



Developing a national pond surveillance strategy for widespread and
localised species

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Draft 1
March 2012

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This report should be cited as:

Williams P, Ewald E, Cannon C, and Biggs J (2012). Developing a national pond surveillance strategy for widespread and localised species. Report to Natural England. Pond Conservation, Oxford.

Acknowledgements

We would like to thank the following people and organisations for their contribution to the development of the strategy outlined in this report:

Tony Gent, John Wilkinson and Dorothy Wright (Amphibian and Reptile Conservation); John Baker and David Orchard (Amphibian and Reptile Groups of the UK); Kevin Walker (Botanical Society of the British Isles); Steve Prentice and Dave Smallshire (British Dragonfly Society); Andy Musgrove and David Noble (British Trust for Ornithology); Vicky Kindemba and Margaret Palmer (Buglife); David Roy (Centre for Ecology and Hydrology/Biological Records Centre); Jim Bacon (Biological Records Centre), Martin Willing (Conchological Society of Great Britain), Dylan Lloyd (Countryside Council for Wales), Bill Brierley (Environment Agency); Mike Dobson (Freshwater Biological Association); Deborah Procter (Joint Nature Conservation Committee); Lee Brady, Mike Phillips (Kent ARG), Ben le Bas, Stephen Herbert Keith Porter, Andy Webb and Katharine Woods, (Natural England); Simon Pickles (North and East Yorkshire Ecological Data Centre); Ian Wallace (Trichoptera Recording Scheme).

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1 Introduction

1.1 Aim of this report

This report summarises work undertaken to design a statistically robust ecological surveillance network that can be used as the basis for volunteer surveillance of ponds in England.

The network aims to:

- Provide stock and change data for widespread and localised pond-associated species of conservation concern (i.e. Habitats Directive, BAP).

Ideally the network should also:

- Provide stock and change data for pond Habitats Directive habitat types, and for Priority Ponds
- Provide trend data that tracks wider countryside pond quality
- Provide habitat-centred data for more widespread species groups
- Provide surveillance trends for non-native species
- Provide data that can enable causes to be linked to observed change.

1.2 Background

The aim of this project, '*Structured surveillance of small standing water bodies*', is to explore the feasibility of a habitat-centred approach to surveillance monitoring. Small water bodies are being used as an initial test of this approach which, if successful, could be applied to other habitats.

The project aims to establish the principles for a strategic network of ponds across England that can provide a focus for volunteer recording activity across taxonomic groups. Specifically, the project aims to:

- Make use of existing networks and initiatives
- Cover the interests of each key taxonomic group
- Optimise the use of existing volunteers
- Provide the basis for feedback products to recorders
- Contain enough sites to provide statistically valid information on status and change
- Provide the basis for reporting on biodiversity outcomes for regional, national and European purposes
- Support the work of the recorder community through the development of new web-based tools and interfaces.

Regional trials will be established in three areas (New Forest, Cheshire and NE Yorkshire) to test the potential to develop the network to fulfil these aims.

2 About the network

2.1 Area of coverage

The initial development of the surveillance network will cover England, and provide national-level data. However, there is scope to extend the approach to other UK countries.

2.2 Key species

Key taxa for the project are species of conservation concern that are of widespread or localised distribution in England. This includes Habitats Directive Annex II and V species, and BAP priority species. These are taxa listed in Table 1 below.

Table 1. Widespread and localised species of conservation concern that are the main focus of the project

Species	Designation	Distribution in England
Common Frog	HD Annex V	Widespread
Common Toad	BAP	Widespread
Grass Snake*	BAP	Widespread
Great Crested Newt	HD Annex II	Widespread
Flat-sedge*	BAP	Localised
Marsh Clubmoss	BAP	Localised
Marsh Stitchwort	BAP	Localised
Pillwort	BAP	Localised
Tassel Stonewort	BAP	Localised
Tubular Water-dropwort	BAP	Widespread
Yellow Centaury	BAP	Localised
Mud Snail	BAP	Localised
White-clawed Crayfish*	HD Annex II, BAP	Widespread
European Eel*	BAP	Widespread
Water Vole*	BAP	Widespread
Otter*	HD Annex II, BAP	Widespread

* Species of lower priority in the project either because of survey difficulties or because ponds are not the primary habitat for the species.

2.3 Other important species and habitats

In addition to the key species, the network aims to encompass the surveillance of a wider range of species and habitats of conservation concern.

Habitats of particular interest include (i) BAP Priority Ponds and (ii) Habitats Directive Annex I habitat types (see Table 2).

More restricted BAP species which also occur in the trial regions, and may be recorded in survey squares are listed in Table 3.

Table 2. Habitats Directive Annex I habitat types that occur in the three trial regions

Habitat Directive Annex I habitat type	Project trial region
3110 Oligotrophic waters containing very few minerals of sandy plains (<i>Littorelletalia uniflorae</i>)	New Forest
3130 Oligotrophic to mesotrophic standing waters with vegetation of the <i>Littorelletea uniflorae</i> and/or <i>Isoeto-Nanojuncetea</i>	New Forest
3140 Hard oligo-mesotrophic waters with benthic vegetation of <i>Chara</i> spp.	New Forest*, NE Yorkshire*
3150 Natural eutrophic lakes with <i>Magnopotamion</i> or <i>Hydrocharition</i> - type vegetation	Cheshire*
3160 Natural dystrophic lakes and ponds	New Forest*, NE Yorkshire*
3170 Mediterranean temporary ponds	New Forest (sub-optimal for this Habitats Directive type)

* Likely to occur, but not currently recognised.

Table 3. Restricted BAP species that occur in the three project trial areas

Trial area	Restricted BAP species
New Forest	One-grooved Diving Beetle, Brown Galingale, New Forest Mud Beetle, Coral-necklace, Foxtail Stonewort, Cut-grass, Heath Lobelia, Floating Water-plantain, Pennyroyal, Starlet Sea Anemone, Small Fleabane, Three-lobed Water-crowfoot, Water Germander, Tadpole Shrimp
Cheshire	Shining Ram's-horn, True Fox-sedge, Coral-necklace, Floating Water-plantain, Pennyroyal, Greater Water-parsnip, Water Germander
NE Yorkshire	True Fox-sedge, Greater Water-parsnip, Water germander

3 Coincidence mapping

3.1 Aim

Coincidence mapping was undertaken to establish the extent of overlap in the occurrence of BAP and Habitats Directive species of key interest to the project (Table 1). Coincidence was investigated at three spatial scales: 10 km grid square, 1 km grid square and pond level. In principle a high degree of overlap between species is beneficial in a surveillance project because it enables surveyors to monitor a range of key taxa within close proximity (e.g. at the same pond, or a number of ponds within a grid square).

3.2 Data sources

Data for these analyses (1988-2011) were gathered from a wide range of sources including regional data centres, data holding NGOs, national recording groups and individuals. Approximately 150,000 species records were gathered in total.

Note that, although the data gathering process was comprehensive, it is likely that very widespread species (e.g. Common Toad, Water Vole, Great Crested Newt, Grass Snake) records represent a considerable underestimate of their true occurrence. Data on most localised BAP species is likely to be more accurate because data collection has often been more systematic. For example, during this period localised plant species have been recorded both in atlas surveys and as the focus of BSBI rare plant monitoring.

Information on pond locations was derived using MasterMap GIS data supplied by Natural England.

Table 4. Known occurrence in England of widespread and localised species of conservation concern

	Number of records		
	All habitat types	Ponds	1 km squares
Common Toad	12841	7219	5615
Water Vole	12885	6225	4476
Great Crested Newt	9686	6038	3373
Grass Snake	7779	3098	3316
White-clawed Crayfish	6738	2914	2052
Tubular Water-dropwort	2365	995	815
Marsh Stitchwort	643	284	291
Pillwort	1254	340	202
Marsh Clubmoss	1215	143	170
Flat-sedge	384	152	121
Yellow Centaury	447	110	93
Mud Snail	129	50	43
Tassel Stonewort	52	36	28

3.3 Species occurrence

In terms of their occurrence, the data show that even widespread species occupy a relatively small proportion of 1 km grid squares and ponds in England (see Table 4). For example although Common Toad has been recorded from a large numbers of sites (>7,000), this represents a small proportion (only 4%) of the total number of ponds mapped (195,000). The findings are similar at 1 km square level with Common Toad occurring in 4.1% (5615 1 km squares) of 135,429 1 km squares in England, and Great Crested Newt 3.3% of 1 km squares nationally.

