The breeding ecology of the Merlin (*Falco columbarius aesalon*), with particular reference to north-east Scotland and land-use change

Thesis

The breeding ecology of the Merlin *(Falco columbarius aesalon)*, with particular reference to north-east Scotland and land-use change

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CONTAINS

PULLOUTS

Dedication

For my mum and dad, who always supported my interest in wildlife and nature study, and my many other hobbies and passions - I miss them badly. In particular, I acknowledge the wisdom of my mum, as when I was a carefree schoolboy, she banned me from collecting any more wild flowers and birds' nests and eggs, at the same time as encouraging me to pursue my interest in ornithology! She was very pleased that I ended up working for the Royal Society for the Protection of Birds.

Declarations

I composed this thesis and declare that no part of it has been submitted to any other university for a higher degree or diploma. All sources of information and collaboration are acknowledged; either by direct reference, quotation marks or *personal communications* in the text, or as listed in the general acknowledgements and acknowledgements in the published appendices. Other than the assistance and collaborations described, I carried out all the work and research presented in the thesis.

During the course of the study, the Merlin was a Schedule 1 species in Britain under the Wildlife and Countryside Act 1981. This meant that licences were required for nest visits, and for photography and ringing of young and adults at the nest. All visits and photography at nests, and ringing of young Merlin by myself were carried out under cover of the appropriate licences, which were issued and administered by the Nature Conservancy Council or Scottish Natural Heritage.

Abstract

The breeding population of the Merlin in Britain in 1993 and 1994 was estimated at 1300 ± 200 pairs following a survey of around 60% of the range and calculated extrapolation of the remaining suitable habitat. This reflected a recovery, following widespread declines in numbers and range earlier in the 20th century. Over 1000 nest records from the survey were analysed, with habitat and nest site described and quantified, and related to clutch size, successful brood size and productivity. Heather moor or mixed grass-heather moor, and tall conifer plantations were the main core habitats at 88% and 9% of territories respectively. Habitat choice influenced nest site, with 77% of nests on the ground, 2% on crags and 19% in trees. Productivity averaged 2.25 fledged young per pair and was indicative of a stable or increasing population.

In north-east Scotland, part of a delimited Merlin study area was afforested with conifers, providing an opportunity to monitor the effects of this land-use change on Merlin breeding ecology. One of the forestry schemes led to public outcry, official objections, Government assessment, Judicial Review and an appeal to the European Commission. These events were unprecedented in British forestry history and were seen as a test-case. Despite modifications to the scheme, by leaving approximately 30% of land unplanted, the Merlins declined to zero, as they also did at the other afforested areas.

Breeding phenology and clutch size at the afforested areas were similar to comparable adjacent and further afield Merlin study areas, where there was minimal change in habitat management. However, productivity was significantly less and it was concluded that commercially afforested moorland was an inappropriate breeding habitat for Merlin in north-east Scotland. Identifying and quantifying prey remains assessed breeding season diet, with small birds accounting for 95% of numbers and 99% of biomass from 11,225 items. It is reasoned that the majority of the new potential prey resource associated with commercial afforestation was unavailable for Merlin, due to the protection provided by dense thicket plantations.

Guidelines for retaining breeding Merlin within commercial forestry schemes in Britain are recommended. These could be requested by conservation planners, adopted by foresters or tested by raptor ecologists, and their use could be a condition within new grant-aided forestry schemes in Britain.

General acknowledgements

The Royal Society for the Protection of Birds (RSPB) was the lead organisation responsible for organising the British Merlin breeding survey in 1993 and 1994. I thank Rhys Green and Ian Bainbridge, the former and then head of Research respectively at the RSPB in Scotland for accepting that additional data should be collected on breeding biology during the survey fieldwork and for agreeing that it could be used in my thesis (Chapter 2.1). The relevant people involved were fully acknowledged in the Merlin breeding survey publication (Appendix 6) and in Chapter 2.1. I thank the following for further information on Merlin regional status and/or nest site selection: Pete Ellis, Eric Meek, Jim Craib, Norrie Russell, Brian Cosnette, Ron Downing, Wendy Mattingley, Alan Heavisides, Roger Broad, Dave Anderson, Arthur French, Geoff Shaw, Ricky Gladwell, Ian Miller, Dave Shackelton, Martin Davison, Brian Little, Mike Nattrass, Peter Wright, Wilf Norman, Tim Melling, Sean Reed, Mick Taylor, Rob Townend and Andy Young.

The relevant people involved in the early period of the Merlin study in north-east Scotland were also fully acknowledged in various publications (e.g. as referred to in Chapter 1 and in Appendices 7 to 9) and in particular in Rebecca *et al* 1992 and Rebecca 1993. I thank those again who have continued to be involved with breeding Merlin in north-east Scotland, and particularly those who have contributed to the study on Deeside, either through practical field-study, logistical support or logical discussion. These were: Brian Cosnette, Alistair Duncan, Alastair Pout, Graeme Ruthven, Alisdair MacHardey, Eddie Duthie, Rab Rae, Sandy Payne, Claire Geddes, Ken Shaw, Neill Cook, Kevin Peace, Ian Francis, and Alister Clunas, Peter Holden and Shaila Rao of the National Trust for Scotland at Mar Lodge Estate, and the Scottish Natural Heritage (SNH) annual officers on Glen Tanar National Nature Reserve. I also thank many Estate owners and their staff for co-operation with my access requests, in particular: Joylen Amos, John Sharpe, David Edwards and Kenny Graham of Fountain Forestry, the late Peter Gladstone, Charles Gladstone, Frank Sheridan and Archie Dykes of Glen Dye Estate, Angus Farquharson and Jimmy Christie of Finzean Estate, Malcolm Nicol and Victor Clements of Ballogie Estate, Robin Callander as representative for Birse Community Trust, Sandy Payne and Claire Geddes of Crannoch Estate and Simon Blackett, Peter Fraser and John Cruickshanks of

Invercauld Estate. I also thank Aberdeen University for access to specimens held in the Zoology Department Museum, which was essential in identifying Merlin prey remains in the earlier years of the study. Sandy Payne collected most of the prey remains from upper Deeside in 1983 to 1986 and I thank him for making these available. John Knight and Philip Newman offered the reproduction of their wonderful photographs of female Merlin and brood and male Merlin respectively, for which I thank them enormously.

The RSPB sponsored the Open University study through their personal development training programme and gave generous field-study and writing time for which I am most grateful. I also thank my colleagues at the RSPB East Scotland Regional Office in Aberdeen for their advice and support, and in particular to Ken Shaw, former regional manager for East Scotland, for listening to my original proposal and for his enthusiastic response and backing. He was very instrumental in enabling me to expand my knowledge and input into Merlins in north-east Scotland and across Britain. Ken also successfully lobbied within RSPB and SNH circles that the lower Deeside Merlins should be a focal point in the afforestation/Merlin/open-country birds conservation debate in the late 1980s to early 1990s. Ian Francis, my current line manager, and Martin Auld, current regional director for East Scotland, continued to support the Deeside Merlin project after Ken moved on within the RSPB. I thank them for this and for understanding the value of the long-term nature of the study, even if this occasionally competed with other RSPB priorities. My biggest thanks however, at the RSPB Aberdeen office, must go to Sheila Adair, the regional administrator for East Scotland, for her administrative expertise and extreme patience at my initial lack of understanding of databases and all things administratively technical! The writing process of papers, notes, annual reports and this thesis would have been so much more difficult without her support, in particular she typed all the publications and most of the thesis, for which I am most grateful. Ellen Wilson (RSPB data manager) and Anne Porteous (RSPB GIS officer for East Scotland) gave me advice and assistance when I was learning the RSPB GIS mapping system, appropriately called 'Merlin'! and this was much appreciated. Lynne Giddings (RSPB librarian) supplied many of the references, and Mike Wood (RSPB forestry officer) made me aware of some relevant forestry publications, I thank them both for their help. Ian Francis, Innes Sim (RSPB scientific assessor) and Steve

Redpath, my external supervisor, helpfully commented on the methods used, various annual reports and thesis Chapters, which was also very much appreciated.

I owe a considerable debt to Steve Redpath for being my main supervisor and critic. He gave me valuable advice on all aspects of the project, and guided me through the thesis writing with appropriate comments and discussion. He also showed patience with my initial lack of statistical awareness and gave me advice on data analysis and a welcome introduction to biological modelling. The latter tuition will benefit me long after the thesis, such as during the publication process of specific Chapters. Steve also introduced me to David Elston from Biomathematics and Statistics Scotland, who gave me additional crucial advice on the statistical treatment of the data. I thank the Centre for Ecology and Hydrology for authorising Steve to be my external supervisor, for library access and for access to David Elston's advice. I also thank Robin Harding, my internal supervisor at the Open University for his administrative input to the study, for general comments on the thesis, and for his understanding during a difficult period in the writing process following the loss of my mother and father.

I thank again Brian Cosnette, who has been a major part of the Deeside Merlin study since the beginning, and is still enthusiastic about breeding Merlins after 26 years of study. Brian has been a source of encouragement throughout, and our friendly competitiveness in locating new territories and nests has been an inspiration. He has excellent nest finding skills and found many of the territories from which data was gathered for this study. It has been a challenge keeping up with him! Underpinning his tenacity to find new territories and nests, Brian has always made his data available for conservation planning. Our healthy debates with other Merlin enthusiasts at meetings and conferences, have often led to new awareness and study. It has been a pleasure working with Brian, and we have had some great days in the field and some great nights in the pub! The Merlin study in north-east Scotland would not have progressed as far without Brian's commitment and skill, and the RSPB and I owe him a huge thank you.

Finally, I thank my wife Kate and daughter Jill for their support and patience, and for putting up with my many week-ends away, late nights, sometimes strange behaviour and lack of interest in all things 'do-it-yourself' around the house and garden! The latter two chores were things I used to enjoy doing before my Open University registration, and I have a lot of catching up to do!

Drawings

Drawing 1, page 7 : Pair of Merlin at breeding site in Glen Dye, north-east Scotland (by Brian L. Cosnette).
Copyright : Graham W. Rebecca.

Drawing 2, page 99 : Sketches of nestling Merlin of known age (by Keith Brockie).
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Photographs

Photograph 1, page 8 : Female Merlin and young, North York Moors, north-east England.
Copyright : John Knight.

Photograph 2, page 9 : Female Merlin and young, Slug Moor, north-east Scotland.
Copyright : Graham W. Rebecca.

Photograph 3, page 9 : Male Merlin at breeding site in Glen Dye, north-east Scotland.
Copyright : Philip J. Newman.

Photograph 4, page 18 : Almost fully fledged young Merlin, aged 25 or 26 days, lower Deeside, north-east Scotland.
Copyright : Graham W. Rebecca.

Photograph 5, page 20 : View from Merlin breeding area, upper Deeside, north-east Scotland.
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Photograph 6, page 20 : View of Merlin breeding area, lower Deeside, north-east Scotland.
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Photograph 7, page 21 : Merlin nest on crag, upper Deeside, north-east Scotland.
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Photograph 8, page 21 : Merlin brood in old Carrion Crow nest in Birch, Rannoch Moor, Perthshire, central Scotland.
Copyright : Graham W. Rebecca.

Photograph 9, page 22 : Merlin nest on the ground in deep heather on managed grouse moor, mid Deeside, north-east Scotland.

Photograph 10, page 29 : The type of preparatory work done by Fountain Forestry for the afforestation of moorland on lower Deeside between 1980-1989.

Photograph 11, page 74 : Merlin breeding territory number 5 in the Fountain Forestry zone before conifer afforestation.

Photograph 12, page 74 : The same Merlin breeding territory as in photograph 11 after preparation for conifer afforestation.

Abbreviations

The following abbreviations were used after their initial full use in each Chapter.

ANOVA	Analysis of Variance
BoCC	Birds of Conservation Concern
BTO	British Trust for Ornithology
CEH	Centre for Ecology and Hydrology
CI	Confidence Intervals
EA	Environmental Assessment
EC	European Commission
ECo	European Community
FC	Forestry Commission
FEs	Fasque Estates
FF	Fountain Forestry
GDE	Glen Dye Estate
GLM	General Linear Model
IFS	Indicative Forestry Strategies
JNCC	Joint Nature Conservation Committee
LDF	lower Deeside forestry
LDMGM	lower Deeside managed grouse moor
MGM	managed grouse moor
MUDMGM	mid and upper Deeside managed grouse moor
NCC	Nature Conservancy Council
NERC	Natural Environmental Research Council
NESRSG	North-East Scotland Raptor Study Group
NGO	non-government organisation
PIT	passive integrated transponder
PNAB	potential nesting area and buffer
RAC	Regional Advisory Committee
RDB	Red Data Birds
RSPB	Royal Society for the Protection of Birds
SAC	Special Area of Conservation
SPA	Special Protection Area
SNH	Scottish Natural Heritage
SOC	Scottish Ornithologists' Club
SSSI	Site of Special Scientific Interest
SWT	Scottish Wildlife Trust
TRSG	Tayside Raptor Study Group
UK	United Kingdom
USA	United States of America
WGS	Woodland Grant Scheme

mm	millimetre	ha	hectare
cm	centimetre	NS	not significant
m	metre	SD	standard deviation
km	kilometre	SE	standard error

Preface

Throughout the thesis, reference to published work is acknowledged by listing the authors and date in brackets, for example (Ellis and Okill 1990). If there are more than two authors for any publication, only the first is named, for example (Newton *et al* 1986). The vernacular and Latin name (in italics) for birds and other fauna and flora, are both given when first used. Thereafter the vernacular name only is used.

Statistical significance was accepted when the probability P was less than or equal to 0.05. In Chapters 4 and 5, the main statistical treatment of the data was analyses using a Mixed Procedure Model and Generalised Linear Mixed Model respectively. In these mixed models, the denominator degrees of freedom are calculated in the model using Satterthwaites formula, as described in Little *et al* (1996). Essentially, in mixed models with more than one error stratum, (e.g. variation between territories, variation between years within territories) each error stratum has its own residual degrees of freedom, and the degrees of freedom associated with a covariate depend on the balance of information that comes from each stratum. Depending on the scale of the latter the residual degrees of freedom will vary accordingly (D. Elston *personal communication*). The mixed models are also designed to control for, or limit bias due to pseudo-replication. Pseudo-replication can occur if the same sets of individuals, or variables, are measured on several occasions, for example, measuring the concentration of pollutants at the same sites every week. Mixed models also control for unequal replication or missing values (Townend 2002).

Appendices 1 and 2 are part of Chapter 2, Appendix 3 is part of Chapter 3 and Appendix 4 is part of Chapter 5. Appendix 5 stands alone, but is linked to Chapters 1, 3, 4 and 5. Appendices 6 to 10 are papers or notes that have been published during the Open University registration period. Chapter 2.1 is a draft manuscript in the later stages of preparation for submission to a peer reviewed ornithological journal, and there is duplication with its reference list and the Bibliography. There is also duplication with the reference lists from the published Appendices and the Bibliography. Chapters 3, 4 and 5 are intended to be modified to journal specific manuscripts for publication.

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CHAPTER 1

GENERAL INTRODUCTION

GENERAL INTRODUCTION

1.1 The rationale behind the Merlin study in north-east Scotland.

In the mid 1970s, two ornithological books stimulated my interest in birds of prey and in particular, of the distribution and ecology of the Merlin *Falco columbarius* a small largely bird-eating falcon. The first book was British Birds of Prey by Leslie Brown, a review of Britain's 24 diurnal raptors (Brown 1976). The first two sentences of the Merlin chapter made a lasting impression and are repeated here. ***"The Merlin is one of the smallest of British falcons and diurnal birds of prey, and one of the least known, although it is relatively common and not particularly shy. No doubt this is because it is small, for among students of birds of prey there is a decided tendency to concentrate on large and rare species, to the exclusion of commoner small species which may be just as rewarding or beautiful, especially when it comes to amassing quantities of scientific facts".*** Brown also stated that an up-to-date ecological study of the Merlin in Britain was badly needed. He was presumably unaware of the breeding study being carried out at that time in Northumbria, north-east England (Newton *et al* 1978). Throughout the chapter, there was regular reference to regional and national Merlin declines and of the lack of a definitive reason for them. Brown recommended an early investigation into the causes of the declines and suggested that who ever did the necessary study would find the Merlin a rewarding little bird. The second book was The Atlas of Breeding Birds in Britain and Ireland (Sharrock 1976) in which the distribution of breeding Merlin in likely areas in north-east Scotland was patchy or non-existent (see Figure 1.6 a later).

There had been reports of Merlin declines from parts of north-east Scotland from the early 1950s to early 1960s (Prestt 1965). However, in the late 1970s there was still much apparently suitable Merlin breeding habitat, as described by Brown (1976), Sharrock (1976) and Newton *et al* (1978) available in north-east Scotland. My interest in Merlin ecology accelerated then, and I was keen to develop a breeding study that was practical and would benefit nature conservation. I began to locate a small number of breeding pairs of Merlin and studied and photographed their behaviour at the nest, and ringed a small number of broods, all under Schedule 1 licence. Through connections with the Aberdeen branch of the Scottish Ornithologists' Club (SOC) and Grampian Ringing Group, it was apparent that no one was seriously studying or monitoring breeding Merlin in north-east Scotland at that time. I was also aware that Merlin could have been under recorded in the area due to their elusive behaviour (Brown 1976, Newton *et al* 1978) since there were frequent sightings from suitable habitat during the breeding season (North-East Scotland Bird Reports). The Nature Conservancy Council (NCC, and now Scottish Natural Heritage (SNH)) who administered the Schedule 1 licensing system, were supportive of a Merlin breeding study developing in north-east Scotland. The Merlin had been identified by the NCC as a key conservation species, particularly in relation to the commercial afforestation of the vast blanket bogs of northern Scotland (see Chapter 1.8 later). I then met Mick Marquiss and Nick Picozzi, two professional biologists from the Natural Environmental Research Council at Banchory (NERC and now Centre for Ecology and Hydrology (CEH)) who had previously worked on moorland birds on Deeside, north-east Scotland. They gave me valuable advice and encouragement and the location of a number of former Merlin breeding areas on Deeside. Brian Cosnette, Phil Shaw and Logan Steele were also interested in breeding Merlin and helped form a small study group. By the late 1970s, it was known that some bird-eating raptors, such as Eurasian Sparrowhawk *Accipiter nisus* and Peregrine *Falco peregrinus*, had been negatively affected by pollutants, particularly from the insecticide DDT (e.g. Newton 1979). There was also some evidence that Merlin in Britain had been similarly affected (Newton 1973, and see Chapter 1.5 later).

Against this background, I began organising a Merlin breeding study in north-east Scotland in 1979. I was then fortunate to meet Brian Little and Eric Meek, two renowned ornithologists who had been heavily involved in the Merlin breeding study in Northumbria (Newton *et al* 1978). They were very supportive of our study and gave me a large amount of practical advice and much encouragement. They also arranged for me to communicate with Ian Newton from the NERC in Cambridgeshire. Ian also gave me advice and encouragement and arranged for the analysis of un-hatched Merlin eggs from north-east Scotland as part of the NERC study on the effects of pesticides and pollutants on birds of prey in Britain (e.g. Newton *et al* 1982, Newton and Haas 1988).

One of my first targets was to establish a potential long-term study area to examine Merlin breeding ecology. Another target was to clarify the breeding distribution and status in north-east Scotland as soon as possible, and a preliminary report was published in the 1984 North-East Scotland Bird Report (Rebecca and Payne 1985). I was also keen for the Merlin chicks to be ringed, in the anticipation this would generate information on movements and migration patterns (e.g. Heavisides 1987, Rebecca 1987 a). In 1987, I started working for the Royal Society for the Protection of Birds (RSPB) as a roving field-surveyor and they agreed that my long-term Merlin study should continue. In 1992 to 1995, I was responsible for organising and reporting on a Merlin breeding survey of Britain on behalf of the RSPB (see Chapter 2.1 and Appendix 6 later). The RSPB continued to support the north-east Scotland Merlin study during and after the national survey and the study was formally registered with the Open University in 1996. The main aim of the current Open University study was, ***to provide further information on the relationship between breeding Merlin and commercial afforestation in Britain.***

The results from long-term studies are valuable for nature conservation planning as they can often identify trends and provide credible information, particularly following habitat or environmental land-use change. By necessity, some of the results from such studies are disseminated as reports or notes, while others are published. ***The relevant publications during my Open University registration are included as Appendices 6 to 10.***

1.2 Merlin breeding studies in north-east Scotland during 1978 to 1996.

In the early 1970s a small number of Merlin broods were ringed in north-east Scotland and a few other breeding sites were reported by ornithologists and other interested naturalists. In 1978, Phil Shaw and I began checking some of these sites for occupancy and searching for others. By the end of 1979, we knew of 27 breeding territories, mainly situated along the River Dee valley. In 1980, I initiated a Merlin population study in north-east Scotland and established a defined area on lower Deeside to study breeding ecology (Figure 1.1). In 1981, the North-East Scotland Raptor Study Group (NESRSG) was formed to act as a forum for amateur and professional raptor enthusiasts. As others from the NESRSG became involved, the area covered by the Merlin population study spread to include the rest of the area administered by the group (Figure 1.1).

