THE FEASIBILITY OF TRANSLOCATING HEN HARRIERS TO SOUTHERN ENGLAND, AND PRIORITISATION OF POTENTIAL TRANSLOCATION SITES AND STRATEGIES

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Executive Summary

1. The hen harrier, *Circus cyaneus,* is a red-listed bird of prey which is currently rare or absent from many parts of upland Britain, and almost entirely absent from lowland Britain, even where suitable habitat within its historic range is available. Reasons for its rarity or absence in upland Britain are predominantly related to ongoing illegal killing, owing to conflict with moorland managed for the driven shooting of red grouse *Lagopus lagopus scoticus* (Watson 1977; Bibby & Etheridge 1993; Etheridge *et al*. 1997; Green & Etheridge 1999; Lovegrove 2007; Anderson *et al*. 2009; Fielding *et al*. 2011).

2. The hen harrier was once found across both upland and lowland Britain, and was widespread and regular throughout many English counties. After 1830, however, it had become an exceptionally rare breeding bird in England (Brown & Grice 2005) and was eventually lost as a breeding species from the British mainland around 1900. Although subsequently its population has recovered, spreading from the northern & western isles to mainland Scotland, and into Wales, southerly range expansion into England has halted upon reaching the grouse-moors of northern England. The hen harrier has never re-established itself in the uplands of south-west Britain, or switched to the lowland habitats that are utilised elsewhere and were once utilised in Britain prior to the species„ original decline. Hen harriers visit southern England in the winter months but rarely breed there (Stroud *et al.* 2001). The lack of natural recovery in a fifty year period since first returning to breed in England provides good evidence that, whilst persecution continues to limit population growth in the uplands of northern England, hen harrier recovery across its former range is unlikely to occur unaided.

3. As there has been no natural recolonisation, we assess the feasibility of translocating hen harriers to southern England.Areas of unoccupied upland habitat in northern England were ruled out owing to their proximity to driven grouse moors. We identify four potential release sites, based on the habitat requirements of hen harriers: three areas of semi-natural habitat (Exmoor, Dartmoor and the Dorset Heaths) and an extensive area of arable farmland and downland grassland (centred in Wiltshire). Each site is assessed according to key aspects of the IUCN guidelines with the following criteria deemed priorities for more in-depth analysis: abundance of the main bird and small mammal

prey, occurrence of predators, probability of persecution, potential impacts on native fauna, human disturbance, access to carry out a release program, and socio-economic impacts.

4. Results suggest that all release sites should provide a sufficient number of prey items: densities of small mammals are suitable, while densities of passerine birds, particularly meadow pipits and skylarks, are lower than, but broadly comparable to, those found in regions which harbour breeding populations of hen harrier currently. Moorland sites harbour high densities of meadow pipits, while arable sites have higher densities of skylarks. Surveys of fox scat densities suggest that the ground-based nests of hen harriers may benefit from protection measures, but found no evidence for variation in fox densities among sites.

5. Persecution risk in all four sites was deemed lower than in areas holding hen harriers in Scotland or northern England. Risks of persecution remain due to the existence of „wild" pheasant shoots on moorland sites and mixed pheasant / partridge shoots on arable land. The Dorset heath sites are considered generally unsuitable for release due to the high conservation value of the extant communities, intensive pressure from tourism, exposed nesting habitat, and limited potential for population spread from the site of release. Based on a risk-assessment framework for the optimisation of multiple ecological criteria, Exmoor National Park scored highest of the remaining three regions examined, followed by Wiltshire then Dartmoor (Part VII). Amongst the release sites dominated by moorland habitat, Exmoor scored highly on account of high quality, unfragmented breeding habitat. As a release site, Exmoor would potentially suit the translocation of birds from Scottish moors, due to their preference for heather moorland (Watson & Thirgood 2001). Unlike the sites dominated by heather moorland habitat, Wiltshire offers significantly greater potential for population expansion as arable land is extensive, covering large tracts of southern England, and forms a mosaic of suitable habitat in combination with areas of downs grassland; areas that already support populations of breeding Montagu"s harriers and wintering hen harriers. Releases into Wiltshire may be more favourable for birds sourced from France or Spain since these birds commonly breed in arable habitats.

6. Population viability modelling, based on a „worst case scenario" that translocated birds will not spread beyond the release sites, suggested that a short translocation campaign (of four years) would need to release at least 20 birds per year to realise a high probability of population persistence. These simulations also highlighted a need to protect nests: this would involve predator control and management of activities that could cause disturbance on moorland sites, or sensitive crop management in arable sites. Further modelling, to determine the potential for spread of hen harrier populations beyond the release sites, suggested that releases into Exmoor's heather moorland could facilitate spread to similar moorland in Dartmoor, Bodmin and Wales. The potential for spread of birds across the arable systems of southern England is large based on a release project in Wiltshire.

7. The ecological evidence points to Exmoor and Wiltshire as being the most suitable release sites for hen harriers. We emphasise that avian prey densities, despite being broadly comparable, are lower in southern English sites than in some established moorland populations of hen harrier in northern Britain, and that detailed prediction of predation and persecution risk is difficult. The risk of nest failure may need to be managed via nest protection schemes during the release programme. The risks of persecution and disturbance should be minimised via wide-scale consultations with the public and stakeholders, prior to and during the release programme.

8. A full-scale translocation would require considerable funding to cover the costs of sourcing, transporting, releasing and monitoring birds in each release site. The work would need to be overseen by a project manager, whose role would be to manage the programme, organise seasonal staff and logistics, and undertake a regional consultation with the public and stakeholders. A disease risk assessment (DRA) would be required and it is suggested that this, together with veterinary examination of translocated birds, could be outsourced to the Zoological Society of London. Seasonal staff would be required to monitor release sites and ensure protection of nests between April and July each year. We would also recommend the engagement of academic researchers to study the ecological dynamics of the release programme, and monitor the demography and movement of birds in the landscape. Ideally, a translocation programme would be adaptive and should respond to changes in nesting success, and public and stakeholder perceptions, during the programme.

9. If sufficient resources are available a reintroduction programme should attempt to release birds sourced from Scottish moors, with affinity to heather moorland, in Exmoor, and continental birds, with affinity to agricultural landscapes, in Wiltshire arable sites. Translocation only into heather moorland risks poor spread of resulting populations across similar but fragmented habitats in southern England. Hence, if the project is constrained by the availability of funds or birds, we recommend a focus on the translocation of continental birds to Wiltshire, given the greater potential for a re-established population to increase and spread to new areas.

Introduction

Background

Hen harriers, C*ircus cyaneus* (Linnaeus 1766), breed across Europe, Asia and North America. There are two subspecies of hen harriers: *C. c. cyaneus* is found in Europe and Asia, while *C. c. hudsonius* is restricted to North America (the latter race being treated as a separate species, the northern harrier, by some authorities (del Hoyo 1994; Simmons 2000)). Once relatively widespread in lowland and upland Britain in the early 19th century (Holloway 1996), the hen harrier is now a red-listed Bird of Conservation Concern and is listed in Annex 1 of the EU Birds Directive (79/409/EEC). The decline in Britain has been linked to a loss of suitable habitat in parts of the range but is primarily due to illegal killing by humans (Watson 1977; Bibby & Etheridge 1993; Etheridge *et al*. 1997; Green & Etheridge 1999; Lovegrove 2007; Fielding *et al*. 2011). Hen harriers are currently rare or absent from many parts of upland Britain, even where suitable habitats are available (Etheridge 1993). A recent estimate suggested there were 806 territorial pairs in the UK with birds mainly restricted to Scotland and the Isle of Man and a few pairs in northern England & Wales (Sim *et al*. 2007). In 2012 there was only a single pair of hen harriers breeding in northern England. The ongoing illegal killing of birds on moorland managed for red grouse (*Lagopus lagopus scoticus*), restricting the vast majority of hen harriers to the north of the UK, is thought to be a main reason that hen harriers have not spread back to some areas of their historical distribution in southern Britain (Anderson *et al*. 2009).

Aims & Objectives

The over-arching aim of a translocation programme would be to establish a stable, free-ranging population, requiring minimal management. More specifically, a translocation would seek to (a) enhance the long-term survival of breeding hen harriers in England by extending their range and abundance, (b) restore biodiversity recently removed through anthropogenic effects and (c) re-establish a top predator species in moorland/arable ecosystems. As there is still an extant population of breeding hen harriers in England, albeit its continuing status is somewhat parlous, the over-arching proposal is part of a national conservation strategy and it is therefore referred to here as a translocation rather than a reintroduction to England. It can also be considered as a

reintroduction to southern England given that the species is currently absent as a breeding species from this part of its former range, and it should be treated as such when assessed against the IUCN guidelines for reintroductions. The objective of this report is to identify the most appropriate site(s) for a hen harrier translocation and assess the feasibility of translocating hen harriers to these site(s), located within their former range in southern England. It is structured in such a way as to represent an assessment against IUCN guidelines (see Appendix IV), but only as a feasibility study. Much of the information contained in this report would also inform the preparatory phase of any translocation, but that phase of the project should also revisit the guidelines, paying particular attention to the sourcing and welfare of the birds, investment in ecological research relating to the translocation, and engaging stakeholders and communities in the project.

Report structure

Before a reintroduction is undertaken, certain criteria established by the IUCN must be fulfilled. The IUCN guidelines (1998) were therefore used to frame this report on the feasibility of a hen harrier translocation to southern England. As not all the IUCN guidelines are relevant to this proposal, and of those that are relevant, some have a greater bearing than others, the main report is split into the following eight parts:

Part I (Harrier Ecology): This section focuses on the species‟ critical needs: a description of hen harrier habitat preferences, home ranges, foraging ecology, social organisation and predators. It also considers the potential for lowland nesting following a reintroduction, reviewing the current status of crop-nesting harriers in England.

Part II (Potential Release Sites): The first stage of Part II rules out inappropriate habitats and geographic locations. The second stage maps the most significant areas of appropriate habitat found within suitable locations, worthy of further assessment. This presents a number of potential release sites that warrant further study.

Part III (Release Site Assessment - predators and prey): Prey density is one of the species‟ key critical needs and is assessed at potential release sites using two main approaches. Using national datasets prey abundance is statistically modelled across Great Britain. Using data gathered by fieldworkers along transects within potential release sites, prey abundance is

statistically modelled at a local scale. Predator abundance is also presented using data collected during transects.

Part IV (Release Site Assessment - anthropogenic issues): Key issues considered for each site were persecution, disturbance and farm management.

Part V (Release Strategy and Population Simulations): This section provides details on the release strategies including the source of birds and a population viability analysis based on various translocation strategy scenarios.

Part VI (Assessing the impact of a hen harrier reintroduction): The preceding five parts concentrate on the needs of the hen harrier and whether these will be met at the proposed release sites. This part concentrates on how a hen harrier translocation could affect the release site, both from an ecological and socio-economic perspective.

PART VII (Risk Assessment and Ranking of Potential Release Sites): We consider the hazards, exposures, proposed mitigations, and adjusted risks associated with the translocation of hen harriers to each proposed site. This promotes an overall assessment and ranking of site-suitability for the planning and delivery phases of a hen harrier translocation programme.

PART VIII (Consultation Plan): The overall feasibility study, including the fieldwork elements, has determined the most suitable sites for a hen harrier translocation. Using this information it is now possible to undertake consultation events. These need to be completed satisfactorily before proceeding further. Part VIII summarises a recommended consultation plan, necessary to gather information on public opinion towards a potential hen harrier translocation.

Appendices: The various appendices provide supplementary information not contained, but cross-referenced, within the main report. Appendix IV provides the IUCN position and guidelines on species reintroductions.

PART I: Ecology of hen harriers

1.1 Literature review of species critical needs

1.1.1 Breeding, feeding habitat and home range

Hen harriers are medium-sized, generalist predators that almost exclusively breed on the ground in tall vegetation (Watson 1977). In continental Europe, hen harriers breed in cereal crops, and occasionally in rough grassland or forest; winter barley is preferred strongly over wheat (Millon *et al*. 2002). In the UK, however, hen harriers principally breed in heather *Calluna vulgaris* dominant vegetation (Redpath *et al*. 1998; Sim *et al*. 2007; Amar *et al*. 2008a). Most nests occur in heather over 40 cm tall (Redpath *et al*. 1998). However, hunting birds show a preference for a mix of heather and rough, unmanaged grass (Amar *et al*. 2008a, Arroyo *et al*. 2009). Such heather-grass mosaics hold high densities of important prey species of hen harriers (e.g. Smith *et al*. 2001; Vanhinsbergh and Chamberlain 2001; see below). In essence, existing populations of hen harriers in most parts of their range in the UK require a mixture of tall heather stands for nesting and rough grassland for hunting.

In the Scottish uplands, hen harriers tend to forage within 2 km of the nest (Amar *et al*. 2004; Arroyo *et al*. 2009). Data from radio-tagged harriers in the breeding season revealed that males used a home range of between 6.5 and 11.8 km^2, whilst female home ranges were only 2.5-3.9 km^2. Female ranges were roughly circular, centred around their breeding site, while most males showed a preferred foraging direction (Arroyo *et al*. 2006). Home ranges of males overlapped extensively, while female home ranges also overlapped but to a lower degree (Arroyo *et al*. 2006).

1.1.2 Foraging ecology

Hen harriers throughout the world forage on similar prey types, notably voles, *Microtus sp.*, and small passerines (Hamerstrom *et al*. 1985; Korpimäki 1985; Simmons 2000, Redpath *et al*. 2002; Amar *et al*. 2004). The common vole, *Microtus arvalis*, is an important prey item for hen harriers in much of continental Europe (e.g. van Manen 1996; Millon *et al*. 2002) as well as Orkney, Scotland (e.g. Picozzi 1980). In other areas outside the geographical range of the common vole, hen harriers forage on the field vole, *M. agrestis*, (Redpath & Thirgood 1997) the

root vole, *M. oeconomus*, (Hagen 1969) or the meadow vole, *M. pennsylvanicus*, (Hamerstrom *et al*. 1985; Simmons *et al*. 1986). The most common avian prey in the diet of UK harriers are meadow pipit, *Anthus pratensis*, and skylark, *Alauda arvensis*, (e.g. Redpath and Thirgood, 1999; Redpath *et al*. 2002; Amar *et al*. 2004; Amar *et al*. 2008b). Further main prey items include other passerines (e.g. Redpath *et al*. 2001a; Amar *et al*. 2003), young lagomorphs (e.g. Redpath *et al*. 2001a; Millon *et al*. 2002; Amar *et al*. 2003), and game birds (Millon *et al*. 2002), such as red grouse (Redpath & Thirgood 1999, Amar *et al*. 2004). The relative contribution of these prey items to the hen harrier diet depends on their availability, which varies widely both temporally and spatially (e.g. Clarke *et al*. 1993; Redpath *et al*. 2002; Redpath & Thirgood 1999). For a more detailed diet analysis see Part VI.

Female hen harriers forage on prey which is on average 75% heavier than the prey foraged by male hen harriers (Potts 1998). As females are food provisioned by males throughout the breeding season, male hen harrier prey items such as voles and passerines are important predictors of hen harrier nesting densities (Redpath & Thirgood 1999).

1.1.3 Social organisation and breeding densities

Hen harriers are social birds, forming winter roosts ranging from a few to several hundred individuals (Clarke & Watson 1990; McCurdy *et al*. 1995). In spring, pairs breed mostly clustered rather than spread out evenly through the available breeding habitat (Simmons 2000; Potts 1998). Such grouping may increase the effectiveness of defence against nest predation (Hamerstrom *et al*. 1985). During the breeding season hen harriers are often polygynous – i.e. one male may attempt to breed with up to six females. Partly as a result of this, harriers can be semi-colonial, with locally high nest densities with up to two females breeding per km^2 in areas without persecution (Potts 1998). This is different from many other territorial species of raptors which tend to be evenly spaced out through suitable habitat.

1.1.4 Dispersal and recruitment

Most hen harrier populations consist of both individuals that originate from the local population and individuals that are recruited from elsewhere (Watson & Thirgood 2001). The distance of the natal dispersal, i.e. the distance dispersed from the natal nest to the nest of the first breeding attempt, has been shown to vary considerably (Etheridge *et al*. 1997; males: 14-150 km,

females: 9.5-51 km). Dispersal also varies among different land classes (Etheridge *et al*. 1997). Harriers fledged from nests in conifer forests dispersed furthest, while harriers fledged from either nests of grouse moorland or unmanaged moorland differed only slightly in their dispersal distance (Etheridge *et al*. 1997). Furthermore, individuals from different land management classes not only differed in how far they disperse from their natal area but also in which land class they settled for their first breeding attempt (Etheridge *et al*. 1997). Both males and females fledged in grouse moor were most likely to also settle in grouse moors for breeding, whereas individuals raised in other moorland or conifer forests were more likely to shift between management classes. Finally, it has been shown that females that have bred in an area are very likely to return to this area and to stay within a proximity of 1 km to their breeding site from the previous year (Etheridge *et al*. 1997; median breeding dispersal of females in consecutive years: 0.71 km, N = 51). However, far distances between breeding sites of females in successive years are also possible (maximum distance recorded: 188 km; Etheridge *et al*. 1997).

1.1.5 Life-history traits

Most female hen harriers (68 %) first reproduce at an age of 1 year, whilst the majority of males (58.9 %) only start reproducing at the age of 2 years (Etheridge *et al*. 1997). In Scotland egg laying starts from mid April each year, although occasionally earlier in northern England, and the mean number of fledglings per nest is around 3 (Etheridge *et al*. 1997; Irwin *et al*. 2008; Whitfield *et al*. 2008). Of those fledglings about 36 % survive until an age of 1 year; later yearly survival rates are about 78 % (Etheridge *et al*. 1997). Further details on hen harrier life-history traits are discussed in Part V as part of a population viability analysis.

1.1.6 Predators

Besides humans, the main predator of the hen harrier is the red fox, *Vulpes vulpes* (Watson 1977, Potts 1998). Similarly, corvids, such as hooded crows, *Corvus corone cornix*, may also be important predators at hen harrier nests (Picozzi 1984). However, recent studies have not found strong evidence that hen harrier nest success or abundance is negatively influenced by either the presence of foxes (Green & Etheridge 1999; Whitfield *et al*. 2008) or hooded crows (Amar & Redpath 2002). In England over the last eight years other, albeit unusual, cases of intra-guild predation have involved peregrine falcon *Falco peregrinus* (n=4) and introduced / escaped eagle owls *Bubo bubo* (n=2+) (data from Natural England's Hen Harrier Recovery Project).

1.1.7 Lowland harrier nesting success

There are three species of harrier native to Britain; the hen harrier, marsh harrier *Circus aeruginosus* and the Montagu"s harrier *C. pygargus* all of which utilise crops for nesting. Within the UK the Montagu"s harrier almost exclusively nests in crops, the marsh harrier increasingly nests in crops (having originally been restricted to areas of reedbed in eastern England) and, finally, the hen harrier frequently uses crops overseas but rarely does so in the UK. Although only a very small number of hen harriers have nested in arable areas, the conservation implications of a farmland population becoming established (potentially following a reintroduction) are significant as this could allow the species to recover away from the well documented persecution issues in upland areas that currently limit the species" recovery.

Farmland areas offer significant potential for range expansion and population increase for all three harrier species. Consequently, however, farm management operations in arable areas also have the potential to negatively impact these species. We use this section to note that the spread of moorland hen harriers into, or direct translocation of birds into, arable habitats, will require intensive liaison with landowners and possible adjustment of harvest timing and technology, to ensure nesting success. We also note that hen harrier translocation should not conflict with conservation priorities or legislation for other species farmland birds. Part VII of this report considers more detail on the potential ecological impacts of hen harrier translocations or spread into farmland.

1.1.8 Diseases

Disease is not thought to be a significant factor in influencing the distribution of hen harriers in the UK, although a heavy burden of nematode parasites was thought to be the likely cause of death for an individual found dead in England (Vaughan-Higgins *et al*. in press). Naturally occurring parasites and other disease vectors may be amplified when birds are under stress and this would need to be considered in more detail through a disease risk assessment (DRA), should the decision be taken to proceed with a translocation project.

1.2 Arable farmland as potential habitat for breeding hen harriers

1.2.1 Background

As farmland hypothetically provides the largest area of potential hen harrier breeding habitat in the UK, it cannot be ignored when assessing the feasibility of a reintroduction to southern England. Despite its favourable extent, however, there are a number of factors that must be assessed when considering farmland as a habitat into which hen harriers could be reintroduced:

1.2.2 Historic hen harrier distribution and the use of farmland

Assessing the historic distribution of hen harriers in southern England and their use of farmland is somewhat problematic. Two types of harrier were recognised by early naturalists; grey birds (males) and ringtails (females or immatures). It was not until the late 1700s that Dr John Heysham"s studies established that brown and grey birds were females and males respectively, belonging to the same species. An historic assessment is further complicated as until 1802, when the English naturalist George Montagu described a second species of sexually dimorphic harrier to which he gave his name, hen and Montagu"s harriers were assumed to be the same species. As they were not distinguished, early records from southern England, where both harriers nested, could relate to either species.

By the 1800s hen harriers were already scarce birds in many southern counties, following declines as a result of persecution and habitat loss. Pattern of loss from an anthropogenic cause, such as persecution, would be related to proximity to man. As with other birds of prey that experienced similar declines around this time, the species disappeared first from those areas closer to man where the intensity of persecution would have been greatest and survived longest in more remote areas where the effects of persecution were not so deleterious (uncultivated land away from human settlement). The early county avifaunas documented the last hen harrier breeding attempts in southern England, by which stage hen harriers were only nesting in wilder, more remote places. The greater abundance of uncultivated rough ground around this time (albeit declining as a result of the various enclosure acts), might have further reduced the likelihood of switching to nest in small enclosed fields; a comparatively new habitat type to be present in abundance. Although historic records do not prove that hen harriers ever regularly nested in arable farmland, both John Clare and Gilbert White did note that hen harriers hunt over fields of corn.

Hen harriers clearly are not an obligate upland bird and their northerly distribution in the UK is an artefact of habitat loss and persecution, rather than an inability to exist at lower altitudes, or more southerly latitudes. For example, hen harriers breed sympatrically with Montagu"s harriers within farmland areas of northern France. Montagu"s harriers nesting in southern England are an edge-of-range species, at the north-westerly point of their European distribution, and an increase in temperature could shift the species„ climate envelope northwards. As with Montagu"s harriers, arable land in England could become more suitable for hen harriers with a rise in mean global temperatures, if climatically it started to more closely resemble the environment in parts of present day northern France.

1.2.3 UK Breeding data

Since 2002, the year English Nature launched its Hen Harrier Recovery Project, there have been three hen harrier nesting attempts in southern England. All three of these nesting attempts have been successful. The first took place in an area of lowland heathland where interestingly, despite an abundance of deep heather, the area selected for nesting was a mix of *Juncus*, bramble and *Phragmites*. The second breeding pair nested in an arable area supporting breeding Montagu"s harrier in central southern England, although, surprisingly, the nest was located in a patch of coppiced woodland. It was thought likely to have been a second nesting attempt, the earlier suspected crop-nest having failed nearby; possibly mid-clutch forcing a rapid relocation. The third successful nest was located in a cereal field in a southern English county. Whilst this demonstrates that isolated hen harrier nesting attempts in southern England can be successful, a sample of this size does not conclusively demonstrate that farmland in southern England could support a viable population of hen harriers following a reintroduction.

1.2.4 Comparative food availability between continental and UK farmland

It could be hypothesised that it is the absence of the common vole from mainland UK that has always prevented hen harriers from becoming established in farmland. However, the historic status of hen harriers as a farmland breeding bird is unequivocal and their current use of farmland in winter is well documented. Second, there are modern records of successful breeding in farmland areas. Finally, hen harriers do nest successfully in upland areas within the UK where, in the absence of the common vole, field voles and passerines are amongst the main prey items; these prey items also found within arable areas of southern England. The analysis presented in Part III of this report suggests that overall prey densities in arable areas in parts of southern England would be sufficient to support breeding hen harriers.

1.2.5 Crops as nesting habitat

A key concern regarding colonisation of arable land by hen harriers is that crop heights during the breeding season may be too short to be attractive to nesters or suitable for nesting. As noted by Millon *et al*. (2002), in continental Europe winter barley is preferred over wheat crops, perhaps for this reason. The rise in popularity of winter-sown grain and rape crops in the UK should promote nesting and nest success, but this utility might trade off against the timing of harvest (late spring/early summer) of winter-sown crops.

PART II: Identifying potential release sites

2.1 Short-listing process

2.1.1 Methodology

Initially a broad-brush approach was adopted, using a number of qualitative parameters, to rule out potential release sites (which at this stage could be located anywhere in England), in order to identify a short-list that warranted more detailed analysis. The first stage of the short-listing process determined the broad geographic area and habitat type.

2.1.2 Geographic area

The search for potential release sites was restricted to southern England owing to both intense conflict arising over the driven shooting of red grouse in northern England, and the existing presence of hen harriers in the northern uplands. With an occasional breeding presence on grouse moors as far south as the Peak District, sites were only considered below an imaginary line running due east-west, from approximately the Wash to mid-Wales.

2.1.3 Habitat types discounted

It has been established that in Britain hen harriers principally breed in heather, and in continental Europe hen harriers often breed in cereal crops. Whilst sites supporting these habitats in southern England potentially meet short-listing criteria and have been retained for further analysis, a number of other habitat types can be used by breeding hen harriers; tundra, river valley meadow, fens, sand dunes, reedbeds, alder-willow carr and even saltmarsh. Use of some of these habitat types, such as reedbed, fen or saltmarsh, appears to be exceptional. There is little information about their use and in the case of saltmarsh nests would be regularly exposed to failure as a result of tidal inundation. A number of the remaining habitat types are either absent or limited in their extent and do not present a single large enough area to support a viable population of hen harriers. For example, tundra is absent and river valley meadows, sand dunes and alder-willow carr woodland are too scarce and fragmented. Therefore, these habitats have been ruled out.

There are two habitats, in addition to heathland and arable farmland, which are both utilised by hen harriers and are also reasonably extensive in parts of southern England; conifer plantation and dry grassland (of varying types). Although conifer plantations facilitated population recovery

in the UK during the mid-20th Century, as young trees provided a safe haven when areas of moorland became afforested, forestry management necessary to ensure plantations in southern England could continue to support hen harriers would be problematic. Existing conifer plantations would need to be managed, as only young trees temporarily provide nesting sites before maturing. The first rotation is the most attractive to hen harriers, presumably as vole numbers often peak following initial planting, but subsequent rotations (as mature plantations are felled and replaced by young trees) tend not to be used. For wider conservation benefit forestry management is increasingly aiming to restore former habitats through tree removal, to thin existing stands and to plant a wider diversity of tree species. It is unlikely, and potentially undesirable, that forestry management could be adapted in order to plant new, or manage existing, woodland in order to provide the high density planting of young conifers temporarily favoured by nesting hen harriers. Forestry sites have therefore been discounted from further consideration.

Areas of chalk grassland / downland and acid grassland supported breeding hen harriers in historic times (pre 1850) and reasonably extensive areas remain today. Such habitats could provide good foraging, and certain sites still attract hen harriers in the winter such as Salisbury Plain. It is likely, however, that deeper vegetation for nesting could be severely limited. Historically, areas of scrubbier marginal habitat would have been commonplace and found in proximity to areas of uncultivated grassland; the mosaic of vegetation types providing plenty of opportunity for both nesting and foraging. The existing grazing regime across large otherwise suitable areas of grassland habitat, such as Porton Down, Salisbury Plain and Breckland, maintains a short-sward for nesting stone curlew *Burhinus oedicnemus*. Therefore, chalk and acid grassland are not considered further owing to the lack of abundant vegetation for nesting.

