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Change in great crested newt Habitat Suitability Index between 1996 and 2007 assessed using lowland Countryside Survey data

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Summary

This study investigated whether lowland pond habitats improved for the great crested newt (*Triturus cristatus*) over the period 1996 to 2007 using data collected for the Countryside Survey. It did not involve records of Great Crested Newts in the analysis, but focussed on habitat suitability for the species. This work was part of a larger project[1] looking at designing a pond based sampling framework for a range of species, including the Great Crested Newt.

Based on a dataset of 77 ponds sampled for the Countryside Survey in both years, there was a small (2.6%) non-significant increase in great crested newt Habitat Suitability Index (HSI) values between 1996 and 2007.

A second analysis comparing data from a larger number of ponds (from 116 1km squares in 1996 and 172 1km squares in 2007) showed a similar (non-significant) increase in HSI over the 11 year period. However, these data were less robust as a measure of change than the re-sampled ponds largely because of differences in the methods used in the 1996 and 2007 surveys.

The most recent Countryside Survey data (2007) suggest that c25% of lowland ponds are currently in 'Good' or 'Excellent' condition for great crested newts. This compares with 22% in 1996. Over this time there was a suggestion that the ponds least suitable for great crested newts improved slightly, with ponds in the 'Poor' category moving to 'Below Average'.

Analysis of the individual Suitability Index variables which are combined to calculate HSI scores showed that two indices changed significantly between 1996 and 2007 and were mainly responsible for the increase in calculated HSI. These were (i) the net number of ponds per 1km square ($P<0.05$) and (ii) the quality of surrounding land use for amphibians ($P<0.01$). The increase in pond density is in agreement with the national trends observed in Countryside Survey between 1998 and 2007.

Overall the findings suggest that there may have been a small, increase in the suitability of ponds for great crested newts in the lowland countryside between 1996 and 2007 as a result of pond creation and possibly land-use change. The observed increase in pond numbers in Great Britain between 1998 and 2007 suggests that this trend is likely to be real. However, a larger sample of ponds would be needed to prove that the HSI trends observed are statistically significant.

[1] Defra research project WC1043 – Developing and Testing New Approaches to Biodiversity Data Collection in the Voluntary Sector

Contents

1 Introduction

1.1 Report aim

This report describes an analysis of Countryside Survey data, undertaken to investigate whether lowland ponds and their surrounds changed in terms of their suitability for great crested newt (*Triturus cristatus*) over the period 1996 to 2007.

1.2 Background

1.2.1 Summary

Countryside Survey (CS) is a regular audit of the UK's rural landscapes, which has been carried out by the Centre for Ecology & Hydrology (CEH) at intervals of six to nine years since 1978.

Within Countryside Survey, a detailed assessment of pond condition has been made in only two years: in 1996, for a thematic survey of ponds in lowland areas of England, Wales and Scotland (Williams *et al* 1998), and as part of Countryside Survey 2007 covering the whole of Great Britain (Williams *et al* 2010).

Great crested newts have not been directly monitored by Countryside Survey. However the 1996 and 2007 pond assessments collected a wide range of environmental data. This makes it feasible to indirectly assess the suitability of Countryside Survey ponds as habitats for great crested newt, based on the presence of environmental attributes known to favour great crested newt occurrence.

The great crested newt Habitat Suitability Index (HSI) developed by Oldham and colleagues (Oldham *et al* 2000) uses a combination of 10 environmental variables (e.g. pond area, shade) to create an index which ranks ponds according to their likelihood of supporting great crested newt.

Although the Countryside Survey did not directly record the 10 HSI variables, there is sufficient overlap in the environmental measures to enable HSI scores to be derived from Countryside Survey data.

The current report describes change in HSI scores derived from Countryside Survey data between 1996 and 2007. Details of how the 10 individual Suitability Index (SI) measures which comprise HSI were calculated from Countryside Survey data are described in Appendix 1.

1.2.2 Countryside Survey

Countryside Survey is a sample-based study of rural areas. It includes the countryside around towns, cultivated land and grassland, and more remote areas including moorlands, mountains and islands. The sample is randomly stratified to be statistically representative of the countryside, excluding urban and sea areas (Barr 1994).

The survey comprises of a set of 'sample squares' measuring 1km x 1km, spread across England, Scotland and Wales, representative of the environmental conditions of the three countries. Squares containing more than 75% of developed land are not included in the field survey. Similarly, within survey squares, urban areas including curtilage directly associated

with buildings are not surveyed. Garden and farmyard ponds are not, therefore, recorded as part of Countryside Survey.

1.2.3 Pond datasets

The current project uses pond data from two Countryside Surveys, collected 11 years apart in 1996 and 2007. These surveys are outlined below. More detailed methodological descriptions are given in the 1996 Lowland Pond Survey report (Williams *et al.* 1998), and the 2007 Freshwater Manual (Murphy & Weatherby 2007).

The Lowland Pond Survey 1996 (LPS1996)

LPS1996 was a thematic survey run jointly by the Centre for Ecology and Hydrology and Pond Conservation in 1996. The survey focused only on ponds and covered the lowland areas of England, Scotland and Wales.

In total 150 1km x 1km lowland squares were surveyed; this included 14 “non-pond” squares. In each square, all ponds that were present (n=377) were surveyed in detail to provide biological and physico-chemical data.

Countryside Survey 2007 (CS2007)

CS2007 was a ‘standard’ Countryside Survey covering all habitat types across rural Great Britain. In total 591 1km x 1km sample squares were surveyed, spread across England, Scotland and Wales.

Ponds were counted in each survey square that supported a pond. However, a detailed assessment of pond condition was made at only one randomly selected pond in each square. This contrasts with LPS1996 where all ponds present in lowland squares were surveyed.

1.2.4 Great crested newt Habitat Suitability Index

The great crested newt Habitat Suitability Index is calculated as the mean of 10 numerical or categorical environmental variables (**Table 2**). The methods used to measure each variable are outlined in ARG-UK (2010).

The 10 factors are scored for a pond, in the field and from map work. The scores are converted to Suitability Index (SI) scores, on a scale from 0.01 to 1 representing unsuitable and optimal habitat respectively. The overall HSI value for each pond is calculated as the geometric mean of the ten suitability indices, derived by multiplying the SI scores together and taking the tenth root of this number. To assess the pond’s suitability for great crested newts, the overall HSI value is classified into one of five categories:

HSI Pond suitability
< 0.5 = poor
0.5-0.59 = below average
0.6-0.69 = average
0.7-0.79 = good
> 0.8 = excellent

2 Methods

2.1 Countryside Survey data used for analysis

For the current project, analysis of Countryside Survey data focussed on ponds in lowland countryside areas, specifically Environmental Zones 1 and 2, respectively lowland arable and lowland grassland landscapes. Ponds in marginal upland and upland areas were excluded because these areas were not surveyed in the Lowland Pond Survey in 1996.

2.1.1 Number of ponds

LPS1996 gathered detailed environmental data from a total of 377 ponds in 116 1km survey squares. In CS2007 172 ponds were surveyed in the lowlands, one from each of 172 1km survey squares containing a pond. Of the individual lowland ponds surveyed in 1996 and 2007, 77 were surveyed in both years (**Table 1**).

