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EVALUATION OF BIRD MONITORING REQUIREMENTS IN NATIONAL PARKS

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1.0 INTRODUCTION

The National Parks in England and Wales are concerned with the status and population trends of breeding bird populations. At the present time, there is no systematic annual monitoring within National Parks nor a national scheme across parks. Parks comprise a very high proportion of upland area in England and Wales and are host to important populations of upland breeding raptors, waders and passerines. Concern for these populations arises from the potential impacts of disturbance, particularly on moorland breeding birds, but also from the general impacts of environmental change (whether man-induced, such as land management, or natural, such as successional change) across habitats. Without a coherent framework of bird monitoring, the National Parks are unable to assess their effectiveness in providing habitats for birds and are unable to identify potentially serious population declines in bird communities.

This report discusses the possibility for establishing an annual monitoring scheme for the National Parks based on the Breeding Bird Survey (BBS). This would enable the population trends and fluctuations of a range of breeding birds to be measured. It is desirable that annual monitoring within the parks is comparable with the national programmes because this allows local changes to be set in the context of a national picture. This is valuable because it is then possible to differentiate local effects, which may be remedied by local action, from national changes which require broader scale remedies. The introduction of BBS within the National Parks has the potential to meet their monitoring needs while contributing to the national monitoring of upland bird populations.

Data of this kind could only provide indirect information on the causes of population change. One such factor, which is of particular relevance to parks is disturbance and more work is required to assess the impact of disturbance, particularly on moorland birds. This issue is quite separate from that of annual bird monitoring, which forms the focus of this document, but we discuss the implications of our findings for disturbance studies.

The results we present provide an indication of the likely level of bird monitoring both within and across National Parks under different sampling frequencies in moorland habitats and across all habitats. Decisions on the suitability of BBS methods to National Park monitoring can therefore be made on the basis of the simulation results below.

1.1 Background

The BBS commenced in 1994, following extensive pilot studies, with the aim of increased observer participation in annual monitoring to achieve greater habitat and geographical coverage, than its predecessor scheme, the Common Birds Census. Pilot studies have assessed the suitability and efficiency of different survey methods and sampling strategies (Gregory & Baillie 1994). The BBS will provide population indices for about 100 of approximately 220 United Kingdom (UK) breeding species, with the national sample of about 2,000 1-km sample squares being surveyed each year. Note that the BBS methods are not designed to estimate absolute population sizes. The current sampling framework of the BBS, which is based on randomly selected squares across BTO regions in the UK, includes by chance only a small number of 1-km squares within National Parks. This sample will be much too small to provide meaningful data on its own.

The BBS is jointly funded by the BTO, JNCC (Joint Nature Conservation Committee, on behalf of the Countryside Council for Wales, English Nature, Scottish Natural Heritage, and the Department of the Environment for Northern Ireland) and the RSPB (Royal Society for the Protection of Birds).

The methodology requires an observer to walk a pair of parallel, north to south transect routes through the 1-km sample square, twice during the period April to June. All bird registrations (sight and sound), at distance categories of <25m, 25-100m and beyond 100m, from the transect line, are recorded. The observer transfers the field visit information on to summary sheets after completion of both visits. A preliminary set up visit includes habitat recording in which volunteers record detailed information at four hierarchical levels using an established BTO coding scheme. Recording birds in different distance categories enables density estimates to be made and provides information on the detectability of different species.

Having established a BBS square, observers are asked to revisit that square year after year to measures population changes. Given the variability between observers it is important that the same observer surveys his or her square each year. If an observer is unable to resurvey their square a new observer is found. Thus the survey squares are constant through time. BBS methods could be applied to year-round recording, if required.

The widespread and abundant bird species are the main target for the BBS. Surveillance of the rarer birds, for example, the merlin, requires species-specific surveys. The increased sample of moorland squares which would be achieved with the additional monitoring effort in the National Parks would increase the number of moorland breeding species for which population indices could be calculated. The advantage of using BBS for monitoring in National Parks is the use of standardised methodology, which is comparable with other studies, notably permitting comparison with national indices. It is hoped that bird monitoring within the National Parks might be extended from moorland to include other habitats and that it would embrace all the National Parks in England and Wales. The standardisation of methodology becomes particularly important if the monitoring scheme is extended in this way. BBS data could contribute to the calculation of indices for individual parks, for the parks as a whole, and for the national statistics.

1.2 Aims

Here we assess an extension of the BBS to provide coverage of the National Parks by:

1. The evaluation of sampling strategies to monitor moorland breeding birds within National Parks.

2. The evaluation of sampling strategies to monitor a larger suite of species across all habitats within National Parks.

3. Assessment of the feasibility of incorporating survey data collected by the National Parks within the national and regional BBS statistics.

The ability to monitor birds is assessed at two levels, (a) indices of population change within individual parks and (b) indices of population change across all parks. We also consider the possibility of calculating indices among subsets of BBS squares within an individual park, for example open-access compared with closed-access areas.

We assess the possibility for the statistical incorporation of National Park data within national and regional BBS databases and analyses. The incorporation of the National Parks within the framework of the BBS would necessitate the development of systems for data handling and analysis. These questions are addressed and the implications of costs assessed.

The implications of varying levels of support from individual National Parks is assessed; particularly whether or not limited sampling would be efficient and whether these could be accommodated within the national BBS scheme.

2.0 METHODS

2.1 Habitat within National Parks

This report covers all eleven National Parks in England and Wales. For the purpose of the analysis, the habitats within national parks are taken from Landscape Change in the National Parks (Anon 1991). This provides the only practical method for deriving this information. The total area of National Parks given is 14,011.8 sq.km. The area of land falling into each of the different land cover types is given in Table 1.

The National Parks Authorities are especially interested in monitoring moorland bird species. For the purpose of the analyses here, habitats within the National Parks were grouped into two categories i.e. moorland and non-moorland. The area of moorland was obtained by summing the individual areas of Upland Heath/Grass mosaic, Grass Moor and Rough Pasture taken from Landscape Change in the National Parks (Anon 1991). Rough pasture was included with the moorland because it is felt that the moorland boundary is important to many moorland species such as Wheatear and Lapwing. The area of non-Moorland was obtained by summing the individual areas of all other land cover types. Due to the heterogeneity within these groups and disparity within this category between parks, it was not feasible to subdivide habitat further. The area of land within these two categories for each of the National Parks is given in Table 2.

2.2 Modelling bird counts within National Parks

The rationale for evaluating the suitability of the BBS as a means of monitoring breeding bird populations within national parks was as follows. The ideal approach to the simulation would be to sample from complete information from 1-km squares in each National Park. However, these data are not available and so we resampled the 1-km datasets described below.

2.2.1 Survey Data

For each of the eleven National Parks, data from three independent surveys were combined and used to create a typical set of 1-km square counts. The survey data used came from:

1. Pilot Census Project (PCP) data. The PCP was the pilot study for the BBS (Gregory & Baillie 1994). Counts were based on two transect visits, one early, and one late in the breeding season. Data were collected from 303 1-km squares in 1992 and 360 1-km squares in 1993. Overall 451 different 1-km squares were sampled over the two years. Although data were collected throughout Britain they have a southern and eastern bias (Figure 1).

2. Upland survey data collected by the RSPB and provided by Dr Lennox Campbell. Data were collected in Sutherland, Perthshire, Lanarkshire, Yorkshire, the Peak District, the Forest of Trawsen and Morayshire between 1980 and 1993. Counts were based on two site visits. Data comes from 1057 different 1-km squares (Figure 2).

3. Upland survey collected by Nature Conservancy Council and provided by Drs Andy Brown and Richard Stillman. Data were collected from the Eastern Highlands and South Pennines between 1989 and 1990. Counts were based on two site visits. Data comes from 1027 different 1-km squares (Figure 3).

Where counts were available from more than one survey or more than one survey year for PCP data the highest count obtained was the one used. Overall these data cover a wide spread of sites across Britain, in total 2371 separate 1-km squares, although Wales and the south-west of England are somewhat under represented (Figure 4). **It should noted that both sets of Upland data specifically exclude raptors because of the sensitivity surrounding these species.** As described above, the BBS is not a suitable method for monitoring these birds.

The squares covered by the RSPB and NCC surveys were considered to be in the moorland category. 1-km squares covered by the PCP were cross referenced to the 32 class ITE land classification (Benefield & Bunce 1982). Of the four hundred and fifty-one squares, forty-two fell into categories which correspond to moorland the majority of the remainder falling into categories corresponding to cultivated and improved land (Table 3).

2.2.2 Sampling rationale

Moorland squares, equal in number to those in the park in question, were randomly selected from the combined PCP moorland class, RSPB and NCC data. Non-moorland squares, equal in number to those in the park in question, were randomly selected from the PCP non-moorland data. Given that for most parks the required number of non-moorland squares exceeded the number of cases in the PCP data, random selection with replacement was used. For reasons of consistency, random selection with replacement was also used when selecting moorland squares although for most parks it would have been possible to select cases randomly without replacement. The resulting datasets, based on the structure of each individual park, are considered typical in that they represent the number of 1-km squares in each of the two broad habitat types (moorland and non-moorland) and the number of different bird species likely to be encountered across a broad spectrum of species distribution pattern, abundance and visibility. **The actual species composition, however, will not be representative of the park in question due to regional biases in the survey data upon which the models were based.** Thus, for example, species such as Greenshank and Red-throated Diver will be included in the model parks although clearly not breeding in any. It also follows that regional specialities such as Red Kite or species with a southern distribution such as Little Ringed Plover will be absent or under represented. **It is, however, the pattern of distribution and abundance represented by a particular species that is important rather than its specific detail.** Also, as all species within the above surveys were accepted into the simulation, some species which would be better surveyed using other techniques were present. These would include some raptors for which one might prefer to monitor nest sites and Grey Herons and gulls for which nest counts at known colonies would be the preferred approach.

From each park dataset, a random sample with replacement was taken to represent those squares which might be surveyed in a typical survey. Two such sets of data were obtained for each park: one set, chosen only from moorland squares was taken to represent the situation if parks were to concentrate monitoring so as to target moorland species by restricting themselves to transects within moorland habitats; and one set, chosen from all

squares was taken to represent the situation if parks were to monitor species across all habitats. Within each of these datasets samples were taken which represented a survey which covered 2.5%, 5.0%, 7.5%, 10.0%, 12.5%, 15.0%, 17.5% & 20.0% of all squares within the park in question (Table 4).

Depending on the remoteness of the squares and constraints on when to visit during the day, a fieldworker dedicated to BBS could cover around 25 squares in a 3 month period (April-June). Thus a team of three employed for a three-month period could cover around 75 squares (based on surveying one square each day). If restrictions on the timing of visits during the day were relaxed, such that counts could begin and end later in the day, these numbers could be doubled or trebled. The BBS suggests that counts should begin between 0600-0700 and not later than 0900, except in remote regions. The restrictions are necessary because bird activity in most habitats varies predictably during the day. For moorland, however, these restrictions could be relaxed so that counts from two or three different squares could be completed in a single day. Note that upland surveys by NCC and RSPB tend not to be as restrictive over visit times as the BBS. For example, the constant search effort method proposed by Brown & Shepherd (1993) for upland waders involves counts between 0830 and 1800 hrs.

As an aside, it should be noted that each run of our simulation model is dependent upon the chance selection of squares and species. In some cases we have repeated this process to assess the sensitivity of our simulations to each particular run (see moorland results below). Replicating our sampling process using bootstrapping techniques (e.g. one thousand repeats) would have provided confidence limits around our assessments of coverage, but this was not generally feasible given the constraints of time within this contract.