3.4 Species coincidence

Coincidence mapping (Figures 1, Annex 1) shows that there is relatively little overlap in the occurrence of species at either pond level or 1 km square level. This is particularly true of more localised species (Tables 6 and 7).

For very widespread species the result may be partly an artefact of under-recording. The strongly overlapping known range of Great Crested Newt and Common Toad, for example, imply that they may co-occur in the same grid square rather more commonly than the current data show (Table 5). However given the different habitat preferences (e.g. water depth, presence of fish) they remain unlikely to occur in the same pond (Table 6).

Amongst the localised species of interest, there is less likelihood that greater recording effort would show a stronger overlap. This is partly because, as noted above, data coverage is better for most localised species. However, in most cases the localised species have specific habitat requirements, and so even where they occur in the same broad landscape type, they rarely occur at the same pond. Thus a maximum of 4 widespread and localised species was recorded together (in 10 ponds), and the majority of ponds (24,345 ponds) supported just one species.

3.5 Implications

The results of the coincidence analysis suggest that it will not be possible to establish a single network (random or stratified), where sampling a small number of squares, or ponds will enable surveillance of multiple widespread or localised species.

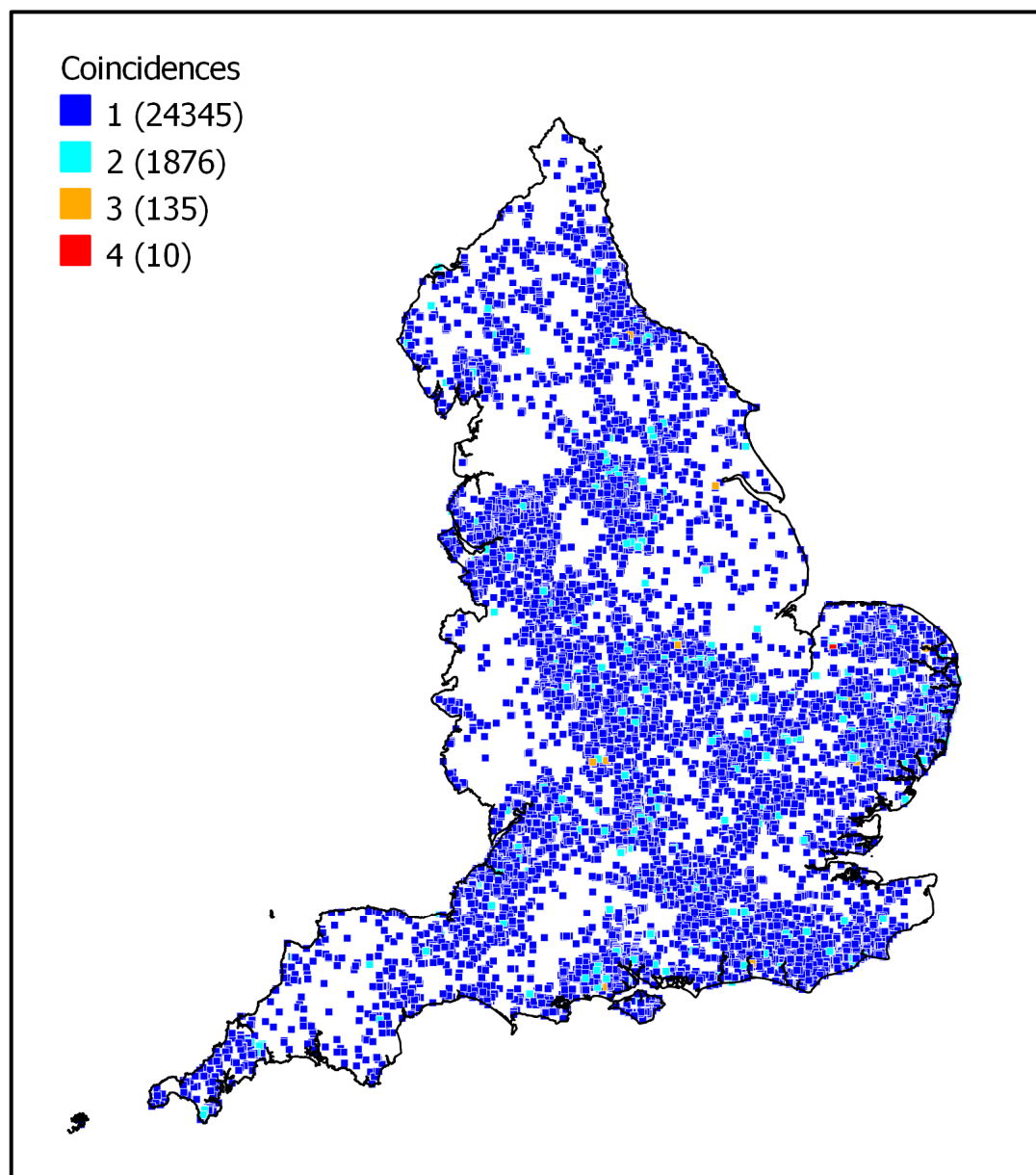


Figure 1. Pond-level coincidence map for widespread and localised species listed in Table 1, showing the number of species overlapping within the same pond (+ the number of ponds each level of overlap applies to).

Table 5. Species coincidence at 1 km grid square level

	Water Vole	White-clawed Crayfish	Flat-sedge	Common Toad	Yellow Centaury	Marsh Clubmoss	Grass Snake	Tubular Water-dropwort	Mud Snail	Pill-wort	Marsh Stitchwort	Tassel Stonewort	Great Crested Newt
Water Vole		206	12	537	2	8	391	119	5	11	43	3	285
White-clawed Crayfish	206		5	143	0	1	106	47	1	2	24	0	61
Flat-sedge	12	5		23	0	1	9	6	1	1	3	0	5
Common Toad	537	143	23		19	21	943	107	15	62	41	8	1036
Yellow Centaury	2	0	0	19		11	9	3	1	31	0	0	9
Marsh Clubmoss	8	1	1	21	11		27	6	1	31	2	0	7
Grass Snake	391	106	9	943	9	27		131	9	42	51	6	512
Tubular Water-dropwort	119	47	6	107	3	6	131		3	11	91	9	60
Mud Snail	5	1	1	15	1	1	9	3		3	3	0	9
Pillwort	11	2	1	62	31	31	42	11	3		3	0	19
Marsh Stitchwort	43	24	3	41	0	2	51	91	3	3		3	16
Tassel Stonewort	3	0	0	8	0	0	6	9	0	0	3		2
Great Crested Newt	285	61	5	1036	9	7	512	60	9	19	16	2	

Table 6. Species coincidence at pond level

	Water Vole	White-clawed Crayfish	Flat-sedge	Common Toad	Yellow Centaury	Marsh Clubmoss	Grass Snake	Tubular Water-dropwort	Mud Snail	Pill-wort	Marsh Stitchwort	Tassel Stonewort	Great Crested Newt
Water Vole		111	9	265	0	0	141	25	7	0	7	0	101
White-clawed Crayfish	111		9	54	0	0	32	2	0	0	3	0	17
Flat-sedge	9	9		5	0	0	3	3	0	0	7	0	0
Common Toad	265	54	5		23	14	347	27	8	93	11	5	582
Yellow Centaury	0	0	0	23		7	1	1	0	30	0	0	1
Marsh Clubmoss	0	0	0	14	7		8	0	1	7	0	0	0
Grass Snake	141	32	3	347	1	8		26	5	16	4	0	246
Tubular Water-dropwort	25	2	3	27	1	0	26		3	4	43	1	17
Mud Snail	7	0	0	8	0	1	5	3		4	3	0	5
Pillwort	0	0	0	93	30	7	16	4	4		4	0	4
Marsh Stitchwort	7	3	7	11	0	0	4	43	3	4		0	0
Tassel Stonewort	0	0	0	5	0	0	0	1	0	0	0		0
Great Crested Newt	101	17	0	582	1	0	246	17	5	4	0	0	

4 Assessing the proportion of occupied sites

4.1 Aims

This section describes analyses undertaken to understand the extent to which randomised surveys could detect ponds currently occupied by widespread and localised species. This provides information about how many sampling sites are needed to provide a good assessment of a species' 'stock' measured as the number of 1 km squares which support populations. The data also provide a 'reality check' for the power analysis discussed in Section 5.