Table 1 Number of lowland Countryside Survey ponds used for calculation of HSI scores

	LPS1996	**Lowland CS2007**	**Direct pond comparison**	
			LPS1996	**CS2007**
Number of sites	377 ponds from 116 1km survey squares	172 ponds from 172 1km survey squares	77 ponds	77 ponds

2.1.2 Deriving HSI variables from CS data

The 10 HSI scores were derived using a range of CS data. The methodology is described in Appendix 1 and is summarised in **Table 2**.

2.1.3 Differences between LPS1996 and CS2007

Although broadly similar environmental variables were measured at ponds in LPS1996 and CS2007, there were also differences. These were mainly for (i) variables that were descriptive in 1996 but given ranked scores in 2007, and (ii) responses to logistical differences between the surveys (e.g. availability of laboratory chemical analysis of water samples in 2007).

The differences between the two CS surveys add a complicating factor to calculating and comparing HSI scores. In some cases, where recording methods changed significantly between 1996 and 2007, it was not possible to meaningfully derive comparable values for both years.

For example waterfowl impact (SI 6) was measured as a ranked score (similar to HSI) in 2007. In LPS1996 waterfowl were only noted in a free text box used to describe animal use of the pond generally. As a result, 1996 waterfowl records were both sparse and not adequate to effectively indicate waterfowl impact, or for assessment of change between the two years.

Re-sampled ponds
For analyses where the same pond was surveyed in both years ('re-sampled ponds'; n=77), if the survey data were not similarly robust in both years, then, the same SI value was used in both 1996 and 2007 datasets (see **Table 3**).

Table 2 Summary of the 10 variables contributing to HSI, and how they were derived from CS results

HSI variable	How measured for HSI	How derived from Countryside Survey data
1 Geographic location	Based on UK location within three map zones	Based on UK location within three map zones
2 Pond area	Surface area of the pond when water is at its highest	Surface area of the pond when water is at its highest
3 Permanence Ranked in 4 categories: 1=Never dries, 4=always dries	Deduced using local knowledge and personal judgement	Based on a range of data including water depth, drawdown height, and whether the pond dried out in the drought year of 1996, but not in the wetter year of 2007
4 Water quality Ranked in 4 categories: 1=good, 4=bad	Subjective assessment based on factors including invertebrate diversity, presence of submerged water plants, water source and agricultural inputs	Based on a range of factors including measured nutrient levels, water source, land use, submerged plant abundance, and plant biotic assessment using PSYM
5 Shade % overhang by trees and buildings	% of the pond margin overhung	% of the total pond area overhung
6 Waterfowl Ranked in 3 categories: 1=absent, 3=major	Based on a 3 category ranked score	Based on a 5 category ranked score of waterfowl impact or text box information
7 Fish Ranked in 4 categories: 1=good, 4=bad	Based on a 4 category ranked score	Based on a 5 point ranked score of fish impact or text box information
8 Pond count	Pond density based on number of ponds occurring within 1km radius around pond	Pond density based on number of ponds in the 1km survey square
9 Terrestrial habitat Ranked in 4 categories: 1=good, 4=bad	Based on availability of suitable habitat within 250m of the pond	Based on surrounding land use type within 100m of the pond
10 Macrophytes % abundance of wetland plants.	% of the pond surface area occupied by emergent, submerged and floating plants excluding duckweed	% of the pond surface area occupied by emergent, submerged and floating plants excluding duckweed

Table 3 Suitability Index (SI) factors that were variable and invariant in the analysis of *re-sampled* ponds using Countryside Survey data

Value type	SI Factor
Same values used in both surveys	Pond permanence Waterfowl impact Fish impact
Values vary between survey	Shade Pond count Terrestrial habitat Wetland plant abundance
Both invariant and variable values	Water quality: using a combination of variables

This approach minimised error due to methodological differences and allowed real trends in HSI to be better identified. However it also reduced the number of variables that could vary between the surveys, and therefore, potentially contribute to change in HSI. The factors which were invariant between surveys are summarised in **Table 3**, and described in more detail in Appendix 1.

Amongst the five environmental factors that still varied between the two CS surveys, some methodological differences remained which could potentially have influenced the results. In particular the distance zones used to estimate landuse categories (% arable, % wood etc) varied between the 1996 and 2007 surveys. In 1996 three different zones were used (0-5m, 5-25m 25-100m). In 2007 these were simplified (0-100m). For the current analysis, 1996 data were re-calculated proportionally to create a 0-100m measure. However, the data may include additional error because the way surveyors calculated landuse proportions could have been influenced by the measurement categories.

All-pond analysis

The second analysis undertaken was an all-pond analysis (see Section 3.2) that included additional ponds that had only been surveyed once in either 1996 or 2007. For these sites it was not possible to minimise methodological differences between the two Countryside Surveys. Thus, although the all-pond analysis includes a greater number of sites than the re-sampled pond analysis, the different survey methodologies makes this a less robust and discriminatory analysis.

2.2 Statistics

HSI and SI are categorical measures, and the majority of SI data are not normally distributed (Anderson-Darling test for normality) so non-parametric statistical approaches were used to test differences in HSI and SI scores between 1996 and 2007. Re-sampled ponds were analysed using a Wilcoxon matched pairs test. Comparison of all-pond data (including both re-sampled ponds and other lowland ponds) compared the mean per 1km square SI values from LPS1996 ponds (n=116), with the value from the single pond per 1km square, surveyed in 2007 (n=172). Mean values were used for LPS1996 ponds to prevent spatial auto-correlation effects. These data were analysed using the Mann-Whitney U statistic.

Post-hoc power analyses were performed to establish whether sample sizes in these analyses were sufficient to detect change.

3 Results: change in HSI scores between 1996 and 2007

HSI scores derived from the LPS1996 and CS2007 lowland pond data were used to carry out two analyses. Both aimed to test whether HSI scores changed between 1996 and 2007.

1. **Re-sampled ponds**: change in HSI scores for 77 ponds sampled in both years.
2. **All ponds**: change in mean HSI scores comparing all ponds in each LPS1996 1km square (n=116) with all CS2007 ponds from the same geographic range (one pond sampled per square in 172 squares).

3.1 Comparison of re-sampled ponds

3.1.1 Did HSI scores change in re-sampled ponds between 1996 and 2007?

Analysis of the 77 ponds sampled in 1996 and 2007 showed that there was a small (2.6%) increase in mean HSI score over the 11 year period (**Table 4, Figure 1**). However the difference was not statistically significant (p=0.479).

Overall, there was a small movement of ponds from Poor to Below Average suitability for great crested newts between 1996 and 2007, and an increase in the number of Excellent ponds (**Figure 2** and **Table 4**). The most recent data (2007) suggest that currently c 25% of lowland ponds are in Good or Excellent condition for great crested newts (**Table 4**).

Post-hoc power analysis shows that the number of ponds available for this analysis was insufficient to show a significant difference at the levels of change observed. The data demonstrate a 2.6% increase in HSI scores between 1996 and 2007 which, for the sample size used, would have a power of 9%. This means that there is only a 9% chance that a statistically significant change (i.e. $p<0.05$) would be seen with the number of sites analysed. Or alternatively, a 91% chance that a significant change will not be seen. A considerably larger network, or a greater level of change, would be needed to prove or refute a significant change in HSI score over this period. The size of network required to show a range of level of change is given in Appendix 2.

