadly conforming to great crested newt breeding pond characteristics) and with an appropriate aspect ratio (to exclude very linear water bodies likely to be sections of river or stream) were included. Pond polygons were allocated to the 1km grid square in which their centroid was located. This allowed determination of which 1km squares contained a pond, as well as how many ponds each square contained. The limitations of this dataset are outlined in the Discussion section.

Table 2.1 Land area and pond number estimates (GB and countries)
Figures derive from GIS-based estimates of area and OS Mast Map pond polygons (see above).

	GB	Scotland	Wales	England
Total land area (km^2)	231,625	78,010	20,880	132,735
No. of 1km squares with at least 1 pond	118,009	24,664	11,394	81,951
No. of ponds per area	402,062	87,805	28,113	286,144
Ponds per km^2	1.74	1.13	1.35	2.16

Table 2.2 Land area and pond number estimates (English regions)
Figures derive from GIS-based estimates of area and OS Mast Map pond polygons (see above). For details of NE regions, see **http://www.naturalengland.org.uk/regions/default.aspx**.

	East of England	East Midlands	London	North East	North West	South East	South West	West Midlands	Yorkshire & Humber
Total land area (km^2)	19,250	15,760	1,570	8,646	14,870	18,540	24,320	12,960	15,510
No. of 1km squares with at least 1 pond	13,664	9,640	866	2,786	8,559	13,310	15,078	10,335	7,713
No. of ponds per region	60,357	26,068	2,298	4,945	40,579	51,842	41,640	41,086	17,329
Ponds per km^2	3.14	1.65	1.46	0.57	2.73	2.80	1.71	3.17	1.12

2. METHODS

2.1 Literature Review

EU Habitats Directive Article 17 reporting for EPS requires the assessment of conservation status using four parameters: range extent, populations, habitat extent and future prospects. The latter is outside the scope of this report although attempts to describe the viability of populations do begin to address this parameter. EU Member States describe range and habitat extents in km^2, (see http://biodiversity.eionet.europa.eu/article17), but there is no standard or consensus approach to describing populations. Among the 17 EU Member States where great crested newts occur, six (including the UK) measured populations using units of *localities*, four used *10X10 grid squares*, two used *number of individuals* and the remaining five were unable to define this metric. The quality of methods used to derive these figures was variable, e.g. divided evenly between expert opinion, comprehensive inventory and extrapolation from surveys or samples (one State used both of the latter methods for different regions). It is desirable that all EU Member States use the same descriptor units for the same species (European Commission, 2006), but this was not accepted by the relevant EU Scientific Working Group (SWG). An objective assessment that explores the different approaches used, and the breadth of their potential utility, both in terms of geo-politics and as to other species, is therefore required. The present attempts to explore and define great crested newt status in GB consider existing and potential status metrics in this context.

2.1.1 Great crested newt range measures

Early national great crested newt surveys, such as Beebee (1975) and Cooke and Scorgie (1983), focused on comparing great crested newt occupancy rates with those of similar species; broadly describing range and population trends. The questionnaire-based study by Cooke and Scorgie (1983) suggested great crested newts occur patchily throughout England but were absent or rare in Cornwall and Devon, most of Scotland and Wales. This survey method was repeated by Hilton-Brown and Oldham (1991) eight years later and this study came to similar conclusions. These studies were, however, based on uneven survey coverage and a reliance on un-standardised and subjective impressions; inaccuracies that were largely artefacts of the methods employed.

Results from the National Amphibian Survey (Swan and Oldham, 1993) formed a more reliable picture of great crested newt range using systematic surveying. This report, the final in a series of three (Nicholson and Oldham, 1986; Swan and Oldham, 1989; Swan and Oldham, 1993), combined data from a 9 year study period covering 61% of mainland Britain at the $10km^2$ level and recruited 874 recorders. Great crested newts were present in 53% of squares surveyed and in approximately 70% of all counties. Few records were found in Scotland, South West England and West Wales, agreeing with previous studies. As with any study of this type, however, the recorded species range may only reflect the location of the surveyors and the sites involved, and species absence may be attributable to low searching effort (Swan and Oldham, 1993).

Metrics for the total area of great crested newt range have been scarce in the literature. Langton *et al.* (1993), however, gave a figure of 37,668 km^2 in a review of British herpetofauna and, more recently, in a government report to the EC (JNCC, 2007) a much higher figure of 157,749 km^2 was suggested. A spatially explicit exploration of the available data is likely to form a more reliable figure and the advances in computing power and Geographical Information Software (GIS) combined with blanket surveys and widely available data sources, such as the National Biodiversity Network (NBN) Gateway, allow more accurate analysis at a 1km^2 resolution. This technology provides a framework for producing more reliable metrics and enables species range to be assessed and monitored at a variety of scales, from regional, to vice counties or National Character Areas (NCAs).

2.1.2 Great crested newt population measures

Since the 1970s, a common theme among the literature has been a decline in the total number of great crested newt populations, largely due to habitat loss and degradation. Accurate figures for total great crested newt populations, however, have been hard to verify and have varied greatly in the literature. Nicholson and Oldham (1986) originally suggested a total number of great crested newt sites of roughly 6,000, which was derived from a compromise between various interpretations of their dataset. Since then, higher figures from 17,800 (Swan and Oldham, 1989) and 18,300 populations (Langton *et al.*, 1993) have been given. The methods involved in producing the recent and much higher figure of 75,000 populations (JNCC, 2007), in particular, attracted criticism from Langton (2009) who dismisses this as an overestimate in his review of great crested newt conservation over the last 30 years. In this review he instead suggests a figure of 15,738 populations by factoring suggested rates of great crested newt decline since the Langton *et al.* (1993) figures were produced.

One obstacle in calculating meaningful population measures has historically been inconsistent terminology in the literature. As noted by Langton (2009), the term “occupied ponds” has frequently been assumed to refer to “breeding ponds.” Conservation measures are likely to benefit from better definition of these terms.

2.1.3 Great crested newt viability measures

Multiple studies in the last 30 years have consistently noted that great crested newts are less flexible in their site preferences than other UK newt species. They prefer large ponds, the absence of fish, some aquatic vegetation but with clear areas, terrestrial vegetation cover and short distances between ponds (Cooke and Scorgie, 1983, Cooke, 1984; Nicholson and Oldham, 1986; Swan and Oldham, 1993, JNCC, 2007*)*. Oldham *et al.* (2000) produced a great crested newt Habitat Suitability Index (HSI) incorporating the majority of these factors into a single practical score for great crested newt habitat quality. This Index may not fully incorporate certain factors emphasised in some of these studies, such as the quality of surrounding terrestrial habitat (Briggs and Rannap, 2006) and the slope or depth of pond, however it does provide an important standardised method for assessing and ranking sites in order of importance. In addition, this process can be updated using larger datasets and the weighting of individual factors to increase overall HSI accuracy (Oldham *et al.*, 2000). The utility of HSI scores in producing metrics for the great crested newt in the UK has, to date, not been fully applied.

2.1.4 Great crested newt habitat measures

Number of suitable ponds (occupied or not)

Previous metrics for pond numbers have broadly ignored the suitability of ponds for great crested newts. Swan and Oldham (1989) suggested 291,000 ponds exist in the UK. However, their figures appear to omit a distinction between garden ponds and field ponds (which great crested newt are known to prefer). Langton *et al.* (1993) make this distinction, estimating the number of field ponds to be between 160,000 and 300,000, though this is still insufficient to predict the suitability of these ponds for great crested newts. The inclusion of HSI data would allow the quality of the ponds to be taken into account, and therefore the number of ponds *suitable* for great crested newt can be calculated, assuming that reliable estimates for overall pond numbers are available. For use in this report, the Countryside Survey 2007 (Williams *et al.*, 2010) was a potential data source in that it estimated 478,000 ponds (95% CI 374,000 – 634,000) in the UK overall. The survey excluded garden ponds and, in addition, measured various pond characteristics; however spatial resolution from this survey was insufficient for the aims of the present project, and so the OS-derived pond layer (described in section 2.1) was used. Comparisons between Countryside Survey pond figures and those generated using OS-derived data are made in the Discussion.

According to Swan and Oldham (1989), national pond densities were between 0.1 and 14.0 per km^2, with generally higher densities in eastern counties (Swan and Oldham, 1989), whereas Langton *et al.* (1993) estimated field pond densities of between 0.7 to 1.3 ponds per km^2. This can be compared to the Countryside Survey 1998 mean figure of 1.86 ponds per km^2 (95% CI: 1.41 -

2.54) and an even higher 2.1 per km^2 (95% CI: 1.64 - 2.78) almost ten years later in the Countryside Survey 2007 (Williams *et al.*, 2010), to suggest pond densities may have increased since the early 1990s. In the absence of better data on pond quality and occupancy, it is unclear as to whether or not this apparent trend has impacted the ponds specifically preferred by great crested newts.

Extent of suitable habitat (aquatic and terrestrial)

A recent report for CCW (ARC and Cofnod, 2010) produced great crested newt habitat figures for three counties in North Wales using Biomapper modelling software (see http://www2.unil.ch/biomapper/), and a suite of environmental variables and presence data. This technique produced maps and figures describing the likelihood of occurrence of great crested newts in a given area, based on habitat suitability. This type of modelling allows not only for various metrics to be produced but for areas of potential great crested newt habitat to be mapped and so potentially aiding future survey placement, planning, sensitivity mapping, conservation priority setting etc. As there are no habitat area estimates for the great crested newt in the UK as a whole (JNCC, 2007), a similar modelling technique could be applied to produce national habitat figures.

2.2 General Methodology

The generation of improved status metrics for the great crested newt in Great Britain was attempted using a combination of (a) consideration of existing targets (see Introduction), (b) a review of the relevant literature to inform the approach (see above) and (c) discussions on appropriate action with relevant stakeholders (NGOs, SNCOs, researchers, ARG representatives – the project Steering Group.).

Several Steering Group meetings were held throughout the project's development. Initial discussions highlighted the desire for improved (i) range estimation and methods of quantification [2.3, below] including use of a finer scale, (ii) population estimation metrics [2.4], (iii) viability measure quantification [2.5] and (iv) habitat measure quantification [2.6]. In each case, re-quantification of existing metrics could be achieved by mapping, simple extrapolation or GIS-based modelling – all based on greater contemporary data availability (as compared to when existing targets were determined) and the use of novel methods. This was carried out using the datasets described above (section 1.4).

The Steering Group determined that improved mapping of great crested newt records at 1km resolution or finer should form the basis for status metric improvement, including extrapolation and model development. Even with the greater availability of records than previously and the use of modern GIS tools, some extrapolation and modelling is required as our knowledge of great crested newt distribution remains imperfect, and the species under-recorded (see Introduction). Approaches to generating each metric are described in the sections below.

All GIS analyses were performed in Mapinfo Professional v.8 (Mapinfo Corporation, 1985-2005). All amphibian datasets used in this report were filtered to exclude pre-1970 records before analyses.

2.3 Great Crested Newt Range Measures

2.3.1 Range polygons

The area of great crested newt range in Great Britain has been calculated based on its 10km square distribution and Alpha Hull software (see JNCC, 2007 and Figure 1). We registered the JNCC range polygon using GIS and used this to break down the total GB range into range values for Scotland, England and Wales. The Alpha Hull approach, however, creates a very gross range polygon, not considering fully the presence of estuaries or large unoccupied areas, and thus creates an overestimate of range extent. We therefore generated a similar polygon and range values using datasets A – H (listed in Section 1.2) at 1km square resolution and with a 1km buffer, manually adjusting the polygon to exclude estuaries, very isolated great crested newt records and areas from which no great crested newts are reported (e.g. parts of Wales, Cornwall, the Pennines and Central Southern Scotland).

Additionally, as a more objective approach, we also created a range map and generated alternative range values based on simple 5km-radius buffers around all known great crested newt-occupied 1km squares from datasets A – H.

2.3.2 National Character Areas in England

Great crested newt occupancy of English National Character Areas (NCAs) was mapped using GIS and datasets A – H and a GIS layer of NCAs supplied under licence from Natural England.

2.3.3 Occupied 10km squares

Datasets A – H were mapped at 10km square resolution and used to generate new GB and country occupancy values.

2.3.4 Occupied vice counties

Great crested newt occupancy of GB Watsonian vice counties was mapped using GIS and datasets A – H and a digitised vice county layer (freely available from **http://www.nbn.org.uk/Useful-things/Mapping/VCB-page1.aspx)**. Numbers of occupied vice counties in GB and the countries was determined.

2.3.5 Occupied 1km squares (mapped from known records)

Datasets A – H were mapped at 1km square resolution and used to generate occupancy values for GB, countries and NE regions of England (for details of NE regions, see **http://www.naturalengland.org.uk/regions/default.aspx**).

2.3.6 Occupied 1km squares (modelled)

On the assumption that our knowledge of great crested newt distribution and 1km square occupancy in GB is incomplete (see Introduction), we generated values for the number of theoretically occupied squares in GB, countries and English regions.

Various approaches were trialled, including the comparison of available NBN Gateway data to blanket newt/pond surveys from known areas (e.g. Herefordshire, Kent). It was found, however, that, because of substantial differences in great crested newt record density by area or part of area, it was not possible to generate a single correction factor that would extrapolate from the NBN Gateway records to realistic predicted occupancy figures for regions or countries. We therefore adopted a different approach using only NBN data (datasets Ai and Aii). These datasets were used (respectively) to map all 1km grid squares positive for great crested newts ($\mathbf{S_G}$) and all 1km grid squares positive for any amphibian species in GB by country and region. Any spatial bias caused by multiple records from the same square is removed by considering presence at the 1km grid square level. Numbers of amphibian-positive squares ($\mathbf{S_A}$**)** were then corrected using regional survey absence rates for all amphibians (**abs**; modified from Swan and Oldham, 1989) to account for negative results (NBN Gateway data do not include absences) in order to generate values for the number of squares in each area that were theoretically surveyed ($\mathbf{S_T}$) to produce these data. The proportional relationship between S_G and S_T can then be applied to the number of squares in each region or country containing at least one pond ($\mathbf{S_{1P}}$; see Tables 2.1 and 2.2) to generate values for the numbers of theoretically occupied squares ($\mathbf{S_{mod}}$), where:

$$\mathbf{S_T = S_A \; X \; (100 - abs) / 100}$$

and

$$\mathbf{S_{mod} = (S_G / S_T) \; X \; S_{1P}}$$

The percentage of great crested newt-occupied 1km squares in GB, countries and English regions was then calculated using $\mathbf{S_{mod}}$ and the size of each area (Tables 2.1 and 2.2).

Confidence intervals for modelled 1km square occupancy were calculated using measures of S_G and S_T from five randomly generated, identically-sized samples from within each geographical area to generate (5X5=) 25 occupancy estimates, thus producing a range from which 95% CI could be determined using the formula **CI = mean ± t X SE** (alpha = 0.05, df = 24, t = 2.064).

2.4 Great Crested Newt Population Measures

2.4.1 Estimates of numbers of ponds occupied and used for breeding

A GB pond density map was created using data described in Section 1.3 and the number of ponds in each area (**P**) used with the S_G/S_T ratio as above to model the number of great crested newt-occupied ponds ($\mathbf{P_{mod}}$) in GB, countries and English regions, where:

$$\mathbf{P_{mod} = (S_G \div S_T) \; X \; P}$$

Percent pond occupancy, numbers of occupied ponds per km^2 and number of breeding ponds were also calculated for each area. The number of breeding ponds has previously been taken as 75% of the number of occupied ponds (Wright and Foster, 2009 and see Discussion) though there is little evidence to support this suggestion. The number of occupied ponds used for breeding was, however, estimated in this way as well as by considering available HSI values. If one considers that the number of ponds actually used for breeding is probably somewhat less than the sum total of those that are nominally suitable (HSI >0.5, see 2.6.1, below) and yet that breeding will occur in more ponds than only those considered of highest quality (HSI >0.7, see 2.5.1, below), a figure of HSI >0.6 is suggested. Therefore, for the purposes of the present investigation only, this method was also used to estimate breeding pond numbers. The proportion of HSI scores >0.6 was derived from datasets C, I and K (n = 835). This value as a percentage of the number of ponds per area was also calculated. Ninety-five percent confidence intervals are based on the pond occupancy estimates derived in Section 2.3.6. For comparisons with the above method, please see Results and Discussion. These are simple arithmetic methods of quantifying this metric for the purposes of status assessment and may not be suitable for identifying breeding (or non-breeding) ponds in the field.

2.5 Great Crested Newt Viability Measures

2.5.1 Occupied ponds with HSI score >0.7

Great crested newt population viability was assessed as the proportion of occupied ponds (from 2.3.6) with HSI score >0.7. This proportion was derived from HSI scores from datasets C, I and K (n = 835). This value as a percentage of the number of ponds per area was also calculated. Ninety-five percent confidence intervals are based on the pond occupancy estimates derived in Section 2.3.6.

