BTO Research Report No. 535

RAPTOR SPECIES CONSERVATION FRAMEWORKS: THE PEREGRINE CONSERVATION FRAMEWORK PROJECT PROGRESS REPORT - PHASE I

Authors

Liz Humphreys[1], Chris Wernham[1] and Humphrey Crick[2]

[1] BTO Scotland, University of Stirling, Stirling, FK9 4LA

[2] BTO, The Nunnery, Thetford, Norfolk, IP24 2PU

November 2007

BTO Scotland
School of Biological & Environmental Sciences, Room 3A120/125, Cottrell Building,
University of Stirling, Stirling, FK9 4LA

Registered Charity No. 216652

British Trust for Ornithology

RAPTOR SPECIES CONSERVATION FRAMEWORKS: THE PEREGRINE CONSERVATION FRAMEWORK PROJECT PROGRESS REPORT - PHASE I

BTO Research Report No. 535

Liz Humphreys, Chris Wernham and Humphrey Crick

Published in November 2007 by
British Trust for Ornithology (Scotland)
School of Biological & Environmental Sciences, Cottrell Building,
University of Stirling, Stirling. FK9 4LA

ISBN 978-1-906204-60-0

CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

1. The British population of Peregrines (*Falco peregrinus*) showed a period of recovery following the deleterious effects of organo-chlorine pesticides in the 1950s and 1960s. The most recent national survey in 2002 showed that the population had continued to increase in Britain as a whole but that the Scottish population had decreased by 8% since 1991, with particularly marked declines in some geographical areas of Scotland. Concerns about this continuing and spreading decline in Scotland led the Scottish Raptor Monitoring Group to instigate a detailed analysis of the factors influencing territory occupancy and loss, following the model undertaken as the 'Golden Eagle Conservation Framework' (Whitfield *et al.* 2008, Section 1). The agreed objectives of the Peregrine Conservation Framework are:

   (i) To investigate correlates of variation in nesting territory occupancy and productivity of breeding Peregrines in Scotland based on the results of the 2002 national survey.
   (ii) To investigate, based on changes between national surveys, correlates of changes in occupancy and productivity of breeding Peregrines in Scotland and hence attempt to identify any possible constraints acting on populations.
   (iii) To assess the annual monitoring coverage for Peregrine against its known geographical range in Scotland.
   (iv) To make any necessary recommendations for improvements to current survey and monitoring in Scotland, and consider any further action required to address the factors apparently affecting the Scottish Peregrine population.

2. This report reviews progress made with the Peregrine Conservation Framework during the first phase of the project, covering:
   (i) progress made with acquisition and preparation of fully geo-referenced datasets for Scotland from the 1991 and 2002 national Peregrine Surveys;
   (ii) environmental and human factors identified as potential constraints, identified as priorities for analysis, and progress with acquiring and processing the appropriate data sets;
   (iii) progress with meeting the original objectives of the Peregrine Conservation Framework; and
   (iv) recommendations for a second phase of work and the feasibility of meeting the original objectives.

3. The compilation of fully geo-referenced datasets of Peregrine nest site locational data for the 1991 and 2002 national survey years is now complete and represents a major step forward. For each year, more than 75% of the locations are at the six-figure British National Grid scale (the remaining are four-figure references). The past use of site codes and/or site names rather than grid references made this data collation task complex and lengthy. Particular problems were encountered due to: between-year changes in the site codes used; changes in Scottish Raptor Study Group Peregrine Coordinators; use of different names for the same nesting site; the ways in which alternate nest sites were recorded; and losses of regional databases of raw data due to staff changes.

4. A range of environmental and human factors with the potential to influence Peregrine territory occupancy and/or productivity are explored in this report (Section 4). Due to time and resources constraints, it was necessary to prioritise for further consideration those factors for which: (i) there was previous suggestion of influence on Peregrine territory occupancy or productivity; and (ii) there were suitable data sets available at an appropriate spatial scale and contemporaneous with the 1991 and/or 2002 Peregrine surveys. This prioritisation was based on a review of published literature,

knowledge of datasets established during the Golden Eagle Conservation Framework, and consultation with the Scottish Raptor Monitoring Scheme Frameworks Steering Group.

5. Four factors were identified as high priority for the first phase of analyses: (i) broad-scale habitat; (ii) racing pigeon prey; (iii) natural prey; and (iv) human persecution. For each of these factors, this report documents progress with obtaining appropriate datasets, any preliminary analyses that have been undertaken, and any outstanding data collation requirements.

6. Other potential constraining factors considered in this report are: climate/weather; recreational (non-intentional) disturbance; grazing; forestry; competitors/predators; pollution; Fulmars; availability of nest sites; and windfarms (Table 4). For each of these factors, this report documents the rationale for their consideration, and relevant datasets that may be available for a later phase of analysis.

7. Recommendations for the second phase of the project include: production of summaries of occupancy and breeding success in 2002 and 1991 by NHZ; determining relative changes by NHZ in occupancy and productivity between 2002 and 1991; analyses of relationships between habitat and Peregrine occupancy and productivity for the whole of Scotland and including a comparison by NHZ and region (inland versus coast). We will then review evidence from these analyses for priority of Level 1 environmental factors before proceeding with the next phase of analyses.

1. BACKGROUND – THE SCOTTISH PEREGRINE POPULATION

During the 19th Century, the Peregrine was virtually eliminated from parts of its range in Britain, particularly from inland areas associated with game-bird preservation and where egg collectors and falconers were active. As a consequence, the highest concentrations of breeding birds were to be found in northern and western Britain at this time (Ratcliffe 2003). Between the years 1900-1939, records suggest that the Peregrine population in Britain was largely stable (Ratcliffe 1963). The baseline assessment of the population in Britain and Ireland in 1930-1939 estimated the breeding population as 1,100 pairs (Ratcliffe 1993), of which 513 were in Scotland (Ratcliffe 1993). During World War II, in a bid to protect carrier pigeons, it became legal for authorised persons to destroy Peregrines and their eggs. Consequently, the UK breeding population was reduced to 87% of its pre-war size by 1945, but the Scottish populations were only believed to be affected at a localised scale and appeared to recover quickly (Ratcliffe 1993, 2003).

During the 1950s and 1960s, the Peregrine population crashed throughout most of Great Britain. Within Scotland, the southern coastal populations showed the greatest decline and only the central and eastern Highland populations were relatively unaffected (Ratcliffe 1993). Organo-chlorine pesticides were identified as the principal cause of the declines; these were used extensively from the late 1940s. The effects observed were not only direct mortality of adults but also a major reduction in breeding success as a result of egg-shell thinning, the production of infertile eggs, and chick mortality. Consequently, by the time of the national surveys of 1961/1962 (Ratcliffe 1963) and 1971 (Ratcliffe 1972), the Scottish populations had fallen to estimates of 388 and 366 breeding pairs respectively. Restrictions on the use of organo-chlorines began in 1962, culminating in an EC-wide ban being imposed in 1981 (Ratcliffe 1993), and by the mid 1980s, the Peregrine was back to its pre-1940s numbers in Britain (Ratcliffe 2003). The Scottish population had not yet fully recovered, however, as the national survey of 1981 estimated the population at 422 breeding pairs and there was some suggestion of a decline in the far north (Ratcliffe 1984). Greater legal protection of nesting birds in combination with education of the general public also contributed to the continued recovery and increase in Peregrine numbers over the last twenty years (Ratcliffe 2003). By the 1991 survey, therefore, the UK breeding population was 145% of the pre-1940s level and the Scottish population was estimated at 626 breeding pairs (Crick & Ratcliffe 1995). Despite this overall increase, the northern Highland and Scottish island populations were showing signs of substantial decline, continuing the trend identified in the 1981 survey (Ratcliffe 1984, Crick & Ratcliffe 1995).

The most recent survey in 2002 (Banks *et al.* 2003) showed that the population has continued to increase in Britain as a whole but that the population in Scotland had decreased by 8% since 1991 (estimated population 542 breeding pairs and 50 sites occupied by single birds or immatures in 2002; Banks *et al.* 2003). Within Scotland, there continue to be strong regional variations in population trends: increases in Southwest, Southeast, Northeast (coastal), Tayside (coastal) and the Western Isles but declines in Argyll (coastal and inland), Central, Northeast (inland), and notably in the Highlands, and with no breeding birds in Shetland. Within regions showing signs of population recession, in terms of territories being abandoned or increasing numbers of territories occupied by non-breeding birds, some new territories were still appearing however, suggesting that the causes of decline were acting at a localised (regional?) scale and that the national (Scottish) decline is unlikely to be attributable to a single factor. It should be noted that although the Peregrine population in the UK is currently healthy overall, the unfavourable conservation status of the species in the rest of Europe has led to its listing as an Amber-list Bird of Conservation Concern (Gregory *et al.* 2002).

Concerns about the continuing and spreading decline of Peregrines in Scotland (Banks *et al.* 2003) led the Scottish Raptor Monitoring Group to instigate a detailed analysis of the factors affecting territory occupancy and loss. This report details the first stage of the 'Peregrine

Conservation Framework' analysis, following the model undertaken as the 'Golden Eagle Conservation Framework' (Whitfield 2000; Whitfield *et al.* 2001; Watson & Whitfield 2002; Whitfield *et al.* 2003; Whitfield *et al.* 2004a & b; Whitfield *et al.* 2006, Whitfield *et al.* 2007a & b), which has been synthesised recently (Whitfield *et al.* 2008). The Golden Eagle Framework project investigated a wide range of potential constraints on territory occupancy and productivity, and concluded that illegal persecution by humans, together with changing grazing pressures by deer and sheep are currently the most important constraints acting nationally, although their importance varies between regions of Scotland, and other factors may contribute at the regional level. They have also established a series of Favourable Conservation Status (FCS) targets (criteria) for Golden Eagles on a regional basis, using the Natural Heritage Zones (NHZs) defined by Scottish Natural Heritage (based on biogeographic zones, landscape character assessment boundaries and SSSI boundaries; see SNH 1998 and http://www.snh.org.uk/futures/Data for further information), as the spatial units for consideration, and carried out a series of tests to establish whether the conservation status of the species is currently favourable regionally and nationally. Conceptually, this study is attempting to fulfil a similar role for the Scottish Peregrine population, although the approaches used will necessarily differ for a number of reasons, including: (i) differences in the likely environmental factors that are acting as constraints; (ii) differences in the population and demographic data available for Peregrine at a national and regional level across the national surveys; and (iii) the need for a different approach to defining FCS because of the difficulties of defining currently unoccupied habitat that is suitable for breeding Peregrines.

2. AIMS OF THE STUDY AND THIS REPORT

The agreed objectives of the Peregrine Conservation Framework are as follows (Wernham & Crick 2005):

(i) To investigate correlates of variation in nesting territory occupancy and productivity of breeding Peregrines in Scotland based on the results of the 2002 national survey.

(ii) To investigate, based on changes between national surveys, correlates of changes in occupancy and productivity of breeding Peregrines in Scotland and hence attempt to identify any possible constraints acting on populations.

(iii) To assess the annual monitoring coverage for Peregrine against its known geographical range in Scotland.

(iv) **To make any necessary recommendations for improvements to current survey and monitoring in Scotland, and consider any further action required to address the factors apparently affecting the Scottish Peregrine population.**

Five national surveys of occupancy of Peregrine breeding sites have been undertaken in the UK, in 1961/62, 1971, 1981, 1991 and 2002 (Ratcliffe 1963, 1972, 1984; Crick & Ratcliffe 1995; Banks *et. al.* 2003). This study aims to use data from the 2002 survey to investigate current relationships between occupancy and productivity within the established range of the species in Scotland and a range of proposed environmental factors that have the potential to act as constraints on occupancy and/or productivity. Initially, analyses of the 1991 data will be used where possible to establish whether these relationships have altered, whilst data from previous surveys may also be used to examine changes in occupancy and productivity, if suitable datasets on key environmental variables can be identified that are comparable in timing with previous national Peregrine Surveys.

In a previous report (Humphreys *et al.* 2006), we considered the range of environmental and human factors that have the potential to act as constraints on the Scottish Peregrine population, and the availability of suitable datasets contemporaneous with those of the Peregrine national surveys. Because there were a large number of potential constraining factors, and limited resources for the first phase of the project, there was a need to prioritise the factors for consideration according to current evidence for their importance and the likelihood of the obtaining datasets suitable for rigorous and objective analyses. This prioritisation was achieved by assessment of the relative usefulness and availability of data, together with lessons learned from the Golden Eagle Conservation Framework (Whitfield *et al.* 2007b and Whitfield *et al.* 2008, and previous publications), and discussion at the Scottish Raptor Monitoring Scheme Science Group meetings.

In this report we review the progress that has been made with the Peregrine Conservation Framework project during the first phase of work. Specifically, we review:

- the progress that has been made with acquisition and preparation of fully geo-referenced datasets for Scotland from the 1991 and 2002 national Peregrine Surveys ;
- the environmental and human factors that have been identified as potential constraints, those that have been identified as priorities for analysis, and the progress that has been made with acquiring and processing the appropriate data sets;
- progress with meeting the original objectives of the Peregrine Conservation Framework;

- recommendations for a second phase of work and the feasibility of meeting the original objectives.

3. GEO-REFERENCED PERERINE BREEDING DATA

3.1 Background and issues arising

Prior to the start of the project, the BTO held the raw data from the national Peregrine Surveys of 1991 (Crick & Ratcliffe 1995) and 2002 (Banks *et al.* 2003), plus a historical database deposited with BTO by the late Derek Ratcliffe, containing information on breeding site use prior to the 1991 survey (and for all the previous national surveys). For many of the Peregrine breeding sites, however, observers had previously submitted only coded information (site codes) rather than fully geo-referenced data. This allowed information on occupancy and breeding success to be gleaned for these sites at a national scale (and within individual Scottish Raptor Study Group areas) without compromising the confidentiality of the breeding locations. Some individual raptor surveyors and Peregrine Co-ordinators use the same site codes to identify individual breeding sites from one year to the next, while others change these codes between years. Some observers link these site codes to full grid references within their personal data sets, while others link them only to site names.

The Peregrine Conservation Framework aimed to carry out spatially explicit analyses for the Scottish breeding population, at both a biologically meaningful regional scale (using NHZs; see Figure 1) and at finer spatial scales (e.g. potentially using individual nesting ranges as the spatial unit for linking occupancy and productivity with constraining factors). To meet these aims, fully geo-referenced breeding site locations were required, to the resolution of four-figure (and preferably six-figure) grid references. A request for this additional information for all breeding sites that were known to exist in Scotland at the time of the 1991 and 2002 national surveys was made through the Chairs of the individual Scottish Raptor Study Groups (SRSGs) at the end of May 2006. Unfortunately, this timing coincided with the most intensive part of the field season for SRSG members (most of whom undertake the survey work and data collation in a voluntary capacity in their own time), which meant that substantial delays were incurred with receiving the data; the last sizeable set of data was not received until February 2007. In addition to a protracted period of data acquisition, a more extensive clean up of the data sets than had previously been anticipated was required, due to a number of issues which are outlined briefly below:

- The most frequent and time-consuming problems arose due to the use of sites codes rather than full geo-referencing. There were some changes in SRSG Peregrine Co-ordinators between one national survey year and the next national survey, and there has been a complete or partial change in the coding system used through time by several SRSGs. This required an often time-consuming and protracted correspondence with relevant Peregrine Co-ordinators, in order to identify the changes that had occurred and cross-check carefully between coding systems. Whilst in some regions site codes were generally linked to six-figure grid references making cross-checking relatively straightforward in most cases (but see below), in others only site names were used. Often different names (up to five) have been used through time or by different observers or Co-ordinators for the same breeding site, making cross-checking extremely difficult.

- The way in which alternate nest sites within a nesting range have been reported was also an important issue. In many instances, survey forms were only returned for the active site within a given nesting range. This is not a problem when the site code system is used correctly, because the site code itself is used to identify the same nesting range, in 1991 and 2002 for example. However, cases have arisen where different alternates within the same nesting range were occupied in the two different survey years, no reference to the other alternate is made, and the site codes used have not been set up effectively to link alternates across years (this was particularly a problem in the 1991 dataset). The problems with multiple names being given for the

same site within a nesting range (above) also compounded the problem when attempting to match up alternates from one survey year to the next.

- In some regions (e.g. Western Isles and Lewis), the relevant organisations thought to hold the raw data were not able to provide geo-referenced information for 1991 as they no longer held it due to staff changes. Wherever possible, we went back to the individual surveyors who were involved at the time of the national survey to acquire the relevant information.

- An issue also arose over sites that were not checked during a survey year but were known historically to be occupied by breeding Peregrines. Importantly for the Peregrine Framework analyses, all such sites have now been entered into the data base for 2002 and 1991. A particular problem arose when sites were visited in 2002 but not in 1991. In such instances, it was important to establish that such nest sites were in fact historical sites that had not been visited in 1991, as opposed to new sites occupied for the first time since 1991.