Simulations were carried out at two levels:

1. A simulation was undertaken in which data across all parks were pooled. This allows us to assess whether species which might not be successfully monitored at the level of the individual park (rare or sparsely distributed species) could be monitored across the entire country (strictly speaking within the national parks).

2. A simulation was undertaken on a park-by-park bases. Sampling the appropriate number of squares for each particular park in turn. This provides an indication of the kind of species to be monitored within each park.

For each combination of national park and survey effort (number of 1-km squares covered) these data were then analyzed as if they had been counts obtained during an actual survey. These simulations give an indication of how many bird species would be encountered and, of these, those which could be monitored, that is, those for which population changes could be made with sufficient precision to detect between-year changes. In moorland simulations, each National Park simulated survey was undertaken 10 times in order to avoid basing the evaluation on a single, possibly uncharacteristic result.

2.3 Estimation of Precision

The estimation of the precision with which we are able to measure between-year changes in population sizes is central to the assessment of various sampling intensities. The threshold

level of precision was set at an ability to detect a 50% between-year change (i.e. a standard error of between year change of <0.25) and for species to be recorded in more than 10 different 1-km squares. [The latter criterion excludes species that are recorded in a small number of squares but occur in comparatively large numbers since standard monitoring would be unreliable.] The threshold level for ability to detect a 50% between-year change was the same as that used to evaluate sampling strategies for the BBS (Gregory & Baillie 1994). **If counts for a particular species attain this threshold then we consider that it is possible to monitor that species.**

The rationale behind derivation of standard errors from the number of bird registrations obtained during surveys is covered fully by Gregory & Baillie (1994). The across species regression equation used to calculate standard error was:

$$\text{Log}_{10}(\text{standard error}) = -0.33677 - 0.27064 * \text{Log}_{10}(\text{number of bird registrations})$$

The threshold limit for the number of 1-km squares in which a species is recorded is less than that used in the assessment of BBS which was set at 20. This resulted in a small increase in the number of species meeting the threshold requirement. Whilst these extra species were ones that we might have predicted because the sample sizes within individual parks is quite small, it is not possible to assess whether or not their inclusion in a list of species which could be monitored is justified when looking at parks in isolation. We could, however, consider the effect on parks overall of adopting these relaxed criterion. We therefore repeated the pooled parks simulation described above while using 10, 15 and 20 1-km squares per sample as the minimum number of squares criterion for each species. The results indicate that for a given level of effort with a constant threshold for standard error (0.25), the number of species which could be monitored differed little when the threshold for number of 1-km squares was reduced. This holds true for both a moorland only survey (Table 5a) and an all habitats survey (Table 5b). The particular suite of species monitored at a given level of coverage was also reasonably consistent when applying different values for number of 1-km square thresholds (see Results, Table 6). Thus, using the reduced threshold criterion within simulations for individual parks should not give an overly optimistic view of the number of species which can be successfully monitored for a given input of effort. At the same time, this approach ensures that species are not unduly rejected.

3.0 RESULTS

3.1 Monitoring Birds within Moorland Habitats

a. Monitoring across all parks

When considering surveys in which data from all parks were pooled, it was possible to compare which species would be monitored when adopting various levels for the threshold number of squares in which a particular species was encountered. The species composition remained reasonably consistent among threshold levels, at least for the lower percentages of coverage which are likely to be achievable targets (Table 6). Most species, characteristic of moorland habitats, would be monitored by a reasonable percentage coverage (e.g. Meadow Pipit, Skylark, Curlew). At higher levels of coverage further species, often found in moorland habitats but not necessarily considered as moorland species would also be monitored (e.g. Wren, Willow Warbler, Starling). Concentrating on the left-hand column of Table 6, this illustrates overall coverage across parks at different sampling effort. Even at the lowest sampling effort (2.5%) the majority of moorland birds would be adequately monitored.

b. Monitoring within individual parks

Tables 7a-i present the results from ten separate simulations at each level of coverage for each park. The values presented are the number of times a species is monitored out of ten runs (as a percentage). For example, in the Brecon Beacons the Curlew is monitored in 20% of the simulations at 7.5% sampling, and 100% of the simulations at 20% sampling.

The simulations show that for a moorland only survey, with the exceptions of Exmoor and North York Moors where no species would be monitored, with 20% coverage, five species (Curlew, Golden Plover, Meadow Pipit, Skylark and Red Grouse) tend to be consistently monitored within the parks (Tables 7a to 7i). Further species (e.g. Wheatear, Twite, Dunlin and Lapwing) would only be monitored if the number of 1-km squares was in excess of about 100. An obvious conclusion is that greater sampling effort provides increasing levels of adequate species coverage to enable detection of between-year changes. The moorland simulations are summarised in Table 8.

Figure 5 shows a roughly linear relationship between sampling effort (number of squares covered) and number of moorland species monitored across the parks. It illustrates the variability of our simulation models but the overall pattern is clear. The core moorland species begin to be adequately monitored approaching 100 squares and almost all are covered at close to 200 squares.

3.2 Monitoring Birds Across All Habitats

a. Monitoring across all parks

When considering surveys in which data from all parks were pooled, all species within the simulation would be monitored for a reasonable input of effort (Table 5b).

The sample size obtained is of the same order as that for the current BBS (around 1500 squares in 1994).

b. Monitoring within individual parks

Simulations representing individual parks show many more species would be monitored for a reasonable input of effort than would be achieved for a moorland only survey (Tables 9a-k). The lists of species that would be monitored included a reasonable proportion of moorland species (Table 10). Thus most of the species that would be monitored for a reasonable input of effort in a moorland only survey (i.e. Meadow Pipit, Skylark, Curlew, Golden Plover and Red Grouse) would also be monitored for a reasonable input of effort in an across all habitats survey. Additionally, further species, characteristic of moorland but commonly found in other habitats (e.g. Willow Warbler, Wheatear, Cuckoo and Lapwing) would also be monitored. This result reflects the fact that the National Parks tend to be dominated by moorland habitat.

To illustrate, surveying all habitats in the Brecon Beacons provides monitoring of Meadow Pipit, Skylark, Curlew and Golden Plover when sampling 5% of the area (=68 squares). Similar coverage at 12.5% of moorland habitat (=70 squares) provides a high probability of monitoring the same four species (Table 7a). A second example, Northumberland National Park indicates coverage of Skylark, Curlew and Meadow Pipit at 5% (=52 squares) across all habitats. Sampling within moorland at a similar level, 7.5% (=48 squares) suggests coverage of these three species with the chance of adding Golden Plover and Red Grouse (Table 7d). Thus the differences between surveying moorland only and all habitats are surprisingly small. In our models, sampling all habitats has the advantage that it monitors a considerable number of species, regularly found on moorland but not moorland specialities, such as Lapwing, Snipe, Cuckoo and Wheatear, would be monitored (Table 10).

Figure 6 shows the asymptotic relationship between sampling effort (number of squares covered) and number of species monitored across all habitats in the parks. The rapid increase in the number of species monitored up to 60 squares reflects the sampling of diverse habitats which are host to a variety of birds. At between 60 and 100 squares the number of new species monitored declines since many of the different bird communities have already been sampled. Sampling at greater than about 150 squares provides diminishing returns in terms of the birds monitored.

4.0 DISCUSSION

4.1 Monitoring Birds within Moorland Habitats

a. Monitoring across all parks

At the lowest level of effort considered (2.5% coverage) out of the 85 species present in the simulation, with 2.5% coverage 76% of species would be detected but only 10 species monitored (Table 5a). The 85 species present however include many species which are rare in moorland habitat having originated from the relatively small contribution from the PCP data, probably from marginal moorland habitats. The majority of the data arise from the RSPB and NCC data which includes counts from typical moorland and includes only 37 species. Thus 76% detection of species at 2.5% coverage will be a conservative estimate of what might be expected. Consideration of which species could be monitored is of greater interest. With a coverage of 2.5% the simulation suggests that it will be possible to monitor populations of abundant and obvious species, typified in the simulation by Skylark and Meadow Pipit, together with species which are more thinly dispersed yet still reasonably obvious, typified by Golden Plover, Red Grouse, Curlew, Dunlin and Lapwing (Table 6). At this percentage coverage it should also be possible to monitor populations of species which are abundant where they occur, but do so in particular moorland habitats leading to a patchy distribution. These are typified in the simulation by Wheatear which might be associated with dry or rocky slopes where they can find dry nest sites, Snipe which might be associated with marshy areas of rough pasture, and Twite which might be associated with heather dominated areas (habitat preferences from Gibbons *et al.* 1993).

The simulation suggests that increasing the percentage coverage to 5.0% would allow further species falling into the latter category to be monitored, including Common Sandpiper, Redshank, Mallard and Whinchat (Table 6). At this level of coverage the results also suggest that it would be possible to monitor populations of a few sparsely distributed, less common species, typified in the simulation by Ring Ouzel, Oystercatcher and Greenshank. If percentage coverage is increased beyond this level, occasional species such as Willow Warbler and Chaffinch, probably associated with habitats at the moorland margins would be monitored. Beyond 10% coverage very few species are added to the list of those monitored, showing that the increasing effort is not justified on a parkwide basis.

It would appear therefore that populations of the majority of bird species favouring moorland habitats, could be monitored at the country level using BBS methodology over moorland habitat contained within the National Parks. This would be possible with a readily achievable percentage coverage in the region of 2.5% to 5.0% of each National Park.

Moorland is a rather under-represented habitat within the current BBS survey (Table 3) and thus any extra level of input into moorland habitats would be a worthwhile addition to this survey. It also follows that as the PCP contained such a low proportion of moorland squares, species which favour this habitat may well have failed to attain monitoring threshold levels in the analysis of these data (Gregory &

Baillie 1994) but might do so with the addition of a large sample from moorland within National Parks.

b. Monitoring within individual parks

The simulations suggest that for moorland habitat only, it would only be possible to monitor populations of the abundant and obvious species, typified by Meadow Pipit and Skylark, and the more thinly dispersed yet still reasonably obvious species, typified by Red Grouse, Golden Plover and Curlew, whilst maintaining what might be considered an achievable number of 1-km square counts (Tables 7a to 7h). This particular suite of species would all be monitored if covering about 70 1-km squares for all simulations where the National Park in question contained a reasonable quantity of moorland (Figure 5). In order to be able to monitor the populations of less abundant or patchily distributed species, typified by Lapwing, Dunlin, Snipe, Wheatear and Twite, in general it would probably be necessary to increase the number of 1-km square counts to between 150 and 200 within a park (Figure 5). The monitoring of even more localised species, typified by Redshank, Common Sandpiper and Mallard would most likely require a sample of 1-km square counts in excess of 200.