2.6 Great Crested Newt Habitat Measures

2.6.1 Numbers of suitable ponds (occupied or not)

The number of ponds theoretically suitable for great crested newts (whether occupied or not) was assessed as the proportion of total ponds per area with HSI >0.5. This proportion was derived from HSI scores from datasets C, I and K (n = 835) and total pond numbers (Tables 2.1 and 2.2).

2.6.2 Correction factors for key metrics

Figures for the metrics described above were arrived at objectively using absolute pond numbers and an extrapolation model (from 2.3.6). Even without a good knowledge of great crested newt distribution for some areas, however, some of these figures are intuitively rather high (see for example London figures, Tables 3.3 to 6.2). Unlike The ARC Removal Model (see next section), these extrapolated figures do not account for ponds in inimical habitat. A region-specific correction factor was therefore applied to these metrics to account for potentially hostile environments where ponds may exist but be unsuitable because of surroundings, lack of connectivity etc. The extent of urbanised habitat was used as the correction factor. Figures describing urban land cover were obtained from the Office for National Statistics (see http://www.ons.gov.uk and especially http://www.neighbourhood.statistics.gov.uk) and figures were corrected accordingly using the unique correction factors obtained for each region. For example, where a region contained 10% urban land cover, figures were reduced by 10%.

N.B. These results are presented with other key metrics at the end of the Results section (Tables 8.1 and 8.2) for clarity and ease of comparison.

2.6.3 Extent of suitable habitat (aquatic and terrestrial)

The extent of habitat suitable for great crested newts was examined using the "ARC Removal Model" process developed for the ARC-SNH Great Crested Newt Distribution Project (currently ongoing, unpublished data). This approach is similar to others being trialled to model habitat suitability (e.g. ARC and Cofnod, 2010) and target survey effort for great crested newts and other species such as adders (S. Langham, *pers. comm.*; ARC, unpublished data) in Wales, Scotland and other areas such as Surrey in SE England and Broughton in NE Wales. The comparability of habitat suitability modelling approaches represents an ongoing challenge in the production of descriptive status metrics (*sensu* Loiselle *et al.*, 2003), so the use of approaches compatible with related work is beneficial. "Removal modelling" is also similar to more complex ecological niche modelling approaches described by e.g. Hernandez *et al.* (2006) and Phillips and Dudik (2008), but remains relatively simple and objective.

Environmental variables (from dataset J) attached to known great crested newt-positive 1km squares (in a given area) are interrogated and the maximum and minimum values from the ranges thus generated for each variable are used to remove "unsuitable" squares from all those available in the same given area. The result of this step (Phase 1) leaves the model with all those squares that match the characteristics of great crested newt-positive squares.

In Phase 2 of this process, further squares are removed by eliminating those with values falling outside the range **mean +/- SD X 1.96** (applied separately for each variable). If these (habitat and environmental) data were normally distributed, this would generate 95% confidence intervals. Many squares, however, contain insignificant amounts of habitat which can be considered to be irrelevant to great crested newt distribution but which may equally contain significant amounts of other habitat which might be important. The Phase 2 process generates a negatively-biased range which does not eliminate these squares (values generated are typically from <0 to ca. 50% by area) but which still generates meaningful and useful ranges for other variables (e.g. mean winter temperature, altitude). The variables used (from dataset J) to generate Phase 1 and 2 Removal Models were extent of (i) horticultural land, (ii) broad-leaved woodland, (iii) built-up land and gardens, (iv) coastal habitat, (v) coniferous woodland, (vi) improved grassland, (vii) open water, (viii) sea, (ix) semi-natural rough grassland and (x) upland, as well as (xi) average annual rainfall, (xii) mean summer temperature, (xiii) mean winter temperature and (xiv) altitude.

Phase 1 and 2 ARC Removal Models were generated independently for Scotland, Wales, England and the South East England region. Model efficacy was assessed using training subsets of great crested newt-positive squares to generate models and maps for each area (as suggested by Liu *et al.*, 2005), and examining the number of *other* great crested newt-positive squares (i.e. those not used for training) that were successfully accounted for. Scotland, Wales and South West England models were each tested using a random 50% subset of great crested newt-positive squares. The Wales model, because of the enormous variability in great crested newt occupancy between different parts of Wales, was further tested with geographic sub-setting (see Peterson *et al.*, 2007) using records from the south and north of the country to generate separate models for the whole of Wales (the dividing line was arbitrarily taken as a line of latitude roughly level with the Dyfi Estuary).

Initial modelling suggested that this process is most discriminating in "range edge" areas (see Figs. 8.1 onwards) such as South West England, Northern England and Scotland, and included broad geographic areas elsewhere. As a further exploration of "most suitable habitat", therefore, the Phase 1 (most inclusive) model was adapted by overlaying Phase 1 model maps with the pond density map (from Section 2.4.1) and filtering the Phase 1 squares to exclude those with a density of <4 ponds per km^2. All areas with pond densities above 4 per km^2 contained great crested newts in Oldham *et al*.'s (2000) habitat suitability study, indicating that this figure is biologically relevant and may be used to identify squares both containing suitable habitat and most likely to be occupied by great crested newts.

2.6.4 Predicting areas of suitable habitat

As an additional exploration of the predictive power of this type of modelling, known great crested newt distribution (at occupied 10km square resolution, from 2.3.3, above) was overlaid with high pond density data (4 or more per km^2) using GIS and used to create a thematic map showing the number of high pond density 1km grid squares within each occupied 10km square. Though this is conceptually complex, this map effectively describes which of the occupied 10km grid squares should have higher densities of great crested newt populations because of their higher density of ponds (remembering that the great crested newt distribution data were earlier considered simply according to the presence of one or more records from a 1km square to avoid spatial bias).

A similar map was then created, overlaying habitat modelled to be suitable for great crested newts (from Phase 1 in 2.6.3) at 10km grid square resolution with the high pond density data. The thematic map ranges used (Fig. 13) are identical to those above (Fig. 12) to allow direct comparison. This map is therefore based only on predictive data (suitable habitat and high pond density). Finally, in an attempt to refine this predictive model to a scale practicable for a number of applications, a map for England showing (i) occupied 1km grid squares, (ii) predicted suitable habitat (Phase 1) and (iii) pond density was produced. This both describes the known distribution of great crested newts and predicts the likelihood of finding the species in any other square where suitable habitat occurs (all at 1km grid square resolution). The potential applications are considered in the Discussion section.

3. RESULTS

Note that, throughout the following results, confidence intervals are not symmetrical about N (i.e. values do not necessarily represent the central point of the confidence interval range).

3.1 Great Crested Newt Range Measures

Table 3.1 Average "amphibian absence rate" (proportion of surveys without amphibians) by country and region
(modified after Swan and Oldham, 1989).

Country / Region	Average amphibian absence (%)
GB (overall)	***33.61***
Scotland	***32.86***
Wales	***58.00***
England (overall)	***33.61***
East of England	30.00
East Midlands	58.00
London	50.00
North East	30.00
North West	24.00
South East	32.00
South West	22.00
West Midlands	16.00
Yorkshire & Humber	56.67

Table 3.2 Range measures (GB and countries)
See also corrected key metrics in Tables 8.1 and 8.2, pp 53 – 54.

	GB	**Scotland**	**Wales**	**England**
Area of range polygon based on original 10km square map (km^2) (from JNCC 2007)	157,749	23,920	13,670	121,200
Area of range polygon (redrawn based on 1km square map) (km^2)	130,884	13,975	8,373	108,535
Range area (based on 1km square map and 5km buffers) (km^2)	83,694	5,241	8,079	70,375
No. of occupied National Character Areas (England only)	N/A	N/A	N/A	136/159
No. of occupied 10km squares	894*	70	102	751
No. of occupied vice counties	86	20	11	55
No. of occupied 1km squares – mapped	3,182	113	519	2,550
No. of occupied 1km squares – modelled (95% CI)	19,074 (8,298 – 37,966)	433 (N/A**)	1,829 (1,322 – 12,247)	16,812 (13,760 – 20,868)
Area of land occupied (%) – modelled (95% CI)	8.23 (3.58 – 16.39)	0.56 (N/A**)	8.76 (6.33 – 58.65)	12.67 (10.37 – 15.72)

*** The GB figure is less than the combined total for constituent countries as some 10 km grid squares contribute to the total for more than one country**
**** Insufficient data to generate meaningful confidence limits**

Table 3.3 Range measures (English regions)
See also corrected key metrics in Tables 8.1 and 8.2, pp 53 – 54.

	East of England	**East Midlands**	**London**	**North East**	**North West**	**South East**	**South West**	**West Midlands**	**Yorkshire & Humber**
No. of occupied 1km squares – mapped	446	294	71	130	245	532	430	265	137
No. of occupied 1km squares – modelled (95% CI)	4,598 (3,421 – 5,128)	994 (893 – 6,960)	218 (129 – 280)	522 (164 – 3,847)	1,855 (1,369 – 11,038)	2,728 (1,654 – 3,139)	4,126 (N/A**)	3,880 (3,527 – 8,062)	516 (455 – 1,043)
Area of land occupied (%) – modelled (95% CI)	23.89 (17.77 – 26.64)	6.31 (5.66 – 44.16)	13.88 (8.22 – 17.81)	6.04 (1.90 – 44.49)	12.48 (9.20 – 74.23)	14.72 (8.92 – 16.93)	16.97 (N/A**)	29.94 (27.22 – 62.20)	3.33 (2.93 – 6.72)

**** Insufficient data to generate meaningful confidence limits**

Figure 1 Great crested newt range polygon mapped on 10km grid square distribution From JNCC, 2007. See also Table 3.2.

Figure 2 Great crested newt range polygon mapped on 1km grid square distribution
Small black dots are known great crested newt-occupied 1 km grid squares, including known or suspected introductions but excluding very isolated records. See also Table 3.2.

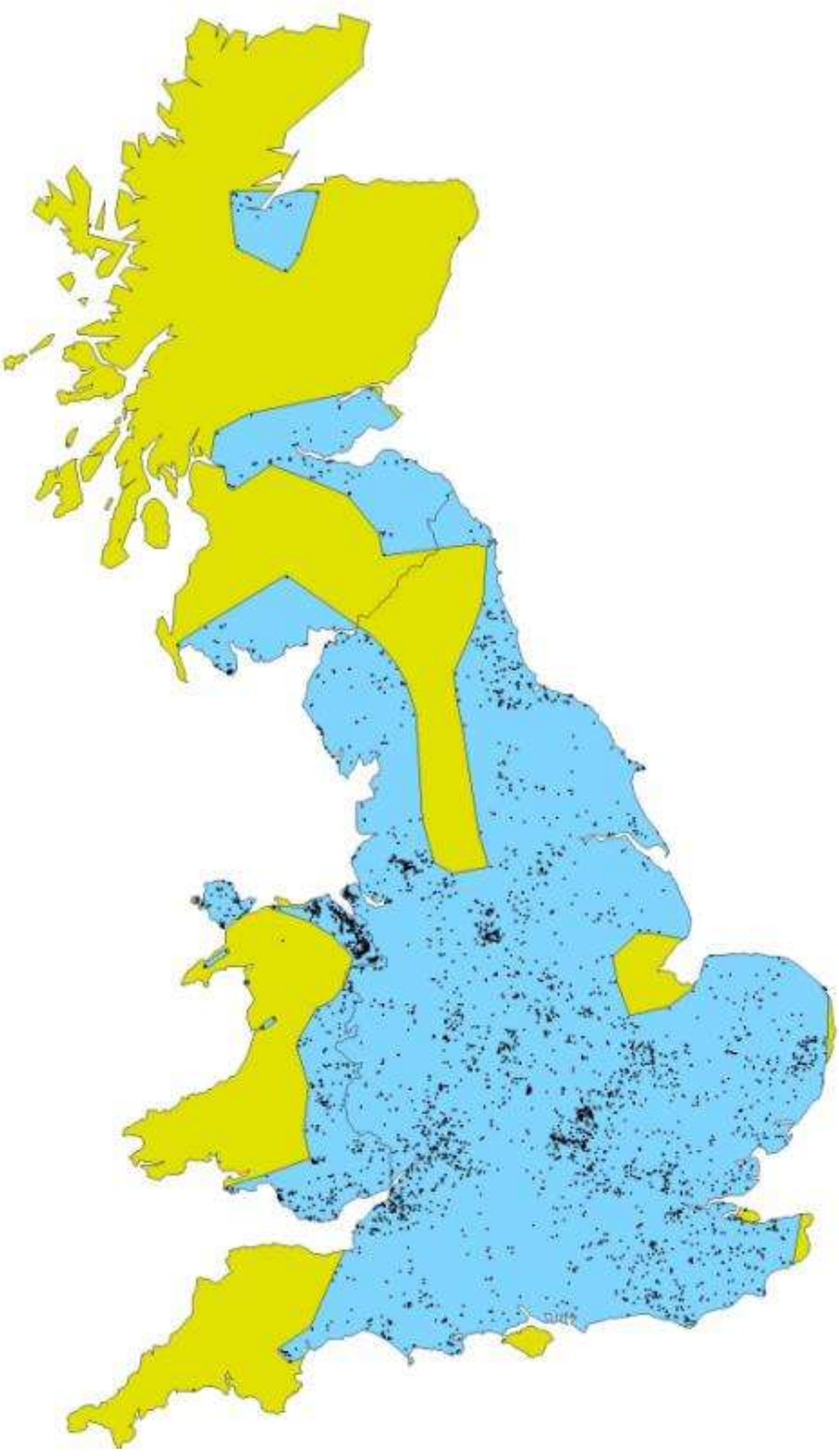


Figure 3 Great crested newt range polygon mapped on known 1km grid square distribution with 5km buffers

Includes known or suspected introductions. See also Table 3.2 and Discussion regarding coverage and data resolution.

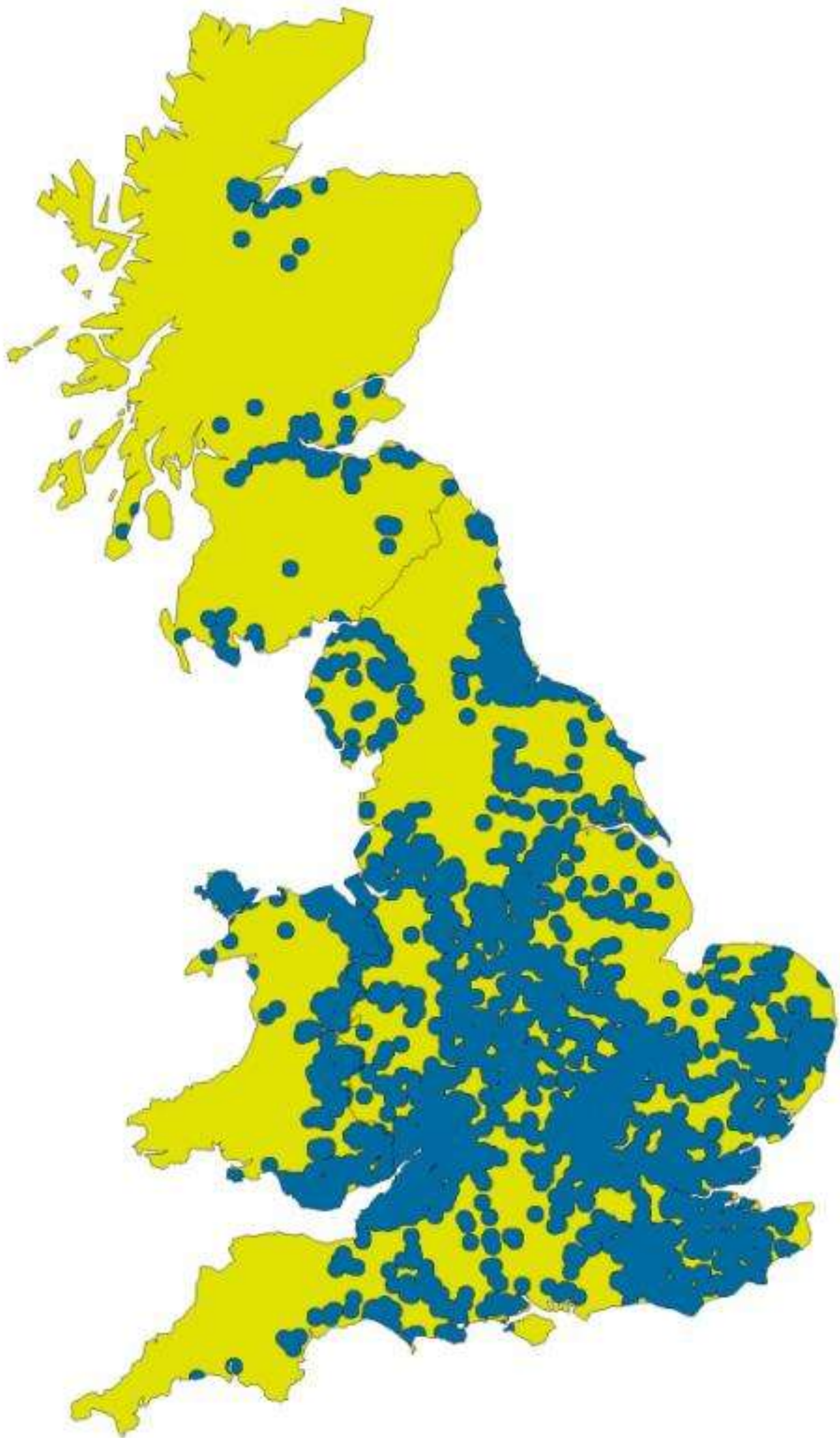


Figure 4 Great crested newt-occupied National Character Areas in England
Based on known records including those of known or suspected introductions. See also Table 3.2.