Table 2.1.1: Habitats discounted as release sites

Habitat type	Reason for exclusion	Site example(s)
Upland heath	Discounted if sites too far north & in proximity to existing conflict	The North York Moors,
Lowland raised mire	Largest site too far north. Other areas smaller or fragmented	Thorne and Hatfield Moors
River valley meadows	Insufficient single area	Lower Derwent Valley
Sand dunes	Use not well documented & insufficient single area	Ainsdale and the Sefton Coast
Reedbeds	Use not well documented – not a preferred habitat type, although reasonable area available	Shapwick Heath
Fens	Use not well documented	Chippenham Fen
Alder-willow carr	Use not well documented & insufficient single area	Bure Marshes
Saltmarsh	Problems with tidal inundation	Hamford Water
Forestry	Problems with ongoing forest management	Thetford Forest
Downland / chalk grassland	Good foraging but lack of deeper vegetation for nesting. Conflict with shooting interest in Sussex.	South Downs
Acid grassland	Good foraging but lack of deeper vegetation for nesting	Breckland

2.2 Potential release sites

2.2.1 Habitat types considered

To identify potential release sites we applied a multi-step process. The initial short-listing process ruled out a any sites in northern England and, given the needs of the hen harriers as outlined in Part I, potential release sites were chosen to encompass the following habitat types :

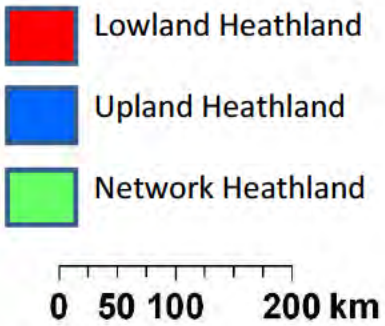
(i) Upland areas of semi-natural habitat in southern England (heathland)
(ii) Lowland areas of natural/semi-natural habitat in southern England (heathland)
(iii) Farmland areas in southern England.

A potential release site should be able to maintain a viable hen harrier population by providing a sufficient number of breeding sites i.e. sufficient heather-grass mosaics (suitable for birds sourced from Scotland), sufficient arable (potentially more suitable for birds sourced from continental Europe), and enough prey items.

2.2.2 Mapping heathland habitat in England

Based on the review of the species" critical needs, an assessment of potential translocation sites was performed with reference to Land Cover mapping of England. The ecology of harriers currently in the UK would suggest that upland or lowland heath should feature as a key habitat in the landscape chosen for hen harrier translocation to southern England (see Part I). Figure 1 shows the extent of upland and lowland heath habitat in England.

There are four blocks of relatively uninterrupted heathland in southern England which are clear contenders for a potential translocation (see Figure 1): (working West to East) Bodmin Moor, Dartmoor, Exmoor and the combined Dorset heaths/New Forest. Given the smaller scale of Bodmin Moor, and its relative geographic isolation from the rest of England, it is only considered further as a potential “sink” region, which may gain hen harriers if they disperse there from other possible translocation sites.



Bodmin	Area
Lowland heather	20.72km²
Upland heather	21.08km²
Total heather	41.8km²
Dartmoor	
Lowland heather	5.78km²
Upland heather	115.3km²
Total heather	121.08km²
Exmoor	
Lowland heather	23.03km²
Upland heather	118.45km²
Total heather	141.48km²
Dorset & New Forest	
Lowland heather	213.79km²
Total heather	213.79km²
New Forest	
Lowland heather	172.68km²
Total heather	172.68km²

Figure 2.2.1: Distribution of upland and lowland heath habitat in England. On the left: main areas (in km^2) of lowland and upland heather in southern England. B, Bodmin; D, Dartmoor; DN, Dorset and New Forest; E, Exmoor. Network heathland is extensive agricultural land designated as having potential to return to upland or lowland heath status by the RSPB (RSPB, Heathland Extent and Potential (HEaP) map).

2.2.3 Selecting arable sites in southern England

As hen harriers in continental Europe preferably breed in arable habitats (Part 1), we also consider arable land in our assessment of potentially suitable release sites. Arable land covers extensive tracts of southern England, yet specific potential release sites need to be selected which offer a greater potential to support hen harriers above a purely random selection. The following criteria, indicating increased site potential, were used to target sites for fieldwork and provide a focus for more detailed analyses:

Proximity to other semi-natural release sites: Greater connectivity between suitable areas of arable land and semi-natural habitat could help to provide adequate prey-rich foraging areas and facilitate population expansion. Furthermore, should two populations become established in discrete areas of habitat, movements of birds between otherwise isolated sub-populations could reduce vulnerability to stochastic events which might lead to localised extinction. In theory, arable areas closest to either (i) upland areas of semi-natural habitat in southern England (heathland), or (ii) lowland areas of natural/semi-natural habitat in southern England (heathland) would offer advantages over more distant locations.

At some point, as distance between a harrier population and a patch of unoccupied habitat increases in relation to the hen harrier‟s dispersal abilities, any advantage would be lost.
Above a certain maximum distance the likelihood of colonisation by dispersing harriers becomes reduced to the extent that comparative proximity to the nearest breeding hen harriers (or nearest potential release area) between two remote sites would have little effect.

Natal dispersal distances have been determined as between 14 - 150km for males and 9.5 - 51km for females (Etheridge *et al*. 1997). There is evidence of even greater natal dispersal distances in England; single pairs of hen harriers have bred at three counties in southern England between 2002-2009. Whilst provenance of the adult birds involved in these isolated breeding attempts was not known, the closest breeding localities were all many hundreds of kilometres away, providing evidence of natal dispersal in excess of distances recorded by Etheridge (1997).

As arable land is scarcer in south-west England, being replaced by pastoral farming, the closest significant areas of arable land to upland areas in south-west England are found in Dorset and Wiltshire. These counties fall well within juvenile dispersal distances (and already attract

wintering adult harriers) and are around the distance of maximum natal dispersal from the south-west uplands. The combined Dorset Heaths/New Forest area is well within typical natal dispersal distances from arable areas of both Wiltshire and Dorset. Arable areas of Hampshire could also be deemed suitable using this criterion.

Proximity to existing wintering areas: Proximity to an area currently supporting wintering hen harriers provides an excellent indication that the surrounding habitat is already suitable. Some of the most important wintering sites for hen harriers in England, supporting 1% or more of the GB wintering population, are classified as Special Protection Areas (Stroud *et al.* 2001). A number of these SPAs are found in eastern England along the coasts of Kent, Essex, Suffolk, Norfolk and Yorkshire. Whilst an arable release site in the vicinity of these SPAs would provide good connectivity to wintering populations, it would offer little connectivity to potential breeding areas in southern England. Similarly, two inland sites, Stodmarsh and the Ouse Washes, offer no potential overlap with arable areas closest to potential semi-natural release sites. Finally, three SPAs classified for wintering hen harriers, Salisbury Plain, The New Forest and the Dorset Heaths, are within the counties containing extensive areas of arable land that are also closest to potential semi-natural release sites (the counties of Dorset, Hampshire and Wiltshire).

Proximity to existing breeding harriers: Montagu"s harriers have similar habitat requirements in relation to arable farmland as hen harriers (Millon *et al*. 2002) and the two species breed sympatrically in parts of France and Spain. Montagu"s harriers breed in small numbers in southern England and two isolated hen harrier breeding attempts have also occurred in arable areas, both of which were successful. Without revealing sensitive site information for these two rare breeding species, it is worth noting that this particular criterion would not shift the focus away from arable areas within Hampshire, Dorset or Wiltshire.

Nationally important farmland bird assemblages: Not all areas of arable farmland are of uniform quality for wildlife. Intensive farmland management can reduce both the abundance and diversity of farmland birds (Wilson *et al.* 2009). Conversely, where farming practices are more extensive specialist farmland birds can persist and generalist species, such as the skylark, will be more abundant. Less intensive farmland management is associated with the retention of a greater extent of uncultivated marginal land, which is not only important for farmland bird assemblages, but is also favoured by the field vole (an important prey item for hen harriers). Therefore, nationally important farmland bird assemblages, as identified within Higher Level

Stewardship Target Areas (Natural England 2010), provide an indication of hen harrier food availability and are found in the following areas of southern England:

- Breckland
- Chilterns
- Chilterns & East Anglia Chalk
- Cotswolds
- Daventry & Banbury, River Nene
- Dorset Downs & Cranborne Chase
- East Kent Downs
- Essex coast and growth areas
- Greensand Ridge & Bedford
- Isle of Wight
- Lincolnshire Limewoods NNR
- Meriden Gap, Tame & Upper Trent River Valleys
- North Kent & Thames Estuary
- North Norfolk Coast & the Wash
- North Wessex Downs
- Peterborough
- Salisbury Plain
- Severn & Avon Vale
- Shropshire Wealds
- Soar & Charnwood
- South Downs
- South East Warwickshire
- Suffolk Coast, Heaths & River Valleys
- The Broads and Norfolk River Valleys
- Upper Thames Tributaries
- Witham on the Hill, Lincolnshire

Table 2.2.1: Review of possible arable release areas by English county

Southern England county	Extensive arable area	Proximity to semi-natural release site	Proximity to wintering area	Farmland bird Assemblage (HLS Target Area)	Presence of other harriers	Chalk downland / plateau

Southern England county	Extensive arable area	Proximity to semi-natural release site	Proximity to wintering area	Farmland bird Assemblage (HLS Target Area)	Presence of other harriers	Chalk downland / plateau
Bedfordshire	Yes	No	No	Greensand Ridge & Bedford	No	No
Berkshire	Yes	No	No	North Wessex Downs, Chilterns	Yes	Yes
Bristol	No	No	No	No	No	No
Buckinghamshire	Yes	No	No	Chilterns	No	No
Cambridgeshire	Yes	No	Yes	Chilterns & East Anglia Chalk, Peterborough	No	No
Cornwall	No	Yes	Yes	No	No	No
Devon	No	Yes	No	No	No	No
Dorset	Yes	Yes	Yes	Dorset Downs & Cranborne Chase	Yes	Yes
East Sussex	Yes	No	No	No	No	Yes
Essex	Yes	No	Yes	Essex coast and growth areas	No	No
Greater London	No	No	No	No	No	No
Gloucestershire	Yes	Yes	No	Cotswolds	No	Yes
Hampshire	Yes	Yes	Yes	South Downs, Isle of Wight	Yes	Yes
Herefordshire	No	No	No	No	No	No
Hertfordshire	Yes	No	No	Chilterns & East Anglia Chalk	No	No
Kent	Yes	No	Yes	East Kent Downs, North Kent & Thames Estuary	No	Yes
Leicestershire	Yes	No	No	Soar & Charnwood	No	No
Lincolnshire	Yes		No	Witham, Limewoods		No
Norfolk	Yes	No	Yes	Breckland, North Norfolk Coast & the Wash, the Broads and Norfolk River Valleys	Yes	No
Northamptonshire	Yes	No	No	Daventry & Banbury, River Nene	No	No
Oxfordshire	Yes	No	No	Upper Thames Tributaries	Yes	Yes
Shropshire	No	No	No	Shropshire Wealds	No	No
Somerset	Yes	Yes	No	No	No	No
Staffordshire	Yes	No	No	No	No	No
Suffolk	Yes	No	Yes	Breckland, Suffolk Coast, Heaths & River Valleys	No	No
Surrey	Yes	No	No	No	No	Yes
Warwickshire	Yes	No	No	South East Warwickshire, Meriden Gap, Tame & Upper	No	No

Southern England county	Extensive arable area	Proximity to semi-natural release site	Proximity to wintering area	Farmland bird Assemblage (HLS Target Area)	Presence of other harriers	Chalk downland / plateau
				Trent River Valleys		
West Midlands	Yes	No	No	Meriden Gap, Tame & Upper Trent River Valleys	No	No
West Sussex	Yes	No	No	South Downs	No	Yes
Wiltshire	Yes	Yes	Yes	Salisbury Plain, North Wessex Downs, Dorset Downs & Cranborne Chase. Cotwswolds	Yes	Yes
Worcestershire	Yes	No	No	Severn & Avon Vale	No	

Chalk soils / plateau: Although difficult to quantify the importance of this particular criterion, it is interesting to note that sub-surface geology appears to have a bearing on hen harrier distribution in northern France, the closest continental nesting area of hen harriers to potential release sites in southern England. Hen harriers in France show a preference for arable land overlying chalk. It is also interesting to note that of the three isolated breeding attempts in southern England that have taken place since 2002, two have been located on arable areas overlying chalk; one in an area near downland and the second near a plateau type area at the top of an escarpment.

Part III: Release site assessment – predators and prey

3.1 Statistical modelling of meadow pipit and skylark

3.1.1 Abundance based on Breeding Bird Surveys and UK Land Cover Map

This section presents estimates of the areas of habitats of likely importance to hen harriers for nesting and/or prey availability within six regions of SW England as identified above as regions with blocks of uninterrupted heathland or likely suitable arable regions (see Part II): Dartmoor (north and south sub-regions), Exmoor (north and south sub-regions), the Dorset heaths of the Purbeck peninsular around Arne (close to the New Forest), and three areas centred around Wiltshire (north, central and south sub-regions). Each sub-region is centred around field survey sites (see 2.2.2; Figure 3.1.1), and comprises two areas for assessment, a 10 km x 10 km square and a 15 km x 15 km square, each aligned with the 1 km squares of the Ordnance Survey National Grid (Figure 3.1.1). Also presented are indices of abundance of two of the most important and numerous passerine prey species of the hen harrier, the meadow pipit and the skylark for these regions. Finally, abundances for meadow pipit and skylark are also estimated for areas within Exmoor and Dartmoor that are dominated by heather.

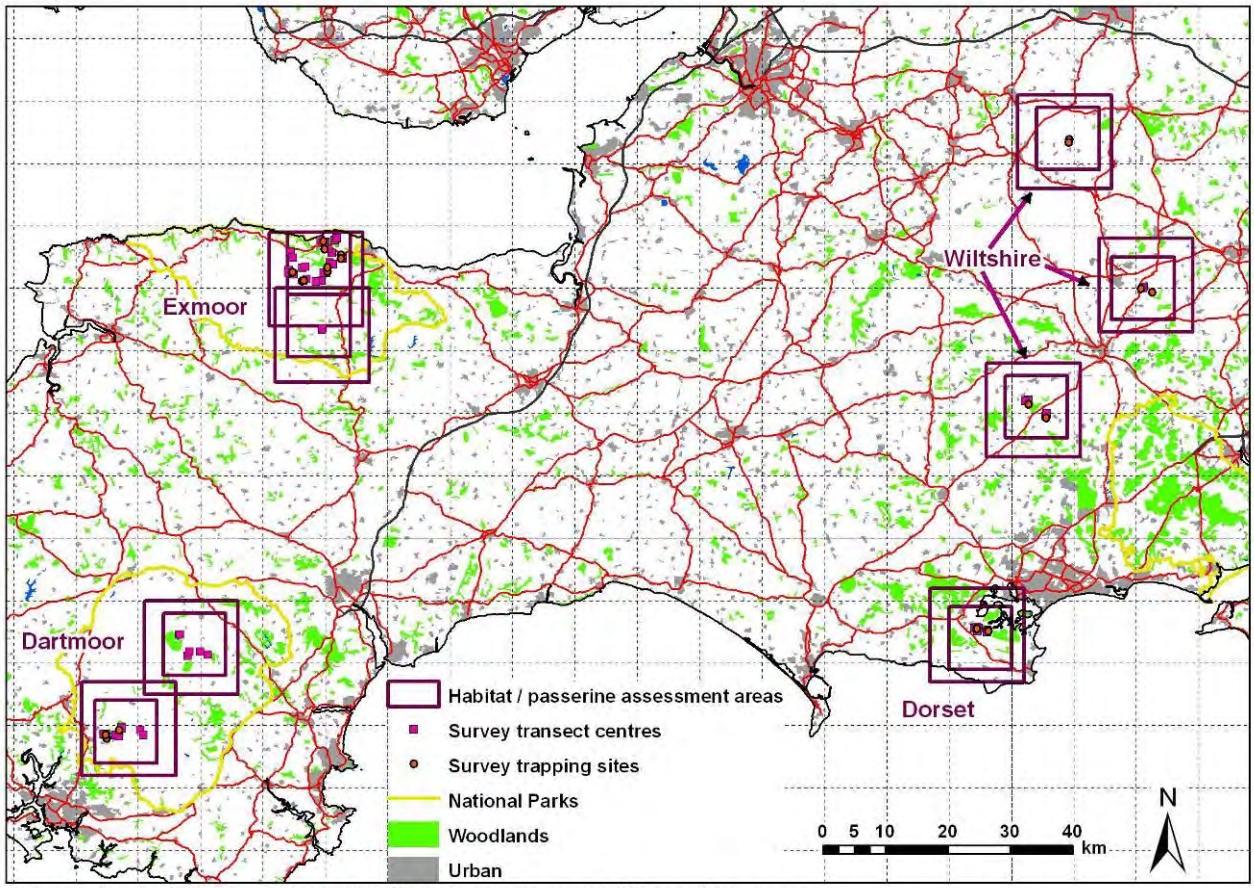


Figure 3.1.1: Locations of assessment areas for habitat availability and passerine prey density within six regions of SW England. Coloured dots represent locations of field surveys (see 5.2).

3.1.2 Habitats

Summary broad habitat data from Land Cover Map 2000 (LCM2000) at the scale of 1 km^2 squares were obtained under licence from the Centre for Ecology and Hydrology. LCM2000 classifies homogenous parcels of land (minimum area 0.5 ha) on the basis of their spectral reflectance recorded in satellite images, principally obtained during 1998, together with contextual information on soil type, peat depth etc.

The total area (in ha) of each of the following habitat classes within each square was extracted from the dataset: woodland (broadleaved and conifer combined), arable, improved grassland, rough grassland (acid, neutral and calcareous grassland combined), bracken, dense dwarf shrub heath, open dwarf shrub heath, blanket bog and inland water. For the purposes of modelling passerine abundance, all these classes were used as possible explanatory variables,

together with the mean altitude of each square extracted from the Countryside Information System. Estimation of habitat availability within assessment areas was limited to arable, rough grassland, heath (total, dense and open) and blanket bog (Table 3), as these habitats are regarded as the most likely to be used by hen harriers for nesting and/or hunting (see Part 2).

3.1.3 Passerine abundance data

Breeding Bird Survey (BBS) data were obtained from the British Trust for Ornithology for meadow pipit during the period 1994-2007 and for skylark during the period 1994-2008. These are the species which are considered likely to be the dominant passerine prey for hen harrier in upland and lowland habitats, respectively (although both species occur in each). The BBS is an annual survey, conducted mostly by volunteers, of a sample of 1 km^2 squares randomly allocated across the UK (for more details see 5.2). The data obtained comprised the total number of meadow pipit and skylark recorded along two 1 km transects on each square during the early (April-May) and late (June-July) visits of each year. In order to be consistent with previous surveys, and to reflect the period when harriers would be feeding young, data from the late visit only were used. The number of years recorded varied greatly between squares, and in some cases, there were gaps in the square"s record. A count was rejected if there was a strong possibility that the late visit was actually missing (i.e. high early visit count and no late visit count for the species in the same year); this could arise if the observer omitted to enter a count for the late visit, or genuinely if the square held birds on migration during spring, but not as a breeding species. Individual counts which were identified as outliers (exceptionally high or low for the square) were also rejected. The mean late visit count over all years for each species was used as the abundance measure, subject to the constraint that there were at least three years" valid counts for the species on the square.

3.1.4 Modelling methods

The data for each species were split randomly into a parameter-estimation set (comprising approx. 2/3 of the squares, N = 2493 for meadow pipit and 2490 for skylark) and a validation set (approx. 1/3, N = 1210 for both species). For both species, the abundance data were heavily positively skewed, i.e. there were many squares having no, or very few, birds (especially so for meadow pipit – almost 70 % of squares in England recorded none) and a few squares where many were recorded. As such “over-dispersed” data present a problem in fitting statistical models, several alternative modelling approaches were adopted (for details see Appendix I): all

models were generalized linear models but differed in their error structure (binomial, normal, Poisson) and data transformation, respectively (see Appendix I). For all models, the approach adopted was firstly to fit all possible explanatory variables, and then to remove them sequentially on the basis of the least significant first until the best-fitting model was reached on according to the model‟s Akaike Information Criterion (an estimate of the information content of the model). Explanatory variables comprised the habitat areas within the square (as described above), plus linear and squared terms of the squares‟ easting, northing and mean altitude. For a few models (see Appendix I), squared terms for rough grass, dense heath, open heath and bog were also included.

3.1.5 Validation and calibration against independent data

Independent estimates of meadow pipit abundance on 37 moorland 1 km^2 squares in Scotland and northern England were obtained from the Game and Wildlife Conservation Trust (GWCT). Each estimate comprised the number of pipits seen per km transect per year. Validation was conducted at two spatial scales. (1) If the GWCT counted square corresponded exactly to a 1 km National Grid square, then that single square was used as the area for prediction; otherwise, the 1 km x 2 km rectangle or 2 km x 2 km square of the National Grid which fully encompassed the counted square was used for prediction, which was then adjusted for the area predicted. (2) Predicted abundances were made for a 5 km x 5 km square of the National Grid which had the GWCT square (approximately) at its centre. At both scales, the predicted pipit abundances were compared with observed data by correlation and simple regression.

Predicted abundances of meadow pipit and skylark were also produced for two other groups of regions in Scotland in order to place the predictions of prey availability for the potential release regions into context: (1) the six moors studied by Redpath and Thirgood (1999), for which observed estimates of hen harrier breeding density and meadow pipit abundance were also available and (2) nine Special Protection Areas (SPA) in Scotland designated for hen harriers.

3.2 Results

3.2.1 Habitat availability

As noted in Part 4, heathland in southern England is focused on larges patches in Dartmoor, Exmoor and New Forest National Parks. As a suitable nesting habitat, heathland is therefore not

extensive but could harbour small populations of breeding hen harriers. Arable habitat, on the other hand, is far more extensive in several regions of England. The region that includes the most suitable mixture of arable breeding habitat and rough grassland hunting habitat, is centred on Salisbury Plain in Wiltshire. While arable habitat may be less suitable in terms of prey densities, the sheer spatial extent of this habitat may compensate and allow a low density breeding population to occur over wide geographical areas. It is also possible that heathland-nesting populations may spread to nearby arable land and vice versa.

The habitats of principal importance in Dartmoor, Exmoor and Dorset are dense heath for nesting, and rough grassland and heath for hunting, whereas in Wiltshire the availability of arable land is important for both purposes (Table 3.2.1). Although the LCM2000 data are now 10 years old, it is unlikely that there have been sufficiently major changes in semi-natural habitats since 1998 to have altered their relative proportions substantially between the regions. Although there may be changes in agricultural habitats from year to year, again it is unlikely that changes in the proportion of arable land have differed substantially between Wiltshire sub-regions. The estimates presented (Table 3.2.1) can therefore be regarded as robust indices of the relative habitat availability between the regions, but not as precise estimates of total areas available. In qualitative terms, there were no major differences between the 10 km^2 and 15 km^2 assessment areas, and their differences are therefore not discussed in detail.

The greatest area of heath lies on Dartmoor, and in total the two sub-regions are similar. However, almost all Dartmoor heath is classified as open (i.e. mosaics of ericoid- and grass-dominated patches) in the south, and most of it in the north, which suggests that rank heather, *Calluna vulgaris,* suitable for hen harrier nest sites, could be a limiting resource on Dartmoor. The high availability of open heath and, especially, rough grassland on Dartmoor indicates that prey availability in general should not be a problem. In contrast, Exmoor provides less heath and less rough grassland than Dartmoor, but more dense heath, particularly in the north (but note that there is overlap between 15 km^2 areas on Exmoor). Thus Exmoor might be expected to hold a lower density of breeding hen harriers than Dartmoor on the basis of suitable foraging habitat, but its greater availability of nesting habitat might compensate for this. Nesting habitat should certainly not be limiting in Dorset, where dense heath is plentiful, but open heath and rough grassland hunting habitats are less plentiful than on the two moors. Harriers could compensate for this in Dorset if they can adapt to hunting arable land surrounding the heaths.

The north and south sub-regions of Wiltshire are very similar in terms of their high availability of arable land, plus, in the south, some rough grassland. The central sub-region differs in having less arable, but its substantially greater area of rough grassland might compensate as hunting (but not nesting) habitat.

Table 3.2.1: Areas of Broad Habitat (in ha) within potential hen harrier release regions estimated from Land Cover Map 2000. Regions are defined by squares of side 10 km or 15 km centred around survey areas and aligned with 1 km National Grid squares. Sub-regions: C, Central; N, North; S, South.

					Total area of Broad Habitat (ha)					
Region	**Sub-region**	**N 1 km squares**	**Extent**		**Arable**	**Rough grass**	**Heath**			**Blanket bog**
			SW corner	***NE corner***			**Total**	***Dense***	***Open***	
10 km square										
Dartmoor	N	100	*263000,78000*	*273000,88000*	246	3221	1821	*527*	*1293*	70
Dartmoor	S	100	*253000,64000*	*263000,74000*	205	5176	1962	*7*	*1955*	5
Dorset	-	100	*390000,79000*	*400000,89000*	1573	675	1205	*1025*	*180*	0
Exmoor	N	100	*284000,139000*	*294000,149000*	1063	1414	1232	*869*	*364*	0
Exmoor	S	100	*284000,129000*	*294000,139000*	443	1252	381	*167*	*214*	0
Wiltshire	C	100	*416000,135000*	*426000,145000*	3640	1536	0	*0*	*0*	0
Wiltshire	N	100	*404000,159000*	*414000,169000*	5034	179	0	*0*	*0*	0
Wiltshire	S	100	*399000,116000*	*409000,126000*	5861	621	25	*12*	*13*	0
15 km square										
Dartmoor	N	225	*261000,75000*	*276000,90000*	728	6990	3203	*653*	*2550*	1068
Dartmoor	S	225	*251000,62000*	*266000,77000*	666	10410	3541	*61*	*3480*	767
Dorset	-	218	*387000,77000*	*402000,92000*	3127	1486	2685	*1999*	*687*	0
Exmoor	N	225	*281000,134000*	*296000,149000*	1801	3650	1926	*1267*	*659*	0
Exmoor	S	225	*282000,125000*	*297000,140000*	1366	2496	1080	*385*	*696*	0
Wiltshire	C	225	*414000,133000*	*429000,148000*	8625	2609	3	*2*	*1*	0
Wiltshire	N	225	*401000,156000*	*416000,171000*	11409	511	0	*0*	*0*	0
Wiltshire	S	225	*396000,113000*	*411000,128000*	13149	1226	68	*29*	*40*	0

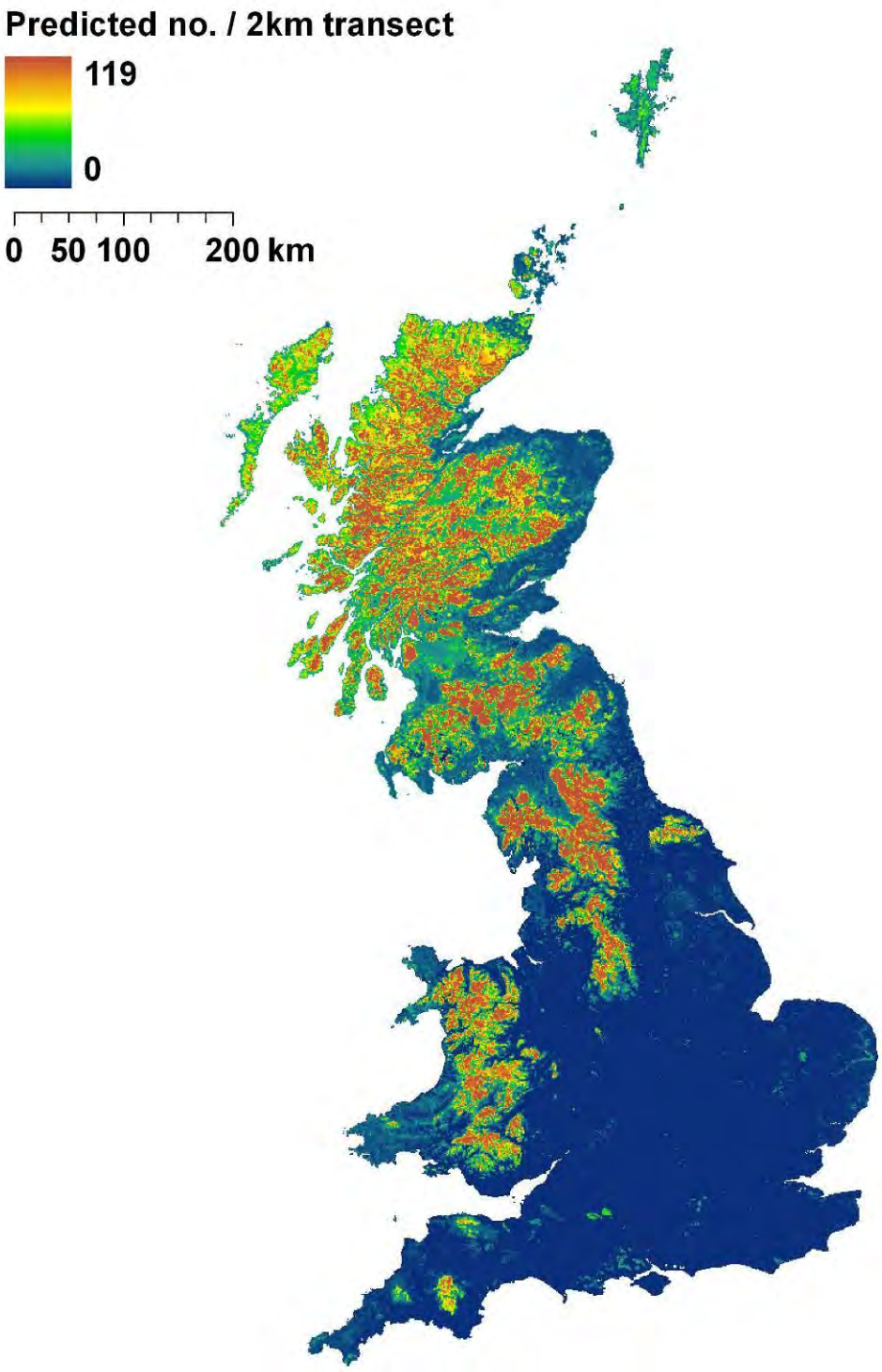


Figure 3.2.1: Predicted abundance index (individuals / 2 km transect) of meadow pipit in Great Britain from Breeding Bird Survey data (model 1a, adjusted, for details see Appendix I).