4.2 Monitoring Birds Across All Habitats

a. Monitoring across all parks

The simulation across all habitats indicated that all but the rarer species present would be recorded, even at the lowest level of effort. Thus, for example, out of the 127 species present in the simulation, 95% of species would be detected for a 2.5% coverage and 100 monitored (Table 5b). Detailed discussion of the use of pooled national park data for monitoring species across all habitats on a country-wide scale is largely unnecessary given the large sample size that would be obtained even at the lowest percentage coverage considered here. The sample sizes that would be obtained, even for the lowest level of coverage considered, are of a similar order to those being used for the present BBS and the validity of this degree of sampling has been shown elsewhere (Gregory & Baillie 1994).

b. Monitoring within individual parks

A far greater number of species would be monitored within individual parks with an across all habitats survey than would be achieved with a moorland only survey (Table 9, Figure 6). Many additional species, characteristic of habitats other than moorland would be covered by such a survey (Table 9). More interestingly, the five moorland species which would be monitored by a moorland only survey, would generally be monitored by an all habitats survey (Table 10). This is particularly true for the parks where moorland constitutes a significant proportion of the habitat. Besides additional species characteristic of non-moorland habitats, species which are characteristic of moorland but also occupy other habitats, such as Cuckoo, Lapwing, Oystercatcher, Snipe and Wheatear would also be monitored by an all habitats survey, whereas they would not be monitored by a moorland habitats only survey.

4.3 Incorporating survey data collected by the National Parks within the national and regional BBS statistics

The incorporation of National Park data within the BBS is a vital part of the monitoring exercise. It is highly desirable that the data are complementary so that National Park data contribute to the national population indices and at the same time BBS data enable population changes in the Parks to be set in the context of the national picture. The use of the same survey methods, recording forms, data checking and processing, and calculation of population indices would be highly efficient. Much of the development of the BBS has already taken place.

The incorporation of National Park data raises both statistical and practical issues both of which are readily overcome. The main point is that the BBS is based on a formal sampling strategy, which involves random sampling of 1-km squares from 83 BTO regions in the UK, weighted by observer density. Essentially, incorporation of the National Parks would mean the creation of pseudo-BTO regions for sampling and analysis. This increases the degrees of freedom in statistical tests of these data but has little effect on the overall design of the scheme. Analysis would then require the appropriate statistical weighting of each of the regions. Figure 7 illustrates how we would create new regions based upon (a) sampling across a National Park and (b) across just moorland habitat within a park. Analysis would then be based on four instead of three regions in both cases. **The creation and incorporation of these regions would require a computerised listing of which 1-km squares fell into each of the new regions.**

The sampling intensity within the new regions would be dictated by the requirements and constraints of the parks themselves and would need to be consistent from year to year. The long-term nature of population monitoring necessitates a committed effort for the set up costs of any incorporation to be justified. Square selection within the parks would have to be based on some kind of randomized design to be compatible with BBS data.

All BBS data are stored within an Oracle database which allows rapid retrieval and updating.

4.4 Alternative approaches

The monitoring of moorland within parks (Table 7) demonstrates an inevitable limitation of the BBS approach, in that a relatively large number of squares must by surveyed to provide a high level of coverage for all the species of interest. Thus any comparison of habitats within moorland (e.g. open access versus closed access) would require large sample sizes to be meaningful. The general point here is that specific questions of this kind are likely to require relatively intensive, and presumably costly investigations. In such cases, alternative methods of survey work which attempt to provide a complete census of an area might be more appropriate. For example, a mixture of territory mapping and nest searches might be suitable, though this would depend on the species of interest and resources available. Another possibility would be the constant search method, designed specifically for upland breeding waders, although this only provides an index of population size (Brown & Shepherd 1993).

4.5 Conclusions

In summary, surveys within the National Parks based on BBS methodology would provide basic long-term bird monitoring of the parks and make an important contribution to the current BBS, particularly towards the monitoring of birds characteristic of moorland habitats. The BBS would provide base-line information on population trends through time for a suite of species depending on sampling design and intensity.

Pooling data from all national parks for moorland habitat only would allow populations of most moorland birds to be monitored at the national level. Pooling data for all habitat surveys would produce a dataset of equal standing to the present BBS, although with a moorland bias.

From our simulation models it would appear that the most productive monitoring strategy for individual parks would be surveying across all habitats. Not only would many species from non-moorland habitats be monitored, but most species which would be monitored by a moorland habitat only survey would be monitored in any case, together with additional species, often associated with moorland.

The final decision on the most suitable bird monitoring strategies for the parks will depend on their individual and collective requirements which will be balanced by the costs involved. The BBS represents a cost-effective method to monitor birds in the National Parks and the simulation results we present allow the suitability of different sampling approaches to be assessed.

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Table 1 Area (with percentage) of different land cover types in National Parks as a whole in the 1980s(sq.km). Derived from Landscape Change in the National Parks (Anon 1991).

Land Cover Type	Area (sq.km)
Upland Heath/Grass mosaic	623.3 (4.45%)
Grass Moor	3137.8 (22.39%)
Broadleaf & Mixed Woodland	649.7 (4.64%)
Rough Pasture	1112.6 (7.94%)
Heathland	1361.6 (9.72%)
Coniferous High Forest	921.1 (6.57%)
Scrub	90.3 (0.64%)
Clearfelled/Newly Planted Forest	210.1 (1.50%)
Bracken	648.5 (4.63%)
Improved Pasture	3958.7 (28.25%)
Cultivated	630.7 (4.50%)
Rock & Coastal	226.6 (1.62%)
Water & Wetland	195.8 (1.40%)
Developed land	217.8 (1.55%)
Unclassified/Other	27.2 (0.20%)
TOTAL	14,011.8

Table 2 Proportion of Moorland and Other Land Cover Types in individual National Parks in the 1980s(sq.km). Derived from Landscape Change in the National Parks (Anon 1991).

National Park	Area of moorland (sq.km)	Area of Non-Moorland (sq.km)
Brecon Beacons	570.2 (42.2%)	781.2 (57.8%)
Norfolk Broads	0.0 (0%)	302.9 (100%)
Dartmoor	430.0 (45.1%)	524.3 (54.9%)
Exmoor	163.1 (23.5%)	529.7 (76.5%)
The Lake District	990.4 (43.2%)	1301.6 (56.8%)
Northumberland	643.8 (61.3%)	405.7 (38.7%)
The North York Moors	387.1 (27.0%)	1048.9 (73.0%)
The Peak District	570.9 (40.0%)	867.4 (60.0%)
Pembrokeshire	37.2 (6.0%)	584.3 (94.0%)
Snowdonia	1204.5 (56.2%)	937.1 (43.8%)
The Yorkshire Dales	1125.9 (63.7%)	642.8 (36.3%)
TOTAL	6085.9 (43.4%)	7925.9 (57.6%)

Table 3 Number (and %) of 1-km squares covered during PCP falling into each of 32 ITE landcover classes and moorland/non-moorland categories used for this analysis. These PCP data were assigned to 42 (9.3%) moorland and 409 (90.7%) non-moorland squares as indicated in the right-hand column.

ITE Landclass	1-km squares covered by PCP, n (%)	moorland (M) /non-moorland (O)
1	35 (7.8%)	O
2	58 (12.9%)	O
3	48 (10.7%)	O
4	20 (4.5%)	O
5	14 (3.1%)	O
6	19 (4.2%)	O
7	8 (1.8%)	O
8	14 (3.1%)	O
9	25 (5.6%)	O
10	34 (7.6%)	O
11	30 (6.7%)	O
12	11 (2.4%)	O
13	20 (4.5%)	O
14	3 (0.7%)	O
15	5 (1.1%)	O
16	7 (1.6%)	O
17	23 (5.1%)	O
18	8 (1.8%)	M
19	7 (1.6%)	M
20	2 (0.4%)	M
21	4 (0.9%)	M
22	7 (1.6%)	M
23	1 (0.2%)	M
24	1 (0.2%)	M
25	12 (2.7%)	O
26	7 (1.6%)	O
27	10 (2.2%)	O
28	4 (0.9%)	O
29	1 (0.2)%	M
30	1 (0.2)%	M
31	5 (1.1)%	M
32	5 (1.1)%	M

Table 4 Number of 1-km squares that would need to be surveyed in order to achieve 2.5%, 5.0%, 7.5%, 10.0%, 12.5%, 15.0%, 17.5% & 20.0% coverage of National Parks, for both moorland only, and all habitat surveys.

National Park	Moorland								All Habitats							
	2.5 %	5.0 %	7.5 %	10.0%	12.5%	15.0%	17.5%	20.0 %	2.5%	5.0 %	7.5 %	10.0%	12.5%	15.0%	17.5%	20.0%
The Brecon Beacons	14	28	42	56	70	84	98	112	34	68	102	136	170	204	238	272
The Broads	0	0	0	0	0	0	0	0	8	16	24	32	40	48	56	64
Dartmoor	11	22	33	44	55	66	77	88	24	48	72	96	120	144	168	192
Exmoor	4	8	12	16	20	24	28	32	17	34	51	68	85	102	119	136
The Lake District	25	50	75	100	125	150	175	200	57	114	171	228	285	342	399	456
Northumberland	16	32	48	64	80	96	112	128	26	52	78	104	130	156	182	208
The North York Moors	10	20	30	40	50	60	70	80	36	72	108	144	180	216	252	288
The Peak District	14	28	42	56	70	84	98	112	36	72	108	144	180	216	252	288
Pembrokeshire Coast	1	2	3	4	5	6	7	8	15	30	45	60	75	90	105	120
Snowdonia	30	60	90	120	150	180	210	240	54	108	162	216	270	324	378	432
The Yorkshire Dales	28	56	84	112	140	168	196	224	44	88	132	176	220	264	308	352

Table 5a Number of species which could be monitored,in a **moorland only survey**, with increasing coverage and varying threshold levels. The threshold for standard error is fixed at 0.25, for the number of 1-km squares in which a species was encountered increasing (10, 15 & 20). The total number of species present in the simulation was 85.

Effort (% 1-km squares covered)	Number of squares required to achieve this coverage (sum from all parks)	Number of species encountered by simulation	Number surpassing overall threshold Threshold number of squares set at -		
			10	15	20
2.5%	304	65	10	8	6
5.0%	608	47	18	12	10
7.5%	912	61	19	16	14
10.0%	1216	79	28	20	18
12.5%	1520	67	24	20	19
15.0%	1824	62	25	21	18
17.5%	2128	85	31	26	23
20.0%	2432	81	27	25	24

Table 5b Number of species which could be monitored, in an **all habitats survey**, with increasing coverage and varying threshold levels. The threshold for standard error is fixed at 0.25, for the number of 1-km squares in which a species was encountered increasing (10, 15 & 20). The total number of species present in the simulation was 127.

Effort (% 1-km squares covered)	Number of squares required to achieve this coverage (sum from all parks)	Number of species encountered by simulation	Number surpassing overall threshold Threshold number of squares set at -		
			10	15	20
2.5%	702	121	100	93	88
5.0%	1404	122	108	105	99
7.5%	2106	126	113	109	107
10.0%	2808	125	117	112	109
12.5%	3510	124	118	115	111
15.0%	4212	125	120	116	113
17.5%	4914	127	119	119	117
20.0%	5616	127	122	118	117

Table 6 Effort levels at which bird species are monitored for a **moorland habitats only survey** with the threshold for the number of 1-km squares in which a species is detected set at 10, 15 & 20. Figures in italics refer to cumulative number of species monitored for the corresponding percentage coverage. The simulation is based on the **pooled National Parks** model.