4.2 Methods

The computer package Resampling StatsTM (Resampling Stats, 2006) was used to randomly select 1 km squares from a pool of 25000¹ 1 km grid squares – including squares known to contain widespread and localised species and grid squares with no records for any of the species of conservation interest. This pool represents 18% of the total number of grid squares nationally..

4.3 Results

For the most widespread species (Table 1) in England, only a moderate number of random sampling sites were needed to correctly predict the proportion of occupied squares. For example, for Common Toad, a network of randomly selected 250 1 km grid squares predicts an occupancy of 23%. This compares well with current data that suggest occupancy is 22% (Figure 3a).

For localised species (Figure 3b) the variability was much higher. An N=250 random survey failed to detect the species of interest. Pillwort was only detected when N=500, Mud Snail when N=1000 and Tassel Stonewort when N=2000. For the latter two species, only 2 1 km squares were found to be occupied when N=2000.

4.4 Implications

The resampling analysis suggests that it is possible to estimate the stock of widespread species by surveying a relatively modest number of random 1 km grid squares (250-500 squares). For localised species, the number of random survey squares needed is much larger (1,000-2,000 squares). In addition, these extensive surveys would only find localised species in a tiny number of squares (2 – 9 squares) providing too little data for analysis of population change (see Section 5).

¹ excludes 1 km grid squares with no ponds and heavily urbanised 1 km grid squares (25,000 1 km squares)

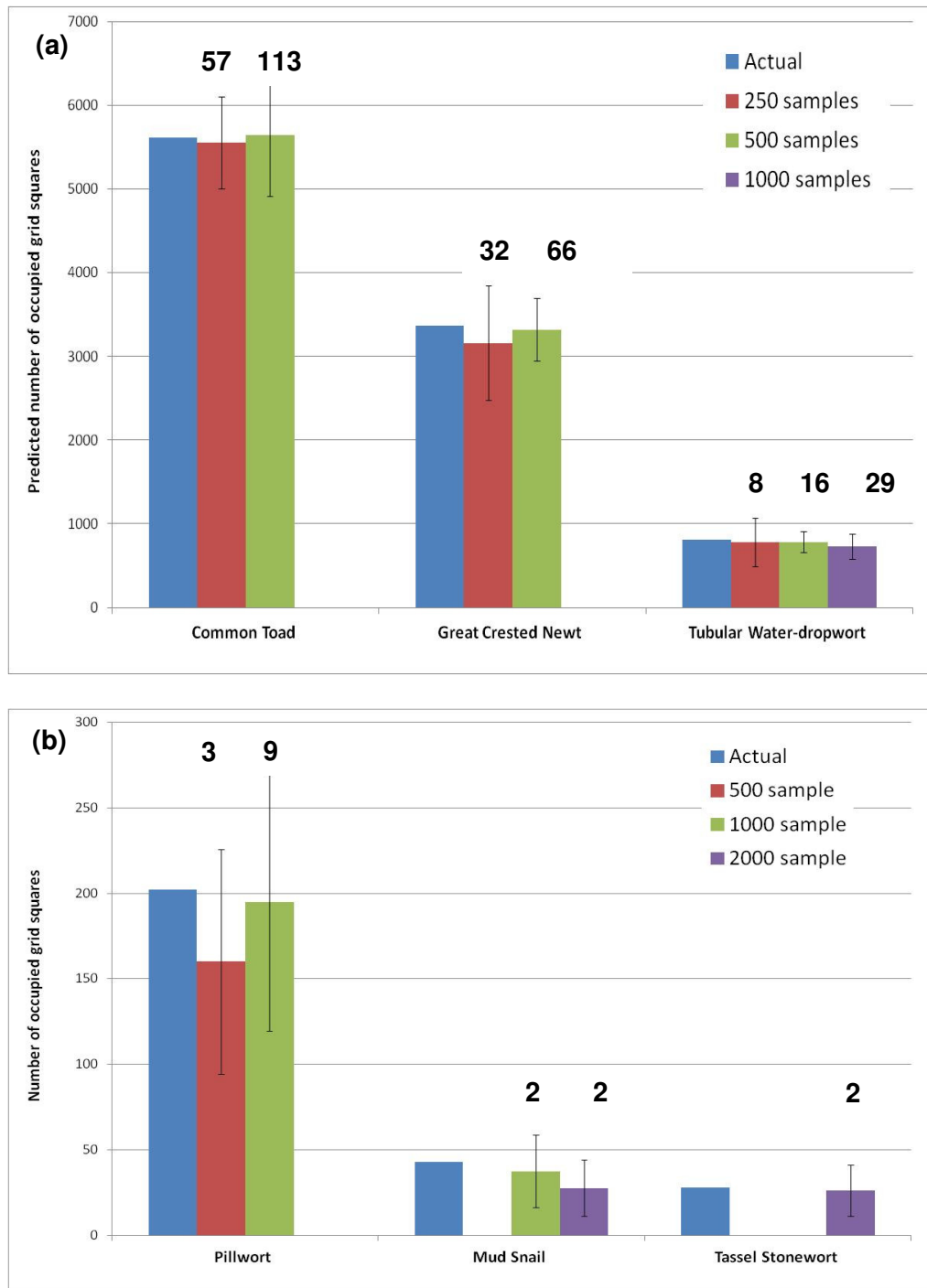


Figure 2. Results of resampling statistics to determine whether, for a given sample size, the estimated number of occupied grid squares is equal to the actual number of occupied grid squares for localised species. (a) representative widespread species (b) representative localised species. Numbers above sample groups represent the average number of grid squares predicted to contain the species of interest for each sample size.

5 Options for a network to assess change in widespread and localised species

5.1 Aims

This section of the report describes the results of power analyses undertaken to assess the size and form of a sampling network that would be needed in order to give confidence that a change in widespread and localised species could be detected if it occurred.

The main questions addressed are:

- Can we use a random network or does the network need stratification by species?
- Which survey unit should we use – ponds per 1 km grid square or individual ponds?
- How many sampling sites do we need?

Five main survey strategy options are examined, each differing in terms of their stratification and/or the survey unit used (pond or 1 km square).

5.2 Power analysis

Power analysis was used to determine the sample size needed to detect changes in species populations. Type II errors (β) may occur if there is a failure to reject the null hypothesis, when in fact the alternative hypothesis were true. Power ($1-\beta$) is the probability of detecting an effect if one exists in the population, and is largely dependent on sample size N and levels of variance in sample groups Σ^2 . In many cases Σ^2 will be a function of the form $\Sigma^2 = \sigma^2/N$, where σ^2 is the variance of the individual measurements and N is the total sample size (Lachin, 1981).

Differences in mean values

A t-test was used to test the hypothesis that the mean of a normal variable, v , equals some specified value $H_0: \mu_0 = v_0$ against some alternative $H_1: \mu_1 = v_1, v_1 \neq v_0$ when the variance is unknown. The test statistic is of the form $t = \text{sqrt}(N(x - \mu_0)/S)$ where x is the sample mean with standard error S^2/N , S^2 being the unbiased sample estimate of the variance σ^2 on $N - 1$ degrees of freedom (df). To solve sample size therefore:

$$N = \left[\frac{Z_{\alpha}\sigma_0 + Z_{\beta}\sigma_1}{\mu_1 - \mu_0} \right]^2 \quad (1)$$

Proportions

In experiments where the basic outcome is the presence or absence of a species, the data are usually expressed as a proportion p . The exact probability distribution of such a proportion is the binomial distribution that has parameters N (sample size) and π (the true

population proportion). For large N the binomial distribution may be approximated by a normal distribution with mean $\mu = \pi$ and variance $\Sigma^2 = \pi(1 - \pi)/N$.