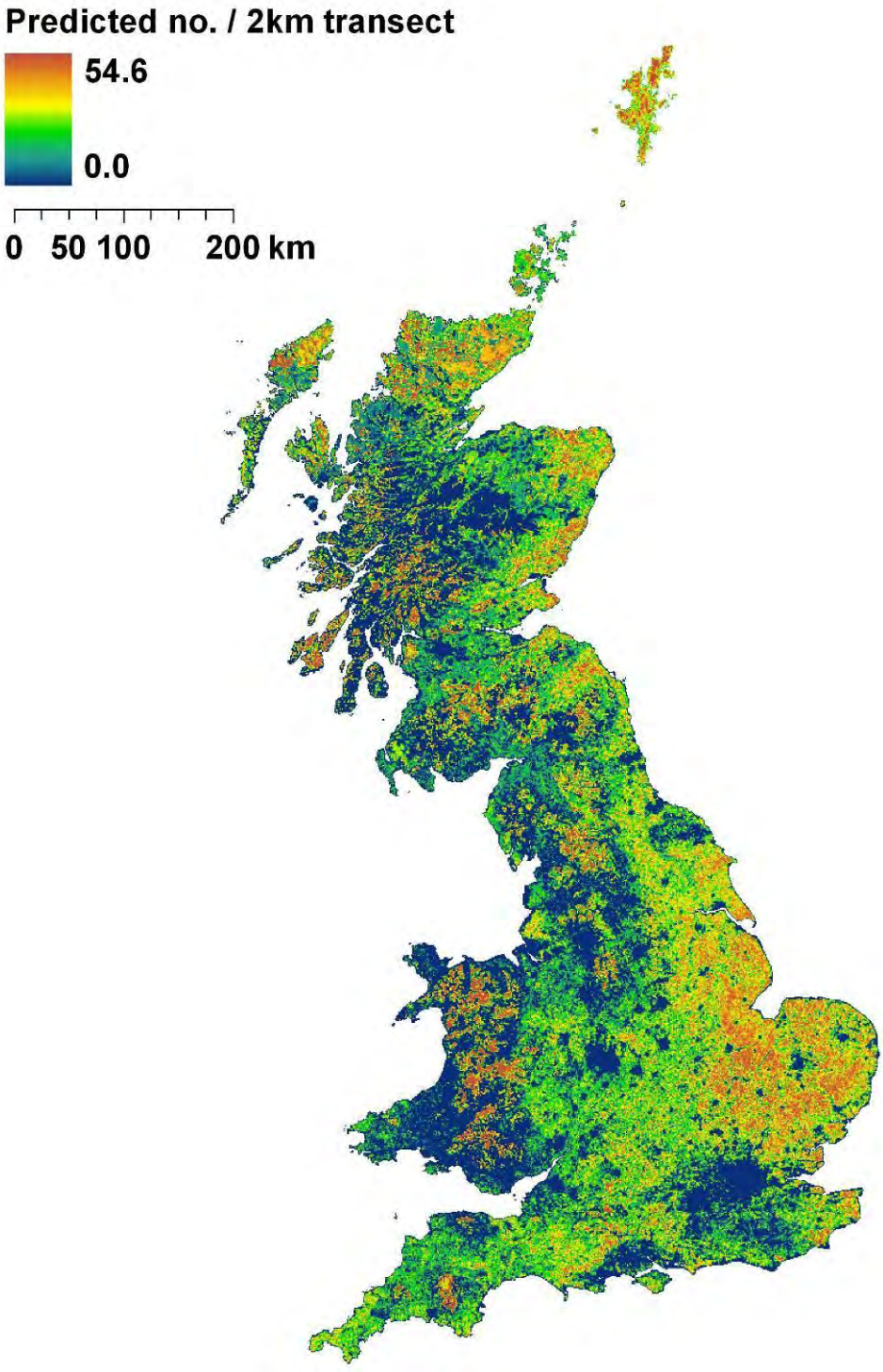


Figure 3.2.2: Predicted abundance index (individuals / 2 km transect) of skylark in Great Britain from Breeding Bird Survey data (model 1, adjusted, for details see Appendix I).

3.2.2 Prey availability

All models for both meadow pipit and skylark without adjusted estimates (see Appendix I) radically underestimated abundance when predicted and observed abundances were compared for the validation sets (for details see Appendix I). Subsequent adjustments for under-estimation resulted in both some reasonable estimations and some quite substantial over-estimations. It should be noted that predicted and observed data did not correlate well in most cases and did not correlate at all in some cases (see Appendix I). Estimates for each individual model and correlations between the model predictions and observations together with a more detailed discussion can be found in Appendix I. Figure 3.2.3 gives the ranges of the estimates for meadow pipit and skylark obtained from the different models for the different regions. Since some models overestimated adundance and some underestimated abundance, the real values are likely to lie within these ranges, which can therefore be used as relative indices to compare the different regions for their prey abundance.

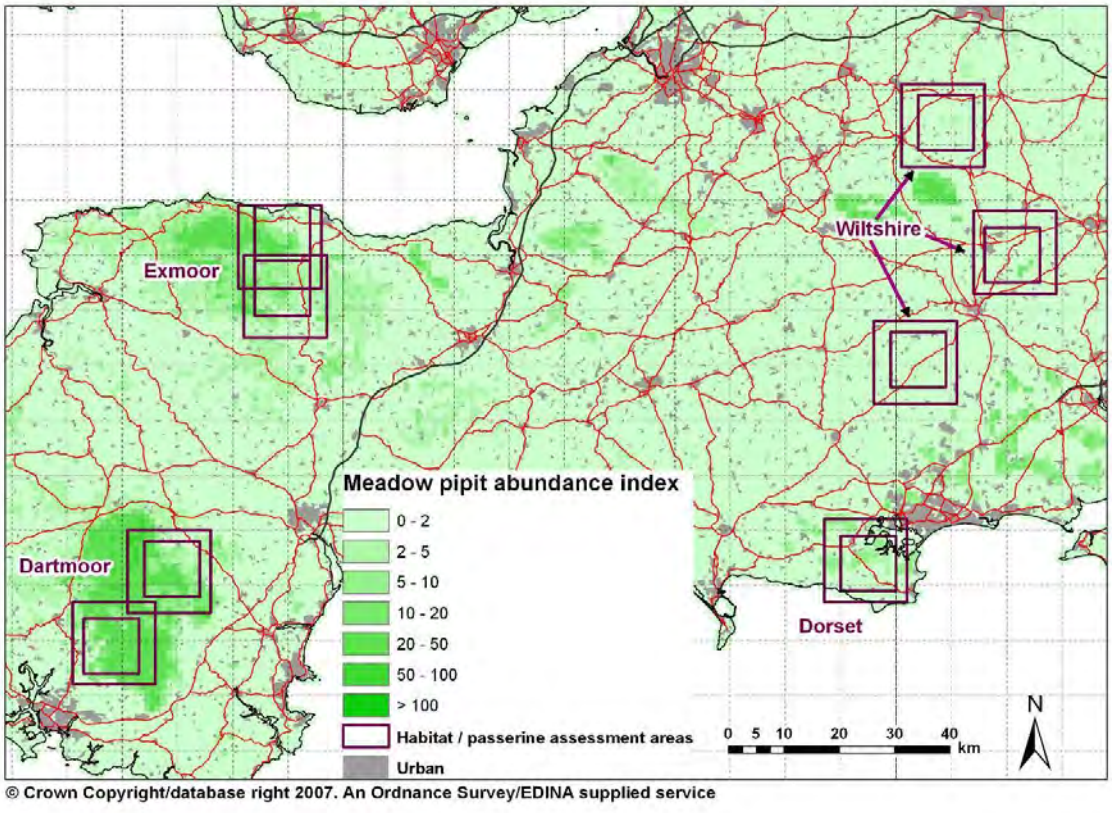


Figure 3.2.3: Predicted abundance index (individuals / 2 km transect) of meadow pipit in SW England from Breeding Bird Survey data (model 1a, adjusted, for details see Appendix I).

Within areas in which we conducted field surveys, the estimates for meadow pipit indicate that the highest abundances are to be found on Dartmoor, and pipits are generally expected to be marginally more plentiful in the south than in the north. Dartmoor also appears to support good numbers of skylarks, also with more in the south. Meadow pipit and skylark numbers are predicted to be lower on Exmoor, where the north has higher abundance than the south. Of the three heathland regions, Dorset has by far the fewest meadow pipits, and hence also the lowest expected combined abundance of the two prey species. In Wiltshire, where meadow pipits are too few to be of any importance, the south sub-region is predicted to have the highest numbers of skylarks and the central sub-region the least, although the differences between areas tend to be much less marked than the differences in pipits between the heath-dominated regions.

Estimated numbers of meadow pipit and skylark are much higher in areas of heather dominated habitat in Exmoor and Dartmoor than in the Exmoor and Dartmoor sites in which we conducted field surveys.

The range of estimates of meadow pipit abundance in the nine SPAs and the six other moors supporting hen harriers varied greatly across all areas. The corresponding estimates for the surveyed sites lie at the low end of these ranges. However, meadow pipit numbers in heather dominated habitat of Dartmoor and Exmoor are comparable to those in a number of hen harrier regions in the North. Skylark estimates for SW England and for the SPAs and the other hen harrier moors are similar. Estimates for Dartmoor are the second highest for all 25 assessed regions in Great Britain.

Estimates of the abundance of (a) meadow pipit and (b) skylark within potential hen harrier release regions (Exmoor, Dartmoor, Dorset & Wiltshire) are shown in Figure 3.2.10, alongside data from hen harrier study moors (Moor A-E & Moor L of Redpath and Thirgood (1999)) and hen harrier Special Protection Areas (derived from Breeding Bird Survey data). Estimates for the SPAs are given for just heath habitat. Estimates for the potential release sites are given for land consisting of dense heather for Exmoor and Dartmoor and for 10 km^2 areas surrounding our field sites (regardless of what kind of heathland). The indices given are the minimal and maximal estimates obtained from various models for the mean number of individual birds expected to be encountered along two 1 km transects walked in every 1 km square of the region in an average year (see Appendix I for details of individual models and their outcomes). The minimal estimates are uncorrected indices (believed to be under-estimates of the true total), while the upper end of

the range is derived from models of data adjusted to compensate for biased under-estimation. In most cases, the upper indices are regarded as over-estimates.

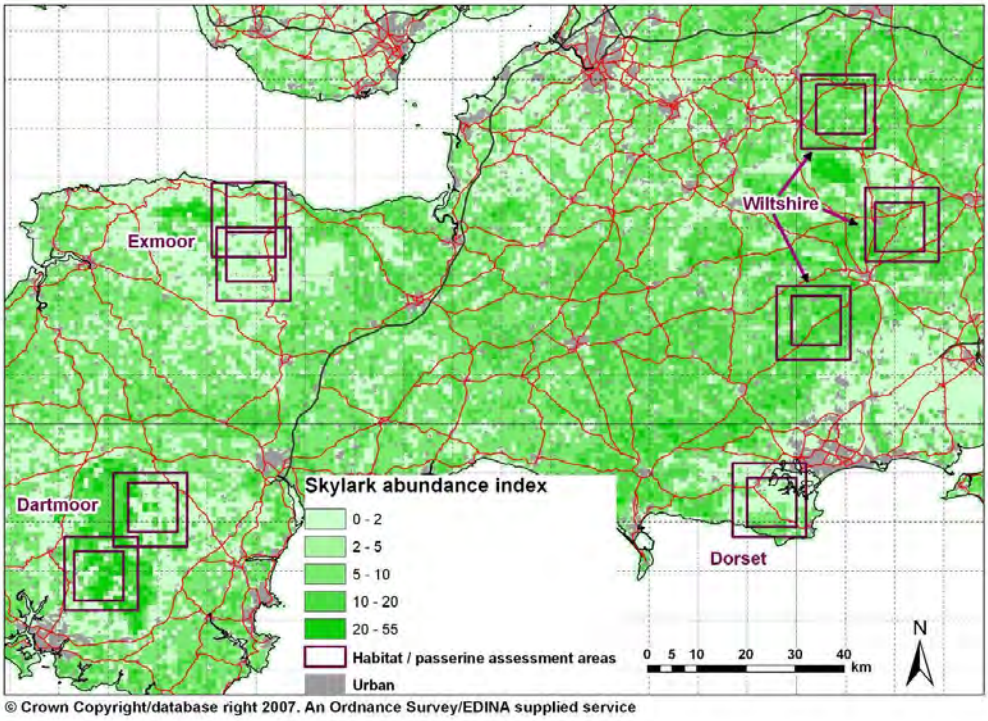


Figure 3.2.4: Predicted abundance index (individuals / 2 km transect) of skylark in SW England from Breeding Bird Survey data (model 1a, adjusted, for details see Appendix I).

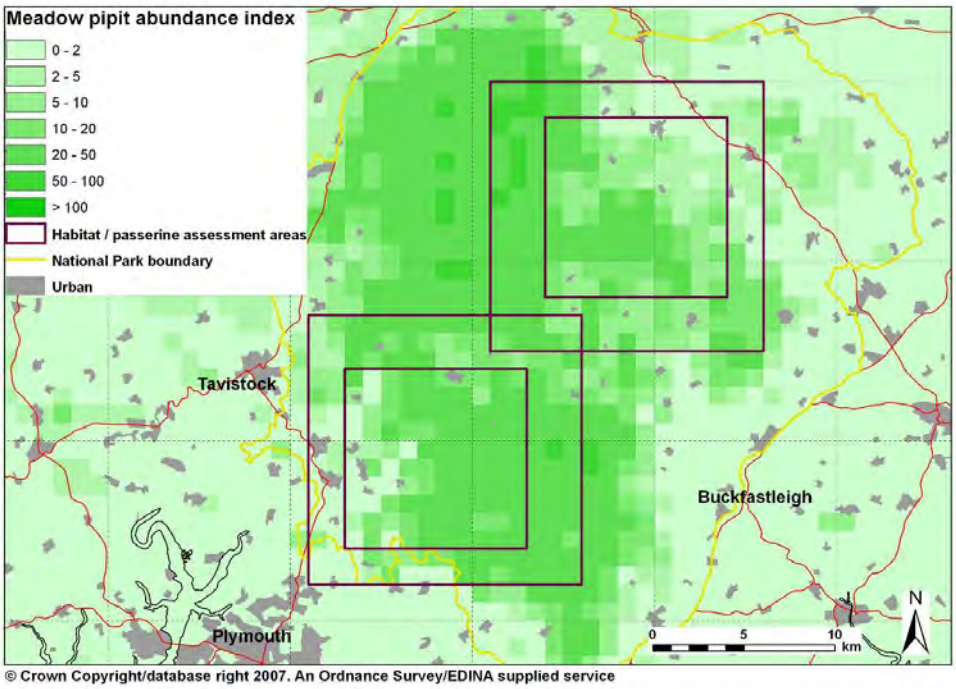


Figure 3.2.5: Predicted abundance index (individuals / 2 km transect) of meadow pipit on Dartmoor from Breeding Bird Survey data (model 1a, adjusted, for details see Appendix I).

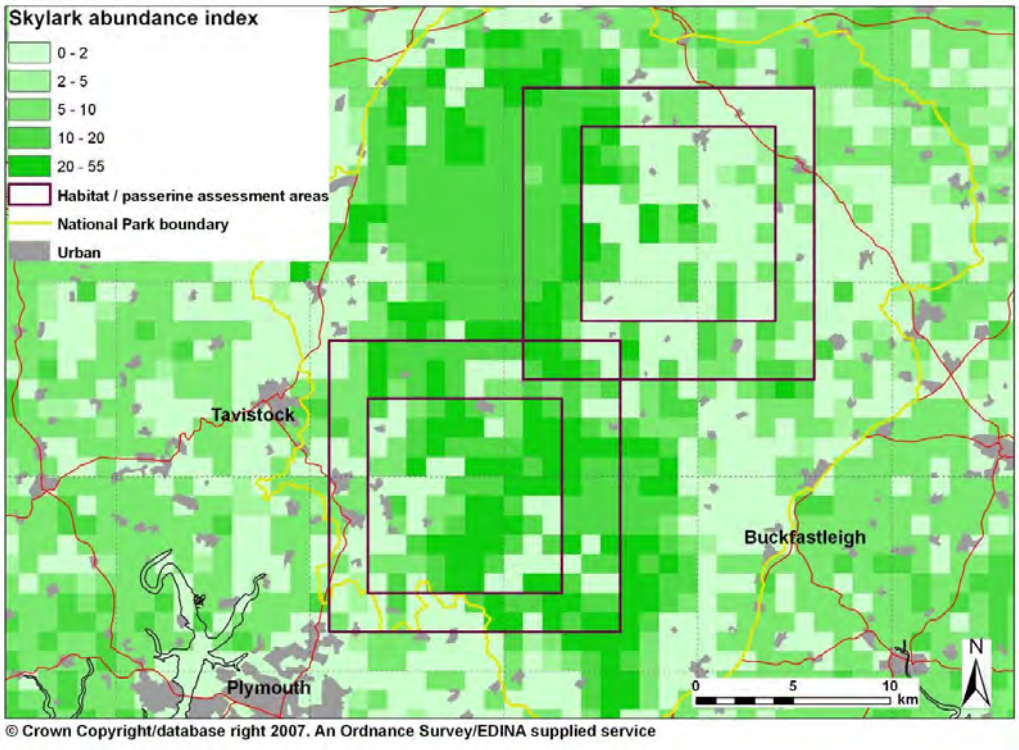


Figure 3.2.6: Predicted abundance index (individuals / 2 km transect) of skylark on Dartmoor from Breeding Bird Survey data (model 1, adjusted, for details see Appendix I).

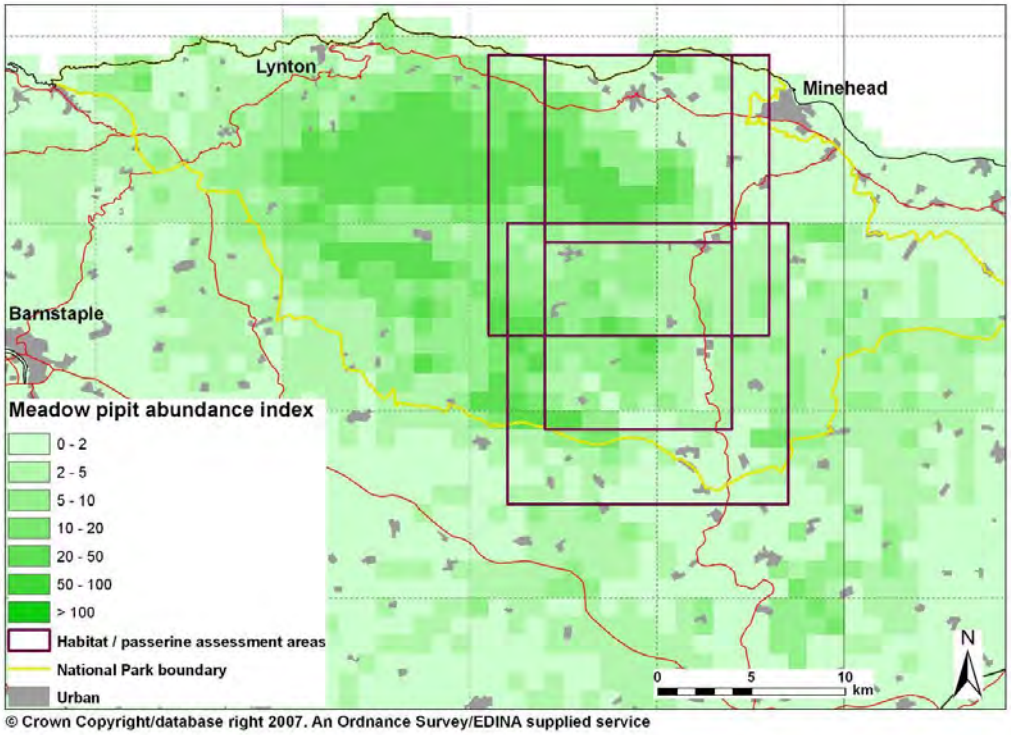


Figure 3.2.7: Predicted abundance index (individuals / 2 km transect) of meadow pipit on Exmoor from Breeding Bird Survey data (model 1a, adjusted, for details see Appendix I).

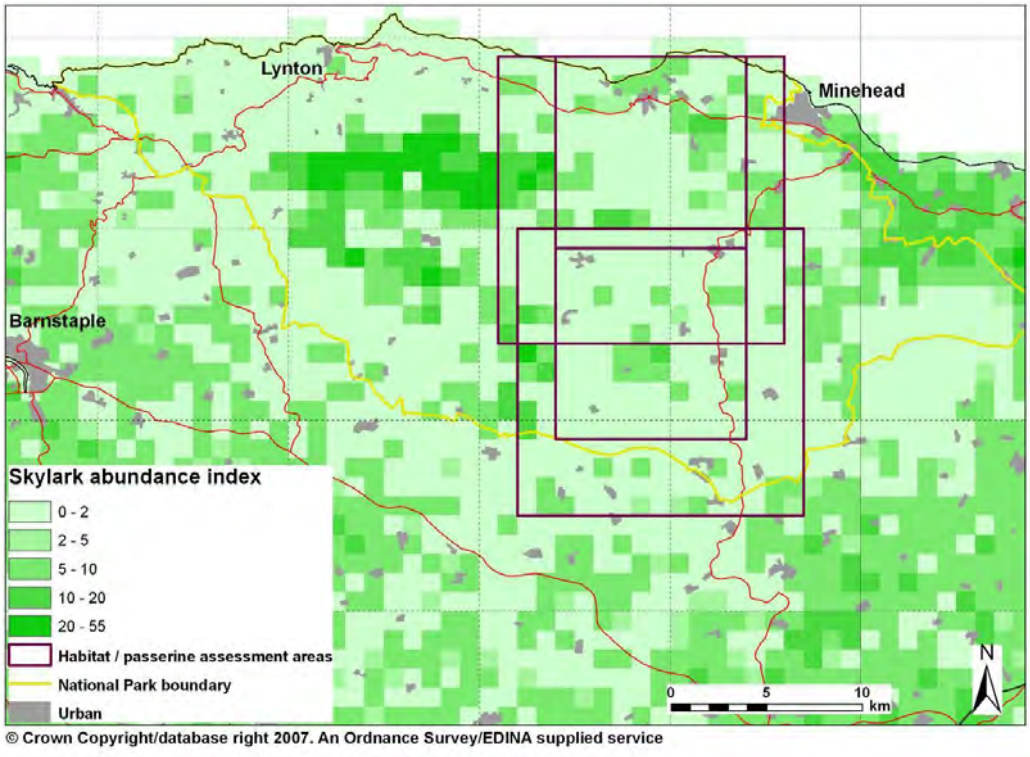


Figure 3.2.8: Predicted abundance index (individuals / 2 km transect) of skylark on Exmoor from Breeding Bird Survey data (model 1, adjusted, for details see Appendix I).