Percentage coverage (number 1-km squares)	*Cumulative list of species monitored by percentage coverage threshold number of squares set at -*		
	10	*15*	*20*
2.5% (304)	Curlew Dunlin Golden Plover Lapwing Meadow Pipit Red Grouse Skylark Snipe Twite Wheatear *(10)*	Curlew Dunlin Golden Plover Lapwing Meadow Pipit Red Grouse Skylark Wheatear *(8)*	Curlew Dunlin Golden Plover Meadow Pipit Red Grouse Skylark *(6)*
5.0% (608)	Crow Cuckoo Common Sandpiper Greenshank Mallard Oystercatcher Redshank Ring Ouzel Whinchat *(19)*	Common Sandpiper Crow Snipe Twite *(12)*	Lapwing Snipe Twite Wheatear *(10)*
7.5% (912)	Black-headed Gull Canada Goose Chaffinch Grey Wagtail Reed Bunting Starling Willow Warbler Wren *(27)*	Cuckoo Greenshank Redshank Ring Ouzel *(16)*	Crow Common Sandpiper Redshank Ring Ouzel *(14)*
10.0% (1216)	None	Grey Wagtail Mallard Oystercatcher Pied Wagtail *(20)*	Greenshank Mallard Pied Wagtail Whinchat *(18)*
12.5% (1520)	Red-throated Diver Teal *(29)*	Teal Whinchat *(22)*	Cuckoo Oystercatcher Teal *(21)*
15.0% (1824)	None	Black-headed Gull Canada Goose Reed Bunting *(25)*	None
17.5% (2128)	Robin *(30)*	None	Canada Goose Reed Bunting *(23)*
20.0% (2432)	None	Red-throated Diver *(26)*	Grey Wagtail *(24)*

Table 7a Proportion of simulations in which individual species are monitored at the corresponding percentage coverage of 1-km squares for a moorland habitat only survey of Brecon Beacons.

Species	Percentage Coverage (and number of 1-km squares)							
	2.5% (14)	5.0% (28)	7.5% (42)	10.0% (56)	12.5% (70)	15.0% (84)	17.5% (98)	20.0% (112)
Carrion Crow								
Common Sandpiper								
Cuckoo								
Curlew			20	60	80	100	100	100
Dunlin								10
Golden Plover			10	70	70	100	90	100
Lapwing							20	10
Mallard								
Meadow Pipit		20	80	100	100	100	100	100
Red grouse					30	80	90	100
Redshank								
Ring Ouzel								
Skylark			30	90	100	100	100	100
Snipe								10
Twite								
Wheatear						10		10

Table 7b Proportion of simulations in which individual species are monitored at the corresponding percentage coverage of 1-km squares for a moorland habitat only survey of Dartmoor.

Species	Percentage Coverage (and number of 1-km squares)							
	2.5% (11)	5.0% (22)	7.5% (33)	10.0% (44)	12.5% (55)	15.0% (66)	17.5% (77)	20.0% (88)
Carrion Crow								
Common Sandpiper								
Cuckoo								
Curlew					70	80	100	100
Dunlin						10		
Golden Plover					60	80	90	100
Lapwing								20
Mallard								
Meadow Pipit		10	70	90	100	100	100	100
Red grouse					30	30	60	40
Redshank								
Ring Ouzel								
Skylark			20	50	80	90	100	100
Snipe							10	
Twite								
Wheatear								10

Table 7c Proportion of simulations in which individual species are monitored at the corresponding percentage coverage of 1-km squares for a moorland habitat only survey of Lake District.

Species	Percentage Coverage (and number of 1-km squares)							
	2.5% (25)	5.0% (50)	7.5% (75)	10.0% (100)	12.5% (125)	15.0% (150)	17.5% (175)	20.0% (200)
Carrion Crow								
Common Sandpiper								
Curlew		50	70	100	100	100	10	100
Dunlin				10		20	40	80
Golden Plover		50	100	100	100	100	100	100
Lapwing					60	80	90	100
Mallard							100	100
Meadow Pipit		100	100	100	100	100		
Red grouse		10	20	80	100	100	100	100
Redshank								
Ring Ouzel								
Skylark		90	100	100	100	100	100	100
Snipe					10	10	30	40
Twite					20	40	30	60
Wheatear				10		20	50	80

Table 7d Proportion of simulations in which individual species are monitored at the corresponding percentage coverage of 1-km squares for a moorland habitat only survey of Northumberland.

Species	Percentage Coverage (and number of 1-km squares)							
	2.5% (16)	5.0% (32)	7.5% (48)	10.0% (64)	12.5% (80)	15.0% (96)	17.5% (112)	20.0% (128)
Carrion Crow						10		
Common Sandpiper								
Curlew		20	80	100	100	100	100	100
Dunlin					20	20	20	80
Golden Plover		30	90	100	100	100	100	100
Lapwing						70	60	70
Mallard								
Meadow Pipit		100	100	100	100	100	100	100
Red grouse			60	70	90	100	100	100
Redshank								
Ring Ouzel								
Skylark		60	100	100	100	100	100	100
Snipe						30	30	40
Twite			10			20	60	60
Wheatear						40	20	20

Table 7e Proportion of simulations in which individual species are monitored at the corresponding percentage coverage of 1-km squares for a moorland habitat only survey of North Yorkshire moors.

Species	Percentage Coverage (and number of 1-km squares)							
	2.5% (10)	5.0% (20)	7.5% (20)	10.0% (44)	12.5% (50)	15.0% (60)	17.5% (70)	20.0% (80)
Carrion Crow								
Common Sandpiper								
Curlew					10	20	20	10
Dunlin								
Golden Plover						20	30	20
Lapwing								
Mallard								
Meadow Pipit						70	100	90
Red Grouse								
Redshank								
Ring Ouzel								
Skylark						30	50	60
Snipe								
Twite								
Wheatear								

Table 7f Proportion of simulations in which individual species are monitored at the corresponding percentage coverage of 1-km squares for a moorland habitat only survey of The Peak District.

Species	Percentage Coverage (and number of 1-km squares)							
	2.5% (14)	5.0% (28)	7.5% (42)	10.0% (56)	12.5% (70)	15.0% (84)	17.5% (98)	20.0% (112)
Carrion Crow								
Common Sandpiper								
Curlew			30	30	70	80	100	100
Dunlin								
Golden Plover		10	30	40	100	90	100	100
Lapwing						10	10	10
Mallard								
Meadow Pipit		30	90	90	100	100	100	100
Red grouse					20	60	70	90
Redshank								
Ring Ouzel								
Skylark			60	90	90	100	100	100
Snipe								
Twite								10
Wheatear								

Table 7g Proportion of simulations in which individual species are monitored at the corresponding percentage coverage of 1-km squares for a moorland habitat only survey of Snowdonia.

Species	Percentage Coverage (and number of 1-km squares)							
	2.5% (30)	5.0% (60)	7.5% (90)	10.0% (120)	12.5% (150)	15.0% (180)	17.5% (210)	20.0% (240)
Carrion Crow					20	10	30	20
Common Sandpiper							20	20
Curlew	20	100	100	100	100	100	100	100
Dunlin				10	50	90	90	100
Golden Plover	50	100	100	100	100	100	100	100
Lapwing			30	60	90	100	100	100
Mallard							30	
Meadow Pipit	90	100	100	100	100	100	100	100
Red grouse		50	100	100	100	100	100	100
Redshank								10
Ring Ouzel							10	10
Skylark	60	100	100	100	100	100	100	100
Snipe				30	50	50	100	100
Twite			10	30	100	90	100	100
Wheatear			10	40	6	90	90	100

Table 7h Proportion of simulations in which individual species are monitored at the corresponding percentage coverage of 1-km squares for a moorland habitat only survey of The Yorkshire Dales.

Species	Percentage Coverage (and number of 1-km squares)							
	2.5% (28)	5.0% (56)	7.5% (84)	10.0% (112)	12.5% (140)	15.0% (168)	17.5% (196)	20.0% (224)
Carrion Crow					20	10	60	80
Common Sandpiper						10	20	20
Cuckoo								10
Curlew	10	90	100	100	100	100	100	100
Dunlin			10	90	90	100	100	100
Golden Plover	40	100	100	100	100	100	100	100
Lapwing			70	100	90	100	100	100
Mallard							10	10
Meadow Pipit	100	100	100	100	100	100	100	100
Red grouse		90	100	100	100	100	100	100
Redshank				10		10		10
Ring Ouzel							20	
Skylark	70	100	100	100	100	100	100	100
Snipe				40	60	70	90	100
Twite			30	60	80	100	100	100
Wheatear			40	40	100	80	100	100

Table 8 Species of moorland birds which would be monitored by a **moorland** only survey. Percentages refer to the percentage coverage at which a given species was monitored in 100% of simulations for the corresponding park (based on Table 7). Values in parentheses refer to the number of 1-km squares which give the corresponding percentage coverage.

National Park	Moorland species monitored by a moorland only survey
Brecon Beacons	Meadow Pipit 10.0% (56) Skylark 12.5% (70) Curlew 15% (84) Red Grouse 20.0% (112)
Dartmoor	Meadow Pipit 12.5% (55) Curlew, Skylark 17.5% (77) Golden Plover 20.0% (88)
The Lake District	Meadow Pipit 5.0% (50) Skylark, Golden Plover 7.5% (75) Curlew 10.0% (100) Red Grouse 12.5% (125) Lapwing 20% (200)
Northumberland	Meadow Pipit 5.0% (32) Skylark 7.5% (48) Curlew, Golden Plover 10.0% (64) Red Grouse 15.0% (96)
The North York Moors	Meadow Pipit 17.5% (70)
The Peak District	Meadow Pipit, Golden Plover 12.5% (70) Skylark 15.0% (84) Curlew 17.5% (98)
Snowdonia	Curlew, Golden Plover, Meadow Pipit, Skylark 5.0% (60) Red Grouse 7.5% (90) Twite 12.5% (150) Lapwing 15.0% (180) Snipe 17.5% (210) Wheatear, Dunlin 20% (240)
The Yorkshire Dales	Meadow Pipit 2.5% (28) Skylark, Golden Plover 5.0% (56) Curlew, Red Grouse 7.5% (84) Lapwing 10.0% (112) Wheatear 12.5% (140) Dunlin, Twite 15.0% (168) Snipe 20.0% (224)

Table 9a Cumulative list of species monitored for increasing coverage of 1-km squares within an **across all habitats** simulation of the Brecon Beacons National Park. The list is restricted to an achievable percentage coverage for the park in question.

2.5% coverage (34 1-km squares)	5.0% coverage (68 1-km squares)	7.5% coverage (102 1-km squares)	10.0% coverage (136 1-km squares)	12.5% coverage (170 1-km squares)	15.0% coverage (204 1-km squares)
Blackbird	Black-headed Gull	Bullfinch	Buzzard	Coot	Dunlin
Blackcap	Chiffchaff	Coal Tit	Corn Bunting	Twite *(72)*	Snipe
Blue Tit	Curlew	Goldcrest	Canada Goose		Yellow Wagtail *(75)*
Carrion Crow	Feral Pigeon	Great spotted	Feral Pigeon		
Collard Cove	Golden Plover	Woodpecker	Garden Warbler		
Chaffinch	Goldfinch	Grey Heron	Lesser Whitethroat		
Cuckoo	Green Woodpecker	Herring Gull	Mute Swan		
Dunnock	House Sparrow	Lesser Black-backed	Nuthatch		
Great Tit	Jay	Gull	Spotted Flycatcher		
Greenfinch	Kestrel	Oystercatcher	Treecreeper		
House Sparrow	Lapwing	Grey Partridge	Turtle Dove		
Jackdaw	Mallard	Reed Bunting	Tree Sparrow *(70)*		
Linnet	Moorhen	Red Grouse			
Mistle Thrush	Stock Dove	Red-legged Partridge			
Magpie	Wheatear *(44)*	Sedge Warbler			
Meadow Pipit		Sparrowhawk *(58)*			
Pheasant					
Pied Wagtail					
Robin					
Rook					
Skylark					
Song Thrush					
Starling					
Swallow					
Swift					
Whitethroat					
Willow Warbler					
Woodpigeon					
Wren *(29)*					

Table 9b Cumulative list of species monitored for increasing coverage of 1-km squares within an **across all habitats** simulation of The Norfolk Broads National Park. The list is restricted to an achievable percentage coverage for the park in question.