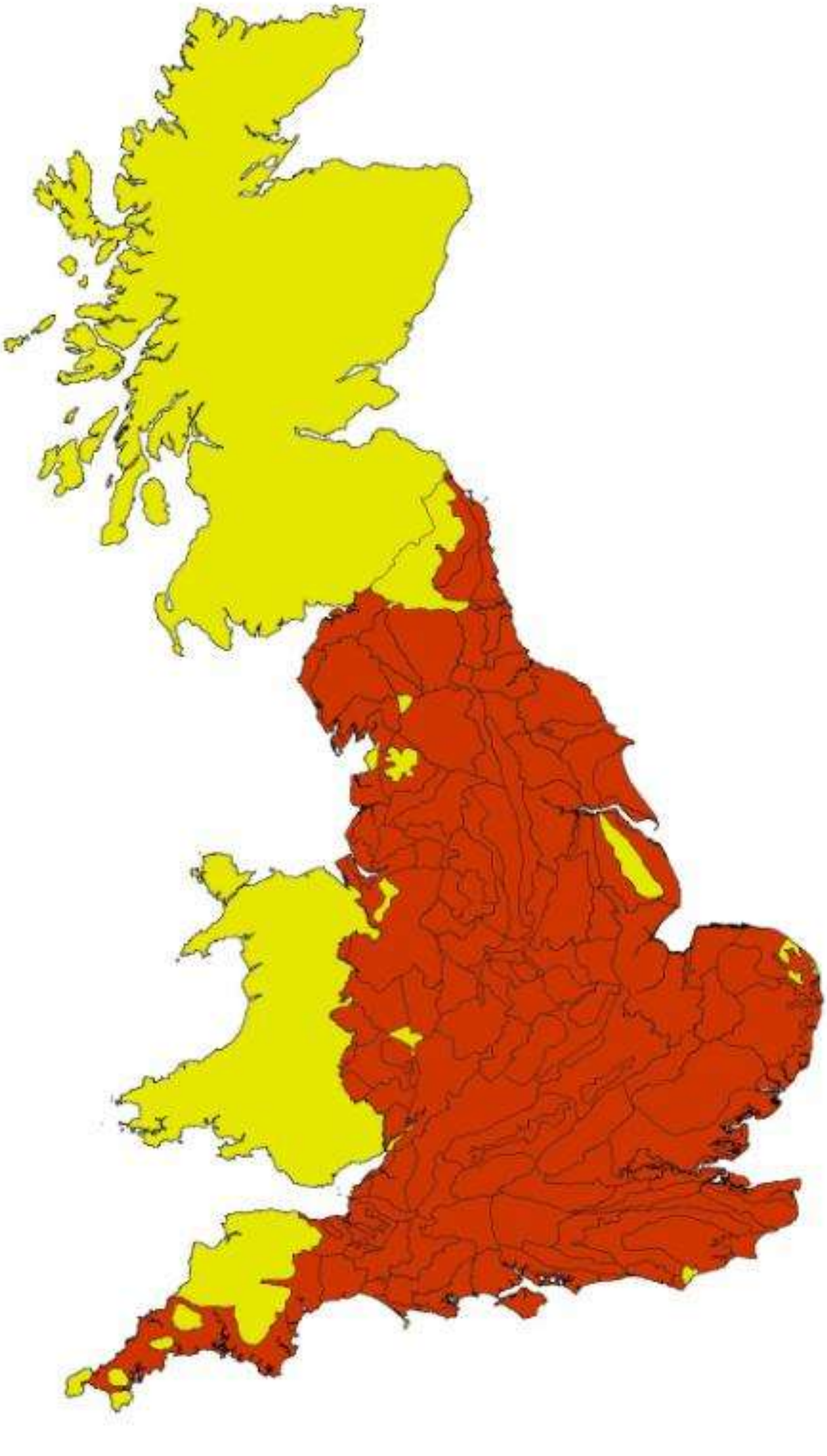


Figure 5 Great crested newt-occupied 10km squares in GB
Based on known records including known or suspected introductions. See also Table 3.2.

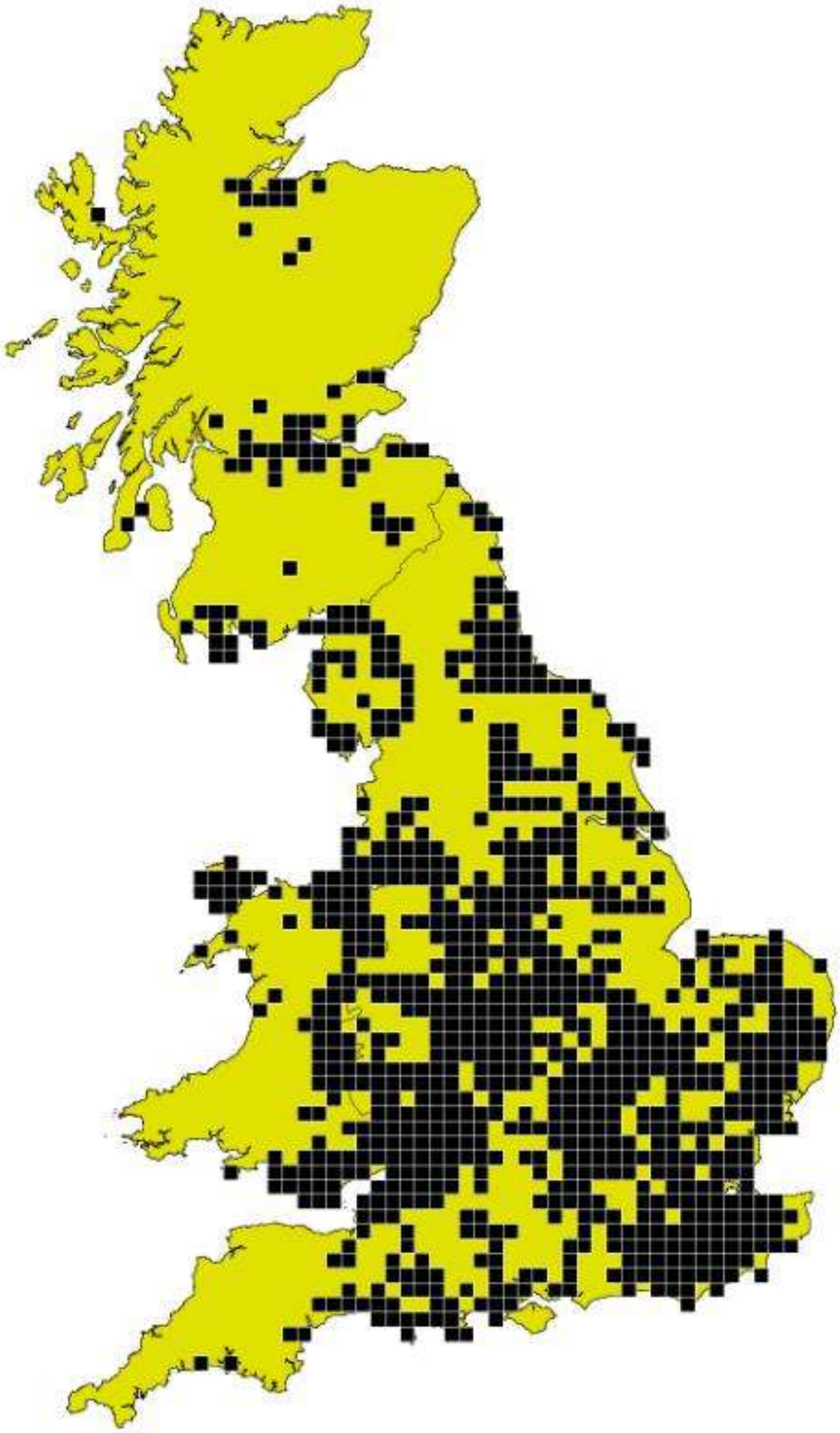
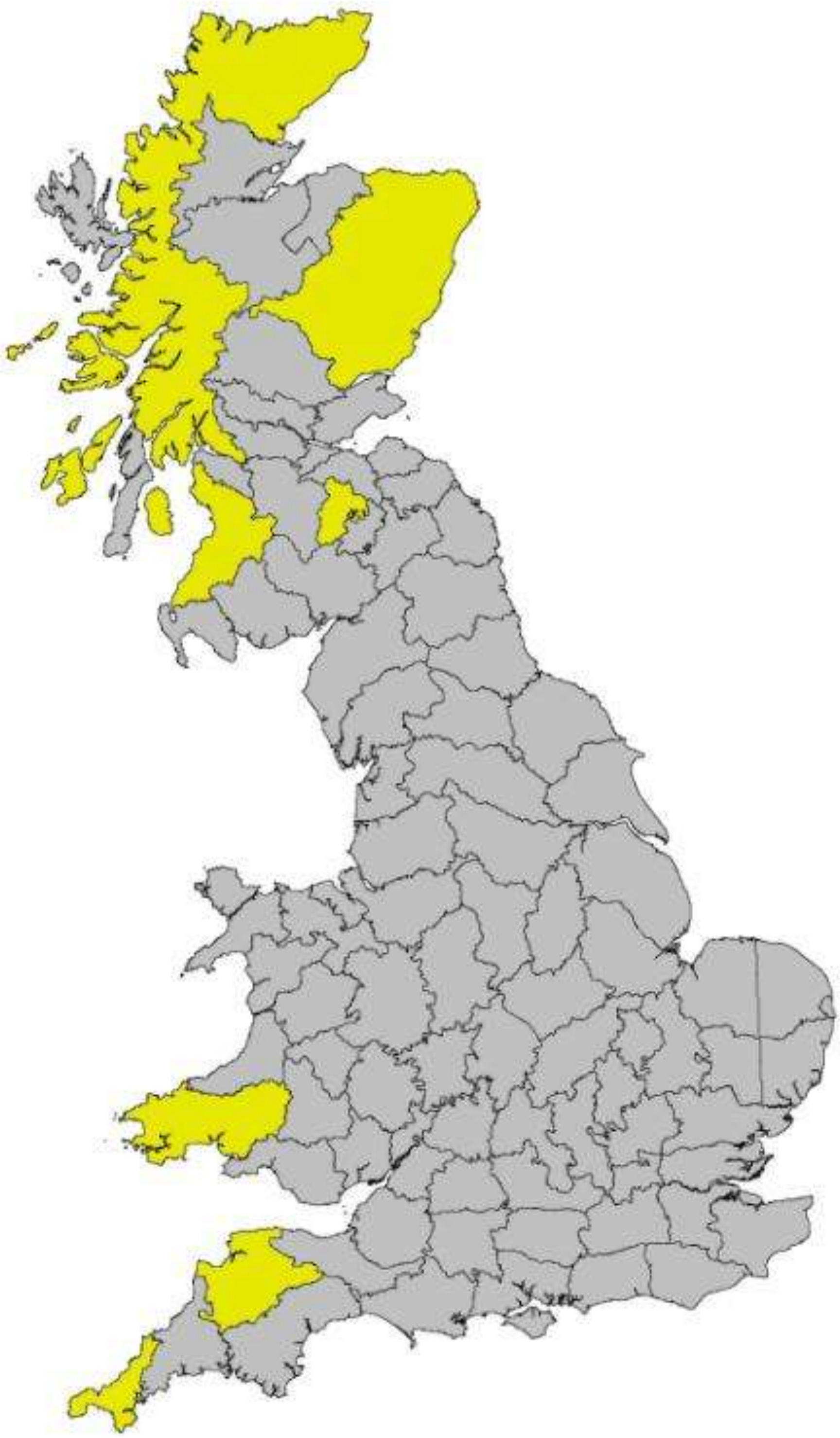


Figure 6 Great crested newt-occupied vice counties in GB
Based on known records including known or suspected introductions. See also Table 3.2.



3.2 Great Crested Newt Population Measures

Figure 7 GB pond density map based on OS Master Map data
See Section 1.2. Darker blue 1km squares indicate a higher density of ponds in those squares.

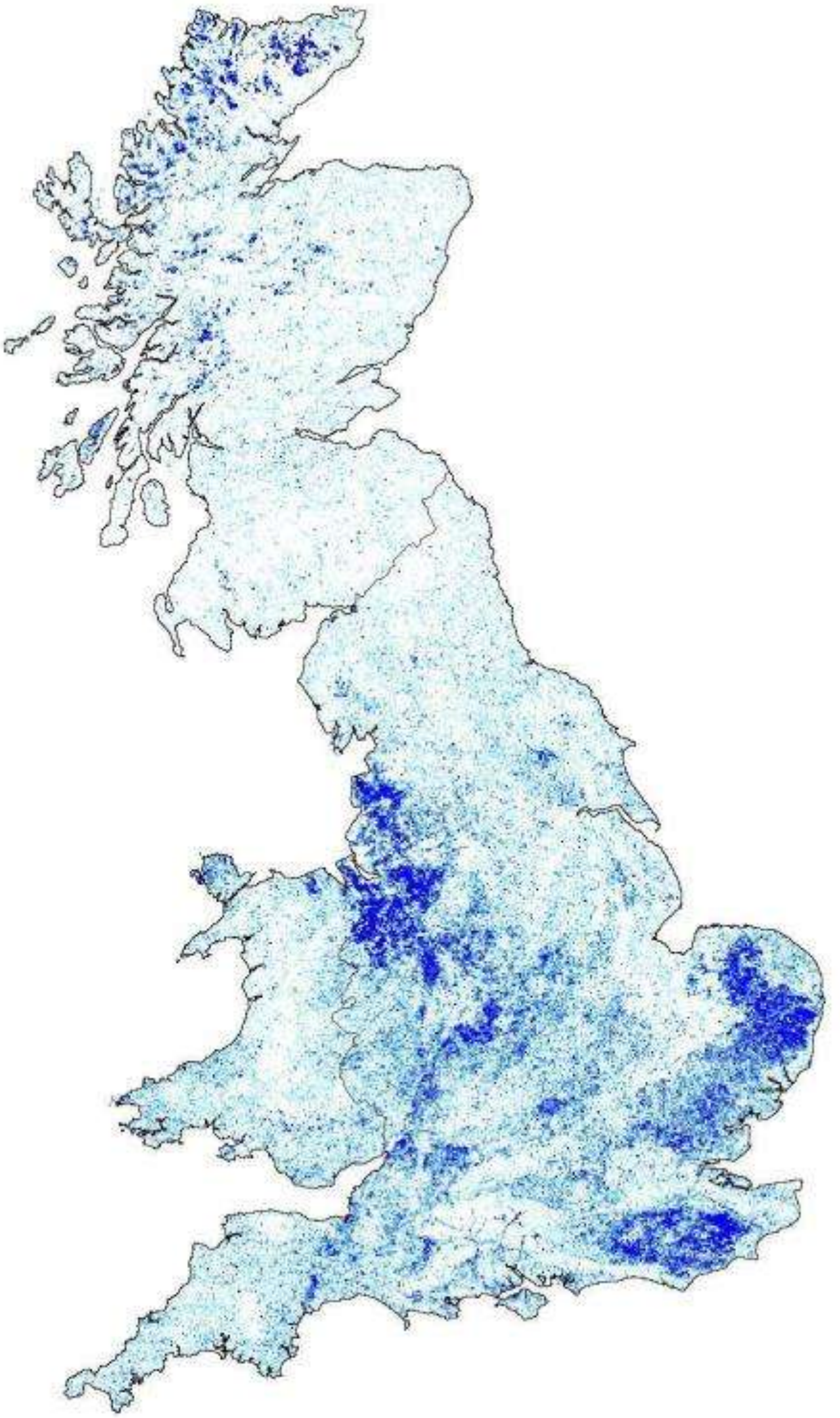


Table 4.1 Great crested newt-occupied and breeding ponds (GB and countries)
Modelled on OS Master Map-derived data. See also corrected key metrics in Tables 8.1 and 8.2, pp 53 – 54.