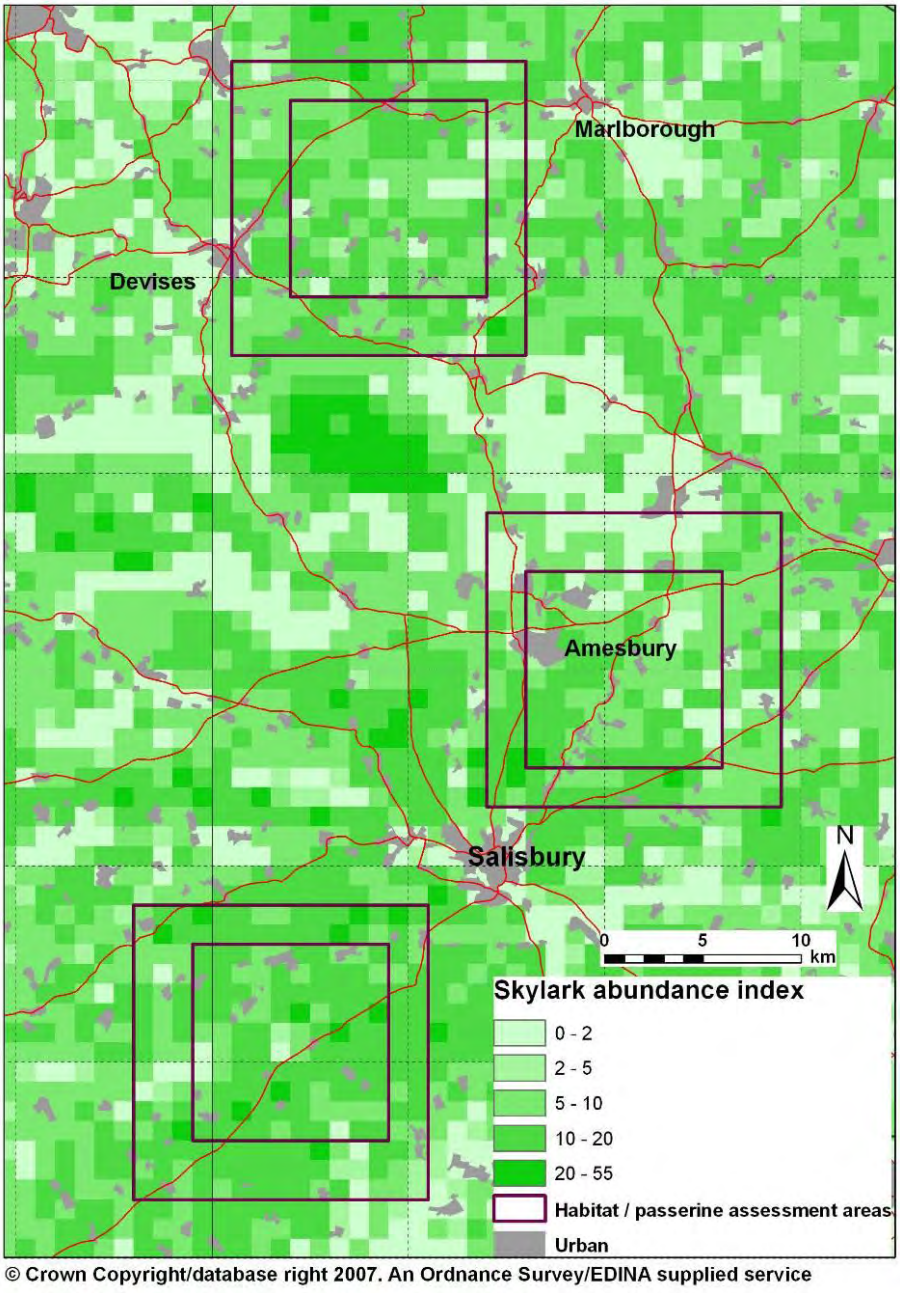
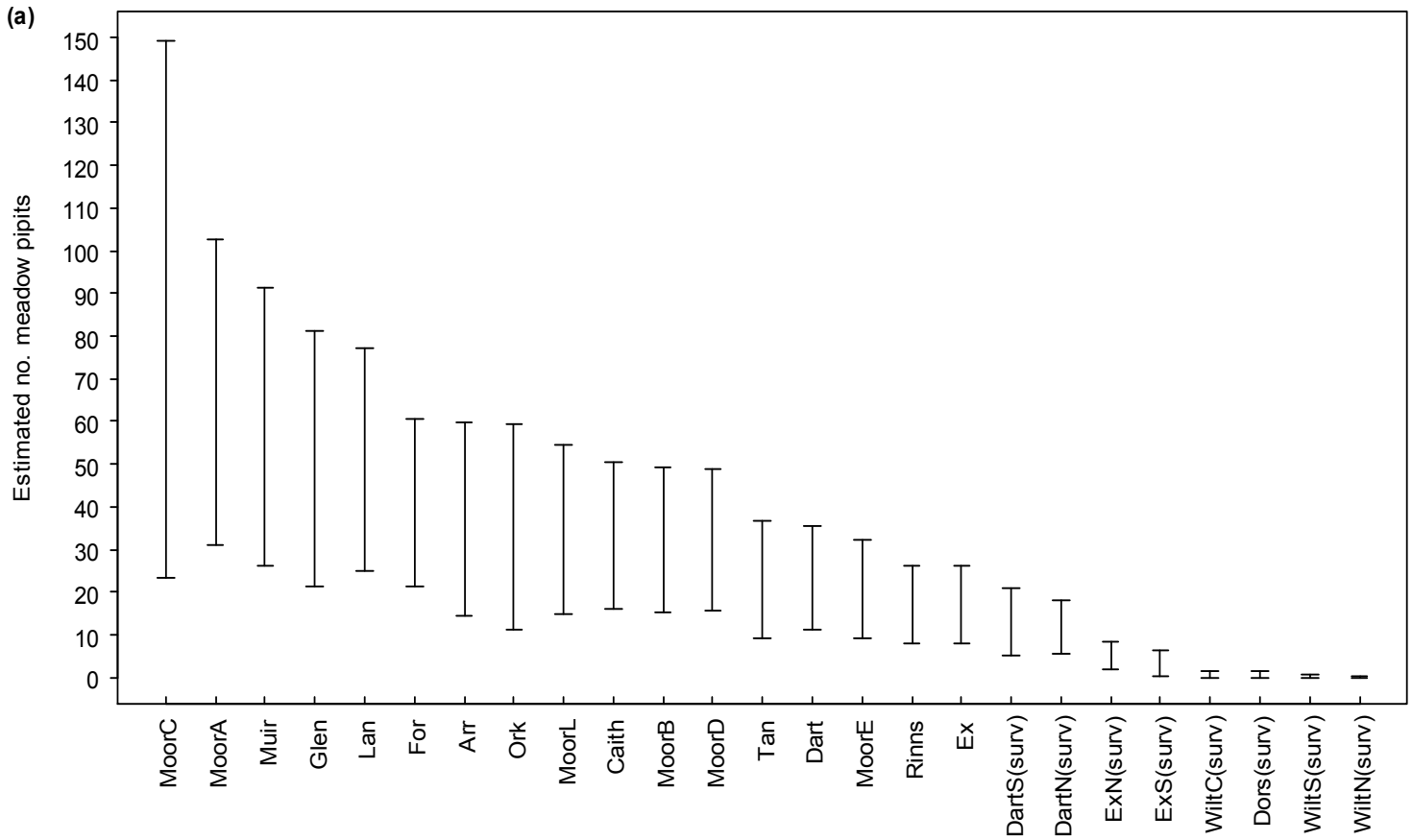


Figure 3.2.9: Predicted abundance index (individuals / 2 km transect) of skylark in Wiltshire from Breeding Bird Survey data (model 1, adjusted, for details see Appendix I).


(a)
Estimated no. meadow pipits
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
MoorC
MoorA
Muir
Glen
Lan
For
Arr
Ork
MoorL
Caith
MoorB
MoorD
Tan
Dart
MoorE
Rinns
Ex
DartS(surv)
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WiltS(surv)
WiltN(surv)

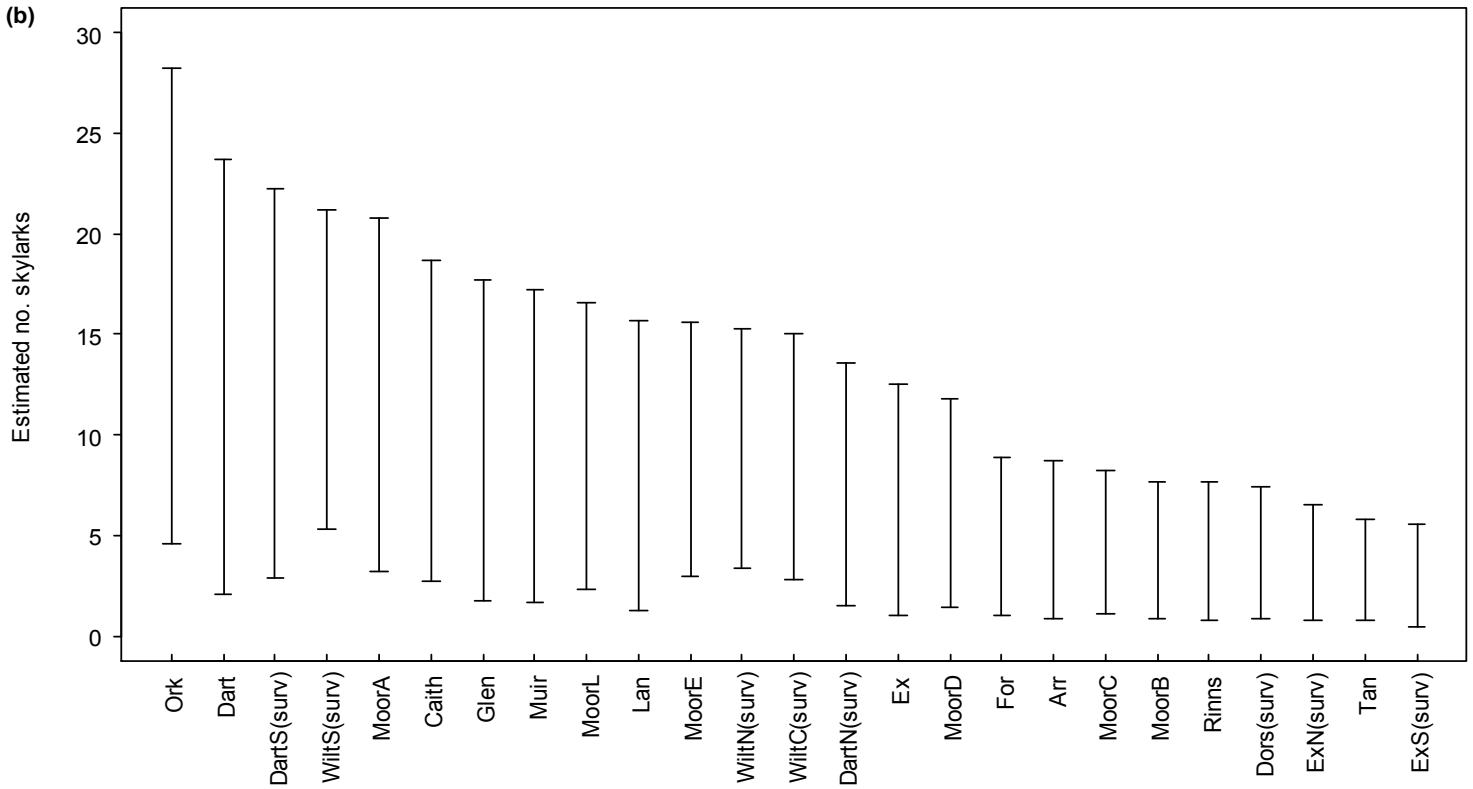


Figure 3.2.10: Estimates of the abundance of (a) meadow pipit and (b) skylark within potential hen harrier release regions (Ex, Dart, Dors, Wilt), hen harrier study moors (Moor A-E & Moor L) of Redpath and Thirgood (1999) and hen harrier Special Protection Areas (derived from Breeding Bird Survey data). Arr, Arran Moors; Caith, Caithness and Sutherland; Dart, Dartmoor (heather); DartN, Dartmoor North; DartS, Dartmoor South; Dors, Dorset; Ex, Exmoor (heather); ExN, Exmoor North; ExS, Exmoor South; For, Forest of Clunie; Glen, Glen App; Lan, Langholm – Newcastleton; Muir, Muirkirk & N Lowther Uplands; Ork, Orkney Mainland Moors; Rinns, Rinns of Islay; (surv), area around surveyed field sites; Tan, Glen Tanar; Wilt, Wiltshire; WiltN, Wiltshire North; WiltS, Wiltshire South.

3.3 Field-based surveys 2009

3.3.1 Transect locations

In regions which were identified by the modelling (Part II) as areas with extensive areas of heathland and high likelihood of presence of the main avian prey items of the hen harrier, the skylark and the meadow pipit, we conducted intensive field work in spring and summer 2009. Field sites were located in the four regions used for the modelling (see 5.1): Dartmoor, Exmoor, Dorset and Wiltshire (Figure 3.3.1; for exact locations see Appendix II). Field work comprised assessment of prey abundance (both passerines surveys and small mammal trapping and tracking), predator abundance and assessment of the local habitat.

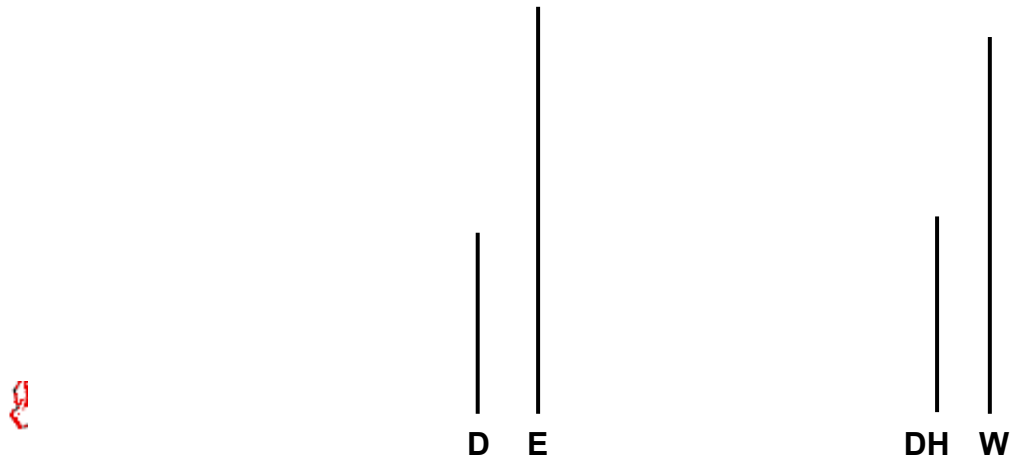


Figure 3.3.1: Locations of field-based surveys conducted in the SW of England (yellow circles). Red, lowland heathland; blue, upland heathland (see also Figure 1). D, Dartmoor; DH, Dorset Heath; E, Exmoor; W, Wiltshire.

3.3.2 Methods: passerine, fox, mustelid and badger surveys

Surveys of passerines were conducted following the Breeding Bird Survey (BBS; BTO, Joint Nature Conservation Committee). In short, one survey is carried out in a 1 km^2 square and is composed of two, 1 km long transect lines which are roughly parallel to each other. These two transect lines are about 500 m apart. Passerines heard and seen from the transect were recorded and their distance to either side of the line estimated (categories: < 25 m, 25-100 m, > 100 m). Furthermore, in each transect line signs of foxes, mustelids and badgers (e.g. scats, sightings) were recorded. We conducted a total of 26 BBS between 4 June and 16 July 2009 in the four regions mentioned above (Figure 3.3.1).

3.3.3 Methods: Small mammal trapping and tracking

Wherever logistically possible we also monitored small mammal abundance within the 1 km^2 sites of BBS, applying two different methods, trapping and tracking, as outlined below (Figure 3.3.2). Monitoring took place on 1 ha plots. Within each 1 ha plot 25 stations were s*et al*ong 5 lines, with 20 m intervals between stations. At each station two live-traps (Longworth, UK) as well as one tube were set. Tubes were layered with white paper at which ends ink pads were mounted so that an animal walking through a baited tube (baits: commercial seed mix) left its footprints on the paper (for similar procedure see e.g. Glennon *et al*. 2002; Nams & Gillis 2003). Traps contained shrewholes, preventing vulnerable juveniles and shrews from being trapped. Each plot was monitored on two consecutive nights, with the exception of one plot (trapped for one night). Previous work showed that trapping for two nights was sufficient to obtain an accurate estimation of small mammal abundance (Redpath *et al*. 1995). Traps were set in the evening, checked in the morning and captures of small mammals were recorded. We conducted small mammal monitoring at a total of 23 plots. For more details on the trapping plots, number of traps and tubes set and triggered see Appendix II.

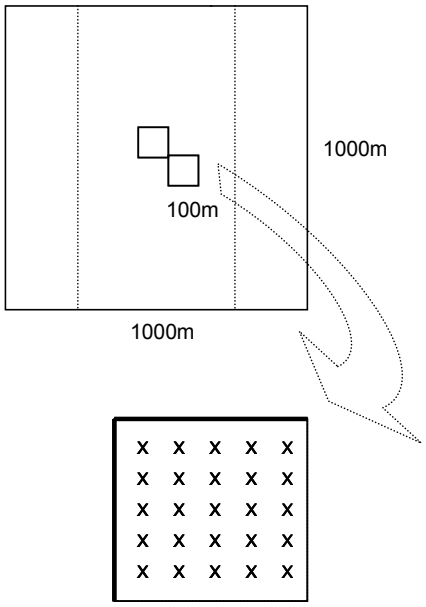


Figure 3.3.2: Site use for small mammal trapping (small quadrats) and for line-transect bird surveys (BBS, dotted line). x, one station consisting of two live-traps and one tube. At each station the vegetation height was measured.

3.3.4 Habitat assessment

In each 1 ha plot in which small mammals were monitored we assessed the habitat as follows. At each of the 25 stations within one plot one 25 cm^2 quadrat was randomly selected (by blindly throwing a light 25 cm^2 frame). In each quadrat all occurring plant species were recorded and the vegetation height was measured. Vegetation height was measured using a round disc (22 cm diameter) attached to a measuring stick. The disc was released at the top of the stick and the height was measured at the point where the disc stopped after gliding along the measuring stick.

3.3.5 Statistics

Data were analysed for differences between regions/sub-regions and for differences between sites/plots within regions. Sites within different regions were grouped to sub-regions as detailed in the Appendix II.

Transect data consisted of count data for each site and was analysed using generalized linear models with Poisson error structure with the deviance scaled to one to control for over-

dispersion. For all transect data the start time of a transect was accounted for in the models as avian abundance detected with surveys varies considerably with time of day (Reed 1985; Thirgood *et al*. 1995; for more details on the statistical models see Appendix II). To compare regions three analyses were performed on the densities of birds observed per km transect: First, we conducted a comparison of the total density of likely prey species. These species, grouped as likely prey, are listed in Appendix II, but in brief they included most passerines and red-legged partridge *Alectoris rufa*. Second, we conducted an analysis of the combined density of meadow pipits and skylarks. Third, separate analyses of densities of meadow pipits or skylarks were performed.

Small mammal trapping data was analysed with generalized linear models with binomial error structure for proportion data. The responses of the model were the number of mammals trapped or tracked divided by the number of traps or tubes (see Appendix II). The duration for which the traps and tubes were out in the field was included as fixed effect.

Vegetation height was classified by mean height (of the 25 measurements per plot) and by its variance. We tested for differences in vegetation height and variance using general linear mixed models, with vegetation height and variance as response variables. Estimates of mean vegetation height were square root transformed for normalisation. Plot was included as a random term and regional area as a fixed effect. We also tested for differences between regions in vegetation height on arable land and on moorland, respectively, with two further models (plot as a random term, region as a fixed effect).

Where possible, densities or numbers of species observed during monitoring are compared to established densities/numbers sourced from literature (Redpath & Thirgood 1999; Thirgood at el. 2003) on areas with established hen harrier populations in Scotland (Langholm).

All box plots presented in the results show the interquartile ranges and medians. Data analyses were carried out in R 2.9.2 and SAS 9.1.

3.4 Results: regional comparisons

3.4.1 Type of comparison

Here we compare data on densities of potential prey, density of predator signs, and vegetation heights recorded during field work. These comparisons are region-wide, providing a comparative view of the relative suitability of selected areas of Dartmoor, Exmoor, Dorset and Wiltshire. Densities of likely prey, and combined meadow pipit and skylark densities, are plotted next to similar figures for Langholm Moor and for a range of Scottish moorland areas supporting hen harrier populations, respectively.

3.4.2 Avian prey

There was no significant difference between regions in terms of likely prey abundance ($\chi^2 = 2.8$, df = 3, P = 0.43; Figure 3.4.1d) or the pooled abundance of meadow pipits and skylarks ($\chi^2 = 1.0$, df = 3, P = 0.80; Figure 3.4.1c). However, region varied significantly in their numbers of meadow pipits ($\chi^2 = 12.9$, df = 3, P = 0.005; Figure 3.4.1a) and skylarks ($\chi^2 = 9.52$, df = 3, P = 0.023; Figure 3.4.1b): While Dorset had high numbers of meadow pipits and low numbers of skylarks, Wiltshire had no meadow pipits but high skylark numbers. Exmoor had higher skylark numbers than meadow pipits and Dartmoor showed little difference in number of the two species. Regions dominated by heathland harboured high densities of meadow pipits and low densities of skylarks, while this was reversed in arable regions. Exmoor and Dartmoor, which are mixtures of moorland and downland, harboured high densities of both species.

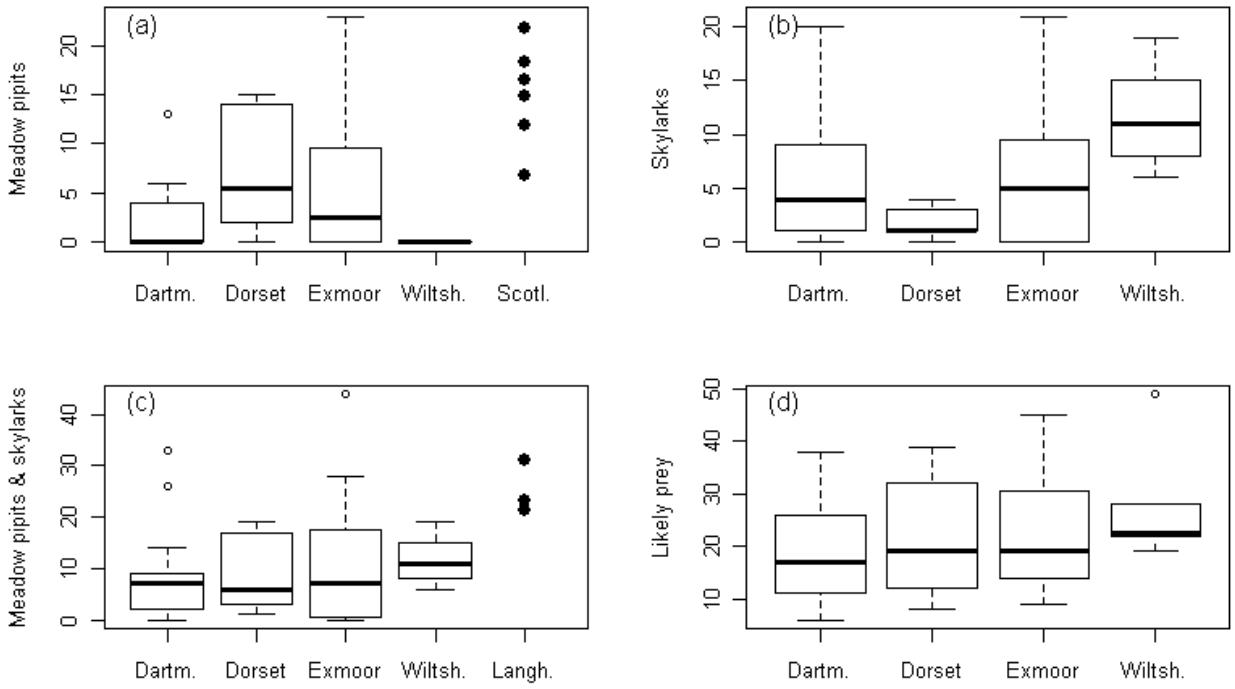


Figure 3.4.1: Avian prey abundance recorded per km transect, based on replicated transects in each of four possible translocation regions: (a) meadow pipits, (b) skylarks, (c) meadow pipits and skylarks combined and (d) likely prey individuals. Langholm and Scotland data points represent means of similar counts made in 6 Scottish grouse moors (Redpath & Thirgood 1999) and made 1994, 1995 and 1996 (from Thirgood *et al*. 2003), respectively. Dartm., Dartmoor; Scotl., Scotland; Wiltsh., Wiltshire.

These results for avian prey abundance in sub-regions of the four regions assessed in the South-West are similar to what has been described in the literature for these areas (Watson & Thirgood 2001; Figure 3.4.2). According to Watson & Thirgood (2001) Exmoor and Salisbury Plain (close to Dorset heath) are similar in their abundance of skylarks and meadow pipits and these are comparable to passerine numbers in Langholm and higher than in Moor “C”. Langholm and Moor “C” are both places in Scotland where hen harriers occur. Skylarks and meadow pipits are somewhat more abundant in Dartmoor than in Langholm (Watson & Thirgood 2001).

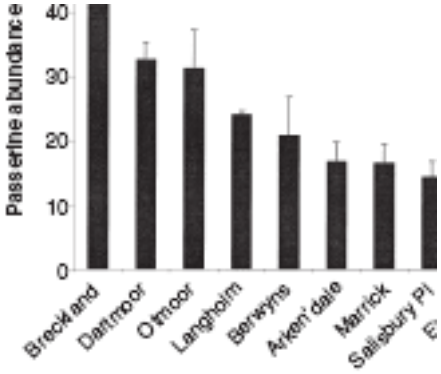


Figure 3.4.2: Meadow pipit and skylark abundance (mean ± SE) from 12 moorland and heathland sites across the UK (using BBS). Source: Watson & Thirgood (2001).

Fig. 1. Comparison of indices of abunda
its and skylarks from 12 moorland and h
error after adjusting for year effects. Dat
ing sites from British Trust for Ornitho
Survey.

Furthermore, results reported here are in line with modelling predictions. Both our field surveys and the modelling suggest low abundances of skylarks in Dorset and low numbers of meadow pipits in Wiltshire. Both data from our field surveys and results from the modelling suggest the abundance of meadow pipits and skylarks are within the range of abundances reported in hen harrier sites but occur at their lower end.

Taken together, our field data suggest that our three assessed moorland regions Dartmoor, Exmoor and Dorset might provide enough meadow pipits to sustain a hen harrier population, although densities are relatively low compared to established hen harrier breeding sites in Scotland (Redpath & Thirgood 1999). Low numbers of meadow pipits in Wiltshire could likely be compensated by high numbers of skylarks. Finally, for Exmoor it has been shown that both meadow pipit and skylark numbers have changed moderately from 1992 to 2002 (Sim *et al*. 2005; Figure 3.4.3): while skylark numbers have declined, meadow pipit abundance has increased considerably. In combination, skylark and meadow pipits seem to be relatively stable in their abundance over relatively long periods of time which would be an important pre-requisite for a successful hen harrier translocation. In Dartmoor, both skylarks and meadow pipits have been reported to be stable between 1979 and 2000 (Stanbury *et al*. 2006).

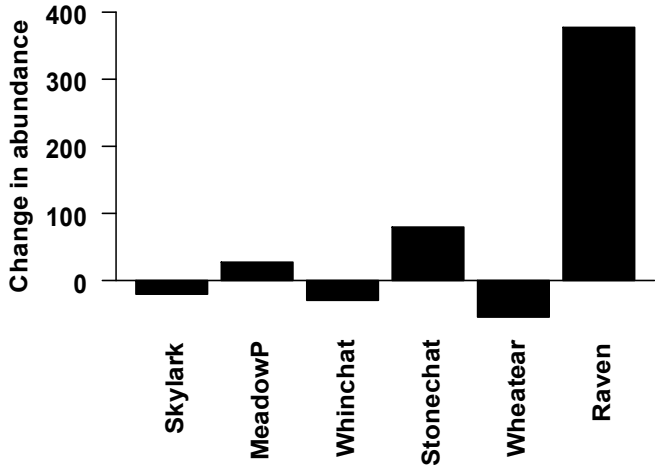


Figure 3.4.3: Change (%) in abundance of passerines in Exmoor in 1992-93 and 2002 in an area of 154 km^2 surveyed. Data: Sim *et al*. (2005).

3.4.3 Small mammal activity

Results for trapped animals (Trap) and mammal tracks in tubes (Tracks) are presented separately. This is because these two measures work on different scales which cannot be combined.

We found no significant effect of region on the density/activity of small mammals observed (Trap: $\chi^2 = 3.0$, df = 3, P = 0.40; Track: $\chi^2 = 0.7$, df = 3, P = 0.87; Figure 3.4.4). Similar, though mainly lower, small mammal abundances as found here have been recorded for hen harrier breeding sites in Langholm and 5 other moors in Scotland (Table 3.4.1; Redpath & Thirgood 1999; Thirgood *et al*. 2003). Abundance there was measured as the proportion of snap traps which contained small mammals. These results suggest all potential release sites would be able to provide a sufficient number of small mammal prey items for hen harriers.