We thank the SRSGs, their individual members and Peregrine Co-ordinators for being so fully co-operative with this process. Unfortunately, the protracted time periods involved and the detailed correspondence that was required, meant that far more time was spent on this part of the project than had been anticipated in the original project proposal of March 2006.

In summary, we now have a complete geo-referenced database for 2002 of all known occupied and historical nesting sites (which has been cross checked with the 1991 database), within which each site has been allocated a unique identifying code. In addition, each of the nesting ranges and their relevant alternates are coded by another unique number. For 1991, according to the original database, we are still missing georeferenced information for one site in Dumfries and Galloway (the site is unknown to the current SRSG Peregrine co-ordinator and was only referenced by name and not site code previously) and one site in the Uists (in this case, no name is given and the site code system used in 1991 was not used in 2002). Of all the known ranges, approximately 80% and 77% are at the accuracy of six-figure grid reference for 1991 and 2002 respectively. The rest are at four-figure grid reference, apart from one site in 1991 (in the Western Isles).

3.2 Definitions of occupancy and productivity

'Occupancy' for the purpose of our analysis is based on sites checked and established as occupied during the breeding season only. The codes used to define the level of occupancy at individual nesting sites differed between the 1991 and 2002 national surveys, and were more explicit in 2002. The ways in which we have categorised sites as occupied or unoccupied during the 1991 and 2002 breeding seasons based on observational evidence are detailed in Tables 1 and 2. In our analyses we also plan to distinguish between sites that were known to be occupied by a pair of birds and sites where only a single bird (and no additional evidence to indicate breeding) was seen in any given breeding season (see Tables 1 and 2). In addition, we will attempt to distinguish sites that received several visits at appropriate times (with a higher probability of recording a pair if present) from sites that were visited less frequently or at less than ideal stages of the breeding season: previous validation work after the 2002 Peregrine Survey indicated that their was only a *ca* 45% chance of recording occupancy at an occupied site on a single visit but this was increased (to *ca* 70%) when two visits were made and less so when further visits were made (Wilson & Crick 2004). We are nearly at the stage where we can establish for the first time the levels of occupancy of all known historical nest sites for each of the NHZs in Scotland in 2002. Before we can do this, a small amount of additional work is needed to take into account the variation in visit schedule. Therefore for all ranges recorded as unoccupied or occupied by a single bird only, we now intend to

distinguish between those that were visited only once and those which were visited on two or more occasions. This will be very important when reporting on occupancy levels by NHZ.

Our aim is to derive robust measures of productivity for the maximum possible number of territories in each of the national survey years. This involves a number of constraints however. If a pair lose their clutch early in the breeding season, and do not relay, then it is generally difficult to prove that a breeding attempt was ever made because of the relatively few visits for the more remote sites. In such instances the nest would be recorded inaccurately as a range occupied by a pair that did not attempt to breed in that particular year. This means that overall we are likely to underestimate the number of pairs that make a breeding attempt at the regional and population level. Difficulties of direct access to the nest during incubation can also restrict the sample sizes with information on numbers of eggs laid and hatching success. Components of breeding success that can be quantified most rigorously at a large number of territories are: (i) the % of known pairs that fledged one or more young or had large young; and (ii) the number of young fledged or number of large young of known pairs. For other breeding parameters (eg. confirmed laying, clutch size) the sample sizes will be much smaller.

3.3 Choice of scale

When considering the environmental data available, the scale at which relationships will be investigated is an important consideration. Initially, we will consider levels of occupancy, productivity, and changes between 1991 and 2002, by NHZ (SNH 1998), to help identify potential constraining factors that are worth exploring further (one approach adopted in the Golden Eagle Framework; Whitfield *et al.* 2008).

McGrady *et. al.* 1997, through the extensive use of radiotracking, demonstrated that the boundary of a Golden Eagle range during the breeding season was equivalent to a 6km buffer (radius) around the centre of the range (since 98% of radio locations of eagles were within 6km of the territory centre). Moreover, they also showed that 50% of activity occurred within a buffer of 2-3km of the centre of the range. These two estimates of spatial use around the centre of a range were then extensively used in order to look at what environmental factors determined occupancy and productivity of the Golden Eagle. This empirical data were then used to inform a predictive model for Golden Eagle foraging territories based on the location of nest sites (the 'Predicting Aquila Territory' or 'PAT' model; McGrady *et al.* 2002; McLeod *et al.* 2002a & b). The existence of such a model was advantageous and it could used to predict use of the area surrounding a nest site by a pair of eagles, thus spatially delimiting a geographical area within which environmental variables could be related to occupancy and productivity, either nationally or for individual NHZs (e.g Fielding *et al.* 2003a; Whitfield *et al.* 2008). This allowed comparisons of potential constraining factors to be made between occupied and unoccupied sites, and sites that fledged young and those that did not fledge young, for example.

Unfortunately, equivalent empirical (remote tracking) data are not available currently for Peregrines, to allow such a predictive model to be constructed. Limited information is available on Peregrine territory size and foraging range during the breeding season. Weir (1977, 1978) concluded that Peregrines in the Central Highlands took 70% of their prey within 2 km of the nest site, although females could hunt up to 6 km away. Other information from the UK and central Europe suggests that breeding Peregrines may hunt up to 15 km or even further from the nest site (Ratcliffe 1993). Ratcliffe (1993) estimated mean nearest neighbour distances between nest sites of 4-8 km for various regions of Scotland at the time of the 1991 national survey. This limited information can be used as a guide to define suitable 'buffer areas' around Peregrine nest locations so that relationships between

occupancy and productivity and potential constraining factors can be investigated at a territory scale.

Analyses are also limited to some extent by scale at which the Peregrine locational data are available. In both 1991 and 2002, around 20% of nest site locations have been provided to the scale of four-figure (rather than six-figure) grid reference. To allow all the locational data to be used, analyses would thus need to be constrained to the resolution of the mid-points of 1-km grid squares.

Many of the key environmental datasets are available at the 1-km square resolution, but some are not. For example, Met Office weather data are available ready-processed at a resolution of 5-km by 5-km grid squares for Scotland (Section 4.6) and interpolations of natural prey abundance from Breeding Bird Survey data have been provided previously at a 10-km scale (Section 4.4.2). Moreover the vast majority of our environmental data sets are only available on a grid system We will therefore recommend that initially analyses are based on a grid system, using the central location of the 1 km square in which each nest location falls and aligning with the appropriate numbers of surrounding squares to represent range use (i.e. a 2 km foraging range and a 8 km nearest neighbour range are approximately equivalent to 3x3 $1km^2$ and 11x11 $1km^2$ respectively, that is grids of squares that completely encircle the radii of a 2 km and an 8 km circle respectively).

4. ENVIRONMENTAL AND HUMAN FACTORS AS POTENTIAL CONSTRAINTS

4.1 Setting priorities for analysis

In the Peregrine Conservation Framework Interim report (Humphreys *et al.* 2006), 12 factors that may influence Peregrine territory occupancy and productivity were discussed in detail (see Table 3). Due to time and resource constraints, it was necessary to prioritise those factors for which: (i) there was previous evidence to suggest that they might influence breeding Peregrine occupancy rates or productivity; and more importantly (ii) there were data sets available at an appropriate spatial scale and for appropriate time periods to coincide with the 1991 and/or 2002 national Peregrine surveys. Prioritisation was based on a review of published literature, knowledge of available datasets established during the Golden Eagle Framework project, and consultation with the SRMS Steering Group for the Raptor Species Conservation Frameworks. At the meeting of this Group on the 10 April 2007, those factors which should be given the highest priority for initial analyses are shown in Table 3 and from hence forth are termed Level 1 factors (Table 3).

Here we consider each of the potential constraints on Peregrine occupancy and/or productivity in turn. We give the rationale for including each factor and examine briefly the possible data sources that are available, their strengths and limitations. For the Level 1 factors (Table 3), we then outline the work that we have carried out to date to acquire and collate relevant data sets, and suggest how analyses might be most effectively taken forward during Phase II of the project.

4.2 Broad-scale habitat

4.2.1 Rationale

Traditionally the breeding distribution of the Peregrine was thought to be limited by the availability of inland and coastal cliffs for nesting, although there were also known examples of Peregrines nesting in quarries and on man-made structures (Ratcliffe 1993). Peregrines have increasingly shown a degree of flexibility in the choice of nesting habitat, with further breeding reported on a variety of man-made structures, such tall buildings, bridges, pylons, masts, and within urban settings. Thus the habitat requirements at the landscape scale for breeding have not been investigated in detail.

Following discussion with the SRMS Frameworks Steering Group, it was agreed that a suite of broad-scale analyses to examine potential relationships between breeding Peregrine occupancy rates/productivity and habitat should be carried out (initially considering occupancy and productivity rates, and changes in occupancy by NHZ and relating any differences to broad biogeographical variation; then at a finer resolution, see section 3.4). The aim would be to identify any broad associations between habitat classes and occupancy/productivity that could provide supporting information when prioritising analyses of other potential constraining factors (e.g. natural prey, persecution).

4.2.2 Available data sets

The closest contemporary UK land use and classification dataset is LCM2000 (Fuller *et al.* 2002), based on Landsat satellite information: there are 27 ‘subclasses’ of habitats, allowing classification of 22 Broad Habitats, and these have been categorised into 12 ‘aggregate classes’ (Table 4). The LCM2000 survey was undertaken within an appropriate timescale for comparison with the 2002 Peregrine survey. LCM2000 used image segmentation to identify land parcels from pixels; these are available as a vector data set (and therefore areas of land are shown as polygons or parcels) in addition to a resolution of 25 m and 1 km. A previous

survey, the LCM1990, was the first complete map of the land cover of the UK since the 1960s and the first survey of its kind to be based on a computer classification of satellite information (from Landsat Thematic Mapper data based on a 25 m grid), generating habitat data as pixels. LCM1990 would have been suitable for comparison with the 1991 Peregrine survey data and, therefore, potentially for considering changes in habitat between the two most recent Peregrine surveys. However, LCM2000 had four key refinements compared to LCM1990: improved accuracy of classification; added thematic detail; greater compatibility with other systems of environmental survey and evaluation; and finally closer integration between field and satellite data (http://www.cs2000.org.uk/mod7_info.htm). Unfortunately, due to the methodological differences, LCM1990 and LCM2000 cannot be used for considering changes in land use between the two most recent Peregrine surveys.

4.2.3 Data collation and analytical approach

- BTO hold the LCM2000 data set summarised into proportions of each habitat land use class at the 1-km square resolution. The vector data set of land parcels is very expensive (£10,000+) and therefore will not be available for use unless additional resources are found.
- In the first phase of the analyses, we suggest that Peregrine occupancy/productivity should be analysed with respect to the percentage cover of each of the aggregate classes (see Table 4) within buffer zones of 2 km and 15 km around the nest site (see section 3.4). Nine of the aggregate classes would be considered: coastal; mountain, heath and bog; broad-leaved / mixed woodland, coniferous woodland, improved grassland, semi-natural grassland, arable and horticulture, and built-up areas and gardens (i.e. excluding the LCM2000 aggregate classes of oceanic seas and standing open water that are not relevant breeding habitats for the Peregrine). Within these aggregate classes, sub classes of specific interest will also be given consideration (i.e. any that may act as appropriate surrogates for constraining factors).

4.3 Pigeon prey

4.3.1 Rationale

Pigeons are an important prey species for the Peregrine (Ratcliffe 1993). In addition to Feral Pigeons and (natural, wild) Rock Doves, racing pigeons are likely to form an important prey component in at least some parts of Scotland. The sport of pigeon racing potentially provides prey to Peregrines from three 'sources': (i) pigeons flying near lofts during training; (ii) pigeons racing between release points and their home lofts during race events; and (iii) racing pigeons that become lost or join feral flocks. The pigeon racing season in Britain runs from April to September, with older birds racing until approximately mid July, and young birds (birds of the current year) racing for the rest of the season. Pigeons racing from April to July in any given year are most likely to influence Peregrine productivity in that year (based on the timing of the Peregrine breeding cycle; Hardey *et al.* 2006). There is also the potential for pigeon abundance to influence territory occupancy through time, if breeding success in the previous year, or years, is related to pigeon abundance, and if previous breeding success and/or adult body condition influence the chances of territory occupation or breeding in a subsequent year.

In response to concerns raised by pigeon racing groups about losses due to raptors (mainly Peregrine and Sparrowhawk), recommendations were made that racing routes and timing in the UK should be changed to areas and times where exposure to potential raptor predation would be minimised (UK Raptor Working Group, 2000). Peregrine populations in Scotland may have been influenced by these changes in racing routes, which occurred between the 1991 and 2002 Peregrine surveys, as the Scottish Homing Union (SHU) was already trialling

this approach to reducing losses and disturbance from Peregrines by 2000 (Shawyer *et al.* 2000; UK Raptor Working Group 2000).

4.3.2 Available data sets

Feral Pigeons/Rock Doves
Information on the distribution and relative abundance of Feral Pigeons and natural or wild Rock Doves is available from the 1988-91 Breeding Atlas (Gibbons *et al.* 1993), which indicated a reduction in Rock Dove but expansion of the Feral Pigeon population in Scotland between 1968-72 and 1988-91. Feral Pigeons were recorded in 50 BBS squares in Scotland in 2002, and interpolated relative abundance maps could be produced (see section 4.4).

Local numbers around lofts
A meeting was held with the Scottish Homing Union (SHU) to assess potential sources of data on the distribution and abundance of racing pigeons across Scotland. There is no central database of the numbers of pigeons kept by each SHU member/loft in Scotland. The only approximation could be obtained from the number of rings issued to each racing federation each year. Not all rings are put onto pigeons each year, however, and not all pigeons that are ringed enter the local loft/training population, so that in using these data it would be necessary to assume that these proportions were similar across all lofts. The SHU can provide the numbers of rings issued in any given year summarised by SHU federation, and the numbers of members per federation, but it is not thought possible to obtain the numbers of pigeons held by individual lofts/members. The SHU would not agree to provide us with grid references of all their members lofts (although they do hold this information). We were able to obtain a list of federations and the main towns within each federation (but not actual boundaries of federations).

Spatial distribution and abundance of pigeons during races
The SHU provided us with "Conveyors and Controller Guides" for the years 2000-2003 and 1989-1990 along with 1993 (the guides for 1991 and 1992 are currently missing). These provide a programme of races and give details of: race date; release site (as represented by town/village); the maximum number of birds predicted to race;[1] and the region to which the birds were returning to as indicated by the SHU federation involved. One problem with these data is that the regions to which birds are returning can be very large (i.e. "Fife", "North of Scotland"), which introduces a first level of uncertainty over the exact race routes (see below for added difficulties). Additional information is available from a previous study (Shawyer *et al.* 2000) for the year 1997 but this is of less use for the current project given the timing of that study. To determine overall numbers and spatial variation in the distribution of pigeons flying through Scotland, information from other racing organisations in England and Wales that liberate birds in Scotland is also needed (see Tables 5 & 6).

The RPRA "British Homing World" journal, as kindly loaned to the BTO by the RPRA, provides a programme of intended races with information on race date, release site and originating federation, but the journal does not generally report the number of birds involved in each race. Therefore, it was necessary to ask the RPRA for contact names and addresses of all English and Welsh federations that raced in Scotland in 1991 and 2002 (54 and 18 federations respectively; Table 6). RPRA was able to provide addresses for the majority of the federations involved but some problem arose due to federations disbanding or no longer operating within the RPRA (see Table 6). For each federation for which a contact was obtained, a letter was sent accompanied by a full list of the races for which the numbers racing were required but the response rate was low (see Table 6). The data from the English and Welsh federations that race in Scotland are important since their release sites are spread

[1] The maximum number of birds that can race is given as a means of estimating the number of vehicles required for transportation

across Scotland as far north as Shetland (Figure 2) and the numbers of birds racing through Scotland are a substantial proportion of the overall numbers thought to race through Scotland (Table 5).

Even with full details of the numbers of pigeons released at each release point in Scotland and the destination lofts for every race held, there are substantial problems in determining the spatial variation in abundance of racing pigeons that might form prey for Peregrines. Topographical features, such as hills and mountains, rivers, and the presence of urban areas are all likely to influence the routes taken by pigeons from liberation to the loft, and flight paths are also likely to change according to wind speed and direction (Shawyer *et al.* 2000, Henderson *et al.* 2004). These further potential constraints must be considered and appropriate assumptions made in any attempt to provide some indication of the spatial variation in the abundance of racing pigeons across Scotland.

Racing pigeons joining feral flocks

Racing pigeons that are lost during the course of a race can be found subsequently free-living in feral flocks of pigeons. Given that it has been estimated that only *c.*4% of Feral Pigeon flocks are made up of racing pigeons (Shawyer *et al.* 2000), it is unlikely that such racing pigeons represent a significant food source for the Peregrine however. Any such pigeons will be covered by the data sources for free-living Feral Pigeons/Rock Doves (above).