	GB	Scotland	Wales	England
No. of occupied ponds (95% CI)	64,756 (28,721 – 129,453)	1,542 (N/A**)	4,512 (N/A**)	58,703 (48,044 – 72,864)
Occupied ponds as % of total ponds per area (95% CI)	16.11 (7.14 – 32.20)	1.76 (N/A**)	16.05 (N/A**)	20.52 (16.79 – 25.46)
Occupied ponds per km^2 (95% CI)	0.28 (0.12 – 0.56)	0.02 (N/A**)	0.22 (0.16 – 1.45)	0.44 (0.36 – 0.55)
No. of breeding ponds (75% method) (95% CI)	48,567 (21,541 – 97,090)	1,156 (N/A**)	3,384 (2,447 – 22,664)	44,027 (36,033 – 54,648)
Breeding ponds as % of total ponds per area (75% method) (95% CI)	12.08 (5.36 – 24.15)	1.32 (N/A**)	12.04 (8.71 – 80.62)	15.39 (12.59 – 19.10)
No. of breeding ponds (HSI >0.6 method) (95% CI)	28,229 (12,520 – 56,432)	672 (N/A**)	1,967 (1,422 – 13,173)	25,590 (20,944 – 31,376)
Breeding ponds as % of total ponds per area (HSI >0.6 method) (95% CI)	7.02 (3.11 – 14.04)	0.77 (N/A**)	7.00 (5.06 – 46.58)	8.94 (7.32 – 11.10)

**** Insufficient data to generate meaningful confidence limits**

Table 4.2 Great crested newt-occupied and breeding ponds (English regions)
Modelled on OS Master Map-derived data. See also corrected key metrics in Tables 8.1 and 8.2, pp 53 – 54.

	East of England	East Midlands	London	North East	North West	South East	South West	West Midlands	Yorkshire & Humber
No. of occupied ponds (95% CI)	20,312 (15,109 – 22,652)	2,687 (2,414 – 18,827)	578 (342 – 742)	927 (291 – 6,828)	8,796 (3,814 – 36,581)	10,627 (6,442 – 12,225)	11,394 (N/A**)	15,426 (14,023 – 32,048)	1,159 (1,022 – 2,343)
Occupied ponds as % of total ponds per area (95% CI)	33.65 (25.05 – 37.53)	10.31 (9.26 – 72.20)	25.17 (14.90 – 32.29)	18.75 (NA**)	21.68 (9.40 – 90.15)	20.50 (12.43 – 23.58)	27.36 (N/A**)	37.55 (34.13 – 78.00)	6.69 (5.90 – 13.52)
Occupied ponds per km^2 (95% CI)	1.06 (0.78 – 1.18)	0.17 (0.15 – 1.19)	0.37 (0.22 – 0.47)	0.11 (0.03 – 0.79)	0.59 (0.26 – 2.46)	0.57 (0.35 – 0.66)	0.47 (N/A**)	1.19 (1.08 – 2.47)	0.07 (0.065 – 0.15)
No. of breeding ponds (75% method) (95% CI)	15,234 (11,332 – 16,989)	2,016 (1,811 – 14,115)	434 (257 – 557)	695 (218 – 5,121)	6,597 (2,861 – 27,436)	7,970 (4,831 – 9,169)	8,546 (N/A**)	11,570 (10,517 – 24,036)	869 (767 – 1,757)
Breeding ponds as % of total ponds per area (75% method) (95% CI)	25.24 (18.77 – 28.15)	7.73 (6.95 -54.15)	18.88 (11.18 – 24.22)	14.06 (N/A**)	16.26 (7.05 – 67.61)	15.37 (9.32 – 17.69)	20.52 (N/A**)	28.16 (25.60 – 58.50)	5.02 (4.43 – 10.14)
No. of breeding ponds (HSI >0.6 method) (95% CI)	8,855 (6,587 – 9,875)	1,172 (1,052 – 8,204)	252 (149 – 323)	404 (127 – 2,976)	3,834 (1,663 – 15,947)	4,633 (2,808 – 5,329)	4,967 (N/A**)	6,725 (6,113 – 13,971)	505 (446 – 1,021)
Breeding ponds as % of total ponds per area (HSI >0.6 method) (95% CI)	14.67 (10.91 – 16.36)	4.49 (4.04 – 31.47)	10.97 (6.50 – 14.08)	8.17 (2.57 – 60.19)	9.45 (4.10 – 39.30)	8.94 (5.42 – 10.28)	11.93 (N/A**)	16.37 (14.88 – 34.00)	2.92 (2.57 – 5.89)

**** Insufficient data to generate meaningful confidence limits**

3.3 Great Crested Newt Viability Measures

Table 5.1 Great crested newt viability measures (GB and countries)
Based on modelled data (see 2.3.6 and 2.5.1, above). See also corrected key metrics in Tables 8.1 and 8.2, pp 53 – 54.

	GB	Scotland	Wales	England
Number of occupied ponds with HSI score >0.7 (95% CI)	15,200 (6,742 – 30,387)	362 (N/A**)	1,059 (766 – 7,093)	13,779 (11,277 – 17,103)
HSI score >0.7 ponds as % of total ponds per area (95% CI)	3.78 (1.68 – 7.56)	0.41 (N/A**)	3.77 (2.72 – 25.23)	4.82 (3.94 – 5.98)

**** Insufficient data to generate meaningful confidence limits**

Table 5.2 Great crested newt viability measures (English regions)
Based on modelled data (see 2.3.6 and 2.5.1, above). See also corrected key metrics in Tables 8.1 and 8.2, pp 53 – 54.

	East of England	East Midlands	London	North East	North West	South East	South West	West Midlands	Yorkshire & Humber
Number of occupied ponds with HSI score >0.7 (95% CI)	4,768 (3,547 – 5,317)	631 (567 – 4,418)	136 (80 – 184)	218 (68 – 1,603)	2,065 (895 – 8,587)	2,495 (1,512 – 2,870)	2,675 (N/A**)	3,621 (3,292 – 7,523)	272 (240 – 550)
HSI score >0.7 ponds as % of total ponds per area (95% CI)	7.90 (5.88 – 8.81)	2.42 (2.17 – 16.95)	5.91 (3.50 – 7.58)	4.40 (1.38 – 32.41)	5.09 (2.21 – 21.16)	4.81 (2.92 – 5.54)	6.42 (N/A**)	8.81 (8.01 – 18.31)	1.57 (1.38 – 3.17)

**** Insufficient data to generate meaningful confidence limits**

3.4 Great Crested Newt Habitat Measures

Table 6.1 Numbers of suitable ponds (GB and countries)

	GB	Scotland	Wales	England
Number of suitable ponds (occupied or not)	267,720	58,467	18,720	190,534

Table 6.2 Numbers of suitable ponds (English regions)

	East of England	East Midlands	London	North East	North West	South East	South West	West Midlands	Yorkshire & Humber
Number of suitable ponds (occupied or not)	40,190	17,358	1,530	3,293	27,020	34,520	27,727	27,358	11,539

Table 7 Extent of suitable habitat (aquatic and terrestrial)

	GB	Scotland	Wales	England	South East England
Suitable habitat (km^2) – phase 1 model	173,599*	30,203	18,998	124,398	17,443
Model fit – phase 1	N/A	65% (50% model)	94% (50% model) 97% (south model) 42% (north model)	N/A	91% (50% model)
Suitable habitat (km^2) – phase 2 model	74,052*	8,466	10,833	54,753	8,997
Model fit – phase 2	N/A	30% (50% model)	52% (50% model) 65% (south model) 25% (north model)	N/A	56% (50% model)
Suitable habitat (km^2) – phase 1 with pond density filter	28,830*	713	1,989	26,128	4,655

*** Aggregated from country values**

Figure 8.1 Phase 1 (black) and Phase 2 (red) model squares in Scotland

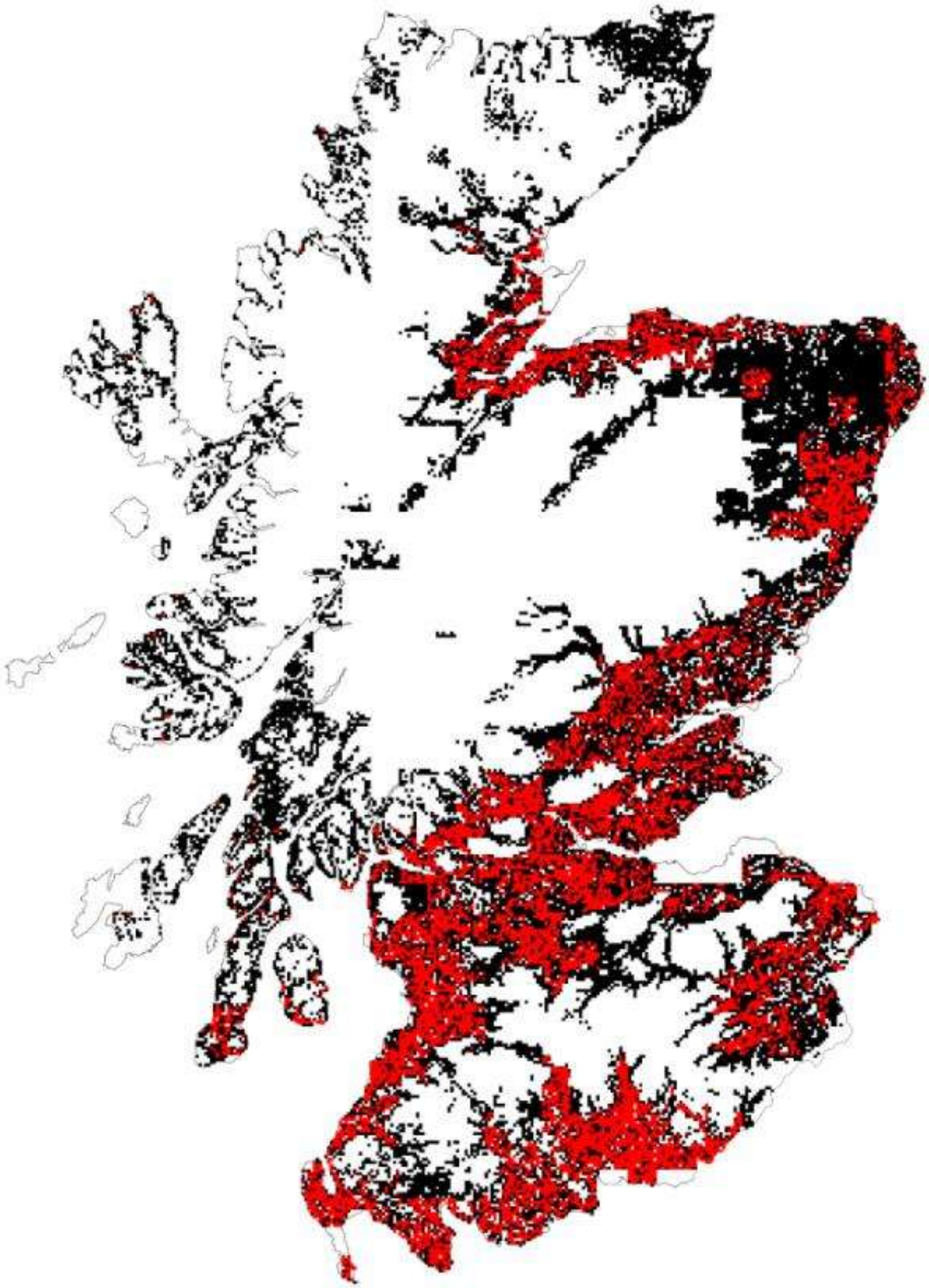


Figure 8.2 Phase 1 model squares in Scotland filtered by pond density (4 or more per km^2)

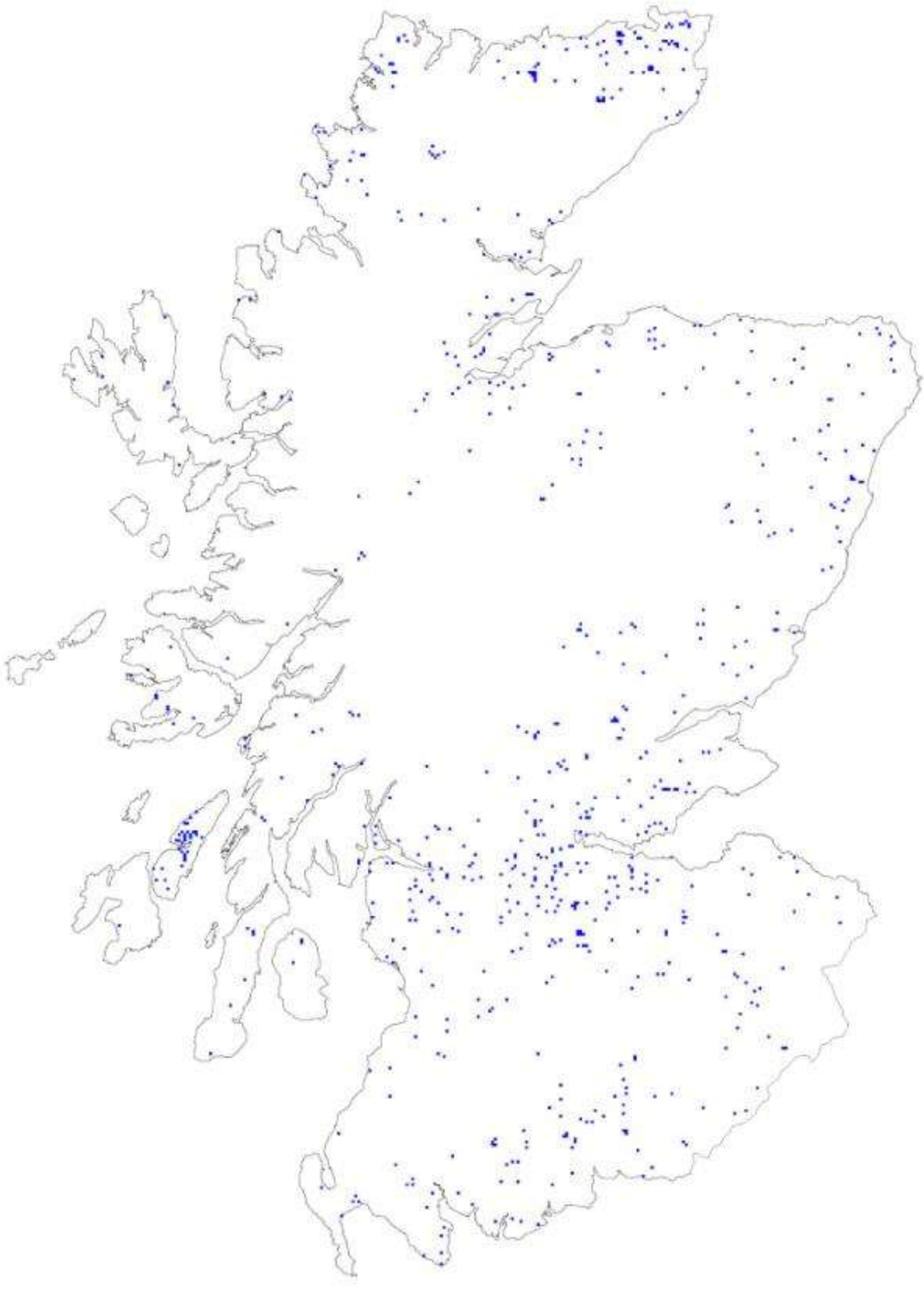


Figure 9.1 Phase 1 (black) and Phase 2 (red) model squares in Wales

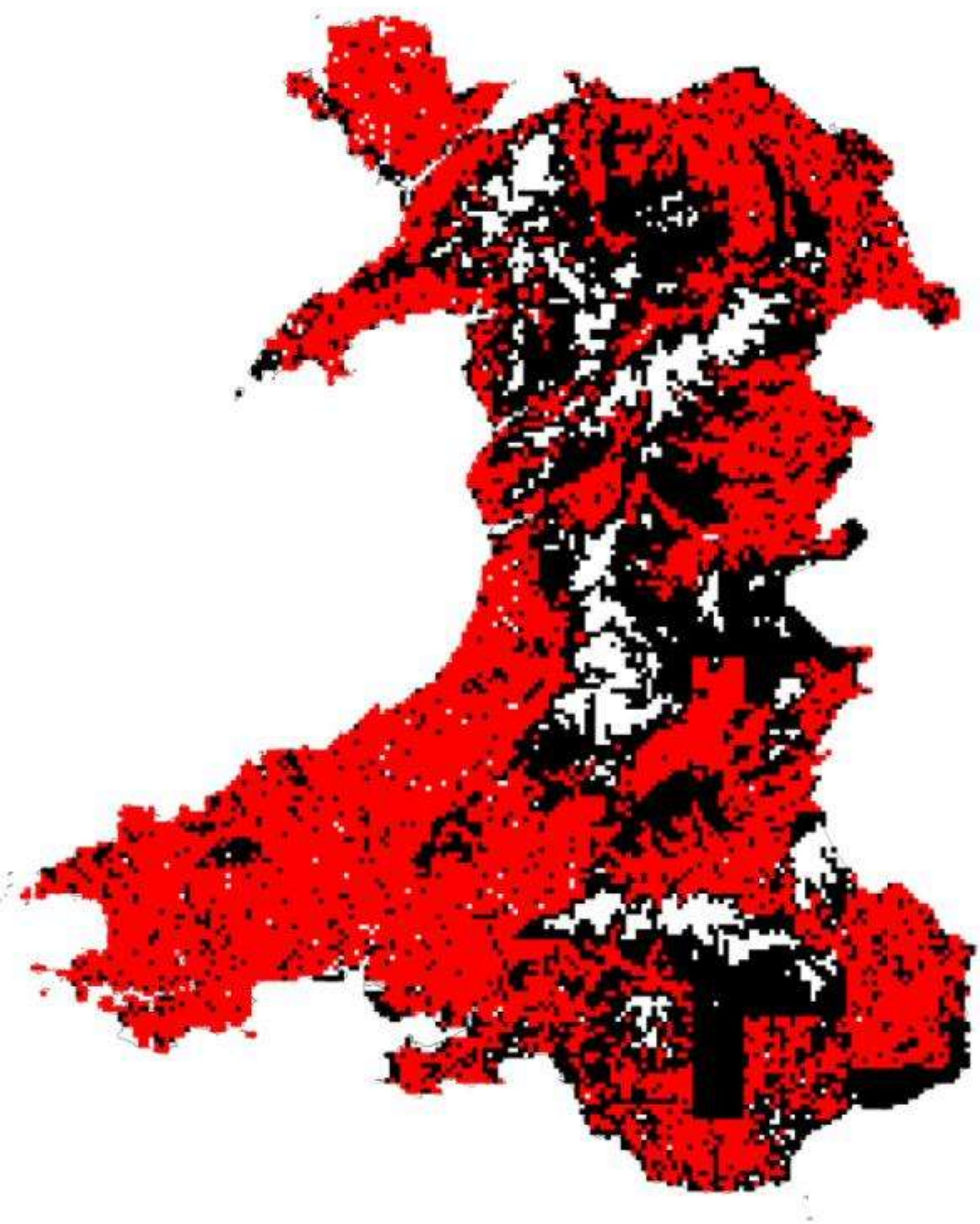


Figure 9.2 Phase 1 model squares in Wales filtered by pond density (4 or more per km^2)