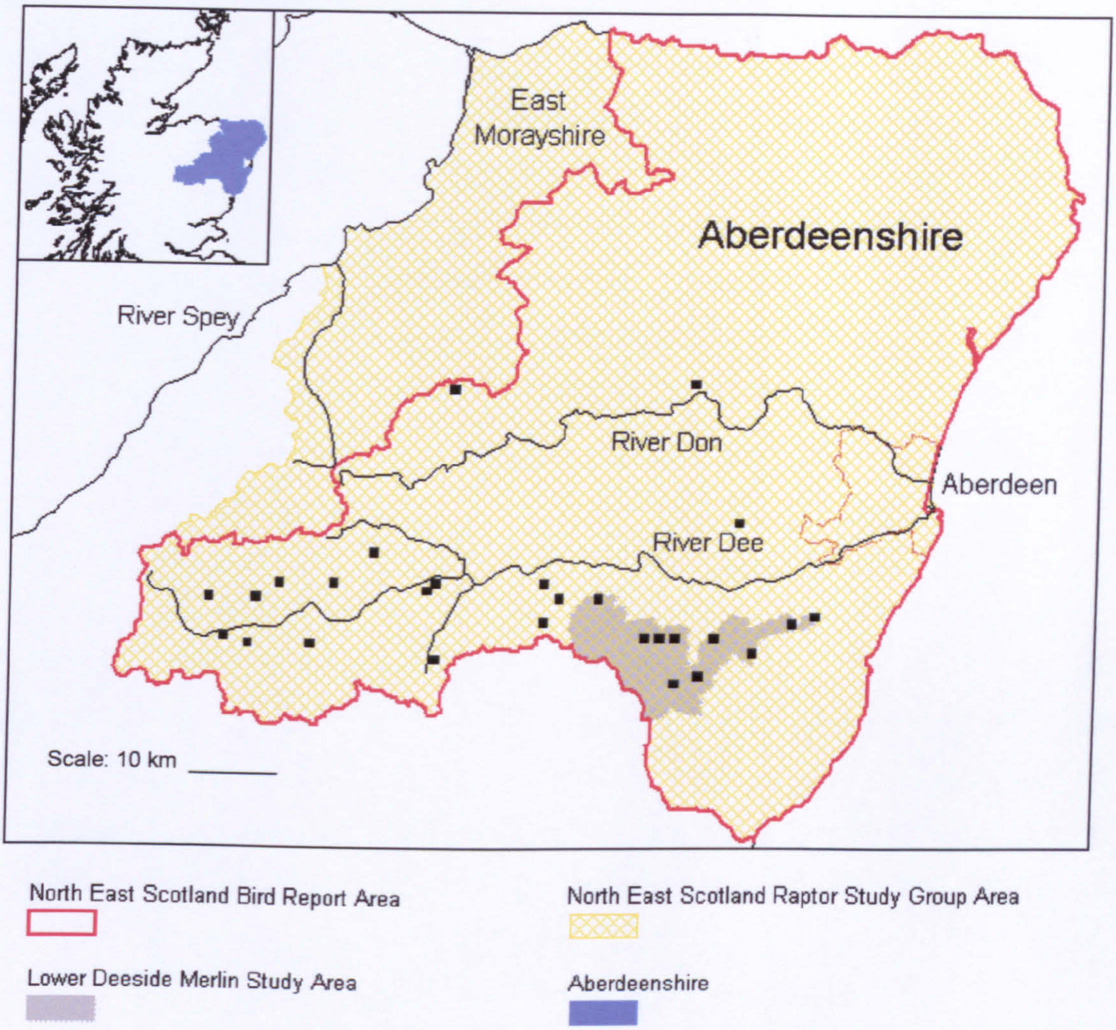


Figure 1.1 Map highlighting the areas covered by the North-East Scotland Raptor Study Group and the North-East Scotland Bird Report. The lower Deeside Merlin study area is shaded grey and the approximate centre of Merlin breeding territories known in 1980 are shown as black one kilometre (km) squares ■.

The main aims of the study were to survey and monitor a sample of breeding territories annually, assess the status of the population, study breeding ecology and contribute to the conservation of the species. Some aspects have been published, including a paper on numbers, distribution and breeding biology in the NESRSG area during the 1980s (Rebecca *et al* 1992). This showed that Merlin were well distributed over upland moorland, with previously unknown breeding territories located annually. The vast majority of 81 discrete territories were at altitudes of 200 to 500 metres (m) (range 190 to 680 m). It was estimated that 80 to 90 pairs could have been present in any one year. In about two-thirds of the territories that were checked annually, breeding was confirmed, with about two-thirds of the pairs producing fledged young. Clutch size for 195 nests averaged 4.4 ± 0.6 standard deviation (SD) and average brood size for 166 successful nests was at least 3.0 ± 0.9 SD. Average productivity for over 230 pairs that were located early in breeding period and followed through to a conclusion was between a minimum 1.7 and maximum 2.2 fledged young per pair. The sex of over 500 fledged young from 147 broods was evenly proportioned to males and females. Of 292 known nests, 261 (89%) were on the ground, 20 (7%) were in old Carrion Crow *Corvus corone* nests in trees and 11 (4%) were on crag ledges.

The population was considered to have been relatively stable, but at a low overall density, during the 1980s and early 1990s (Rebecca *et al* 1992, Rebecca 1993). As part of the British Merlin breeding survey in 1993 and 1994, all known territories in the NESRSG area were monitored and at least 70 pairs were estimated (Rebecca and Bainbridge 1998, and reproduced as Appendix 6). The area covered by the annual North-East Scotland Bird Report is less than that of the NESRSG (Figure 1.1) and all Merlin breeding territories in the former area are in Aberdeenshire. The Aberdeenshire Merlin population was estimated at 45 to 55 breeding pairs during the early to mid 1990s (Cosnette and Rebecca 1997) and remained relatively stable during the remainder of that decade (Appendix 8).

A number of short notes on breeding behaviour have also been published. The presence of unmated Merlins in the Deeside population was recorded when, in different years, two females quickly replaced females that had been depredated at the nest (Cosnette 1984, Rebecca 1991). Further, the presence of two males attending the same nest was recorded in two different years (Rebecca *et al* 1988). On both occasions, yearling males had apparently initiated the breeding attempt and were then replaced by adult males. Merlin are generally regarded as monogamous, however in 1989, a case of two breeding females with only one male was recorded. The nests were approximately 300 m apart and interestingly, both broods came together at fledging (Cosnette 1991). Some data was also recorded on the hunting distance from nests (Rebecca *et al* 1990). Rings from unfledged waders, 15 Lapwing *Vanellus vanellus* and one Golden Plover *Pluvialis apricaria* were found at Merlin nests or nearby plucking places. These waders were the subjects of detailed studies, allowing calculation of the minimum distance from Merlin breeding sites to where they were taken. The mean minimum distance was 3.4 km ± 1.1 SD (range 2.0 to 5.6 km) and the hunting ranges of at least two pairs were shared. A female Merlin was seen dust-bathing at the roadside at an occupied breeding territory (Rebecca 1987 b) an occurrence apparently rarely observed in the wild (BWP 1980, Sodhi *et al* 1993). Most of the young were ringed each year generating some interesting recaptures or recoveries. These indicate that some Merlin spend the winter at estuaries, coastal areas or low altitude farmland in north-east Scotland while others, particularly first year birds, migrate to other Scottish or English estuaries and coasts and then on to France or Spain (Rebecca 1987 a, Rebecca *et al* 1992, Heavisides 2002, G. W. Rebecca and B. L. Cosnette *unpublished data*).

1.3 Description of Merlin.

Merlins are the smallest diurnal raptor breeding in the western Palearctic, and have the typical falcon silhouette of long pointed wings (Trimble 1975, BWP 1980, Cade 1982, Figure 1.2). Their flight is usually fast and dashing, with quick, shallow wing beats and short glides and has been described as the most rapid of all the falcons (BWP 1980).

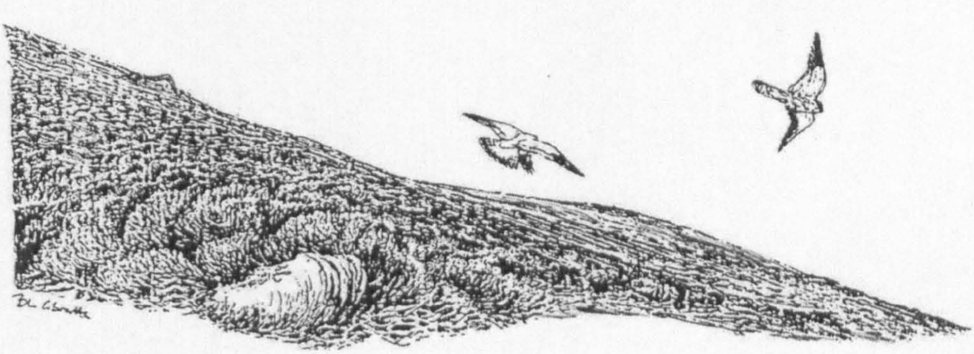


Figure 1.2 Pair of Merlin at breeding site in Glen Dye, north-east Scotland. Male about to pass food to the female in mid air (drawing by B. L. Cosnette).

The adults of all sub-species are sexually dimorphic in size and plumage, with females approximately 10% larger than males (BWP 1980, Sodhi *et al* 1993). European Merlins measure 25 to 30 centimetres (cm) from head to tail with the wingspan 50 to 62 cm (BWP 1980). The colour of sub-species varies, but generally adult males have slate-blue dorsal plumage and rufous-brown and cream under-parts streaked black, with dark, almost black primaries and black terminal tail band. In contrast, females are predominantly dark brown above with a lighter brown and cream barred tail. The rump and upper tail coverts of adult females are light brown to light grey and the primaries, and secondary and primary coverts are darker brown than the rest of the back and head. Both sexes have yellow legs, talons and ceres and thin cream superciliums but lack the obvious moustachial facial pattern of many other falcons. First year males and females are similar in colour to adult females but lack the light grey-brown rump and upper tail coverts. Like adults, yearling females are larger than yearling males (BWP 1980, Cade 1982, Sodhi *et al* 1993). Photographs 1 to 3 illustrate breeding adult female and male Merlin.

Photograph 1. Female Merlin and young, North York Moors, north-east England (J. Knight).

Photograph 2. Female Merlin and young, Slug Moor, north-east Scotland (G. W. Rebecca).

Photograph 3.

Male Merlin at breeding site in Glen Dye, north-east Scotland (P. J. Newman).

1.4 Distribution of Merlin.

The Merlin has a circumpolar distribution in the northern hemisphere. They breed in northern North America, northern Eurasia and some mountains in central Asia and generally migrate south in autumn and winter, the non-breeding period (Figure 1.3). There are six sub-species of Merlin in Eurasia and three in North America including the nominate race *Falco columbarius columbarius* (Vaurie 1965, Sodhi *et al* 1993). The sub-species that breeds in Britain *Falco columbarius aesalon* also breeds in Scandinavia and Russia east to north-west Siberia (Figure 1.4). The Icelandic sub-species *Falco columbarius subaesalon* also occurs in western Britain and Ireland in winter (Heavisides 2002). In addition, some Merlin in Britain and Iceland only undertake an altitudinal migration to low ground and coasts, spending the winter there (BWPC 1998, Heavisides 2002). Some breeding areas on mainland Europe also hold wintering Merlin but it has not been established whether these records relate to residents or migrants from elsewhere (BWPC 1998, Figure 1.5).

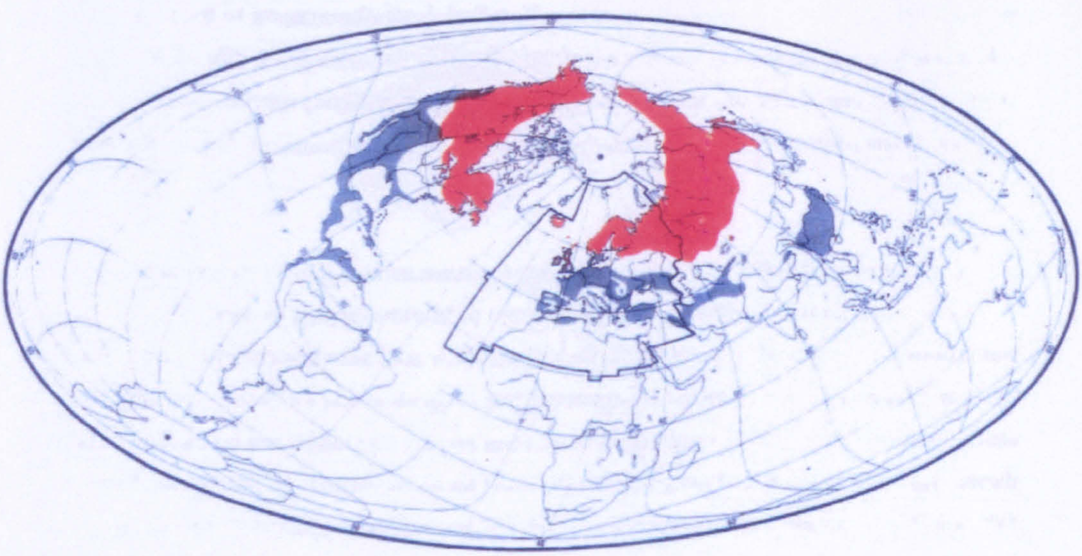


Figure 1.3 The world range of the Merlin: red shading represents the breeding range and blue shading the non-breeding autumn and winter range (from BWP 1980). The area within the black insert covers the western Palearctic and is featured in Figure 1.5.

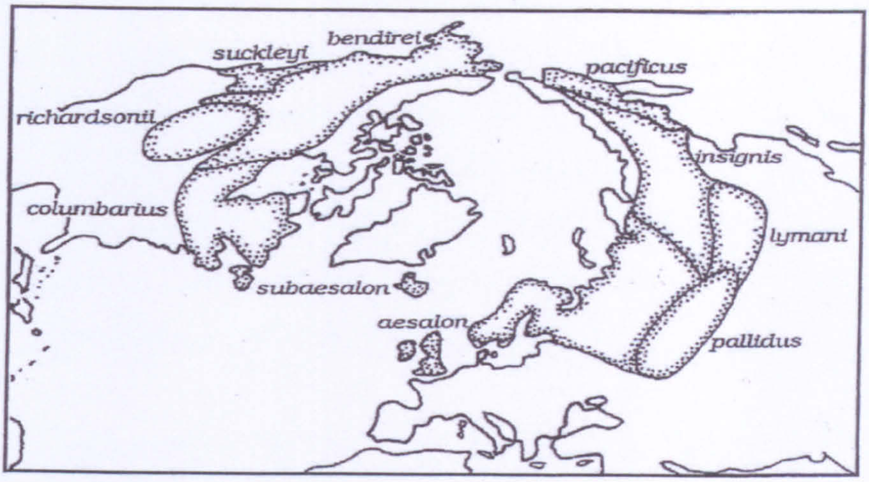


Figure 1.4 The world breeding range of Merlin sub-species (from Peterson 1992). In the Birds of North America, Sodhi *et al* (1993) only recognise three sub-species, with the western Taigi Merlin *Falco columbarius bendirei* combined with the eastern Taigi Merlin *Falco columbarius columbarius* with both described as the latter.

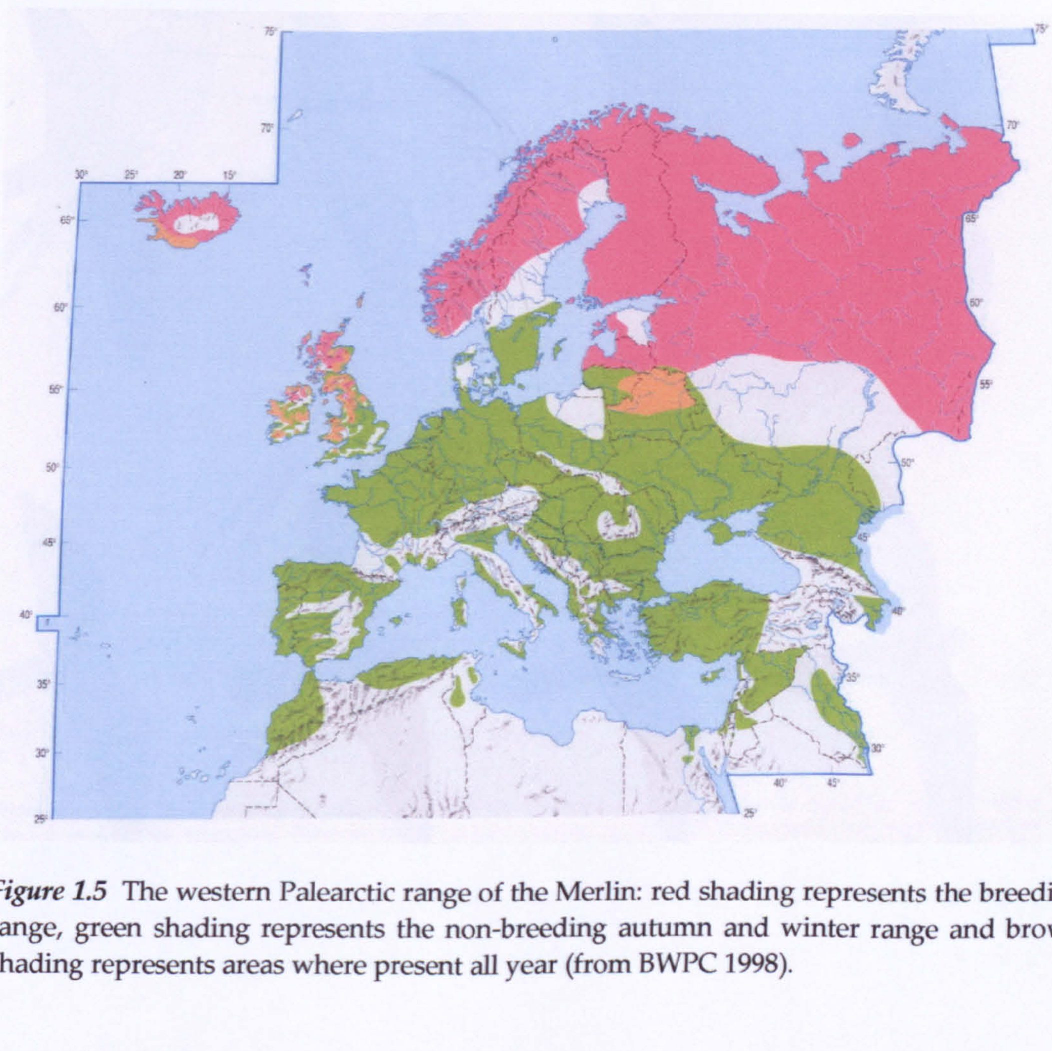


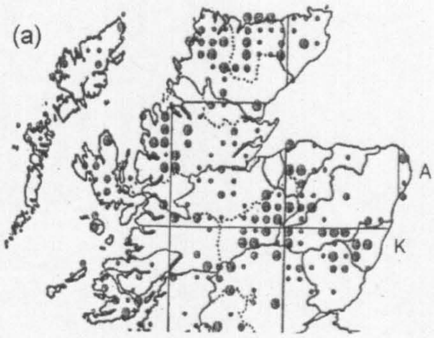
Figure 1.5 The western Palearctic range of the Merlin: red shading represents the breeding range, green shading represents the non-breeding autumn and winter range and brown shading represents areas where present all year (from BWPC 1998).