4.3.3 Data collation and analytical approach

As detailed information on the numbers of pigeons around lofts is not available and the numbers of racing pigeons found living free amongst feral flocks are thought to represent only a small proportion of such flocks, preliminary work has focussed on generating an index of pigeon availability based solely on racing events.

Data on race routes and numbers racing

In order to generate a simple index of racing pigeon abundance based on race events within Scotland, the following information was required for each race: the release site; the number of birds racing; and the race destination. Information was obtained from the SHU (racing birds that are released in Scotland and elsewhere within the UK and returning to lofts within Scotland) and the Royal Pigeon Racing Association and affiliated federations (RPRA; birds racing from Scottish release sites and returning to English or Welsh lofts i.e. also passing through Scotland and potentially available as prey for Scottish Peregrines). As the region encompassed by some federations can be very large, the most pragmatic approach to generating a destination was to request a list from the SHU of the major towns within each Federation that contain lofts (see Appendix 1). Information on the main towns encompassed by RPRA federations also needs to be obtained. Further correspondence is also required if we are to obtain the remaining race data (numbers of birds raced), largely from federations outside Scotland, although a smaller quantity of SHU data are still outstanding (Table 5).

Generation of a Racing Pigeon Abundance Index at the NHZ scale

In order to produce indices of spatial variation in racing pigeon abundance the following initial assumptions were necessary:

1. Each scheduled race actually took place; or, if not, there was no bias towards races from/to some locations being cancelled more frequently.
2. Race capacity (the maximum number of racing birds for which transport was arranged) is generally representative of the number of birds that actually race.
3. Pigeons fly in straight lines between the release and the destination point.
4. The estimated central point of any specific racing federation area is a representative end point (i.e. lofts/numbers of racing birds are uniformly distributed within the federation area).

5. Losses of birds from the start of the race to the end of the race (deaths or birds turning feral) are a minor component of the overall number racing (Shawyer *et al.* 2000).

A further assumption is necessary if pooling racing pigeons of different age classes (eg. 'young birds': birds of that year and 'old birds'): that there is no difference in risk of predation from Peregrines between racing pigeons of different ages.

Federation locations were derived by determining the centroid point of the polygon formed around the main towns with racing pigeon lofts (using ArcGIS). Race routes were then produced in the GIS environment by drawing lines between release points and central points of the destination federations (see Figure 3). A preliminary pigeon availability index can then be calculated for each NHZ by multiplying the length of each race line segment that fell within the zone by the number pigeons involved in the given race, and then summing these for the NHZ: i.e:

Pigeon Abundance Index = Σ ([segment length] x [birdage]).

Using all the current SHU data that have been collated (Table 5), and pooling both age classes of racing birds, suggested that the highest concentration of races in 1991 were in the western Southern Uplands and the border hills, followed by the western Central Belt and the eastern lowlands. Some suggestion of a shift is apparent in 2002, with apparent highest concentrations of race routes in the eastern lowlands and the border hills (Figure 3). What appears to happening is a shift from the south west to the south east and eastern parts of Scotland for the main routes from 1991 to 2003. It is evident however, that the number of races declined notably between 1991 and 2002 (Table 5), such that further work based on regional pigeon abundance indices (above) and a more complete data set will hopefully provide a clearer picture of changes in the spatial distribution of racing pigeon numbers between 1991 and 2002, at least on a broad scale.

Racing Pigeon Abundance Index at the Peregrine territory scale

The assumptions that need to be made to estimate abundance at the NHZ scale (above) also apply when considering racing pigeon abundance at a finer resolution. We have carried out some exploratory analyses with the existing SHU data to generate indices initially at a 1-km square resolution but the generation could equally be carried out at the 2-km and 15-km radius from the nesting site (see section 3.4). We have also explored methods to take account of the likely deviation of racing pigeons from straight-line travel between the release site and the destination (due to route selection or temporary straying). We carried out interpolation of the information from the 1-km scale (to incorporate information from surrounding 1-km squares) using inverse distance weighting (in ArcGIS 9): each value generated at the 1-km scale is re-estimated by taking a weighted average of neighbouring values, the weighting being a decreasing function of distance. Index values were then inversely weighted by elevation (in SAS 9.1) to attempt to account (at least partly) for pigeons tending to fly at lower elevations and avoiding very high ground (Shawyer *et al.* 2000). Elevation data are available at the 1-km square scale to the nearest 100 feet from ESRI (2001). This inverse-weighting by elevation also takes into account, to some degree, that racing pigeons often follow major river routes and coastlines (Shawyer *et al.* 2000), as these features will be associated with areas of lower ground, at least relative to neighbouring areas. The production of such indices at the nesting range scale could be advantageous as an approximation to the foraging range of the average pair during the breeding season. However, such an approach would compound the false accuracy that is likely to be introduced by assuming that pigeons follow straight lines when they race, and an initial assessment of index values calculated at larger spatial scales (initially by NHZ) is the logical first step.

4.3.4 Outstanding data and analytical issues

- Birdages are still required for some SHU races and a larger number of federations in England and Wales (Table 5). It will also be necessary to obtain some additional data from years prior to the two Peregrine survey years, and process these data (next bullet point). For the English and Welsh federations in particular, considerable correspondence may be required to obtain these data because there are not one or two large federations responsible for the majority of races but rather a large number of federations each responsible for a small number of races. Alternatively, consideration could be given to producing indices for the non-SHU racing federations based on the size of each federation and the numbers of rings issued per year, as the race release points are known, but a representative sample of complete data would be required to validate this approach.
- Any pigeon abundance indices that are produced need to consider the data requirements for relationships with Peregrine territory occupancy and productivity separately, using pigeons racing from April to July in any given year (largely older birds) to relate to Peregrine productivity in that year but pigeons racing in previous years to test for relationships with subsequent occupancy.
- Because the SHU (maximum numbers of pigeons that could race) and English/Welsh racing federation (actual number of birds racing) data differ, separate abundance indices will need to be generated for each data set and combined to produce an overall index for each spatial unit.
- SHU data are not currently available for 1991, and 1990 data will need to be used as a proxy.

4.4 Natural prey

4.4.1 Rationale

The abundance of natural prey is a fundamental factor when considering potential constraints on the range and breeding success of any species. Changes in the abundance of the natural prey of Peregrines have occurred during the time between the two most recent national surveys, which in turn could have affected Peregrine territory occupancy and productivity.

There is known to be substantial regional and individual variation in Peregrine diet (Ratcliffe 1993). However, the following 12 species, termed by Ratcliffe (1993) as ‘constants’, occurred in over 80 % of diets at 14 different study areas (although the actual number of territories on which these are based is not reported) in North Wales, northern England, southern Scotland, and the Highlands, and formed 78 % by mass of all prey recorded: Feral Pigeon / Rock Dove, Red Grouse, Lapwing, Golden Plover, Snipe, Curlew, Redshank, Skylark, Fieldfare, Song Thrush, Blackbird, and Starling. Seven additional species, termed by Ratcliffe as ‘near constants’, occurred in over 70 % of Peregrine diets at these sites, forming an additional 5 % by mass of recorded prey: Woodcock, Woodpigeon, Jackdaw, Redwing, Ring Ouzel, Meadow Pipit, and Chaffinch. Other species taken frequently in parts of Scotland are Ptarmigan, auks, petrels, Fulmar, Black-headed Gull and Oystercatcher, but note that gulls are not thought to be taken in proportion to their abundance (Ratcliffe 1993). There is also anecdotal evidence to suggest that pigeons and grouse may be important in the north east regions of Scotland (Phil Whitfield and Jon Hardey *pers. comm*) and corvids may be more important in the west (Patrick Stirling-Aird *pers. comm.*) .

4.4.2 Available data sets

Breeding Bird Survey (BBS)
The annual BTO/JNCC/RSPB Breeding Bird Survey is an extensive volunteer-based survey that is the principle UK monitoring scheme for widespread breeding bird populations since 1994 (Raven & Noble 2006). BBS uses a formal stratified random sampling design, in which 1-km survey squares selected at random from the National Grid are stratified by observer population density to allow representative coverage of regions and habitats, whilst making the most of available volunteer resources (Raven & Noble 2006). The BBS obtains sufficient data to monitor a wide range of possible Peregrine prey species including waders, gamebirds and passerines. As the survey was only initiated in 1994, the data are only really relevant to the 2002 Peregrine survey. Although the BBS is the most widespread breeding survey throughout Scotland (and the UK), there is still a lack of geographic coverage in certain areas, in particular in much of the north and west of Scotland (Figure 4 for 2002 coverage). Trends in relative abundance based on BBS data are generated annually and all-Scotland changes are available for the years 1994-2002 for 59 species (Raven *et al.* 2003; Table 7). Species are only included for formal BBS analysis if they are monitored on more than 30 BBS squares in any given geographical area under consideration, the scope for identifying regional trends within Scotland (either by Natural Heritage Zones, local authority regions or counties) is currently severely limited for all but a handful of species.

Geostatistical methods have been used previously by BTO to produce maps of relative abundance derived from BBS data for the whole of the UK (Newson & Noble 2003; Newson & Noble submitted). Simple Kriging has been adopted, in which the counts at sites that have been surveyed are weighted to provide estimates of relative abundance for sites that were not surveyed, taking into account autocorrelation (the statistical relationship between measured points). To date, values of interpolated relative abundances (and hence maps of relative abundance across the UK) have been produced for 96 bird species at a 10-km square resolution, based on BBS data collected in 2003. These predictions have been compared with the abundance maps from the most recent Breeding Atlas (Gibbons *et al.* 1993). As expected, abundance is predicted most satisfactorily in areas where a species is widely spread. When species are localised in their distribution and BBS coverage is limited, small populations are likely to be missed and consequently areas of low or no abundance are incorrectly predicted (Newson & Noble, 2003).

Repeat Upland Bird Survey (RUBS)
The RSPB's Repeat Upland Bird Survey collected data for a range of wader and passerine species in six discrete areas across Scotland (Figure 5). The timings of the original surveys and resurveys varied markedly in their comparability to the two most recent national Peregrine surveys (Table 8). In addition, although comparisons for temporal changes within any given study unit are valid, there are problems in comparing prey abundance between the different study areas due to differing survey methodologies and different measures of abundance (Table 8). The range of species covered was also relatively restricted: data for wader species are available for all six areas but data for passerine species only for four areas (Table 9). In the context of the Peregrine Framework project, the use of the RUBS dataset appears to be limited to a possible second stage of region-specific analyses or perhaps for some limited verification of interpolated BBS data (above and section 4.4.3).

Breeding bird atlases
Two breeding atlases of Britain and Ireland, covering all regularly occurring bird species, have been published by the BTO, for the years 1968-72 (Sharrock 1976) and 1988-1991 (Gibbons *et al.* 1993). In the first atlas, information on the distribution of breeding birds was collected at a 10-km square resolution (and species were categorised as 'confirmed', 'probable' and 'possible' breeders within each 10-km square). In the more recent atlas, (suitable in timing for comparison with the 1991 national Peregrine survey data), information

on relative abundance was collected using timed counts. Changes in distribution between the two atlases were also documented, and the timings are appropriate for comparison with changes observed between the 1971 and the 1991 national Peregrine surveys.

Regional atlases

The Scottish Ornithologists' Club has 14 regional branches, of which 4 have produced regional atlases: Grampian (Buckland *et al*. 1990), Lothian and Borders combined (Murray *et al*. 1998), and Fife (Elkins *et al.* 2003). The Clyde regional branch has also collected data but not published a book. In addition, the SOC's Grampian branch and the Moray Bird Club have completed fieldwork for a new breeding bird atlas for North East Scotland, and a breeding and winter atlas for Clackmannanshire is also in progress. None of these data are likely to be usable in the analyses to look at changes between the two most recent Peregrine survey years unfortunately (Table 10) although they could be of use at a later stage in the Framework project if more detailed questions need to be asked at a regional scale.

Seabird 2000 and Seabird Colony Register

The Seabird 2000 project, which was co-ordinated by JNCC, represents the third complete census of the entire breeding seabird population within the UK and covers the breeding seasons of 1998-2002 (Mitchell *et al.* 2004). The dataset corresponds well with the most recent national peregrine survey of 2002. Additional information is held in the Seabird Colony Register database for 1969 to 1998. This includes data from the first two complete censuses: Seabird Colony Register Census (1985-1988) and Operation Seafarer (1969-70), which are comparable to the national Peregrine surveys of 1991 and 1971 respectively. Data collected outwith the national census years are unlikely to be usable due to incomplete geographic coverage and irregular recording effort between years.

The main species of interest as Peregrine prey are the small gulls (Black-headed Gull, Common Gull and Black-legged Kittiwake) and the terns (Common Tern, Sandwich Tern and Artic Tern). However, the first two censuses did not collate data on the size and location of inland breeding gull colonies (Black-headed and Common): this was only attempted during Seabird 2000 (Mitchell *et al.* 2004). Therefore it will not be possible to look at the impact of changes in inland gull colonies on Peregrine occupancy and breeding success. Coastal data will provide useful information on seabird abundance and changes in abundance, as prey for coastal breeding Peregrines. Experience during the Golden Eagle Framework suggests that data may be incomplete for some areas however (P. Whitfield, pers. comm.).

Wild Bird Abundance Score

The BTO, in collaboration with the Centre of Epidemiology and Risk Analysis and the Wildfowl and Wetlands Trust, has recently generated abundance scores across all 10-km squares for all wild bird species in the UK using data taken from the most recent national surveys for each species (Newson *et al. in prep*). In combination with information on bird movements, these abundance scores were developed as a means of predicting spatial variation in the risks from Avian Influenza carried by wild birds. Monitoring data from 10 schemes were collated and, for each species and at the 10-km level, a monthly abundance score (0-5) was assigned for each survey wherever possible. The surveys were then ranked in order of importance (data quality) and the final abundance score for any species was based on the abundance score of the survey ranked highest within the hierarchy (Table 12), such that the final abundance scores were based on the most comprehensive survey for each of the species and on the most recent data. In theory, such abundance scores could be used to generate a single prey availability index for each 10-km square throughout the country for each month, covering all potential natural Peregrine prey species. Whilst this was an interesting approach, which could be considered further perhaps particularly in relation to winter prey abundance, the current scores are not considered suitable for use in the Peregrine Framework because of the wide span of survey years on which they are based.

4.4.3 Data collation and analytical approach

- Use of BBS data has been agreed with the BTO/JNCC/RSPB BBS partnership and is held by BTO. Previous interpolations for 2003 are also available for use.
- The RSPB has kindly supplied all of the RUBS data to BTO Scotland.
- National bird atlas data is held by BTO and available for use.
- Full access is available to the JNCC seabird datasets and the complete Seabird 2000 database has been supplied to BTO Scotland.

Natural Prey Index using BBS data

We have carried out preliminary investigations of whether Natural Prey Indices for individual key prey species can be generated for the purposes of our analyses based on the BBS data. The sample sizes (number of BBS 1-km squares in Scotland where species were recorded) for the above Ratcliffe 'constant' species for 1994 to 2005 are shown in Table 12. Of these species, sample sizes are too low for spatial interpolations for Fieldfare. Mean sample sizes are increased to some degree for most species by including the year of the national Peregrine survey (i.e. 2002) plus one or two additional years. Ideally, years prior to the study year (i.e. 2000 and 2001) would be added to increase sample sizes, since it would be biologically reasonable to assume that prey levels in these previous years could influence Peregrine occupancy (and perhaps even productivity) in 2002. Unfortunately, however, all sample sizes were low in 2001 due to problems of access owing to the foot and mouth outbreak in that year (Raven *et al*. 2002). Our preliminary investigations indicated that the addition of 2003 and 2004 data to 2002 data increased the spatial spread of sites covered in the three years for two test species: Skylark (Figure 6) but a similar improvement could result from the use of data from 1999 and 2000 (i.e. years preceding 2002, and thus more biologically meaningful), at least for some species.

Spatial interpolations were carried out by simple cokriging, using habitat data from LCM2000 (section 4.2.2) in ArcGIS 9 (Johnston *et al.* 2001) for a selection of test species: Feral Pigeon/Rock Dove; Red Grouse; Golden Plover; and Skylark. In order to investigate the most important habitat predictors for each species, log-linear models with a negative binomial error distribution were used, using the GENMOD procedure in SAS (SAS Institute 2001). The three most important habitat groups were selected using backward selection. The bird abundance data were also first transformed using a natural logarithm to improve normality. Since three years of BBS data were used (2002-2004 in these exploratory analyses), the mean count was used for sites visited in multiple years. An example of an interpolated relative abundance map is given in Figure 7, for Skylark.