In one-sample problems that yield a single proportion, the hypothesis $H_0: \mu_0 = \pi_0$ is tested where one wishes to detect a clinically relevant alternative $H_1: \mu_1 = \pi_1$ where $\pi_1 > \pi_0$ or $\pi_1 < \pi_0$. Given a proportion p from a sample of size N , the test statistic employed is $Z = (p - \pi_0)/\Sigma_0$ where $\Sigma_0^2 = \pi_0(1-\pi_0)/N$ and where $Z \sim N(0, 1)$ if H_0 is true. As an example, in a population change study, one might test that for a given survey year, the proportion of occupied 1 km squares equals that obtained in a previous survey, where π_0 is the proportion observed in the follow up survey.

For the determination of sample size we substitute $\sigma_0^2 = \pi_0(1-\pi_0)$ and $\sigma_1^2 = \pi_1(1-\pi_1)$ into equation 1, giving the equation for sample size N as:

$$N = \left[\frac{Z_\alpha \sqrt{\pi_0(1-\pi_0)} + Z_\beta \sqrt{\pi_1(1-\pi_1)}}{\pi_1 - \pi_0} \right]^2 \quad (2)$$

5.3 Abundance vs occupancy

In the network options that follow, the majority of survey options are based on occupancy (i.e. presence of the species as a 0 or 1 value), rather than a species' abundance at a site.

Abundance measures are an option for surveillance of some taxa, particularly plant species, which are (a) relatively static and (b) often surveyed using a census, rather than sampling, approach. For most widespread species, however, surveillance will need to be based on presence/absence data alone. For amphibians, for example, natural between-year population fluctuations are too great to allow sufficient statistical power to detect significant change in numbers D Sewell (*pers comm*). The variability of abundance measures for other non-plant species (e.g. White-clawed Crayfish, Water Vole) is unknown.

5.4 Sampling issues

For amphibians, in particular, the current analyses are based on an assumption that optimal sampling methods are used to detect species presence. It does not take into account additional variability introduced through use of different survey techniques e.g. below optimal number of site visits, or uses of different methods. A separate analysis, undertaken by Dr David Sewell and colleagues, will be undertaken this year (2012) to address this.

5.5 Option 1: Network of random ponds

Option 1 is based on the premise of a national surveillance network of randomly selected survey ponds, with repeat surveys at the same ponds in subsequent years.

The network is based on a random sampling strategy that:

- uses optimal sampling methods to detect the species *presence* (not abundance)
- includes known ponds in England (195,000 ponds).

The analysis:

- identifies the proportion of occupied ponds for each species
- simulates a change in occurrence (10, 20, 30, 40 or 50%)
- uses a z-test to detect a significant difference in the proportion of occupied ponds between time 1 and time 2
- uses power analysis to derive different levels of power (60, 65, 70, 75, 80, 85, 90 and 95%) for each change scenario (equation 2).

5.5.1 Results

The results show that even for a minimum desirable level of power and change (70% power to detect a 30% change), a substantial number of sites would be required to monitor even the most widespread species. i.e. Common Toad 1667 sites, and Great Crested Newts 2005 sites for 70% power and 30% change (Table 7).

The number of ponds required to monitor Tubular Water-dropwort exceeded 3500 even at the lowest level of power (60%) detecting the biggest change (50%).

Table 7. Outputs for Option 1: showing the sample size (number of ponds) required for each level of power (0.60-0.95) to detect different levels of change (10-50%)

(a) Common Toad

	10% change	20% change	30% change	40% change	50% change
0.60	12593	3111	1365	757	477
0.65	14069	3458	1508	831	520
0.70	15714	3842	1667	913	567
0.75	17590	4280	1847	1005	621
0.80	19804	4795	2058	1114	683
0.85	22551	5433	2318	1247	759
0.90	26260	6291	2668	1425	860
0.95	32276	7680	3232	1711	1022

(b) Great Crested Newt

	10% change	20% change	30% change	40% change	50% change
0.60	15161	3743	1642	911	574
0.65	16938	4160	1814	1000	626
0.70	18917	4622	2005	1098	682
0.75	21176	5148	2221	1209	746
0.80	23841	5768	2475	1339	821
0.85	27146	6534	2788	1499	912
0.90	31610	7567	3209	1713	1034
0.95	38851	9236	3886	2056	1229

5.5.2 Implications

The pros and cons of a random pond-based network are summarised in Table 8 below. In principle, a random approach is statistically optimal in terms of flexibility, and its potential to detect change (increases and decrease). However, the number of sites required to detect changes in even the most widespread species is challenging for a *random* network, and would be prohibitively large if it was to include localised species.

Table 8. Pros and cons for Option 1: Network based on random selection of ponds

Pros	Cons
<ul style="list-style-type: none"> Possibly achievable for very widespread species (e.g. for Great Crested Newt a sample of c.2,000 ponds is required to detect a 30% change at 70% power) 	<ul style="list-style-type: none"> The number of grid squares required for less widespread and localised species is not feasible (e.g. for Tubular Water-dropwort a survey of 12,467 ponds is needed to detect a 30% change at 70% power)
<ul style="list-style-type: none"> Ponds are selected randomly anywhere in England – if it proves difficult to survey any one pond, a replacement can be chosen instead 	
<ul style="list-style-type: none"> Will detect an increase in the number of occupied ponds as well as decreases because the sampling strategy includes currently unoccupied ponds 	
<ul style="list-style-type: none"> If the proportion of occupied ponds increases considerably for less widespread species (e.g. Tubular water dropwort) this range expansion could be picked up 	<ul style="list-style-type: none"> If the proportion of occupied ponds decreased significantly for currently widespread species it becomes progressively harder to detect future declines using the same strategy

5.6 Option 2: Stratified random sampling strategy at the level of 1 km grid square

Option 2 is based on a random sampling strategy where all ponds are surveyed within a 1 km grid square. A single level of stratification is employed to exclude squares where no pond is mapped or heavily urbanised areas.

The network is based on a strategy that:

- randomly samples only grid squares which are known to contain ponds (25,000 1 km squares)
- samples all the ponds within the 1 km square
- uses optimal sampling methods to detect species presence (not abundance).

The analysis:

- calculates the proportion of occupied grid squares for each species
- simulates a change in occurrence (10, 20, 30, 40 or 50%)
- uses a z-test to detect a significant difference in the proportion of occupied 1 km grid squares between time 1 and time 2
- uses power analysis to derive different levels of power (60, 65, 70, 75, 80, 85, 90 or 95%) for each change scenario (equation 2).

5.6.1 Results

The results show that using this approach, relatively small numbers of survey squares are required to show minimum acceptable levels of change in widespread species (Table 9). For Common Toad 225 1 km grid squares, and for Great crested Newt 414 1 km grid squares, are needed to show 30% change at 70% power. For less widespread species, however, the number of grid squares becomes prohibitively high. For Tubular Water-dropwort, 1,901 1 km squares would be required. The number of grid squares required to monitor Pillwort exceeds 2200 even at the lowest level of power (60%) detecting the biggest change (50%).

5.6.2 Implications

The pros and cons of a random 1 km grid square-based network where all ponds in the square are sampled are summarised in Table 10 below. In terms of the number of sites required, this approach is viable for surveillance of the most widespread taxa. However the approach has two significant disadvantages (i) all (or most) ponds in the square need to be surveyed, (ii) more significantly – a species would need to become extinct at all ponds in the square before a change (i.e. from 1 to 0) would be recognised as a loss in the analysis. The high levels of species loss that could potentially occur before change was seen statistically using this approach makes it unattractive as a basis for surveillance.