In north-east Scotland, there was little published information on the distribution of Merlin prior to the first British breeding bird atlas (Sharrock 1976). Historical records from the latter half of the 19th century and first half of the 20th century indicate that they were probably common during the former period and widespread but uncommon during the latter period (summarised in Rebecca *et al* 1992). Merlin declined throughout their British breeding range in the early-to-mid 20th century (Chapter 1.5) and in south Aberdeenshire there was a noticeable decrease by 1953 to 1963 (Prestt 1965).

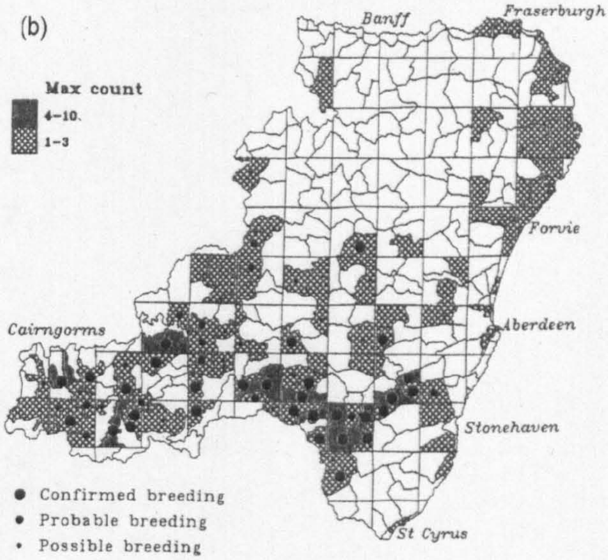
In the first British breeding bird atlas, covering fieldwork in 1968 to 1973, Merlin were recorded in 19 10 x 10 km ordnance survey squares in Aberdeenshire and Kincardineshire. Breeding was confirmed in 10 squares, probable in three squares and possible in six squares (Figure 1.6 a). In the Birds of North-East Scotland covering fieldwork in Aberdeenshire and Kincardineshire in 1981 to 1984, Merlin were recorded in 30 10 x 10 km squares. In that regional breeding bird atlas, 10 x 10 km squares were divided into convenient ornithological recording sites, and Merlin were recorded in 59 of them; 30 confirmed, 12 probable and 17 possible breeding sites (Figure 1.6 b). This suggests that Merlin breeding distribution had increased in north-east Scotland between the early 1970s and early 1980s. However, observer effort was probably a reason for part of the increase, since a detailed Merlin breeding study began on lower Deeside in 1980 (Chapter 1.2, Appendix 8). The distribution of breeding Merlin per north-east Scotland atlas-ornithological-site during 1993 to 1996 is shown in Figure 1.6 c. Merlin were recorded in 30 10 x 10 km squares with breeding confirmed in 45 atlas-ornithological-sites, probable in five sites and possible in six sites. This reflects a degree of stability in overall distribution per 10 x 10 km square and atlas-ornithological-site in the 1980s to mid 1990s.

In 1993 to 1996, there was an increase in sites where breeding was confirmed and a decrease in probable or possible sites. This was mainly a consequence of a second detailed Merlin study area being established on upper Donside in 1986 (Appendix 8) and of the improvement in quality and commitment of field ornithologists (Cosnette and Rebecca 1997). The knowledge of Merlin breeding range in Aberdeenshire progressed throughout the 1990s with approximately 100 territories known by 2000 (Figure 14.2 in Appendix 8).

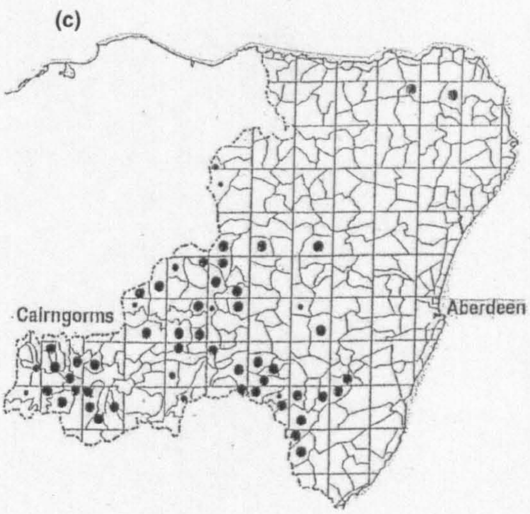
Figure 1.6



(a) The distribution of breeding Merlin, in mainland north Scotland and the Western Isles, per 10 x 10 km square in 1968 to 1973. A and K are Aberdeenshire and Kincardineshire and small dots = possible breeding, medium dots = probable breeding and large dots = confirmed breeding (from Sharrock 1976).



(b) The distribution of breeding Merlin in Aberdeenshire and Kincardineshire per north-east Scotland atlas ornithological recording site in 1981 to 1984. These recording sites are contained within 10 x 10 km squares and some may have held more than one pair (from Rebecca 1990).



(c) The distribution of breeding Merlin in Aberdeenshire per north-east Scotland atlas ornithological recording site in 1993 to 1996. Small dots = possible breeding, medium dots = probable breeding and large dots = confirmed breeding. These recording sites are contained within 10 x 10 km squares and some may have held more than one pair (from Cosnette and Rebecca 1997).

1.5 Numbers, status and the effects of environmental pollutants on Merlin.

In Britain and Scandinavia Merlins were shown to have been negatively affected by environmental pollutants during the 1960s to 1980s. In particular by DDE, the main metabolic breakdown product from the insecticide DDT, by HEOD derived from the insecticides Dieldrin and Aldrin, and PCBs (industrial polychlorinated biphenyls) and Mercury, mainly from agricultural and industrial sources (e.g. Newton 1979, Olsson 1980, Newton *et al* 1982, Newton and Haas 1988, Nygard *et al* 1994). These pollutants, mainly DDT, caused egg-shell thinning and breakage, and embryo mortality resulting in depressed reproductive performance and a decrease in Merlin numbers. British Merlin (see Chapter 1.2 for north-east Scotland) and many of their breeding season prey species (see Chapter 5 later and Lack 1986) largely migrate to lower altitude farmland or coastal and estuarine habitats in autumn and winter. It is in these non-breeding habitats, where pesticides are widely used, that British and Scandinavian Merlin are believed to accumulate pollutants (e.g. Olsson 1980, Newton *et al* 1999, Nygard 1999).

In a review of egg-shell thinning in raptors, Newton (1979) concluded that populations were likely to decline if egg-shell quality averaged 16 to 18 % thinning over several years. In Sweden, Merlin egg-shell quality decreased on average by 20% in eggs from 1973 to 1978 in comparison to eggs from before 1948, the year when DDT was introduced. There was also a decrease in breeding productivity and a decrease of about 50% in the number of migrant Merlins counted during 1975 to 1977. The effects of biocides on Swedish Merlin were considered so serious it was recommended that there should be international bans on their uses (Olsson 1980). A similar study in Norway showed that Merlin egg-shell quality had decreased by 15% on average after DDT use (Nygard *et al* 1994). By the mid 1990s, Merlin in Fennoscandia were thought to be relatively stable, with an estimate of 7,000 to 16,500 breeding pairs (Crick and Wiklund 1997).

A similar situation occurred in North America during the 1960s and 1970s when the negative effects of organochlorine pesticides lowered Merlin productivity and in particular reduced the numbers of Prairie Merlin *Falco columbarius richardsonii* (Risebrough *et al* 1970, Fox 1971, Temple 1972, Fyfe *et al* 1976, Fox and Donald 1980). In 1972, the United States of

America (USA) and Mexico added the Merlin to their lists of protected migratory birds and Trimble (1975) recommended banning or severely restricting the use of persistent pesticides in the Merlin's American wintering areas. There are no official population estimates for the three North American Merlin sub-species as a whole (Cade 1982, James 1988). However, following increases in urban populations there are now thought to be thousands of pairs of Prairie Merlin (James 1988). The increase of urban and rural populations followed restrictions on the use of insecticides such as DDT and other organochlorine pesticides in Canada and the USA (Trimble 1975, Cade 1982). Although some Merlin in North America were still affected by pesticide contamination in late 1980s (Noble and Elliot 1990) most regional populations were no longer in decline and were reproducing well (Sodhi *et al* 1993, Houston and Hodson 1997).

The status of British Merlin also fluctuated during the 20th century (BWP 1980). Earlier declines over much of their breeding range were believed to have been caused by loss of suitable habitat, disturbance and persecution (Alexander and Lack 1944, Prestt 1965, Parslow 1967). Further studies in the 1970s to mid 1980s described continuing declines; with low productivity, degradation and loss of breeding habitat, disturbance, weather and the effects of organochlorine pesticides and other pollutants all implicated (Newton *et al* 1981, 1982, 1986, Roberts and Green 1983, Bibby 1986, Meek 1988). In the mid 1980s, the Merlin was considered the most heavily contaminated British raptor, and still in decline despite a wide reduction in pesticide use (Newton 1984, Newton and Haas 1988).

The regional declines from the 1970s and early 1980s were considered so serious that the RSPB organised a breeding census throughout Britain during 1983 and 1984 in an attempt to clarify the Merlin's status. After a partial survey and extrapolation, the population was estimated at 550 to 650 breeding pairs (Bibby and Nattrass 1986). Following this estimate the Merlin was identified as one of the most threatened species in Britain in the RSPB Bird Conservation Strategy (Bibby *et al* 1989). It was then listed as a "species of special concern" in Red Data Birds (RDB) in Britain (Batten *et al* 1990). RDB in Britain was published by the NCC and RSPB and covered 117 species of conservation importance according to the following criteria: A) the international significance of British populations, B) scarcity as

British breeders, C) declining breeding numbers, D) restricted distribution in vulnerable sites or habitats, E) species of special concern (a category covering species believed to be under threat but for which there was insufficient data). The Merlin was subsequently retained in a revised United Kingdom (UK) RDB list in 1996 mainly on the strength of its historical decline during 1800 to 1995 (Gibbons *et al* 1996).

Following the 1983 to 1984 survey additional Merlin breeding studies were documented, with some contrasting results in regional status. For example, there were reports of increases from Kielder Forest in Northumbria (Little and Davison 1992) and the south Pennines (Brown and Shepherd 1991) and decreases from Wales (Bibby 1986), Northumbria (Newton *et al* 1986), Orkney (Meek 1988) and Shetland (Ellis and Okill 1990), and stable populations from north-east Scotland (Rebecca *et al* 1992, Rebecca 1993) and Wales (Parr 1994). It was also reported from some areas that some Merlin had changed nest site, from traditional ground sites on moorland, to old Carrion Crow, Hooded Crow *Corvus corvix* or Magpie *Pica pica* nests in trees at the edges of maturing post-thicket conifer plantations. In Wales, this change in nesting behaviour was initially largely overlooked, at a time when the Merlin population there was reported to be declining and as such, had probably remained stable between 1970 and 1991 Parr (1994). It was also suggested that plantation nesting by Merlin might have been more widespread in Britain (Parr 1991, 1992, Little and Davison 1992, Orchel 1992).

Against this background, the RSPB initiated the second breeding survey of Merlin in Britain during 1993 and 1994. I was responsible for planning and organising the survey, co-ordinating the fieldwork and reporting on the results. The main aims of the study were to formally estimate the population for the entire breeding range including plantations and to assess regional trends by comparing the results with areas covered thoroughly in 1983 to 1984, or where population estimates had subsequently been documented. Following the survey, a figure of 1300 ± 200 pairs of breeding Merlin was recommended as the revised estimate for Britain (Rebecca and Bainbridge 1998 and Appendix 6). This new, more rigid figure was twice the previous maximum estimate of 650 pairs. Breeding range also increased between surveys in England and Wales, with the number of 10 x 10 km squares rising from 74 to 115 (55%) and from 30 to 46 (53%) in the two countries respectively (see Figure 1 in Appendix 6). In all areas where comparison was made Merlin had increased or remained relatively stable (see Table 5 in Appendix 6). It was suggested that a decrease in persecution and an increase in productivity might have been reasons for some of the increases. An analysis of British Trust for Ornithology (BTO) Merlin nest record cards for the period 1937 to 1989 showed there had been a gradual increase in breeding success over time (Crick 1993). It was further suggested by Rebecca and Bainbridge (1998) that the Merlin could have recovered from the effects of environmental pollutants, as had the more widely studied Eurasian Sparrowhawk and Peregrine. The most recent work on pesticides and Merlin in Britain has confirmed that they have probably overcome the worst effects of these pollutants following decreases in the environment (Newton *et al* 1999).

1.6 Basic ecology of Merlin.

Falcons mainly nest on cliff ledges, in holes in trees, on buildings or in an old stick nest of another species in trees or cliffs. Merlin also nest on the ground in dense vegetation or under tree branches. Like other falcons, Merlin do not build true nests and usually just form a scrape on the ground, or on a cliff ledge or in an old stick nest (BWP 1980, Cade 1982). Merlin are primarily monogamous during their annual breeding period (BWP 1980, Sodhi *et al* 1993) with polygyny only rarely recorded (Sodhi 1989, Cosnette 1991). They attempt to raise one brood each year, with a repeat nesting occasionally occurring after an early failure (BWP 1980). Pairs defend their nesting site against potential predators and in that sense are territorial (Newton *et al* 1978). Breeding territories in Britain, which can contain numerous potential nesting sites, are usually separated by at least 1 km (e.g. Newton *et al* 1978, Bibby 1986, Bibby and Nattrass 1986, Wright 1997, Appendix 8). Merlin diet has been well documented in Europe and North America, particularly in the breeding period (e.g. BWP 1980, Sodhi *et al* 1993) and consists largely of small birds weighing 20 to 80 grams. The prey is caught in mid air, usually after a prolonged chase, or on the ground, after a surprise low-level attack. In autumn and winter, they have been recorded hunting in pairs (Wilson 1996) and will associate with larger raptors such as Hen Harrier *Circus cyaneus*, taking prey flushed by them (e.g. Bourne 1960, Dickson 1993).

In North America, Britain, Scandinavia and Russia egg-laying begins in late April with most clutches complete by the third week in May (Sodhi *et al* 1993, BWPC 1998). Eggs are laid every two days with an incubation period of 28 or 29 days per egg and clutch size is usually 3 to 5 eggs. The female does the bulk of the incubation with the male providing food. After the young hatch, they are semi-altricial and nidiculous and are brooded almost constantly by the female for the first week, with the male providing virtually all the food. The female continues to regularly brood the young up to about 10 to 12 days, especially in cold or wet weather. During the second half of the fledgling period, the young are left for long spells, although the female is often within visual or audible distance of the nest. The female will increasingly provide food for the young at this stage and continue to cover them during heavy rain (Dickson 2005, G.W. Rebecca *unpublished data*). The young fledge in 28 to 30 days (BWP 1980) but are capable of partial flight or short glides from 24 to 25 days (Dickson 2003, Wright 2005, G.W. Rebecca *unpublished data,* Photograph 4).

Photograph 4.

Almost fully fledged young Merlin, aged 25 or 26 days, lower Deeside, north-east Scotland. This Merlin could fly about 70 m and land comfortably, but was still dependant on its parents for food (G. W. Rebecca).

The young are independent approximately two to three weeks after fledging (Newton *et al* 1978, Rebecca *et al* 1992, Heavisides 2002, Wright 2005). In north-east Scotland Merlin usually leave their breeding areas in autumn, although some remain on the lower eastern moors in mild winters (Rebecca 1990). They return to breeding areas in north-east Scotland in March to early April when vocal and flight displays can be observed as pair forming, and territory and nest site selection occurs (Rebecca 1990, Rebecca *et al* 1992).

1.7 Merlin breeding habitat and nest sites.

Merlins generally occur on open to semi-open country that facilitates hunting methods and are usually absent from dense uninterrupted forests. In Britain, they prefer open country with low rough vegetation on undulating land giving a good overall view from breeding territories. Typical areas are upland moorland, blanket bogs, rough grazing and young conifer plantations (BWP 1980, Photographs 5 and 6). The vast majority of nest sites in Britain are on the ground in Heather *Calluna vulgaris*, a medium sized shrub that is widespread in the uplands. The next most regular nest site in Britain is an old crow nest in a tree, with a small proportion of nests on crags (e.g. Bibby 1986, Newton *et al* 1986, Meek 1988, Ellis and Okill 1990, Orchel 1992, Rebecca *et al* 1992, Brown and Stillman 1998, Dickson 2000, Photographs 1 and 2 and 7 to 9 and see Chapter 2.1 and 2.2 later).

In North America, Taiga Merlin usually breed near forest openings in fragmented woodland, often near lake shores, islands, rivers or bogs. Prairie Merlin breed where native grassland provides adequate prey and suitable tree nesting sites (Trimble 1975, Sodhi *et al* 1993). Since the 1970s, Prairie Merlin have colonized a number of cities and towns on the Canadian prairies (James 1988). In these urban areas, nests are usually in conifers in residential areas, school gardens, parks or cemeteries. The third and least known North American sub-species, the Black Merlin *Falco columbarius suckleyi*, is generally found along coasts and rivers in the Pacific north-west forests of south-east Alaska, British Columbia and Washington. The most frequent nesting site for all three sub-species is an old nest of crow, magpie or other bird in a tree. Black Merlin also occasionally use tree cavities and Taiga Merlin also nest on the ground under tree branches at the northern edge of their range and on cliffs in Newfoundland (Trimble 1975, Cade 1982, Sodhi *et al* 1993). Similarly, in Scandinavia old crow nests in trees are the predominate nesting site, for example in open sub-alpine Birch *Betula* woods in northern Sweden (Wiklund 1977) and in Iceland, vegetated ledges on high cliffs are the normal nesting site (Nielson 1995).

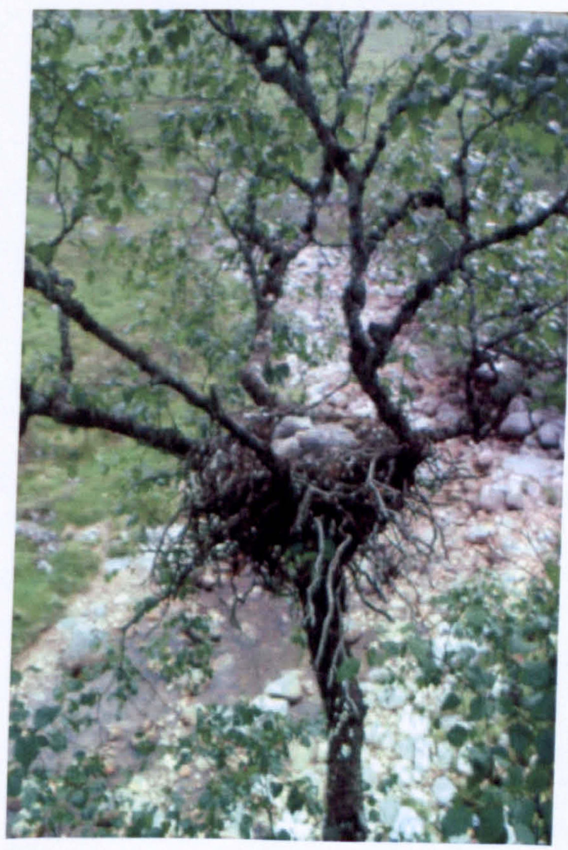
Photograph 5. View from Merlin breeding area, upper Deeside, north-east Scotland (G. W. Rebecca).

Photograph 6. View of Merlin breeding area, lower Deeside, north-east Scotland (G. W. Rebecca).

Photograph 7. Merlin nest on crag (brood arrowed red), upper Deeside, north-east Scotland (G. W. Rebecca).

Photograph 8 .

Merlin brood in old Carrion Crow nest in Birch, Rannoch Moor, Perthshire, central Scotland (G. W. Rebecca).



Photograph 9. Merlin nest on the ground in deep heather (clutch arrowed red) on managed grouse moor, mid Deeside, north-east Scotland (G. W. Rebecca). Many Merlin ground nests in north-east Scotland have nearby 'markers' such as these boulders (Rebecca *et al* 1992).