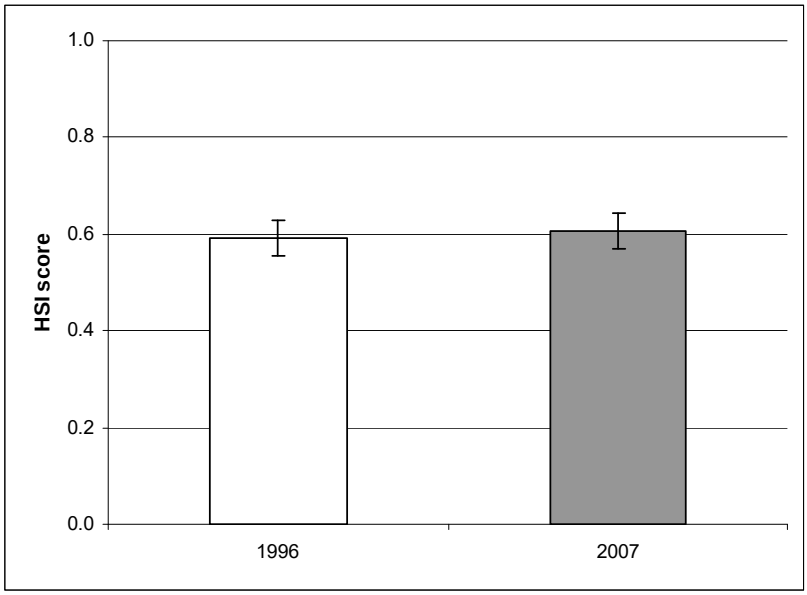

Figure 1 Comparison of HSI scores in 77 re-sampled ponds between 1996 and 2007
Error bars show 95% confidence intervals

Table 4 Comparison of HSI scores and categories for lowland ponds between 1996 and 2007 (a) 77 re-sampled ponds (b) all ponds. CI=Confidence Interval

		HSI score			Ponds in HSI categories				
		Mean	CI -95%	CI+95%	Poor	Below average	Average	Good	Excellent
Re-sampled ponds	1996	0.59	0.56	0.63	26%	10%	19%	16%	6%
	2007	0.61	0.57	0.64	23%	13%	16%	15%	10%
All ponds	1996	0.55	0.53	0.57	31%	26%	26%	16%	2%
	2007	0.59	0.56	0.61	33%	15%	20%	19%	14%

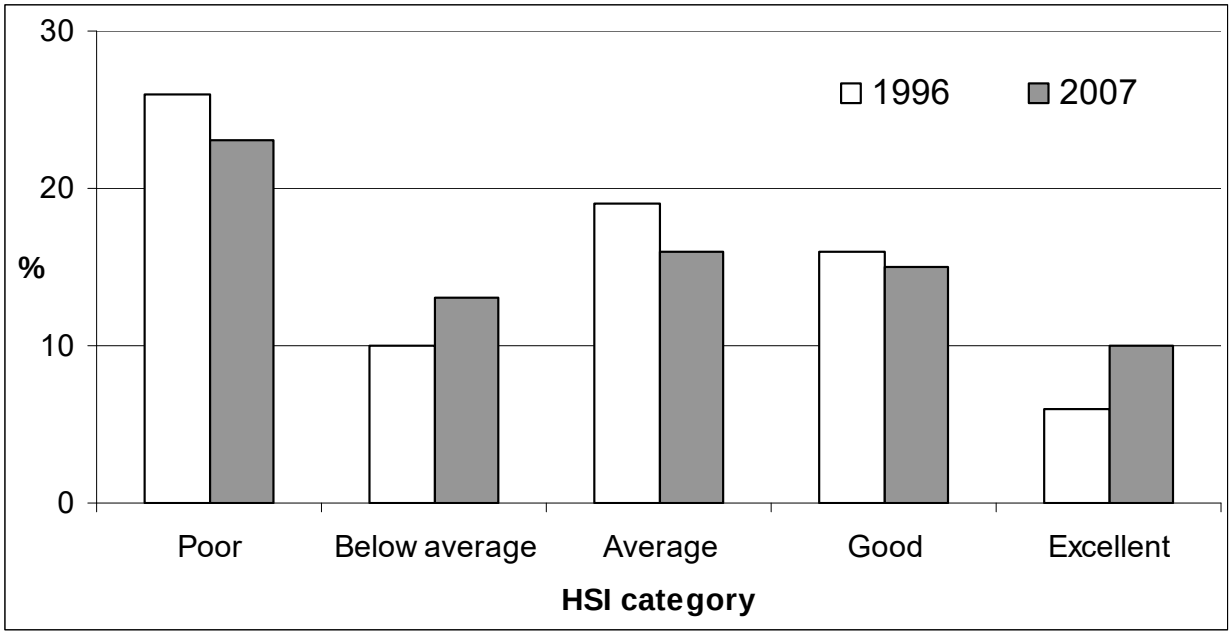

Figure 2 Comparison of HSI categories in 77 re-sampled ponds between 1996 and 2007

3.1.2 What caused the change in re-sampled pond HSI?

Analysis of the SI measures which combine to give the HSI score showed that, of the five measures which varied in the re-sampled pond dataset (see **Table 3**), two changed significantly between 1996 and 2007 and were responsible for the increase in overall HSI: (i) the number of ponds per 1km square which increased from an SI value of 0.80 to 0.82 ($p<0.05$) between surveys (ii) the quality of surrounding land use for amphibians, which increased from an SI value of 0.48 to 0.58 ($P<0.01$).

Of the two measures, surrounding land-use is the less robust. Interrogation of the components used to calculate the proportion of land use favourable for great crested newt from CS data shows that the differences between the surveys were mainly due to an increase in (i) proportion of trees and woodland in the pond surrounds, and (ii) to a change from improved grassland to rank grassland categories. Given that categorising grassland types can be difficult, and that landuse distance zones varied between the 1996 and 2007 surveys (see section 2.1.3), it is possible that at least some of this difference was due to between-year recorder error.

The increase in the number of ponds observed in the survey concurs with wider Countryside Survey data indicating that pond numbers increased by 1.4% per annum in Great Britain between CS1998 and CS2007 (Williams *et al* 2010).

3.2 Comparison of all lowland ponds in 1996 and 2007

3.2.1 Did all-pond HSI scores change between 1996 and 2007?

A broader analysis of change in lowland pond HSI was carried out by comparing the average HSI score for ponds in the each of the 116 LPS1996 squares with the single ponds surveyed in each of the 172 CS2007 squares.

The results show a similar trend to the re-sampled ponds, with a 6% increase in mean HSI between 1996 and 2007. The observed change was closer to significance (p=0.077), however note the caveats below. *Post-hoc* power analysis shows that the sample size used has a power of 33%. A considerably larger network, or a greater level of change, would be needed to prove or refute a significant change in HSI score over this period (see Appendix 2).

In terms of habitat suitability categories (**Table 4**) the data suggest that there was a reduction in the number of Below average quality ponds and an increase in Excellent ponds during this period. However these findings should be viewed with considerable circumspection given methodological differences between the surveys (see below). In addition, it should be noted that the LPS1996 data are based on mean per square values (see Section 2.1.3). This is likely to explain why only one LPS1996 value is classed as Excellent: to get an Excellent average score most or all ponds in the square would need to be Excellent quality.