For all localised species, too many grid squares would need to be sampled to make a random square-based approach with all ponds surveyed viable.

Table 9. Outputs for Option 2: showing the sample size (number of 1 km grid squares) required for each level of power (0.60-0.95) to detect different levels of change (10-50%)

(a) Common Toad

	10% change	20% change	30% change	40% change	50% change
0.60	1677	416	183	102	64
0.65	1876	463	203	112	71
0.70	2098	515	225	124	77
0.75	2351	575	250	137	85
0.80	2649	646	279	152	94
0.85	3020	733	315	171	104
0.90	3521	851	364	196	119
0.95	4334	1042	443	236	142

(b) Great Crested Newt

	10% change	20% change	30% change	40% change	50% change
0.60	3110	769	338	188	119
0.65	3476	856	374	207	130
0.70	3885	952	414	227	142
0.75	4351	1061	459	251	155
0.80	4901	1190	512	278	171
0.85	5584	1350	578	312	190
0.90	6506	1565	666	357	216
0.95	8002	1913	809	430	258

(c) Tubular Water-dropwort

	10% change	20% change	30% change	40% change	50% change
0.60	14372	3550	1557	864	544
0.65	16057	3945	1720	948	593
0.70	17934	4383	1901	1041	647
0.75	20075	4882	2106	1147	708
0.80	22601	5470	2347	1270	778
0.85	25735	6197	2644	1422	865
0.90	29967	7176	3043	1625	981
0.95	36832	8760	3686	1951	1165

Table 10. Pros and cons for option 2: network based on random selection of 1 km grid squares

Pros	Cons
<ul style="list-style-type: none"> For very widespread species (>3000 1 km grid squares) relatively few grid squares need to be monitored (e.g. Great Crested Newt 414 1 km grid squares to detect 30% change at 70% power) 	<ul style="list-style-type: none"> The number of grid squares required for less widespread and local species is still not feasible (e.g. Pillwort 7852 1 km grid squares to detect a 30% change at 70% power)
<ul style="list-style-type: none"> Once presence of the species confirmed in one pond in a grid square, surveyors can move on to the next grid square 	<ul style="list-style-type: none"> All ponds in a grid square must be surveyed until absence is confirmed A decline cannot be shown until all ponds in the grid square lose the species
<ul style="list-style-type: none"> Will detect an increase in the number of occupied grid squares as well as declines because the sampling strategy includes currently unoccupied squares 	<ul style="list-style-type: none"> Does not include 1 km grid squares which currently don't contain ponds, therefore any increases as a result of pond creation in these squares would not be detected

5.7 Option 3: Stratified sampling that targets each species at the level of ponds per 1 km grid square

Option 3 is based on surveys of all (or most) ponds across a 1 km grid square, but with surveys targeted only at squares where the species is already known to occur.

The network is based on a stratified sampling strategy that:

- samples only grid squares with ponds that currently contain records of the species
- calculates the average number of occupied ponds per grid square for each species
- uses optimal sampling methods to detect species presence.

The analysis:

- simulates a change in the average number of occupied ponds per grid square (10 - 50%)
- uses a t-test to detect a significant difference in the average number of occupied ponds per grid square between time 1 and time 2
- uses power analysis to derive different levels of power (60, 65, 70, 75, 80, 85, 90 and 95%) for each change scenario (equation 1)

5.7.1 Results

The results (Table 11) show that targeting grid squares where species are known to occur considerably reduces the number of samples required to detect change. Only 89 Common Toad squares and 121 Great Crested Newt squares are required to show a significant difference if one existed for a 30% change at 70% power.

For Pillwort, a more localised species, 139 squares would be required at this level of change and power. However, in reality, only 202 1 km squares are known to be occupied by Pillwort in England, so such a survey would sample almost 70% of the species' currently occupied grid squares.

For species that are more localised still, the number of grid squares needed to adequately show change is greater than the number of sites where the species is known to occur. For example, for Mud Snail (43 1 km squares) it would only be possible for a 50% change to be detected at 65% power even if all the squares were surveyed.

5.7.2 Implications

The pros and cons of a survey targeted on a 1 km network where species are known to occur are summarised in Table 12 below. There are advantages in using a targeted approach to survey widespread species, particularly in terms of the relatively small numbers of sites required. A significant disadvantage, however, is that a focused network of squares needs to be established for *each* species. In addition this sampling strategy can show species change in grid squares where the taxon is known, but will not show change (e.g. new sites for the species), outside the square.

This approach is still insufficient to sample most localised species, because the number of squares that are needed to show change adequately, generally approaches, or exceeds, the number of squares where the species actually occurs.

Table 11. Outputs for Option 3: showing the sample size (number of 1 km grid squares) required for each level of power (0.60- 0.95) to detect different levels of change (10-50%)

(a) Common Toad

	10% change	20% change	30% change	40% change	50% change
0.60	628	158	71	41	27
0.65	705	177	80	45	30
0.70	791	199	89	51	33
0.75	890	224	100	57	37
0.80	1006	253	113	64	42
0.85	1151	289	129	73	47
0.90	1346	338	151	86	55
0.95	1665	417	186	105	68

(b) Great Crested Newt

	10% change	20% change	30% change	40% change	50% change
0.60	891	224	97	55	36
0.65	1000	251	108	62	41
0.70	1122	282	121	70	45
0.75	1262	317	136	78	51
0.80	1427	358	154	88	57
0.85	1632	409	176	100	65
0.90	1910	479	205	117	76
0.95	2362	591	254	145	94

(c) Tubular Water-dropwort

	10% change	20% change	30% change	40% change	50% change
0.60	1288	323	144	82	53
0.65	1446	363	162	92	59
0.70	1622	407	182	103	66
0.75	1824	457	204	115	74
0.80	2062	517	230	130	84
0.85	2359	591	263	149	96
0.90	2761	691	308	174	112
0.95	3414	855	381	215	138

(d) Pillwort

	10% change	20% change	30% change	40% change	50% change
0.60	981	246	110	63	41
0.65	1102	276	124	70	45
0.70	1236	310	139	79	51
0.75	1390	348	156	88	57
0.80	1571	394	176	100	64
0.85	1797	450	201	114	73
0.90	2103	527	235	133	86
0.95	2600	651	290	164	105

Table 12. Pros and cons for Option 3: Network based on surveys of 1 km grid squares targeted to at squares known to support the species

Pros	Cons
<ul style="list-style-type: none"> For widespread species and some local species, few grid squares need to be monitored (e.g. Pillwort – all ponds in 139 1 km grid squares to detect 30% change at 70% power) 	<ul style="list-style-type: none"> The number of grid squares required for local species is close to, or exceeds, the number of grid squares they currently occupy (e.g. Pillwort currently known from 202 grid squares; sampling strategy demands that 69% of these are monitored)
	<ul style="list-style-type: none"> All ponds in a grid square must be surveyed and presence or absence must be recorded for each pond
<ul style="list-style-type: none"> Will detect an increase in the number of occupied ponds per grid square as well as declines because the sampling strategy includes currently unoccupied ponds in each grid square 	<ul style="list-style-type: none"> Does not include 1 km grid squares which currently don't contain records, therefore any increases as a result of pond management/ creation in these squares would not be detected

5.8 Option 4 – Stratified random sampling strategy at the level 1 km grid square combining Option 2 and 3 approaches

Option 4 is a compromise solution, based on Options 2 and 3, which aims to create a network structure for surveillance of widespread amphibians. It combines a targeted approach to assess species change at sites where a species is already known (Option 3) with a random sample (Option 2) to look at species trends outside the squares where the species is known.

The network is based on a sampling strategy that includes:

- randomly selected grid squares (50%) known to contain records of the species – allowing a sufficient number of occupied grid squares to show change
- randomly selected grid squares (50%) that currently do not contain records of the species – allowing species to extend their current distribution
- sampling all the ponds within the 1 km square

The analysis:

- uses optimal sampling methods to detect species presence (not abundance)
- calculates the proportion of occupied grid squares for each species
- calculates the number of occupied ponds per grid square for each species
- simulates a change in occurrence (10, 20, 30, 40 and 50%)
- uses a z-test to detect a significant difference in the proportion of occupied 1 km grid squares between time 1 and time 2
- uses a t-test to detect a significant difference in the number of occupied ponds per grid square
- uses power analysis to derive different levels of power (60, 65, 70, 75, 80, 85, 90 and 95%) for each change scenario (equation 2).