Figure 10.1 Phase 1 (black) and Phase 2 (red) model squares in England

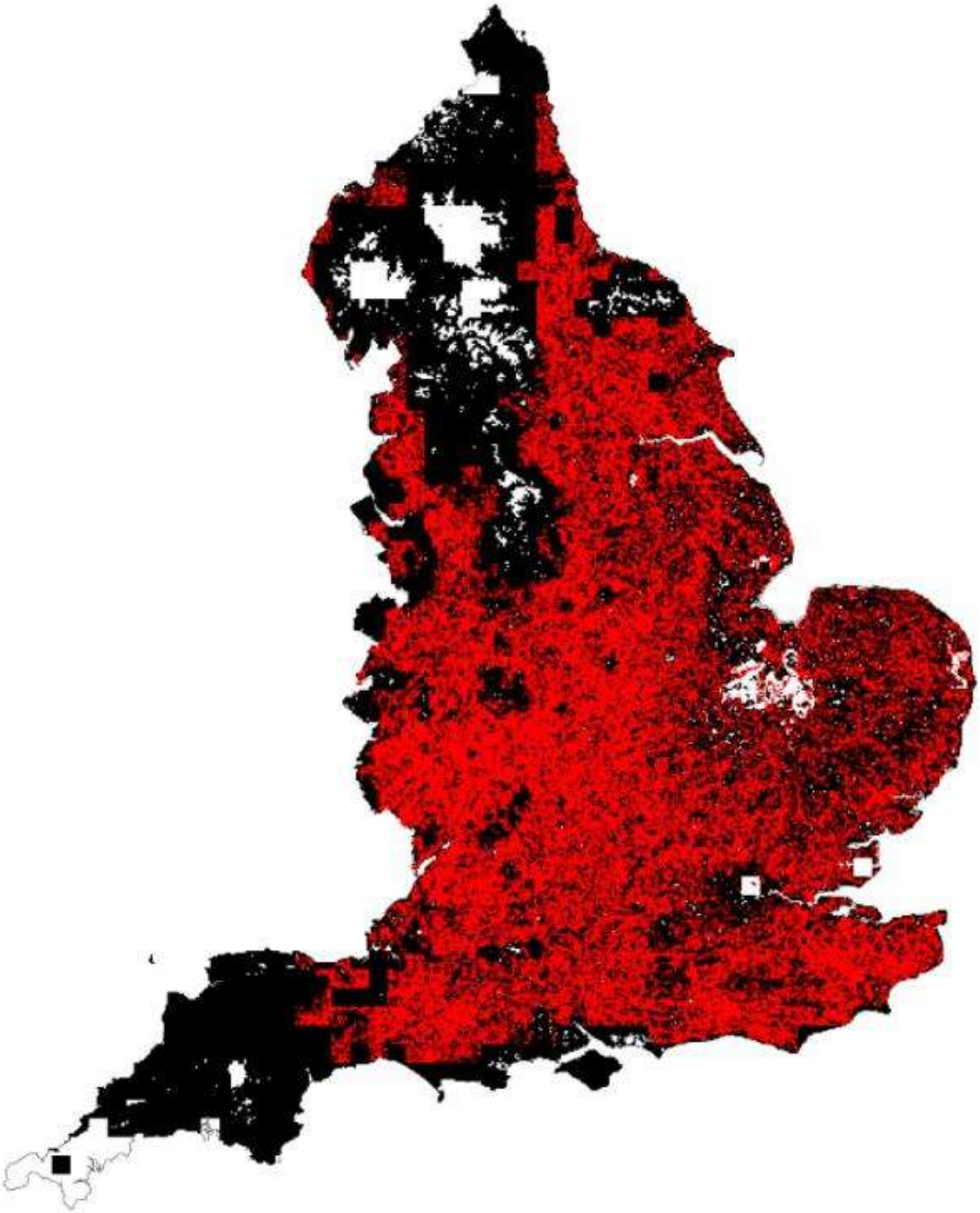


Figure 10.2 Phase 1 model squares in England filtered by pond density (4 or more per km^2)

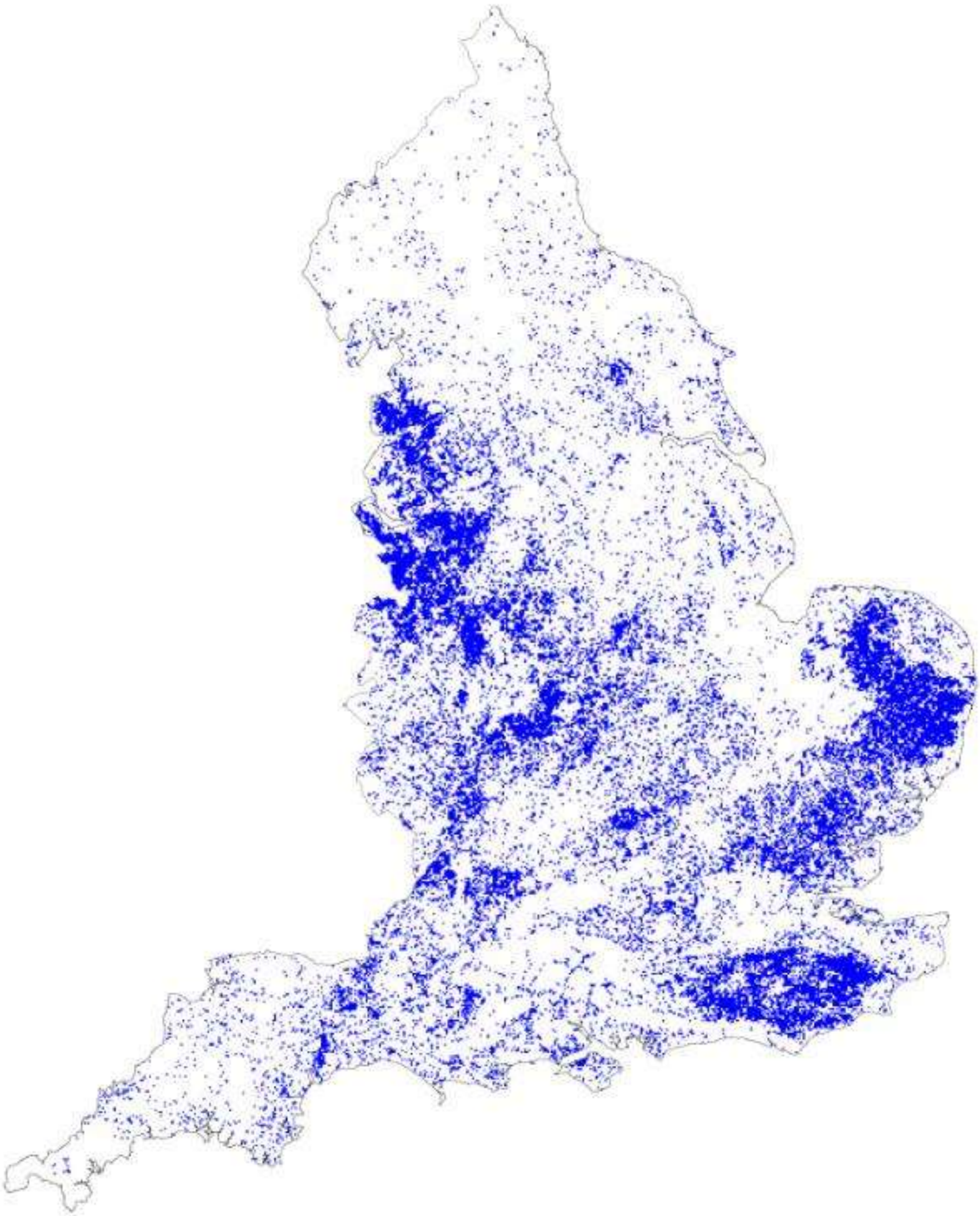


Figure 11.1 Phase 1 (black) and Phase 2 (red) model squares in South East England

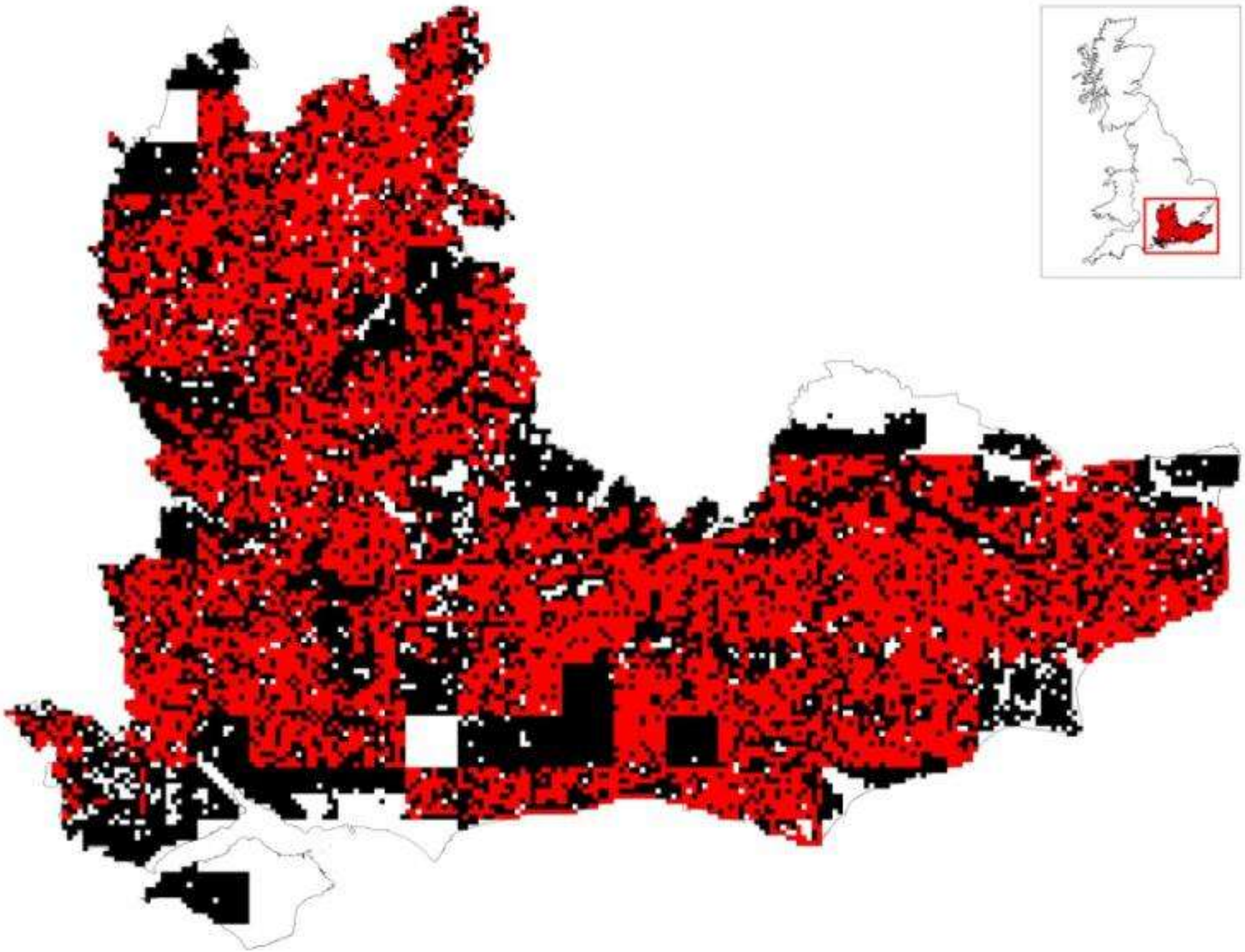


Figure 11.2 Phase 1 model squares in South East England filtered by pond density (4 or more per km^2)

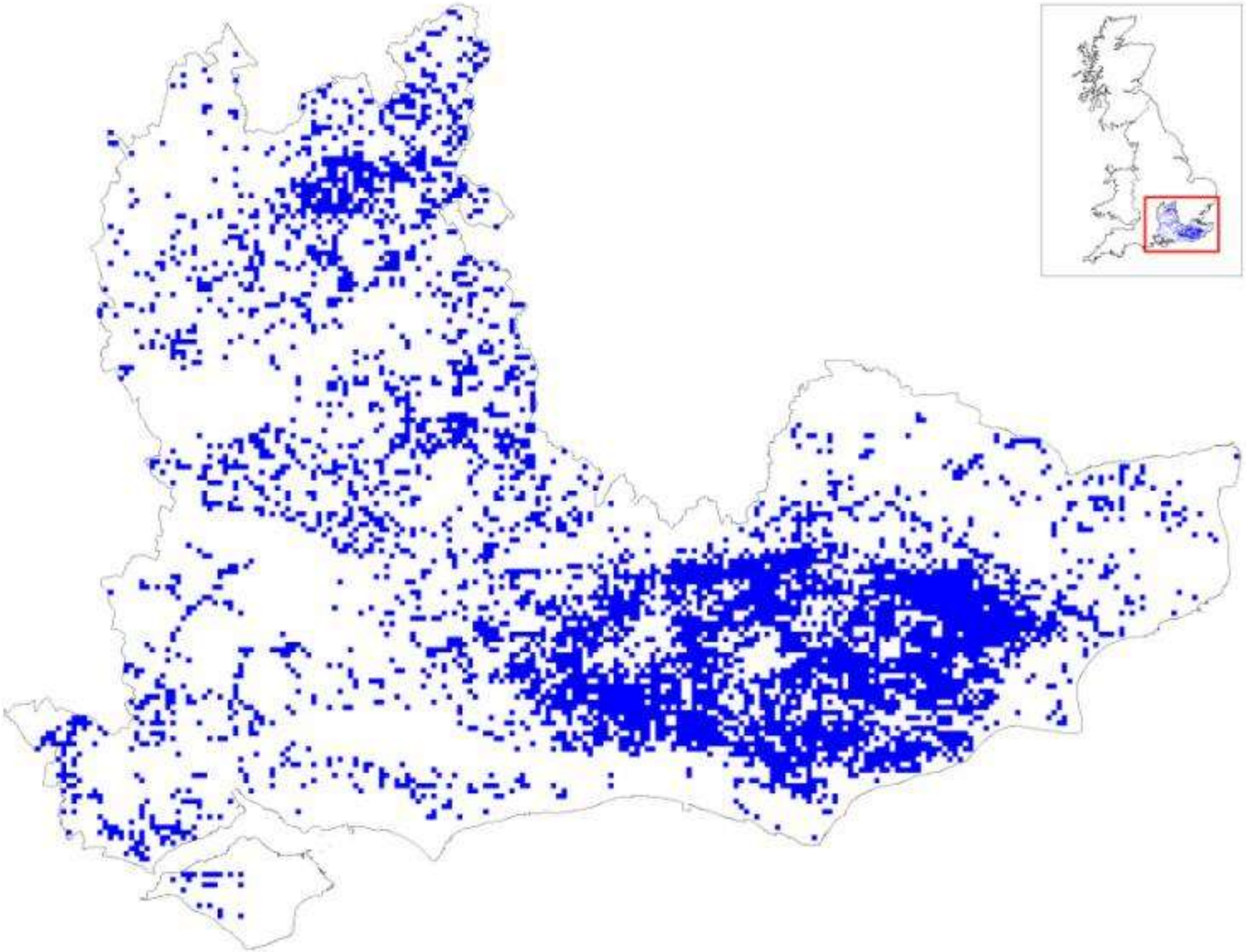


Figure 12 Descriptive thematic map of known great crested newt-occupied 10km squares in GB Darker 10km squares contain more 1km grid squares with 4 or more ponds.