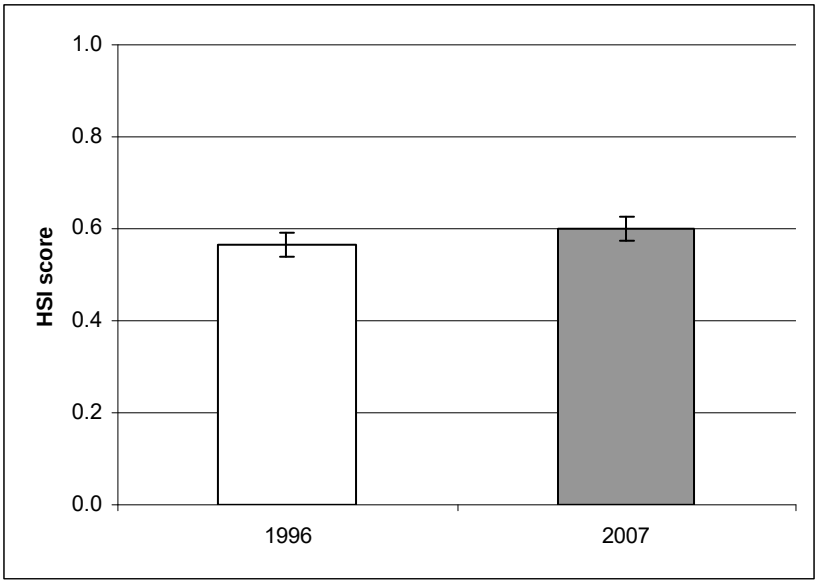

Figure 3 Comparison of HSI scores in all survey ponds between 1996 and 2007.
Error bars show 95% confidence intervals

3.2.2 What caused the change in the all-pond HSI analysis?

Analysis of individual SI measures showed that six SI measures varied significantly between the 1996 and 2007 datasets (See Appendix 4). However, because of methodological differences between the 1996 and 2007 surveys it is probable that many of these relationships are spurious. These methodological differences are problematic mainly because the all-pond analysis is based mainly on ponds which are *not* revisited in the two years. In Countryside Survey, change analysis is normally based on changes *at the same location* (i.e. the same pond), which substantially improves confidence that changes observed are real.

SI Pond Desiccation: ponds in 1996 were classified as significantly more prone to desiccation than ponds in 2007 ($p<0.01$). This result is likely to be mainly an artefact of weather conditions. Within standard HSI assessments, desiccation is based on judgement about whether the pond is likely to dry out. In the current analysis, desiccation in ponds that were not re-sampled (i.e. visited only once in 1996 or 2007), was largely based on water depth at the time of survey. More ponds were likely to have had low water levels, or to dry out, in 1996 because of the drought in this year, leading surveyors to presume ponds were more likely to dry out.

SI Shade: ponds in the 2007 dataset were classified as less favourable for great crested newts because they were significantly more shady than ponds in the 1996 dataset ($p<0.05$). This trend is similar to more detailed analysis of Countryside Survey pond data which suggest similar or increasing shade over this period (e.g. Williams *et al* 2010).

SI Fish: ponds in the 2007 dataset had significantly greater negative fish impact values than ponds in the 1996 dataset ($p<0.05$). In practice, this trend is almost certainly an artefact of differences in survey methodology. LPS1996 fish data are poor because assessment of the presence of fish was optional and noted in a free text box. In 2007 fish impact was categorised. The lower SI score in 2007 is likely to reflect the more systematic recording in this year.

SI Number of ponds: 1km squares in the 2007 dataset supported significantly fewer ponds than 1996 sites ($p<0.05$). This is the reverse of trends shown in CS between 1998 and 2007 (Williams *et al* 2000), and differs from the results of the re-sampled ponds (above). The results are likely to reflect differences in the sampling square locations, with 2007 squares including less pond-rich landscapes.

SI Macrophytes: ponds in the 2007 dataset were significantly less suitable in terms of macrophyte cover compared to cover in 1996 ($p<0.01$). This contrasts with CS data reported in Williams *et al* (2010), which shows no change in plant cover over this period. Given caveats about the other SI variables (above), it is not clear whether this trend is real or a sampling effect artefact.

4 Conclusions and recommendations

Analysis of great crested newt Habitat Suitability Indices, derived from Countryside Survey data, suggest that:

1. Based on a survey of 77 re-sampled ponds, there was a 2.6% increase in mean HSI values between 1996 and 2007. This suggests a *possible* small increase in the suitability of ponds for great crested newts over this 11 year period.

   These findings are not statistically significant. *Post-hoc* power analysis shows that the number of ponds available for this analysis was insufficient to show significant change at the levels observed. A greater number of sites may have shown a significant change. Specifically, there is only a 9% likelihood that a statistically significant change would be seen with the number of re-sampled pond sites analysed. A change of c15% would have been reasonably likely (70%+ power) to have recorded a significant change – hence it is likely that a change of this scale has not occurred.

2. The most recent data (2007) suggest that c25% of lowland ponds are currently in Good or Excellent condition for great crested newts. This compares with 22% in 1996. There was also a suggestion of a small shift in ponds from Poor to Below Average value in this time.

3. Analysis of the individual measures which are combined to calculate the HSI score showed that two changed significantly between 1996 and 2007 and were mainly responsible for the increase in overall HSI values calculated. These were:
   a. the net number of ponds per 1km square ($p<0.05$);
   b. the quality of surrounding land use for amphibians ($p<0.01$) which appeared to increase due to greater proportion of trees/woodland and rank grassland in the surrounds.

   The increase seen in the number of ponds is in agreement with national trends observed in Countryside Survey between 1998 and 2007.

4. Data comparing a larger number of ponds from 116 1km squares in 1996 and 172 1km squares in 2007 showed a similar (non-significant) increase in HSI over the 11 year period. However, these data are less robust as a measure of change than the re-sampled ponds largely because of uncontrolled differences in the methods used in the LPS1996 and CS2007 surveys.

If future Countryside Surveys continued with the current level of site numbers (i.e. re-sampled ponds from c170 1km squares in England), such a survey would be would be likely to detect a c10% change in HSI at 85% power.

Future pond survey methodologies could usefully include (i) consistent recording of pond variables in Countryside Survey (based on CS2007 parameters) to assess post-2007 change, and (ii) direct inclusion of HSI variables.

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Appendix 1 Protocols used to calculate HSI scores from CS data

1 Aim

This Appendix describes the protocols used to calculate great crested newt Habitat Suitability Indices using pond data collected for the Countryside Survey in 1996 and 2007.

1.1 The great crested newt Habitat Suitability Index

The great crested newt (GCN) Habitat Suitability Index is calculated using ten numerical or categorical environmental variables:

1. Geographic location
2. Pond area
3. Pond permanence
4. Water quality
5. Shade
6. Waterfowl impact
7. Fish impact
8. Pond count
9. Terrestrial habitat
10. Macrophyte proportion

The methods used to measure each variable are outlined in: ARG UK (2010). For any pond, the ten variables are calculated using either field or map data. Each variable is converted to a Suitability Index (SI) score which varies on a scale from 0.01 to 1. The numerical field scores are converted to SIs by reading-off values from a graph.

The overall HSI value for each pond is calculated as the geometric mean of the ten suitability indices, derived by multiplying the ten SI scores together and taking the tenth root of this number. i.e. $HSI = (SI_1 \times SI_2 \times SI_3 \times SI_4 \times SI_5 \times SI_6 \times SI_7 \times SI_8 \times SI_9 \times SI_{10})^{1/10}$.