5.8.1 Results

The results (Table 13) show that for the most widespread species (e.g. Common Toad and Great Crested Newt) it is possible to develop a network that can detect a change of 30% with 70% power. For Common Toad, surveillance based on a network of 164 known grid squares and 164 randomly selected 1 km grid squares, where Toad is unknown, would achieve this level of power. For Great Crested Newt a network of 188 known grid squares and 188 unknown 1 km grid squares is required. A total network combining surveillance for both species can be developed using 540 1 km grid squares (Figure 4).

A network of 540 1 km grid squares would be sufficient to detect a change in the number of occupied grid squares. It can also be used to detect within-square change in the number of occupied ponds as a measure of change.

5.8.2 Implications

The pros and cons of Option 4 are summarised in Table 14 below. For amphibians this approach provides an acceptable compromise, with a relatively modest number of survey squares, the potential to measure within-square pond loss and gain, and a random element to look at change outside known survey squares.

This is not an approach that works for localised species however. So an alternative approach is required for these taxa.

Table 13. Outputs for Option 4: showing the sample size (number of grid squares – 50% known/50% unknown) required for each level of power (0.60-0.95) to detect different levels of change (10-50%)

(a) Common Toad

	10% change	20% change	30% change	40% change	50% change
0.60	2555	557	260	140	93
0.65	2868	626	292	158	104
0.70	3218	702	327	177	117
0.75	3619	789	368	198	131
0.80	4092	892	416	224	148
0.85	4681	1021	475	256	169
0.90	5478	1194	556	300	197
0.95	6774	1476	687	370	244

(b) Great Crested Newt

	10% change	20% change	30% change	40% change	50% change
0.60	2475	695	298	175	110
0.65	2779	780	334	196	123
0.70	3118	875	375	220	138
0.75	3506	984	421	247	155
0.80	3964	1112	476	279	175
0.85	4535	1272	545	319	200
0.90	5307	1488	637	373	234
0.95	6563	1840	788	461	289

Table 14. Option 4 pros and cons for a stratified random sampling strategy at the level of 1 km grid square combining Option 2 and 3 approaches.

Pros	Cons
<ul style="list-style-type: none"> For widespread species – Common Toad a network of 164 known ponds and 164 unknown 1 km grid squares are required. Great Crested Newt a network of 188 known ponds and 188 unknown 1 km grid squares is required Total network for both species = 540 1 km grid squares (Figure 4) 	<ul style="list-style-type: none"> Not possible to detect localised species as part of the amphibian network See Option 5
<ul style="list-style-type: none"> It is possible to use levels of within-square pond occupancy as a measure of change in the number of occupied ponds per grid square 	<ul style="list-style-type: none"> All (or most) ponds in a grid square must be surveyed and presence or absence must be recorded for each pond

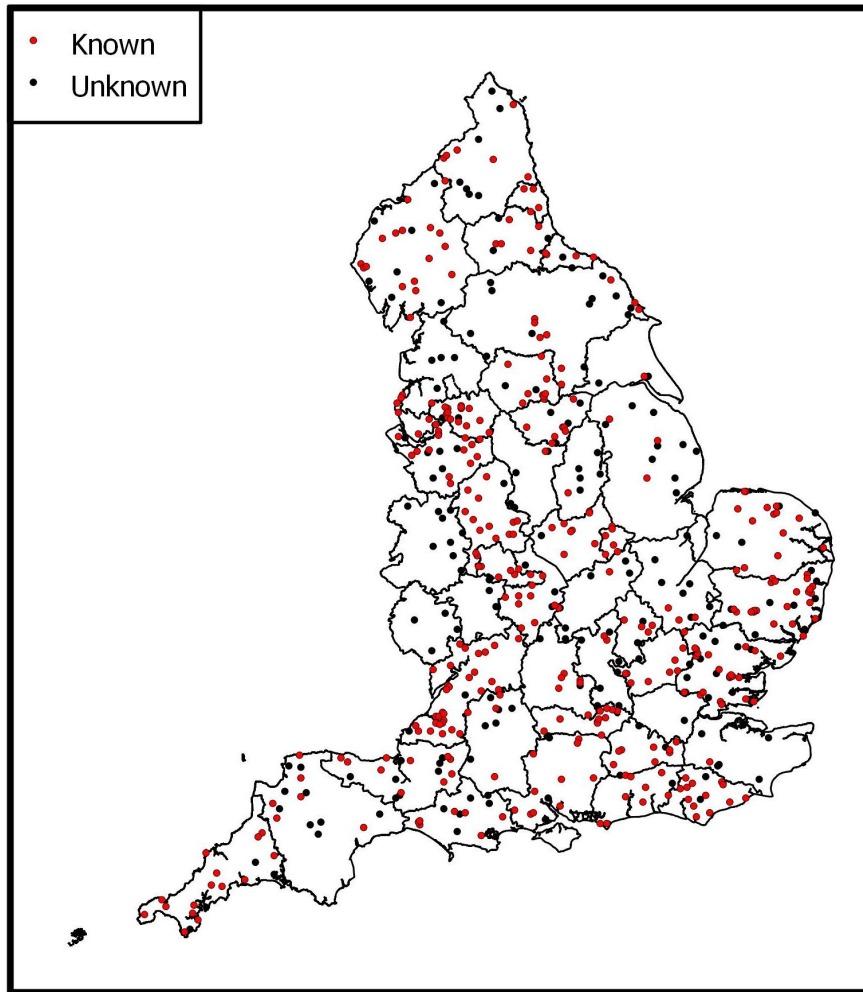


Figure 4. Pond surveillance network – 540 1 km squares including known Common Toad (164) and Great Crested Newt (188) and unknown (188) 1 km grid squares.

5.9 Option 5 – Stratified sampling based on measuring species abundance at known ponds

Option 5 is targeted at localised species which occur at too few sites to be surveyed using Option 1-4 approaches.

This network:

- samples ponds that are currently known to contain records of the species of interest
- uses optimal sampling methods to record the abundance of the species at each pond.

The analysis:

- simulates a change in abundance at each pond (10, 20, 30, 40 and 50%)
- uses a t-test to detect a significant difference in the average abundance of a species per grid square between time 1 and time 2
- uses power analysis to derive different levels of power (60, 65, 70, 75, 80, 85, 90 and 95%) for each change scenario.

5.9.1 Results

It is currently difficult to estimate the number of sites likely to be required to assess change using an abundance approach because, for all localised species, there are exceptionally few abundance studies on which to base power analysis.

However, preliminary investigation using New Forest data for Pillwort (Ewald, unpublished data) shows that the sampling size required depends, in part, on how abundance is measured. Based on this limited evidence it seems probable that surveys of between 20 and 40 grid squares may be necessary to monitor each taxon effectively. This gives a total network of c 220 squares to cover localised species monitoring.

5.9.2 Implications

Because previous survey options (Options 1-4), do not provide viable approaches for surveying more localised species, an abundance approach targeted at known ponds is the best available option for these taxa. There are, however, inherent disadvantages in this method, particularly its inability to detect species range extensions (i.e. new sites).

The project's forthcoming trials will collect new abundance data for localised species that can be used to improve future estimates of the number of sites required for this element of the survey network.

Table 15. Option 5: pros and cons of a network based on stratified sampling measuring species abundance at known ponds

Pros	Cons
<ul style="list-style-type: none"> Can provide a measure of change for localised species (e.g. Pillwort) based on increase or decrease in abundance at a site 	<ul style="list-style-type: none"> The number of ponds needed to assess change is not known because there are currently very few abundance data available for the species of interest Abundance may be difficult to measure or, for invertebrates, be highly variable (e.g. Mud Snail)
	<ul style="list-style-type: none"> Does not include ponds which currently do not have records, Does not detect an increase in the number of occupied ponds
	<ul style="list-style-type: none"> Needs a tailored survey for each species

6 Community-based and environmental measures

This section describes an alternative approach to surveillance, based on monitoring biotic metrics or other attributes, rather the species-based measures discussed in Section 5.