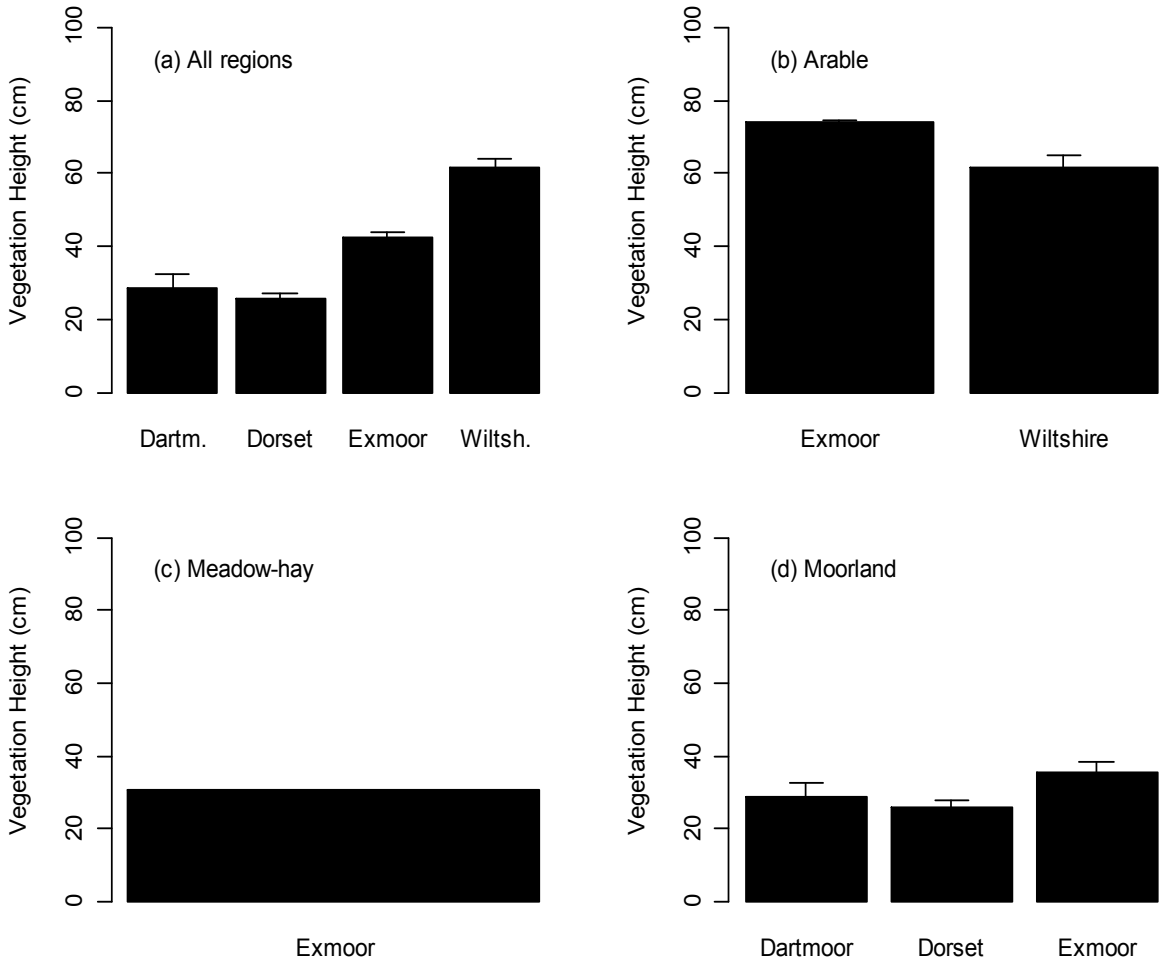
Figure 3.4.4: Small mammal activity recorded. (a) Proportion of Longworth traps triggered by small mammals and (b) proportion of tracking tubes showing evidence of small mammal tracks.

Table 3.4.1: Proportion of snap traps (mean ± SE) containing small mammals on six Scottish moors with breeding hen harriers. [a]Data from Thirgood *et al*. (2003); [b]Data from Redpath & Thirgood (1999).

Small mammal abundance	Location	Year
0.027±0.008	Langholm	1994[a]
0.000±0.000	Langholm	1995[a]
0.023±0.008	Langholm	1996[a]
0.022±0.006	Langholm	1992-97[b]
0.026±0.01	Moor A	1992-96[b]
0.024±0.008	Moor B	1992-96[b]
0.017±0.005	Moor C	1992-97[b]
0.015±0.013	Moor D	1992-96[b]
0.016±0.007	Moor E	1992-96[b]

3.4.4 Vegetation height

Vegetation height varied between regions ($F_{2,552}$ = 9.5, P < 0.0001; Figure 3.4.5) with Wiltshire having the tallest vegetation. However, this was arable land and therefore the height of vegetation will vary considerably with time of year. There was a significant difference in the variance in vegetation heights between regions ($F_{3,19}$ = 9.0, P = 0.0006; Figure 3.4.5), with Dartmoor having the most variable vegetation height. Vegetation on arable land was not significantly higher in Exmoor than in Wiltshire (χ^2 = 3.0, df = 4, P = 0.09) but moorland vegetation differed in its height in different regions (χ^2 = 5.9, df = 5, P = 0.02): vegetation on Exmoor was higher than on Dartmoor and lowest in Dorset (Figure 3.4.5d).



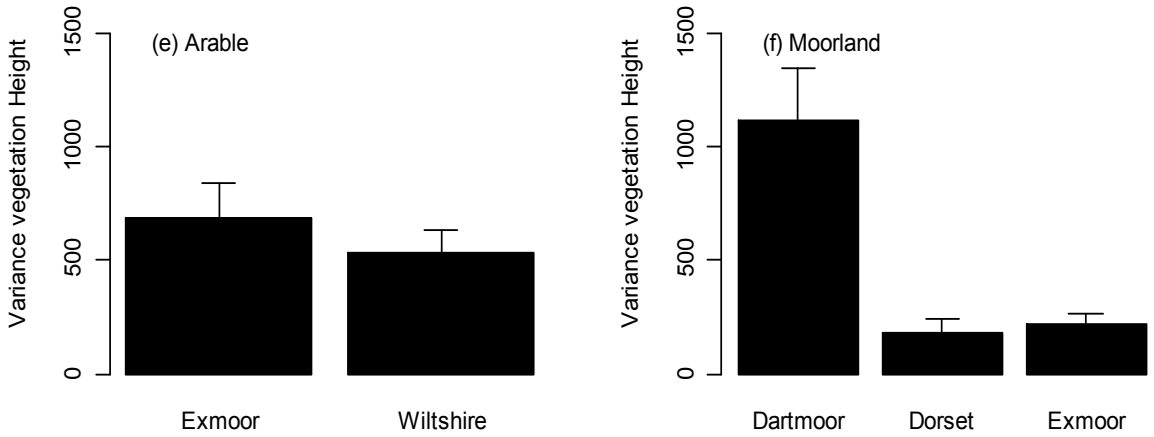


Figure 3.4.5: Vegetation characteristics across regions and habitats (mean ± SE): heights of (a) all regions (b) arable, (c) meadow-hay, (d) moorland, and mean variance of (e) arable and (f) moorland. All values are based on replicated measurements in each plot in sub-regions of each of four possible translocation regions.

3.4.5 Signs of predators

There were significant differences between the number of predators in each region, both looking at all potential predators together (χ^2 = 24.9, df = 3, P < 0.0001), just badgers and foxes combined (χ^2 = 30.3, df = 3, P < 0.0001; Figure 20) and badgers and foxes separately (Badgers: χ^2 = 32.5, df = 3, P < 0.0001; Foxes: χ^2 = 17.7, df = 3, P = 0.0005). Wiltshire had the highest abundance of predators, while all other areas showed very low evidence for predators.

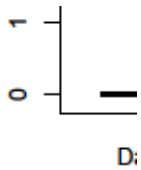


Figure 3.4.6: Number of signs of fox and badger recorded per km transect, based on replicated transects in each of four possible translocation regions.

Although the red fox has been mentioned as the main predator of the hen harriers in the literature (Watson 1977; Potts 1998), recent studies have not found a negative influence of the presence of foxes on harrier nest success (Green & Etheridge 1999) or have reported only small effects (Whitfield *et al*. 2008). Furthermore, little evidence of hen harrier predation by foxes has been found in a study by Leckie *et al*. (1998; Table 3.4.2). MacDonald *et al*. (1981) estimated fox densities per km^2 over the UK (see Figure 3.4.7). While these estimations showed a clear North-South-divide, with higher fox densities in the South than in the North, there was also a significant habitat effect on the densities. Low densities were found in upland areas, both in extensive Scottish uplands, but also smaller regions such as Exmoor and Dartmoor (MacDonald *et al*. 1981; Figure 3.4.7). However, areas with intensive mixed agriculture were shown to have high densities of foxes (MacDonald *et al*. 1981). Similarly, we showed here that predator signs were more abundant in Wiltshire, on arable sites, than in the other regions we assessed; Exmoor, in which we assessed both arable and moorland sites had intermediate numbers of fox signs (Figure 3.4.6). Finally, our results should be treated with caution given that surveys were carried out on a relatively small scale (for comparison: Baines *et al*. (2008) used 10 km long transects); therefore multiple scats recorded on one transect could in principle be made by just one individual fox (or badger).

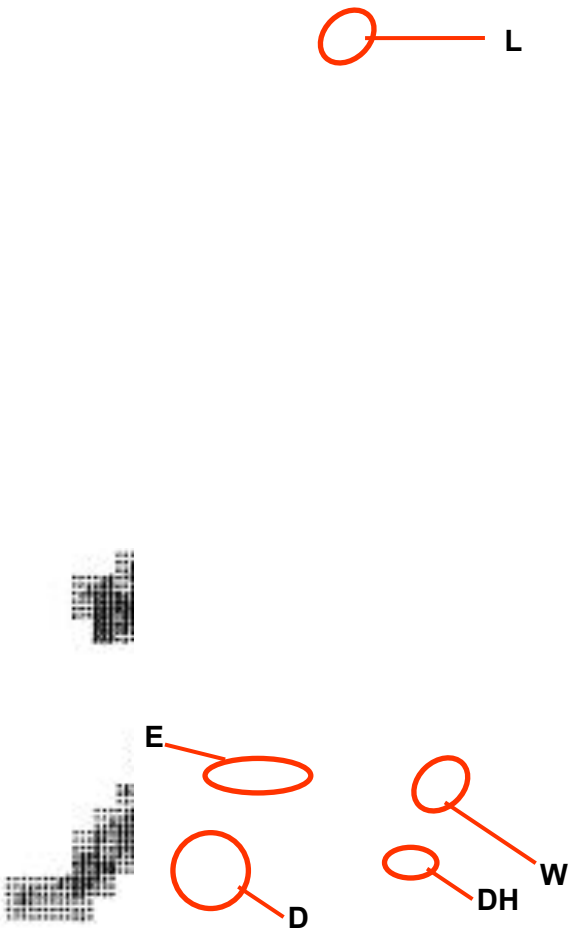


Figure 3.4.7: Estimated adult fox densities in the UK (densities divided into six intervals from 0-<4 (light) to 20-<24 (darkest) foxes per km^2). Map from MacDonald *et al*. (1981). D, Dartmoor; DH, Dorset heath; E, Exmoor; L, Langholm; W, Wiltshire.

Table 3.4.2: Food composition (%) of fox scats in six sites at Langholm, Scotland, between 1992-96 in heather and grassland during winter (win) and summer (sum). Table redrawn from Leckie *et al*. (1998).

Food type	Heather win (N =154)	Heather sum (N = 55)	Grass win (N = 104)	Grass sum (N = 27)	All (N = 340)
Game	35	31	14	22	27
Rodents	53	58	80	81	63
Lagomorph	29	36	14	18	25
Ungulate carrion	17	9	10	15	13
Insectivores	7	11	11	11	9
Other					
Passeriformes	3	4	3	4	3
Columbiformes	1	0	1	0	1
Charadriiformes	1	4	0	7	1
Egg	1	4	0	0	1
Coleoptera	2	2	2	4	2
Berry	2	0	1	0	1

3.4.6 Addendum: Prey and predator surveys 2010

Two concerns were raised during prey and predator sampling in 2009. First, the seasonal timing of prey surveys occurred later than the natural nesting period of hen harriers. Second, the predator sign surveys were carried out along short transects, rather than the standard 10 km transect established in the literature. We addressed these concerns in 2010 by surveying for passerines and fox scat along 10 km transects through heather moorland on Exmoor, mixed moorland on Dartmoor, and mixed arable / downland in both North and South Wiltshire (equivalent to the Marlborough Downs and Martin Downs sites surveyed in 2009, respectively). Results are presented separately because sampling strategies were changed between years, and because inter-annual variation in prey and predator densities provides additional information in assessment of habitat suitability.

2010 transects were surveyed monthly in April, May, June and July. All counts of meadow pipits, skylarks, total passerines, and fox scats, were converted to per-km densities. These data are displayed in Figures 3.4.8 and 3.4.9 below. Results for bird densities were broadly comparable to 2009 data. There was a significant difference between sites in terms of the pooled densities of meadow pipits and skylarks (X^2 = 13.3, df = 3, p = 0.004). Sites also varied significantly in their densities of meadow pipits (X^2 = 26.2, df = 3, p = 0.001) and skylarks (X^2 = 8.5, df = 3,

p = 0.036). The combined densities of meadow pipit and skylark were also significantly different in relation to habitat. Exmoor and Dartmoor, which contain mixtures of moorland and grassland, harboured high densities of ground nesting birds in comparison to the lowland arable dominated sites of North Wilts and South Wilts (X^2 = 12.3, df = 1, *p* = 0.004).It is notable that regions support high densities of *either* meadow pipits *or* skylarks, but when summarised as total potential prey density, median values are similar among Exmoor, North Wilts and Dartmoor. Densities are clearly lower in South Wilts (Figure 3.4.8 (d)).

However, there is a potential trade-off between higher prey densities and densities of fox signs (Figure 3.4.9): Exmoor and North Wilts have the highest median densities of fox scats. But, there exists no statistically significant variation among regions in fox scat density (χ^2 = 5.9, df = 3, *p* = 0.116). Furthermore, there was no significant difference between moorland and arable dominated regions with regard to fox scat densities (χ^2 = 0.21, df = 1, *p* = 0.643).

It should also be noted that fox scats are surveyed along linear features (footpaths). The risk of nest predation is likely to be reduced when nests are placed in deep, dense heather or crop fields.

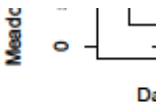


Figure 3.4.8: Avian prey abundance recorded per km transect, based on replicated transects in each of four possible translocation regions: (a) meadow pipits, (b) skylarks, (c) meadow pipits and skylarks combined and (d) likely passerine prey individuals.

Figure 3.4.9: Number of signs of fox recorded per km transect, based on replicated transects in each of four possible translocation regions.

3.5 Results: within region analysis

3.5.1 Likely prey, meadow pipits and skylarks

There was a significant difference between the two Dartmoor sub-regions in likely prey number (χ^2 = 8.6, df = 1, P = 0.003) and meadow pipit and skylark number, both combined (χ^2 = 4.4, df = 1, P = 0.036; Figure 3.5.2b) and individually (Meadow Pipits: χ^2 = 14.5, df = 1, P = 0.0001; Figure 3.5.1a; Skylark: χ^2 = 1.8, df = 1, P = 0.18). These results are driven by a higher abundance of all likely prey species, including meadow pipits and skylarks in the Southern groups.

There was no significant difference between Exmoor sites in number of likely prey (χ^2 = 2.7, df = 3, P = 0.44) but there was a significant difference in the number of meadow pipits and skylarks (Pooled: χ^2 = 13.7, df = 1, P = 0.003; Figure 3.5.2c) and separately (Meadow pipits: χ^2 = 9.8, df = 3, P = 0.020; Figure 3.5.1c; Skylarks: χ^2 = 16.0, df = 3, P = 0.001). The difference between areas showed the same pattern in both meadow pipits and skylarks with Porlock having highest numbers of both, followed by Dunkery. Luccombe Farm had low numbers of both, while around Tivington Farm neither meadow pipits nor skylarks were recorded.

There was no significant difference between the two Wiltshire sites in likely prey number ($\chi^2 = 0.8$, df = 1, P = 0.37) but there was a significant difference in meadow pipit and skylark numbers pooled ($\chi^2 = 10.2$, df = 1, P = 0.001; Figure 3.5.2d). No meadow pipits were seen in Wiltshire and therefore the result for skylarks alone is the same as that for meadow pipits and skylarks pooled. Martin Down had significantly more skylarks than the RSPB site.

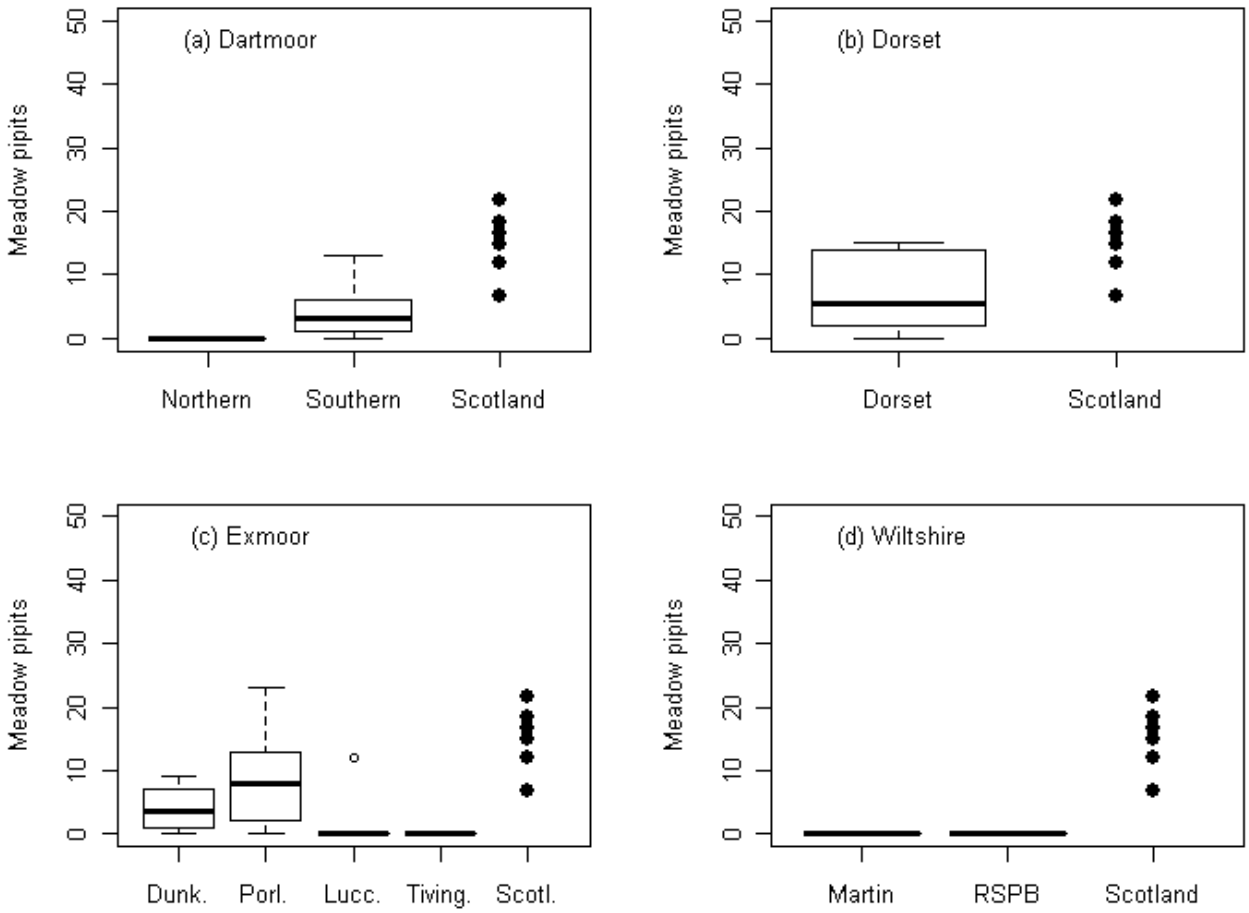


Figure 3.5.1: Number of meadow pipits recorded across study sites within different regions of the SW: (a) Dartmoor, (b) Dorset, (c) Exmoor and (d) Wiltshire in comparison to numbers recorded in Scotland (from Redpath and Thirgood 1999). Dunk., Dunkery Beacon; Porl., Porlock; Lucc., Luccombe; Tiving., Tivington; Scotl., Scotland.

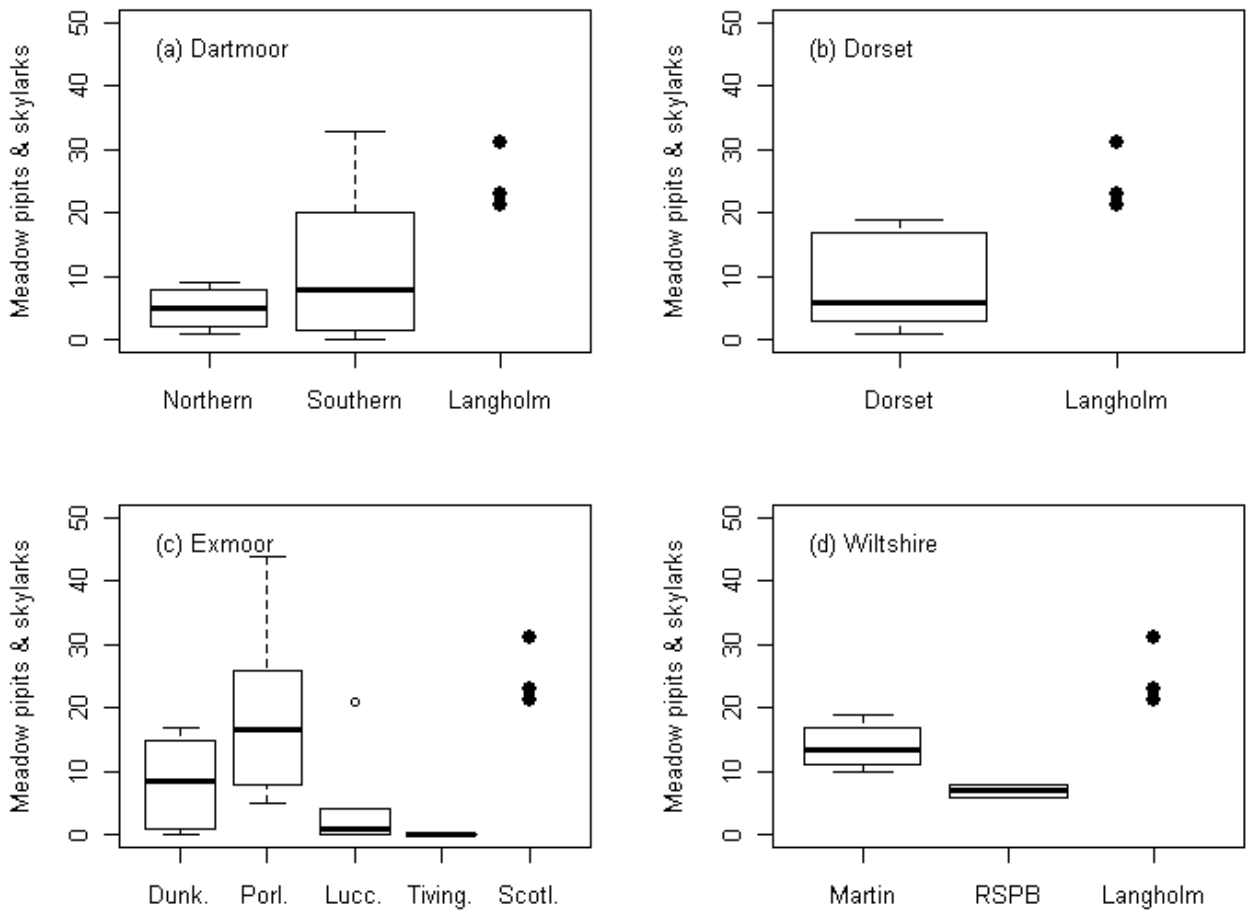


Figure 3.5.2: Number of meadow pipits and skylarks recorded across study sites within different regions of the SW: (a) Dartmoor, (b) Dorset, (c) Exmoor and (d) Wiltshire. Langholm points represent means of similar counts made in 1994, 1995 and 1996 (from Thirgood *et al*. 2003). Dunk., Dunkery Beacon; Porl., Porlock; Lucc., Luccombe; Tiving., Tivington; Scotl., Scotland.

3.5.2 Mammal trapping

There were significant differences in small mammal abundance between the Exmoor sites, using both trapping data ($\chi^2 = 70.1$, df = 3, $P < 0.0001$; Figure 3.5.3c) and track data ($\chi^2 = 89.0$, df = 3, $P < 0.0001$; Figure 3.5.4). Tivington showed high numbers of small mammals using both methods with Luccombe having intermediate numbers. Both Porlock and Dunkery had low numbers of small mammals.

There were no difference in small mammal abundance between the three Wilshire sites where mammals were monitored (Trap: $\chi^2 = 1.1$, df = 2, $P = 0.58$; Track: $\chi^2 = 5.5$, df = 2, $P = 0.065$; Figures 3.5.3d & 3.5.4d).

Small mammal monitoring only took place at one cluster of sites in each of Dartmoor and Dorset and therefore no within-region comparisons could be made in these regions.

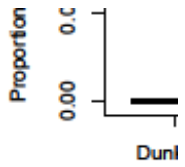


Figure 3.5.3: Proportion of life traps containing small mammals across study sites within different regions of the SW: (a) Dartmoor, (b) Dorset, (c) Exmoor and (d) Wiltshire.

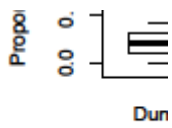


Figure 3.5.4: Proportion of tubes containing small mammal footprints across study sites within different regions of the SW: (a) Dartmoor, (b) Dorset, (c) Exmoor and (d) Wiltshire.

3.5.3 Vegetation height

There was a significant difference in vegetation heights between the 1 ha plots of the different Exmoor sites ($F_{3,240} = 17.2$, $P < 0.0001$; Figure 3.5.5c), with Porlock having the longest vegetation and Dunkery the shortest. The variance in vegetation height was significantly different between sites ($F_{3,6} = 7.41$, $P = 0.019$), with Tivington having highly variable vegetation height, possibly because it is arable land.

There was no significant difference in vegetation height ($F_{2,144} = 1.2$, $P = 0.32$; Figure 3.5.5d) or its variance ($F_{2,3} = 2.1$, $P = 0.27$) at the Wiltshire sites.

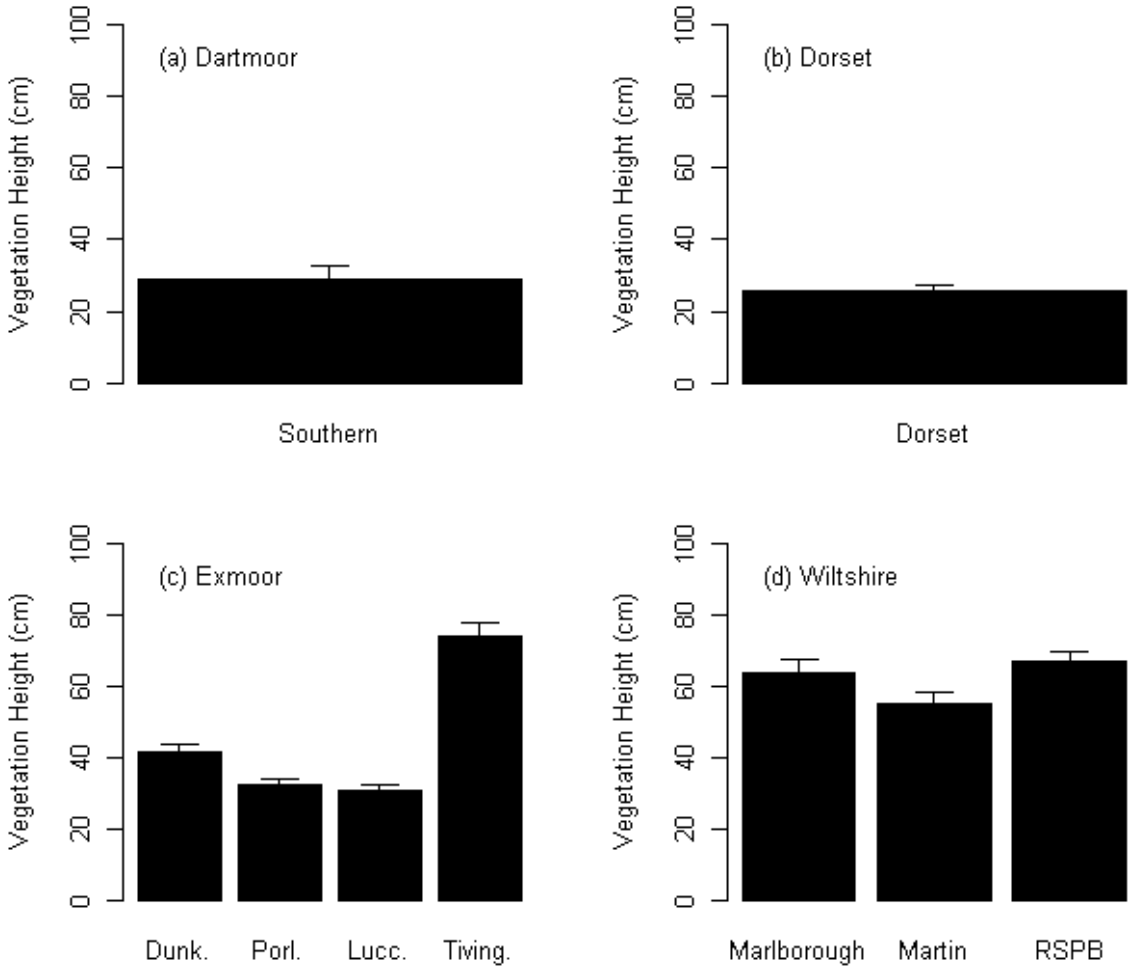


Figure 3.5.5: Vegetation heights (mean ± SE) across study sites within different regions of the SW: (a) Dartmoor, (b) Dorset, (c) Exmoor and (d) Wiltshire. Dunk., Dunkery Beacon; Porl., Porlock; Lucc., Luccombe; Tiving., Tivington.