1.8 Forestry and Merlin in Britain.

In Britain, native forest cover was at its peak about 5000 years ago, covering most of the suitable land surface. Forest clearance was evident after that and by 1700, forest cover was estimated at 12%, reducing to around 5% by 1900 (Thompson *et al* 1988, Petty 1996). During the 19th century, Merlin bred in over 100 counties in Britain, covering much of Scotland, Wales and northern England (Holloway 1996). Tree nesting was widespread then, but Merlins must also have adapted to deforested areas by nesting on crags and on the ground (Holloway 1996, Petty 1996). In Shetland, Orkney, the Outer Hebrides and parts of Caithness and Sutherland ground or crag nesting would have been normal then and earlier, as extensive forest cover never existed in these areas (Ratcliffe 1986, Thompson *et al* 1988). The British countryside changed dramatically during the 19th century, with fertile low ground being converted to agriculture and large areas of the uplands used for sheep rearing (e.g. Stoate 1995). Concurrently, game shooting for sport, mainly Red Grouse *Lagopus scoticus* and Red Deer *Cervus elaphus*, developed on a huge scale over the upland moors

(Petty and Avery 1990, Ratcliffe 1990). As part of the overall management on sheep and grouse moors game-keepers reduce potential predators of Merlin, which probably improves the suitability of these habitats for Merlin (Avery and Leslie 1990, Petty and Avery 1990, Ratcliffe 1990, Brown and Bainbridge 1995). However, the maintenance of deforested land was not uniform during the 19th century and in Scotland, some large areas of conifers were planted in Aberdeenshire, Perthshire and Speyside (Petty and Avery 1990). In total over 200,000 hectares (ha), of mainly Scots Pine *Pinus sylvestris,* was established and was probably the source for much of the valued semi-natural pinewood in these areas now.

Following world war one (1914 to 1918), forest cover in Britain was at its lowest, at less than 5% (Avery and Leslie 1990). The country required a large steady supply of timber as it recovered from the ravages of war and there was an urgent need to re-afforest. In 1919, a major turning point in British forestry saw the formation of a new state funded government body, the Forestry Commission (FC). The main objective of the FC was to produce a steady supply of timber as quickly and cheaply as possible and by the early 1980s, there was approximately 10% forest cover in Britain (Avery and Leslie 1990). The amount of forest cover in 1982 was about 2.1 million ha, with about 1.5 million ha (70%) as new upland forest (Avery and Leslie 1990). The distribution of this new forestry largely mirrored the distribution of low cost rough grazing and moorland on mainland Britain and reflected the FC's economic objective from 1920 (Figure 1.7). The second part of the FC's main objective was also achieved in that large areas of fast growing timber had been established. These new upland plantations (Figure 1.7 b), largely composed of non-native species, particularly Sitka Spruce *Picea sitchensis* and Lodgepole Pine *Pinus contorta,* also overlapped the breeding ranges of the Merlin (Chapter 2, Figure 2.1) and Carrion and Hooded Crows, (Gibbons *et al* 1993).

Up until about the late 1970s, the plantations were established without any serious considerations given to landscapes or the environment (Avery and Leslie 1990, Mather 1991). Around that time, public interest in nature conservation was accelerating and the 1981 Wildlife and Countryside Act came into force. The NCC and other conservationists had also recognised that the fauna and flora of the uplands were of outstanding nature conservation value (e.g. Ratcliffe 1977, Watson 1977). During the mid 1980s, much information was published by the NCC of the negative effects that modern forestry was having on upland habitats and birds (e.g. Nature Conservancy Council 1986, Ratcliffe 1986, Thompson *et al* 1988). The scale of this habitat change was extensive in some areas such as in south-west Scotland (Figure 1.7 b), resulting in a rapid decrease of some typical open-country birds, such as Raven *Corvus corax* and Golden Eagle *Aquila chrysaetos* (Marquiss *et al* 1978, 1985).

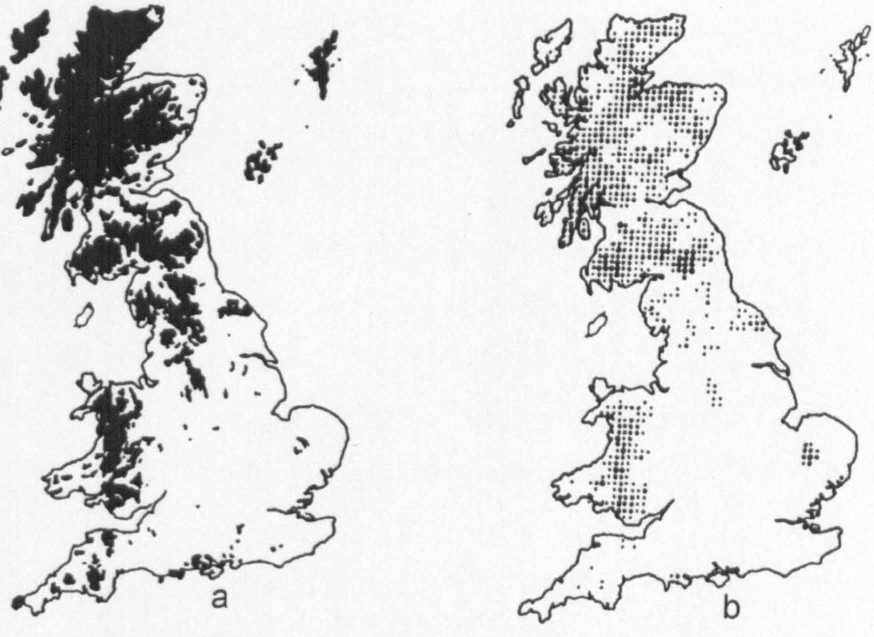


Figure 1.7 The area of rough pasture and moorland in Britain in 1986, shaded dark (a) and (b) existing forests in 1986 in every 10 x 10 km square planted since 1920. No dot = no planting, small dot = less than 10%, medium dot = 10 to 50%, large dot = at least 50%. The Orkney and Shetland Isles have been moved for convenience (maps adapted from Nature Conservancy Council 1986).

The RSPB supported the NCC in their effort to stop inappropriate forestry and became heavily involved in the debate when the blanket bog "flow country" of Caithness and Sutherland began to be afforested in the 1980s (RSPB 1985, Bainbridge *et al* 1987). The flow country ecosystem was considered to be of international importance and it became a matter of huge contention that public money, in the form of FC planting grants and tax concessions, was indirectly being used to destroy such important habitat and associated wildlife (Nature Conservancy Council 1986, Stroud *et al* 1987, Lindsay 1987, Thompson 1987, Scottish Wildlife Trust 1987). A scenario had developed where one government organisation was meeting its targets at the expense of a previously unthreatened (and possibly not fully recognised) ecological asset of international significance. At the same time, another government organisation, backed and lobbied by wildlife charities and conservationists, was advocating that British forestry policy should be reviewed, and include a nature conservation target and remit.

Merlin featured regularly in this debate, being highlighted as a species that would suffer in the short term, from loss of nest sites and prey as the plantations were established, and in the long term from loss of suitable hunting habitat as the plantations matured (e.g. Nature Conservancy Council 1986, Ratcliffe 1986, Bainbridge *et al* 1987, Petty and Avery 1990). Other factors were also controversial, for example, planning permission was not necessary for establishing new forests, and there was no requirement for consultation away from areas designated as Sites of Special Scientific Interest (SSSIs)[1]. Further, in addition to the grants and tax concessions at the planting stage, another incentive for private sector applicants was future tax exemption at harvesting (Nature Conservancy Council 1986).

By the late 1980s, environmental and conservation objectives were being addressed through a changing forestry policy in Britain and timber production was no longer the main aim of the FC (Mather 1991, Reid 1997). In 1985 the Wildlife and Countryside Act (forestry amendment) required the FC to ***"endevour to achieve a reasonable balance between A) the development of afforestation, the management of forests and the production of timber, and B) the conservation and enhancement of natural beauty and the conservation of flora, fauna and geological and physiographical features of special interest"***. Conservationists had

[1] *SSSIs were the backbone of statutory sites protection in Britain in the 1980s and 1990s. They were mostly in private ownership and were selected and notified in Scotland by the NCC or SNH on scientific grounds relating to floristic and faunistic, geological or physiographical interest. Special consultation arrangements apply to land-use operations on these sites, but adequate protection depends on voluntary co-operation by owners and occupiers and the availability of funds to back management agreements or compulsory purchase where necessary.*

argued the question of balance for many years and this new duty, imposed on the FC, was seen as a progressive step towards a sustainable and diverse forestry environment in Britain.

Another important change was the introduction of Indicative Forestry Strategies (IFS) as part of the planning process at regional level (Reid 1997). Their inception was co-ordinated by a third government organisation, the Joint Nature Conservation Committee (JNCC), with input from many interested parties. For example, in 1988 in north-east Scotland, representatives from District Councils, NCC, RSPB, NESRSG, SOC, Scottish Wildlife Trust (SWT) and others all contributed to the discussion that formulated the IFS. The Merlin was one of the key species identified by the JNCC and the representatives, and I provided the information for north-east Scotland (Bates *et al* 1993). The contributors assessed and identified suitable ground for forestry and separated it into three types: **A)** ***areas where there was likely to be no objection to forestry, the preferred areas,*** **B)** ***areas where some constraints were evident, the potential areas and*** **C)** ***areas where there were serious constraints to planting, the sensitive areas.*** It was anticipated that IFS would limit conflict by directing new planting to non-contentious areas (Avery and Leslie 1990). Although they were an improvement to the previously uncontrolled system IFS were largely superficial and lacked specific details about the habitat requirements of many birds. For example, fundamental to most discussion concerning Merlin and commercial afforestation was the lack of knowledge of the proportion of open habitat and plantation that could sustain Merlin numbers (Petty and Avery 1990). The FC recognised this, and funded or supported research into the relationship between breeding Merlin and afforestation in Wales, north-east England and south-west Scotland (Parr 1991, 1992, 1994, Little and Davison 1992, Orchel 1992 and summarised by Petty 1995).

In the late 1980s, further important changes to British forest policy included the new Woodland Grant Scheme (WGS) and the introduction of the European Commission (EC) Environmental Assessment (EA) Afforestation Directive. The new WGS had much broader aims; with landscape improvement, wildlife habitat creation, recreation and economic development being promoted alongside timber production (Mather 1991, Reid 1997) and the system of EA was an established planning mechanism that was required within the

European Community for many types of proposed development. It required developers to produce an independent appraisal of any adverse effects the development would have on the general environment and on any designated nature conservation sites or protected fauna and flora. EAs were open to public scrutiny and the EA afforestation regulations of 1988 required the submission of an Environmental Impact Statement with forestry grant applications (Reid 1997). The 1990s therefore saw a much more regulated forestry system in Britain with the two main Government aims being: ***"the sustainable management of our existing woods"*** and ***"a steady expansion of tree cover to increase the many diverse benefits that forests provide"*** (Forestry Commission 1991).

1.9 Aims and structure of the thesis.

The main aim of the study is to provide further information on the relationship between breeding Merlin and commercial afforestation in Britain.

The first area of study was to detail the current distribution and extent of commercial conifer plantation nesting by Merlin in Britain (Chapter 2). The use of post-thicket plantations by breeding Merlin was well established in Wales, north-east England and south-west Scotland by the early 1990s (Little and Davison 1992, Orchel 1992, Parr 1991, 1992) and may have been more widespread (Chapter 1.5, Petty 1995). In Scotland, there were also isolated records from Perthshire in 1984, Morayshire in 1987 and Sutherland in 1990 (Sandy Payne, Brian Etheridge and Mick Canham *personal communications respectively*) and Caithness and Aberdeenshire in 1991 (Orchel 1992, Rebecca 1992). This trait may therefore have been established throughout the rest of the Merlin's British breeding range, excluding Orkney, Shetland and the Outer Hebrides where there are no extensive plantations. The distribution of new upland plantations (Figure 1.7 b), and the breeding range of Carrion and Hooded Crows and Magpie (Gibbons *et al.* 1993) could facilitate such nesting behaviour and leads to the first hypothesis for the thesis.

In their British breeding range, Merlin are nesting in substantial numbers in post-thicket commercial conifer plantations where these are available.

To investigate this hypothesis three sections of study were proposed. First, the nest record forms from the national Merlin survey in 1993 and 1994 were analysed, and the occurrence of pairs breeding in post-thicket plantations quantified spatially. Second, publications on British breeding Merlin since 1994 were examined for nest site selection. Third, key contributors or the co-ordinators of Merlin breeding studies in Britain were contacted to request an up-to-date assessment of the status of post-thicket plantation nesting Merlin in their areas between 1995 and 2004.

The second area of study was to monitor the effects of commercial coniferous afforestation on the breeding ecology of Merlins in part of the lower Deeside study area. The lower Deeside Merlin study began 1980 (Chapter 1.2, Figure 1.1), concurrently, some of the breeding territories were subject to varying degrees of afforestation over four phases during 1980 to 1994.

The first three phases of afforestation were overseen by Fountain Forestry (FF) and the FC and were established during 1980 to 1989 using typical methods. The preparatory work included burning off nearly all the shrub layer of heather, road construction, drainage and deep ploughing (e.g. Photograph 10). Commercial forestry schemes at that time typically composed of 90 to 95% plantation and 5 to 10% open ground, made up from forest roads and verges, riparian zones and land classed as un-plantable (Avery and Leslie 1990). The FF and FC schemes were planned with little consideration given to important fauna or flora. However, I was able to re-direct or delay some of the work in certain years to enable one or two pairs of Merlin or Short-eared Owl *Asio flammeus* to complete their breeding attempts without excessive disturbance. Further, in an effort to maintain the viability of one Merlin breeding territory, I installed an artificial crow nest (Appendix 7). Apart from these small concessions, the schemes were established to plan and this leads to the second hypothesis for the thesis.

Merlin breeding territories within the areas afforested by Fountain Forestry and the Forestry Commission will become less suitable for Merlin as the plantations age, leading to low occupancy and eventual abandonment.

Photograph 10. The type of preparatory work done by Fountain Forestry for the afforestation of moorland on lower Deeside during 1980 to 1989. The vegetation has been burned, and the ground drained and deep ploughed (G. W. Rebecca).

The fourth phase of afforestation was on part of Glen Dye Estate (GDE) and was initiated by Fasque Estates (FEs) in 1988. This created an unprecedented amount of local objection leading to a FC Regional Advisory Committee (RAC) assessment. The case was not resolved and was passed to the relevant Government Minister at the Scottish Office who approved it. The main objectors then proceeded with a Judicial Review, essentially a legal appeal. This was not successful and a complaint was then made to the EC in Brussels, concerning a breach of both the Birds and EA Directives. The objections, assessment, appeal and complaints lasted for years (full details are in Appendix 5). The planting actually began in 1990, and in an unofficial mitigation I negotiated with the head forester in an attempt to secure the viability of the three Merlin breeding territories involved. This included us re-planning the silvicultural procedure to avoid changing the habitat at the previous Merlin nesting sites and ensuring that disturbance nearby was minimal. The final scheme comprised of approximately 70% plantations and 30% open habitat (details in Appendix 5) and leads to the third hypothesis for the thesis.

Merlin breeding territories within the area afforested by Fasque Estates (the Glen Dye Estate area) will remain suitable for Merlin as the plantations age, and will be occupied at a similar level to those in the un-forested parts of the lower Deeside study area.

To investigate hypotheses two and three, the afforested areas were surveyed annually during 1980 to 2003 for the presence of Merlin. The remainder of the lower Deeside study area was also surveyed over the same period using the same methods allowing relevant comparison (Chapter 3).

The four phases of commercial afforestation were adjacent or close and formed a contiguous area, hereafter called the lower Deeside forestry zone (LDF). This area was largely separate from the remainder of the lower Deeside study area, which was mainly managed as "grouse moor" to promote the commercial shooting of Red Grouse (Watson and Millar 1976) and is hereafter called the lower Deeside managed grouse moor zone (LDMGM) (see Figures 3.1 and 3.2 later). A number of other Merlin territories on Deeside were monitored annually to the same qualitative level as in the lower Deeside study area (Rebecca *et al* 1992, Rebecca 1993, Cosnette and Rebecca 1997, Appendix 8). Most of them were in areas that were managed for Red Grouse, but included two on degenerate moor where the natural regeneration of Scots Pine was the main management objective. This allowed me to compare the Merlin's breeding ecology in two contrasting land-use zones, managed grouse moor (MGM) and commercially afforested moorland, covering two study areas, lower Deeside and mid and upper Deeside combined. It has been well documented that the avifauna of afforested moorland changes over time as the plantations mature (e.g. Jessop 1982, Moss *et al* 1979, Petty and Avery 1990). These environmental and ecological changes could impact on the breeding behaviour of Merlin; for example, by altering the quality of territories (the subject of hypotheses two and three), by changing prey availability, or by influencing the timing of breeding (phenology) and egg and clutch sizes, or by affecting productivity. Using the comparative approach, the following hypothesis was formulated to test whether there were any significant differences in aspects of Merlin breeding ecology during and after the establishment of the plantations in the LDF zone, compared to the LDMGM zone and the MGM areas in the mid and upper Deeside study area, hereafter called the mid and upper Deeside managed grouse moor zone (MUDMGM).

Merlin breeding in the afforested zone will have a different diet and breeding phenology, have different egg and clutch sizes and different productivity from those Merlin breeding in the managed grouse moor areas of the lower Deeside and mid and upper Deeside study areas.

To investigate this hypothesis, a large sample of occupied Merlin territories on Deeside were monitored during 1980 to 2003, with a full suite of relevant data on breeding ecology collected (Chapters 4 and 5).

The final chapter of the thesis summarises and concludes on the various aspects of the study. Recommendations are provided to foresters and conservation planners, with the aim of reducing conflict when land-use changes are proposed for large areas of Merlin breeding and hunting habitat (Chapter 6).

CHAPTER 2

BREEDING MERLIN AND COMMERCIAL CONIFEROUS AFFORESTATION IN BRITAIN DURING THE 1990s TO 2004

BREEDING MERLIN AND COMMERCIAL CONIFEROUS AFFORESTATION IN BRITAIN DURING THE 1990s TO 2003

2.1 Spatial and habitat related influences on the breeding performance of Merlin *Falco columbarius* in Britain in 1993 to 1994.

Summary

Capsule Some aspects of Merlin breeding biology are presented following a national survey in Britain during 1993 and 1994.

Aims To describe breeding habitat and nest site choice, and to assess and compare clutch size, successful brood size and productivity across years, habitat types, regional study areas and countries.

Methods The breeding range was compiled using data from two previous atlas publications, supplemented with more recent records. Regional study areas, where coverage was thorough, covered 53% of the range. For the remaining areas a random selection of 10 x 10 km squares were thoroughly surveyed. Data on breeding area location, habitat, nest site and clutch and brood sizes were noted on nest record forms, of which over 1000 were analysed.

Results Breeding areas were located near sea level to an altitude of 650 m, with a mean of 360 m. The main habitat surrounding nests was heather moor, found at 78% of breeding areas, with tall-conifer plantation or shelterbelts, and mixed grass-heather moor plus grass moor combined recorded at 9% and 9.5% of areas respectively. Nests were located on the ground at 77% of breeding areas, with 19% in old stick nests in trees and 2% on crags (2% changed nest site between years). Mean clutch size was 4.2 and 4.3 and mean productivity was 2.0 and 2.5 for 1993 and 1994 respectively. Unenclosed grass moor and mixed grass-heather moor held the most productive pairs with means of 2.7 fledged young. Dry heather moor, and mixed wet-dry heather moor held pairs with means of 2.3 and 2.1 fledged young respectively. Tall-conifer plantation or shelterbelts, and wet heather moor held the least productive pairs, with means of 1.9 fledged young.

Conclusions The habitat surrounding the vast majority of breeding areas composed of heather moor or a combination of heather-grass moor. Over 75% of nests were on the ground, with about 20% in trees. There were few tall-conifer plantation breeding areas located away from the well-documented localities. Compared to earlier studies, clutch and successful brood sizes had not changed significantly. Unseasonable harsh weather in 1993 negatively effected breeding success, however overall productivity for the two years, at 2.25 fledged young per pair, was probably adequate to maintain a stable population.