This type of measure includes:

1. Taxon richness and rarity measures: e.g. number of plant or dragonfly species recorded at a site, species rarity indices, number of non-native plant species.
2. Waterbody quality indices: e.g. PSYM, Great Crested Newt Habitat Suitability Index.
3. Environmental indices: e.g. Ellenberg scores, Trophic Ranking Scores and most physico-chemical metrics e.g. water chemistry.

These measures are valuable in their own right as measures of biotic or environmental change. They also include criteria used to identify and/or monitor Priority Ponds, and Habitats Directive Annex I habitat types.

6.1 Methods

In practice, there are rather few national data sets which are ideal for power analysis to explore the number of ponds or survey squares required to establish significant change in community-based and environmental measures.

So for the current assessment a provisional assessment was made using one of the few available datasets, Countryside Survey data gathered from lowland ponds in 1996 and 2007, to provide an indicative measure.

6.2 Results

The results (Table 16) are based on change in lowland pond plant richness (submerged and emergent wetland plant species) in re-sampled ponds. They show that, for this measure, relatively low numbers of sites are likely to be required to detect a significant change: for example, 77 sites give 70% power to detect a 30% change.

Table 16. Countryside Survey plant species 1996-2010. The sample size (number of ponds) required for each level of power (0.60-0.95) to detect different levels of change (10-50%)

	10% change	20% change	30% change	40% change	50% change
0.60	543	135	61	35	23
0.65	610	152	69	39	26
0.70	684	170	77	44	29
0.75	769	191	86	49	32
0.80	869	216	97	55	36
0.85	994	247	111	63	41
0.90	1164	289	130	73	48
0.95	1439	357	160	90	58

6.3 Implications

The results shown in Table 16 provide an order-of-magnitude example of the numbers of squares / ponds needed to show change using biotic and environmental metrics. The example also demonstrates a wider principle: that the power to detect change increases where measures have few (or no) zero values.

Thus, if ponds are monitored using scalar biotic measures or environmental attributes, far fewer sites are required to show change than if species occupancy (0, 1) measures are used. This, in turn, means that it is likely to be possible to measure scalar community metrics using *randomised* networks of the sort outlined in Options 1 and 2 in Section 5.

7 Monitoring common taxa

The focus of the current analysis has been to establish the shape of a surveillance network that can monitor change in widespread and localised BAP and Habitats Directive Annex II species. However the principles established apply equally to surveillance of other taxa.

An important subsidiary aim of the Pond Surveillance Network is to provide a focus for monitoring a wide range of taxa, including common species and groups, as part of a habitat-based approach.

The current analyses suggest that a random network approach is only likely to pick up significant change in occupancy for very *common* and widespread species. Where abundance is a viable measure (e.g. for taxa with little natural inherent or sampling variability), moderately *widespread* species monitoring may be possible. However this needs to be explored further using empirical data from the project's trials.

Surveillance of more *localised* non-BAP species is unlikely to be a practical option as part of the general surveillance network and is likely to be best addressed either indirectly, through other measures (e.g. species rarity indices), or through alternative, more targeted, monitoring approaches outside the current network.

For groups such as non-native taxa it appears unlikely that trends will be picked up for individual species in the current network because most non-natives remain relatively uncommon. However data collected on individual species have the potential to be incorporated into wider (meta) analyses for these taxa beyond the scope of the current project.

8 A rationale for surveillance monitoring

8.1 Summary of key findings

8.1.1 Widespread and localised species surveillance

Power analyses show that, even for the most widespread BAP species, a considerable number of sites are required to show change if monitoring is based on a random network of ponds. Thus for Common Toad (the most widespread pond-associated BAP species) a random sample of 1500 ponds is required for a 70% chance of detecting 30% change in occupancy; for Tubular Water-dropwort a survey of 12,000 randomly selected ponds would be needed.

A range of strategies can be used to reduce the number of sites required to detect change to levels more likely to be viable for a volunteer monitoring network. Targeting surveys at ponds or 1 km squares *known* to support each species is effective at reducing site numbers, but has the disadvantage that increases in occupancy cannot be detected outside these areas.

A compromise solution for the most *widespread* species is to use a network comprising 50% of sites targeted for key taxa to provide an indication of change in landscapes where the species is known occur, and 50% random non-occurrence sites to detect wider trends. Applying this approach to the two widespread BAP amphibians (Great Crested Newt and Common Toad), a combined network of 540 1 km grid squares, where all (or most) ponds are surveyed in each square, will give a 70% chance of detecting 30% change in occupancy for both species.

For *localised* species like Pillwort (currently known from only 202 1 km squares in England), analysis suggests that even highly targeted surveys focussing on occupancy within grid squares where the species is known, are inadequate to assess change. The best remaining option is to monitor known sites, and use species *abundance*, rather than occupancy, to measure change.

Abundance assessments have the advantage that declines (as well as increases) will be detected before the species becomes absent from a pond. However, an *increase* in the number of occupied 1 km grid squares would not be detected, and other approaches (e.g. Bioblitzes designed to search squares or ponds on the species range edges), would be needed to assess this. An additional practical issue is that, for all localised species, there are currently insufficient abundance data to test how many sites are likely to be needed to show significant change using abundance measures.

8.1.2 Community and environmental measures

A preliminary analysis of the number of sites needed to monitor significant change using environmental indices and metrics (e.g. species richness, HSI, PSYM), suggests that relatively low numbers of ponds ($N < 100$) are likely to be required to detect a significant change using measures such as these where there are few (or no) zero values.

These measures are valuable in their own right as indicators of biotic or environmental change. They also include criteria that can be used to identify and/or monitor Priority Ponds, and Habitats Directive Annex I habitat types.

8.2 Recommendations

The recommendations which follow outline the structure of a pond surveillance network which, can as its priority, be used to assess stock and change in widespread and localised BAP and Habitats Directive species. The network will also, as far as practicably possible, addresses the subsidiary aims of the project (Section 1.1).

In total the network comprises c 700 1 km squares. This is divided into a number of overlapping sub-networks:

1. The largest proportion of the network is a core of c.550 1 km grid squares used to detect stock and change in **widespread amphibians** (e.g. Great Crested Newt, Common Toad, Common Frog). Of the 550 squares, 50% are sites known for GCN or Common Toad and 50% are a random selection of sites from which these species are unknown. All (or a good proportion of) ponds in each survey square need to be surveyed for amphibians. Great Crested Newt Habitat Suitability Index values, and other environmental data, will also be gathered.
2. A proportion (c 200 sites) of the 550 grid square amphibian network can be used as a fully random network for the surveillance of **very widespread pond species** (e.g. widespread dragonflies, common wetland plants) and, more significantly, to assess and explore **change in pond quality** using plant, animal and environmental metrics (Figure 5).
3. Additional ponds will be surveyed for localised BAP species, based on species abundance, and Habitat Directive habitat types, based on the occurrence of indicator taxa. The number of sites required to show change is not yet known, and gathering abundance data to investigate this will form part of the project's regional trials. However provisional analysis for BAP species suggests a total of c.220 sites could be adequate to monitor change in most species including: Marsh Stitchwort, Flat-sedge, Yellow Centaury, Marsh Clubmoss, Mud Snail, Pillwort, and the more widespread Tubular Water-dropwort. Random selection of these sites (Figure 6) showed that, because of overlap in the 1 km squares in which localised species occur, these 220 ponds were recorded from 134 1 km squares.
4. A small number of additional **Priority Ponds** will be selected randomly, stratified to include a proportion of sites designated, using the range of criteria used to identify Priority ponds. Preliminary assessment suggests that this would need no more than 50 additional ponds.