5.0% coverage (16 1-km squares)	7.5% coverage (24 1-km squares)	10.0% coverage (32 1-km squares)	12.5% coverage (40 1-km squares)	15.0% coverage (48 1-km squares)	17.5% coverage (56 1-km squares)	20.0% coverage (64 1-km squares)
Blackbird	Blackcap	Black-headed Gull	Bullfinch	Green Woodpecker	Great Spotted	Lesser Black-backed Gull
Blue Tit	Bullfinch	Garden Warbler	Feral Pigeon	*(49)*	Woodpecker	*(57)*
Carrion Crow	Chiffchaff	Goldcrest	Jay		Grey Heron	
Chaffinch	Collard Dove	House Martin	Moorhen		Herring Gull	
Dunnock	Cuckoo	Kestrel	Meadow Pipit		Lesser Whitethroat	
Great Tit	Goldfinch	Lapwing	Reed Bunting		Nuthatch	
Greenfinch	House Sparrow	Stock Dove	*(48)*		Grey Partridge	
Jackdaw	Linnet	*(42)*			Red-legged Partridge	
Magpie	Long-tailed Tit				*(56)*	
Robin	Mallard					
Rook	Mistle Thrush					
Song Thrush	Pheasant					
Starling	Pied Wagtail					
Swallow	Skylark					
Willow Warbler	Swift					
Woodpigeon	Whitethroat					
Wren	*(35)*					
Yellowhammer						
(18)						

Table 9c Cumulative list of species monitored for increasing coverage of 1-km squares within an **across all habitats** simulation of Dartmoor National Park. The list is restricted to an achievable percentage coverage for the park in question.

2.5% coverage (24 1-km squares)	5.0% coverage (48 1-km squares)	7.5% coverage (72 1-km squares)	10.0% coverage (96 1-km squares)	12.5% coverage (120 1-km squares)	15.0% coverage (144 1-km squares)	17.5% coverage (72 1-km squares)	20.0% coverage (168 1-km squares)
Blackbird	Blackcap	Black-headed Gull	Corn Bunting	Canada Goose	Coot	Lesser Whitethroat *(72)*	Great Black-backed Gull
Blue Tit	Carrion Crow	Bullfinch	Moorhen	Cuckoo	Dunlin		Mute Swan
Chaffinch	Chiffchaff	Coal Tit	Grey Partridge	Goldcrest	Lesser Black-backed Gull		Raven
Dunnock	Collard Dove	Garden Warbler	Reed Bunting	Moorhen	Spotted Flycatcher *(71)*		Tree Sparrow
Great Tit	Curlew	Golden Plover	Red-legged Partridge	Oystercatcher			Yellow Wagtail *(77)*
Linnet	Feral Pigeon	Great spotted Woodpecker	Snipe *(57)*	Sparrowhawk			
Meadow Pipit	Goldfinch	Grey Heron		Sedge Warbler			
Robin	Greenfinch	Herring Gull		Turtle Dove			
Skylark	Green Woodpecker	Kestrel		Twite			
Woodpigeon	House Martin	Lapwing		Wheatear *(67)*			
Wren *(12)*	House Sparrow	Long-tailed Tit					
	Jackdaw	Nuthatch					
	Mistle Thrush	Red Grouse *(51)*					
	Mallard						
	Magpie						
	Pheasant						
	Pied Wagtail						
	Rook						
	Song Thrush						
	Starling						
	Stock Dove						
	Swallow						
	Swift						
	Whitethroat						
	Willow Warbler						
	Yellowhammer *(38)*						

Table 9d Cumulative list of species monitored for increasing coverage of 1-km squares within an **across all habitats** simulation of Exmoor National Park. The list is restricted to an achievable percentage coverage for the park in question.

2.5% coverage (17 1-km squares)	5.0% coverage (34 1-km squares)	7.5% coverage (51 1-km squares)	10.0% coverage (68 1-km squares)	12.5% coverage (85 1-km squares)	15.0% coverage (102 1-km squares)	17.0% coverage (119 1-km squares)	20.0% coverage (136 1-km squares)
Blackbird	Blackcap	Black-headed	Bullfinch	Corn Bunting	Buzzard	Oystercatcher	Garden Warbler
Blue Tit	Chiffchaff	Gull	G Spotted	Goldcrest	Canada Goose	*(66)*	Moorhen *(68)*
Chaffinch	Collard Dove	Carrion Crow	Woodpecker	Lesser	Nuthatch		
Dunnock	Curlew	Coal Tit	Green	Whitethroat	Grey Partridge		
Robin	Garden Warbler	Cuckoo	Woodpecker	Sedge Warbler	Spotted		
Skylark	Goldfinch	Feral Pigeon	Herring Gull	Turtle Dove	Flycatcher		
Song Thrush	Great Tit	Kestrel	Lesser B-backed	*(56)*	Sparrowhawk		
Woodpigeon	Greenfinch	Long-tailed Tit	Gull		Treecreeper		
Wren	Grey Heron	Reed Bunting	*(51)*		Tree Sparrow		
(9)	House Martin	Stock Dove			Wheatear		
	House Sparrow	*(46)*			*(65)*		
	Jay						
	Jackdaw						
	Lapwing						
	Mallard						
	Magpie						
	Meadow Pipit						
	Mistle Thrush						
	Pheasant						
	Pied Wagtail						
	Red-legged Partridge						
	Rook						
	Starling						
	Swallow						
	Swift						
	Whitethroat						
	Willow Warbler						
	Yellowhammer						
	(37)						

Table 9e Cumulative list of species monitored for increasing coverage of 1-km squares within an **across all habitats** simulation of The Lake District National Park. The list is restricted to an achievable percentage coverage for the park in question.

2.5% coverage (57 1-km squares)	5.0% coverage (114 1-km squares)	7.5% coverage (171 1-km squares)
Blackbird	Black-headed Gull	Corn Bunting
Blackcap	Bullfinch	Canada Goose
Blue Tit	Feral Pigeon	Coal Tit
Carrion Crow	Green Woodpecker	Coot
Collard Cove	Grey Heron	Dunlin
Chaffinch	Grey Partridge	Goldcrest
Chiffchaff	Herring Gull	Great Spotted Woodpecker
Cuckoo	Jay	Garden Warbler
Curlew	Kestrel	Lesser Black-backed Gull
Dunnock	Long-tailed Tit	Mute Swan
Golden Plover	Moorhen	Oystercatcher
Goldfinch	Nuthatch	Sparrowhawk
Great Tit	Stock Dove	Sedge Warbler
Greenfinch	Red-legged Partridge	Twite *(73)*
House Sparrow	Reed Bunting	
Jackdaw	Snipe	
Lapwing	Spotted Flycatcher	
Linnet	Treecreeper	
Mistle Thrush	Turtle Dove	
Mallard	Wheatear *(59)*	
Magpie		
Meadow Pipit		
Pheasant		
Pied Wagtail		
Red Grouse		
Robin		
Rook		
Skylark		
Song Thrush		
Starling		
Stock Dove		
Swallow		
Swift		
Whitethroat		
Willow Warbler		
Woodpigeon		
Wren		
Willow Warbler		
Yellowhammer *(39)*		

Table 9f Cumulative list of species monitored for increasing coverage of 1-km squares within an **across all habitats** simulation of Northumberland National Park. The list is restricted to an achievable percentage coverage for the park in question.

2.5% coverage (26 1-km squares)	5.0% coverage (52 1-km squares)	7.5% coverage (78 1-km squares)	10.0% coverage (104 1-km squares)	12.5% coverage (130 1-km squares)	15.0% coverage (156 1-km squares)	17.5% coverage (182 1-km squares)
Skylark *(1)*	Blackbird Blackcap Blue Tit Carrion Crow Collard Dove Chaffinch Cuckoo Curlew Dunnock Goldfinch Great Tit Greenfinch House Sparrow Jackdaw Lapwing Linnet Magpie Meadow Pipit Mistle Thrush Pheasant Pied Wagtail Robin Red Grouse Rook Song Thrush Starling Stock Dove Swallow Whitethroat Willow Warbler Woodpigeon Wren Yellowhammer *(34)*	Black-headed Gull Chiffchaff Coal Tit Feral Pigeon Garden Warbler Great spotted Woodpecker Green Woodpecker House Martin Kestrel Long-tailed Tit Mallard Spotted Flycatcher Swift *(47)*	Grey Heron Lesser Whitethroat Moorhen Reed Bunting Red-legged Partridge Twite Wheatear *(54)*	Buzzard Canada Goose Dunlin Jay Lesser Black-backed Gull Nuthatch Treecreeper *61)*	Herring Gull Snipe Turtle Dove *(64)*	Oystercatcher Redshank Spotted Flycatcher *(67)*

Table 9g Cumulative list of species monitored for increasing coverage of 1-km squares within an **across all habitats** simulation of The North York Moors National Park. The list is restricted to an achievable percentage coverage for the park in question.

2.5% coverage (36 1-km squares)	5.0% coverage (72 1-km squares)	7.5% coverage (108 1-km squares)	10.0% coverage (144 1-km squares)	12.5% coverage (180 1-km squares)
Blackbird	Bullfinch	Canada Goose	Buzzard	Mute Swan
Blackcap	Black-headed Gull	Goldcrest	Corn Bunting	Marsh Tit
Blue Tit	Collard Dove	House Sparrow	Jay	Redstart
Carrion Crow	Curlew	Lesser Whitethroat	Lesser Black-backed Gull	Stonechat
Chiffchaff	Feral Pigeon	Nuthatch	Oystercatcher	Sparrowhawk
Collard Dove	Garden Warbler	Grey Partridge	Sedge Warbler	Treecreeper
Chaffinch	Great spotted Woodpecker	Reed Bunting	Yellow Wagtail *(68)*	Tawny Owl *(75)*
Coal Tit	Green Woodpecker	Tree Sparrow		
Cuckoo	Grey Heron	Wheatear *61)*		
Dunnock	Herring Gull			
Goldfinch	House Martin			
Great Tit	Kestrel			
Greenfinch	Long-tailed Tit			
House Sparrow	Moorhen			
Jackdaw	Red-legged Partridge			
Lapwing	Spotted Flycatcher			
Linnet	Turtle Dove *(52)*			
Mistle Thrush				
Magpie				
Meadow Pipit				
Pheasant				
Pied Wagtail				
Robin				
Rook				
Skylark				
Song Thrush				
Starling				
Stock Dove				
Swallow				
Swift				
Whitethroat				
Willow Warbler				
Woodpigeon				
Wren				
Yellowhammer *(35)*				

Table 9h Cumulative list of species monitored for increasing coverage of 1-km squares within an **across all habitats** simulation of The Peak District National Park. The list is restricted to an achievable percentage coverage for the park in question.