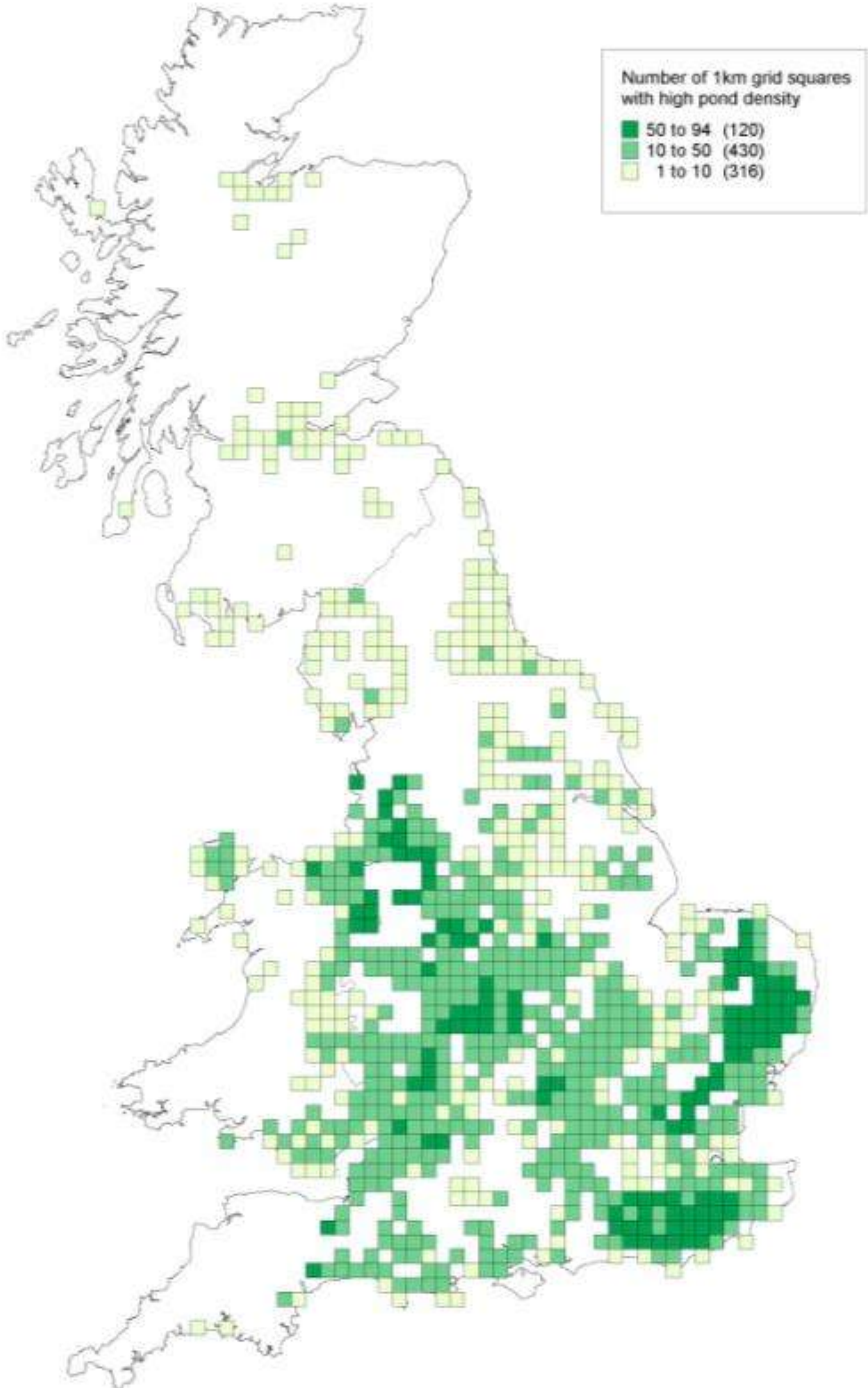


Figure 13 Predictive thematic map of 10km squares with habitat modelled to be suitable for great crested newts (Phase 1) in GB
Darker 10km squares contain more 1km grid squares with 4 or more ponds. For full explanation see Discussion.

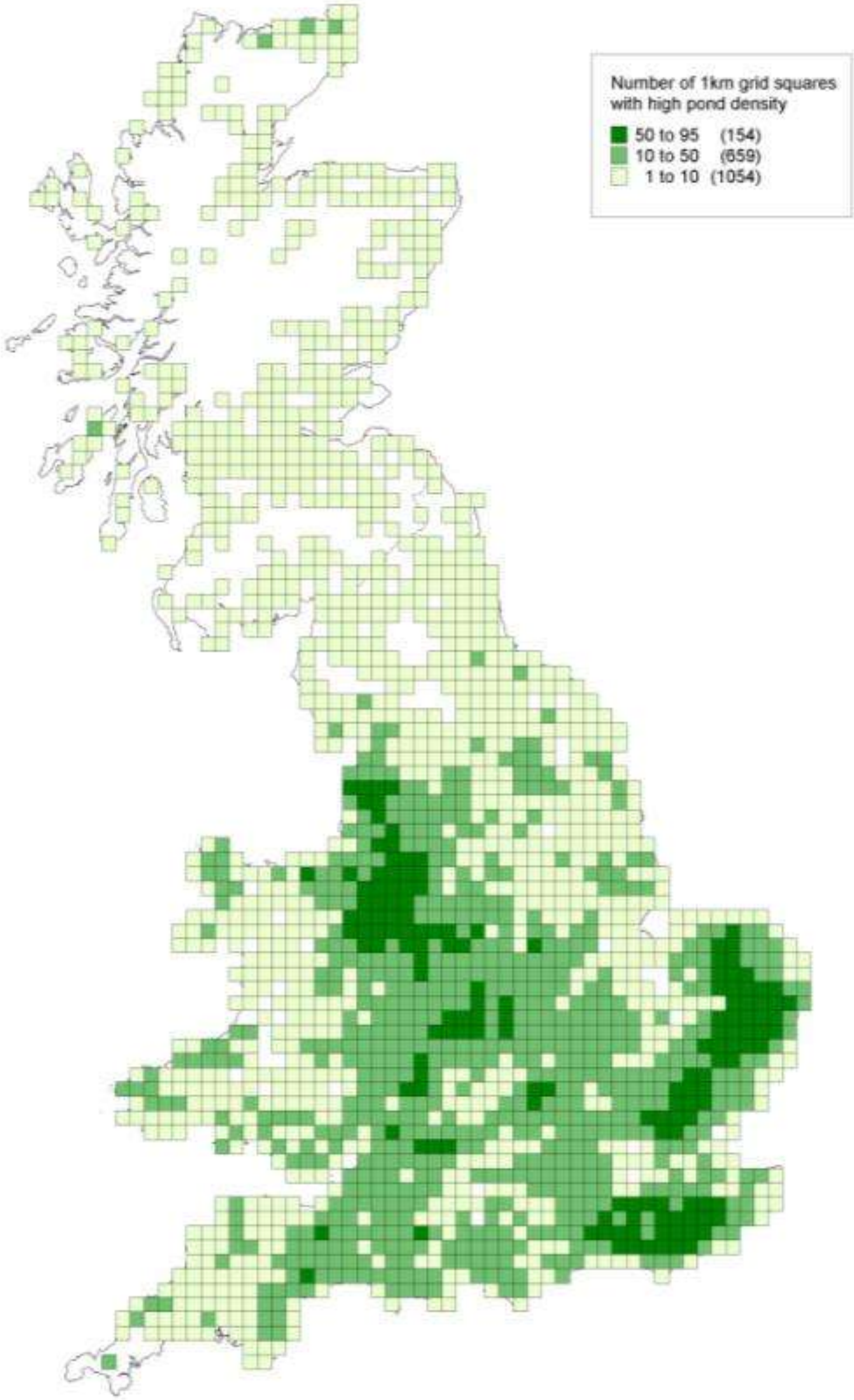


Figure 14 Predictive thematic map of modelled (Phase 1) 1km squares with habitat suitable for great crested newts in GB
Darker squares contain more ponds. See Fig. 15 for area of detail.

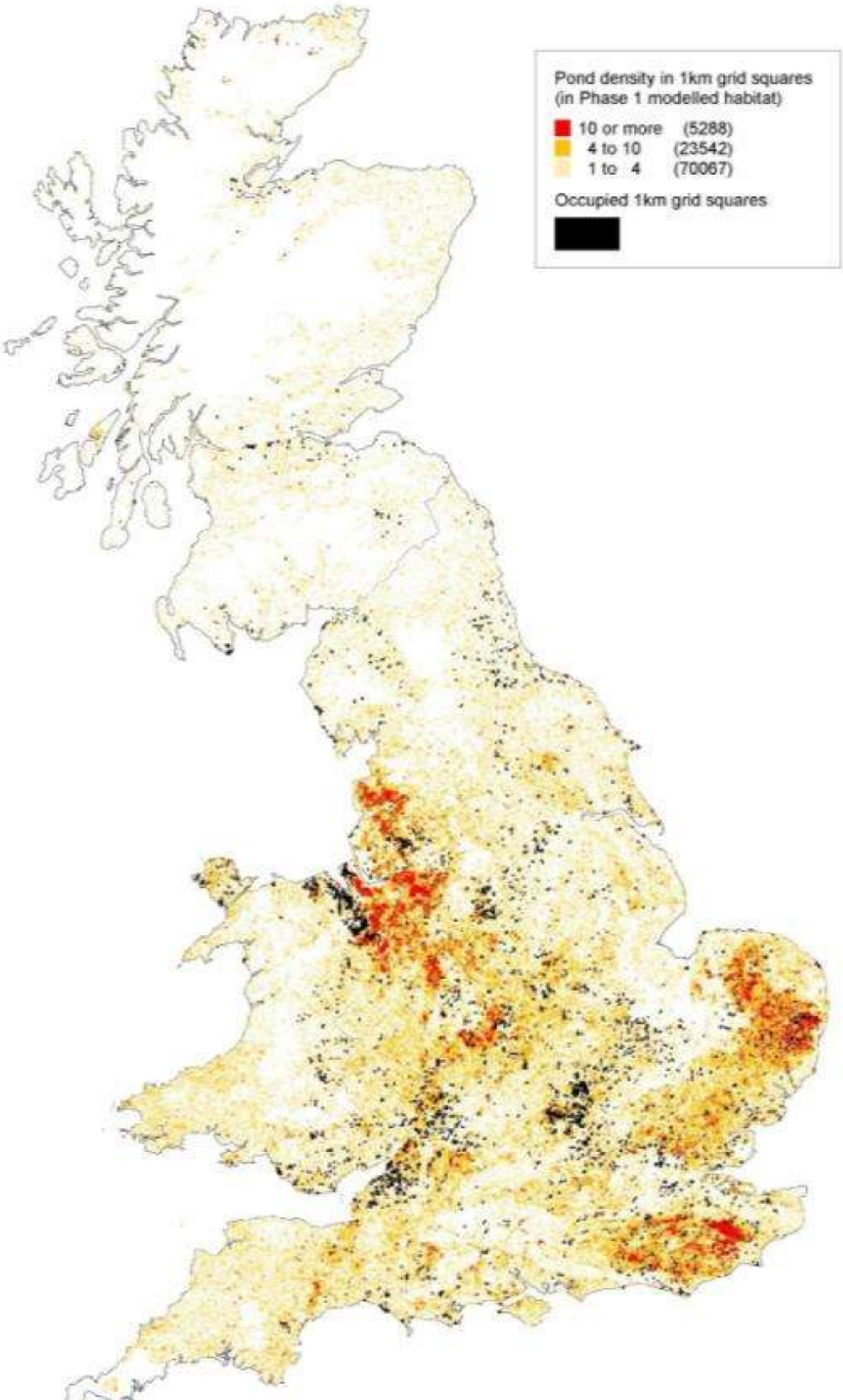


Figure 15 South East England detail of Fig. 14

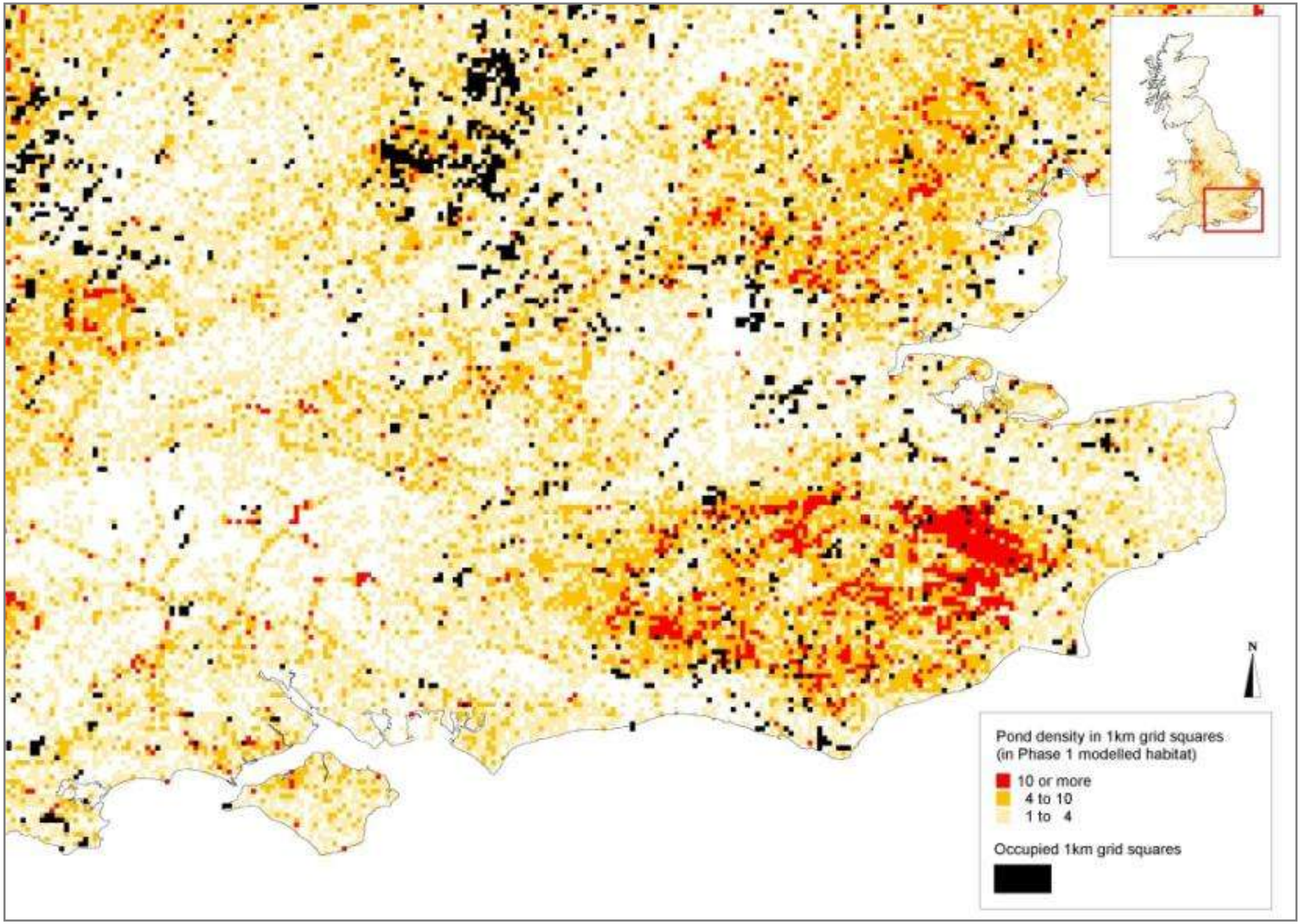


Table 8.1 Summary of key metrics corrected for urban areas (GB and countries)
[correction factor = % urban land cover in each country/region]

	GB	**Scotland**	**Wales**	**England**
No. of occupied 10km squares - mapped	***894****	***70***	***102***	***751***
No. of occupied 1km squares - mapped	***3,182***	***113***	***519***	***2,550***
Correction factor for metrics below	5.80	1.94	3.12	8.49
No. of occupied 1km squares – modelled (95% CI)	17,967 (7,817 – 35,792)	425 (N/A**)	1,772 (1,281 – 11,865)	15,385 (12,591 – 19,096)
Area of land occupied (%) – modelled (95% CI)	7.76 (3.37 – 15.44)	0.54 (N/A**)	8.48 (6.33 – 58.65)	11.59 (9.49 – 14.39)
No. of occupied ponds (95% CI)	60,998 (26,632 – 121,945)	1,512 (N/A**)	4,371 (3,161 – 29,275)	53,719 (43,965 – 66,678)
No. of breeding ponds (75% method) (95% CI)	45,748 (20,291 – 91,459)	1,134 (N/A**)	3,278 (2,371 – 21,956)	40,289 (32,974 – 50,008)
No. of breeding ponds (HSI >0.6 method) (95% CI)	26,591 (11,794 – 53,159)	659 (N/A**)	1,906 (1,387 – 12,762)	23,418 (19,166 – 29,067)
Number of occupied ponds with HSI score >0.7 (95% CI)	14,318 (6,351 – 28,624)	355 (N/A**)	1,026 (742 – 6,872)	12,610 (10,320 – 15,651)