3.5.4 Badgers and foxes

There were no significant differences in predator abundance between the two Dartmoor sub-regions when considering all predators ($\chi^2 = 3.4$, df = 1, P = 0.066), or badgers and foxes either combined ($\chi^2 = 3.4$, df = 1, P = 0.066; Figure 3.5.6a) or for badgers individually ($\chi^2 = 1.3$, df = 1, P = 0.26). There was insufficient data to test for between area differences in fox numbers.

There were no significant differences between predator abundance in the four Exmoor sites ($\chi^2 = 4.8$, df = 3, P = 0.19). There was also no significant differences between sites in the

number of badgers and foxes (Pooled: $\chi^2 = 2.1$, df = 3, P = 0.55; Figure 3.5.6c; Badgers: $\chi^2 = 6.8$, df = 3, P = 0.078; Foxes: $\chi^2 = 0.8$, df = 3, P = 0.86).

We found no significant difference in predator number between the two Wiltshire sites ($\chi^2 = 0.02$, df = 1, P = 0.90) nor in the number of badgers and foxes (Pooled: $\chi^2 = 0.02$, df = 1, P = 0.90; Figure 3.5.6d; Badgers: $\chi^2 = 0.22$, df = 1, P = 0.64; Foxes: $\chi^2 = 0.1$, df = 1, P = 0.81).

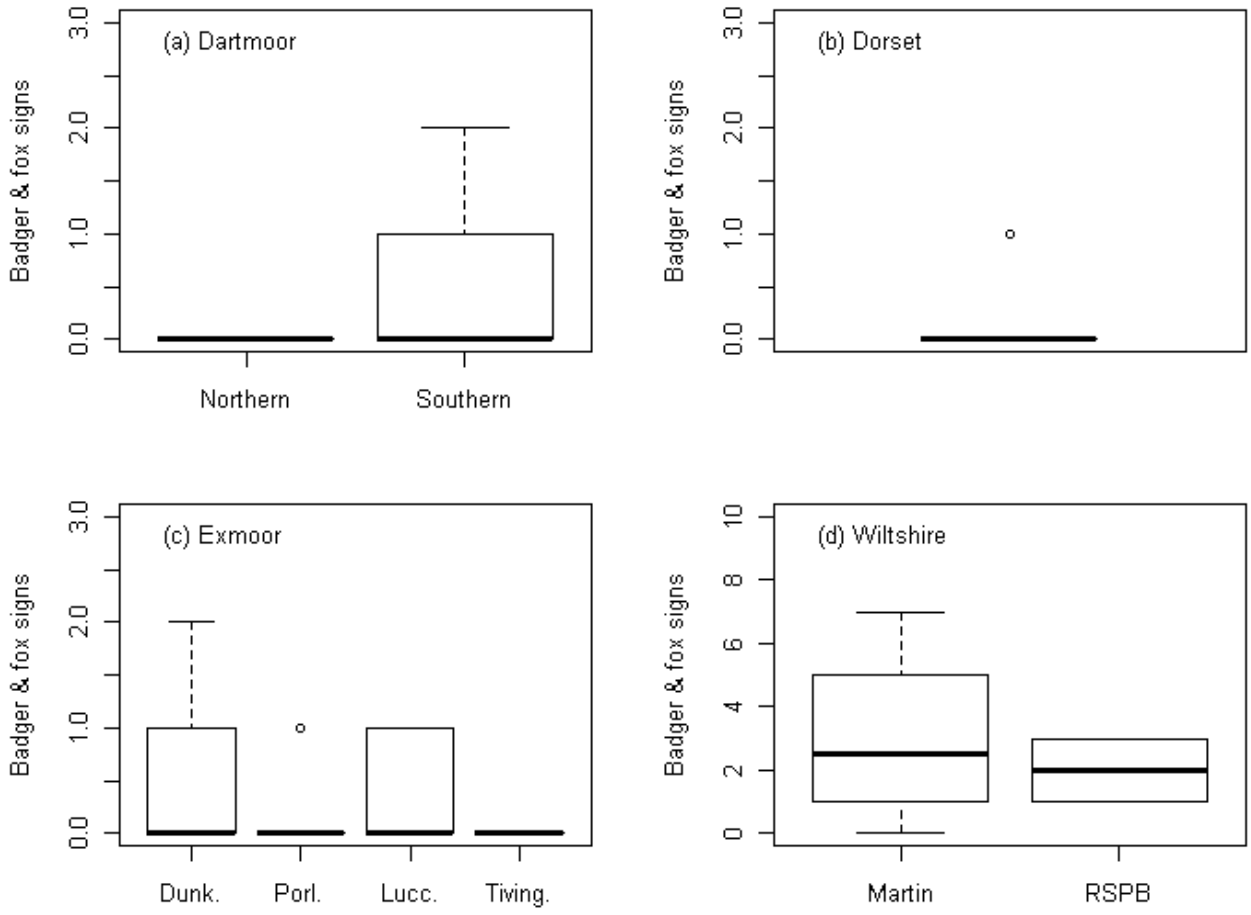


Figure 3.5.6: Number of badger and fox signs recorded across study sites within different regions of the SW: (a) Dartmoor, (b) Dorset, (c) Exmoor and (d) Wiltshire. Please note the different scales of the graphs. Dunk., Dunkery Beacon; Porl., Porlock; Lucc., Luccombe; Tiving., Tivington.

Table 3.5.1: Summary table field surveys: Regions, and areas within Exmoor and Wiltshire, ranked according to their habitat suitability for hen harriers. Mammal traps recorded mammal captures in Longworth traps; mammal tubes recorded small mammal activity; densities of meadow pipits and skylarks recorded during 2 km transects; predator signs and other raptor densities recorded during transects. Trapping was normally performed in core nesting habitat (heather moorland, lowland heath or arable crop), except in Luccombe Farm on Exmoor (coarse grassland). Raptor density ranked as most suitable for harriers if density was HIGH (considered sign of available prey). NA indicates lack of transect data at this site or in this year. Among regions, Exmoor ranked highest for suitability (34.5 aggregate points), while Dartmoor, Dorset and Wiltshire shared similar aggregate values (30, 29.5, 29.5 respectively).

Region	Area	Site name (Clusters of sites)	Small mammal traps (high=4)	Small mammal tubes (high=4)	Meadow pipits & skylarks (high=4)		Meadow pipits (high=4)		Skylarks (high=4)		Badgers & foxes (low=4)		Other raptors (high=4)	Vegetation height (high=4)	Habitat
					2009	2010	2009	2010	2009	2010	2009	2010			
Dartmoor	All	Dartmoor all	3	1.5	2	3	2	3	3	4	3	2	1.5	2	Grassland & Moor
Dorset	All	Dors*et all*	4	3	1	NA	4	NA	1	NA	4	NA	4	1	Heathland Moorland, Grassland
Exmoor	All	Exmoor all	2	4	4	4	3	4	2	2	2	3	1.5	3	, Arable
Wiltshire	All	Wiltshire all	1	1.5	3	2	1	2	4	3	1	4	3	4	Arable
Exmoor		Dunkery	1	2	4	NA	3	NA	3	NA	4	NA	3	3	Moorland
Exmoor		Porlock Post	2	1	3	NA	4	NA	4	NA	2	NA	2	1	Arable
Exmoor		Luccombe	3	3	2	NA	2	NA	2	NA	3	NA	4	2	Moorland
Exmoor		Tivington	4	4	1	NA	1	NA	1	NA	1	NA	1	4	Hay-meadow
Wiltshire		Martins Down	2	2	1	1	1	1	1	1	1	1	1	1	Arable
Wiltshire		Marl-borough	1	1	NA	2	NA	1	NA	2	NA	2	NA	2	Arable
			Mean based												

Summary of table 3.5.1:

Average ranks across habitat-suitability criteria are taken for each region, thus allowing us to identify the region with the highest score for habitat suitability. Exmoor is the most suitable region according to the summary table with an average score of 2.875. However, the remaining regions, Dartmoor, Wiltshire and Dorset, have similar average scores of 2.5, 2.46 and 2.46 respectively. Mean scores are then taken again for the sites within the regions of Wiltshire and Exmoor. Exmoor Dunkery scored the highest at 1.82 followed in descending order by Post, Luccombe, Tivington, Martin Down and Marlborough with average scores of 1.55, 1.55, 1.45, 1.18 and 1. **According to the summary table, Exmoor is the most highly recommended region and Dunkery is the most suitable site in which to serve as a platform for a reintroduction programme, at least according to habitat suitability.** A „risk-spreading" approach to translocation might consider two release sites of contrasting habitat types: in which case Exmoor ranks as the „best" moorland site, and Wiltshire as the „best" arable site. However these ranks do not account for the numerous other factors that must be considered prior to translocation: full consideration of multiple hazards, exposures, mitigation measures and resultant risk factors is made in Part VII of this report.

PART IV: Release site assessment – anthropogenic issues

4.1 Disturbance/ access assessment

While habitat suitability is a prime criterion for species translocations, pressures imposed by human use of the landscape must also be considered. In southern England, tourism imposes significant pressure on native biota in moorland and downland landscapes. While visitors and tourists to conservation areas can support the local community, they can also have negative influences on the native fauna via disturbance, pollution or habitat destruction, especially if not managed sustainably (see discussion in Part VI). Annual estimated tourist numbers in Dartmoor National Park have increased steadily over the last two decades (Figure 4.1.1; but see 2003) and are now oscillating around 10 million visitors per year (but see 2003). With around two million tourists per year, Exmoor has far less visitors than Dartmoor (but note also the smaller scale of Exmoor). Therefore, the potential for disturbance to reintroduced hen harriers is expected to be lower in Exmoor than in Dartmoor (see also Box 4.1). However, even within Dartmoor there are areas with expected low human disturbance such as M.O.D. land in the NW of Dartmoor. Human disturbance in agricultural Wiltshire is expected to be low, whereas high visitor numbers are expected in Dorset. All four potential translocation regions are expected to have good access for a release program (see Box 4.1).

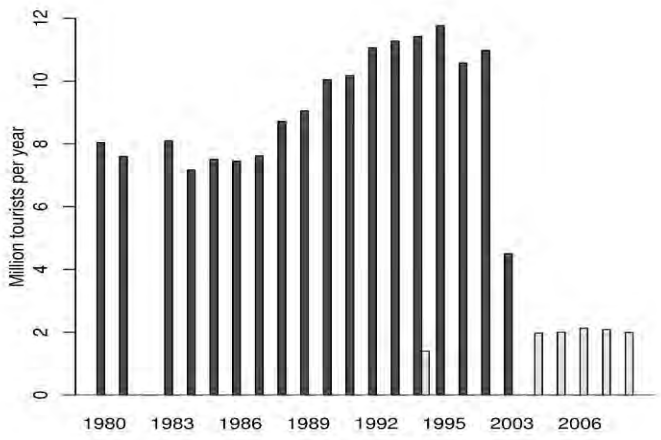


Figure 4.1.1: Number of tourists (in millions per year) in Dartmoor (black) and Exmoor (grey) National Park. Dartmoor data between 1980-1997 based on traffic counters; Exmoor data 2004-2008 & Dartmoor 2003 based on STEAM; Data sources: Dartmoor: Dartmoor National Park State of the Park Report 2008; Recreation and Tourism – Dartmoor Factsheet; Exmoor: Exmoor National Park State of the Park Report 2008; Exmoor National Park Authorities personal communication; Exmoor National Park Management Plan 2007 to 2012.

Box 4.1: Expected degree of access for a hen harrier release and degree of human disturbance post-release in the four regions for a potential release.

Dartmoor:
- high disturbance and intermediate to high access in areas with open public access (tourist numbers far more than for Exmoor, National Trust part)
- MOD land: low disturbance by tourists, potentially high disturbance by military, high access for program

Exmoor:
- intermediate to high disturbance in area with open public access (but they mainly restrict to view points according to NT wardens); good access for release.

Wiltshire:
- agricultural land: low human disturbance expected on private land, good access
- RSPB reserve: intermediate to high disturbance due to public access, good release access

Dorset:
- High disturbance in summer due to tourists; good access.

4.2 Persecution assessment

Even if the hen harrier‟s critical needs for prey and habitat are fulfilled in a potential release site, and predator numbers are low, hen harrier densities may still be limited, for instance via persecution (Etheridge *et al*. 1997). Despite being protected, persecution of hen harriers is a serious problem and has been assessed extensively in the literature (e.g. May 1997; Potts 1998; Thirgood *et al*. 2000a; Amar *et al*. 2004; Redpath *et al*. 2004; Marshall *et al*. 2007; Park *et al*. 2008). The illegal killing of hen harriers and other birds of prey is especially high in Scotland (Figure 4.2.1) and strong associations have been found between the extent of persecution and management for game bird hunting (Bibby & Etheridge 1993; Etheridge *et al*. 1997; Whitfield *et al*. 2008; Anderson *et al*. 2009). There is a strong North-South-divide in the extent of persecution with the Southwest of England having very few reported cases of predator persecution incidents. Particularly few incidents have been recorded in Cornwall, Devon, Somerset, Dorset, Wiltshire, Sussex, Kent and Essex (Figure 4.2.1). Therefore, all our assessed regions for a potential translocation have low levels of persecution. Within these regions Exmoor, Wiltshire and Dorset have lower persecution rates than Dartmoor. One thing to note, however, is that the abundance of birds of prey per area is not considered in Figure 4.2.1, making it difficult to judge if persecution in some areas is low just because the abundance of birds of prey is low or because the human-wildlife conflict *per se* is low (or both). It seems unlikely that persecution is solely based on high abundance of birds of prey, given positive correlations between management for game bird hunting and persecution in the North (see above).

Figure 4.2.1: Persecution incidents in Great Britain and Northern Island between 1995-2006. Figure from the RSPB.

4.3 Farmland management practices

Whilst farmland areas offer significant potential for range expansion and population increase for a reintroduced hen harrier population, farm management operations in arable areas also have the potential to negatively impact on this species. This section considers the effects of farm management practices on crop-nesting birds and the conservation measures that could be used to mitigate these effects.

4.3.1 Review of UK Montagu's harrier and marsh harrier breeding success

In order to help assess the potential impacts on breeding hen harriers, the breeding success of marsh and Montagu"s harriers nesting in farmland areas of southern England has been reviewed. Monitoring and nest intervention work on Montagu"s harriers has been carried out for several decades with apparent high success in boosting productivity but, until recently, limited success in terms of population increase. However, in recent years there has been an increase in the population and with the likely influence of climate change, the prospects for continued increase and range expansion are now considered good. Marsh harriers have been extensively monitored in the past but due to the rapidly increasing population this species is no longer seen as a priority for annual monitoring and nest interventions.

Montagu"s harriers used to nest more commonly in semi-natural habitats than in arable crops, attempting to nest in lowland heathland, saltmarsh and occasionally in areas of upland dry-heath in northern England. Increasingly, the majority of nests are located inland in areas of arable farmland, rather than lowland heathland. There are two main population centres; an area around north-west Norfolk/the Wash and an inland area of central southern England.

4.3.2 Farm management conservation measures

Agricultural practises pose two main problems for nesting harriers. Firstly, increased use of pesticides and herbicides and a reduction of field margins mean a decrease in prey items which in turn could have a detrimental effect on breeding success. Prey availability for hen harriers in

selected arable areas is reviewed in Part III. Secondly, agricultural operations, particularly harvesting often coincides with the time when birds are still in the nest (Arroyo *et al*. 2002). This is particularly a problem in southern Mediterranean regions where the overlap between the breeding cycle and post-harvest period is greatest but is also an issue with harriers in lowland England. High levels of nest destruction caused by harvesting could prevent a reintroduced hen harrier from becoming established if no protection measures were adopted.

For many years marsh and Montagu"s harriers have been recorded nesting in crops and some nests have required interventions to protect them from harmful farming practices. This work has taken place on the Continent and also in England as part of a joint RSPB/Natural England project on crop nesting harriers. Crop-nesting harriers most frequently nest in winter cereals, oilseed rape and grass silage with the nest forming a platform of vegetation on the ground within the crop. This often means a high possibility of accidental damage to the nests during harvest, spraying or other farm operations. Predation has also been an issue with crop nesting harriers. Minimal intervention to nesting harriers is often considered to be the best option, with the following specific measures undertaken only if it is clear that agricultural operations will otherwise threaten the nest:

- **Harvest.** The timing of harvest is crucial to the success of any harrier nest and with good planning this can cause minimal inconvenience to the farmer. Delayed harvest is often the best option available if the birds are to fledge soon after the planned harvest. A square no smaller than 10m x 10m is left uncut around the nest with operations resuming once the birds can fly. Alternatively, a total harvest method can be adopted by raising the level at which the crop is cut. This leaves long stubble around the nest which provides cover and protection. The nestlings are briefly removed from the nest under licence and replaced immediately after operations have ceased. This method should only be undertaken if the nestlings are able to feed themselves. It is also important to leave enough cover so as not to leave the birds vulnerable to predation. Harriers have occasionally already fledged by the time harvesting takes place but may need to be flushed from the field during harvest to avoid the young being killed. Best practice would include the presence of a licensed harrier worker during harvesting operation near to nest sites.

- **Crop fall.** In certain cases the nest area may have to be visited by a licensed individual in order to trim the crop close to the nest. This is usually carried out within half a metre of the nest to prevent crop fall and is only required in crops which may be prone to collapse in on the nest such as oilseed rape.

- **Predation.** When nesting in grass, and particularly oilseed rape, predation has been a particular problem. Electric fencing has occasionally been used as a deterrent to mammalian predators with varying results. Again, an area around the nest is marked and the electric fence is erected around the nest area. This is usually carried out at an early stage during nesting and it is important to keep disturbance to a minimum and to ensure that human activity does not attract predators (Corbacho & Sanchez 1999). Poultry mesh and sheep mesh is ideally used and, in oilseed rape, it is beneficial to have fencing high enough to reach the top of the crop.

It is difficult to develop a prescriptive approach to these issues due to varying seasonal conditions affecting the structure of crops and the timing of farming operations. Most situations must be considered on an individual basis. If a farmland area is selected as the release site for a lowland reintroduction project then it will be necessary to develop a programme of monitoring and associated interventions in order to ensure that the nests of birds breeding in crops are not lost due to agricultural operations. This will be especially important in the early years of a project when numbers are small and the outcomes at a small number of nests may have a major impact on the chances of a self-sustaining population becoming established.

4.3.3 Use of Environmental Stewardship

There would be the potential to use Environmental Stewardship (ES) money as well as direct funding from the reintroduction project to help fund farmland management measures to improve breeding success. This is a complex area and once a release area has been selected further work would be required involving Natural England national specialists and local advisors to clarify how the required nest interventions would best be funded.

PART V: Population Viability Assessment - Release Strategy Simulations

5.1 Demographic simulations without population spread

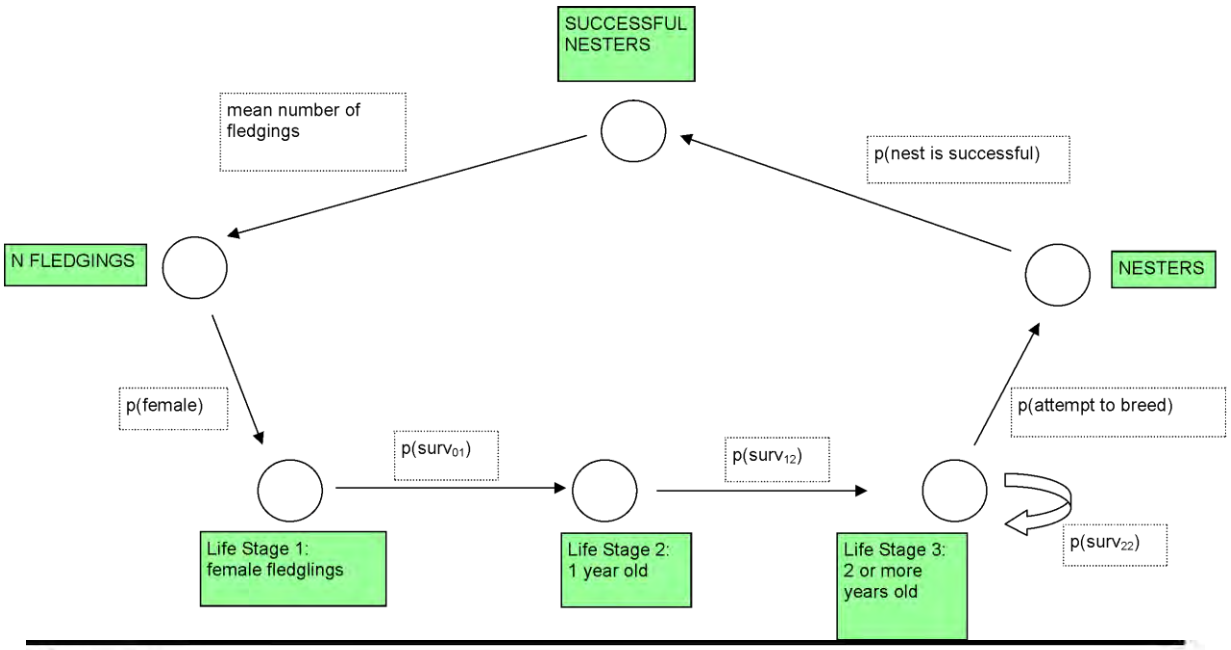
5.1.1 Introduction

Several studies have quantitatively assessed reintroduction/translocation successes, i.e. translocations / reintroductions that led to self-sustaining populations, for multiple avian and mammalian species (e.g. Griffith *et al*. 1989; Wolf *et al*. 1996) and more taxonomic groups (Fischer & Lindenmayer 2000). For the more than 420 assessed studies in Griffith *et al*. (1989) and Wolf *et al*. (1996) the median number of animals translocated was 32 and 51, respectively, and the total duration of releasing campaign 2-3 years, while 46 % and 68 % studies, respectively, released more than 30 individuals in their program. Releases of more than 80-120 individuals did not increase the chances of a successful translocation but increasing durations of releasing campaigns showed positive effects (Griffith *et al*. 1989). Despite some general tendencies from these multi-species analyses, the species-specific characteristics have to be taken into account as well for an estimation of the number of birds to release and the duration of a reintroduction campaign (e.g. Griffith *et al*. 1989; Watson & Thirgood 2001). Therefore, we simulated different release strategies for a translocation of hen harriers and their influences on population viability. For that we considered species-characteristic survival rates and breeding values reported in the literature (see Figure 5.1.1).

5.1.2 Methods

We used a stage-structured one-sex individual based demographic model with overlapping generations and a yearly time step to describe the dynamics for a reintroduced population of hen harriers. Our model contained three stages (Figure 5.1.1): (1) female fledglings, (2) females one year old and (3) females two years or older (reproductive female). All stages had transitions to older classes but stages differed in their mean survival rates according to values reported in the literature (probability to survive from (a) fledging to year 1: 0.36, (b) year 1 to year 2: 0.78, (c) year 2 to next year: 0.78, see Figure 5.1.1; see Etheridge *et al*. 1997). We set fecundity using empirical data from the literature as follows (Figure 30): adult females aged two or older reproduced with a mean probability of 0.7 (Sim *et al*. 2007) and raised a brood successfully with

a probability of 0.44 (see Saunders 2009; Irwin *et al*. 2008; Whitfield *et al*. 2008) with a mean of 3.01 fledglings (Saunders 2009). Of the produced fledglings we assumed 50 % to be female. We allowed for demographic stochasticity on all survival and fecundity parameters on an individual basis by drawing each survival and breeding event from a binomial function, and the number of fledglings produced from a Poisson distribution with the age-specific survival rates and breeding values as outlined above. With this approach we could account for high uncertainty and high probability of stochastic events occurring in small populations (see McGowan *et al*. 2009 for detailed discussion).



Parameters:

		Etheridge et al. (1997)	Picozzi (1984)
$p(surv_{01})$	=	36.10%	f: 29%
$p(surv_{12})$	=	gm: 0.397, om: 0.778	
$p(surv_{22})$	=		f: 90%

		Sim *et al*, 2007
p(attempt to breed)	=	definitely: 66% probably: 86%

		Saunders (NE 2009)	Irwin et al. (2008)	Whitfield et al. (2008)
p(nest is successful)	=	0.561	62.80%	60% (44% over prev 30 years)
mean no fledglings	=	3.01	2.6	3.08 (3.21 over prev 30 years)

n chicks	=	taken from the poisson distribution
n females	=	taken from the binomial distribution, p=0.5

Figure 5.1.1: Life-cycle used for hen harrier population modelling. Data from Saunders, R (2009, unpubl,): latest figures (2002-2009) on hen harrier breeding.

Using the parameters set above we estimated the probability of a hen harrier population surviving for 50 years depending on the number of fledglings introduced per year and the number of years of the translocation campaign.

We allowed for a density-independent population growth for populations containing up to 10 reproducing females (i.e. 10 breeding pairs); the maximum population size was set at 10 breeding females as this is the minimum expected number of females the proposed release sites could maintain.

5.1.3 Results

Projections suggested a probability of over 0.8 that a population of hen harriers would survive for 50 years if at least 20 fledglings are introduced per year for four years with breeding females having a successful nest in 80% of the breeding events (Figure 5.1.2). Several other reintroduction strategies achieve this goal (fewer birds per annum, spread across more years of campaign), but this "20-4" strategy is conservative and provides a useful rule-of-thumb.

In our models we restricted population size to a maximum of 10 pairs. It is most likely that all 4 surveyed regions have a sufficient carrying capacity to sustain such a population size and to support such a long term population. As detailed in Part I female home ranges vary between 2.5 and 3.9 km^2, depending on the analytical method used. Males have bigger home ranges of about 10 km^2 but their home ranges can overlap quite substantially (see Part I). Areas of heathland in Dartmoor, Exmoor and Dorset are 121 km^2, 141 km^2, 214 km^2 (Figure 2.2.1), respectively, and therefore should provide more heathland area than needed for supporting populations of 10 pairs of hen harriers.