Because of the inaccuracies that may be introduced by this approach for species not covered effectively by BBS in parts of Scotland (e.g. more localised species) and due to coverage issues in the north and west, the approach will probably need to be restricted to a subset of the 'constant' species only (perhaps key prey species that can be used as an indicator of habitat quality/other prey), and/or omit areas of Scotland with poor coverage. There might also be possibilities of verifying the spatial interpolations using BBS data against data on prey abundance from an independent source. The possibility of using RUBS data for this has been raised by the Frameworks Steering Group and considered briefly but because of variations in the RUBS survey methods between regions there may be very limited scope to take this approach.

The BBS data only extend back to 1994, when for most of the target prey species the number of 1-km squares in which they occurred was lower than in 2002 (and there were of course no previous years of data with which to increase the sample for interpolation). For this reason, the use of BBS data to consider changes in Peregrine prey abundance between 1991 and 2002 is very limited. It may be possible to compare spatial variation in the relative abundance of

some prey species in 2002 (from BBS) with that in 1988-91 (from the national breeding bird atlas; Gibbons *et al.* 1993) if each set of data is scaled spatially relative to maximum and minimum index values in the respective data set. Data from the 1988-91 atlas could also be used (with the 1991 Peregrine survey data) to test any relationships between Peregrine occupancy/productivity and prey abundance established using the BBS datasets and the 2002 Peregrine survey data.

4.4.4 Outstanding data and analytical issues

- The sample sizes of BBS squares for two of the most likely important 'constant' prey species are small: Feral/Rock Pigeon and Red Grouse (see Table 12 for samples sizes from 1994-2005). Higher numbers of BBS squares are available for other constant 'species' e.g. Skylark and Curlew and there is a need to consider whether BBS data for a number of species can be used to form some index of prey abundance. There are, however, reasonable numbers of BBS squares for the corvid species Rook and Carrion Crow which may prove to be key prey species for the Peregrine (see Table 7 for sample sizes in 2002).
- Possible methods for validating the interpolated BBS relative abundance maps (perhaps using RUBS data or new data collection) need to be considered.
- Relationships between grazing equity data (section 4.8) and BBS data for key prey species could be explored to further inform the interpolation process.

4.5 Persecution by humans

4.5.1 Rationale

Peregrines face potential persecution from two main sources: grouse-moor gamekeepers and pigeon racers (Ratcliffe 1993). Persecution has been demonstrated within the Golden Eagle Framework to be an important constraint acting on the Scottish population, most notably in the central and eastern highlands (Whitfield *et al.* 2008). Similarly, persecution might be acting as a constraint on the Scottish Peregrine population at a regional level. There is anecdotal evidence that persecution might be an important factor for the Scottish population of Peregrines. In the 2002 survey, although direct evidence was not provided, up to 95 sites were thought to have failed due to persecution notably in the north east and central Scotland[2]. Comparison of occupation by breeding pairs has been shown to be significantly lower in areas managed as grouse moors when also controlling for year and regional effects within three regions of Scotland (Hardey *et al.* 2003). In the same study, it was also shown that mean brood size per territorial pair was lower on grouse moors compared to land managed for other uses. These results were interpreted as further evidence for effects of persecution but further investigation is clearly important in order to determine true cause and effect.

4.5.2 Available data sets

Land Cover of Scotland 1988

The LCS88 is a full census carried out by the Macauley Land Use Research Institute (MLURI 1993) of the vegetation resources of Scotland. It is based on interpretation of 1:25,000 resolution aerial photographs taken between 1987 and 1989, and therefore provides vegetation data that is most comparable to the timing of the 1991 national Peregrine Survey. There are 11 broad classifications of land cover categories[3]. Whitfield *et al.* (2003) used the distribution of "strip muirburn", a subclass of heather moorland, as a measure of the distribution of land

[2] http/wwww/bto.org/survey/complete/peregrine_results.htm

[3] Arable land and improved Pasture , Heather Moorland, Wetland , Coarse grassland, Smooth grassland, Montane vegetation, Blanket bog and peatlands, Bracken , Woodland, Duneland/Maritime grassland/heaths, and miscellaneous.

actively managed for Red Grouse. Given that Red Grouse management practices have been linked to persecution of raptors (see Gibbons *et al.* 1994; Whitfield *et al.* 2008), the presence of strip muirburn could indicate an increased likelihood of persecution of all birds of prey including the Peregrine. There has not been a comparable land cover survey based on aerial photography for Scotland since the LCS88, and therefore there will be no scope to use this database for looking at causes of change in occupancy and breeding success of Peregrines between the two most recent national surveys.

RSPB data on persecution events

Compiling evidence for persecution relies on the discovery of carcasses (including those of birds of prey and poison bait laid out in situations where birds of prey may be the target) or the witnessing of actual events. All known persecution events are collated by the RSPB (see RSPB 2006) but it is not known to what extent the information held under represents the true extent of persecution in Scotland. Although, poisoning is the most frequently documented persecution event for all raptors, Peregrines are possibly less susceptible compared than other raptor species (e.g. Golden Eagle, Red Kite or Buzzard) as they tend not be carrion feeders. Consequently, since 1991 there have been only nine recorded incidents of poisoning involving Scottish Peregrines. In addition, the RSPB collate records of all other forms of persecution, including nest destruction or removal of eggs or chicks, and cases of trapping and shooting. These incidents are classified into confirmed, probable and possible cases (see RSPB 2006 for further explanation).

Using the RSPB data, Whitfield *et al.* 2003 used a summary class from Land Cover of Scotland 1988 (LCS88), which they termed as 'Strip muirburn', as a proxy of the distribution of land actively managed for Red Grouse, to demonstrate that poisoning events of raptors were disproportionately linked to grouse moors compared to other upland habitats. They then went on to show that distance to strip muirburn was an important predictor of whether Golden Eagle territories were more likely to be occupied by adults pairs, mixed aged pairs or single sub-adult birds; adult pairs were least associated with strip muirburn. Moreover, where the density of poisoning events (per 1000 $km^{2)}$ was high, the proportion of sites occupied by pairs decreased, with an associated increase in single sub-adult birds and mixed-age pairs (Whitfield *et al.* 2004a).

SRSG information on persecution events

Additional information on persecution events may also be available from the records of individual SRSG members. Earlier events were less likely to be reported to the RSPB or the Police and subsequently will have not been incorporated into the RSPB datasets. Although much of the evidence may be regarded as circumstantial, it may provide a complementary data set to the one held by RSPB. However, such datasets may prove impractical for use in this project due to a lack of standardisation in recording and data collation. Time would need to be spent cross-checking between SRSG data and the RSPB dataset, and SRSG members would need to be asked to compile their data in as standardised a manner as possible.

4.5.3 Data collation and analytical approach

- BTO Scotland holds the full LCS88 data set. Phil Whitfield (pers. comm.) has confirmed the classes that were used to categorise land as 'strip muirburn' for the Golden Eagle Framework, so that we can take a consistent approach.
- Data on all confirmed cases of persecution (for all raptor species) for the years 1991 to 2002 have been provided to BTO Scotland by the RSPB (Table 13). In total for Peregrine there have been 111 confirmed cases of direct disturbance at the nest and 37 cases of trapping and shooting since 1991.
- No attempt has been made to obtain more circumstantial data from SRSG members.

4.5.4 Outstanding data and analytical issues

- In the first stage of analyses, and given the analyses of Whitfield *et al.* (Whitfield *et al*. 2003; Whitfield 2008) that link persecution to 'strip muirburn', it seems reasonable to use distance to 'strip muirburn' from Peregrine nest sites in order establish whether there is a link between areas specifically managed for grouse moors and Peregrine occupancy and productivity.

4.6 Climate/weather

4.6.1 Rationale

Rainfall has been shown to be correlated with Peregrine breeding productivity and territory occupancy (e.g. Norriss 1995; Horne and Fielding, 2002). Jon Hardey is currently looking at the effects of weather on breeding Peregrines in North-east Scotland for his Ph.D; results should be available in late 2007 and could usefully inform further analyses to look at the effects of weather at the national scale. Given current concerns about the possible impacts of global climate change on Scotland's biodiversity, knowledge of any variation in Peregrine territory occupancy or, more likely, productivity in relation to weather will play a role in predicting the possible effects of climate change on the Scottish Peregrine population.

4.6.2 Available data sets

Met Office data
The Met Office has produced monthly and annual gridded (5-km x 5-km) data sets for the years 1914-2005, including the following parameters: mean monthly daily max temperature (°C); mean monthly daily minimum temperature (°C); monthly mean temperature (°C); and total monthly precipitation (mm). These data sets are based on the archive of weather observations made at all land surface stations throughout the country and have been created using multiple regression with inverse-distance weighted interpolation (Perry & Hollis 2005). Weather data are therefore currently available that correspond to the 1991 and 2002 Peregrine surveys.

British Atmospheric Data Centre (BADC)
Daily (and hourly) measurements are available by county for the whole of the UK from 1853 to present. Weather parameters include maximum and minimum daily temperature (°C) and daily rainfall (mm); these are potentially available for all weather stations but there will be missing data issues. These data could be used to look at changes between the 1991 and 2002 national Peregrine Survey but the data are not interpolated, however, and would require substantial further processing.

SRSG weather data
It has been suggested that some SRSGs hold long-term datasets on rainfall and temperature. If such complementary datasets do exist, however, they are unlikely be standardised or complete in terms of geographic coverage across the whole of Scotland. Hence we do not feel that it is useful to pursue these for the first stage of analyses.

4.6.3 Data collation and analytical approach

- We suggest further liaison with Jon Hardey over the results of his research for the North-east of Scotland, to inform selection of weather parameters.
- We suggest initial investigation of broad associations with Peregrine occupancy and productivity using the 5-km by 5-km gridded Met Office data sets.

4.7 Recreational disturbance

4.7.1 Rationale

Peregrines could be subject to the effects of unintentional disturbance directly at the nesting site. Potential sources of disturbance could arise from hill walkers, climbers, hang- or para-gliders, or from the use of roads and tracks (road vehicles, agricultural machinery, quad bikes etc). It is likely, however, that disturbance will be more of a problem if people come into the close proximity of a nest e.g. by scrambling/climbing up to or near the nesting ledge, or if nesting crags are small or alternatives are very limited (Ratcliffe 1993). Peregrines are generally thought to be tolerant to disturbance (Banks *et al.* 2003), compared to some other species and there is evidence that the species is breeding increasingly in suburban/urban habitats.

4.7.2 Available data sets

Walking
To our knowledge, despite the extensive number of books published, digitised information on recommended routes for walkers and hikers (for both hill walks and low level walks) do not exist. It would be a very time consuming exercise to generate a data set on routes for importing into ArcGIS. Another approach, as adopted in the Golden Eagle Framework (Fielding *et al.* 2003a**;** Whitfield *et al.* 2008) would be to look at the distance to "Munros" (Scottish hills greater than 3000ft high). Fielding *et al.* (2003a) were unable to find any supportive evidence for an effect of potential disturbance resulting from proximity to Munros on occupancy in Golden Eagles based on data from the 1992 survey. Similarly, Whitfield *et al.* (2007) showed that changes in territory occupancy between the 1991 and 2003 Golden Eagle Survey could not be accounted for by the distance to Munros and other centres of recreational activities. An analysis including other recognised hill groupings as well as Munros might be worth considering: 'Tops' (Scottish hills greater than 3000 ft but not counted as separate Munros), 'Corbetts' (Scottish hills between 2000 and 2500 ft), 'Grahams' (Scottish hills between 2500 and 2000 ft) and 'Donalds' (hills greater than 2000ft in Central or Southern Scotland but less than 2500 ft). Data on all Scottish hills are given in Bearhop (1997), which is the list endorsed by the Scottish Mountaineering Club (SMC). The altitude of Peregrine nest sites should also be considered in any analyses of such datasets (as the distance of Peregrine nest sites to such recognized hill groupings is likely to be confounded with altitude). To our knowledge (and as indicated by Whitfield *et al.* 2008) there is no recent survey information available on spatial variation in the intensity of recreational use of Scottish hills, which might provide better information on the likelihood of disturbance.

Climbing
As for walking routes (above), digitised maps of climbing routes do not exist. It would be possible, however, to generate a data set with the locations of crags and bouldering sites from the series of climbing guides written by the SMC and edited by Brian Davidson. Again this would be a time-consuming exercise and, once again, no information is available on intensity of use, limiting the usefulness of such data.

Roads and tracks
Digitised spatial data on roads, tracks and paths (the last category being incomplete) are available from the OS Mastermap as vector data but the use of such data is problematic. Whitfield *et al.* (2008) have already highlighted the limitations of trying to identify the effect of proximity of roads on occupancy and breeding success in the Golden Eagle. Such simple analyses do not distinguish between the different intensity of road usage, and, for example, do not take into account important features such as topography (which might influence birds' perceptions of disturbance levels) or proximity to agriculture (where there may additional disturbance from farm machinery).

Proximity to human populations
The distance of Peregrine territories from centres of dense human populations might reflect the likelihood of disturbance (from local people and recreational walkers/climbers). Information on the number of people, the area and therefore the densities (number of people per ha) are available from all 32 Scottish council areas for 2001 and 1991 (http://www.scrol.gov.uk and http://www.gro-scotland.gov.uk/census/1991-census-products/index.html respectively). The distance to cities and towns in combination with the actual population size could also act as a proxy for potential disturbance. Information on 587 localities and 493 settlements (which can include a number of localities) plus their four-figure Ordnance Survey National Grid Reference are also freely available for 2001 and 1991 (e.g. General Register Office for Scotland, 2003) and could be incorporated into analyses.

4.7.3 Data collation and analytical approach

- BTO Scotland holds data on the locations of summits of 'Munros', 'Tops', 'Corbetts', 'Grahams' and 'Donalds' in electronic form.
- BTO does not have a licence for OS Mastermap. Distances to roads, tracks and paths cannot be incorporated into future analyses unless this can be done under the SNH OS licence agreement.
- Data on proximity to human populations (above) are freely available for use if required.

4.8 Grazing

4.8.1 Rationale

Large grazing herbivores such as sheep and deer, in the form of carrion, can be a potentially important source of winter food for raptors such as the Golden Eagle (e.g. Watson *et al.* 1992). Carrion is less likely to be important to Peregrines, since they generally hunt live prey (Ratcliffe 1993). Sheep and deer numbers may of course influence Peregrines indirectly, however, as differences in grazing levels can influence the habitat suitability for a variety of prey species (section 4.4) and therefore prey abundance (e.g. Fuller & Gough 1999).

4.8.2 Available data sets

Sheep numbers
Data are available from Scottish Executive Environmental and Rural Affairs Department (SEERAD) for sheep numbers (as classified into ewes for breeding, rams for service, other Sheep older than 1 year and lambs) and stocking densities for total sheep (and without lambs) for total grass area including rough grazing. Data are subdivided into the old local authority designations (giving a total of 33 counties) and geographic coverage appears reasonably complete. Information is available for the two most recent national Peregrine survey years and the intervening years. Therefore, it would be possible to look at regional variation/change in sheep numbers and how this is related to Peregrine occupancy and productivity but not to look at relationships at a finer spatial scales because of the resolution of the data (see also Whitfield *et al.* 2008 for details of data constraints).

Deer
Annual data on Red Deer counts for Scotland have been provided by The Deer Commission of Scotland (DCS) for the years 1983 to 2002. There are limitations with this data set, however. Geographic coverage is not complete, as counts tended to be carried out in areas where deer were known to be present in high numbers, and moreover, counts were focussed in areas where there was traditionally a strong sporting interest (Mike Daniels, pers. comm.).

Only single counts per area per year were carried out, so that there may be biases caused by: observer error; movements of deer; and variation in deer detectability between habitats. No national datasets are available for Roe Deer numbers.

"Grazing Equity" values
The ratio of biomass offtake by grazers (sheep, Red Deer and cattle) in relation to the biomass production of the vegetation has been calculated at the parish scale, for the years 1982 and 1998, in order to produce what have been termed 'Grazing Equity values' (Armstrong unpublished data; Mackey *et al.* 2001; Fielding *et al.* 2003a). Whitfield *et al.* (2008) have proposed that these values can be used a proxy for the availability of the key prey species for Golden Eagles. It is possible therefore that these values might give a useful indication of spatial variation in live natural prey availability for the Peregrine.

4.8.3 Data collation and analytical approach

- Data on sheep and deer numbers (as detailed above) have been supplied to BTO Scotland by SEERAD and DCS respectively and are available for analysis. Datasets processed to NHZ boundaries were used as part of the Golden Eagle Conservation Framework (see Whitfield *et al.* 2008), and is held by Natural Research Ltd.
- BTO Scotland holds the full grazing equity dataset for Scotland (obtained via Helen Armstrong) with grazing equity values calculated for individual parishes. Datasets processed to NHZ boundaries were used as part of the Golden Eagle Conservation Framework (see Whitfield *et al.* 2008), and is held by Natural Research Ltd.