To assess the pond's suitability for great crested newts, the overall HSI value is classified into one of five categories:

<u>HSI Pond suitability</u>

< 0.5 = poor
0.5-0.59 = below average
0.6-0.69 = average
0.7-0.79 = good
> 0.8 = excellent

1.2 Using Countryside Survey data to calculate great crested newt HSIs

Pond environmental data have been gathered in two previous Countryside Surveys: Lowland Pond Survey 1996 and Countryside Survey 2007. The methods used to collect these data are described in the 1996 Lowland Pond Survey report (Williams *et al* 1998), and the 2007 Freshwater Manual (Murphy & Weatherby 2007).

The environmental factors used to calculate great crested newt Habitat Suitability Indices (HSIs) are broadly nested within the set of attributes included within Countryside Survey. In most cases the specific way in which these attributes are measured differs from HSI. However, there are enough similarities that, with some adjustments, Countryside Survey data can be used to approximate HSI measures.

1.3 CS datasets used in analysis

In the current analysis two Countryside Survey datasets were used: the Lowland Pond Survey 1996 and lowland ponds from Countryside Survey 2007 (**Table 5**). These are described in the main project report.

Table 5 Number of lowland Countryside Survey ponds used for calculation of HSI scores.

	LPS1996	**Lowland CS2007**	**Direct pond comparison**	
			LPS1996	**CS2007**
Number of sites	377 ponds from 116 1km survey squares	172 ponds from 172 1km survey squares	77 ponds	77 ponds

HSI scores derived from the LPS and from CS lowland pond data were used to carry out two analyses. Both aimed to test whether HSI scores changed between 1996 and 2007.

1. **Re-sampled ponds**: change in HSI scores for 77 ponds sampled in both years

2. **All ponds**: change comparing mean HSI scores for all ponds in each LPS1996 1km square (n=116), with all CS2007 ponds from the same geographic range (one pond sampled per square in 172 squares).

1.4 Methods used to equate CS and HSI attributes

Details of how Countryside Survey pond data were analysed to give attributes that equate as closely as possible to the ten HSI variables are given below, and form the main body of this Appendix.

This analysis is made more complex because there are differences in the way that some variables were measured in the two CS surveys. Specifically, methodological changes were made to a number of variables in CS2007 to (i) simplify or categorise the 1996 variables, and (ii) to respond to logistical differences between the surveys (e.g. inclusion of laboratory water chemistry in CS2007).

In some cases, where recording methods changed significantly between 1996 and 2007, it was difficult to meaningfully derive comparable values for both years. Because the main aim of the current analysis has been to assess whether the habitat suitability for great crested newts changed between 1996 and 2007, care was taken to optimise variables for this analysis where possible.

Thus, in the re-sampled pond analyses (where the same pond was surveyed in both years), if the survey data from LPS1996 was not sufficiently robust, the 2007 value was used in both 1996 and 2007 datasets. This approach minimised error due to methodological differences and allowed real trends in HSI to be better identified in the re-sampling analysis (see **Table 6**).

Table 6 Suitability Index (SI) factors that were variable and invariant in the analysis of *re-sampled* ponds using Countryside Survey data

Value type	**SI Factor**
Same values used in both surveys	Pond area Pond permanence Waterfowl impact Fish impact
Values vary between survey	Shade Pond count Terrestrial habitat Wetland plant abundance
Both invariant and variable values	Water quality: using a combination of variables

2 Methods used to equate CS and HSI attributes

Factor 1 - Geographic location

HSI measure

The Habitat Suitability Index divides Great Britain into three zones which relate to the known geographical distribution of great crested newts:

Zone A, location is optimal, SI = 1

Zone B, location is marginal, SI = 0.5

Zone C, location is unsuitable, SI = 0.01.

Countryside Survey

To calculate the appropriate zone for Countryside Survey ponds an Ordnance Survey 100 x 100km national grid was superimposed on the HSI map. The grid reference data from each CS pond was used to identify the correct zone.

The results from this analysis showed that the proportion of ponds which occurred in Zone A was considerably higher than in those in Zones B and C (**Table 7**).

The LPS1996 also had a higher proportion of ponds located in Zone A (86%), than did CS2007 (72%).

Table 7 Proportion of lowland ponds in each HSI geographic zone

	Number of ponds	Zone A optimal	Zone B marginal	Zone C unsuitable
LPS/CS Comparison	77	78%	10%	12%
LPS1996	377	86%	8%	6%
CS2007	172	72%	13%	15%

Factor 2 - Pond area

HSI and Countryside Survey use the same method for assessing pond area. Area is measured as the surface area of the pond when water is at its highest level (excluding flooding events) in winter and spring. At other times of year when the water is lower, this outer boundary is usually evident from vegetation change or other evidence (such as water marks on trees).

Ponds larger than 2000m^2 are omitted from the HSI calculation because there are few data for great crested newt occupancy of ponds of this size and above.

To calculate a suitability index, the HSI pond area score is read off a graph. Increasing pond area is beneficial to great crested newts up to 500m^2, but has a negative impact above 700m^2.

Surface area estimates are usually made by pacing the waterbody sides. Pond area rarely changes significantly between years. For this reason, for ponds that were surveyed in both 1996 and 2007, the area estimates given in 1996 and 2007 were averaged to ensure that

between-surveyor variability was minimised between surveys. The exception was where surveyors specifically noted a change in CS check boxes to indicate pond extension or infilling since the previous survey.

Factor 3 - Permanence

HSI measure

For HSI calculation, pond permanence is deduced using local knowledge and personal judgement. Where there is no information from a landowner, a judgement is made based on water level at the time, and season of the survey.

SI permanence categories

Never dries, SI = 0.9
Rarely dries (i.e. dries no more than two years in ten or only in drought), SI = 1.0
Sometimes dries, (i.e. dries between three years in ten to most years), SI = 0.5
Dries annually, SI = 0.1

Countryside Survey

Water permanence was not a variable that was directly included in either LPS1996 or CS2007 so, for the present assessment, other data were used to indicate or infer the permanence category of waterbodies (**Table 8**).

The main measures used were:
- Water depth, measured as the mean of five readings taken along two perpendicular transects;
- Pond dried in 1996 (a very dry year) but not 2007 (a normal to wet year).

Two supplementary measures were also used as logic checks:
- Fish presence/absence;
- Aquatic plant (submerged and floating-leaved species) presence/absence.

Table 8 Measures from LPS1996 and CS2007 that were used to derive HSI water permanence suitability indices

Dataset	Main measures		Supplementary measures	
	Water depth	Dried in 1996 but not 2007	Fish present	Aquatic plants
LPS/CS Comparison	✓	✓	Not needed	Not needed
LPS1996	✓		✓	✓
CS2007	✓		✓	✓

Different approaches were required to derive comparable HSI indices for LPS1996, CS2007 and LPS1996/CS2007 comparison analyses.

LPS1996/CS2007 comparison

Assessment of permanence for the 77 ponds surveyed in both LPS96 and CS2007 was straightforward because of a fortunate co-incidence in weather differences between the years.

Rainfall data shows that 1996 was an unusually dry year with annual precipitation around 80% of the 20 year mean. Rainfall in 2007 was close to average, although the summer was exceptionally wet, with over 50% more rainfall than the seasonal mean (Williams *et al* 2010).

SI permanence categories were therefore derived on the following basis:
Never dries - permanent in both 1996 and 2007;
Rarely dries - water depths of 6-20cm in 1996, wet in 2007;
Sometimes dries - water depth 0-5cm in 1996, wet in 2007;
Dries annually - dried in1996 and dried or had very shallow water (<10cm) in 2007.