2.5% coverage (36 1-km squares)	5.0% coverage (72 1-km squares)	7.5% coverage (108 1-km squares)	10.0% coverage (144 1-km squares)	12.5% coverage (180 1-km squares)
Blackbird	Bullfinch	Garden Warbler	Corn Bunting	Buzzard
Blackcap	Black-headed Gull	Goldcrest	Canada Goose	Coot
Blue Tit	Coal Tit	Lesser Black-backed Gull	Nuthatch	Dunlin
Carrion Crow	Curlew	Reed Bunting	Oystercatcher	Herring Gull
Chiffchaff	Garden Warbler	Red-legged Bunting	Spotted Flycatcher	Lesser Whitethroat
Collard Dove	Golden Plover	Snipe	Sedge Warbler	Marsh Tit
Chaffinch	Great spotted Woodpecker	Treecreeper	Shelduck	Raven
Cuckoo	Green Woodpecker	Turtle Dove	Yellow Wagtail *(69)*	Tree Sparrow
Dunnock	Grey Heron	Wheatear *(61)*		Twite *(78)*
Feral Pigeon	Herring Gull			
Goldfinch	Jay			
Great Tit	Kestrel			
Greenfinch	Lapwing			
House Martin	Long-tailed Tit			
House Sparrow	Mistle Thrush			
Jackdaw	Moorhen			
Linnet	Red Grouse			
Mallard	Stock Dove *(52)*			
Magpie				
Meadow Pipit				
Pheasant				
Pied Wagtail				
Robin				
Rook				
Skylark				
Song Thrush				
Starling				
Swallow				
Swift				
Whitethroat				
Willow Warbler				
Woodpigeon				
Wren				
Yellowhammer *34)*				

Table 9i Cumulative list of species monitored for increasing coverage of 1-km squares within an **across all habitats** simulation of The Pembrokeshire Coast National Park. The list is restricted to an achievable percentage coverage for the park in question.

2.5% coverage (15 1-km squares)	5.0% coverage (30 1-km squares)	7.5% coverage (45 1-km squares)	10.0% coverage (60 1-km squares)	12.5% coverage (75 1-km squares)	15.0% coverage (90 1-km squares)	17.5% coverage (105 1-km squares)	20.0% coverage (120 1-km squares)
Blackbird	Blackcap	Bullfinch	Coal Tit	Canada Goose	Coot	Corn Bunting	Tree Sparrow
Blue Tit	Chiffchaff	Black-headed	Herring Gull	Goldcrest	Buzzard	*(65)*	Yellow Wagtail
Carrion Crow	Collard Dove	Gull	Jay	Grey Partridge	Reed Bunting		*(67)*
Chaffinch	Curlew	Garden Warbler	Lesser B-backed	Meadow Pipit	Sparrowhawk		
Dunnock	Feral Pigeon	G-Spotted	Gull	Oystercatcher	*(64)*		
Great Tit	Goldfinch	Woodpecker	Lesser Whitethroat	Sedge Warbler			
Greenfinch	House Martin	Green	Moorhen	Turtle Dove *(60)*			
Magpie	House Sparrow	Woodpecker	Nuthatch				
Pheasant	Jackdaw	Grey Heron	Reed Bunting				
Robin	Kestrel	Grey Partridge	Red-legged				
Starling	Linnet	Lapwing	Partridge				
Woodpigeon	Mallard	Long-tailed Tit	Spotted Flycatcher				
Wren *(13)*	Mistle Thrush	Stock Dove *(42)*	Treecreeper *(53)*				
	Pied Wagtail						
	Rook						
	Skylark						
	Song Thrush						
	Swallow						
	Swift *(32)*						

Table 9j Cumulative list of species monitored for increasing coverage of 1-km squares within an **across all habitats** simulation of Snowdonia National Park. The list is restricted to an achievable percentage coverage for the park in question.

2.5% coverage (54 1-km squares)	5.0% coverage (108 1-km squares)	7.5% coverage (162 1-km squares)
Blackbird	Black-headed Gull	Bullfinch
Blackcap	Coal Tit	Corn Bunting
Blue Tit	Dunlin	Garden Warbler
Carrion Crow	Feral Pigeon	Green Woodpecker
Chiffchaff	Goldcrest	Goldcrest
Collard Dove	Great spotted Woodpecker	Grey Heron
Chaffinch	Herring Gull	Grey Partridge
Cuckoo	Jay	Lesser Black-backed Gull
Curlew	Long-tailed Tit	Lesser Whitethroat
Dunnock	Moorhen	Oystercatcher
Golden Plover	Stock Dove	Reed Bunting
Goldfinch	Swift	Red-legged Partridge
Great Tit	Wheatear *(52)*	Sedge Warbler
Greenfinch		Sparrowhawk
House Martin		Spotted Flycatcher
House Sparrow		Treecreeper
Jackdaw		Turtle Dove
Kestrel		Twite *(70)*
Lapwing		
Lesser Whitethroat		
Linnet		
Mallard		
Magpie		
Meadow Pipit		
Mistle Thrush		
Pheasant		
Pied Wagtail		
Red Grouse		
Robin		
Rook		
Skylark		
Song Thrush		
Starling		
Swallow		
Whitethroat		
Willow Warbler		
Woodpigeon		
Wren		
Yellowhammer *(39)*		

Table 9k Cumulative list of species monitored for increasing coverage of 1-km squares within an **across all habitats** simulation of The Yorkshire Dales National Park. The list is restricted to an achievable percentage coverage for the park in question.

2.5% coverage (44 1-km squares)	5.0% coverage (88 1-km squares)	7.5% coverage (132 1-km squares)	10.0% coverage (176 1-km squares)
Blackbird	Blackcap	Black-headed Gull	Corn Bunting
Blue Tit	Chiffchaff	Coal Tit	Dunlin
Carrion Crow	Collard Dove	Feral Pigeon	Lesser Black-backed Gull
Chaffinch	Goldfinch	Garden Warbler	Nuthatch
Curlew	Grey Partridge	Green Woodpecker	Spotted Flycatcher
Dunnock	House Sparrow	Goldcrest	Snipe
Golden Plover	Lapwing	Grey Partridge	Sedge Warbler *(64)*
Great Tit	Linnet	Lesser Whitethroat	
Greenfinch	Mallard	Long-tailed Tit	
House Sparrow	Magpie	Moorhen	
Jackdaw	Pied Wagtail	Oystercatcher	
Kestrel	Reed Bunting	Red-legged Partridge	
Meadow Pipit	Swift	Stock Dove	
Mistle Thrush	Wheatear *(41)*	Treecreeper	
Pheasant		Turtle Dove	
Red Grouse		Twite *(57)*	
Robin			
Rook			
Skylark			
Song Thrush			
Starling			
Swallow			
Whitethroat			
Willow Warbler			
Woodpigeon			
Wren			
Yellowhammer *(27)*			

Table 10 Species of **moorland** birds which would be monitored during an **across all habitats** survey. This table gives the percentage coverage and number of 1-km squares (in parentheses) at which species would be monitored for an across all habitats survey, for each National Park. Additional species **(in bold)** are those often associated with moorland which would be monitored by an across all habitats survey but not by a moorland habitats only survey.

National Park	Moorland species monitored by a all habitats survey
The Brecon Beacons	Meadow Pipit, Skylark, **Cuckoo** 2.5% (34) Curlew, Golden Plover, **Lapwing** 5.0% (68) Red Grouse, **Oystercatcher** 7.5% (102)
The Norfolk Broads	**Cuckoo, Skylark** 7.5% (24) **Lapwing** 10.0% (32) **Meadow Pipit** 12.5% (40)
Dartmoor	Meadow Pipit, Skylark 2.5% (24) Curlew 5.0% (48) Red grouse, **Lapwing** 7.5% (72)
Exmoor	**Skylark** 2.5% (17) **Meadow Pipit, Curlew** 5.0% (34) **Cuckoo** 7.5% (51) **Wheatear** 15.0% (102)
The Lake District	**Cuckoo**, Curlew, Golden Plover, **Lapwing** Meadow Pipit, Red grouse,Skylark 2.5% (57) **Snipe, Wheatear** 5.0% (114)
Northumberland	Skylark 2.5% (26) Curlew, **Lapwing**, Meadow Pipit 5.0% (52)
The North York Moors	**Lapwing**, Meadow Pipit, Skylark 2.5% (36) Curlew 5.0% (72)
The Peak District	**Cuckoo**, Meadow Pipit 2.5% (36) Curlew, Golden Plover, **Lapwing**, Red Grouse 5.0% (72) **Snipe, Wheatear** 7.5% (108)
The Pembrokeshire Coast	**Curlew, Skylark** 5.0% (30) **Lapwing** 7.5% (45) **Meadow Pipit, Oystercatcher** 12.5% (75)
Snowdonia	**Cuckoo**, Curlew, Golden Plover, **Lapwing**, Meadow Pipit, Red Grouse, Skylark 2.5% (54) **Dunlin, Wheatear** 5.0% (104)
The Yorkshire Dales	Curlew, Golden Plover, Meadow Pipit, Red Grouse, Skylark 2.5% (44) **Lapwing, Wheatear** 5.0% (88)

Figure 1: 1km-squares covered by PCP (1992 + 1993)

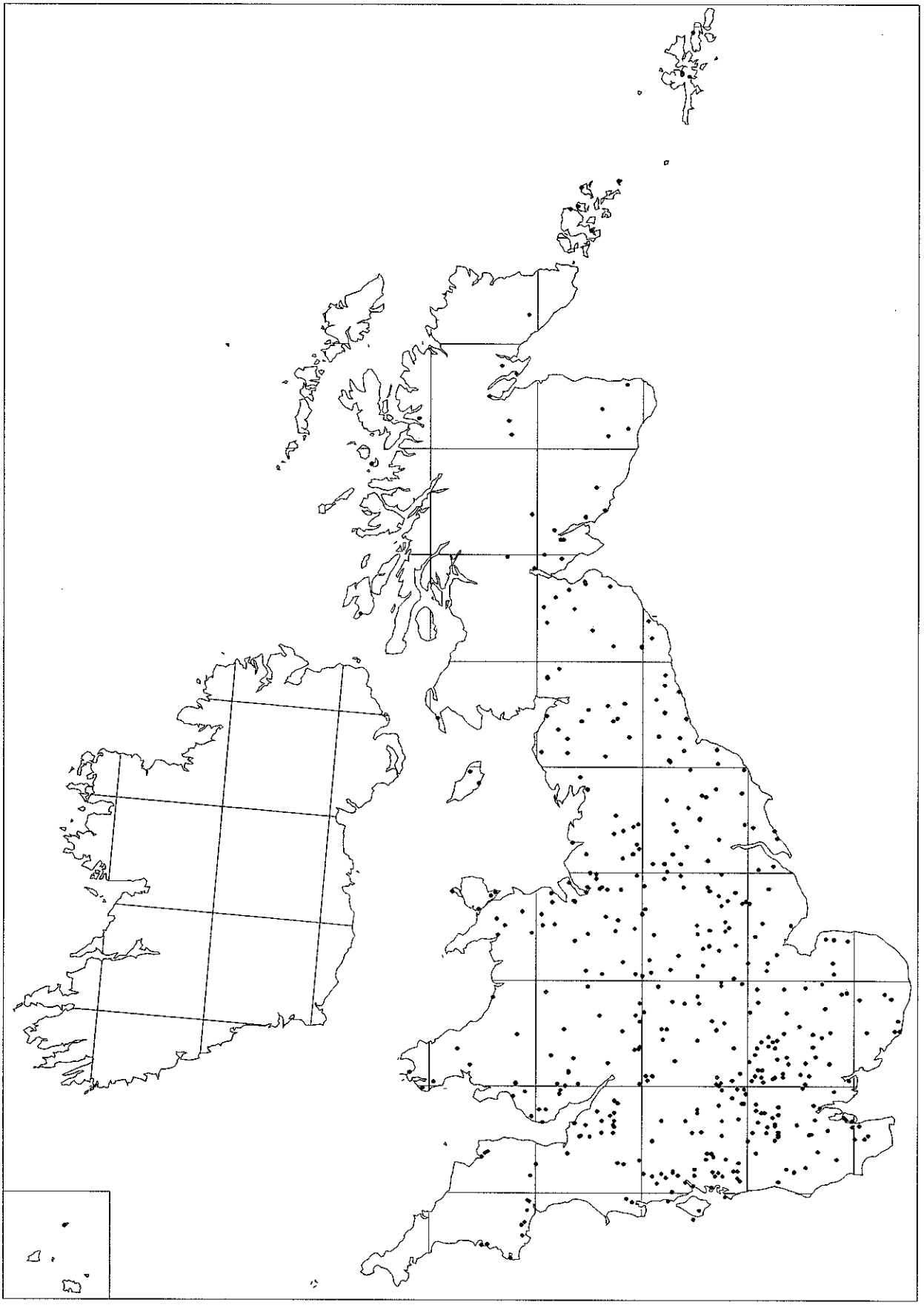


Figure 2: 1km-squares covered by RSPB (1980-1993)