4.9 Forestry

4.9.1 Rationale

During the period of 1940s-1980s there were notable increases in conifer plantations across Scotland (Mackey *et al.* 1998). The effects of forestry on Golden Eagles have been reviewed extensively by Whitfield *et al.* (2008). They highlighted that despite initial concerns about the effects of commercial afforestation, subsequent studies have not reported consistently any negative effects on Golden Eagle breeding success (Marquiss *et al.* 1985 for Galloway; Watson 1992 for Argyll; Whitfield *et al.* 2001 for Mull) or territory occupancy (Watson *et al.* 1987; Whitfield *et al.* 2007a), Whitfield *et al.* 2008). In some areas where sites have been abandoned apparently in response to forest planting, adjacent pairs moved the boundaries of their territories, which resulted in increased productivity. Based on research in Argyll, the response of individual Golden Eagle pairs to afforestation has been shown to be highly variable, with some pairs abandoning territories with relatively small increases in forest cover and others showing improved productivity even when up to one-third of their territory was lost to forestry (Whitfield *et al.* 2007a). Although little has been reported on the possible effects of forestry on the Peregrine, it is possible that afforestation could influence prey abundance/availability due to loss of key foraging habitat in the Scottish uplands (Ratcliffe 1993). However, there is no reason to assume that such effects would be any less complex for Peregrines than for Golden Eagles.

4.9.2 Available data sets

Land Cover of Scotland 1988
Within the LCS88 (see section 4.5.2), woodland is one of the 11 broad classifications of land cover, and is in turn divided into broadleaved and coniferous woodland. There has not been an update to this particular database and therefore there will be no scope to use this database to assess changes in woodland cover between the 1991 and 2002 Peregrine surveys.

Land Cover Map 1990 and 2000
The classes of interest in LCM1990 would be Deciduous/Mixed wood and Coniferous/Evergreen Woodland. Within LCM2000, Broadleaved/Mixed/Yew Woodland and Coniferous Woodland would be of specific interest. However, differences in methodology between these two classification systems mean that they cannot be used to compare changes in woodland cover between the 1991 and 2002 Peregrine surveys (see section 4.2.2 for further details).

National Inventory of Woodland Trees (NIWT) Scotland
The Forestry Commission NIWT data set (version as updated 31 March 2002) contains Scottish woodland areas mapped using a variety of data sources including: LCS88 (section 4.5.2); Woodland Grant Schemes (1988-2002) and Forestry Commission New Planting (1988-2002); urban woodland; and 'miscellaneous' (updates that have been made to the LCS88 dataset). This data set covers only woodlands and forests over 2 ha in size. The specific classifications of interest are as follows: conifers; broad leaves; mixed; coppice with standards; young tress and shrubs; ground prepared for planting; and felled. Although the data set is updated regularly from its original version in 1995, most of the data originate from the LCS88. Other potential pitfalls of this data set include: the category of young trees was never updated to show what species these plantings grew into; mature woodland that was felled has not been recorded (nor whether felled woodland was restocked or not); and other potential changes in land uses have not been considered. It is arguable how relevant this data set is to either of the two most recent Peregrine surveys.

4.9.3 Data collation and analytical approach

- BTO Scotland holds the NIWT database (version as updated 31 March 2002).

4.10 Competitors/predators

4.10.1 Rationale

Golden Eagle
Golden Eagles are likely to compete directly with the Peregrine for a relatively wide range of prey species (Ratcliffe 1993) and may also be potential predators of Peregrines (Watson, 1997). Quantitative analyses to compare cliffs occupied by Peregrines and those that were unoccupied, have shown that the distances to the nearest Golden Eagle territory were significantly different, indicating that Peregrines actively avoid nesting in close proximity to Golden Eagles (Ganzarain *et al.* 2000) or are forced to abandon sites. On the island of Mull, Scotland, the breeding distributions of Raven, Common Buzzard and Peregrine suggested that they nest further than expected from Golden Eagle range centres (Fielding *et al.* 2003b).

Raven
Relationships between Ravens and the occupancy and productivity of Peregrines are likely to be complex. Despite little apparent overlap in their dietary requirements, Ravens nesting in close proximity to Peregrines can interact aggressively, resulting in injury or fatality to either of the species (Ratcliffe 1997). However, there is strong evidence that Peregrines can nest near to Ravens due to preferences for similar types of crag (and possibly advantages conferred in terms of early warning against predators), and that Peregrine productivity can be negatively associated with distance to the nearest Raven nest (Sergio *et al.* 2004). Peregrines are also known to take over former Raven sites (Ratcliffe 1993).

4.10.2 Available data sets

Golden Eagle
Data on Golden Eagle nesting sites and occupancy are available from the Golden Eagle national surveys of 1992 and 2003. These data are owned jointly by the SRSGs, RSPB, SNH and Natural Research Ltd, and a request would need to be made to use them within the Peregrine Conservation Framework. The national survey years for Golden Eagle differ from those for Peregrine (albeit by one year), and there could also be lag effects of the presence of eagles on Peregrine territory occupancy. For these reasons, additional data on Golden Eagle territory occupancy in intervening years would also be required in order to look rigorously at any effects of Golden Eagles on Peregrines. Such data are available (although coverage of all territories in Scotland is not comprehensive) from the annual monitoring carried out by the Scottish Raptor Study Groups; they could be used to assess whether nesting sites used in the Golden Eagle national survey years were notably different in the years of 1991 and 2002, the years of the two most recent Peregrine surveys. These datasets have already been compiled, checked and analysed extensively by Natural Research Ltd for the Golden Eagle framework, and they wish to use them to look at intra-guild relationships across a range of raptor species in the future (Phil Whitfield, pers. comm.).

Raven
Data on Raven abundance are available from the BBS (including the associated long-term trend data (Table 7) and the interpolated data described in section 4.4.2). The two breeding bird atlases (Sharrock 1976; Gibbons *et al.* 1993) could also be used to compare changes in distribution and abundance between the 1971 and the 1991 national Peregrine Surveys. Some additional more recent information may be available from the SRSGs, although these are not held centrally at present. In 2002, numbers of known Raven home ranges and breeding success were recorded by four SRSGs (North-east; Tayside (not including Angus); Central; and Argyll, Anon 2004). These data could be useful for region-specific analyses. Data on Ravens appear not to be available for 1991 (see Anon 1992) but a specific request for data could be made to the SRSGs.

4.10.3 Data collation and analytical approach

- **Golden Eagle –** we propose that competitive interactions between Peregrines and Golden Eagles should form a later stage of analysis because of the likely complexities of the relationships and a need to liaise further with the data owners regarding their aspirations for use of the data.
- **Raven** – a preliminary investigation of broad associations between Peregrines and Ravens might be carried out for some regions using a combination of BBS abundance data and SRSG data but further explicit locational information will be required from the SRSGs.

4.11 Pollution

4.11.1 Rationale

The negative effect of organo-chlorine pesticides on the British Peregrine population during the 1950s and 1960s has been documented extensively (e.g. Ratcliffe 1993). Organo-chlorine pesticides caused not only mortality of adults but also led to a reduction in breeding success as a result of egg-shell thinning, the production of infertile eggs, and chick mortality.

4.11.2 Available data sets

The Predatory Bird Monitoring Scheme
The Centre for Ecology and Hydrology (CEH) has co-ordinated a long-term monitoring programme to look at the levels of pollutants found in a number of bird species in the UK. Data are available for trends in organo-chlorines [4] and mercury found in Peregrine eggs for the years 1963 –1997 for the regions of Southern Scotland, Southern Island Fringe, Central & Eastern Highlands and North & Western Highlands (Newton *et al.* 1999). Data on measured pollutant levels in eggs co-incident with the most recent Peregrine survey in 2002 are therefore not available (Table 14). Shell thickness index data from the same regions are also available from 1963 to present. Although these data could be used as an indication of the levels of DDE, the sample sizes are small (Table 14) and are unlikely to provide enough information on geographic variation in shell thickness.

Peregrine livers were also analysed for organochlorines and mercury until 1998 but there were little or no data collected from Scotland. Additional information is available from the analysis of livers of Sparrowhawks but, despite being the largest data set for any raptor (Shore *et al.* 2005), the sample sizes are still too small to assess any geographic variation or trends in contaminants for Scotland (Table 15).

CEH acidification data
Acid deposition is known to influence the availability of calcium in the environment. It has been shown in a range of passerines that low levels of calcium can lead to reduced breeding success either through effects on egg shell production or by increasing sensitivity to toxic metals (Graveland & Drent 1997). It is unlikely that calcium deficiency will have a direct affect on Peregrines since they regularly ingest bones as part of their diet. It is possible that an indirect impact may arise through calcium affecting populations of their prey species however. The BTO, as part of a joint project with CEH, investigated the potential affects of acidification on the breeding performance and distribution of terrestrial birds (Chamberlain *et al.* 2000). Acidification levels were measured using two methods: (i) by determining the absolute difference between the deposition rates of Sulphur and Nitrogen and the critical loads of habitats (defined as the deposition below which significant harmful effects on the environment do not occur; these exceedance values are generally regarded as a crude indication of environmental damage); and (ii) by determining the ratio of exceedance in relation to the critical load (known as 'exceedance ratios', which are thought to provide a more accurate indicator of environmental damage). The values and definitions of the critical loads for habitats have been recently revised however (Rachel Warren pers.comm.) and therefore cannot be used as part of the Peregrine Framework, without substantial work to recalculate them.

4.11.3 Data collation and analytical approach

To investigate any relationship between acidification and Peregrine occupancy and productivity, we could in the first instance use soil critical load data from 1990 and 2002 to calculate exceedance values and exceedance ratios. Soil critical load data are available for the whole of the UK, whereas not all habitats have critical loads data (arable, improved grassland and urban areas are excluded). If any evidence for relationships is revealed, further work on habitat critical load could be carried out (this would involve time input from CEH to calculate the values for the appropriate years, at additional cost).

[4] (Dichloro-diphenyl-trichloroethane (DDE), HEOD (Dieldrin) and Polychlorinated Biphenyls (PCBs)

4.12 Fulmars

4.12.1 Rationale

There is anecdotal evidence that oiling by Fulmars could have contributed to a decline in some coastal Peregrine populations (Ratcliffe 1993). Substantial increases in the Scottish breeding Fulmar population were recorded between the first census of Operation Seafarer (1969 to 1970) and the Seabird Colony Register Census (1985 to 1989). The overall Scottish population of Fulmars did not alter substantially between the Seabird Colony Register and Seabird 2000, although there were marked regional increases and decreases in the population (Mitchell *et al.* 2004).

4.12.2 Available data sets

The JNCC Fulmar data should be suitable to explore whether regional changes in Fulmar numbers can be linked to regional changes in coastal nesting Peregrines. Experience during the Golden Eagle Framework suggests that data may be incomplete for some areas however (P. Whitfield, pers. comm.).

4.12.3 Data collation and analytical approach

Full access to the JNCC seabird data is available, and BTO Scotland has been supplied with the entire database.

4.13 Availability of nesting sites

4.13.1 Rationale

Traditionally Peregrines were viewed as crag nesters and, consequently, their breeding distribution was thought to be restricted by the availability of suitable cliffs (Ratcliffe 1993). Peregrines are now known to be capable of using a wide range of additional nesting sites, such as quarries, pylons, trees and buildings, in addition to low-level hills and essentially 'walk-in' ground sites. It is not practical to obtain information of the distribution non-quarry sites since they are ubiquitous in distribution. It is potentially more feasible to look at quarry sites.

4.13.2 Available data sets

The locations of all Scottish quarries (active, 'mothballed' and dormant sites) are available from the British Geological Survey from the directory of Mines and Quarries; are not available electronically for the years of the most recent Peregrine surveys however. Published directories are available for the years 1991, 1994, 1998 and 2002 but would require a substantial amount of time to input the data.

4.13.3 Data collation and analytical approach

Since Peregrines are so flexible in the type of nesting site they will use, quarry site availability is unlikely to constrain occupancy levels. Hence we do not propose quarry data to be of value at least for the first phase of this project.

4.14 Windfarms

4.14.1 Rationale

The possible impacts of onshore windfarm developments in Scotland were considered in the Golden Eagle Conservation Framework (Whitfield *et al.* 2008). Work has been carried out to document the spatial association between windfarm development proposals (over 500; up to January 2005) and Golden Eagle breeding territories/other areas potentially suitable for breeding eagles (Fielding *et al.* in press). As the overlap between these breeding areas and the windfarm footprints was generally very low (<4%), and evidence suggested that most of the proposed windfarms were unlikely to be built, it was concluded that, in comparison with other constraints, windfarms were not a serious concern to the Scottish Golden Eagle population (assuming that best practice in locating these windfarms and minimising their impact was maintained). Despite this overall conclusion, possible pressures on eagles from windfarms in two NHZs were highlighted, and continued monitoring was recommended (Whitfield *et al.* 2008).

It may be assumed that bird species that are more aerially manoeuvrable will generally be at less risk of collision with wind turbines, which would suggest a lower collision risk for Peregrines than for Golden Eagles. However, there is little empirical data available to test this assumption. Even in the absence of a substantial risk of collisions, windfarm developments could result in displacement effects and therefore loss of breeding/foraging habitat for Scottish Peregrines. It may be important to consider the possible pressures posed to Peregrines by windfarm development at the regional scale in Scotland, taking into account the apparent current health of the regional Peregrine populations (as indicated by proportions of occupied territories and breeding success).

4.14.2 Available data sets

A similar spatial analysis to that for Golden Eagles could be carried out between Peregrine nesting locations and proposed windfarm development sites, if the latter were made available to BTO Scotland by SNH.

5. RECOMMENDATIONS FOR PEREGRINE FRAMEWORK: PHASE II

Summaries

- Produce summaries of occupancy in 2002 and 1991 by NHZ. These figures will take into account the numbers of visits made to ranges that were classified as unoccupied or occupied by a single bird to ensure that occupancy rates are not an underestimate.
- Produce summaries of as many breeding success parameters as possible by NHZ for 2002 and 1991.
- Determine relative changes in occupancy and productivity between 1991 and 2002 by NHZ

Analyses

- Analyses of relationships between habitat and Peregrine occupancy and productivity across Scotland The use of complete data set may help identify factors operating across the scale of the whole country.
- Analyses of relationships between habitat and Peregrine occupancy and productivity by NHZ. By looking at the data by NHZ we may be able to tease apart factors that may be operating at a more regional level.
- Analyses of occupancy and productivity comparing inland and coastal sites as means of identifying any different influences that may be operating on the coast and inland.
- Analyses will focus on the situation in 2002, and changes in occupancy and productivity between 1991 and 2002.
- Review evidence from these analyses for priority of Level 1 environmental factors before proceeding with the next phase of analyses.

Acknowledgements

We would like to thank all the SRSG Peregrine co-ordinators and other SRSG Members who have provided locational data specifically for this project namely Dave Okill (Shetland Ringing Group), Erik Meek (Orkney), Brian Etheridge (Highland RSG), Jamie Boyle (Uist RSG), Ali Maclennan (Lewis), Alison Rothwell (Lewis) John Hardey (North East RSG), Mike Nicholl (Tayside RSG), Roger Hayward (Tayside RSG), Harry Bell (Tayside RSG), Patrick Stirling-Aird (Central and Tayside RSG), Roger Broad (Argyll), George Smith (Lothian and Borders RSG), Chris Rollie (Dumfries and Galloway RSG) and of course all those who have contributed data to the national Peregrine surveys. Brian Etheridge (Raptor Monitoring Officer) helped to facilitate access to some of these data sets. We would also like to thank the following for the provision of data sets and advice: Linda Brookes and John Barlow (SHU): Peter Bryant and Linda Smith (RPRA), Jean Richmond (Notts and Derby Border Federation), Steven Spinks (North Road Championship Club), John Purton (London North Road Combine), C. Hudson (Yorks and Lincs NR combine) and John Humphreys (Welsh NR Federation), Innes Sim and Keith Morton (RSPB); Amanda Thompson, Lee Walker, Rachel Warren, Jane Hall, Richard Broughton and Tony Doro (CEH); Graham Austin, Stuart Newson and David Noble (BTO); Roddy Mavor and Helen Baker (JNCC); Andrew Kesteron (SNH); Matthew Perry (Met Office); Linda Legge and Graham Bull (Forest Research); Andy Reid (SEERAD); and Mike Daniels (DCS). We thank members of the SRMS Raptor Frameworks Steering Group for their advice: Des Thompson and Nigel Buxton (SNH); Arjun Amar and Jerry Wilson (RSPB); Jon Hardey, Wendy Mattingley and Patrick Stirling-Aird (SRSGs); David Stroud (JNCC); Mark Holling (RBBP); Gordon Riddle (SOC); and Helen Riley (Greenwings). In addition we would like to acknowledge the input of statistical advice from Graham Austin, Stuart Newson and Chris Pendlebury.

References

Anon. 1992. *Scottish Bird News* 1991: June 1992. No 26 (pp1-3).