*** The GB figure is less than the combined total for constituent countries as some 10 km grid squares contribute to the total for more than one country.**
**** Insufficient data to generate meaningful confidence limits**

Table 8.2 Summary of key metrics corrected for urban areas (English regions)
[correction factor = % urban land cover in each country/region]

	East of England	East Midlands	London	North East	North West	South East	South West	West Midlands	Yorkshire & Humber
No. of occupied 1km squares – mapped	***446***	***294***	***71***	***130***	***245***	***532***	***430***	***265***	***137***
Correction factor for metrics below	7.52	6.93	51.44	6.05	9.30	10.88	6.13	9.64	7.26
No. of occupied 1km squares – modelled (95% CI)	4,253 (3,163 – 4,742)	925 (831 – 6,478)	106 (63 – 136)	491 (154 – 3,614)	1,683 (1,241 – 10,011)	2,432 1,474 – 2,797)	3,873 (N/A**)	3,506 (3,187 – 7,284)	478 (422 – 967)
Area of land occupied (%) – modelled (95% CI)	22.09 (16.43 – 24.64)	5.87 (5.27 – 41.10)	6.74 (3.99 – 8.65)	5.68 (1.78 – 41.80)	11.32 (8.35 – 67.32)	13.12 (7.95 – 15.09)	15.93 (N/A**)	27.06 (24.59 – 56.21)	3.08 (2.72 – 6.23)
No. of occupied ponds (95% CI)	18,785 (13,973 – 20,948)	2,501 (2,247 – 17,516)	281 (166 – 360)	871 (273 – 6,414)	7,977 (3,460 – 33,197)	9,472 (5,741 – 10,895)	10,696 (N/A**)	13,940 (12,671 – 28,959)	1,075 (948 – 2,173)
No. of breeding ponds (75% method) (95% CI)	14,088 (10,480 – 15,711)	1,876 (1,685 – 13,137)	211 (125 – 270)	653 (205 – 4,811)	5,983 (2,595 – 24,844)	7,104 (4,306 – 8,171)	8,022 (N/A**)	10,455 (9,503 – 21,719)	806 (711 – 1,629)
No. of breeding ponds (HSI >0.6 method) (95% CI)	8,189 (6,091 – 9,132)	1,090 (979 – 7,636)	122 (72 – 157)	380 (119 – 2,796)	3,478 (1,508 – 14,464)	4,129 (2,503 – 4,749)	4,663 (N/A**)	6,077 (5,524 – 12,624)	469 (413 – 947)
Number of occupied ponds with HSI score >0.7 (95% CI)	4,409 (3,280 – 4,917)	587 (527 – 4,112)	66 (39 – 85)	204 (64 – 1,506)	1,873 (812 – 7,786)	2,223 (1,348 – 2,557)	2,511 (N/A**)	3,272 (2,974 – 6,798)	252 (223 – 510)

4. DISCUSSION AND RECOMMENDATIONS

The present project is one of a number of similar recent, ongoing or imminent attempts to investigate and better define the status of the great crested newt in Great Britain. The recent report on applying the concept of favourable conservation status (FCS) to the species in North Wales (ARC and Cofnod, 2010) addressed this issue using sophisticated modelling techniques with the programme Biomapper. This software uses ecological niche factor analysis to model habitat suitability without the need for absence data (that would be required, for example, to use in logistic regression analysis). The resulting model maps generated zones within the study area showing different percentage likelihood of occurrence for great crested newt. The project sets the stage for a forthcoming (early 2011) investigation by ARC and CCW into setting favourable reference values at a local level in Flintshire and adjacent authorities. Currently ongoing is the ARC/SNH Great Crested Newt Distribution in Scotland project, for which the ARC Removal Model was initially developed. This uses habitat modelled to be suitable for great crested newts to target survey effort in order to identify newly-recorded populations.

Though all these projects have a degree of overlap, there are differing but compatible goals for each one. For example, modelling developed for the ARC/SNH project has informed the assessment of suitable habitat for the present report. Development of that model with the addition of pond density data has enabled the production of the predictive presence maps (see Figs. 14 and 15) shown here, and these will in turn help to further target survey effort in Scotland and identify pond creation opportunities in Wales. The culmination of these projects is intended to result in a suite of tools that will describe known distribution, model suitable habitats and assess the status of great crested newts for practical applications including maximising survey effort, informing conservation priority and target setting at multiple levels, targeting habitat creation and informing planning sensitivity mapping. The results of the present project are discussed with particular reference to quantifying status and developing methods by which changes in status can be assessed in a robust, repeatable way. Further investigation will be required to establish means by which status, once assessed, can be described as “favourable” or otherwise (setting favourable reference values).

4.1 Great Crested Newt Range Measures

4.1.1 Range polygons

The gross great crested newt range polygon generated specifically for this report (Figure 2) is likely more reflective of reality than the original (Figure 1; JNCC, 2007), being based on 1km resolution data and filtering out pre-1970 records. However, generation of the polygon was subjective and based on our incomplete knowledge of great crested newt distribution. This incomplete knowledge is exacerbated by the need to omit some known great crested newt record locations that are available only at 10km square resolution. The inclusion of such records in what is relatively precise GIS mapping could result in some records being mapped as much as 14km from their "true" location. Figures 1 – 5 each contain at least small gaps apparently for this reason. More pertinently, the incomplete mapping of known record localities makes the separation of biological differences (for example between NCAs) and record inconsistencies more difficult. See for example the apparent lack of records in Cheshire, a known great crested newt hotspot. Despite this caveat, the exclusion of low-resolution records does not appear to have negatively impacted modelling efforts (compare Figs. 12 and 13 and see below).

A potentially useful and more objective way of describing and measuring "range" *per se* is shown in Figure 3, which would be relatively simple to update periodically based on time-limited records (e.g. by including a "rolling" record filter covering the last 30 years) and therefore could be used to measure any changes. This is, of course, assuming that there are no dramatic changes in recording effort encountered by excluding a year at the front of a year range and including one from the end. Because of the issues involved with resolution of records, however, the method used to produce Fig.2, which combines the GIS generation of a range polygon with manual exclusion of very isolated records, is probably most preferable for generating an overall range metric. Though more subjective than the method adopted by JNCC (2007), this avoids the inclusion of large unoccupied areas and thus helps prevents overestimation of range size.

4.1.2 National Character Areas in England

Assessment of occupancy of NCAs is instructive as regards great crested newt distribution in that it highlights those which are apparently unsuitable (though note potential confusion from excluding low-resolution records, discussed above). Most English NCAs, however, do have at least a few great crested newt records, so this metric is most useful probably only as a broad baseline which may indicate problems with great crested newt populations should occupancy from any one currently-occupied NCA disappear in time. Additionally, surveyors do not carry out targeted blanket surveys on the basis of NCAs so that information (records of presence or absence) in any one NCA are likely to be (and remain) uneven. Assessment of presence and record density within local administrative areas (county, unitary authority) is likely to represent a more practical approach which would at the same time provide data for local target setting and disaggregation from national targets.

4.1.3 Occupied 10km squares (existing target metric)

Application of modern GIS mapping means that this metric is probably still the most useful for gaining an overall view of great crested newt distribution in GB and, moreover, any apparent changes to great crested newt occupancy at 10km resolution probably represent genuine, large-scale changes (losses or gains). Target figures will probably need regular revising in order to present an accurate overview based on a rolling record filter (e.g. the one used for this report filtered out pre-1970 records).

Numbers of occupied 10km grid squares in GB generated by mapping analyses for this report are slightly lower for England and GB than in the revised SAP baseline values (see Table 1) but higher for Scotland and Wales based on the improved information from datasets D to H. Apparent 10km grid square gaps, currently seen in the present figures due to the inclusion of data at only 1km or finer resolution, may be an issue in terms of accuracy. This, however, could easily be rectified in the long-term by stressing the need for record accuracy and encouraging providers of data to the NBN Gateway to allow higher-resolution access. The temporal range of records used to generate this metric also needs agreement. We have effectively used a temporal record range of some 40 years (from 1970 onwards) for the purposes of this report, though a narrower range would be more appropriate if survey effort can be considered comparable over time. A balance should be struck between the inclusion of older records and the potential for undetected population extinctions in locations where great crested newt presence has not been confirmed or recorded for many years. Limited access to contemporary data at good spatial resolution remains a barrier to assessing species' status and to describing changes in that status. Subject to these caveats regarding data, the SAP baseline figures for this metric certainly need revising, particularly those for Scotland and Wales. Target increases in range need careful reconsideration.

4.1.4 Occupied vice counties (existing target metric)

As a gross measure of great crested newt distribution in GB, this metric is of most use in showing losses or gains at the periphery of the species' GB range. Again, a rolling record filter could be applied to assess apparent changes over time and re-assess figures. Our figures differ from those in the SAP targets because of the pre-1970 filter and our access to additional information. The only unoccupied vice county in Wales (Pembrokeshire) does apparently have suitable habitat (see later in Discussion) but it is likely that unoccupied vice counties in SW England and Northern Scotland are broadly unsuitable for this species. This particular metric to assess status and set targets may therefore be less useful than previously, based on our improved information and the fact that assessment can be carried out equally easily at occupied 10km square resolution or finer.

Only the grossest large-scale changes can be detected by examining occupancy at vice county level. It would certainly be more practical in terms of target setting and measurement of progress against targets to consider occupancy and status in Local or Unitary Authorities.

4.1.5 Occupied 1km squares (mapped)

We include this metric here as an indication of how GIS mapping based on improved information can generate more detailed figures than at 10km resolution, for both countries and regions. Despite this, however, our collective knowledge of great crested newt-occupied 1km squares is still substantially incomplete and, moreover, varies between areas or regions. This is because of variability in survey effort and/or reporting (for example the varying propensity of recorders to supply records to Local Records Centres [LRCs], and of LRCs to supply data to the NBN Gateway), as well as record resolution (see above). Our figures certainly represent an underestimate of the actual number of occupied 1km squares and, for these reasons, a sound approach requires the modelling of square occupancy by extrapolation from available high-resolution records. The modelling described below is therefore based on information gleaned from records at 1km square resolution or better.

4.1.6 Occupied 1km squares (modelled)

This method of modelling, by extrapolating from known records, possibly provides a useful approach to generating numbers that better reflect the reality of great crested newt 1km square occupancy, particularly when area values are compared as a percentage of land area (by country, region etc.). The figures corrected for urban land cover (see Tables 8.1 and 8.2) suggest that the actual numbers of occupied 1km squares are between 1.5 X the mapped number in London and as much as 13 X the mapped number in the West Midlands. Though the modelled figures overall are intuitively realistic, this does highlight that survey effort, recording effort and resolution of available records all affect assessments of status and that more region-specific models may need to be developed long-term in order, for example, to set local targets. Some important country-level differences in square occupancy rate are also revealed. The revised great crested newt SAP baseline values derived in 2005-6 treat Wales and Scotland very similarly (Table 1), but our analyses generate figures for Wales that are consistently an order of magnitude higher than those for Scotland (see Table 8.1 and elsewhere, this Discussion). This may be a real indication that much of Scotland is actually less suitable for great crested newts than elsewhere in GB. See also Fig. 8.2, which shows only scattered 1km squares in Scotland with high pond density as compared to England and Wales (Figs. 9.2 and 10.2). Furthermore, it is likely that our collective knowledge of great crested newt locations in Scotland could represent a more complete picture of the species' presence there than was previously thought. This question is being addressed by the ARC-SNH Great Crested Newt Distribution Project.

In areas where great crested newt occupancy varies dramatically across the area (e.g. Wales, East Midlands, North East England; Tables 3.2 and 3.3) CIs may be conservatively high. In light of this, it is interesting that the CIs for England overall are relatively tight, probably because there exist a lot of data for England when it is taken as a single unit and the effects of differing great crested newt record density have lower importance where records are relatively abundant. Indeed, low or highly variable record density is probably sufficient to account for variations in magnitude of CI range between the geographic areas, as well as the relative sizes of those areas (compare values in Table 3.3). Percentagewise, the highest great crested newt-occupancy of 1km squares in GB appears to be in the West Midlands (though with broad CIs) though this may reflect regional differences in data availability and it is probably best to consider the numbers of 1km squares modelled to be occupied at the country level for comparison purposes. For further discussion on the implications of wide CIs, see below.

This extrapolation modelling technique generates putative numbers of occupied 1km squares for each region or country, but does not suggest their locations. This is considered later (this Discussion).

4.2 Great Crested Newt Population Measures

4.2.1 Estimates of numbers of ponds occupied (existing target metric) and used for breeding

Pond occupancy per region and country is generated using the same ratios as for the above. Generation of more accurate figures has previously been hampered not only by incomplete knowledge of great crested newt distribution but by a lack of good pond data on which to base extrapolated numbers. The pond number and location data used here (Tables 2.1 and 2.2) are probably imperfect, though the figures compare well with country figures given in the Countryside Survey 2007 (Williams *et al.*, 2010).

The present pond figures fall within the 2007 confidence interval ranges presented by the Countryside Survey report (*ibid.*) with the exception of the figure for Scotland. Our Scottish figures apparently underestimate the total number of ponds in Scotland by a factor of around two. A brief validation assessment, where the number of ponds present in a random sample of 1km grid squares was counted using on-line maps and aerial photos and compared to the data used here, suggested that our pond data may be a slight underestimate of pond numbers in rural areas (noting the stated pond area range it was designed to pick up on) of ca. 1.5 ponds per 1km square on average; ranging to a very slight overestimate in highly urban areas of ca. 0.15 ponds per 1km square on average. Detection of a pond and/or pond boundaries was particularly difficult in the Scottish Highlands in our validation exercise and it seems reasonable that the pond data we used for the present report have inadequately described Highland ponds, possibly because of pond size, transience or, in some cases, their being long and thin (so that the aspect ratio excluded them as possibly being lengths of flowing water features). Our great crested newt habitat suitability (Removal) modelling strongly indicates that the Scottish Highlands are inimical to the species, so that figures based on the present pond data are probably not significantly affected (see Fig. 8.1 and discussion, below). It is worth noting, however, that absolute number of ponds in Scotland presented here (Table 2.1) almost certainly represents an underestimate.

The use of OS pond data is discussed by Langton *et al.* (2007). They suggest that such data may generate significant overestimates of pond numbers in rural areas. It is probably because of the size range (50 – 750 m^2 in area) chosen to describe ponds for the present study that this has apparently not happened here, as most discrepancies between the extant ponds observed by field study and those seen on a map can probably be accounted for by the loss, succession and lack of detection of smaller-sized ponds. Validation suggested that our only (small) overestimates in pond number occur in urban areas, and this is accounted for by the presence of small sections of river, canal etc. that show up as detached segments behind “higher priority” landscape features such as road and rail bridges.

Ultimately, however, it is clear that there is no single consistent method of assessing pond numbers by country or region, or attaching location data to ponds where their numbers have been extrapolated by standardised methodology (as in the Countryside Survey; Williams *et al.,* 2010). The development of a consensus on ways by which this can be usefully achieved (for periodic status assessments of great crested newts and other aquatic organisms) is essential in the long term. We nevertheless believe the pond data used for the present report represent the best spatially-explicit pond dataset available and that the size-range chosen removes many of the inconsistencies inherent in using OS-based data.

The present figures for occupied ponds (compare Table 4.1 with Table 1) suggest that current SAP baseline values are overestimates. Differences in putative numbers of occupied ponds are similar between countries and regions to putative numbers of occupied squares (see above) and, in particular, figures for Scotland and Wales ponds are again markedly different (see Tables 8.1 and 8.2 for corrected figures). Among the English Regions, the greatest numbers of occupied ponds are predicted to be found in the East of England, North West, South East, South West and West Midlands, an assertion that fits with perceptions of great crested newt “hotspots”, but which is perhaps not necessarily apparent on simple distribution maps (see also the sections 2.6.3 and 2.6.4, and Figs. 14 and 15, discussed later). Confidence interval ranges for occupied ponds (see Tables 4.1 and 4.2; Tables 8.1 and 8.2) are again broad in some cases; this is further discussed below. We do, however, have sufficient evidence to suggest that relative targets for Scotland and Wales are urgently in need of revision within the context of overall GB SAP target figures. Indeed, the baseline for occupied ponds in Scotland is some four times greater than the number predicted by our modelling (Table 8.1). This, assuming our modelled figures are closer to the truth than the estimates presented in the SAP, is the greatest overestimate but it seems likely that all targets will need some downward revision in order to be achievable. Perhaps more importantly, the way in which progress against stated targets is measured and assessed needs agreement so that this progress can be demonstrated. Modelling of the type employed in the present report, but carried out at a local administrative scale and aggregated to regional and higher levels, may be the most practical way of achieving this.