Introduction

A survey of breeding Merlin *Falco columbarius* in Britain took place in 1993 and 1994. The main aims were to formally estimate the population for the entire breeding range and to assess regional trends. The revised estimate of 1300 ± 200 breeding pairs was twice the previous maximum from 1983 to 1984 and in all areas where comparisons were made with earlier studies Merlins had increased or remained relatively stable (Rebecca and Bainbridge 1998). The survey was initiated in part because of inconsistent trends reported from regional studies (Newton *et al.* 1981, 1986, Roberts and Green 1983, Bibby 1986, Meek 1988, Ellis and Okill 1990, Brown and Shepherd 1991, Rebecca *et al.* 1992). Further, by the early 1990s in Wales, north-east England and south-west Scotland, Merlin were shown to have switched breeding areas, from traditional moorland localities to post-thicket conifer plantations, where they nested in old Carrion Crow *Corvus corone,* Hooded Crow *Corvus corvix* or Magpie *Pica pica* nests and were considered more elusive (Parr 1991, Little and Davison 1992, Orchel 1992). In Wales, this change was believed to have occurred by the early 1980s and been largely overlooked, at a period when the Welsh Merlin population was reported as declining (Parr 1994).

Conventional opinion in the 1970s and 1980s was that large-scale commercial afforestation of moorland or blanket bog had detrimental effects on breeding Merlin (and some other birds of high conservation interest e.g. Marquiss *et al.* 1978, 1985) particularly by reducing nesting and hunting habitat availability (Nature Conservancy Council 1986, Ratcliffe 1986, 1990, Bainbridge *et al.* 1987, Thompson *et al.* 1988, Avery and Leslie 1990, Petty and Avery 1990). In a review of the relationship between breeding Merlin and commercial forestry in Britain, Petty (1995) concluded that afforestation in Wales and north-east England had little detrimental effect, largely because there was extensive moorland nearby. Petty suggested that Merlins may have been utilising plantations throughout the rest of their breeding range and that it was a priority for this to be ascertained, endorsing the earlier views of Parr (1991) and Little and Davison (1992). The breeding distribution of Merlin (Rebecca and Bainbridge 1998) Carrion and Hooded Crows and Magpie (Gibbons *et al* 1993) and distribution of recent conifer plantations (Nature Conservancy Council 1986) could facilitate such nesting behaviour.

There appeared therefore to be a conservation dilemma: extensive conifer plantations were believed by many, to have negative effects on breeding Merlin, whereas in some areas plantations were providing suitable (possibly preferable) nest sites. The grant and taxation structure driving commercial forestry in Britain in the 1980s led to many conflicts between forest developers and nature conservationists, with the Merlin often one of the key species under debate (e.g. Bainbridge *et al.* 1987, Thompson *et al.* 1988, Avery and Leslie 1990). The nest record forms from the 1993 to 1994 survey provided an opportunity to quantify the Merlin's use of post-thicket conifer plantations as breeding sites, and examine spatial and habitat related variation in their breeding performance, from at least 57% of their recent range.

Methods

For the 1993 and 1994 survey, the breeding range was defined as all 10 x 10 km (10-km) ordnance survey squares from two British breeding bird atlases covering 1968 to 1972 and 1988 to 1991 plus any other squares with confirmed or probable breeding records up to 1992. Following discussion with experienced Merlin enthusiasts, the range was separated into **A** and **B** areas and survey instructions and methods were compiled, with the aim of ensuring consistent and thorough coverage. The **A** areas largely had existing Merlin breeding studies (e.g. Newton *et al.* 1986, Meek 1988, Ellis and Okill 1990, Rebecca *et al.* 1992) and were thoroughly surveyed covering 53% of the range. In the **B** areas, a number of 10-km squares were selected at random from a systematic sample of representative squares, and 36 were thoroughly surveyed (7.5% of the B areas) plus some additional pairs were located outwith the squares. A number of efficiency tests were undertaken that confirmed the methods were appropriate for locating breeding Merlin (Rebecca and Bainbridge 1998). For this paper, study areas in south Scotland were separated into south-east Scotland and south-west Scotland (Figure 2.1).

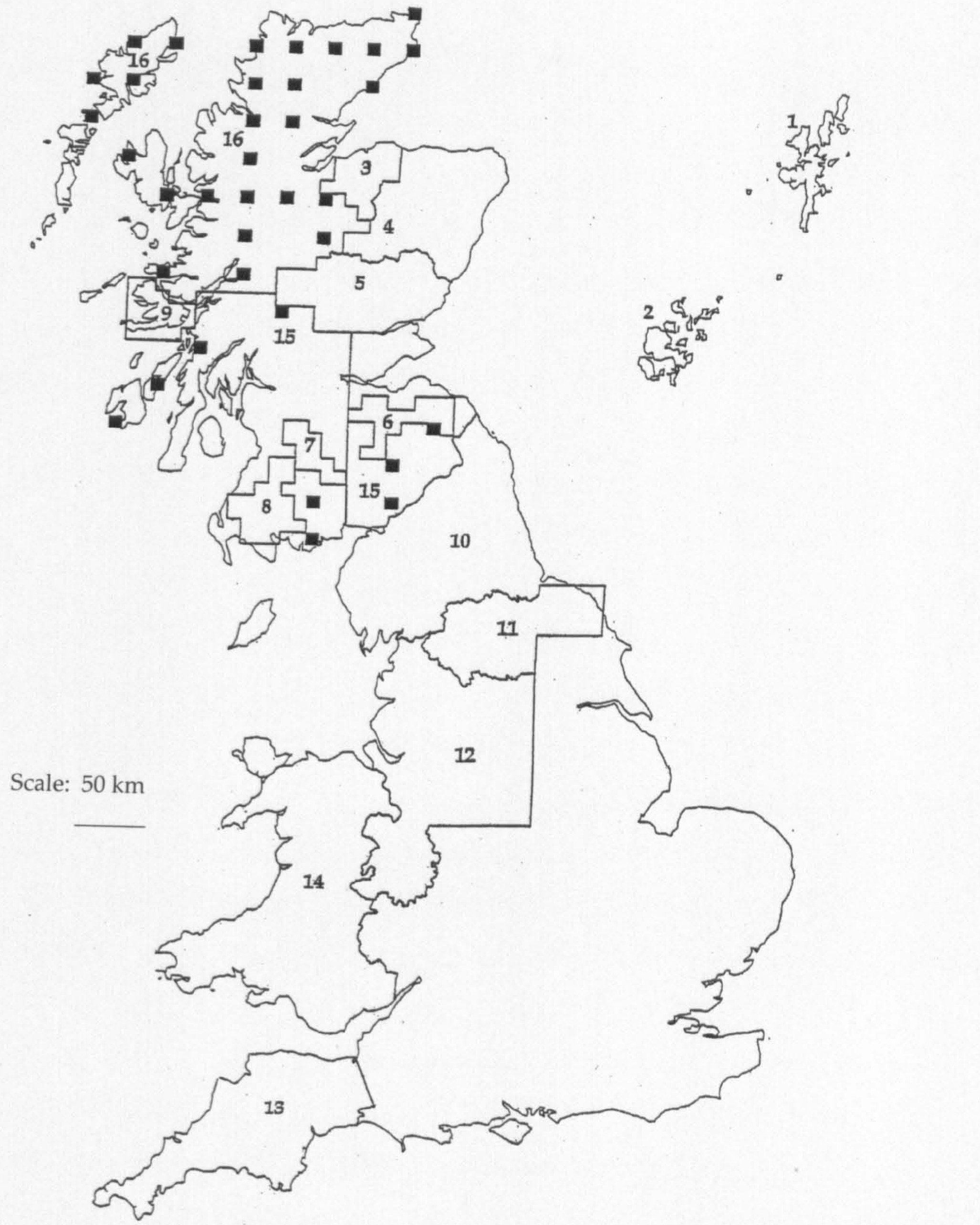


Figure 2.1 Division of the British Merlin breeding range for the 1993 and 1994 national survey. Study areas 1 to 14 were where coverage was essentially complete (apart from places with access restrictions) and were classed as **A** areas (see earlier text). Study areas 15 and 16 were where a random sample of 10 x 10 km squares were surveyed ■ and were classed as **B** areas (see earlier text). The Orkney and Shetland Isles have been moved for convenience (map adapted from Rebecca and Bainbridge 1998).

1 Shetland; 2 Orkney; 3 west Moray-east Highland; 4 north-east Scotland; 5 Tayside (excluding the Ochill Hills); 6 Lothian and Borders, and 15 east, represent south-east Scotland; 7 Muirkirk-Lowther, 8 Galloway, 9 Mull, and 15 west, represent south-west Scotland; 16 Highlands and Western Isles; 10 north Pennines and Lake District; 11 north Yorkshire; 12 south Pennines, Bowland and Shropshire; 13 south-west England; 14 Wales.

For some analyses, study areas in England and Scotland were each amalgamated as these countries and Wales have separate government conservation agencies, and country statistics can be required for some aspects of conservation planning. Observers recorded the six-figure grid reference and altitude of a nest, or central point of the breeding signs or behaviour, and classed the habitat according to the British Trust for Ornithology (BTO) system within a 1-km radius (Appendix 1). The upper altitudinal cut-off point for survey was set at 600 m following a review of published breeding site altitudes (e.g. Newton *et al.* 1978, Orchel 1992, Rebecca *et al.* 1992) and discussions with **A** area co-ordinators.

Confirmed or probable breeding was recorded if adults were seen going to or leaving an active nest, if eggs or eggshells were found, if young were seen or heard, if adults were repeatedly alarm calling, if a food delivery by the male was seen during May to July or if a pair were present and the signs found, such as prey remains, regurgitated pellets and faecal whitewash were consistent with breeding having occurred (e.g. Newton *et al.* 1978, Meek 1988, Ellis and Okill 1990, Rebecca *et al.* 1992). Nests were recorded on the ground, on a crag, or in a stick nest in a tree, with any other relevant information noted (e.g. tree species, type of stick nest). Details from the nest record forms and 1:25000 maps were combined and tree nest sites categorised as **a)** tall-conifer plantation (> 5 m) or shelter-belt (shelter plantation), **b)** isolated or low-density trees on moor, **c)** broad-leaved wood, **d)** native Scots Pine *Pinus sylvestris* wood or mature semi-natural pinewood. If the nest site was recorded in both years and was the same type, it was only described once. Data were provided for one year only from some areas; for example from parts of Wales, mainly covered in 1993 (Williams and Parr 1995) and north Yorkshire, mainly covered in 1994 and from the 10-km squares in the **B** areas.

Clutch size was determined if multiple checks were made during incubation, or if the date of a single visit was judged to be after the clutch was complete and there was no evidence of depletion. Previously in some **A** areas, some nests were not visited after the young were ringed (usually at 2 to 3½ weeks old), and this was taken as fledging (cf Newton *et al.* 1978). Merlins fledge at about four weeks old (Cramp and Simmons 1980) and in forested breeding areas it can be difficult to get an accurate count at that stage. To enable comparison between study areas and earlier published studies the brood size at the latter half of the fledgling period was used to measure success (at 2 to 4 weeks and described as late brood). This represented the maximum potential fledging rates, as some young may have been lost later (e.g. Newton *et al.* 1978, Rebecca *et al.* 1992). Dividing the total number of late brood young by the number of confirmed or probable breeding pairs, including nests that had failed earlier, assessed mean productivity for each study area.

A general linear model (GLM) was used to highlight relationships between year, study area, primary habitat and nest site on clutch size and productivity. Altitude was included in the model as a covariate. One-way analysis of variance (ANOVA) was used to compare differences in these parameters and successful brood size across countries, study areas and between years. All means are presented with 95% confidence intervals (CI). Calculations were done using Minitab software, version 13 (Minitab 2001).

Results

Habitat, altitude and nest sites

The primary and secondary habitat was recorded for 751 breeding areas (Appendix 2). Details of the primary habitat from study areas are in Table 2.1. Dry heath (D1) and wet heath (D2), dominated by *Calluna* and *Erica* heathers and a mixture of both (D3), when combined, were the most numerous primary habitat types in England (81.5%), Scotland (80%) and Wales (47.5%), and together covered 78% of breeding areas in Britain. Waterlogged bog (D4) was the primary habitat at 11% of breeding areas in the Highlands and Western Isles, with them all described as blanket bog "flow country" (see Stroud *et al.* 1987 for description). In south-west Scotland and Wales tall-conifer plantations or shelter-belts were the primary habitat at 48% and 45% of breeding areas respectively. In the north Pennines and Lake District, tall-conifer plantations or shelter-belts were the primary habitat at eight breeding areas (5%, Table 2.1) and the secondary habitat at 30 breeding areas (Appendix 2 b). For all of Britain, tall-conifer plantations or shelter-belts were the primary habitat at 9% of breeding areas. The other primary habitat to feature widely was mixed grass-heather moor, for example, at 7.5% of breeding areas in the Highlands and Western Isles, 8.5% in south-west Scotland, 10% in south-east Scotland and 25% in south

Pennines, Bowland and Shropshire. For all of Britain, mixed grass-heather moor was the primary habitat at 7% of breeding areas (Table 2.1).

Table 2.1 Primary habitat from BTO codes (far left column) as detailed in Appendix 1, within a 1-km radius of a Merlin nest or the centre of behaviour or signs. Figures in the main part of the table are percentages (%) from each study area for 751 nesting areas in Britain in 1993 or 1994.

SH = Shetland, OR = Orkney, H & WI = Highlands and Western Isles, WM & EH = west Moray and east Highland, NES = north-east Scotland, T = Tayside, SES = south-east Scotland, SWS = south-west Scotland, NP & LD = north Pennines and Lake District, NY = north Yorkshire, SPB & S = south Pennines, Bowland and Shropshire, S = Scotland, E = England, W = Wales, B = Britain.

BTO habitat codes	Study areas and number of nesting areas														
	SH	OR	H & WI	WM & EH	NES	T	SES	SWS	NP & LD	NY	SPB & S	S	E	W	B
	32	18	66	25	65	74	49	48	151	59	97	377	307	67	751
A1						5				5		1	1		1
A2			1.5		3	1	2	48	5	2		7	3	45	9
A3			3			1						1		1.5	0.5
B3					2							0.5			-
B5			1.5		2	3		2	1			1.5	0.5		1
C2			6			3			5		3	1.5	3.5	3	2.5
C3	3		7.5		2	3	10	8.5	6		25	5	10.5	3	7
D1	63	33	51.5	16	83	35	71.5	35.5	67	74	33	52	58	36	53
D2	6	56	4.5			7	4	2	3		1	6	2	10	5
D3	28	11	12	84	8	42	12.5	4	13	19	38	22	21.5	1.5	20
D4			11									2			1
I1			1.5									0.5			-

Note: Data from Appendix 2.

Altitude was recorded for 493 breeding areas in 1993 and 509 in 1994. Details of minimum, maximum and interquartile ranges, medians and means are shown in Figure 2.2. Maximum altitude was 650 m in Tayside, south-east Scotland and the north Pennines and Lake District, and the minimum was 10 m in Shetland. The mean altitude, from 1993 and 1994 respectively, was 450 ± 17 and 466 ± 21 m for Wales, 392 ± 12 and 389 ± 12 m for England and 315 ± 19 and 318 ± 19 m for Scotland. This gave means of 360 ± 11 m in 1993 and 358 ± 12 m in 1994 for Britain.

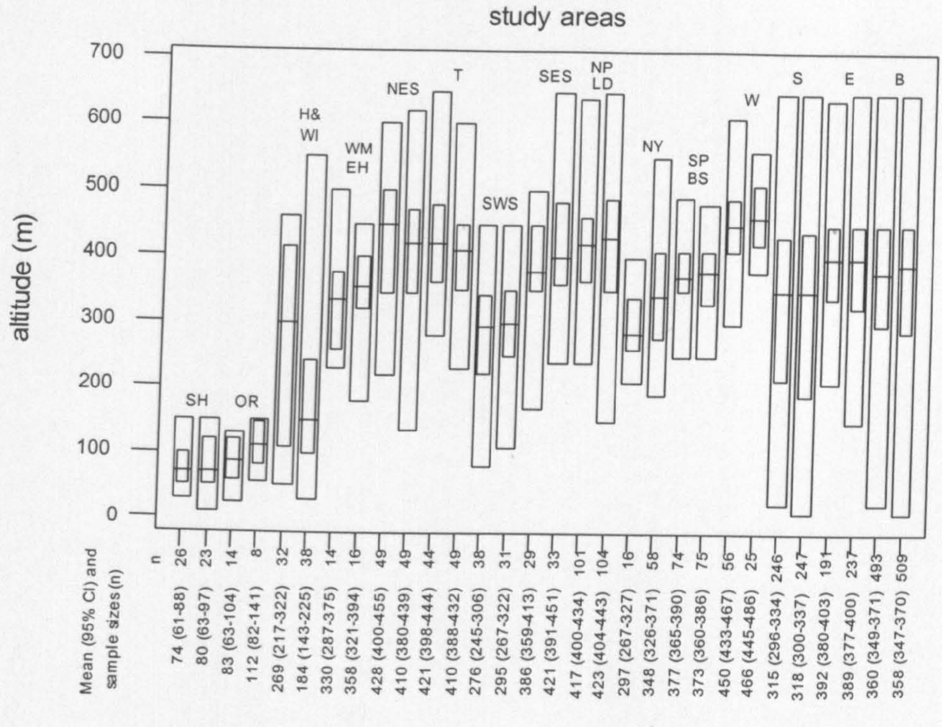


Figure 2.2. Altitudes (m) of Merlin breeding areas in Britain in 1993 and 1994. Study areas are labelled as abbreviated in Table 2.1 and have two columns each. Left and right columns represent 1993 and 1994 respectively. Large outer boxes show minimum and maximum ranges, small inner boxes show the interquartile ranges and horizontal bars show medians. Means and sample sizes, with 95% confidence intervals, are shown below the x axis.

The nest site was recorded from 730 breeding areas for all of Britain (Table 2.2) with 77% on the ground (86% of English, 74% of Scottish and 48% of Welsh sites). Old stick nests in trees were the next most numerous nest sites, with 13% in tall-conifer plantations or shelter-belts, 4% in scattered or isolated moorland trees, 1% in broad-leaved wood and 1% in Scots Pine wood or semi-natural pinewood, with crags providing 2% of sites. At 13 breeding areas (2%), the nest site type changed between years (Table 2.2 notes). Crag, Scots Pine wood or semi-natural pinewood and broad-leaved wood sites were all in Scotland, with the latter all in Tayside Birch *Betula* woods. There were few tall-conifer plantation or shelter-belt breeding areas away from the known localities in Wales, north-east England and south-west Scotland. Only six other tall-conifer plantation and three shelter-belt breeding areas were located, with a further two plantation and two shelter-belt sites among the breeding areas where the nest site type changed between years.

Table 2.2 Nest site situations used by Merlins in Britain in 1993 or 1994.

Study areas	Number of nesting areas	Ground	(%)	Crag	(%)	Old stick nest in tree: Tall conifer plantation or shelterbelt	(%)	Old stick nest in tree: Scattered or isolated on moor	(%)	Old stick nest in tree: Broad-leaved wood	(%)	Old stick nest in tree: Scots or semi-natural pinewood	(%)
Shetland[1]	30	25	(83)	1	(3)								
Orkney	16	16	(100)										
Highlands & Western Isles[2]	62	41	(66)	10	(16)	1	(2)	4	(6)			4	(6)
W. Moray and E. Highland[3]	22	20	(92)					1	(4)				
N.E. Scotland[4]	63	55	(87)			2	(3)	3	(5)			2	(3)
Tayside[5]	71	49	(69)	2	(3)	2	(3)	6	(8)	7	(10)	4	(6)
S.E. Scotland[6]	45	40	(89)					3	(7)				
S.W. Scotland[7]	50	21	(42)	3	(6)	24	(48)	1	(2)				
Scotland	359	267	(74)	16	(4)	29	(8)	18	(5)	7	(2)	10	(3)
North Pennines and Lake District	143	112	(78)			31	(22)						
North Yorkshire	59	58	(98)					1	(2)				
South Pennines, Bowland & Shropshire	98	91	(93)					7	(7)				
S.W. England	6	2	(33)			1	(17)	3	(50)				
England	306	263	(86)			32	(10)	11	(4)				
Wales[8]	65	31	(48)			31	(48)	2	(3)				
Britain	730	561	(77)	16	(2)	92	(13)	31	(4)	7	(1)	10	(1)

Notes : [1] and [2], includes four and two nesting areas respectively, where nest site was crag in one year and ground in other. [3] and [4], includes one nesting area where nest site was shelterbelt in one year and ground in other. [5], includes one nesting area where nest site was broad-leaved wood in one year and ground in other. [6], included two nesting areas where nest site was plantation and moorland tree in one year and ground in other. [7], includes one nesting area where nest site was young plantation in one year and ground in other. [8], includes one nesting area where nest site was plantation in one year and ground in other.
1-8 = 2% of British total.