Anon 2004. Raptor Round UP 2002. Scottish Birds 24 supplement

Banks, A.N., Coombes, R.H. & Crick, H.Q.P. 2003. *The Peregrine Falcon breeding population of the UK and the Isle of Man in 2002*. BTO Research Report No.330. BTO, Thetford.

Bearhop, D.A. 1997. *Munros Tables*. Scottish Mountaineering Club (Publications) Ltd.

Buckland, S.T., Bell, M.V. and Picozzi, N. 1990. *The Birds of North-East Scotland*. Skeneprint, Aberdeen.

Chamberlain, D.E., Warren, R.W., Crick, H.Q.P, Hall, J., Metclafe, S., Ormerod, S., Whyatt, D and Vickery, J.A. 2000. *Acidification and terrestrial birds.* BTO Research Report 236.

Crick, H.Q.P. & Ratcliffe, D.A. 1995. The Peregrine (*Falco peregrinus*) breeding population of the United Kingdom in 1991. *Bird Study* **42**: 1-19.

Elkins, N., Reid, J., Brown A., Robertson, D and Smout, A-M. 2003. *The Fife Bird Atlas.* Woodlands Studio, Dunfermline.

ESRI. 2001. ESRI Data and maps.

Fielding, A.H., McLeod, D.R.A. & Howarth, P.F. 2003a. *Analytical foundation for a conservation framework for the golden eagle.* Report under contract BAT/AC309/01/02/46, Edinburgh: Scottish Natural Heritage.

Fielding, A.H., Whitfield, D.P., Mcleod, D.R.A., McGrady, M.J. & Howarth, P.F. 2003b. Modelling the impact of land use change on Golden Eagles (Aquilla chrysaetos). *In: Thompson,D.B.A., Redpath, S.M., Fielding, A.H., Marquiss, M., Galbraith, C.A. (Eds.), Birds of Prey in a Changing Environment.* Edinburgh: The Stationery Office, pp. 221-244.

Fuller, R.J. and Gough, S.J. 1999. Changes in sheep numbers on Britain: implications for bird populations. *Biological Conservation* **91**: 73-89.

Fuller, R.M, Smith, G.M., Sanderson, J.M., Hill, R.A., Thomson, A.G., Cox, R., Brown, N.J., Clarke, R.T., Rothery, P. and Gerard, F.F. 2002. *Countryside Service 2000 Module 7: Land Cover Map 2000, final report.* Centre for Ecology and Hydrology, Huntingdon.

General Register for Scotland 2003. *Scotland's Census 2001: Key statistics for Settlements and Localities Scotland.* Edinburgh SE/2003/68.

Gibbons, D.W., Reid, J.B. & Chapman, R.A. 1993. *The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991*. T. & A.D. Poyser

Gibbons, D.W., Gates, S., Green, R.E., Fuller, R.J. & Fuller, R.M. 1994. Buzzards *Buteo buteo* and Ravens *Corvus corax* in the uplands of Britain: limits to distribution and abundance. *Ibis* **137** (suppl.): 75-84.

Graveland, J. and Drent, R.H. 1997. Calcium availability limits breeding success of passerines on poor soils. *Journal of Animal Ecology* **66**: 279-288.

Gregory, R.D., Wilkinson, N.I., Noble, D.G., Robinson, J.A., Brown, A.F., Hughes, J., Proctor, D.A., Gibbons, D.W. & Galbraith, C.A. 2002. The population status of birds in the United Kingdom, Channel Islands and the Isle of Man: an analysis of conservation concern 2002–2007. *British Birds* **95**: 410–450.

Hardey, J., Rollie, C.J & Stirling-Aird, P.K. 2003. Variation in breeding success of Inland Peregrine Falcon in three regions of Scotland 1991-2000. In *Birds of prey in a Changing Environment*. Edited by Thompson, D.B.A., Redpath, S.M., Fielding, A.H., Marquiss, M. & Galbraith, C.A. Pp. 99-109. The Stationery Office, Edinburgh.

Hardey, J. Crick, H.Q.P., Wernham, C., Riley, H., Etheridge, B., & Thompson, D. 2006. Raptors – a field guide to survey and monitoring. The Stationery Office, Edinburgh, UK.

Henderson, I., Parrot, D and Moore N. 2004. *Racing Pigeons - Impact of Raptor Predation*. Report to Scottish Natural Heritage (SNH) and The Scottish Homing Union (SHU).

Horne, G. and Fielding, A.H. 2002. Recovery of the peregrine *Falco peregrinus* in Cumbria, UK, 1966-99. *Bird Study* **49**: 229-236.

Humphreys, L., Wernham, C. and Crick, H.Q.P. 2006. *Peregrine interim report: datasets and plans for analyses*. Report to SNH.

Johnston. K., Ver hoef, J.M., Krivorucho, K. and Lucas, N. 2001. *Using ArcGIS Geostatistical Analyst*. ESRI.

Mackey, E.C., Shewry, M.C. & Tudor, G.J. 1998. *Land Cover Change: Scotland from the 1940s to the 1980s.* Edinburgh: The Stationery Office.

Mackey, E.C., Shaw, P., Holbrook, J., Shewry, M.C., Saunders, J. and Ellis, N.E. 2001. *Natural Heritage Trends: Scotland 2001*. Scottish Natural Heritage.

Marquiss, M., Ratcliffe, D.A. and Roxburgh, R. 1985. The numbers, breeding success and diet of Golden Eagles in southern Scotland in relation to changes in land use. *Biological Conservation* **33**:1-17.

McGrady, M.J., McLeod, D.RA. McLeod, Petty, I. and Grant. J. 1997. *Golden eagles and forestry*. Research Information Note 292. Forestry Commission.

McGrady, M.J., Grant, J.R., Bainbridge, I.P. & McLeod, D.R.A. 2002. A model of golden eagle (*Aquila chrysaetos*) ranging behaviour. *Journal of Raptor Research* **36** (supplement 1): 62-69.

McLeod, D.R.A., Whitfield, D.P. & McGrady, M.J. 2002a. Improving prediction of golden eagle (*Aquila chrysaetos*) ranging in western Scotland, using GIS and terrain modelling. *Journal of Raptor Research* **36** (supplement 1): 70-77.

McLeod, D.R.A., Whitfield, D.P., Fielding, A.H., Haworth, P.F. & McGrady, M.J. 2002b. Predicting home range use by golden eagles *Aquila chrysaetos* in western Scotland. *Avian Science* **2**: 183-198.

Mitchell, P.I., Newton, S.F., Ratcliffe, N. and Dunn, T.E. 2004. *Seabird populations of Britain and Ireland.* T &AD Poyser.

MLURI. 1993. *Land Cover of Scotland 1988. Final Report*. Macauley Land Use Research Institute, Aberdeen.

Murray, R., Holling, M., Dott, H. and Vandome, P. 1998. *The Breeding Birds of South-East Scotland: A tetrad Atlas 1988-1994.* The Scottish Ornithologists' Club.

Newson, S.E. & Noble, D.G. 2003. *Producing statistically valid maps of species abundance from UK BBS counts using Geostatistical Analyst in ArcGIS.* BTO Research Report No. 318. British Trust for Ornithology, Thetford.

Newson, S.E. & Noble, D.G. (submitted). The BBS for mapping Britain's birds. *Submitted to the Turkish Journal of Zoology.*

Newton, I., Dale, L, Finnie, J.K., Freestone, P., Wright, J., Wyatt, C. & Wyllie, I. 1999. *Wildlife and pollution: 1997/98 Annual Report.* JNCC Report No. 285. JNCC, Peterborough.

Norriss, D.W. 1995. The 1991 survey and weather impacts on the Peregrine *Falco peregrinus* breeding population in the Republic of Ireland. *Bird Study* **42**: 20-30.

Perry, M.C. and Hollis, D.M. 2005. The generation of monthly gridded datasets for a range of climatic variables over the UK. *International Journal of Climatology* **25:** 1041-1054

Ratcliffe, D. A. 1963. The status of the Peregrine in Great Britain. *Bird Study* **10**: 56-90.

Ratcliffe, D. A. 1972. The Peregrine population of Great Britain in 1971. *Bird Study* **19**: 117-156.

Ratcliffe, D.A. 1984. The Peregrine breeding population of the United Kingdom in 1981. *Bird Study* **31**: 1-18.

Ratcliffe, D. A. 1993. *The Peregrine Falcon.* T. & A.D. Poyser.

Ratcliffe, D. A, 1997. *The Raven: a natural history in Britain and Ireland.* T. & A.D. Poyser.

Ratcliffe, D. A. 2003. The Peregrine Saga. In *Birds of prey in a Changing Environment*. Edited by Thompson, D.B.A., Redpath, S.M., Fielding, A.H., Marquiss, M. & Galbraith, C.A. Pp. 91-98. The Stationery Office, Edinburgh.

Raven, M.J., Noble, D.G. & Baillie, S.R. 2002. *The Breeding Bird Survey 2001*. BTO Research Report 295. British Trust for Ornithology, Thetford.

Raven, M.J., Noble, D.G. and Baillie, S.R. 2003. *The BBS 2002 Report Number 8.* The British Trust for Ornithology.

Raven, M.J. & Noble, D.G. 2006. *The Breeding Bird Survey 2005*. BTO Research Report 439. British Trust for Ornithology, Thetford.

RSPB. 2006. *Persecution: A review of bird of prey persecution in Scotland in 2005.* RSPB Scotland, Edinburgh.

SAS Institute 2001. *SAS/Stat Software: changes and enhancements through release 6.11*. SAS Institute Inc., Cary, North Carolina.

Sergio, F., Franco, R., Marchesi, L and Pedrini, P. 2004. The importance of interspecific interactions for breeding –site selection: peregrines seek proximity to raven nests. *Ecography* **27**: 818-826.

Sharrock, J.T.R. 1976. *The Atlas of Breeding Birds in Britain and Ireland*. T. & A.D. Poyser.

Shawyer, C., Clarkem R. and Dixon, N. 2000. *A study into the raptor predation of domestic pigeons.* A report for the Department of the Environment, Transport and the Regions.

Shore, R.F., Osborn, D., Wienberg, C.L., Sparks, T.H., Broughton, R. & Wadsworth, R. 2005. *Potential modifications to the Predatory Bird Monitoring Scheme (PBMS): second report.* JNCC Report No. 353. JNCC, Peterborough.

Sim, I.M.W., Gregory, R.D., Hancock, M.H. and Brown, A.F. 2005. Recent changes in the abundance of British upland breeding birds. *Bird Study* **52**: 261-275.

SNH 1998.*Annual Report*. SNH, Battleby, UK.

Watson, J. 1992. Golden Eagle Aquila chysaetos breeding success and afforestation in Argyll. *Bird Study* **39**: 203-206.

Watson, J. 1997. *The Golden Eagle*. London: T. & A.D. Poyser.

Watson, J., Langslow, D.R., and Rae, S.R.1987. *The impact of land-use changes on golden eagles in the Scottish Highland.* CSD Report 720. Peterborough. Nature Conservation Council.

Watson, J., Rae, S.R. and Stillman, R. 1992. Nesting density and breeding success in relation to food supply in Scotland. *Journal of Animal Ecology* **61**: 543-550.

Watson, J. & Whitfield, P. 2002. A conservation framework for the golden eagle (*Aquila chrysaetos*) in Scotland. *Journal of Raptor Research* **36** (suppl. 1): 41-49.

Weir, D.N. 1977. The Peregrine in N.E. Scotland in relation to food and to pesticides. Pp.56-58 in *Pilgrimsfalk. Report from a Peregrine conference held at Grimsö Wildlife Research Station, Sweden, 1-2 April 1977.* Ed. P. Lindberg. Swedish Society for the Conservation of Nature, Stockholm.

Weir, D.N. 1978. Wild Peregrines and Grouse. *Falconer* **7**: 98-102.

Wernham, C.W. and Crick, H.Q.P. 2005. *Raptor Species Conservation Frameworks: Peregrine.* A proposal to SNH. BTO, Thetford.

Whitfield, D.P. 2000. *Golden Eagle* Aquila chysaetos *ecology and conservation issues.* Scottish Natural Heritahge Review 132. Battleby, Scottish Natural Heritage.

Whitfield, D.P, McLeod, D.R.A., Fielding, A.H., Broad, R.A., Evans, R.J. and Howarth, P.F. 2001. The effects of forestry on golden eagles on the island of Mull, western Scotland. *Journal of Applied Ecology* **38**;1208-1220.

Whitfield, D.P., McLeod, D.R.A., Watson, J., Fielding, A.H. and Haworth, P.F. 2003. The association of grouse moor in Scotland with the illegal use of poisons to control predators. *Biological Conservation* **114**: 157-163.

Whitfield, D.P., Fielding, A.H., McLeod, D.R.A. and Howarth, P.F. 2004a. The effects of persecution on age of breeding and territory occupation in golden eagles in Scotland. *Biological Conservation* **118**: 249-259.

Whitfield, D.P., Fielding, A.H., McLeod, D.R.A. and Howarth, P.F. 2004b. The effects of persecution on the population dynamics of golden eagles in Scotland. *Biological Conservation* **119**: 319-333.

Whitfield, D.P., Fielding, A.H., McLeod, D.R.A. and Howarth, P.F. 2006. A conservation framework for the golden eagle in Scotland: Refining condition targets and assessment of constraint influences. *Biological Conservation* **130**: 465-480.

Whitfield, D.P., Fielding, A.H., Gregory, M.J.P., Gordon, A.G., Mcleod, D.R.A. and Howarth, P. F. 2007a. Complex effects of habitat loss on Golden Eagles Aquila chrysaetos. *Ibis* **149** (1): 26-36.

Whitfield, D.P., Fielding, A.H., McLeod, D.R.A., Morton, K., Stirling-Aird, P. and Eaton, M.A. 2007b. Factors constraining the distribution of Golden eagles Aquila chrysaetos in Scotland. *Bird Study* **54**: 199-201.

Whitfield, D.P., Fielding, A.H., McLeod, D.R.A. and Howarth, P.F. (2008) *A conservation framework for the golden eagle: implications for conservation and management in Scotland*. Scottish Natural Heritage Commissioned Report No 193.

Wilson, A. & Crick, H. 2004. *Peregrine Survey Validation Exercise 2003.* BTO Research Report No. 348. BTO, Thetford.

UK Raptor Working Group. 2000. *Report of the UK Raptor Working Group*. Bristol DETR/JNCC.

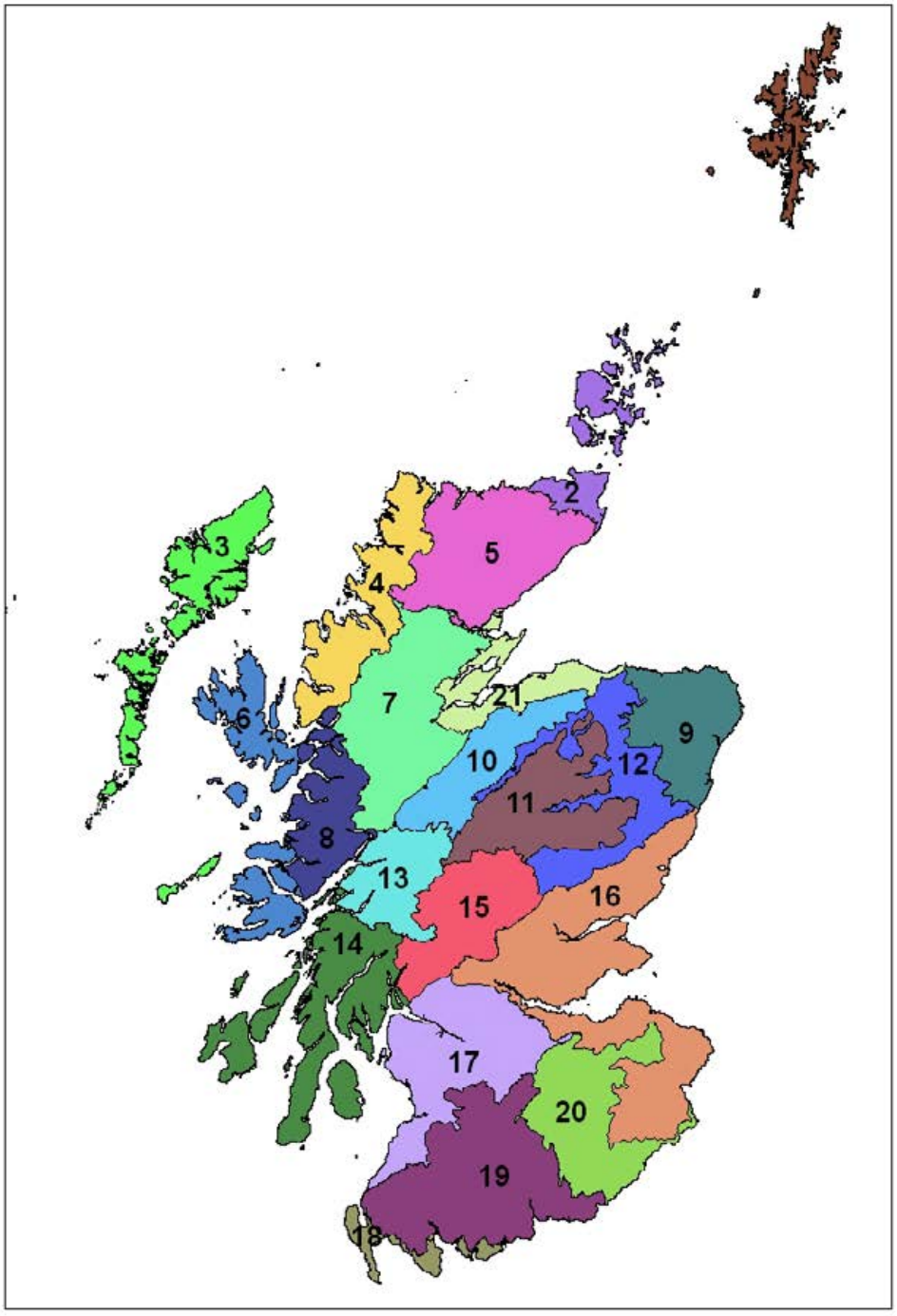
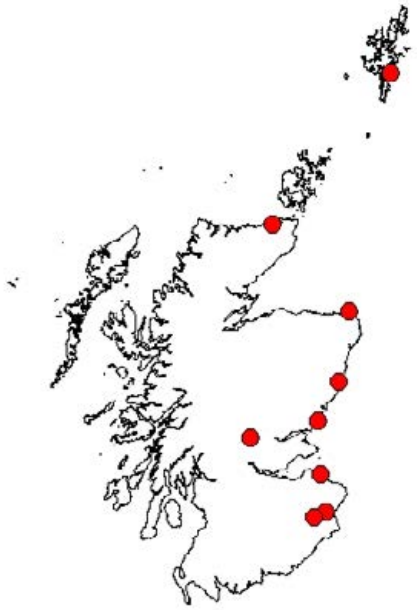