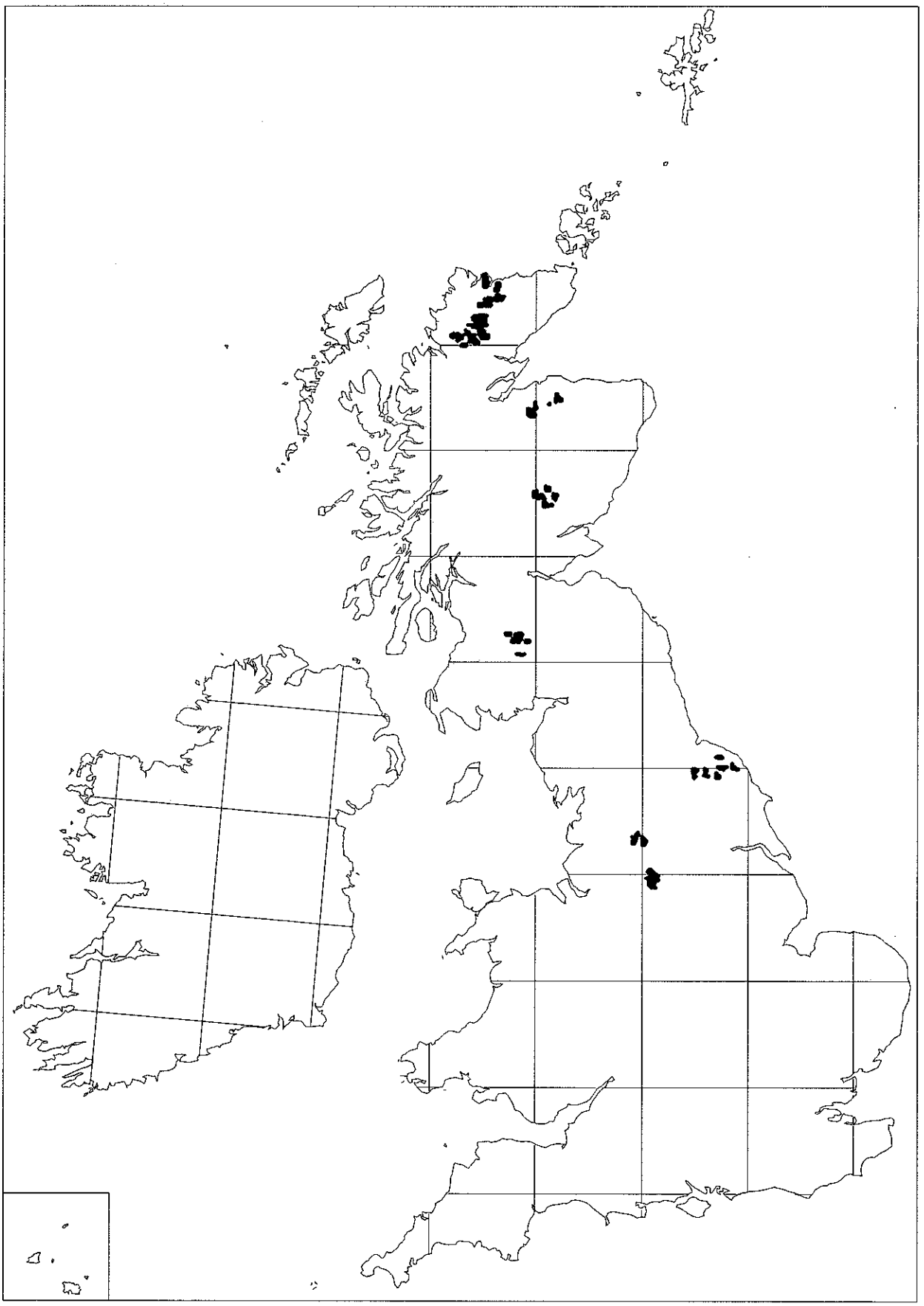


Figure 3: 1km-squares covered by NCC (1989-1990)