Clutch size, productivity and successful brood size

Mean clutch sizes, productivity and successful brood sizes for 1993 and 1994 are detailed in Tables 2.3 and 2.4 respectively. The GLM revealed that the only variable significantly influencing clutch size was study area ($F_{11, 503} = 2.43$, $P = 0.006$). In 1993, there was no significant difference in clutch size across study areas or countries (one-way ANOVA, $F_{11, 247} = 1.29$, $P = 0.23$, and $F_{2, 247} = 1.38$, $P = 0.254$ respectively) but there was in 1994 ($F_{11, 255} = 2.27$, $P = 0.012$, and $F_{2, 255} = 3.98$, $P = 0.02$ respectively). In 1994, mean clutch size in Tayside was 4.7, compared to 4.1 in Shetland, north-east Scotland, north Pennines and Lake District and north Yorkshire, and 3.9 in Wales (Table 2.4). The overall mean clutch size for Britain was not significantly different between years (GLM, $F_{1, 503} = 2.00$, $P = 0.158$).

The GLM for productivity revealed that the effects of altitude and nest site were not significant ($F_{1, 882} = 0.87$, $P = 0.351$ and $F_{2, 882} = 0.22$, $P = 0.806$ respectively). In contrast, there was a highly significant influence of year and study area on productivity ($F_{1, 885} = 12.21$, $P < 0.001$ and $F_{11, 885} = 2.97$, $P = 0.001$ respectively) and a significant influence of primary habitat ($F_{11, 885} = 2.02$, $P = 0.017$). There was a highly significant difference between years for productivity in England (one-way ANOVA, $F_{1, 389} = 11.95$, $P = 0.001$) and a significant difference in Scotland ($F_{1, 435} = 5.78$, $P = 0.017$) but not in Wales ($F_{1, 66} = 2.68$, $P = 0.107$). Irrespective of the result from Wales, there was 0.5 (25%) more fledged young per pair for all of Britain in 1994 (Tables 2.3 and 2.4). In 1993 and 1994, there were significant differences in productivity across study areas (one-way ANOVA, $F_{11, 445} = 2.77$, $P = 0.002$ and $F_{11, 446} = 1.94$, $P = 0.033$ respectively). In 1993, the south Pennines, Bowland and Shropshire, north Yorkshire, Highland and Western Isles and west Moray and east Highland study areas all had means of at least 2.5 fledged young per pair, whereas the Wales, north Pennines and Lake District, south-west Scotland, south-east Scotland, Tayside and Orkney study areas all had means of less than 2.0 fledged young per pair (Table 2.3). In 1994, Wales had a mean of 1.1 fledged young per pair whereas all other study areas had means of between 2.0 and 3.0 fledged young per pair (Table 2.4).

***Table* 2.3** Mean clutch, maximum productivity (late brood/pairs) and successful brood sizes of Merlins in Britain in 1993. 95% confidence intervals are within brackets and n = sample sizes. Abbreviated study areas are as Table 2.1.

Study areas	Clutch size				Productivity				Successful brood			
	mean	(95% CI)	n	range	mean	(95% CI)	n	range	mean	(95% CI)	n	range
Shetland	4.3	(4.1-4.6)	21	3-5	2.1	(1.3-3.0)	26	0-5	3.9	(3.3-4.5)	14	2-5
Orkney	4.5	(4.2-4.9)	11	4-5	1.4	(0.3-3.0)	14	0-4	3.3	(2.1-4.6)	6	1-4
Highland & W Isles	4.4	(4.0-4.8)	9	4-5	2.8	(2.2-3.4)	26	0-5	3.2	(2.7-3.6)	23	1-5
W Moray & E Highland	4.3	(3.8-4.7)	7	4-5	3.2	(2.3-4.0)	13	0-5	3.4	(2.7-4.1)	12	2-5
north-east Scotland	4.3	(4.1-4.5)	33	3-5	2.0	(1.4-2.6)	44	0-5	3.3	(2.7-3.8)	27	1-5
Tayside	4.3	(4.1-4.5)	19	4-5	1.9	(1.4-2.5)	38	0-5	2.9	(2.4-3.4)	25	1-5
south-east Scotland	4.5	(4.2-4.8)	18	4-5	1.5	(0.8-2.1)	26	0-4	2.7	(2.1-3.3)	14	1-4
south-west Scotland	3.8	(3.2-4.4)	12	2-5	1.5	(1.0-2.0)	32	0-5	2.5	(2.0-3.0)	19	1-5
SCOTLAND	4.3	(4.2-4.4)	130	2-5	2.0	(1.8-2.2)	219	0-5	3.1	(2.9-3.3)	140	1-5
north Pennines & L D	4.3	(4.1-4.6)	43	2-5	1.7	(1.4-2.1)	99	0-5	2.9	(2.5-3.2)	59	1-5
north Yorkshire	4.1	(3.6-4.7)	8	3-5	2.6	(1.8-3.3)	16	0-4	3.2	(2.7-3.6)	13	2-4
south Pennines, B & S	4.4	(4.2-4.6)	46	2-5	2.6	(2.1-3.0)	63	0-5	3.5	(3.2-3.9)	46	1-5
south-west England			1	3			4	0-4			4	3-4
ENGLAND	4.3	(4.2-4.5)	98	2-5	2.1	(1.9-2.4)	182	0-5	3.2	(3.0-3.4)	122	1-5
WALES	4.1	(3.8-4.4)	21	3-5	1.9	(1.4-2.3)	49	0-5	3.0	(2.7-3.4)	30	1-5
BRITAIN	4.3	(4.2-4.4)	249	2-5	2.0	(1.9-2.2)	450	0-5	3.1	(3.0-3.3)	292	1-5

Table 2.4 Mean clutch, maximum productivity (late brood/pairs) and successful brood sizes of Merlins in Britain in 1994. 95% confidence intervals are within brackets and n = sample sizes. Abbreviated study areas are as Table 2.1.

Study areas	Clutch size				Productivity				Successful brood			
	mean	(95% CI)	n	range	mean	(95% CI)	n	range	mean	(95% CI)	n	range
Shetland	4.1	(3.8-4.5)	17	3-5	2.3	(1.5-3.1)	22	0-5	3.4	(2.9-3.9)	15	2-5
Orkney	4.3	(3.8-4.9)	6	4-5	3.0	(1.4-4.6)	8	0-5	4.0	(3.3-4.6)	6	3-5
Highland & W Isles	4.5	(4.2-4.9)	13	4-5	2.4	(1.8-3.1)	29	0-5	3.3	(2.9-3.8)	21	1-5
W Moray & E Highland	4.5	(4.1-4.9)	10	4-5	2.7	(1.6-3.7)	12	0-5	3.2	(2.4-4.0)	10	1-5
north-east Scotland	4.1	(3.9-4.3)	33	3-5	2.2	(1.6-2.8)	46	0-5	3.7	(3.3-4.1)	28	1-5
Tayside	4.7	(4.5-4.9)	19	4-5	2.6	(2.0-3.2)	43	0-5	3.8	(3.4-4.1)	29	2-5
south-east Scotland	4.4	(4.1-4.7)	20	3-5	2.0	(1.3-2.7)	30	0-5	3.3	(2.9-3.9)	18	2-5
south-east Scotland	4.2	(3.7-4.7)	10	3-5	2.6	(2.1-3.1)	27	0-4	3.0	(2.6-3.3)	24	1-4
SCOTLAND	4.3	(4.2-4.4)	128	3-5	2.4	(2.2-2.6)	217	0-5	3.5	(3.3-3.6)	151	1-5
north Pennines & L D	4.1	(3.9-4.3)	46	2-5	2.7	(2.4-3.0)	98	0-5	3.4	(3.2-3.6)	78	1-5
north Yorkshire	4.1	(3.9-4.3)	32	3-5	3.0	(2.6-3.4)	49	0-5	3.4	(3.1-3.7)	43	1-5
south Pennines, B & S	4.3	(4.1-4.5)	40	3-5	2.5	(2.1-3.0)	65	0-5	3.7	(3.4-4.0)	44	2-5
south-west England			3	1-4			4	0-4			2	1-4
ENGLAND	4.1	(4.0-4.2)	121	1-5	2.7	(2.5-2.9)	216	0-5	3.5	(3.3-3.6)	167	1-5
WALES	3.9	(3.7-4.1)	10	3-4	1.1	(0.3-2.0)	18	0-4	3.3	(2.5-4.2)	6	2-4
BRITAIN	4.2	(4.1-4.3)	259	1-5	2.5	(2.3-2.6)	451	0-5	3.5	(3.4-3.7)	324	1-5

The primary habitats that featured in 1% or less of breeding areas (A1, A3, B3, B5, D4 & I1 (Table 2.1)) were unlikely to have influenced productivity for all of Britain. For the remaining habitats, mean productivity for 1993 and 1994 was 2.70 ± 0.70 (n = 20) and 2.66 ± 0.47 (n = 59) for unenclosed grass moor and mixed grass-heather moor respectively. The next most productive habitats were dry heather moor and mixed wet-dry heather moor with means of 2.34 ± 0.16 (n = 504) and 2.14 ± 0.28 (n = 162) respectively. The least productive habitats were tall-conifer plantation or shelter-belt and wet heather moor with means of 1.94 ± 0.39 (n = 70) and 1.86 ± 0.56 (n = 42) respectively.

There were significant differences between years in successful brood size in England, Scotland and Wales (one-way ANOVA, $F_{1,282} = 5.83$, $P = 0.016$, $F_{1,290} = 6.98$, $P = 0.009$ and $F_{1,35} = 0.58$, $P = 0.0451$ respectively). When combined there was a highly significant difference for all of Britain ($F_{1,609} = 15.11$, $P < 0.001$) with an additional 0.4 (13%) fledged young per successful nest in 1994 (Tables 2.3 and 2.4).

Discussion

Habitat, altitude and nest sites

The association between breeding Merlin and heather or grass moorland and blanket bog is well known in Britain (e.g. Newton *et al.* 1978, Williams 1981, Bibby 1986, Haworth and Fielding 1988, Ellis and Okill 1990, Ratcliffe 1990) and the recent use of tall-conifer plantations was detailed earlier. Heather moor, unenclosed grass moor and mixed grass-heather moor were important habitats for breeding Merlin in Britain in the early-1990s holding 87.5% of the breeding areas under review. The latter two primary habitats held pairs that were the most productive, with means of 2.7 fledged young. Dry heather moor and mixed wet-dry heather moor held pairs that produced 2.3 and 2.1 fledged young respectively. These productivity figures are indicative of a stable or increasing population (see later).

The variety of primary and secondary habitats in Appendix 2, indicate that Merlin utilise a mosaic of habitats surrounding their immediate breeding environs. In the north Pennines and Lake District, the secondary habitat at 30 breeding areas was tall-conifer plantation or shelter-belt (20%, Appendix 2 b). At 23 of the areas, the nest was in a plantation or shelter-belt implying that these nests were probably situated at the edges or corners of the woods, and as such were adjacent to more open habitats (Table 2.2, Appendix 2 b). A similar situation can be inferred from the plantation or shelter-belt breeding areas in Highlands and Western Isles, north-east Scotland and Tayside. In the breeding areas where tall-conifer plantations or shelter-belts, or wet heather moor were the primary habitats, mean productivity was 1.9 fledged young per pair. One possible reason for the poorer productivity in tall-conifer plantations could be the increased risk of predation from Goshawks *Accipiter gentilis* and Tawny Owls *Strix aluco* (I. Williams *personal communication* for Wales, M. Davison and B. Little *personal communication* for Kielder Forest Northumbria, see also Petty *et al.* 2003).

In the early 1990s, open moorland was still considered vital for Merlin, as foraging habitat, in study areas with a high proportion of conifer plantation breeding areas (Little and Davison 1992, Orchel 1992, Parr 1992). Further evidence of the reliance of open habitats to breeding Merlin in Britain can be seen in recent studies of breeding season diet. In all areas the importance of open-country prey species prevailed (Newton *et al.* 1984, Bibby 1987, Meek 1988, Ellis and Okill 1990, Heavisides *et al.* 1995, Petty *et al.* 1995, Roberts and Jones 1999).

Breeding areas covered a wide altitudinal range from close to sea level in Shetland, Orkney and the Highlands and Western Isles up to 650 m in central and southern Scotland and northern England. There was no apparent difference in clutch size or productivity across the range, which was perhaps surprising considering that harsher climates are generally found at higher altitude (e.g. Elkins 1983, Newton 1998). In previous Merlin studies in Northumbria during 1961 to 1976 (maximum nest altitude 486 m, Newton *et al.* 1978) and north-east Scotland during 1980 to 1989 (a few breeding areas above 600 m, Rebecca *et al.* 1992) there was also no significant difference in breeding success across altitude zones.

Most Merlin in Britain appear to avoid nesting above 600 m, possibly because of the effects of climate, which also restricts tree and shrub growth above that approximate altitude in

Britain. At the other end of the altitudinal range the availability of suitable habitat was likely to be the main limiting factor in most areas. For example, in Wales Merlin bred on coastal heaths and sand dunes during 1967 to 1978 (Williams 1981). In 1993, no coastal or lowland Merlin were located in Wales, and most of these low altitude historical breeding areas are now believed to be unsuitable due to habitat change and recreational disturbance (Williams and Parr 1995). In 1993 to 1994, extensive heather moorland still existed at low altitude in Shetland, Orkney and the Highlands and Western Isles, and in the former two archipelagos, all Merlin breeding areas were at or below 150 m.

Nest site details were recorded at 730 breeding areas, approximately half the maximum estimate of breeding pairs. In 11 out of 14 **A** study areas, co-ordinators accurately predicted how many Merlin were breeding in a random selection of intensively surveyed 10-km squares (Rebecca and Bainbridge 1998). For the other three areas, the numbers located were slightly less than predicted. This implies that field-surveyors also previously knew the nest site types from their areas, and indeed there were no real surprises from the **A** areas. In particular, there were few tall-conifer plantation breeding areas located away from the well known localities in Wales, north-East England and south-west Scotland, and those that were located were previously known. Similarly, in the **B** areas there were no previously unknown tall-conifer plantation breeding areas located.

There were no crag nest sites reported from England or Wales, and the majority from Scotland were in the Highlands and Western Isles. A preference by Merlin for crag nesting in north-west Scotland had been reported previously (Thompson *et al.* 1989). Apart from Wales and south-west Scotland, where the proportion of ground and tree nesting areas were similar, and excluding the small population in south-west England, ground nest sites predominated in all other study areas (Table 2.2).

There were only 48 (6%) breeding areas in what could be described as natural or semi-natural tree sites, whereas there were 92 (13%) tall-conifer plantation or shelter-belt breeding areas. The distribution of mature conifer plantations and rough grazing in Britain in the early 1990s, largely overlapped the breeding ranges of the Merlin, Carrion and Hooded Crow (Nature Conservancy Council 1986, Gibbons *et al.* 1993, Rebecca and

Bainbridge 1998). However, in some study areas a lack of suitable old stick nests in trees, for example following game-keeping activities, could have limited the choice of nest site and biased selection towards ground nesting. Alternatively, the predominance of ground nesting over most of the breeding range may have occurred because of a long established habit and imprinting. Since the late 1980s, there have been different targets and incentives for new forestry in Britain (Mather 1991, Reid 1997), resulting in a large increase in new native pinewood and broad-leaved schemes. These new native woodlands, often established on heather or grass moor, will potentially provide future nest sites for Carrion and Hooded Crows and Magpies, and subsequently for Merlin, and the percentages above may change in future years.

This study has shown that tall-conifer plantation nesting by Merlin was not widespread across their British breeding range in the mid 1990s. Although there was only a partial survey in some areas, it is unlikely that there were any large numbers of tall-conifer plantation nesting Merlin away from the well-studied areas. There is a good network of Merlin study teams within the established raptor, upland and ringing groups, including parts of the **B** areas, and these enthusiasts are well positioned to detect if Merlin were regularly using plantations. The history of conifer plantation nesting by Merlin in Britain has been well documented and largely occurred after a combination of overgrazing and extensive afforestation of heather or grass moor (Newton *et al.* 1978, Parr 1991, 1994, Little and Davison 1992, Orchel 1992, Petty 1995). The events in Wales, where earlier reported declines were probably overestimated, and the studies in north-east England and south-west Scotland have alerted raptor workers to be aware of Merlin switching nest sites (e.g. Cosnette and Rebecca 1997, Wright 1997, Roberts and Jones 1999). Such nest site switching is likely to follow long-term habitat degradation, particularly the overgrazing of heather moor and, because of the commitment and quality of Merlin study teams, is now likely to be predictable and observed. Interestingly, some tall-conifer plantation breeding areas in Kielder Forest, Northumbria have recently been unoccupied and nearby ground nesting sites have been re-occupied. A decrease in the number of Carrion Crow nests, following increased culling by game-keepers to encourage Black Grouse *Tetrao tetrix*, and predation of crow broods by Goshawks and Buzzards *Buteo buteo* was believed to be the reason for this change in Merlin breeding behaviour (M. Davison and B. Little *personal communication*).

Clutch size, productivity and successful brood size

The mean clutch sizes for all of Britain, of 4.3 in 1993 and 4.2 in 1994 were within the range reported from recent Merlin studies (Table 2.5). There was no significant difference in clutch size between study areas or countries in 1993 but there was in 1994. Presumably, environmental conditions in the pre-egg-laying period were particularly favourable in Tayside in 1994 but not in England, north-east Scotland, Shetland and Wales (Table 2.4). An analysis of Merlin BTO nest record cards from 1937 to 1989 showed no trend in clutch size over time or between habitats or regions with an overall mean of 4.2 (Crick 1993). The sample sizes and means from 1993 and 1994 indicate that Merlin clutches have changed little since these earlier records (Table 2.5).

Table 2.5 Mean clutch, successful brood size and productivity of Merlins from studies in Britain during 1937 to 1997. n = sample sizes.

Areas	Years	Mean clutch	n	Mean successful brood	n	Mean productivity	n	Comments
Wales[1]	1967-78	3.9*	55	3.2	72	-	-	broods in last week
Northumbria[2]	1961-76	4.4	106	3.3	130	-	-	broods > ½ grown
Northumbria[3]	1974-83	4.2	194	3.3	153	-	-	broods > ½ grown
Britain[4]	1983-84	-	-	3.5	325	2.3	498	national survey
Orkney[5]	1981-87	3.9	51	2.9	27	1.3	61	declining
Shetland[6]	1984-87	4.2	59	3.4	61	2.4	90	recovering
N-E Scotland[7]	1980-89	4.4	195	3.5>3.0	166	2.2>1.7	232	stable
Britain[8]	1937-89	4.2	615	3.6	280	2.1	140	BTO nest records
N Yorkshire[9]	1983-94	4.2	82	3.4	82	2.9	82	stable
N-E Wales[10]	1964-97	4.2	72	3.3	43	1.8	68	declining
Britain[11]	1993	4.3	249	3.1	292	2.0	450	broods > ½ grown
Britain[12]	1994	4.2	259	3.5	324	2.5	451	broods > ½ grown

[1] Williams 1981, [2] Newton *et al.* 1978, [3] Newton *et al.* 1986, [4] Bibby & Nattrass 1986, [5] Meek 1988, [6] Ellis & Okill 1990, [7] Rebecca *et al.* 1992, [8] Crick 1993, [9] Wright 1997, [10] Roberts & Jones 1999, [11&12] this study. * Possibly includes some incomplete or depleted clutches.

Merlin increased in Britain between successive national surveys in 1983 to 1984 and 1993 to 1994, with the population almost doubling in size. In all areas where it was possible to make realistic comparisons, Merlin were either relatively stable or had increased (Rebecca and Bainbridge 1998). This implies that overall productivity and over-winter survival must have been at an adequate level, at least during that decade, to facilitate the recovery. Previous estimates of the productivity likely to maintain a stable Merlin population, at 2.5 fledged young per pair per year, were based on ringing data and breeding success (Brown 1976, Olsson 1980). Further, Bibby (1986) reasoned that if Merlin had similar survival rates to the well-studied Eurasian Sparrowhawk *Accipiter nisus* and bred at two years old, productivity would need to be about 2.6 young per pair per year to maintain numbers. However, Petty (1995) questioned these figures because of the inadequacy of the data, and highlighted that Merlin in Shetland (1978 to 1987), north-east Scotland (1980 to 1989) and Kielder Forest, Northumbria (1978 to 1989) produced less than 2.5 fledged young annually and were either increasing or stable. Petty also highlighted that once productivity reached 2.0 fledged young per pair per year, previously depressed populations began to recover. This suggests that the productivity in 1993, at 2.0 young per pair and in 1994, at 2.5 young per pair was representative of an increasing or stable population, which was the main conclusion from the 1993 to 1994 survey (Rebecca and Bainbridge 1998). Further evidence of similar productivity figures and Merlin breeding status are shown in Table 2.5.