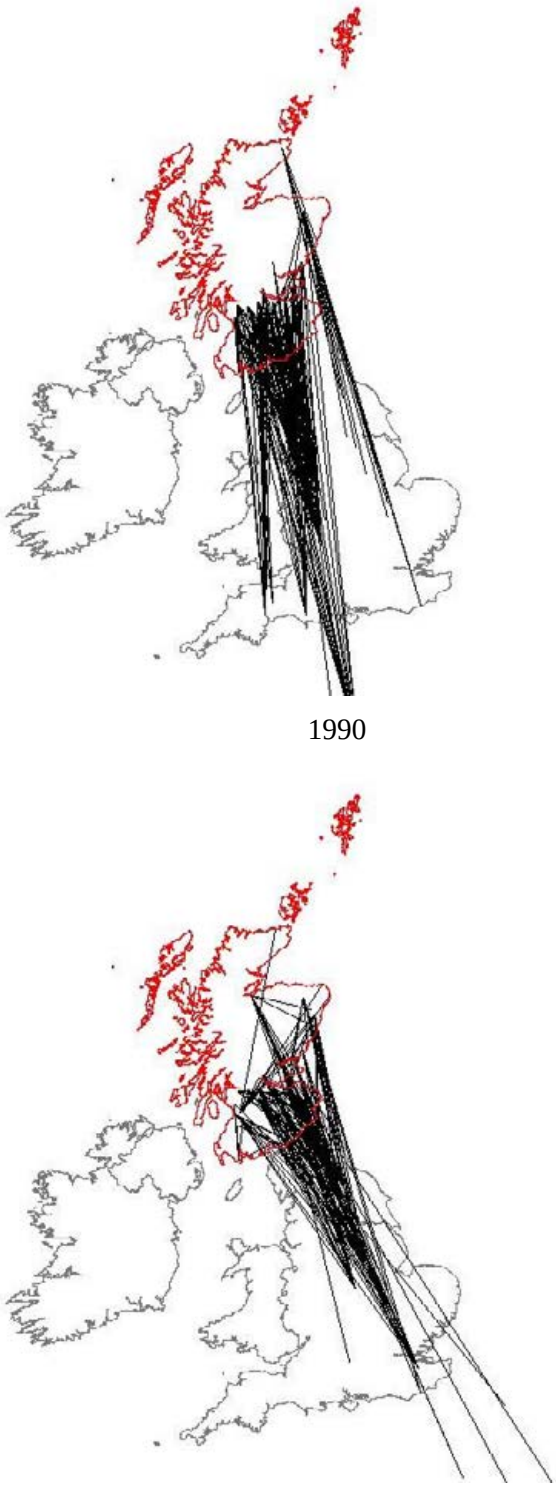
Figure 1 Natural Heritage Zones (data supplied by SNH)
1= Shetland, 2 = North Caithness and Orkney, 3= Coll, Tiree and the Western Isles, 4 = North West Seaboard, 5 = The peatlands of Caithness and Sutherland, 6 = Western Seaboard, 7 = Northern Highlands, 8 = Western Highlands, 9 = North East Coastal Plain, 10 = Central Highlands, 11 = Cairngorm Massif, 12 = North East Glens, 13 = East Lochaber, 14 = Argyll West and Islands, 15= Loch Lomand, the Trossachs and Breadalbane, 16 = Eastern Lowlands, 17 = West Central Belt, 18 = Wigtown machairs and Outer Solway Coast, 19 = Western Southern Uplands and Inner Solway, 20 = Border Hills and 21 = Moray Firth.

1990



2002

Figure 2 Release sites used by the RPRA in 1990 and 2002 in Scotland.



1990

2002

Figure 3 Generated routes for SHU races in 1991 and 2002 (data not fully complete; see Table 6).

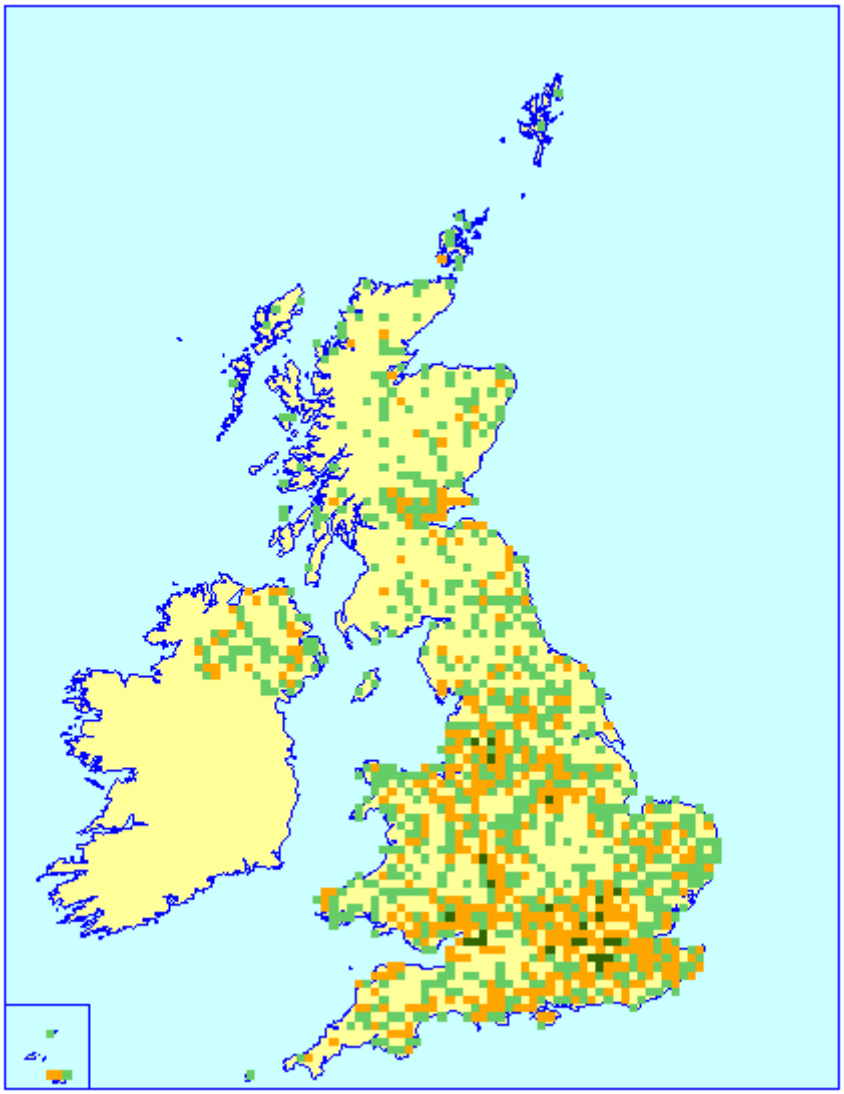
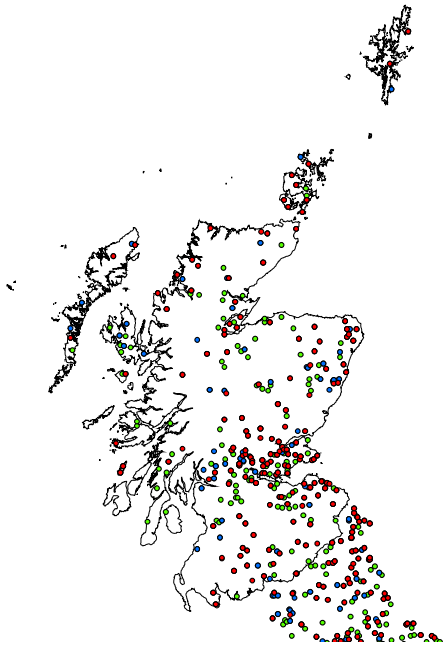


Figure 4 Number of BTO/JNCC/RSPB Breeding Bird Survey squares surveyed in 2002 (Light Green = 1 BBS square in this 10-km square, Orange = between 2 and 5, and Dark Green = more than 5).

Figure 5 Location of study sites used in the RSPB Repeat Upland Bird Survey (reproduced with permission from Sim *et al.* 2005).



Skylark

Figure 6 The location of BBS squares, in Scotland and northern England, in which Skylark was recorded (Red =2002 locations, blue = additional sites in 2003, green = 2004 additions).

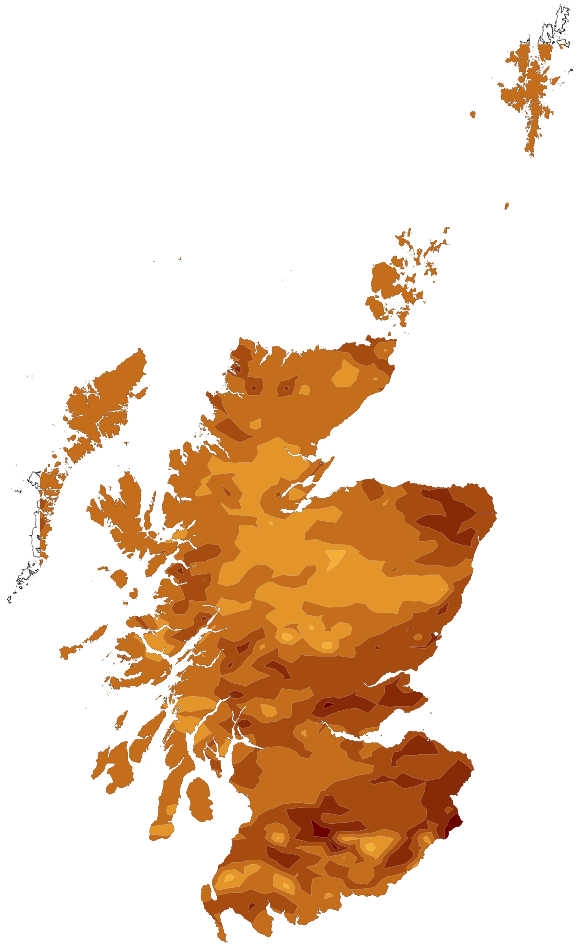


Figure 7 Interpolated abundance maps based on BBS data for the Skylark 2002-2004

Table 1 Summary Codes used in 2002 and definitions of occupancy

Code 2002	Definition of code	Occupied	Occupied as a pair
A	No sign	No	No
B	Bird with no scrape	**Yes**	No
C	Pair with no scrape	**Yes**	**Yes**
D	Pair nested - no eggs	**Yes**	**Yes**
E	Scrape with eggs	**Yes**	**Yes**
F	Scrape with young	**Yes**	**Yes**
G	Large young probably fledged	**Yes**	**Yes**
H	Not checked	Unknown	Unknown

Table 2 Summary codes used in 1991 and definitions of occupancy

Code	Definition of code	Occupied	Occupied as a pair
0	No sign	No	No
1	Single bird	**Yes**	No
2	Pair	**Yes**	**Yes**

Table 3 Potential environmental and human factors that may constrain the Scottish breeding Peregrine population, agreed priorities for analysis, and data sets available.

Constraining factor	Priority level assigned[1]	Available datasets identified to be of use (scale)	Further processing of datasets required	Comparison with 2002 survey	Change from 1991 to 2002 possible
Broad-scale habitat	LEVEL 1	LCM2000 (1km^2)	No	✓	×
Pigeon prey	LEVEL 1	SHU/RPRA racing data	Yes (section 4.3.4)	✓	✓
Natural prey	LEVEL 1	BBS data (1km^2) BBS interpolations (10km^2) Seabird 2000 data (colony)	Yes (section 4.4.4) Yes (section 4.4.4) No	✓ ✓	? ✓
Human persecution	LEVEL 1	LCS88 (parcel data of resolution of 50m) RSPB Persecution data sets (6 and 4 fig. grid ref.)	No No	?	×
Climate/weather	LEVEL 1	Met office rainfall and temperature data (5km^2)	No	✓	✓
Recreational disturbance	LEVEL 2	Munro, Corbett, Graham and Donald data (6 fig. grid ref.)	No		NA
Grazing	LEVEL 3	Red Deer counts (varying but mostly to estates) Sheep numbers (parish) Grazity Equity data (parish)	No No Yes (section 4.8.3)	✓	✓
Forestry	LEVEL 3	NIWT (forests > 2ha) LCS88 (parcel data of resolution of 50m) LCM2000 (1km^2)	No No No	✓ ? ✓	× × ×
Competitors/predators	LEVEL 3	Golden Eagle 1992/ 2002 national survey (6 fig grid ref.)	No	✓	✓
Pollution	LEVEL 3	CEH soil critical load and deposition data	Yes (see 4.11.3)	✓	✓
Fulmars	LEVEL 3	Seabird 2000 data (colony)	No	✓	✓
Availability of nesting sites	LEVEL 3	BGS directory of mimes and quarries (quarry)	Yes	✓	✓
Windfarms	LEVEL 3	?	?	?	?

Notes

1. Suggested priorities for Level I analysis with limited time and resources (see section 4.1).

Table 4 Subclass code number and definition for the 'subclasses' and 'aggregate classes' defined in the LCM2000 data set.

Code	LCM2000 subclass (Level 2)	LCM2000 aggregate class	To be used in analysis
1	Sea / Estuary	Oceanic seas	No
2	Water (inland)	Standing open water	No
3	Littoral rock	Coastal	Yes
4	Littoral sediment	Coastal	Yes
5	Saltmarsh	Coastal	Yes
6	Supra-littoral rock	Coastal	Yes
7	Supra-littoral sediment	Coastal	Yes
8	Bog (deep peat)	Mountain, heath, bog	Yes
9	Dense dwarf shrub heath	Mountain, heath, bog	Yes
10	Open dwarf shrub heath	Mountain, heath, bog	Yes
11	Montane habitats	Mountain, heath, bog	Yes
12	Broad-leaved / mixed woodland	Broad-leaved / mixed woodland	Yes
13	Coniferous woodland	Coniferous woodland	Yes
14	Improved grassland	Improved grassland	Yes
15	Neutral grass	Semi-natural grass	Yes
16	Setaside grass	Semi-natural grass	Yes
17	Bracken	Semi-natural grass	Yes
18	Calcareous grass	Semi-natural grass	Yes
19	Acid grassland	Semi-natural grass	Yes
20	Fen, marsh, swamp	Semi-natural grass	Yes
21	Arable cereals	Arable and horticulture	Yes
22	Arable horticulture	Arable and horticulture	Yes
23	Arable non-rotational	Arable and horticulture	Yes
24	Suburban / rural development	Built up areas and gardens	Yes
25	Continuous urban	Built up areas and gardens	Yes
26	Inland bare ground	Mountain, heath, bog	No
27	Unclassified habitat	Unclassified habitat	No

Table 5 Numbers of pigeon races in Scotland by year and racing organisation (SHU = Scottish Homing Union; RPRA = Royal Pigeon Racing Association).

Year	Organisation	Number of races in Scotland	Races in Scotland for which maximum numbers racing is known
1990	SHU	386	354
1991	RPRA	197	48
2002	SHU	295	295
2002	RPRA	60	22

Table 6 Summary of pigeon racing associations outside Scotland that have been approached for race information.