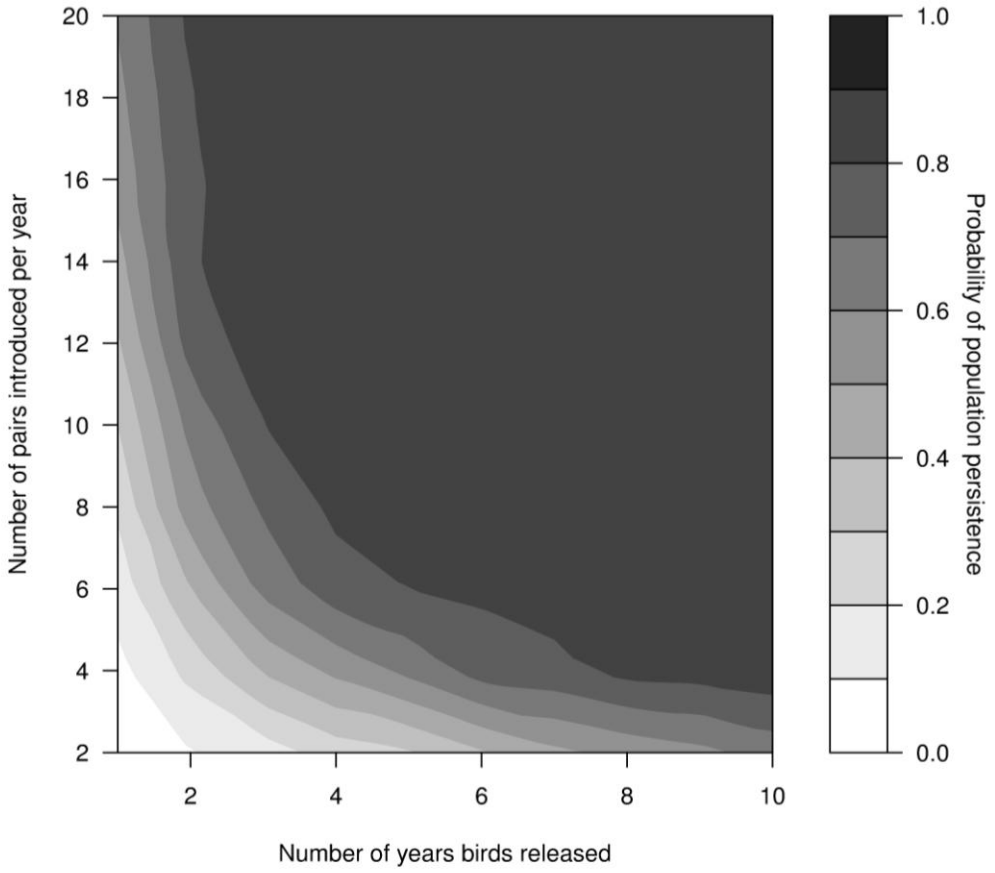


Figure 5.1.2: Probability of a hen harrier population surviving for 50 years depending on the number of years in the release programme, the number of fledglings introduced per year and the probability of nest success.

5.2 Individual-based modelling with population spread

5.2.1 Introduction

We developed an individual-based model of harriers to simulate possible outcomes of a release of hen harriers into south west England. We took demographic data from Etheridge *et al*. (1997) in Scotland to provide estimates of survival, productivity and dispersal. We ran the model under different scenarios, varying:

i) release numbers. Releasing 30, 60 or 90 birds in one year
ii) release time. 30 birds in one year, or 10 birds per year for three years
iii) release site (Exmoor, Dartmoor or Wiltshire crop breeders)
iv) breeding success (1.9, 2.1, 2.4 fledged young per pair) and
v) nest site habitat (>1%, >10% or >25% heath for moorland breeders).

5.2.2 Methods

We assumed no illegal activity. The percentage of first-year individuals undertaking a long-distance dispersal movement was set at 5.0%. First year survival was set at 36% and adult survival at 78%. For moorland breeders we used a heath index threshold and an index of meadow pipit abundance to determine suitability. For the crop-breeders, we used an index of skylark abundance. For each set of scenarios, 20 simulations were run for 50 years and we estimated extinction rate, the mean number of breeding harriers after 50 years and the time it took birds released from one moorland site (Dartmoor or Exmoor) to reach the other site.

5.2.3 Results

1. <u>Number released.</u>

The success of a release programme, as estimated by this model, increases with the number of juveniles released (Figure 6.1.1).

It seems clear from the model that the likelihood of success is dependent on the numbers of birds released. When 90 juveniles are released, extinction probability is near 5% and average breeding number after 50 years is approximately 130 pairs (Figure 6.1.2).

2. Release Time

Releasing 30 birds in one year tended to lead to slightly more successful outcomes than releasing 10 birds per year over three years (Figures 6.1.3 - 6.1.6). There was a slightly higher risk (6%) of extinction when 10 birds were released per year. Generally, it took roughly 20 years for the population to start to increase.

3. Release Site

The likelihood of success was greater when birds were released on both Dartmoor and Exmoor at the same time (Figures 6.1.3 – 6.1.6). Extinction risk was 57% for single site releases, and 31% for combined releases.

4. Breeding success

One of the big unknowns in any potential release programme such as this is how high breeding success will be. For this reason we set three levels of productivity as low (1.9), medium (2.1) or high (2.4 chicks per pair). This had a strong influence on likely success of a reintroduction programme. When breeding success was poor then the simulations suggest that the populations did not increase and had a 70% chance of extinction. If breeding success was good, then even when pairs are restricted to sites with >25% heath, the average population size is expected to reach up to almost 200 pairs after 50 years, and there was a 34% chance of extinction (Figure 6.1.5).

5. Nest Site habitat

We estimated the potential impact of nest site selectivity on moorland breeders (Figure 6.1.3 – 6.1.6). If birds nested only in areas with at least 25% heather, final numbers were reduced, although this didn't affect the probability of extinction which was the same for all three nest habitat types.

6. Likelihood of reaching Dartmoor from Exmoor and vice versa.

We assessed the likelihood that birds would be able to colonise Dartmoor from Exmoor and vice versa. On average the model suggested it would take 19 years before birds were able to colonise the other site (range 9 to 33 years).

7. Crop breeders

We lastly considered what would happen if birds were released into crops rather than moorland sites. There is much less certainty about these findings as, although we know birds can breed successfully in these habitats, we know less about the factors that would limit their numbers and productivity. Our model suggested that the likely success of crop breeders will vary with breeding success and years of release (Figure 6.1.7). The big difference, however, is that if the population does not go extinct, there is a huge amount of suitable habitat available throughout the UK, so that the population would not be limited by habitat in contrast to moorland breeders in the south west.

Illustrative maps for three simulations are given in Figure 6.1.7. They show how under certain conditions (good breeding success and limited habitat restrictions) harriers can spread throughout the south west and further afield.

5.2.4 Discussion

Our individual-based model suggests that the likely success of a re-introduction programme will depend primarily on the number of individuals released and the breeding success of those birds. The more birds released and the greater their productivity the greater the chance of success. Clearly, any re-introduction programme would need to be adaptive to take into account observed survival and productivity of released birds, as there are many uncertainties in a model such as this. The model suggests that a combined release programme in two places would be better than a single release site. Also, if birds are able to breed well in crops, the likelihood of long term success of a reintroduction programme would be increased by releasing into arable habitats.

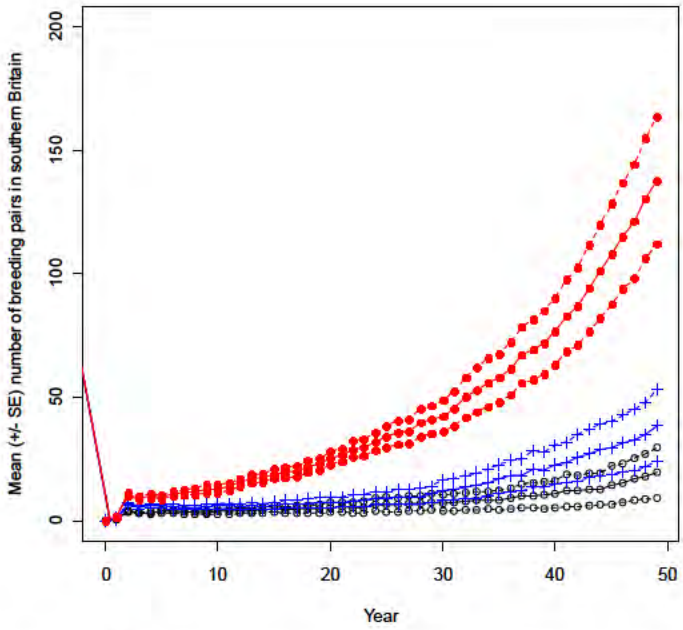


Figure 5.2.1: The mean (± standard error) of the number of territorial birds, following the reintroduction of 30 (black open circles), 60 (blue crosses), or 90 (red solid circles) juvenile hen harriers in Exmoor and Dartmoor. The threshold value for the minimum percentage of dense and open dwarf shrub heath (combined) required for settlement in a territory was set as 10.0%. The mean fledged brood size was set as 2.1. Numbers were split between Exmoor and Dartmoor.

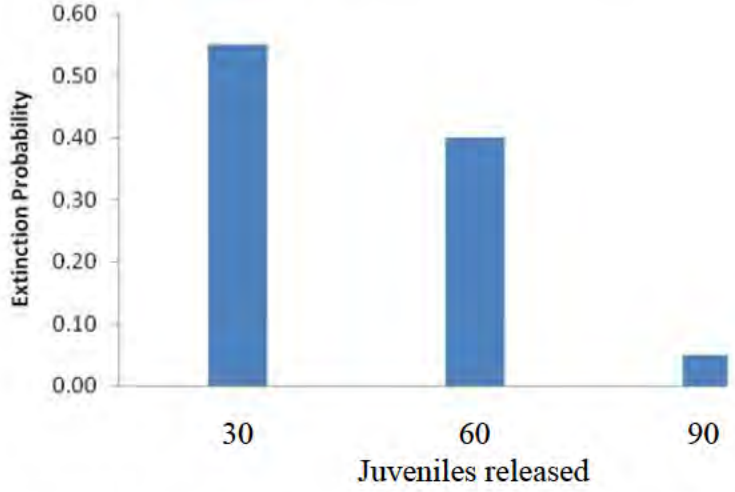


Figure 5.2.2: The extinction probability, calculated as the number of independent replicate simulations where the population became extinct within 50 years of the first reintroduction, for three different scenarios where juvenile pairs were released in Exmoor and Dartmoor.

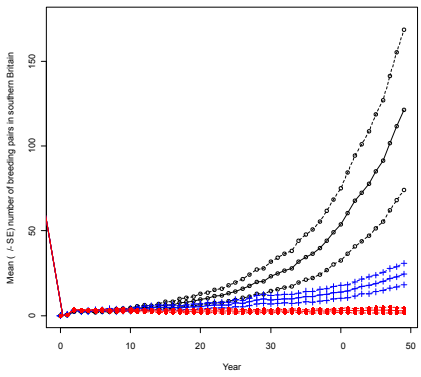
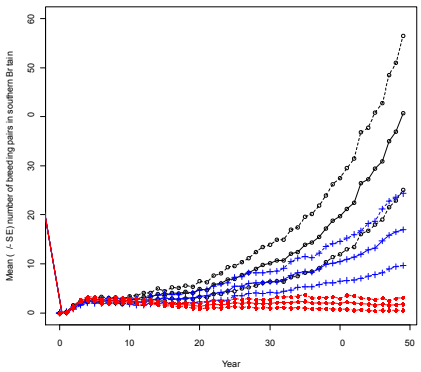
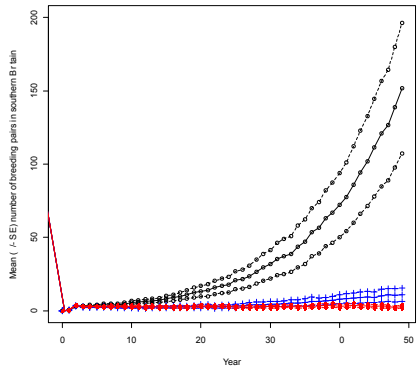
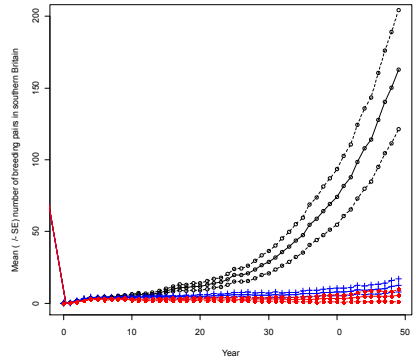
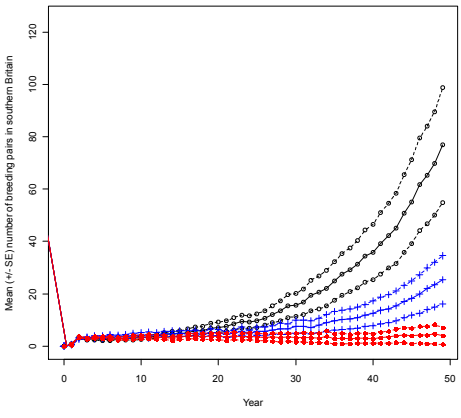
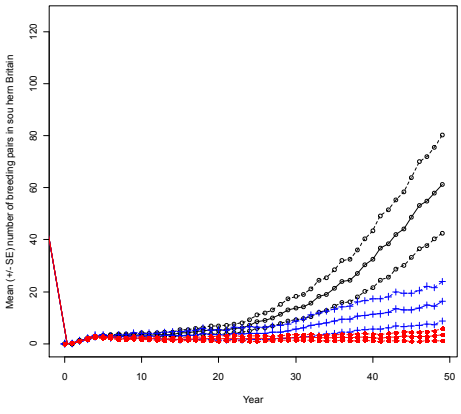
Habitat (%)	30 birds released in first year	10 birds released in each of the first 3 years
1.0		
10.0		
25.0		

Figure 5.2.3: The mean (± standard error) number of territorial birds, averaged across twenty replicate simulations, following the reintroduction of 30 juvenile hen harriers in Exmoor. Two different reintroduction scenarios were explored: either the hen harrier population was initialised with 30 birds in Exmoor (left) or with 10 birds per year for three years. Three different threshold values for the minimum percentage of heath were explored: 1.0% (top), 10.0% (middle) and 25.0% (bottom). Three different values for the mean fledged brood size were explored: 1.9 (red, solid circles), 2.1 (blue crosses) and 2.4 (black, open circles).

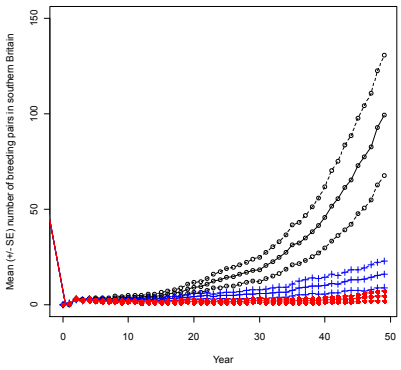
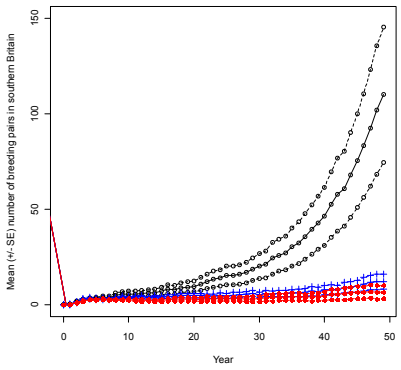
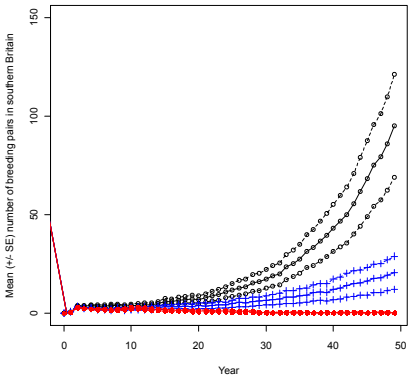
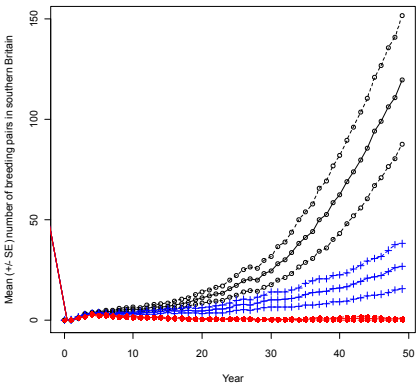
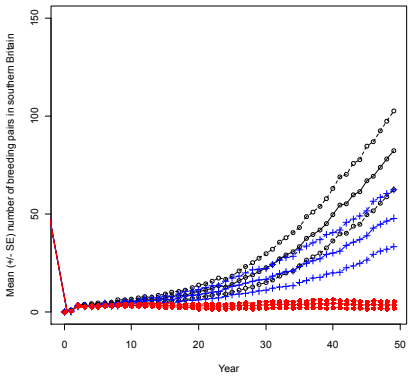
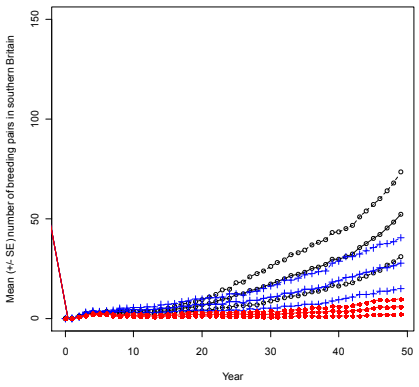
Habitat (%)	*30 birds released in first year*	*10 birds released in each of the first 3 years*
1.0		
10.0		
25.0		

Figure 5.2.4: The mean (± standard error) number of territorial birds, averaged across twenty replicate simulations, following the reintroduction of 30 juvenile hen harriers in Dartmoor. Two different reintroduction scenarios were explored: either the hen harrier population was initialised with 30 birds in Dartmoor (left) or with 10 birds per year for three years. Three different threshold values for the minimum percentage of heath were explored: 1.0% (top), 10.0% (middle) and 25.0% (bottom). Three different values for the mean fledged brood size were explored: 1.9 (red, solid circles), 2.1 (blue crosses) and 2.4 (black, open circles).

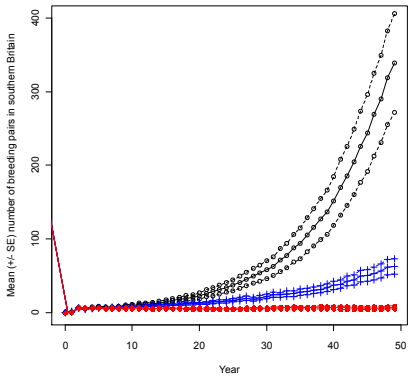
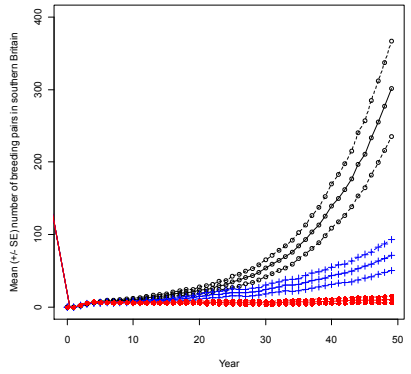
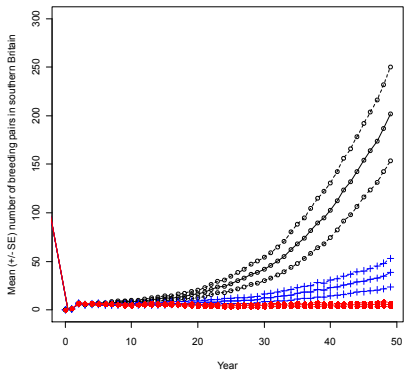
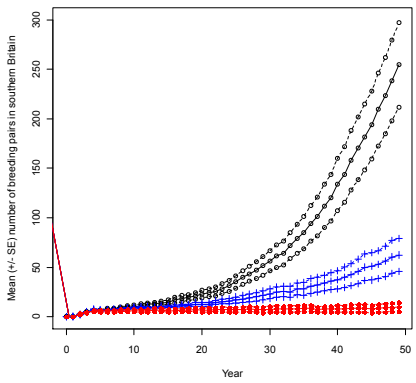
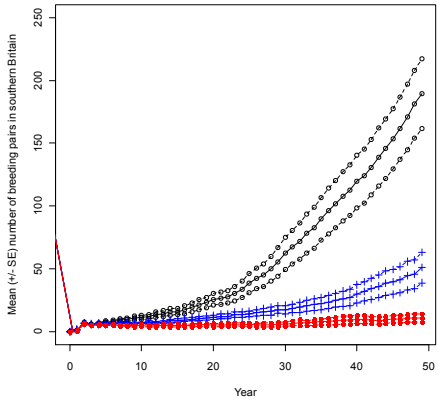
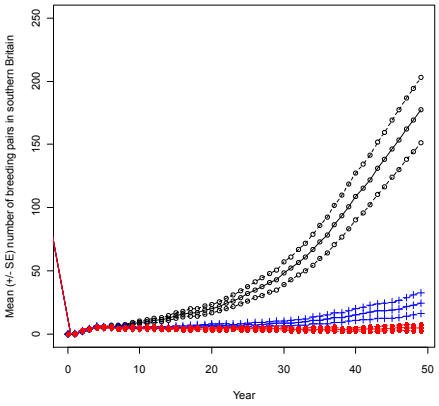
Habitat (%)	30 birds released in first year	10 birds released in each of the first 3 years
1.0		
10.0		
25.0		

Figure 5.2.5: The mean (± standard error) number of territorial birds, averaged across twenty replicate simulations, following the reintroduction of 30 juvenile hen harriers in Dartmoor & Exmoor. Two different reintroduction scenarios were explored: either the hen harrier population was initialised with 30 birds (left) or with 10 birds per year for three years. Three different threshold values for the minimum percentage of heath were explored: 1.0% (top), 10.0% (middle) and 25.0% (bottom). Three different values for the mean fledged brood size were explored: 1.9 (red, solid circles), 2.1 (blue crosses) and 2.4 (black, open circles).

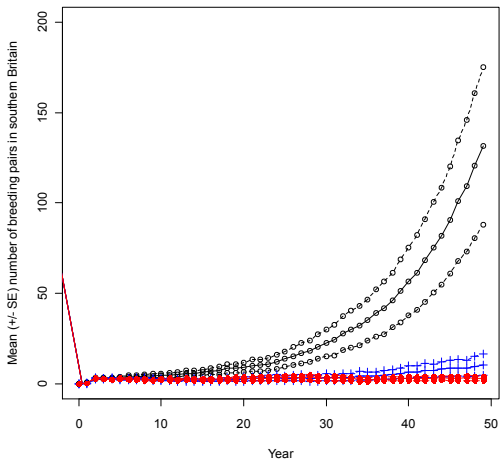
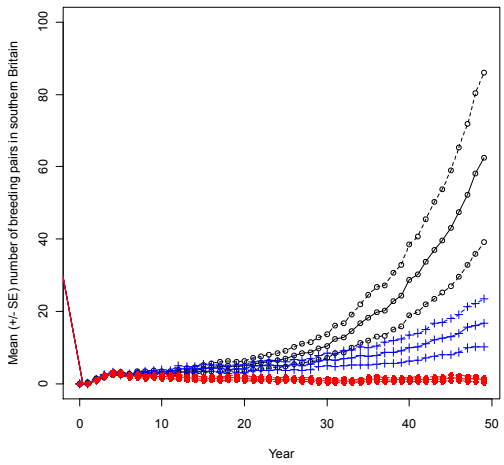
30 birds released in first year	10 birds released in each of the first 3 years
	

Figure 5.2.6: The mean (± standard error) number of territorial birds, averaged across twenty replicate simulations, following the reintroduction of 30 juvenile hen harriers in Wiltshire. Two different reintroduction scenarios were explored: either the hen harrier population was initialised with 30 birds (left) or with 10 birds per year for three years. Three different threshold values for the minimum percentage of heath were explored: 1.0% (top), 10.0% (middle) and 25.0% (bottom). Three different values for the mean fledged brood size were explored: 1.9 (red, solid circles), 2.1 (blue crosses) and 2.4 (black, open circles).

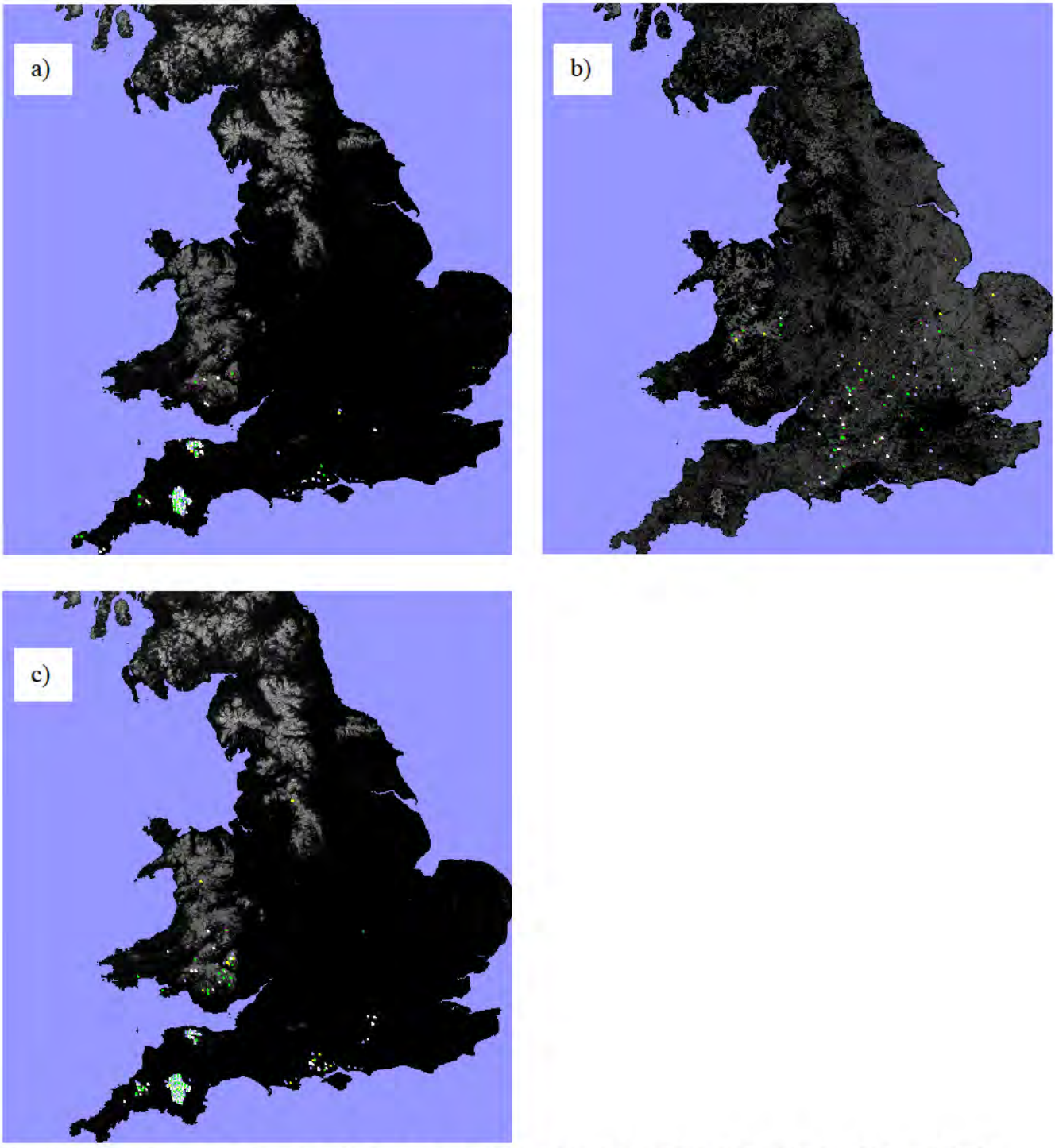


Figure 5.2.7: Examples of maps of single simulations, showing spread of harrier population after 50 years. The colour-coding of the squares, representing individuals, is as follows: yellow: non-breeding; white: breeder; light blue: failed breeder; green: natural death. a) Dartmoor release with breeding success of 2.4, habitat of <1% heath, 30 birds released in year 1. After 50 years, the spring population size was 629 adults. b) Wiltshire crop breeders with breeding success of 2.4 and 30 birds released in year 1. After 50 years, the spring population was 214 adults. c) Dartmoor and Exmoor release with breeding success of 2.4, habitat of <1% heath, 30 birds released in each area in year 1. After 50 years, the spring population size was 1303 adults.