Adverse weather can negatively affect breeding performance in a variety of birds (Elkins 1983, Newton 1998) with ground nesting species particularly vulnerable to excessive precipitation (e.g. Moss 1985). In mid-May 1993, there was unexpected heavy snow over many areas of upland Britain. This unseasonable weather coincided with the usual main egg-laying or early incubation periods of the Merlin in Britain (Cramp and Simmons 1980). The worst effected areas appear to have been in north England, south Scotland and Tayside in central Scotland. For example, approximately 12 to 25 cm of snow was lying over Merlin breeding areas in the north Pennines and Lake District during 13 to 15 May (M. Davison, I. Findlay, W. Johnston, B. Little, M. Nattrass and M. Stott *nest record forms*). Heavy snow also lay over breeding areas in south-west Scotland during 13 to 16 May (R. Roxburgh and R. Stakim *nest record forms*) and approximately 15 cm covered breeding areas on Tayside on 14 May (W. Mattingly *nest record forms*). Overall, the snow was given as the main cause of the reduced productivity in these areas in 1993 (e.g. Little *et al* 1995). This unseasonable harsh weather and resulting low overall productivity led to 1993 being described as a bad year for breeding Merlin. In comparison, 1994 could logically be described as either an average or a good year (although data from a run of years would be necessary to determine which of these was the case).

Mean brood sizes from successful nests from all of Britain in 1993 and 1994 were also within the range reported from recent Merlin studies in Britain apart from the declining population in Orkney in 1981 to 1987 (Table 2.5). However, in 1993 there were many partial failures linked to the adverse weather in mid-May, particularly in north England, and south and central Scotland, and this reduced mean overall successful brood size to 3.1 in comparison to 3.5 for 1994.

Conservation status in Britain

The improving status of the Merlin during the 1990s, led to the species being moved from the Red to the Amber list of Birds of Conservation Concern (BoCC) (Gregory *et al.* 2002). The criterion used for this assessment was based on short-term population recovery. The factors determining changes from Red to Amber were; an increase by more than 100% in 25 years, a minimum of 100 breeding pairs and not on the globally threatened list as classified by the International Union for the Conservation of Nature. The Merlin would, however, return to the Red list category at the next BoCC review in 2007, if the recovery were to falter (J. Hughes *personal communication*).

Brown (1976) recognised that biases were likely in his productivity estimate for Merlin, and stated that there was a need for detailed study of productivity with meaningful samples from several areas. Other authors have endorsed this view stating that more details of Merlin breeding behaviour and ecology, such as adult survival and mortality, age of first breeding, movements between populations and productivity over time are necessary to evaluate population structure (Newton *et al.* 1986, Rebecca *et al.* 1992, Petty 1995, Rebecca and Bainbridge 1998). This study has provided further information into improving our understanding of some of the factors that underpin the population dynamics of this enigmatic small falcon.

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Appendix 1. Selected BTO habitat codes to levels one and two, assessed as suitable for use for the Merlin breeding survey in Britain in 1993 to 1994 (from Crick 1992). One code was used for the primary habitat and a second for the secondary habitat if there was a mixture. Habitats B6, C4, D6, E4, I3 and I5 were not recorded as primary or secondary habitats in any of the nest records forms and were not included in Appendix 2. Habitats B1, C5, E1, E2, E3 and I2 were not recorded as primary habitat in any of the nest records forms and were not included in Table 1.

A	***Woodland: more than 5 m tall***	***B***	***Scrubland: or very young woodland less than 5 m tall***
1	broadleaved	1	regenerating natural or semi-natural woodland
2	coniferous	3	heath scrub (on heath)
3	A1/A2 mix >10% of each	5	new plantation
		6	clear-felled woodland
C	***Semi-natural Grassland***	***D***	***Heath and Bogs***
2	unenclosed grass moor	1	dry heath } dominated by *Calluna*
3	mixed grass and heather moor	2	wet heath } and *Erica* heathers
4	machair	3	mixed wet and dry heath
5	other dry grassland	4	waterlogged bog
		6	drained bog
E	***Farmland***	***I***	***Inland Rock***
1	improved grassland	1	cliff or crag
2	unimproved grassland	2	scree and boulder slope
3	mixed grass and tilled fields	3	limestone pavement
4	annually tilled land	5	quarry

Appendix 2 a. Primary and secondary habitat, from BTO habitat codes as detailed in Appendix 1, within a 1-km radius of a Merlin nest or the centre of behaviour or signs in Britain in 1993-94. If no secondary habitat was recorded, the primary habitat was used. The number of breeding areas in the study areas are in brackets.

SHETLAND (32) — Secondary Habitat (columns); Primary Habitat (rows)

	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	E3	I1	I2
A1																		
A2																		
A3																		
B1																		
B3																		
B5																		
C2																		
C3												1						
C5																		
D1							1	15	1					2	1			
D2								1					1					
D3								2				4		2	1			
D4																		
E1																		
E2																		
E3																		
I1																		
I2																		

ORKNEY (18) — Secondary Habitat (columns); Primary Habitat (rows)

	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	E3	I1	I2
A1																		
A2																		
A3																		
B1																		
B3																		
B5																		
C2																		
C3																		
C5																		
D1										2		2	2					
D2											9		1					
D3												1	1					
D4																		
E1																		
E2																		
E3																		
I1																		
I2																		

HIGHLAND & WESTERN ISLES (66) — Secondary Habitat (columns); Primary Habitat (rows)

	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	E3	I1	I2
A1																		
A2													1					
A3													1				1	
B1																		
B3																		
B5													1					
C2										4								
C3								2		2	1							
C5																		
D1	1	2		1				4		16	3		5				1	1
D2								1			1							1
D3		4		1								1	1				1	
D4							1	1		2		3						
E1																		
E2																		
E3																		
I1										1								
I2																		

W. MORAY & E. HIGHLAND (25) — Secondary Habitat (columns); Primary Habitat (rows)

	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	E3	I1	I2
A1																		
A2																		
A3																		
B1																		
B3																		
B5																		
C2																		
C3																		
C5																		
D1					1					3								
D2																		
D3	1	4				3						12			1			
D4																		
E1																		
E2																		
E3																		
I1																		
I2																		

N. E. SCOTLAND (65) — Secondary Habitat (columns); Primary Habitat (rows)

	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	E3	I1	I2
A1																		
A2					1					1								
A3																		
B1																		
B3						1												
B5					1													
C2																		
C3										1								
C5																		
D1	1	9		6	2	1		7		17	4	3						5
D2																		
D3		4											1					
D4																		
E1																		
E2																		
E3																		
I1																		
I2																		

TAYSIDE (74) — Secondary Habitat (columns); Primary Habitat (rows)

	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	E3	I1	I2
A1							1	2		1								
A2											1							
A3												1						
B1																		
B3																		
B5						1						1						
C2							1					1						
C3								1						1				
C5																		
D1		2				2		2		18					2			
D2						1					3			1				
D3	3	6	3	1		1						15	1	1				
D4																		
E1																		
E2																		
E3																		
I1																		
I2																		

Appendix 2 b. Primary and secondary habitat, from BTO habitat codes as detailed in Appendix 1, within a 1-km radius of a Merlin nest or the centre of behaviour or signs in Britain in 1993-94. If no secondary habitat was recorded, the primary habitat was used. The number of breeding areas in the study areas are in brackets.

S. E. SCOTLAND (49)

Primary habitat \ Secondary Habitat	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	E3	I1	I2
A1																		
A2								1										
A3																		
B1																		
B3																		
B5																		
C2																		
C3								5										
C5																		
D1								1		34								
D2																		2
D3												6						
D4																		
E1																		
E2																		
E3																		
I1																		
I2																		

S. W. SCOTLAND (48)

Primary habitat \ Secondary Habitat	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	E3	I1	I2
A1																		
A2						2	2	15		1	1	2						
A3																		
B1																		
B3																		
B5						1												
C2																		
C3		2						2										
C5																		
D1								6		10	1							
D2											1							
D3												2						
D4																		
E1																		
E2																		
E3																		
I1																		
I2																		

N. PENNINES & LAKE DISTRICT (151)

Primary habitat \ Secondary Habitat	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	E3	I1	I2
A1																		
A2								6		2								
A3																		
B1																		
B3																		
B5		1																
C2		8																
C3		8						1										
C5																		
D1		12					1	4		84								
D2						1	1				3							
D3		1										18						
D4																		
E1																		
E2																		
E3																		
I1																		
I2																		

NORTH YORKSHIRE (59)

Primary habitat \ Secondary Habitat	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	E3	I1	I2
A1										3								
A2										1								
A3																		
B1																		
B3																		
B5																		
C2																		
C3																		
C5																		
D1	2	2	1				4	1		29	2			1		2		
D2																		
D3		1						1				9						
D4																		
E1																		
E2																		
E3																		
I1																		
I2																		

S. PENNINES, BOWLAND & SHROPSHIRE (97)

Primary habitat \ Secondary Habitat	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	D3	I1	I2
A1																		
A2																		
A3																		
B1																		
B3																		
B5																		
C2							2				1							
C3								24										
C5																		
D1		1						3		28								
D2									1									
D3		3						6			28							
D4																		
E1																		
E2																		
E3																		
I1																		
I2																		

Appendix 2 c. Primary and secondary habitat, from BTO habitat codes as detailed in Appendix 1, within a 1-km radius of a Merlin nest or the centre of behaviour or signs in Britain in 1993-94. If no secondary habitat was recorded, the primary habitat was used. The number of breeding areas in the study areas are in brackets.

SCOTLAND (377)

Secondary Habitat

PRIMARY HABITAT	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	E3	I1	I2
A1							1	2		1								
A2					1	2	2	16		2	2	2	1					
A3												1	1				1	
B1																		
B3						1												
B5					1	2						1	1					
C2							1			4		1						
C3		2						10		3	1	1		1				
C5																		
D1	2	13		7	3	3	1	35	1	100	8	5	7	2	3		1	6
D2						1		2			13		2	1				4
D3	4	18	3	2		4		2				41	4	3	2		1	
D4							1	1		2		3						
E1																		
E2																		
E3																		
I1										1								
I2																		

ENGLAND (307)

Secondary Habitat

PRIMARY HABITAT	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	E3	I1	I2
A1										3								
A2								6		3								
A3																		
B1																		
B3																		
B5		1																
C2		8					2				1							
C3		8						25										
C5																		
D1	2	15	1				5	8		141	2			1		2		
D2						1	1		1		3							
D3		5						7				55						
D4																		
E1																		
E2																		
E3																		
I1																		
I2																		

WALES (67)

Secondary Habitat

PRIMARY HABITAT	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	D3	I1	I2
A1																		
A2							15	9			6							
A3										1								
B1																		
B3																		
B5																		
C2		1						1										
C3		1																1
C5																		
D1		4						1		7	12							
D2										2	5							
D3							1											
D4																		
E1																		
E2																		
E3																		
I1																		
I2																		

BRITAIN (751)

Secondary Habitat

PRIMARY HABITAT	A1	A2	A3	B1	B3	B5	C2	C3	C5	D1	D2	D3	D4	E1	E2	E3	I1	I2
A1							1	2		4								
A2					1	2	17	31		5	8	2	1					
A3										1		1	1				1	
B1																		
B3						1												
B5		1			1	2						1	1					
C2		9					3	1		4	1	1						
C3		11						35		3	1	1		1				1
C5																		
D1	4	32	1	7	3	3	6	44	1	248	22	5	7	3	3	2	1	6
D2						2	1	2	1	2	21		2	1				4
D3	4	23	3	2		4	1	9				96	4	3	2		1	
D4							1	1		2		3						
E1																		
E2																		
E3																		
I1										1								
I2																		

2.2 Nest site selection from publications on British breeding Merlin during 1995 to 2004.

I located eight relevant publications on British breeding Merlin between 1995 and 2004. They covered studies in north-east Scotland, Tayside, south-west Scotland, Kielder Forest in Northumbria, the Yorkshire Dales, the south Pennines and north-east Wales. The studies were all part of larger areas that were identified as A study areas for the Merlin survey in 1993 to 1994 (Chapter 2.1 Methods and Appendix 6). There were no previously unknown large numbers of conifer plantation nesting Merlin reported, and the various nest site choices are summarised below in general chronological order.

In Kielder Forest Northumbria, Little *et al* (1995) reported a significant increase in conifer plantation edge Merlin nesting, from one pair in 1979 to 20 pairs in 1992 and 1993. They reasoned that the increase was facilitated by some plantations reached the size that Carrion Crows and Magpies would nest in. The existence of this plantation nesting population had previously been documented (Little and Davison 1992). In Angus Tayside, a Merlin population was estimated at 15 to 20 breeding pairs following surveys during 1983 to 1995 (Downing 1996). The vast majority of nests were on the ground in heather, with occasional nests in isolated moorland trees or fragmented semi-natural Scots Pine wood (Bruce Anderson, Ron Downing, Sandy Payne and Graham Rebecca *personal observations*). In Aberdeenshire north-east Scotland, an annual Merlin survey in 1993 to 1996 located an average of 33 breeding pairs (Cosnette and Rebecca 1997). Ground nesting in heather occurred at 86% of the nesting areas, with the remainder in old stick nests in isolated trees (e.g. see Appendix 7) or in open fragmented Caledonian Scots Pine forest surrounded by moorland, and once each in an old Common Buzzard *Buteo buteo* nest in a shelter-belt and old Carrion Crow nest in a mature conifer plantation. In the Yorkshire Dales, Wright (1997) reported on a stable, ground nesting Merlin population of 6 to 8 pairs during 1983 to 1994. In total, 82 nests were located on moorland managed for Red Grouse shooting. The study moor had scattered Scots Pine and various native broad-leaves with some crow nests, and was partly bordered by conifer plantations. Despite targeted searches, there were no records of tree nesting Merlin during the study. In the south Pennines, Brown and Stillman (1998) reported on the dramatic recovery of the Merlin, from two pairs in 1980 to 65 in 1992. The vast majority of nests were on the ground with a few in moorland trees.

There was no nests located in conifer plantations and the authors suggested that since the area held a smaller proportion of plantations, in comparison to parts of Wales, north-east England and south-west Scotland, this may have biased the Merlin nest site choice towards ground nesting. In a smaller area of the south Pennines, covering 152 km², Fielding and Haworth (2003) reported on an increasing Merlin population of three pairs in 1982 to 11 in 1995. They located 96 nests on the ground and one in an old crow nest in a tree. In a fluctuating Merlin population in north-east Wales, 24 nests were located during 1983 to 1997, with 23 on the ground and one in an old stick nest in a mature conifer plantation (Roberts and Jones 1999). In Galloway south-west Scotland, 54 Merlin breeding areas were identified during 1965 to 1998, with 89 nests located. Ground nesting occurred on 52 occasions (58%), 17 (19%) were in old stick nests in trees, 18 (21%) on crags and two (2%) on top of boulders (Dickson 2000). The boundaries in Dickson's Galloway study area were not defined and it is likely that most of the tree sites were in plantations and previously reported (Shaw 1994).

2.3 Current assessment of commercial conifer plantation nesting by Merlins in well-studied areas in Britain during 1995 to 2004.

During 2003 and 2004, I contacted many Merlin study area co-ordinators or key field surveyors to request up-to-date information on the current nest site choices from their areas. I specifically discussed the coverage at, and usage of commercial conifer plantations. This was a logical step after similar discussions in 1992 during the planning of the 1993 to 1994 national Merlin survey. Some individuals were unavailable or had given up a co-ordinating role. In these cases, the RSPB regional network and raptor or upland bird-study groups were used to identify the relevant people to contact. The study regions used for the Merlin survey in 1993 to 1994 were followed here (Appendix 6) and are discussed from a general north to south perspective.

In the Shetland and Orkney Isles, there are no commercial conifer plantations and all recent Merlin nests have been located on the ground or on small crags (Pete Ellis and Eric Meek *personal communications respectively)*. In Shetland, Merlins have declined since 1987, with the population now considered to be below 20 pairs. Some of these pairs regularly use old Hooded Crow nests on the ground in this largely treeless landscape (Okill 2004). In the

Highlands and Western Isles, there was no general increase in the use of conifer plantations by Merlin during 1995 to 2003 (Jim Craib *personal communication*). However, the annual Merlin monitoring in this region focuses on typical moorland territories. Further, on the island of Skye, in the Inner Hebrides, two pairs of Merlin nested in commercial conifer plantations in 2002. This was the first time on record that Merlins had used old Hooded Crow nests in trees on Skye (Bob McMillan *personal observations* via Jim Craib). Interestingly, at Forsinard RSPB Nature Reserve in the blanket bog 'flow country' of Sutherland (see Chapter 2.1 habitat results) many contentious conifer plantations (Chapter 1.7) have recently been removed as part of a habitat improvement scheme, funded by a European Community Life Peatland Restoration Project (Norrie Russell *personal communication).* In the 1990s, two or three out of six regular breeding pairs of Merlin on the Nature Reserve, were nesting in old crow nests in commercial conifer plantations, but in 2003 all nests were on the ground, situated on dry heather knolls (Norrie Russell *personal communication*).

In east Highland and west Moray, no conifer plantation nesting by Merlin was recorded during 1995 to 2003 (Jim Craib *personal communication*). Similarly, in the adjoining north-east Scotland study area, no conifer plantation breeding attempts were located during 1997 to 2003, despite some targeted survey of plantations (Brian Cosnette and Graham Rebecca *personal observations*). In Tayside, Merlins were still using a small number of conifer plantations in Perthshire in 2003. A slight decrease in Merlin numbers at typical moorland areas in Perthshire in the late 1990s did not result in a proportional increase in the use of conifer plantations (Wendy Mattingley *personal communication*). In Angus, the other county in Tayside, there were no records of Merlin occupying conifer plantations during 1983 to 2003, but there was one successful nest in a conifer shelter-belt in 1996 (Ron Downing *personal communication*).

In south Scotland, one of the main Merlin study areas covers the Lammermuir Hills (see Heavisides *et al* 1995 for details). This area holds around 15 breeding pairs annually, with virtually all nests on the ground and an occasional one in an old crow nest in a moorland tree. However, in 2002 the first record of a conifer plantation nesting Merlin occurred in a large plantation to the east of the main study area (Alan Heavisides *personal* *communication*). In Galloway, in the far south-west of the region a specific forest edge Merlin study was carried out in 1993 to 1994 as part of the national survey (Shaw 1994). Since then, the annual coverage has been patchy and not systematic. Although this has resulted in the population not being accurately assessed during 1995 to 2004, it is believed that numbers are similar to those in the early 1990s (Geoff Shaw *personal communication*). In the heavily afforested Cowal peninsula in Argyll, a number of conifer plantation nesting Merlin have recently been located, with 6 or 7 pairs estimated (Dave Anderson and Arthur French *personal communications*). For the remainder of south-west Scotland there has been no reported change in conifer plantation use by Merlins (Roger Broad, Ricky Gladwell and Ian Miller *personal communications*).

In the north Pennines and Lake District, there are a number of long-term Merlin studies. For example, the well studied uplands of Northumbria, where some of the earliest records of commercial conifer plantation nesting by Merlin were documented (Newton *et al* 1978, 1986 and details in Chapter 2.2). The plantation nesting Merlin population in Northumbria had levelled off by the late 1990s, and in 2002 and 2003, a number of areas were unoccupied. This coincided with nearby ground nesting areas being re-occupied. A likely reason for this change in Merlin breeding behaviour was a decrease in Carrion Crow nests. This followed an increased cull of adult crows by game-keepers to encourage Black Grouse and predation of crow broods by Goshawks and Common Buzzards (Martin Davison and Brian Little *personal communications*). In the long-term Merlin study on the Durham grouse moors during 1983 to 2003, there has been no recorded conifer plantation nesting by Merlin, and all nests were on the ground in heather (Mike Nattrass *personal communication*). In Cumbria, there has not been adequate coverage of the commercial conifer plantations since the survey in 1993 to 1994. However, the ground nesting Merlin population has been monitored, and is considered relatively stable, suggesting that the small number of plantation sites located in 1993 and 1994 are probably still occupied (Dave Shackelton *personal communication*). In north Yorkshire, there have been no records of conifer plantation nesting by Merlin since the two main studies began (Peter Wright and Wilf Norman *personal communications*). These studies developed after the first Merlin breeding survey in 1983 to 1984 (Bibby and Nattrass 1986), with one covering parts of the Yorkshire Dales National Park and the other covering the North York Moors National Park.