LPS1996

Assessment of water permanence in the remaining LPS1996 ponds was mainly based on water depth, using compatible depth categories to the LPS/CS comparison above:

Never dries - water depth of 21cm+;

Rarely dries - water depths of 6-20cm;

Sometimes dries - water depth 1-5cm;

Dries annually – dried, water depth <1cm

The presence of fish was used as a logic check to distinguish permanent (‘never dries’) from other ponds. The presence of aquatic plants was used as a logic check to divide ‘always’ and ‘sometimes’ dries categories.

CS2007

Assessment of water permanence for the remaining CS2007 ponds was mainly based on water depth. However, the depth categories used were deeper than 1996 ponds to compensate for the wet year. The category boundaries were chosen after examination of typical water depth differences evident where the same pond was surveyed in 1996 and 2007.

Never dries - 51cm+

Rarely dries - water depths of 26-50cm;

Sometimes dries - water depth 11-25cm ;

Dries annually – dried, water depth 0-10cm.

Again, the presence of fish was used as a logic check to distinguish permanent (‘never dries’) from other ponds. The presence of aquatic plants was used as a logic check to divide ‘always’ and ‘sometimes’ dries categories.

Factor 4 - Water quality

HSI measure

HSI water quality indices are based on a subjective assessment of water quality derived from multiple criteria. These include invertebrate diversity, the presence of submerged water plants and knowledge of the water sources feeding the pond. Other cues are also used: for

example, 'ponds subject to agricultural inputs are likely to have poor water quality'. A rough biotic water quality index is provided.

SI water quality categories

Good 1.0	Water supports an abundant and diverse invertebrate community. Netting reveals handfuls of diverse invertebrates, including groups such as mayfly larvae and water shrimps.
Moderate 0.67	Moderate invertebrate diversity.
Poor 0.33	Low invertebrate diversity (e.g. species such as midge and mosquito larvae). Few submerged plants.
Bad 0.01	Clearly polluted, only pollution-tolerant invertebrates (such as rat-tailed maggots), no submerged plants.

Countryside Survey

No Countryside Survey has collected pond invertebrate data so an assessment that is directly compatible with HSI categories is not possible. However the HSI index is relatively crude, and CS includes a range of variables, including water chemistry data, which can be combined to create a four-category index which is at least as robust as that used in HSI.

The variables used to derive this index from CS data are summarised in **Table 9** and described in **Table 10**. The choice of variables has been based on variables known to be water quality metrics and linked to water quality declines seen in CS2007 (Williams *et al* 1998, Williams *et al* 2010).

To create a score each variable was ranked on a three point scale. The exception was inflow (scored 0 or 2), (see **Table 10**). An overall water quality category was calculated for each pond as the mean score, and placed into four HSI compatible water quality categories where Bad = <1, Poor = 1-1.5 Moderate = 1.6-2 Good = >2.

The measures used to derive a water quality score were more restricted because (i) PSYM scores have not been calculated for LPS1996 ponds. Laboratory assessment of nutrient water chemistry was not available for LPS1996 and conductivity has been used as a proxy in the current analysis.

Table 9 Measures from LPS1996 and CS2007 that were used to derive HSI water quality suitability indices

Dataset	**Invariant in current analysis**			**Varies between surveys**		
	Nutrients (P & N)	Conductivity	Stream inflow	PSYM	% aquatic plants	Land use (% Arable)
LPS1996 /CS2007 Comparison	✓		✓	✓	✓	✓
LPS1996		✓	✓		✓	✓
CS2007	✓		✓	✓	✓	✓

Table 10 Measures from LPS1996 and CS2007 that were used to derive HSI water quality suitability indices

CS variable	Score	Relevance
Water chemistry	For each determinand: Above threshold = 0 Below threshold = 1 Summed to give a combined 0-2 water chemistry score	Based on whether nutrient levels measured were above threshold suggesting the pond is likely to be experiencing pollution impacts resulting from elevated nutrient concentrations (a) phosphorus levels greater than 0.12mg/l PO_4-P (b) nitrogen levels greater than 2.0mg/l TON
Conductivity	< 350µS cm^2 = 2 350-850 µS cm^2 = 1 >850µS cm^2 = 0	Based on levels which are commonly associated with nutrient pollution in lowland landscapes
Stream inflow	Wet inflow absent = 2 Wet inflow present = 0	In the lowlands inflow streams usually increase the pollutant loading of ponds and their presence is associated with declining pond quality in CS2007
PSYM	PSYM <25=score 0, 25-75=score 1, >75= score 2	PSYM (Predictive SYstem for Multimetrics) is a biotic measure for assessing pollution (see Williams *et al* 2010)
% aquatic plant cover	0% = 2 1-50 = 1 >50 = 0	Submerged plants are sensitive to water pollution; abundance decline is a measure used in HSI water quality assessment (see above)
% arable land use	0% = 2 1-50 = 1 >50 = 0	The % cover of arable land is associated with poor water and biotic quality in CS2007.

Factor 5 - Shade

HSI measure

Within HSI shade is measured as a percentage estimate of the pond perimeter shaded by trees or buildings, to at least 1m from the shore. It does not include shade from emergent pond vegetation. To produce an index value, the HSI shade score is read off a graph. Optimum shoreline shade is 0-60%. HSI score declines as shade increases above 60%.

Countryside Survey

In Countryside Survey shade is measured as the percentage of the whole waterbody overhung by trees. In the current analysis this variable is used as a proxy for the pond perimeter measure used in HSI.

Analysis of data gathered for the National Pond Survey (Pond Conservation unpublished data, n=292), shows a strong correlation between measures of perimeter shade and total pond overhung ($P<0.0001$). However examination of the data indicated that the closest relationship between the two measures was seen in smaller waterbodies and ponds with little shade. The relationship was weakest for larger waterbodies, where the pond perimeter can be heavily shaded, whilst the centre remains sunlit.

Factor 6 - Waterfowl

HSI measure

The HSI waterfowl variable aims to assess the impact of waterfowl upon both the pond and on newts. 'Waterfowl' includes most water birds, such as ducks, geese and swans, but excludes moorhens. It is noted that at high densities, waterfowl can remove all aquatic vegetation, pollute water and persistently stir sediments. Some waterfowl may also actively hunt adult newts and their larvae. Waterfowl impact is scored as one of three categories.

SI waterfowl categories

- Absent 1 - No evidence of waterfowl impact (moorhens may be present).
- Minor 0.67 - Waterfowl present, but little indication of impact on pond vegetation. Pond still supports submerged plants and banks are not denuded of vegetation.
- Major 0.01 - Severe impact of waterfowl. Little or no evidence of submerged plants, water turbid, pond banks showing patches where vegetation removed, evidence of provisioning waterfowl.

Countryside Survey

In CS2007 waterfowl impact was ranked on a six point scale where 0 = absent and 5 = high impact duck pond with little vegetation. To derive HSI categories, the CS2007 scores were allocated as follows:

HSI category	CS007 ranked score
Absent	0
Minor	1, 2, 3
Major	4, 5

Waterfowl recording in LPS1996 was less robust than in CS2007 because records are limited to comments written in a text box for recording animal use of the pond including stock, wildfowl, amphibians and fish.

To allocate an HSI category for the current analysis, where no mention was made of waterfowl presence at a pond a zero score was given. Where waterfowl were noted as present, a subjective assessment was made of their impact on a site-by-site basis using the text box information together with data on water turbidity and vegetation abundance.