Numbers of breeding ponds by region and country are based on the suggestion that 75% of occupied ponds are actual great crested newt breeding ponds (Wright and Foster, 2009). This needs further investigation, in particular with reference to definition of a breeding pond and assessing whether or not any given pond experiences successful breeding, as well as consideration of how this may change at a given pond in a given year and over time. In particular, the proportion of ponds that experience successful breeding is likely to vary by area as a function of pond density and amounts of suitable habitat. These aspects may in fact be so difficult to quantify on a large and comparable scale that numbers of breeding ponds are of little value as a status assessment metric. The method of assessing breeding pond numbers using HSI figures has possibly more potential if and when good data on local and regional HSI scores become available. As things stand, the figures resulting from the two methods vary greatly. It seems clear that we currently lack any adequate ways to define, assess or model the number of ponds used for breeding by great crested newts so it would be inappropriate to adopt this metric for the purposes of status assessment at this time. It should rather be considered a region-specific variable that requires region-specific definition before its long-term usefulness can be determined.

4.3 Great Crested Newt Viability Measures

4.3.1 Occupied ponds with HSI score >0.7 (existing target metric)

HSI values of over 0.7 are considered to indicate "good" or "excellent" ponds (as suggested by L. Brady, see HSI information at www.calummaecologicalservices.com) and are therefore likely to represent the most suitable ponds for great crested newts. Our figures are based on the proportion of these ponds in a fairly large sample comprising data from three datasets. As it stands, our figure of 23.47% of ponds with a high HSI is substantially lower than the figure of 60% indicated by the existing targets, which arose from the original HSI development work (see Oldham *et al.*, 2000). As more HSI data are generated, numbers and proportions can easily be amended based on our improving knowledge and, with sufficient access to contemporary data, time-constrained and region-specific sample proportions can be used to assess the numbers of high-quality ponds surveyed within known periods, thus allowing changes over time to be assessed. The large amount of data generated by consultants for planning and development purposes would greatly aid this if made widely available at high resolution. This is probably an important status metric to continue using as it embraces elements of population viability and habitat quality and can easily be assessed and/or amended with the latest information. The Countryside Survey 2007 **(**Williams *et al.*, 2010) suggests a general decline in pond quality in GB and it will be interesting and informative to see if this is reflected in measures of great crested newt population viability as more HSI data become available over time. As above, however, this metric is only as good as the pond data on which it is based.

4.4. Great Crested Newt Habitat Measures

4.4.1 Numbers of suitable ponds (occupied or not)

Our data indicate that 66.59% of ponds have an HSI of >0.5 and may therefore be broadly suitable for great crested newts. Again, more detailed data from known time periods and on a regional basis will be required to assess changes in this metric by area and over time. This is particularly important when one considers that great crested newt occupancy rate will vary by region (or parts thereof) with density of ponds so that, in areas with very high pond density, it is more likely that a given pond will be occupied even if its HSI is relatively low. The great crested newt populations in these ponds may be bolstered by animals from nearby better quality ponds and experience successful breeding only irregularly. As things stand, this measure has low usefulness as a status metric.

4.4.2 Extent of suitable habitat (aquatic and terrestrial)

The Removal Modelling process used to generate these figures was developed for the ARC-SNH Great Crested Newt Distribution Project (unpublished data) and its development is ongoing. Our testing of the models using training subsets of data demonstrates that Phase 1 model "fit" (in this case the proportion of positive records not included in model generation that are successfully predicted by it) works very well where records are abundant (South East England, Wales; scores >90% indicate excellent fit, Table 7) and reasonably well even where record density is low (Scotland; 65%). The use of different subsets of data to investigate model parameters in Wales shows that a model for all Wales based on data from great crested newt-positive squares originating only in North Wales has a poor fit, even at the broadest level (Phase 1). This indicates, potentially, that great crested newts in North Wales inhabit squares with a narrower or slightly different range of habitat and environmental parameters than elsewhere, possibly because the very high pond density in some areas promotes metapopulation persistence there. This is supported by the fact that a Phase 1 model based on data from the south is just as good as predicting great crested newt-positive squares throughout Wales as is a random 50% subset.

Interestingly, all of the Wales models predict a large number of suitable squares in Pembrokeshire (south west Wales), from which no extant great crested newt records exist. It seems likely, in this instance, that a combination of the central Wales uplands, the Brecon Beacons and the River Towy represent a historical and existing barrier to great crested newt dispersal that means this area has simply never been colonised by this species (see Figures 5 and 9.2), though it may be true that the model misses some subtle aspect of climate or geology not accounted for by the model as it stands. On the other hand, great crested newts apparently colonised Anglesey prior to the formation of the Menai Strait during the Flandrian transgression, some 6-7,000 years ago (Embleton, 1964). Similarly, we can speculate that the species occupies its northernmost record locations in the Inverness area of Scotland only because it has historically spread from the Central belt up along the Eastern Scottish coast. Highland areas of Scotland appear to be completely inhospitable to it (see Fig. 8.2). Elevation was the most important variable in predicting newt presence in Ćirović *et al.*'s (2008) paper on the distribution of newts in Montenegro.

The success of the Phase 2 models is lower than for Phase 1 (as would be expected) such that the Phase 2 model in Scotland now fails at this level of resolution (i.e. falls below 50% fit). The Phase 2 model is probably most useful, therefore, at predicting squares falling within the "central" occupancy range for great crested newts in any given area, but this warrants further investigation and development. The use of datasets with a larger number of accurately-measured parameters (such as WorldClim environmental data, see www.worldclim.org) will likely render this method more effective in the long term (though use of the latest and most accurate datasets is likely to incur considerable costs).

The next stage of this modelling process was to attempt to account for pond density. The pond data used throughout this report were not available when the Removal Model was initially developed. Phase 1 model squares overlaid with high pond density squares produced figures which may be a better indication of the extent of habitat suitable for great crested newts (in GB, the countries and South East England; see Table 7 and Figures 8.1 to 11.2). The figures in the last row of Table 7 represent the number of 1km squares in those areas with characteristics both matching squares occupied by great crested newts and which have a pond density of 4 or more per km^2. This figure was predictive of newt presence in the original investigation of great crested newt habitat suitability (see Oldham *et al*., 2000). Interestingly, comparison of the number of occupied 1km squares (corrected values shown in Tables 8.1 and 8.2; modelled in a completely different way) and the area of suitable habitat (Table 7, last row) shows high concordance in that the number of squares predicted to be occupied is a subset of the squares that should be most suitable. These data are reproduced here (Table 9).

Table 9 Predicted number of great crested newt-occupied squares (corrected) as compared to predicted suitable habitat
(Phase 1 + pond density filter)

	GB	**Scotland**	**Wales**	**England**	**South East England**
Predicted suitable habitat (km^2)	28,830*	713	1,989	26,128	4,655
Predicted area occupied (km^2)	17,967	425	1,772	15,385	2,432
Proportion of predicted suitable habitat predicted to be occupied	66.16%	60.73%	91.96%	64.34%	58.60%

*** Aggregated from country values**

Proportional figures in Table 9 are remarkably similar, with the exception of that of Wales, which is much higher. The figures effectively represent an estimate, based on multiple modelling techniques, of the areas of *potential* and *realised niche.* Our testing of the Removal Models in Wales suggests that the realised niche of great crested newts there appears greater because of their ability to occupy what might be broadly poorer habitats in areas of high pond density. The good availability of records from North East Wales also inflates this impression but, in any case, this highlights the long-term need for sub-national and sub-regional models in order to describe suitable habitat and apply the information to status assessments. Current models are not yet sufficiently explanatory at the scales used, especially where pond density and occupancy varies across a “region” (as in Wales). The techniques described here should, however, be equally applicable at smaller scale.

Fig. 12 represents a visual summary of earlier figures, showing pond density per km^2 at 10km resolution. Only known great crested newt-occupied squares are shown (from Fig. 5). The map effectively shows an unbiased description of the 10km squares where most great crested newt populations are likely to be found based on the density of high-density pond areas within each and noting that the records used were earlier pooled by 1km square-occupancy to avoid spatial bias. There is good agreement with Fig. 13, which is predictive rather than descriptive, showing 10km squares with suitable habitat (from Phase 1 of the Removal Model) and pond density. Known great crested newt hotspots in North West England (for example), where gaps appear in other figures due to lack of good-resolution records, are picked up and areas of lower suitability because of fewer suitable ponds (Cornwall, North-East England, Central Wales, Scotland) are also described.

The use of habitat modelled to be suitable combined with a pond density approach appears, therefore, to have some application. As a final stage in modelling for the present report, Fig. 14 displays essentially the same information at 1km square resolution overlaid with known occupied 1km squares. Though this is visually difficult to interpret at GB level, it can be seen from Fig. 15 that this may have a variety of uses at a local level. For example, for the purposes of planning sensitivity and targeting of local surveys, known occupied squares are displayed alongside those predicted to have a “higher”, “moderate” and “lower” probability of the presence of great crested newts. Habitat and pond creation efforts can also be targeted. Ground truthing of the model(s) would be beneficial and may in fact suggest further model adaptations that would expand the technique’s usefulness. The grid references of squares falling into each category can be extracted from the GIS layer used to create the maps for these purposes (noting that the data on occupied squares remain limited by survey effort and data resolution). Once again, it would be advisable for this modelling process to be carried out at relevant finer scales (e.g. county or local authority) so as to generate the most spatially-specific models. Fig. 15, however, shows good agreement with other modelling work carried out independently in Kent (see http://calumma.typepad.com/lee_bradys_recording_blog/). It is possible that, with further development of the modelling techniques employed in this report, the proportional relationship between predicted suitable and occupied habitat (and its changes over time) could be used as a metric for assessment of conservation status and prospects. However, we currently lack a rationale for describing the levels at which conservation status can be described as favourable for any given geographical unit or group of units (e.g. country, local authority, vice county etc.); this is outside the scope of the current project.

4.5 Recommendations on Existing and Potential Status Metrics

Existing metrics used for describing the status of great crested newts and setting SAP targets are summarised in Table 10. Potential descriptive metrics are considered in Table 11.

Table 10 Existing great crested newt status metrics

Metric	Dependent on	Usefulness for status assessment and target setting	Notes
Range (10km squares)	• Access to data • Data resolution	High	• Assesses genuine large-scale range changes • Targets need revision
Range (vice counties)	• Access to data	Low	• Less useful than above • All suitable vice counties may be considered to be occupied already, so no use to set targets
Number of occupied ponds	• Access to data • Data resolution • Good pond data • Regionally specific data	Moderate	• Modelled figures generated here probably improve on previous “best guess” figures • Perhaps best carried out at local authority scale and aggregated to form country/GB baselines • Targets need revision
Number of ponds with HSI score >0.7	• Surveys generating HSI data • Access to data • Regionally specific data	Moderate	• Likely high variability by area and must be considered at regional level or below • Usefulness will improve as more HSI data is generated

Table 11 Potential great crested newt status metrics

Metric	Dependent on	Usefulness for status assessment and target setting	Notes
Occupied 1km squares (mapped)	• Access to data • Data resolution • Data completeness	Low	• Incomplete data availability probably renders this useless as a possible status metric
Occupied 1km squares (modelled)	• Access to data • Data resolution • Regionally specific data	Low-Moderate	• Possibly generates more realistic numbers than simple mapping but is not spatially explicit regarding locations of occupied squares • Differences in data availability between regions will produce inconsistencies
Number of breeding ponds	• Definition of terms • Access to data • Regionally specific data	Very low	• See Discussion, above • Will anyway be a variable function of pond and habitat suitability by region
Number of suitable ponds	• Surveys generating HSI data • Access to data • Regionally specific data	Potentially good	• Usefulness likely to improve if more regional HSI data can be obtained and what score is "suitable" in a given area is defined
Extent of suitable habitat	• Access to data • Data resolution • Model development	Potentially good	• Contemporary habitat data at good resolution may be hard to obtain • Possibly useful as measure of FCS "future prospects"
Proportion of predicted suitable habitat predicted to be occupied	• Complex interaction between metrics each with a variety of potential inconsistencies	Low	• Potential for variability reduces the current comparative power of this metric

Occupancy at 10km square resolution probably remains the metric with most potential to detect real, large-scale changes. This metric should be used in preference to occupancy at vice county level and it is recommended that the latter is discontinued as a status metric and means of setting targets. Its utility is low as (probably) all suitable vice counties in GB now have great crested newts recorded from them. The loss of great crested newt populations from any vice county should be regarded as a cause for considerable alarm.

Though the present report trials a number of extrapolative and modelling approaches to generating status metrics, the wide confidence intervals generated in some cases are cause for concern. This leaves open the potential for future assessments of status to generate confidence intervals overlapping those presented here, effectively meaning that it would be impossible to be certain if any apparent status change was a real one. It seems, therefore, sensible to keep status metrics as simple as possible whilst making best use of some of the techniques described here. It is suggested that future status assessments and targets for great crested newts are described by:

- 10km square occupancy
- Number of occupied ponds, modelled nationally but using the best available local or county level data to produce region-specific estimates which can then be aggregated
- Numbers of suitable (HSI >0.5) and good quality (HSI >0.7) ponds assessed based on data generated at local authority, county or regional level
- Extent of suitable habitat, modelled using a combination of agreed habitat parameters and local pond density data.

The latter probably requires an amount of further development and agreement from stakeholders and government, but the simple modelling approach presented here has potential in contributing to assessments of future prospects in consideration of FCS, which in itself suggests potential as a status measurement metric. This would also be useful for fulfilling UK obligations on EU Article 17 reporting. It should be noted again that this approach will be most effective at a local level and based on the best, spatially-explicit and regional (or finer) information. Extrapolation and modelling on a local scale should help to reduce the variability in confidence intervals which is produced in part by consideration of scales at which great crested newt records occur at highly variable density. Local assessments should be aggregated to regional scales and above. These metrics also have wider applicability to other low-vagility EPS and especially to pond-dwelling organisms (e.g. natterjack and pool frog in the UK). The simple Removal Model (Phase 1) could equally be applied to any EPS where data are sufficient to generate a range for environmental variables associated with occupied squares, and perhaps amended accordingly to include species-specific factors (as in this case with pond density) depending on the organisms involved. The means by which favourable levels for these metrics (favourable reference values) can be set, for the great crested newt or any other species is, however, outside the scope of this report.

Whether or not these metrics are adopted, it is apparent that surveillance of great crested newts in Great Britain needs to collect and separate high-resolution data at relevant, local scales, preferably those of local government (local authority or county) on the basis that this is the most appropriate scale for targets to be set and at which conservation action should be carried out. Amended baselines and targets can then be aggregated to regional, country and GB levels. Good spatial and temporal resolution access to data will be the key factor in the success of more accurate status assessments on which progress towards targets can be based, specifically:

- Frequently-updated, high resolution access to records of great crested newts and other amphibians via the NBN Gateway.
- Good local data on negative records (ponds NOT occupied by great crested newts or other amphibians).
- Regional (or better resolution) HSI data.
- Agreed means by which to describe or model pond numbers and density by region or at a finer scale.
- Access to a suite of agreed habitat and environmental variables that will be updated periodically and which can be used in modelling areas of suitable habitat.

The NARRS Widespread Amphibian Survey is designed specifically to include the collection of both HSI and negative records, so these data will steadily accumulate. Some 100 amphibian survey records per year on average originate with NARRS volunteers, however, and this is unlikely to provide a sufficient regional picture of HSI scores within a time-frame appropriate for improving status assessments. The addition of data from local blanket surveys (where available) will need to augment NARRS data to generate local or regional status estimates that can be aggregated to form a national assessment and on which amended targets can be based. The potential importance of HSI and absence data also needs more emphasis in the NARRS protocols so that the usability of data obtained from these volunteers is maximised. Similarly, non-NARRS surveys need to collect these data and they must be made available (by contractors, consultants etc.) for use in assessments. Quantification and mapping of local and regional pond numbers, perhaps by Local Record Centres rather than reliance on a national dataset, would also greatly facilitate status assessments for the great crested newt at local level and help the development of area-specific models.

Local information on distribution, ponds etc. can be augmented with predictive mapping, as demonstrated for example by Fig. 14, and used to target survey effort as well as for other potential applications as discussed above. This ability is effectively a by-product of the modelling developed to assess habitat suitability. The process could also be employed to target agri-environment schemes, for strategic land-use planning and development control, as well as in determining local BAP targets. Indeed, it seems clear that the determination of highly-specific local baselines and targets, based on agreed techniques with high stakeholder buy-in, will ultimately be the rock on which country and GB status assessments are built and by which amended targets are determined.

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