Federation	year	no races	Information requested	Information provided
Anglian N R Amalg	1991	3	No contact available	NA
Berks, Bucks & Oxon N R Fed	1991	2	✓	
Birmingham D N R Fed	1991	3	✓	
Bournemouth & D	1991	1	✓	
Bristol & D N R Fed	1991	2	Disbanded in 2003	NA
Cannock Chase Fed	1991	4	✓	
Central Fed Peterborough	1991	4	✓	
Chilterns N R Fed	1991	2	No contact available	NA
City of Leeds N R Federation	1991	10	No contact available	NA
Coalville D N R Fed	1991	4	✓	
Devon Fed	1991	3	✓	No info recorded
Dyfed Federation	1991	4	Disbanded in 1999	NA
East London Fed	1991	2	✓	
Essex & Suffolk Border Fed	1991	3	✓	
Essex Central Fed	1991	3	✓	
Essex Combine	1991	3	✓	
Gloucester N R Fed	1991	3	No contact available	NA
Grantham D. Fed	1991	4	No contact available	NA
Havering N R Fed	1991	2	✓	
Heads of the Valley Federation	1991	5	Disbanded	
Leicestershire N R Fed	1991	4	✓	
London N R Combine	1991	2	✓	yes
Matlock D.N.R. Fed	1991	5	✓	
Mid Essex Fed	1991	3	✓	
Mid Lincs N R Federation	1991	10	No contact available	NA

Midlands C.C.	1991	4	✓	
New North Road Federation	1991	6	✓	
Norfolk N R Fed	1991	4	No contact available	NA
North East Kent Fed	1991	2	✓	
North Road C. C.	1991	3	✓	Yes
North Thames N R Combine	1991	2	✓	
Northampton Town D Fed	1991	4	✓	
North-east Kent Fed	1991	1	✓	
Nottingham D.N.R. Fed	1991	6	✓	
Notts & Derby Border Fed	1991	5	✓	Yes
Peterborough D Fed	1991	4	✓	
Plymouth N R Combine	1991	2	✓	
Portsmouth D N R Fed	1991	2	✓	
South of Crouch Fed	1991	3	No contact available	NA
South of England N R F C	1991	2	No contact available	NA
South West Glamorgan P Fed	1991	3	✓	
Southwest Glamorgan	1991	3	✓	
Swansea Valley Federation	1991	6	✓	
Thames Valley N R Fed	1991	2	✓	
Three Counties Fed	1991	3	No contact available	NA
Thurrock Fed	1991	2	✓	
W of England N R Combine	1991	2	✓	
Warwickshire D N R Fed	1991	4	No contact available	NA
Welsh G N F C	1991	4	No contact available	NA
Welsh N R Fed	1991	5	✓	
Welsh New North Road	1991	5	✓	Yes
West of England N R Combine	1991	2	✓	
West Wales Federation	1991	5	No contact available	NA

Yorks & Lincs N R Combine	1991	10	✓	Yes
Berks, Bucks & Oxon	2002	2	✓	
Bournemouth & D	2002	1	✓	
Bristol & D N R Fed	2002	1	Disbanded in 2003	NA
Chilterns N R Fed	2002	3	No contact available	NA
Hull N R Fed	2002	8	✓	
Kent & Sussex N R Combine	2002	5	Resigned from RPRA in 2003	NA
Leigh-on-Sea R P C	2002	1	✓	
London N R Combine	2002	3	✓	Yes
New North Road Federation	2002	4	✓	
North East Kent Fed	2002	1	✓	
North Road C. C.	2002	5	✓	Yes
Peterborough D Fed	2002	5	✓	
Portsmouth D N R Fed	2002	1	✓	
Thames N & E Counties F C	2002	3	✓	
Thames Valley N R Fed	2002	3	✓	
Welsh North Road Federation	2002	3	No contact available	NA
Yorks & Lincs N R Combine	2002	6	✓	Yes
Yorkshire N R Fed	2002	6	✓	Yes

Table 7 Population changes for in Scotland from BBS, 1994 –2002.

Species	Number of BBS squares in Scotland	Change in relative abundances 94-02	Significant Change	Lower Confid. limits	Upper Confid. limits	Prey Species as listed in Ratcliffe 1993
Grey Heron	41	113	*	37	229	
Mallard	82	50	*	17	93	*
Red Grouse	57	-3		-28	32	*
Common Pheasant	98	-14		-29	6	*
Common Buzzard	95	73	*	34	122	*
Common Kestrel	39	-42	*	-61	-15	*
Eurasian Oystercatcher	116	-24	*	-35	-12	*
Eurasian Golden Plover	44	-33	*	-52	-7	*
Northern Lapwing	84	-39	*	-50	-26	*
Common Snipe	52	71	*	27	130	*
Eurasian Curlew	122	-24	*	-35	-11	*
Common Sandpiper	36	-23	*	-46	9	*
Black-headed Gull	72	-68	*	-76	-56	*
Common Gull	66	-31	*	-46	-11	*
Lesser Black-backed Gull	60	-5		-31	30	*
Herring Gull	95	13		-13	47	*
Great Black-backed Gull	34	67	*	10	155	*
Feral Pigeon	50	4		-28	51	
Common Wood Pigeon	156	-12		-24	1	*
Eurasian Collared Dove	34	-27		-52	13	*
Common Cuckoo	64	30		-2	73	*
Common Swift	39	-51	*	-68	-25	*
Skylark	186	-1		-11	11	*
Barn Swallow	131	-5		-20	13	
House Martin	43	174	*	68	346	*
Meadow Pipit	195	-11	*	-20	-1	*
White/Pied Wagtail	114	30	*	5	61	*
Winter Wren	174	38	*	19	59	
Hedge Accentor	99	15		-9	47	
European Robin	150	-8		-21	7	*
Northern Wheatear	73	10		-13	39	*

Species	Number of BBS squares in Scotland	Change in relative abundances 94-02	Significant Change	Lower Confid. limits	Upper Confid. limits	Prey Species as listed in Ratcliffe 1993
Common Blackbird	144	10		-3	24	*
Song Thrush	131	8		-10	31	*
Mistle Thrush	57	33		-6	88	*
Sedge Warbler	47	53	*	11	110	
Common Whitethroat	53	12		-20	57	
Willow Warbler	172	25	*	9	43	
Goldcrest	69	137	*	82	210	
Blue Tit	117	11		-7	33	*
Great Tit	104	25		0	57	
Coal Tit	95	13		-8	39	*
Black-billed Magpie	33	29		-10	83	*
Eurasian Jackdaw	88	15		-9	46	*
Rook	97	5		-21	40	*
Carrion Crow	147	3		-14	24	*
Hooded Crow	50	-59	*	-73	-39	*
Common Raven	37	71	*	10	167	
Common Starling	119	38	*	8	75	*
House Sparrow	72	29	*	4	59	*
Chaffinch	189	1		-8	12	*
European Greenfinch	80	18		-10	55	*
European Goldfinch	59	56	*	9	123	*
Eurasian Siskin	56	-18		-42	15	*
Common Linnet	78	34	*	3	75	*
Lesser Redpoll	36	26		-16	88	
Yellowhammer	86	8		-11	32	
Reed Bunting	39	28		-11	83	*

Table 8 Areas surveyed as part of the RSPB Repeat Upland Bird Survey (adapted from Sim et al. 2005).

Area	Original survey period **(Years difference to 1991)**	Repeat survey period **(Years difference to 2002)**	Area resurveyed (km^2)	Survey Methodology	Measure of Abundance
West Flows	1980-82[1] **(-11 to 9)**	2000 **(-2)**	325	Line transects	Max count
East Flows	1988 **(-3)**	2000 **(-2)**	197	Line transects	Max count
Lewis and Harris	1987 -**(4)**	2002 **(0)**	109.9	Line transects	Max count
NE Scotland	1986/1989/1991 **(-5/2/0)**	2000 **(0)**	201.2	Line transects Brown and Shepherd	Max count
South Scotland	1980-1982 [1] **(-11 to 9)**	1998 **(-4)**	78.5	Line transects	Total encounters
SW Scotland	1989 **(-2)**	1999 **(-3)**	51.4	Brown and Shepherd	Breeding territories

[1] Relevant to the 1981 national Peregrine survey.

Table 9 Species data available from the RSPB Repeat Upland Bird Survey (information taken from Sim et al. 2005).

Species	West Flows	East Flows	Lewis and Harris	NE Scotland	South Scotland	SW Scotland	Prey species as listed in Racliffe (1993)
Oystercatcher	✓	✓	✓	✓	✓	✓	*
Golden Plover	✓	✓	✓	✓	✓	✓	*
Lapwing	✓	✓	✓	✓	✓	✓	*
Dunlin	✓	✓	✓	✓	✓	✓	*
Snipe	✓	✓	✓	✓	✓	✓	*
Curlew	✓	✓	✓	✓	✓	✓	*
Redshank	✓	✓	✓	✓	✓	✓	*
Greenshank	✓	✓	✓	✓	✓	✓	*
Skylark	✓	✓	✓	✓			*
Meadow pipit	✓	✓	✓	✓			*
Whinchat	✓	✓	✓	✓	✓		
Stonechat	✓	✓	✓	✓			*
Wheatear	✓	✓	✓	✓			*
Ring Ouzel	✓	✓	✓	✓	✓		*
Raven	✓	✓	✓	✓			
Twite	✓	✓	✓	✓			

Table 10 Summary of Regional Atlas Data (breeding data only).

SOC Regional Branch	Publication	Sampling methodology	Years	Most relevant national Peregrine Survey	Information recorded
Grampian	Buckland et. al. (1990)	Habitat based study areas	1981-1984	1981	Breeding status (possible, probable and confirmed)
Grampian	Not published yet	Tetrads 2 km x 2 km	2002-2006	2002	
Fife	Elkins et. al. (2003).	Tetrads 2 km x 2 km	1991-1999	1991/2002	Breeding status (possible, probable and confirmed
Lothian	Murray et. al. (1998)	Tetrads 2 km x 2 km	1988-1994	1991	Breeding status (possible, probable and confirmed) + Observed
Borders	Murray et.al. (1998)	Tetrads 2 km x 2 km	1988-1994	1991	Breeding status (possible, probable and confirmed) + Observed
Clacks	In prep.				
Clyde	Unpublished				

Table 11 Hierarchy of surveys (and years) used to determine abundance scores during and outside the breeding season.

Hierarchy	April-August	September-March
1	Rook Survey (1996) Heron Survey (2003) Seabird 2000 Survey (2000-2002)	Winter Gull Roost Survey (2003/2004) Wetland Bird Survey (2000-2005) Goose and Swan roost counts
2	Wetland Bird Survey core counts (2000-2005)	Wetland Bird Survey Core counts (2000-2005)
3	Waterways BBS (1998-2004)	Winter Farmland Bird Survey (1999/2000, 2000/2001 and 2002/2004)
4	BBS (2000-2005)	Winter Atlas (1981/1982-1983/1984)
5	Breeding Atlas (1988-1991)	

Table 12 The sample sizes (number of BBS 1km squares in Scotland where species were recorded) for Ratcliffe's 'constant' prey species of the Peregrine for 1994 to 2005

Species	94	95	96	97	98	99	00	01	02	03	04	05
Feral / Rock Pigeon	48	56	55	60	68	69	55	21	60	63	77	78
Red Grouse	52	61	66	70	73	59	46	16	44	45	48	45
Lapwing	83	84	94	92	90	88	79	17	78	87	79	91
Golden Plover	52	49	51	65	53	36	36	8	28	37	30	37
Snipe	51	61	68	57	51	51	44	11	42	49	51	63
Curlew	109	124	137	146	137	127	118	25	109	113	107	118
Redshank	22	26	25	23	20	16	23	5	15	18	22	18
Skylark	167	199	214	223	217	178	162	47	156	176	184	205
Fieldfare	0	6	1	2	5	1	4	0	3	4	0	0
Song Thrush	103	124	140	130	148	147	142	39	136	139	161	183
Blackbird	115	134	151	157	158	158	153	41	148	165	179	204
Starling	90	121	127	123	132	130	123	33	129	133	143	162

Table 13 Scottish Persecution events data obtained from the RSPB (note that some datasets will be subsets of others)

Type of persecution	Species	Years	N	Published	BTO hold
Poisoning incidents	Peregrine	1991-2002	9		✓
Poisoning incidents	Raptors	1981-2000	394	Whitfield et al 2003	×
Poisoning incidents	All species	1981-2003	505	Whitfield et al 2007	✓
Trapping, shooting, nest destruction or removal of eggs/chicks and poisoning	Golden Eagle	1981-2002	60	Whitfield et al 2007	✓
Nest destruction or removal of eggs/chicks	Peregrine	1991-2002	111		✓
Trapping and shooting	Peregrine	1991-2002	37		✓

Table 14 Number of Peregrine Eggs (one per clutch) from Scotland analysed for organochlorines levels, mercury content and shell thickness index for 1990-1992 and 2001-2003.

Year	DDE	HEOD	PCB	Hg	Shell Indices
1990	2	2	2	2	1
1991	24	24	24	24	9
1992	12	12	12	12	11
2001	0	0	0	0	11
2002	0	0	0	0	19
2003	0	0	0	0	4

Table 15 Number of Sparrowhawk livers (one per clutch) from Scotland analysed for organochlorines levels and mercury content for 1990-1992 and 2001-2003.

Year	DDE	HEOD	Hg
1990	25	22	25
1991	22	20	21
1992	24	24	21
2001	5	4	1
2002	6	6	6
2003	1	0	1

Appendix 1 List of SHU federations and main component towns.

Aberdeen Foundation
Aberdeen; Inverurie; Banchory; Bridge of Don; Kincorth; Torry; Northfield; Bucksburn; Dyce; Petercoulter; Mastrick; Ellon

Almond Valley
Broxburn; Currie; Newbridge; Uphall; Ratho; East Calder; Bo'ness; Linlithgow; West Calder

Angus
Arbroath; Forfar; Gourdon; Montrose; Letham; Carnoustie

Ayrshire
Ardeer; Beith; Ardrossan; Crosshouse; Dalry; Largs; West Kilbride; Galston; Hurlford; Irvine; Kilmarnock; Kilwinning; New Cumnock; Stevenson

Ayr North Road
Ayr; Cumnock; Drongan; Mauchline; Kilmarnock

Ballochmyle
Annbank; Ayr; Girvan; Maybole; Mauchline; Dalmellington; Newmilns; Kirkconnel; Patna

Central
Bo'ness; Broxburn; Uphall; Newbridge; Philipstown; Pumpherston; Winchburgh

Dundee
Dundee; Lochee; Broughty Ferry; Wellbank

East of Scotland
Haddington; Gladsmuir; Prestonpans; North Berwick; Tranent; Elphinstone

Fife
Cardenden; Coaltown; Crossgates; Dunfermline; Glenrothes; Kennoway; Kirkcaldy; Leven; Lochgelly; Methilhaven; Newburgh; Oakley; Rosyth; St Andrews

Highlands & Islands
Orkney; Shetland; Thurso; Wick

Lanarkshire
Blantyre; Hamilton; Larkhall; Wishaw; Newmains; Burnbank; Cambuslang; Rutherglen; Shotts; Motherwell; Newarthill; Carluke; Lanark; Carstairs; Biggar; Chryston; Bishopbriggs; Coatbridge; Bellshill; East Kilbride; Busby; Forth; Airdrie; Uddingston; Strathaven; Netherburn

Midland
Airdrie; Coatbridge; Slamannan; Chapelhall; Salsburgh; Falkirk; Denny; Kirkintilloch; Kilsyth; Greengairs

Midlothian
Gorebridge; Arniston; Bonnyrigg; Edinburgh; Musselburgh; Loanhead; Newtongrange; Rosewell; Pathhead; Dalkeith

North of Scotland
Buckie; Banff; Elgin; Inverness; Forres; Peterhead; Fraserburgh; Keith; Inverurie; Aberdeen

North West
Falkirk; Stirling; Clackmannan; Grangemouth; Crieff; Auchterarder; Tillicoultry

Pentland Hills
Edinburgh; Musselburgh; Dalkeith; Peeblesshire; Penicuik; Rosewell

Renfrewshire
Giffnock; Barrhead; Paisley; Bridge of Weir; Greenock; Johnstone; Renfrew; Dunoon

Scottish Border
Duns; Earlston; Selkirk; Galashiels; Hawick; Jedburgh; Kelso

Solway
Annan; Dumfries; Castle Douglas; Dalbeattie; Locharbriggs; Eastriggs; Lockerbie; Kirkcudbright; Langholm; Gretna

South West
Stranraer; Whithorn; Newton Stewart

West Lothian
Armadale; Blackburn; Bathgate; Whitburn; Fauldhouse; Harthill

West of Scotland
Dumbarton