Part VI: Assessing the impact of a hen harrier reintroduction

6.1 Assessment of the potential effect on native fauna

6.1.1 Overview

In the following section we assess the potential impact of hen harriers on the native fauna in the potential release sites. This includes a review of existing literature on the composition of hen harrier diet in different areas of Europe. Secondly, we will assess if any of these prey items are protected in Special Protection Areas (SPAs) around the potential release sites, before we evaluate the occurrence of wild native and non-native game in Southern England and the potential impact of hen harrier on t hose. Finally, we will suggest mitigation measures to reduce the potential effect of hen harriers on wild game. A suitable release site would neither have wild game nor be a SPA for a prey item of the hen harrier.

6.1.2 Composition of hen harrier diet

Hen harriers are quite generalist birds of prey (see Part I, Table 7.1.1 & 7.1.2; Appendix III), foraging mainly on small mammals, lagomorphs and birds but rarely also on reptiles, insects and other taxa. The actual composition of hen harrier diet depends both on temporal and spatial variation in prey availability (e.g. Clarke *et al*. 1993; Redpath *et al*. 2002; Redpath & Thirgood 1999). Of mammalian prey, small mammals are most often the dominant prey items but in some studies lagomorphs were eaten more frequently than small mammals (Table 7.1.2). Bird prey items involve mainly passerine species. Of those, skylarks or meadow pipits by themselves can contribute up to 62 % of the hen harrier diet by number (Table 7.1.2; Redpath & Thirgood 1997). Other, non passerine, birds only make up small proportions of the total hen harrier prey items. Finally, game can make up quite a substantial proportion of the diet (Table 7.1.2, but see e.g. Clarke *et al*. 1997; Millon *et al*. 2002). Where there is not much game available we can expect that hen harriers would shift more to other prey items. From the diet composition reported in the literature we could expect that a translocation could impact locally on skylark and meadow pipit populations (Amar *et al*. 2008b), whilst impacts on other prey are less likely.

Hardly any studies have assessed the actual influence of the presence of the hen harrier on the native fauna. Exceptions are a study conducted by Amar *et al*. (2008b) over a period of 8 years

and a study by Baines *et al*. (2008). Both studies found that an increased population of hen harriers and other birds of prey was followed by a dramatic decline in meadow pipit and skylark abundance in comparison to control sites. The populations of meadow pipits and skylarks decreased by about 34 % and 40 %, respectively. Abundance of other prey species was less clearly related to changes in raptor numbers: golden plovers, *Pluvialis apricaria*, declined, while lapwings, *Vanellus vanellus*, and curlews, *Numenius arquata*, increased in numbers (Amar *et al*. 2008b).

Table 6.1.1: Species list of hen harrier prey items recorded in the literature. List compiled from Picozzi (1978), (1980); Clarke *et al*. (1997); Redpath & Thirgood (1997); Millon *et al*. (2002).

Species	Species	Species
Adder	Great tit	Reed bunting
Black grouse	Greenfinch	Rook
Black headed gull	Green grasshopper	Sedge warbler
Blackbird	Lapwing	Skylark
Blue tit	Linnet	Snipe
Brown hare	Meadow pipit	Songthrush
Brown rat	Merlin	Starling
Chaffinch	Mistle thrush	Stonechat
Common lizard	Mole	Twite
Common sandpiper	Mountain hare	Water vole
Common shrew	Orkney vole	Wheatear
Common vole	Oystercatcher	Willow warbler
Cuckoo	Partridge	Winchat
Curlew	Pheasant	Wood mouse
Dartford warbler	Pied wagtail	Wood pigeon
Dunnock	Quail	Wren
Feral pigeon	Rabbit	Yellow wagtail
Field vole	Red grouse	
Golden plover	Redshank	

Table 6.1.2: Relative frequencies of prey items in the diet of hen harriers in different countries, habitats and seasons. (For more details see Appendix III).

Study	Birds	of those birds					Small mammal	Lagomorph	Other/UID
		Game	SL	MP	Pass	NonPass			
1	0.76	0.05	0.21	0.01	0.46	0.04	0.12	0.1	0.018
2	0.35	0.02						0.53	0.12
3	0.18	0					0.81		0.01
4	0.55	0.03					0.27	0.18	0
5	0.04	0					0.96	0.002	0.003
6	0.28	0					0.03		0.69
7	0.44	0.05					0.05		0.51
8	0.6	0.02					0.29	0.077	0.03
9							0.9		
10	0.65	0.04					0.15	0.12	0.08
11	0.67	0.02					0.26	0.07	
12	0.46						0.16	0.33	0.04
13	0.34	0.03	0.07		0.24		0.63	0.01	0.001
14	0.68	0.28	0.04	0.25	0.07	0.03	0.12	0.05	0.15
15	0.28	0.28			0.07			0.03	0.69
16	0.79	0.12	0.05	0.44	0.14	0.03	0.11	0.02	0.08
17	0.9	0.17	0.07	0.62	0.02	0.02	0.08	0.01	0
18	0.48	0.07	0.02	0.1	0.2	0.09	0.05	0.47	
19	0.86	0.34	0.01	0.45	0.03	0.03	0.02	0.11	0.001
20	0.37				0.37		0.37	0.1	
21	0.82	0.15			0.67		0	0	
21	0.81	0.35			0.46		0.03	0	
21	0.53				0.53		0.05	0.18	
22	0.76	0.29			0.47		0.21	0.01	

Ref (Reference): 1, Clarke *et al*. (1997); 2, Tombal (1982); 3, Robert & Royer (1984); 4, Clarke & Tombal (1989); 5, Chartier (1991); 6, Delcourt (1977); 7, Robert & Royer (1984); 8, Farcy (1994); 9, Maurel (1995); 10, Nore (1979); 11, Grafeuille (1983-1984); 12, Garcia & Arroyo (2005); 13, Millon *et al*. (2002); 14, Redpath (1991); 15, Redpath (1992); 16, Redpath & Thirgood (1999); 17, Redpath & Thirgood (1997); 18, Picozzi (1978); 19, Picozzi (1980); 20, Balfour & Macdonald (1970); 21, Watson (1977); 22, Schipper (1973); [a]from Bro *et al*. (2006); [b]from Redpath (1991); MP: meadow pipit; NonPass: non passerine bird; Other/UID: other items, unidentified prey item or not specified; Pass: passerine bird; SL: skylark;

6.1.3 Special Protection Areas (SPA)

Releasing harriers onto SPAs may lead to conflicts over the management of other designated species. Figure 7.1.1 shows the distribution of SPAs in the UK with special focus on SPAs in the South West. Of the SPAs in the South West there are five within the broader area we surveyed which may be of interest from a hen harrier perspective (Figure 7.1.1). East Devon Heaths, New Forest and Dorset Heathlands are SPAs for the Dartford warbler, *Sylvia undata,* and the nightjar, *Caprimulgus europaeus,* and New Forest and Dorset Heathlands are also protected areas for the woodlark, *Lullula arborea*. Of those species only the Dartford warbler has previously been recorded as a hen harrier prey item (Table 7.1.2). The Dartford warbler made up to 30 % of the total hen harrier prey in a study of wintering birds by Clarke *et al*. (1997). Both Porton Down and Salisbury Plain are protected areas for the stone curlew (Figure 7.1.1). It is possible that nightjar, woodlark and stone curlew may occasionally turn up in the diet of this generalist predator, but it seems unlikely that any predation would be to the extent that it would have an impact on their populations.

Taken together, Dartmoor and Exmoor with no SPAs for any potential harrier prey seem most suitable for a hen harrier translocation. More caution would have to be taken with a release on the Dorset Heathlands or near Salisbury Plain.

A 7.5

A 7.4

Figure 6.1.1: Distribution of SPAs in the UK and detailed maps of Special Protection Areas (SPAs) in the South of England (Source: http://www.jncc.gov.uk/page-2598). Special Protection Areas: protected species/areas of potential interest for hen harrier translocation. **Area No. 5 (in A7.4): East Devon Heath:** Dartford warbler, *Sylvia undata*; Nightjar, *Caprimulgus europaeus;* **Area No. 7 (in A7.5): Dorset Heathland:** Dartford warbler, *Sylvia undata*; Nightjar, *Caprimulgus europaeus*; Woodlark, *Lullula arborea*; Over-wintering: Hen harrier (20 individuals); Merlin, *Falco columbarius*; **Area No. 13: New Forest:** Dartford warbler, *Sylvia undata*; Nightjar, *Caprimulgus europaeus*; Honey Buzzard, *Pernis apivorus*; Woodlark, *Lullula arborea*; Over-wintering: Hen harrier (15 individuals); **Area No. 14: Porton Down:** Stone curlew, *Burhinus oedicnemus;* **Area No. 24: Salisbury Plain:** Stone curlew, *Burhinus oedicnemus;* Over-wintering: Hen harrier (14 individuals).

6.2 Game birds in southern England

6.2.1 Scale and distribution of shooting

Game bird shooting occurs across the whole of the UK (PACEC 2006). In 2004, 15 M pheasants and 2.6 M partridges were shot in the UK. In South West England there are about 10,000 providers of sport shooting and approximately 110,000 guns (PACEC 2006). In the South West UK there are three main species of game birds on which hen harriers may prey: pheasant, grey partridge and red-legged partridge. The vast majority of shot birds are reared and released during July and August. GWCT estimate approximately 6 M red-legged partridges and 35 M pheasants are released per year across the whole country. Grey partridge *Perdix perdix* declined dramatically during the 20th century and are now the focus of a Biodiversity Action Plan to maintain and restore numbers. Its population in 2009 was estimated at approximately 72,500 pairs (GWCT 2009).

Distribution maps produced by the British Trust for Ornithology clearly indicate that south west England is not a stronghold for any of these species (Gibbons *et al*. 1993).

6.2.2 Potential impact of hen harriers on game birds

There are two relevant studies that have considered the impact of hen harriers on game birds: the work by Redpath and Thirgood *et al*. (1997, 1999, 2000a, b, 2008) on harriers and grouse and the work by Bro and colleagues (2006) on harriers and grey partridge. The long-term studies on grouse found that when harriers attained high breeding densities, there was convincing evidence that their predation limited the grouse population and reduced shooting bags (Thirgood *et al*. 2000b, 2000c). In France, partridges figure occasionally in the diet of hen harriers (< 3.2 % by number). Despite this relatively small proportion, Bro *et al*. (2006) suggested that harrier predation may have an impact on wild partridge populations in certain areas, although there was only limited evidence to back up his conclusion.

These studies, taken together, suggest that hen harriers have the potential to have an impact on wild game bird populations. The primary impact appears to be through predation of adults during the spring and on chicks in the summer. Conflicts may therefore arise where high densities of breeding harriers overlap with areas where shooting of wild grey partridge or released red-legged partridge or pheasant takes place. Released populations are likely to be at lower risk, as birds are normally released in late summer, after the harrier breeding season. This is not to say

that harriers will not take released birds. Indeed, there is some evidence that dispersing harriers at the end of summer may spend time hunting around gamebird release pens (unpubl. data from Natural England"s Hen Harrier Recovery Project). However, such predation is likely to be relatively small and could be compensated for through a slight increase in the numbers of gamebirds released.

6.2.3 Mitigation to reduce potential impact on game birds

As part of the consultation plan, it will be necessary to ascertain the number of game bird shoots in the region and in particular the number of wild game bird shoots. Where possible, a precautionary approach should be adopted and hen harrier release sites, where birds are likely to be concentrated at least in the short term, should avoid wild shoots. In situations where a successful translocation leads to harriers moving into areas with wild partridge, predation could be reduced through the use of diversionary feeding (Redpath *et al*. 2001b). Where predation is occurring around release sites, there may be ways to mitigate their impact through the management of vegetation and site location as is currently advised for mitigating the impacts of other birds of prey (e.g. Kenward *et al*. 2001).

6.3 Socio-economic impact assessment

6.3.1 Effect of nature conservation

Recently, organisations have started assessing the impact of nature conservation on local economics and vice versa in the UK (e.g. Shiel *et al*. 2002). Understanding such relationships is important for the sustainable management of nature conservation such as the reintroduction of a bird of prey species. A translocation of hen harriers would be a substantial conservation program to restore and recreate biodiversity, likely to result in wide-ranging benefits to both nature and the local community in different ways as outlined below. Especially charismatic species, e.g. rare birds of prey, have previously been shown to have beneficial impacts on local areas (see below).

6.3.2 Tourism & the local economy

Nature conservation benefits rural economies. Recently, there has been a major growth in conservation related activities which supports employment and substantially contributes to the local economy in several ways: staff employed directly to work in the conservation sector;

expenditures by conservation organisations profit local suppliers and businesses; and visitors, attracted by wildlife, spend money in the area.

6.3.3 Direct employment

Direct employment in conservation activities can be significant as shown in recent surveys (for details see the Report of the UK Raptor Working Group 2000; Shiel *et al*. 2002): In the UK there are an estimated 15,000-18,000 full time equivalent (FTE) jobs in nature and landscape conservation. RSPB reserves on their own support more than 1000 FTE jobs in local economies across the UK (Shiel *et al*. 2002); and heathland management in Dorset provides 38 FTE jobs (Rayment 1997). Direct employment involves site management such as species protection, surveys and monitoring, and visitor services. In the case of a hen harrier translocation programme staff would be employed to monitor released individuals and to provide protection and management advice in the longer term in order to increase the chance of a self-sustaining population becoming established.

6.3.4 Expenditure by conservation organisations

In addition to direct employment, expenditure by conservation organisations benefits the local economy and further supports indirectly employment. About £500 million are spent every year in England and Wales for conservation activities (Shiel *et al*. 2002).

6.3.5 Tourism

Visitors to nature reserves and other areas of conservation interest support the local economy and often result in more jobs than provided in the conservation sector directly. For instance, RSPB reserves in the UK have about 1.2 million visitors per year, which spend about £19 million annually (Shiel *et al*. 2002). On Orkney, for example, the RSPB estimates that visitors spent £1.3 million to see wildlife, resulting in 36 FTE jobs in this sector (Rayment & Dickie 2001). Annual amounts spent by tourists in the Dartmoor and Exmoor National Park are around £120 million and £70-80 million respectively (see Figure 34.).

Eco-tourism to provide people with opportunities to view reintroduced hen harriers could provide economic benefits to areas around release sites. Such direct economic benefits associated with

increases in visitor numbers to areas with reintroduced, charismatic species have repeatedly been reported in previous release programmes. As part of a reintroduction scheme for bearded vultures *Gypaetus barbatus* in southern Spain a thematic visitor centre attracted more than 50,000 visitors in its first year of opening (Simon *et al*. 2007). Furthermore, reintroduced white-tailed eagles *Haliaeetus albicilla* on Mull bring in about £2 million each year to the local economy and attract about 6,000 visitors annually to an eagle hide (Forestry Commission, 2010). Red kites *Milvus milvus* on the Scottish Black Isle attract tourists spending about £120,000 annually, which supports 3 FTE jobss (Rayment & Dickie 2001). An estimated £55,000 was spent by visitors to the Symond"s Yat Peregrine Project in 1999 alone (Rayment & Dickie 2001).

While tourism benefits the local economy, it can also have negative impacts on biodiversity, for instance through pollution or by damaging the landscape or biodiversity, either directly or through disturbance, if not managed sustainably. If high number of visitors wish to observe reintroduced hen harriers they may deliberately or accidentally disturb the birds and reduce breeding success. Increased numbers of visitors to areas of heathland may damage sensitive habitats. The potential negative effects of high tourism caused by a desire to view hen harriers are discussed further in Part IV of this report.

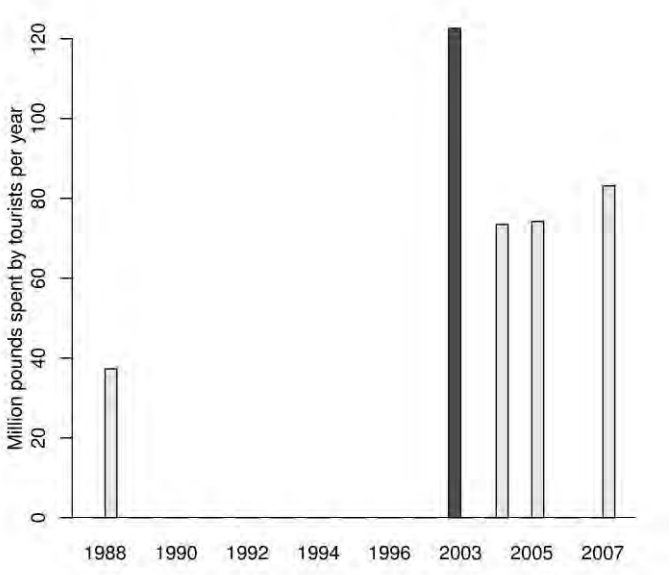


Figure 6.3.1: Spending of tourists (in million pounds per year) in Dartmoor (black) and Exmoor (grey) National Park. Data sources: Dartmoor: Dartmoor National Park State of the Park Report 2008; Exmoor: Exmoor National Park Authorities personal communication; Exmoor National Park Management Plan 2007 to 2012.

6.3.6 Game birds

The main potential cost of releasing hen harriers into South West England is through its impact on game bird shooting. As discussed above, impacts on game populations are considered most likely where high densities of hen harriers are breeding in the vicinity of wild game populations.

Sport shooting creates large economic benefits and supports approximately 12,000 jobs in the South West (PACEC 2006). However, it is unclear how many wild game bird shoots there are in this part of the country, or indeed how many of those occur in the vicinity of potential nesting habitat. Given that harriers can, under certain conditions, have an impact on game bird populations (see above), we might expect an economic impact in areas where high densities of breeding harriers coincide with areas where wild game bird shooting forms an important economic activity. As 91 % of partridge and pheasant shooting is of released birds and the South West is not a stronghold for any of the three species, it seems unlikely that harriers will have a significant economic impact in the region. However, some assessment is necessary of wild game bird shooting around potential release sites.

Released game bird shoots may also suffer some predation and disturbance during the shooting season as well as earlier in the year. This is most likely to occur at a time when harriers are dispersing, post-breeding. This predation and disturbance may lead to some loss of earnings, but estimates of potential loss are not available.

As part of any release programme it may be sensible to attempt to gain the support of local shoots near release sites, and of regional/national shooting organisations , to minimise conflict and work with shoots to quantify losses and impact of released harriers on wild game birds and income.

PART VII: Risk Assessment and Site Ranking

Table 7.1: Potential hazards of a hen harrier re-introduction to different regions in the Southwest of England. Score A is the likelihood of exposure, i.e. an index of the probability of suffering the hazard in each site (5 levels: low, low-moderate, moderate, moderate-high, high). Score B is the severity of an effect if exposure happened (3 levels: low, moderate, high). Risk is then calculated as the severity index multiplied by the exposure probability index. Mitigation measures are then identified, via which the probability of exposure to each hazard can be reduced. The feasibility of these mitigation measures is identified for each site. This allows calculation of an adjusted exposure (Adjusted A), and therefore an adjusted risk. Adjusted risks are then totalled across hazards, for each site. Sites with lower total adjusted risk scores are considered better candidates for translocation. **Exmoor has the lowest total adjusted risk score (79), followed closely by arable Wiltshire (80) then Dartmoor (92).**

Hazard	Location	Score A		Score B		Risk A*B	Mitigation	Feasibility	Adjusted A	Adjusted Risk	Comment
Insufficient food	Exmoor	L-M	2	H	3	6	Longterm: HLS, habitat management	possible	1	3	a
	Dartmoor	M	3	H	3	9	Longterm: HLS, habitat management	possible	2	6	
	Wiltshire	M-H	4	H	3	12	Longterm: HLS, habitat management	greater potential for habitat improvement in arable	2	6	b
Exposure to predation	Exmoor	H	5	H	3	15	Fencing	easiest	1	3	c
	Dartmoor	H	5	H	3	15	Fencing	more difficult	1	3	
	Wiltshire	M	3	H	3	9	Fencing	difficult	1	3	
Predator abundance	Exmoor	M?	3	H	3	9	Shooting	possible	2	6	d
	Dartmoor	M?	3	H	3	9	Shooting	possible	2	6	
	Wiltshire	H	5	H	3	15	Shooting	easiest	3	9	
Persecution basic	Exmoor	M	3	M	2	6	Stakeholder engagement	easier	2	4	
	Dartmoor	M	3	M	2	6	Stakeholder engagement	easier	2	4	
	Wiltshire	M	3	M	2	6	Stakeholder engagement	possible	2	4	
Persecution-	Exmoor	L	1	H	3	3	Guarding	possible	1	3	

important to bird population	Dartmoor	L	1	H	3	3	Guarding	possible	1	3	
	Wiltshire	L	1	H	3	3	Guarding	possible	1	3	
Disturbance (important?)	Exmoor	M-H	4	M	2	8	Guarding & information	easier	2	4	
	Dartmoor	H	5	M	2	10	Guarding & information	easier	3	6	
	Wiltshire	L	1	M	2	2	Guarding & information	difficult	1	2	
Limited nesting habitat (establishment)	Exmoor	M	3	H	3	9	not possible in short term	N/A	3	9	e
	Dartmoor	H	5	H	3	15	not possible in short term	N/A	5	15	
	Wiltshire	L	1	H	3	3	not possible in short term	N/A	1	3	f
Limited nesting habitat (long term)	Exmoor	H	5	H	3	15	Habitat management	easiest	2	6	
	Dartmoor	H	5	H	3	15	Habitat management	easier	3	9	
	Wiltshire	L	1	H	3	3	Habitat management	difficult	1	3	
Poor nesting habitat quality	Exmoor	M	3	M	2	6	Habitat management (e.g. less grazing)	possible	1	2	
	Dartmoor	M-H	4	M	2	8	Habitat management (e.g. less grazing)	possible	2	4	h
	Wiltshire	M	3	M	2	6	Habitat management	difficult	2	4	g
Disease	Exmoor	L	1	H	3	3	Vaccinations, health-check pre-release	easy	1	3	
	Dartmoor	L	1	H	3	3	Vaccinations, health-check pre-release	easy	1	3	
	Wiltshire	L	1	H	3	3	Vaccinations, health-check pre-release	easy	1	3	
Limited hunting habitat (extent) (establishment)	Exmoor	L	1	H	3	3	Habitat management	difficult short term	1	3	
	Dartmoor	L	1	H	3	3	Habitat management	difficult short term	1	3	
	Wiltshire	L	1	H	3	3	Habitat management; stewardship	difficult short term	1	3	
Limited hunting habitat (extent) (long term)	Exmoor	H	5	H	3	15	Habitat management	possible	2	6	
	Dartmoor	M	3	H	3	9	Habitat management	possible	1	3	
	Wiltshire	L	1	H	3	3	Habitat management; stewardship	more difficult	1	3	
Limited hunting habitat (quality)	Exmoor	M	3	M	2	6	Habitat management	possible	1	2	
	Dartmoor	M	3	M	2	6	Habitat management	possible	1	2	
	Wiltshire	M	3	M	2	6	Habitat management; stewardship	more difficult	2	4	
Hunting habitat	Exmoor	M-H	4	M	2	8	Habitat management (create a mosaic)	possible	2	4	

linkage (i.e. lack of availability to breeding birds)	Dartmoor	M	3	M	2	6	Habitat management (create a mosaic)	possible	2	4	
	Wiltshire	L-M	2	M	2	4	Habitat management (create a mosaic)	possible	1	2	
Conflict (stakeholder opposition: national)	Exmoor	L	1	M	2	2	Environment Council, compensation	possible	1	2	
	Dartmoor	L	1	M	2	2	Environment Council, compensation	possible	1	2	
	Wiltshire	M-H	4	M	2	8	Environment Council, compensation	possible	3	6	
Conflict (stakeholder opposition: local)	Exmoor	M-H	4	M	2	8	Information, engagement	possible	2	4	
	Dartmoor	M	3	M	2	6	Information, engagement	possible	1	2	
	Wiltshire	M	3	M	2	6	Information, engagement	possible	1	2	
Landowner withdraws/lack of cooperation	Exmoor	L	1	H	3	3	Payment? Choice of landowner	possible	1	3	
	Dartmoor	L-M?	2	H	3	6	Payment? Choice of landowner	possible	1	3	
	Wiltshire	M?	3	H	3	9	Payment? Choice of landowner	possible	2	6	
Need for sustained intervention (establishment)	Exmoor	M-H	4	M	2	8	Site selection, planning, HLS	possible	2	4	h
	Dartmoor	M-H	4	M	2	8	Site selection, planning, HLS	possible	2	4	h
	Wiltshire	H	5	M	2	10	Site selection, planning, HLS	possible	3	6	i
Need for sustained intervention (longterm)	Exmoor	H	5	M	2	10	Site selection, planning, HLS	possible	2	4	j
	Dartmoor	H	5	M	2	10	Site selection, planning, HLS	possible	2	4	j
	Wiltshire	L	1	M	2	2	Site selection, planning, HLS	possible	1	2	
Poor choice of provenance	Exmoor	L	1	M	2	2	Pre-planning	Possible: likely Scotland	1	2	
	Dartmoor	L	1	M	2	2	Pre-planning	Possible: likely Scotland	1	2	
	Wiltshire	M	3	M	2	6	Pre-planning	Possible: likely continental	2	4	
Project difficult to manage on-ground	Exmoor	L-M	2	M	2	4	Site selection, project resources, pre-planning	possible	1	2	
	Dartmoor	M-H	4	M	2	8	Site selection, project resources, pre-planning	possible	2	4	k
	Wiltshire	L	1	M	2	2	Site selection, project resources, pre-planning	possible	1	2	

a. HLS: Higher Level Stewardship

b. lowest densities of passerines and small mammals. Concerns due to low numbers of small mammals. BUT there are Montagu"s harriers in the region and the hen harrier has bred in the area.

c. could check data on p(brood survives)~habitat (this would be exposure for this and next row combined)
d. requires further study
e. require more detailed information on heather cover
f. difficult to source figures on arable habitat coverage. Also consider field sizes and boundaries…do they only nest in BIG fields?
g. depends on species, seasonal sowing and height
h. depends on predation risk by foxes
i. depends on risks associated with foxes and timing of cropping
j. possibility of low density harrier population caused by habitat limitation
k. high if site chosen is central/western Dartmoor

PART VIII: Consultation

7.1 Consultation events to gauge public opinion at favoured site(s)

The attitude of the public towards the hen harrier is expected to have a huge impact on the success of a potential translocation to South West England. Therefore, meetings would be required at the national, regional and local level in order to engage with all key stakeholders and other interested parties, including local community representatives. Such meetings would seek to discuss the nature of a proposed translocation scheme and take into account any reservations that might be expressed about potential impacts. A number of reviews have stressed the importance of involving local stakeholders in conservation management proposals; see, for example, Redpath *et al*. (2004), Sarewitz (2004) or Marshall *et al*. (2007).

The aim of this process of engagement is to:

- Enable stakeholders to input, comment upon and generally influence the translocation scheme
- Create a common vision, priority and purpose, built upon goodwill and common interest for translocation
- Disseminate/Increase public awareness of hen harrier issues locally and nationally

The process would be expected to include the following aspects:

- Identification of potential release sites in South West England, focussing primarily on Exmoor and Wiltshire based on the recommendations of this report
- Identification of the main stakeholder groups nationally, regionally and locally including (a) shooting groups, (b) conservation groups and (c) local farmers and landowners
- Development of key questions that are likely to arise during the consultation process and preparatory work so that these can be adequately addressed based on the best available knowledge. The review work undertaken for this report will provide a useful starting point for this work

- Resources to help inform the consultation process including posters, display panels and information sheets
- An opinion survey/questionnaire to help clearly assess public attitudes in the local community towards a translocation proposal

Full details, logistics and a timescale for consultation work would need to be developed further if a decision is taken to proceed with plans for a hen harrier reintroduction in South West England. The nature of a reintroduction proposal and the final decision on whether to proceed would, of course, be influenced by the consultation process.

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