Because of the limitations of the LPS1996 data, waterfowl SI values in the re-sampled pond analysis (n=77), were invariant and based on CS2007 values.

Factor 7 - Fish

HSI measure

In HSI, information on fish is gleaned from local knowledge including discussion with landowners, and the surveyor's own observations. Ideally netting is used to detect smaller fish, such as sticklebacks (which can be significant predators of great crested newt larvae, when present in large numbers), or the fry of larger species.

SI fish categories

- Absent 1 - No records of fish stocking and no fish revealed by netting or observed by torchlight.
- Possible 0.67 - No evidence of fish, but local conditions suggest that they may be present.
- Minor 0.33 - Small numbers of crucian carp, goldfish or stickleback known to be present.
- Major 0.01 - Dense populations of fish known to be present.

Countryside Survey

In CS2007 fish impact was recorded in three categories:

a. Fish likely to be present based on available evidence e.g. turbid water etc;
b. Fish known to be present;
c. Clear evidence of fish e.g. fishing (platforms, pegs, swims) or of ornamental fish (e.g. Goldfish, Koi Carp).

In addition a text box was used to record information about fish species and abundance.

To allocate an HSI category to CS2007 data for the current analysis, where no mention was made of fish presence at a pond, a zero score was given. The three other categories were ascribed to the three HSI categories. In addition all permanent ponds with a permanent inflow were given a 'possible' suitability index as minimum.

In LPS1996, fish recording was limited to comments written in a text box for recording animal use of the pond including stock, wildfowl, amphibians and fish. Information was also available indicating whether the pond was used for fishing.

Allocation of an HSI category to LPS1996 data was based on the following procedure. Where no mention was made of fish presence at a pond, a zero score was given. If fish were noted as present, a subjective assessment was made of their impact using the CS1996 text box information together with data on water permanence, the presence of a permanent inflow and amenity use as summarised in **Table 11**.

Because of the limitations of the LPS1996 data, in the re-sampled pond analysis (n=77), SI values for fish were invariant and based on CS2007 values.

Table 11 Summary of measures from LPS1996 and CS2007 that were used to derive HSI fish impact suitability indices

HSI Suitability Index category	CS2007 and LPS1996 measure
Absent	No evidence of fish presence
Possible	Fish stated as 'likely to be present', or the pond is permanent and has an inflow
Minor	Stated as 'known to be present'
Major	Stated as having 'evidence of fishing', or evidence noted that a large number of fish are present

Factor 8 - Pond count

HSI measure

In HSI this measure refers to the number of ponds occurring within 1km of the survey pond not counting the survey pond itself. However it excludes ponds on the far side of major barriers, such as main roads.

To calculate SI the number of ponds is divided by π (3.14) to calculate the density of ponds per km^2 and the SI read-off from a graph. The HSI score increases as pond density increases with a maximum HSI score reached at c12 ponds/km^2.

Countryside Survey

For the current analysis the pond count measure used was the number of ponds within the 1km Ordnance Survey grid square in which the pond was located.

Superficially pond count appears to be a simple measure. In practice, pond stock calculations in Countryside Survey have always been fraught with difficulty (see Williams *et al* 2010)

This is, in part, because some Countryside Surveys have not counted ponds in areas such as woodland and golf courses. In addition there are always difficulties in determining whether a dried-up pond is a 'seasonal ponds' or a 'lost' ponds, particularly in areas like woodland.

Countryside Survey does not include ponds in curtilage, and ponds which became enclosed within an urban areas between 1996 and 2007 would normally be counted as a loss. However, since these ponds are not truly lost, for the current analysis ponds moving into curtilage were retained in the pond count. In a small number of cases where unaccountable pond number disparities were evident in the data between 1996 and 2007, this SI value was removed in both years.

The current analysis is based on surveyor fieldsheet data listing the number of ponds per square in LPS1996 and CS2007. The fieldsheets included categories describing whether a newly recorded pond was actually newly created or had just been missed before.

New ponds were included in the 2007 count if surveyors indicated they were newly created. Ponds which were identified as pre-existing were back-counted and included in the 1996 total.

The HSI pond count value is, like Countryside Survey data, based on a measure of ponds per 1km^2. However the HSI value is originally calculated as a circle with a radius of 1km, and an area of 3.14km^2. This area is then divided by Pi to convert to a 1km^2. The HSI variable therefore inherently includes a measure of pond number outside the 1km square in which the survey pond is located.

A complicating factor is that in HSI, the 1km^2 count *excludes* the survey pond. Countryside Survey data are expressed as the total number of ponds per km^2. However, simply subtracting 1 pond from the Countryside Survey 1km^2 total to mimic excluding the survey pond, is not a true statistical equivalent to HSI. This is because, as noted in the previous paragraph, the HSI value includes ponds from a 3.14km^2 area, whereas the Countryside Survey count only includes ponds within the 1km square. This difference is a particular issue where there are few ponds in a Countryside Survey square. For example, where there is one pond per 1km^2, removing that pond to give a zero value for the 1km square would suggest, in HSI terms, that there are no ponds in the 3.14km^2 area around the pond. Clearly, this will often be an underestimate, and is important because, in reality, 38% of CS ponds have only one in the 1km square, and the majority (73%) have three ponds or fewer. An alternative approach which more closely mimics the HSI calculation was therefore used in the current analysis: the Countryside Survey pond per km^2 value, was multiplied by Pi, to give a mean number of ponds for a 3.14km^2 area, *then* the survey pond was removed by subtracting 1, and the remaining value divided by Pi to give a value per 1km^2.

Factor 9 - Terrestrial habitat

HSI measure

Within HSI, terrestrial habitat is considered within approximately 250m from the pond, but on the near side of any major barriers to dispersal (e.g. main roads or large expanses of bare habitat). Assigning landuse to SI terrestrial habitat categories depends on the surveyor's understanding of newt habitat quality. Good terrestrial habitat includes cover and foraging opportunities and includes meadow, rough grassland with tall sward height, scrub, woodland or mature gardens.

The four SI categories for terrestrial habitat are listed in **Table 12**.

Countryside Survey

Within Countryside Survey, terrestrial landuse categories (woodland, intensive grassland etc) are measured as percentage cover within 100m of the pond. However there was a difference in the approach taken to assessing land cover between the two Countryside Surveys in 1996 and 2007. In LPS1996 cover was estimated in three different zones (0-5m, 5-25m 25-100m). In CS2007 these were simplified to a single zone of 0-100m. For the current analysis, 1996 land cover data were re-calculated proportionally to create a 0-100m measure.

To conform with HSI categories CS landuse was divided into two broad land classes based on land use intensity and opportunity to provide newt-friendly habitats:

Low intensity landuse - trees, hedges, woodland, heathland, moorland, unimproved grassland, rank vegetation bog, fen, marsh, flush;

High intensity landuse - arable, improved grassland, urban buildings, parks and gardens, roads, tracks, paths.

Terrestrial SI scores were ascribed depending on the proportion of low intensity / newt friendly land around the pond (see **Table 12**).