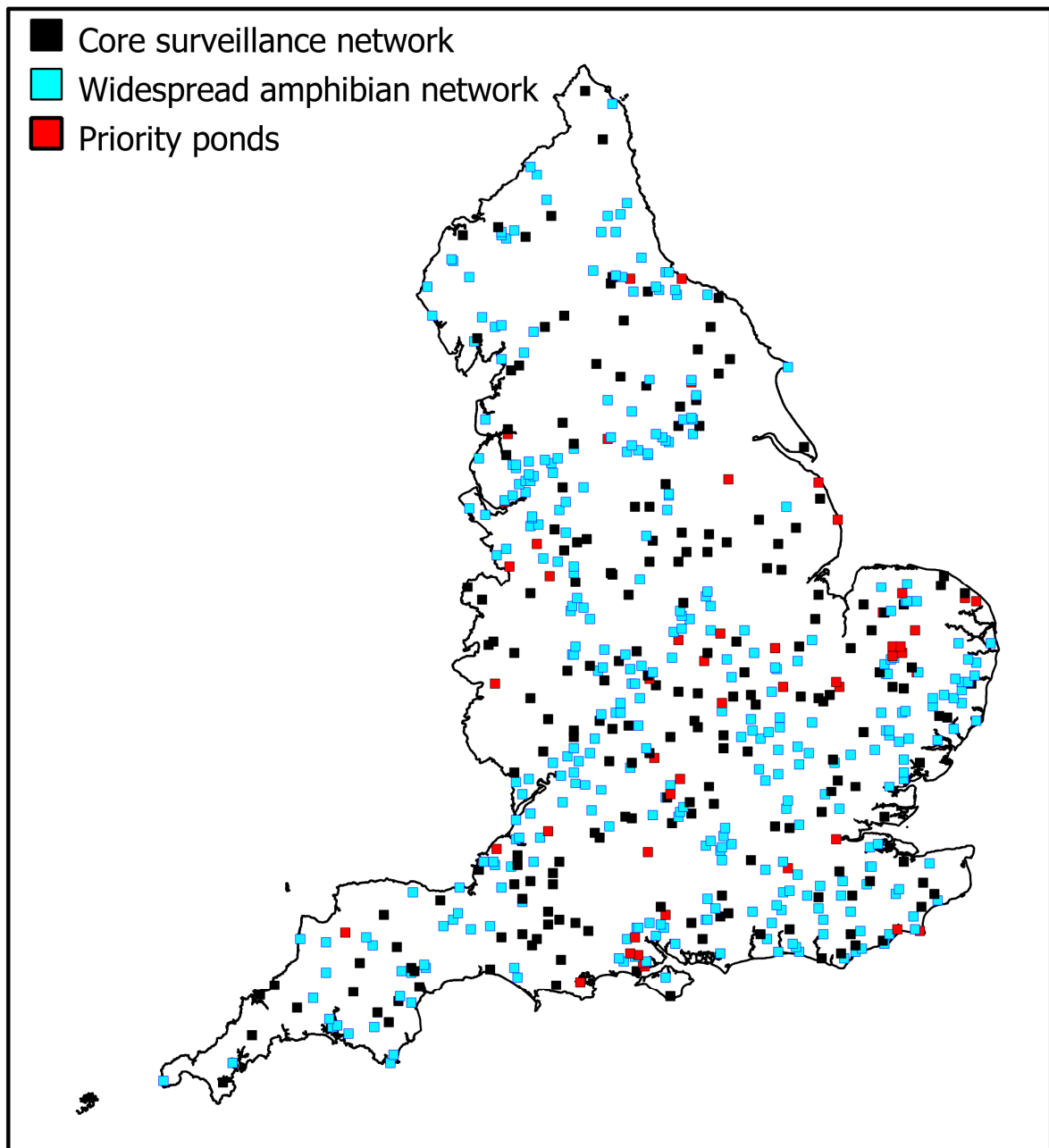


Figure 5. Pond surveillance network for widespread species and habitats, with a core of random ponds for general surveillance.

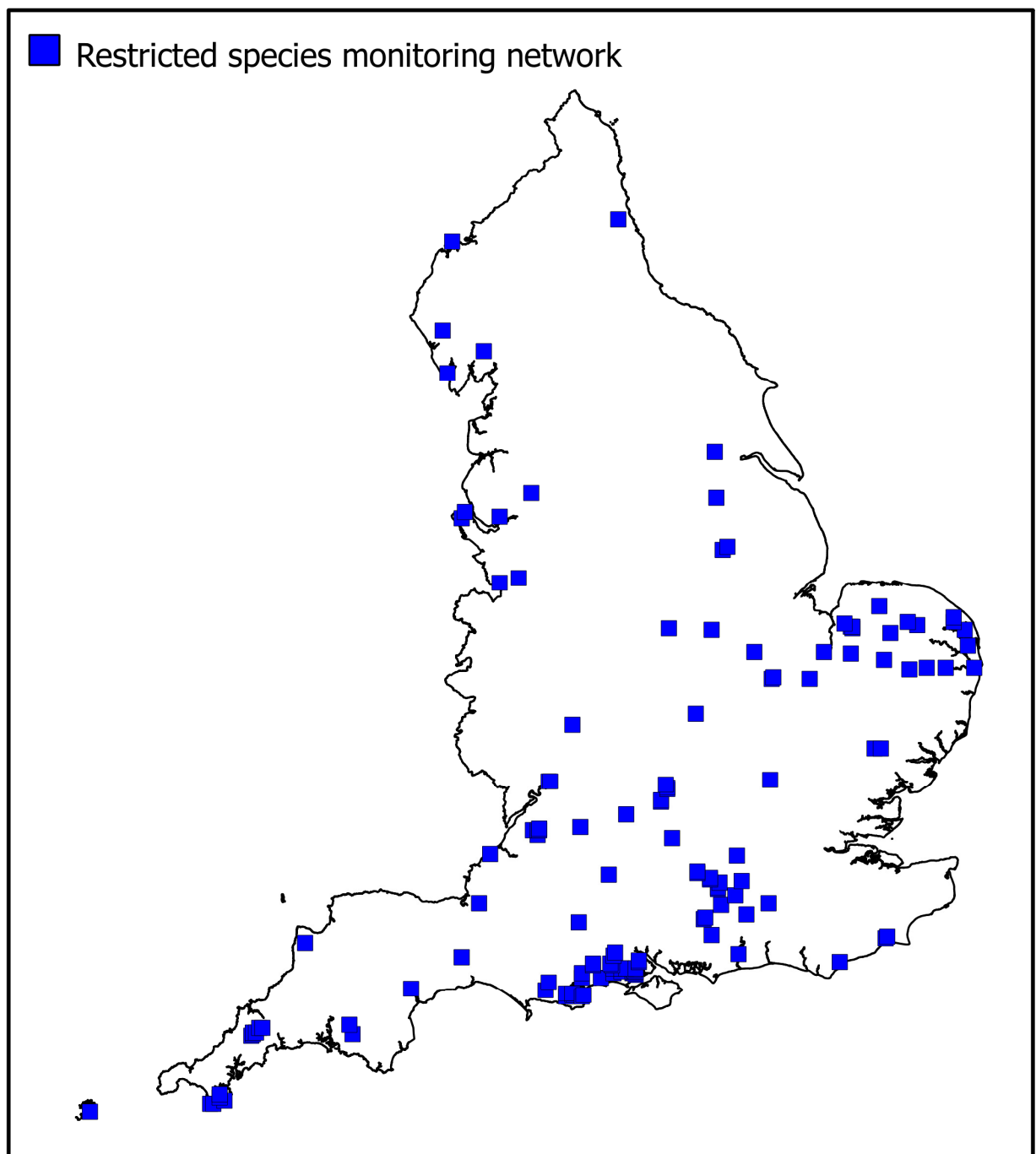


Figure 6. Pond surveillance network for localised species comprising 220 ponds within 134 1 km grid squares.

9 References

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Annex 1. 1 km grid square coincidence map for widespread and localised species

Map shows the number of species overlapping within the same 1 km grid square (+ the number of grid squares each level of overlap applies to).