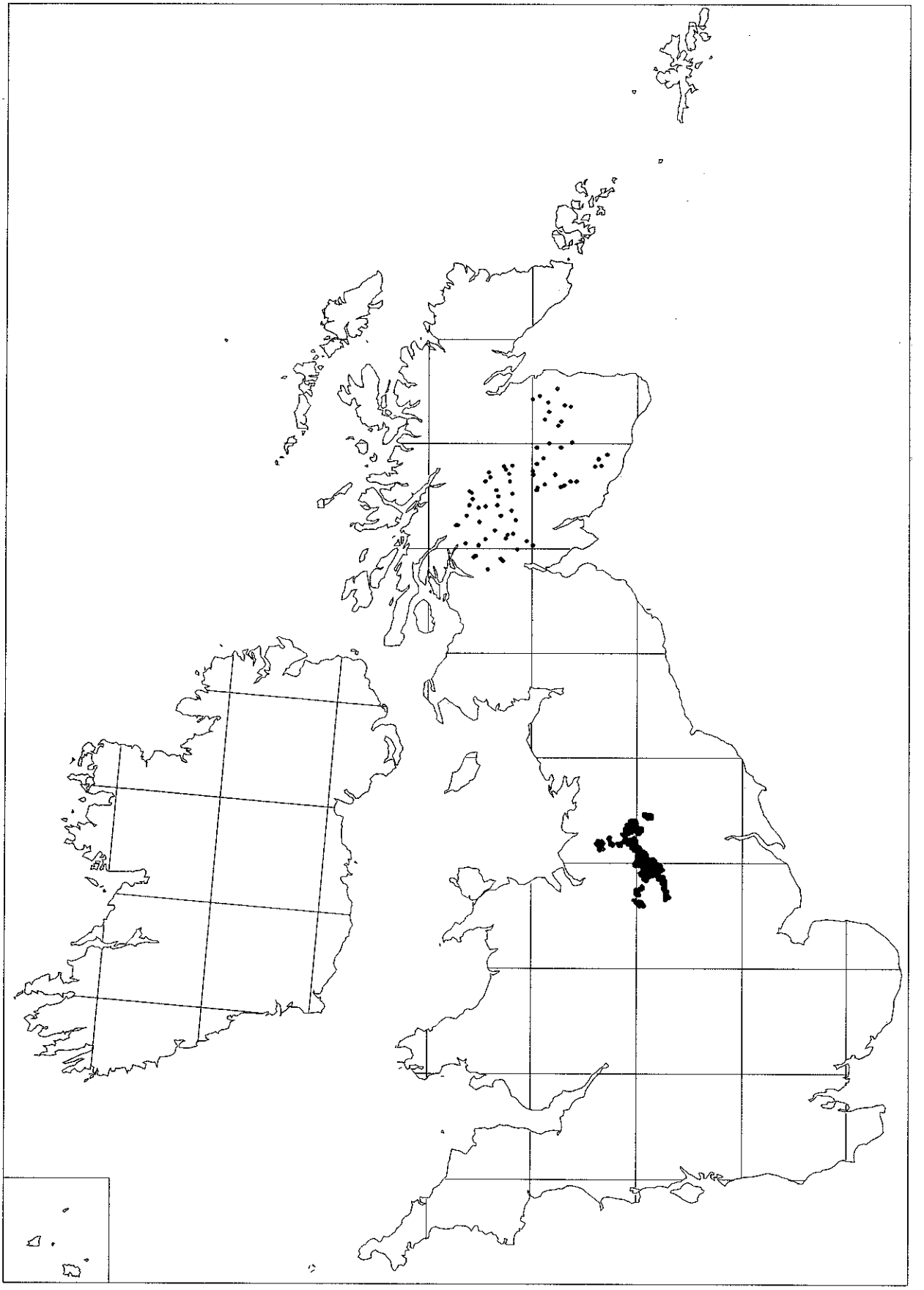


Figure 4: 1km-squares covered by all surveys

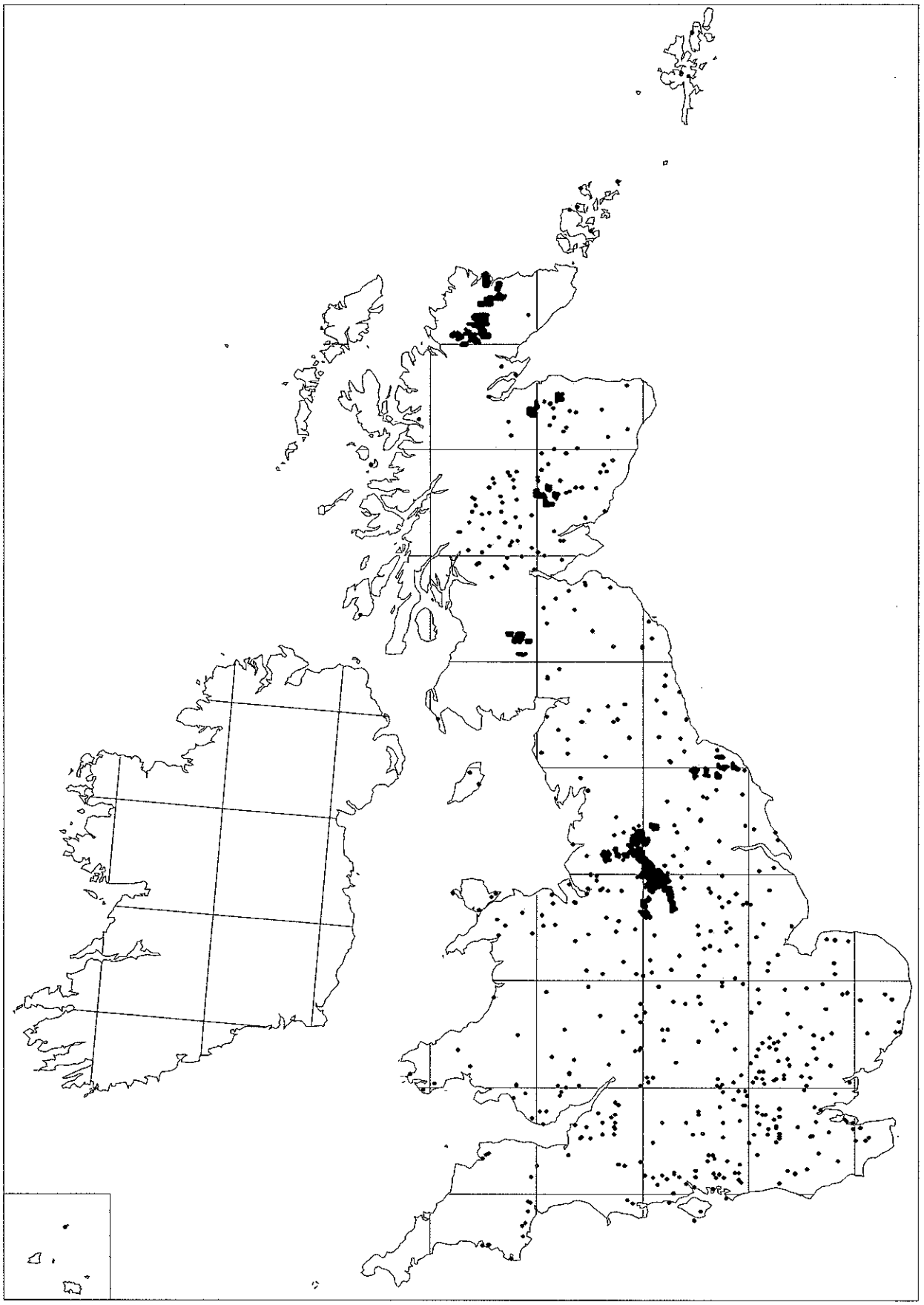


Figure 5. The relationship between number of species monitored and sampling effort within moorland. Each line represents an individual National Park.

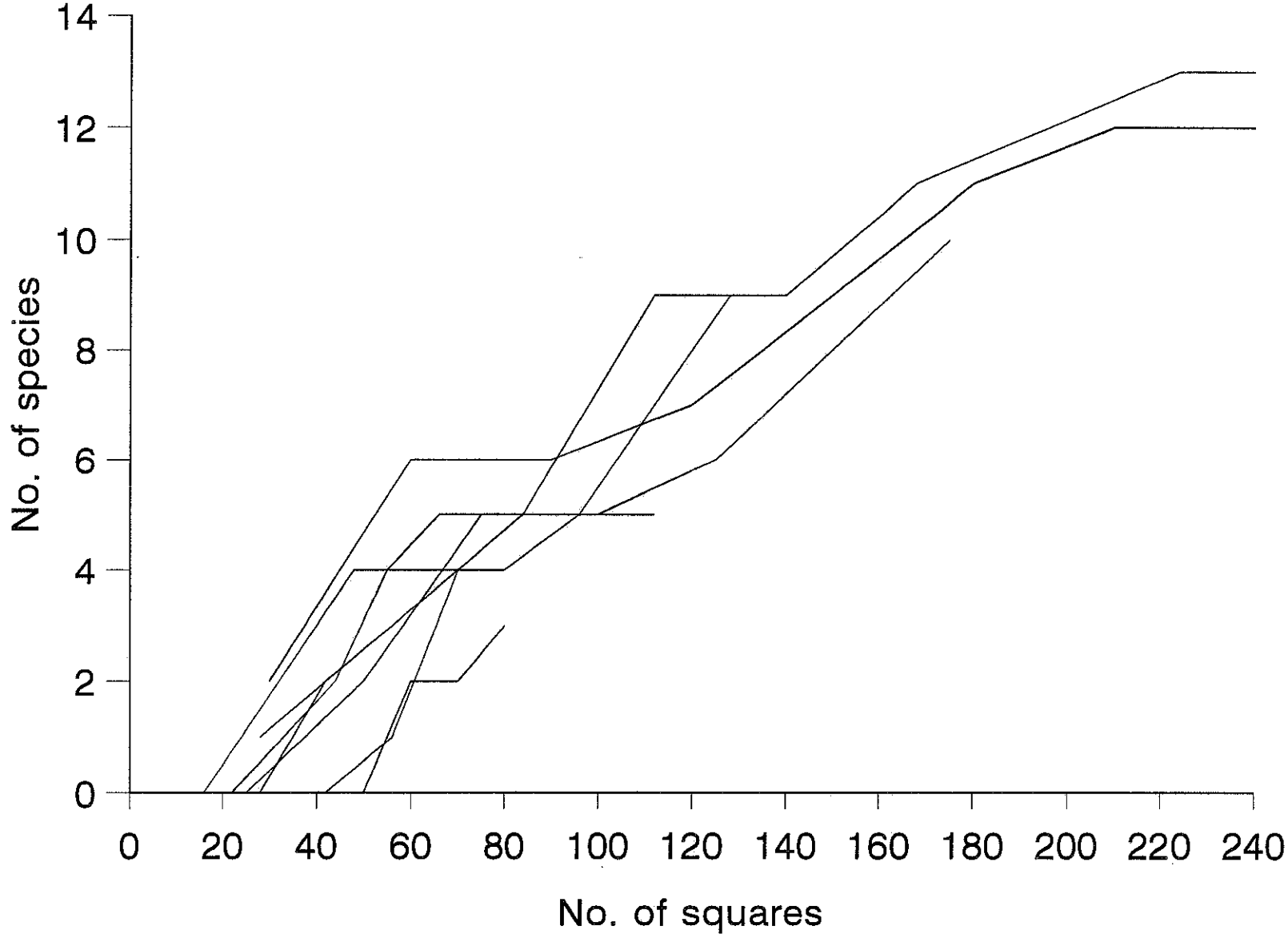


Figure 6. The relationship between number of species monitored and sampling effort across all habitats. Each line represents an individual National Park.

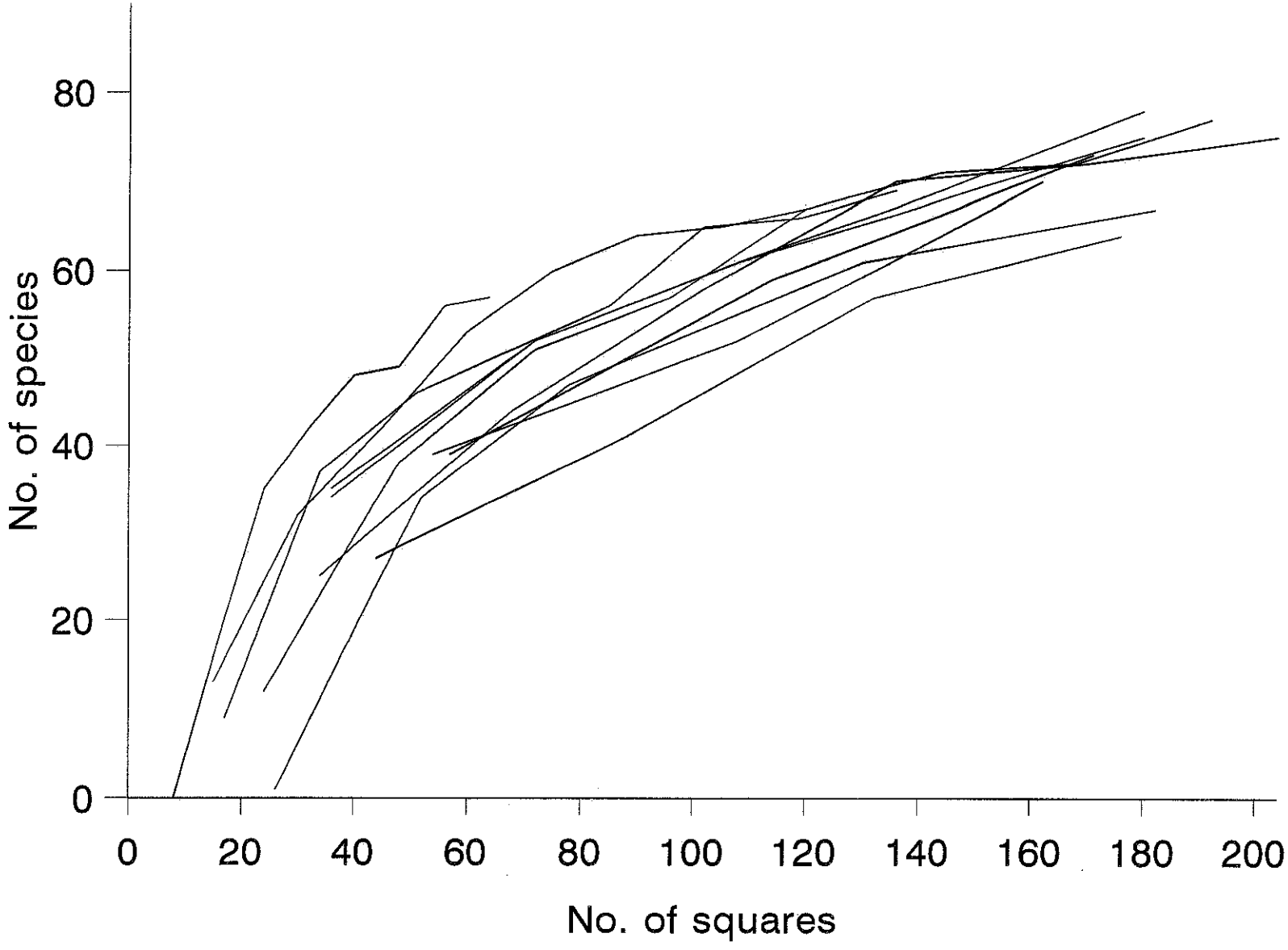
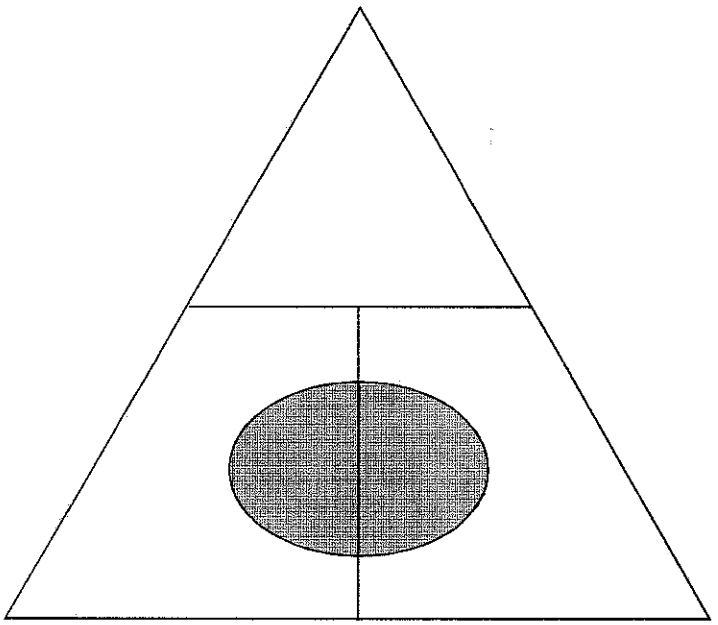


Figure 7. A schematic representation of BBS sampling units. The triangle represents three BTO regions. In (a) the shaded portion represents a National Park which overlaps two of the BTO regions. In (b) the shaded areas represent areas of moorland within a National Park. In both cases the shaded areas would be treated as a single new region within the BBS (see text for details).

(a)



(b)