Table 12 Measures from LPS1996 and CS2007 that were used to derive HSI terrestrial habitat suitability indices

HSI category	SI	HSI criteria	LPS1996 and CS2007 equivalent
Good	1	Good opportunities for foraging and shelter (e.g. most semi-natural environments, such as rough grassland, scrub or woodland, also brownfield sites and low intensity farmland) covering more than 75% of available area.	Low intensity landuse covers more than 75% of the available area.
Moderate	0.67	Habitat offers opportunities for foraging and shelter but may not be extensive (25-75%) of available area.	Low intensity landuse covers 25-75% of the available area.
Poor	0.33	Habitat with poor structure (e.g. amenity grassland, improved pasture and arable) that offers limited opportunities (less than 25% of available area) for foraging and shelter.	Low intensity landuse covers less than 25% of the available area
None	0.01	No suitable habitat around pond (e.g. centre of arable field or large expanse of bare habitat).	No low intensity landuse cover

Factor 10 - Macrophytes

HSI measure

In HSI macrophytes are assessed in terms of the percentage of the pond surface area occupied by macrophyte cover. This includes emergents, floating plants (excluding duckweeds) and submerged plants reaching the surface. To produce an index value, the HSI macrophyte score is read off a graph. Optimum macrophyte cover is 70-80%. The HSI score declines with either more or less vegetation cover.

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Countryside Survey

In both LPS1996 and CS2007 macrophytes were recorded in two ways.

1. The total percentage surface cover of wetland vegetation was recorded in three categories: (i) emergent plants (ii) floating-leaved plants (iii) submerged plants.

2. The abundance of each wetland species was recorded using a quantified DAFOR scale:

Rare	0-5% cover
Occasional	6-20% cover
Frequent	21-50% cover
Abundant	51-90% cover
Dominant	91-100% cover

For the current analysis macrophyte cover was calculated as the sum of the three wetland vegetation categories, with an adjustment made to remove duckweed (*Lemna* species) and the very similar water fern (*Azolla* spp). As noted above, in LPS1996 and CS2007 duckweed was recorded as a DAFOR category. Calculations to remove duckweed from total vegetation cover were therefore made on a logical basis, using the midpoint of the cover range to estimate duckweed abundance (e.g. rare =2.5%). For example: if total the floating cover was 60% and duckweed was 'Rare', the total floating cover was adjusted to 57.5% prior to being combined with emergent and submerged categories to give a final percentage cover score.

Appendix 2 Power analysis results for re-sampled ponds

Results of power analysis used to determine the sample size (number of ponds) needed to detect a significant difference if one existed for different levels of power and different levels of change.

1 Re-sampled ponds analysis

Level of power	Percentage Change					
	2.6%	**10%**	**20%**	**30%**	**40%**	**50%**
0.60	1076	76	20	10	6	5
0.65	1208	85	22	11	7	5
0.70	1356	95	25	12	7	5
0.75	1524	107	28	13	8	6
0.80	1723	121	31	15	9	6
0.85	1971	138	36	17	10	7
0.90	2307	161	41	19	12	8
0.95	2852	199	51	23	14	9

2 ‘All ponds’ analysis

Level of power	Percentage Change					
	6%	**10%**	**20%**	**30%**	**40%**	**50%**
0.60	246	91	24	11	7	5
0.65	276	102	27	13	8	6
0.70	309	114	30	14	9	6
0.75	348	128	33	16	9	7
0.80	393	144	37	17	10	7
0.85	450	165	42	20	12	8
0.90	526	193	49	23	13	9
0.95	650	238	61	28	16	11

Appendix 3 Summary data

Comparison of Habitat Suitability Index data from Lowland Pond Survey 1996 (LPS1996) and Countryside Survey 2007 (CS2007).
SI = Suitability Index

1 Re-sampled ponds analysis

		SI Geographic location	SI Pond area	SI Pond permanence	SI Water quality	SI Shade	SI Waterfowl	SI Fish	SI Pond count	SI Terrestrial habitat	SI Macrophytes	HSI score
Number of sites	LPS1996	77	64	77	77	77	77	77	65	76	77	**77**
Mean	LPS1996	0.83	0.64	0.73	0.52	0.90	0.86	0.82	0.80	0.48	0.61	**0.592**
Std deviation	LPS1996	0.34	0.34	0.25	0.33	0.21	0.21	0.31	0.16	0.23	0.25	**0.16**
Number of sites	CS2007	77	64	77	77	76	77	77	65	73	75	**77**
Mean	CS2007	0.83	0.64	0.73	0.53	0.87	0.86	0.82	0.82	0.58	0.60	**0.607**
Std deviation	CS2007	0.34	0.34	0.25	0.32	0.25	0.21	0.31	0.16	0.25	0.25	**0.16**

2 'All ponds' analysis

		SI Geographic location	SI Pond area	SI Pond permanence	SI Water quality	SI Shade	SI Waterfowl	SI Fish	SI Pond count	SI Terrestrial habitat	SI Macrophytes	HSI score
Number of sites	LPS1996	116	114	116	116	116	116	116	114	116	116	**116**
Mean	LPS1996	0.83	0.62	0.72	0.43	0.90	0.89	0.83	0.81	0.51	0.65	**0.57**
Std deviation	LPS1996	0.28	0.30	0.26	0.28	0.15	0.13	0.21	0.16	0.17	0.18	**0.13**
Number of sites	CS2007	172	172	172	172	172	172	172	172	172	172	**172**
Mean	CS2007	0.78	0.56	0.76	0.52	0.86	0.87	0.83	0.79	0.55	0.55	**0.60**
Std deviation	CS2007	0.37	0.38	0.28	0.32	0.29	0.20	0.29	0.16	0.27	0.28	**0.17**

Appendix 4 Summary of statistical test results

Text in bold indicates statistically significant values.

1 Wilcoxon matched pairs test comparison of re-sampled ponds

	T	Z	p-level	Valid N
SI Geographic location (invarient)				
SI Pond area (invarient)				
SI Pond permanence (invarient)				
SI Water quality	499.0	0.208820	0.834589	77
SI Shade	126.5	1.244501	0.213316	76
SI Waterfowl (invarient)				
SI Fish (invarient)				
SI Pond count	**90.5**	**2.158828**	**0.030864**	**65**
SI Terrestrial habitat	**28.5**	**3.605526**	**0.000312**	**72**
SI Macrophytes	735.5	0.929082	0.352847	75
HSI score	1291.0	0.707595	0.479198	77

2 Mann-Whitney U Test comparison of 'All ponds' data

	Rank Sum Group 1	Rank Sum Group 2	U	Z	p-level	Valid N Group 1	Valid N Group 2
SI Geographic location	17594.00	24022.00	9144.000	1.20025	0.115041	116	172
SI Pond area	16028.50	24726.50	9587.500	-0.19174	0.847642	113	172
SI Pond permanence	**14595.00**	**27021.00**	**7809.000**	**-3.12613**	**0.001158**	**116**	**172**
SI Water quality	**15009.50**	**26606.50**	**8223.500**	**-2.52817**	**0.009899**	**116**	**172**
SI Shade	**15370.00**	**26246.00**	**8584.000**	**-2.00811**	**0.013795**	**116**	**172**
SI Waterfowl	16092.50	25523.50	9306.500	-0.96583	0.280284	116	172
SI Fish	**15367.50**	**26248.50**	**8581.500**	**-2.01172**	**0.024347**	**116**	**172**
SI Pond count	**17913.00**	**23128.00**	**8250.000**	**2.26926**	**0.020453**	**114**	**172**
SI Terrestrial habitat	15643.00	25973.00	8857.000	-1.61428	0.088461	116	172
SI Macrophytes	**18649.00**	**22967.00**	**8089.000**	**2.72220**	**0.006334**	**116**	**172**
HSI score	15534.50	26081.50	8748.000	-1.77080	0.076594	116	172