Throughout the 1990s, the plantation edges were surveyed for Merlin in both study areas. In addition, other ecological studies in the respective National Parks have complemented the Merlin monitoring and the co-ordinators are confident that very few, if any, plantation nesting Merlin occur in north Yorkshire. In the south Pennines, Forest of Bowland and Shropshire area, no records of conifer plantation nesting by Merlin have been recorded. Virtually all the breeding territories hold ground nesting pairs, with a few moorland tree sites (Tim Melling, Sean Reed and Mick Taylor *personal communications*). Similarly, there have been no recent records of conifer plantation breeding Merlin from the small population in south-west England (Rob Townend *personal communication*).

In Wales, recent coverage of Merlin breeding areas has varied. In the south, there have been no systematic surveys since 1993, with the occasional breeding record usually from a conifer plantation or shelter-belt. In mid Wales coverage has been poor. However, a systematic survey of the Elenydd Special Protection Area[2] in 2003 located eight breeding pairs, seven in conifer plantations and one on the ground on moorland (a similar survey in 1993 found eight conifer plantation pairs). In the north, where coverage is relatively good, there has been no obvious change in the proportion of conifer plantation to ground nesting. In summary, the best recent evidence indicates no significant change in the proportion of conifer plantation nesting by Merlin in Wales (Andy Young *personal communication*).

2.4 Summary

The first hypothesis for the thesis stated that Merlins were ***"nesting in substantial numbers in post-thicket commercial conifer plantations where these were available in their British breeding range"***. I have not found any serious evidence to suggest that this is the case. In contrast, it would appear that Merlins are not widespread users of commercial conifer plantations throughout their British breeding range.

[2] *The 1979 EC Wild Birds Directive and the 1992 EC Habitats Directive provide an opportunity for areas in Britain to be given International recognition. These Directives aim to establish a series of protective sites on land and at sea – Natura 2000 areas – which will represent some of the finest nature conservation areas in the European Community. Natura 2000 areas include Special Protection Areas for birds designated under the Wild Birds Directive (Scottish Natural Heritage 1996).*

The analysis of over 1000 nest records from 1993 and 1994 did not reveal any unknown large numbers of plantation nesting Merlin. Further, there was only an occasional plantation nesting record from the recent publications (as had been previously reported from these well studied areas). The personal contact with study co-ordinators, experienced field-surveyors and raptor groups enabled an up-to-date assessment to be made for many areas where local Merlin populations are well known. In the vast majority of areas, coniferous plantation nesting by Merlins was infrequent. Interestingly, at two widely separate areas, north Scotland and north-east England, a change in management resulted in Merlins re-occupying ground nesting sites. The only areas to reveal a hitherto unknown population of conifer plantation nesting Merlin were at the Cowal Peninsula in Argyll, where 6 or 7 pairs were estimated and in Skye, where two pairs were recently located.

Combining the evidence from the mid-to-late 1990s to 2004 shows that conifer plantation nesting by Merlins was widespread and established in north England and south-west Scotland, and probably also in Wales (as had been described earlier). Outwith these areas, there were a few scattered records from Scotland. Although there are still some parts of north and west Scotland where the annual coverage of Merlin breeding areas, or apparently suitable Merlin breeding habitat is poor, it is unlikely that any large numbers of plantation Merlin remain unknown. There have been many other national bird surveys within the relevant areas in recent years, for example, Golden Eagle (2002) and Hen Harrier (1998 and 2004, where plantations were searched). In addition, there have been many local bird surveys in north-west Scotland, in response to proposed wind-farms, hydro-electric schemes and pipelines (Stuart Benn and Kenny Graham *personal communications*). It is highly likely that these surveys, covering similar habitat, would have detected any large numbers of breeding Merlin.

The first hypothesis for the thesis is therefore refuted based on the up-to-date evidence available.

CHAPTER 3

THE EFFECTS OF COMMERCIAL AFFORESTATION ON THE OCCUPANCY OF MERLIN BREEDING TERRITORIES IN LOWER DEESIDE, NORTH-EAST SCOTLAND DURING 1980 to 2003

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3.1 Introduction

For a wide range of birds, high quality breeding territories are occupied more often than poor quality ones, with the categorising of territories related to their temporal production of young (Newton 1998). In general, territory quality in raptors is influenced largely by food and nest site availability (Newton 1979) and these can be influenced by habitat and land-use. In solitary breeding migratory raptors, the better territories are often occupied earlier in the breeding season, with poorer ones occupied later, and generally in high-density years (Newton 1979, 1998). For example, in the Black Kite *Milvus migrans* adults settled earlier on high quality territories, as measured by occupancy. Occupancy was related positively to food availability and negatively to mortality risks, and low quality territories were occupied more in high-density years (Sergio and Newton 2003). Sergio and Newton also reviewed 22 studies from 17 birds in which occupancy was used to measure territory quality. In all studies, occupancy was significantly related to productivity, and in some of them, with other measures such as food availability.

If habitat or land-use change is extensive, this can alter the quality of breeding territories for certain birds. For example, following large scale coniferous afforestation in south-west Scotland (Figure 1.7 b) there was a rapid decrease in open-country species such as Raven and Golden Eagle (Marquiss *et al* 1978, 1985). The negative response by some birds to afforestation in south-west Scotland and elsewhere (e.g. Ratcliffe 1986) was not used as guidance when large areas of north Scotland were planned to be afforested (Chapter 1.8). There was much debate as to the likely decrease of many specially protected open-country birds, including the Merlin, following such proposals (e.g. Ratcliffe 1986, Bainbridge *et al* 1987, Stroud *et al* 1987). Despite these concerns, coniferous afforestation proceeded on a large scale in north Scotland during the 1980s (Chapter 1.8). It was not known then what the minimum amount of open habitat would be necessary to support a pair of breeding Merlin (Petty and Avery 1990). In 1992, recommendations from two studies helped to address that anomalous situation. The first, from south-west Scotland, reported that a mosaic of approximately 60% moor and 40% plantation within a 4 kilometre (km) radius of known Merlin nest sites would keep the territory viable. Territories with less than this area of open-country were abandoned (Orchel 1992). The second, from Wales, suggested that 70 to 80% moor and 20 to 30% plantation would keep Merlin territories viable, based on a mean nearest neighbour of 5 km (Parr 1992). Following these studies and another in north-east England (Little and Davison 1992) the habitat requirements of breeding Merlin in Britain were reviewed by Petty (1995). Petty concluded that afforestation in north-east England and Wales had little detrimental effect on Merlin, largely because there was extensive moorland nearby. Petty speculated that the use of conifer plantations might have been similar in the remainder of the Merlin breeding range in Britain. He also suggested that further research should be a priority to establish if this was the case, endorsing the earlier views of Parr (1991, 1992, 1994) and Little and Davison (1992).

In 1980, the lower Deeside Merlin study area was delimited covering 215 km^2 (Figure 3.1) and fully surveyed by 1982. Concurrently, part of the study area began to be commercially afforested using typical methods (e.g. see Photograph 10 in Chapter 1 and Photograph 12) and was completed by 1994 over four phases (Figure 3.2). This provided an opportunity to study Merlin breeding ecology during and after the establishment of the plantations in comparison to the reminder of the study area. Previously, most of the study area had been managed to promote Red Grouse (Watson and Miller 1976) with the remainder largely degenerate moor, scrub and hill farming. The areas not managed as grouse moor were mainly near to mature plantations east of the B974 road (Figures 3.1 and 3.2) and had been identified as potential forestry areas for at least the previous decade (e.g. Appendix 5, Article I). This meant that in 1980 the study area could broadly be classified into two land management types: **1)** managed grouse moor (MGM) and **2)** a combination of degenerate moor earmarked for afforestation and young conifer plantations. The main differences of these land management types are that MGM is an open and relatively treeless habitat, due to regular burning of the vegetation and grazing from herbivores such as sheep, deer and lagomorphs whereas plantations and degenerate moor are rarely burned intentionally, have light grazing and eventually become forest and scrub (see Ratcliffe 1990 and Etheridge *et al* 1997 for further details of these land-uses).

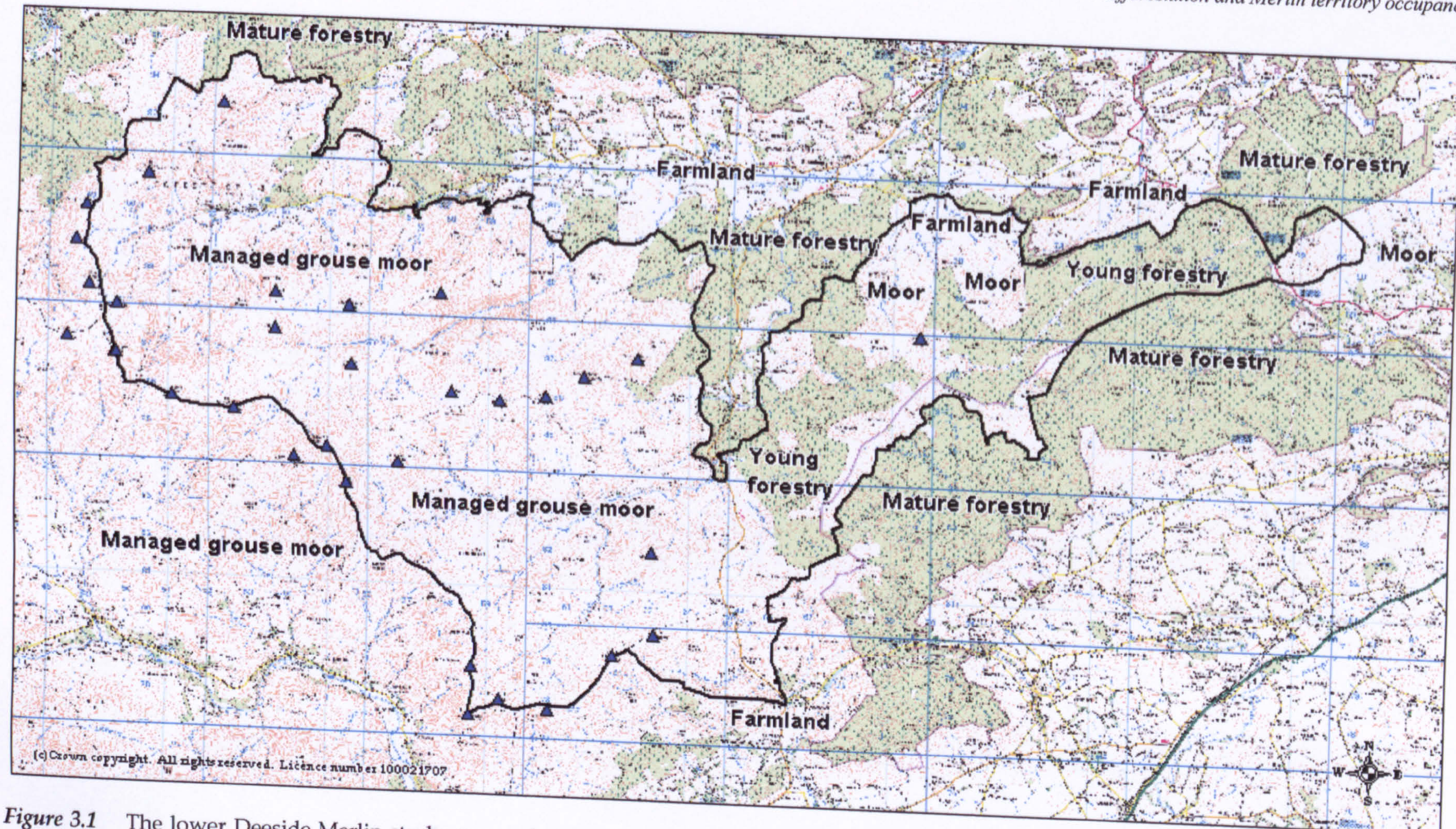


Figure 3.1 The lower Deeside Merlin study area and general habitats within and surrounding it in 2003 (see Figure 1.1 for location in north-east Scotland). Blue triangles ▲ are spot heights over 500 m. Scale: 5 km ______

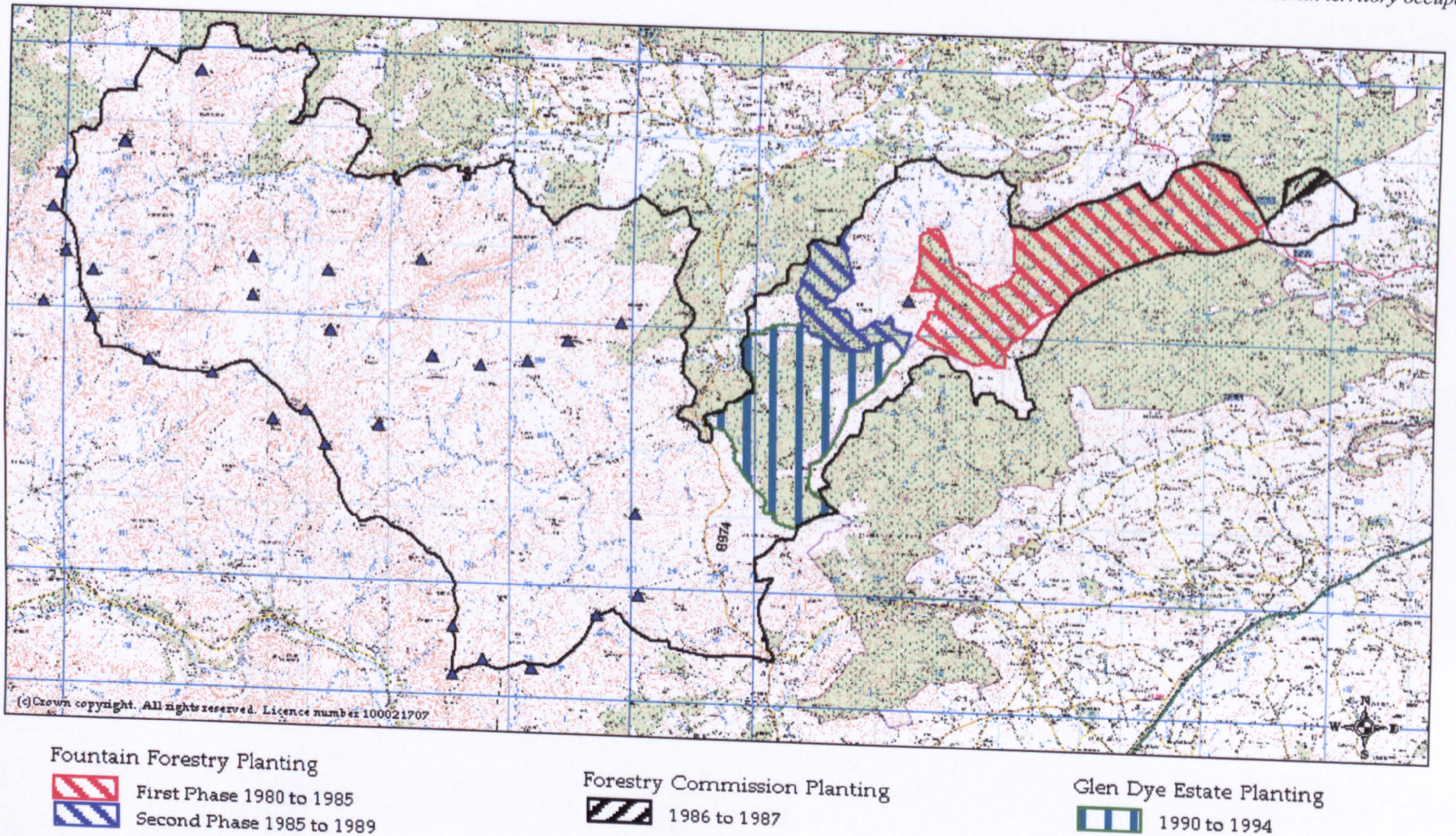


***Figure* 3.2** The lower Deeside Merlin study area showing the zones afforested during 1980 to 1994. Blue triangles ▲ are spot heights over 500 m.
Scale: 5 km ______________

The main aims of this Chapter were to quantify the impact of commercial afforestation on the occupancy at Merlin breeding territories on lower Deeside, and to assess the occupancy by breeding pairs in the forestry zones in comparison to the un-forested MGM zone. This addresses the second and third hypotheses for the thesis which were: ***"Merlin breeding territories within the areas afforested by Fountain Forestry and the Forestry Commission will become less suitable for Merlin as the plantations age, leading to low occupancy and eventual abandonment"*** and ***"Merlin breeding territories within the area afforested by Fasque Estates (the Glen Dye Estate area) will remain suitable for Merlin as the plantations age, and will be occupied at a similar level to those in the un-forested parts of the lower Deeside study area".***

3.2 Methods

3.2.1 Survey

In Britain, Merlin breeding territories are often occupied in consecutive years (Brown 1976, BWP 1980) or re-occupied after a gap (Newton *et al* 1978). They can contain numerous nesting sites, and are usually separated by at least 1 km (e.g. Newton *et al* 1978, BWP 1980, Bibby 1986, Bibby and Nattrass 1986). In north-east Scotland, a typical Merlin territory was defined as a number of nest sites in the same glen or catchment area and used in different years with only one pair ever present. Alternate nest sites could be separated by up to 3 km. Conversely, separate territories could be in adjacent 1 km squares or even closer (further details in Appendix 8). At the start of the study, a list of places where it was known or suspected that Merlin had bred was compiled (see Figure 1.1 earlier). These areas, and the remaining suitable breeding habitat was watched or searched for the presence or signs of Merlin following conventional guidelines (Brown 1976, Newton *et al* 1978, BWP 1980, Feldsine and Oliphant 1985) and area specific knowledge.

First, extensive watches from carefully chosen vantage points were undertaken during the display and pair forming, and pre-egg-laying periods, which was usually mid-March to mid-May in north-east Scotland. Female Merlin solicit the male for food during that period, using a distinct high pitched repetitive eee-eee-eee-eee-eee call, that can be heard up to 500 metres (m) away. Further, the male calls loudly to the female when delivering food and she usually answers him. These watches were intended to establish the general area where Merlins were likely to settle, as display and courtship feeding can occur over an area of 1-2 km^2. Occasionally however, the food exchange is close to the eventual nest, or the male will prospect for a potential nest site after the delivery. As egg-laying approaches, the female becomes very sedentary and spends time loafing near the chosen nest site. At this stage, the male often stays in the area after a food delivery and if the female is receptive, copulation usually occurs. The food begging call of the female, food deliveries by the male, nest prospecting, copulation and loafing by the female are all indicative behaviour of an imminent breeding attempt. Similar watches were done at occupied territories during the incubation and early chick brooding periods, covering May to mid-June, to confirm breeding and locate nests. Pinpointing where nests were was possible following noisy food exchanges, when the male virtually always covers the eggs or guards the chicks while the female feeds, or when the adults changed over incubation duties. Further, Merlin often noisily mob and try to distract potential predators when they are in an occupied territory (Newton *et al* 1978, Rebecca *et al* 1992) and the intensity of this behaviour can often indicate the general area of a nest.

Second, physical checks of suitable habitat to search for signs left by Merlins were done during April to July (and occasionally in autumn and winter). Merlin often use distinct perching or plucking places near their nest, such as rocks, fallen trees, stumps, fence posts, hummocks, shooting butts and bare areas of ground. The signs left include faecal droppings (whitewash), regurgitated pellets, prey remains and moulted feathers. At occupied territories, the signs can accumulate to such an extent that whitewash can be seen on rocks at 300 to 400 m using good quality binoculars. If Merlin were inadvertently disturbed, or seen or heard at a distance, the searches were curtailed. When Merlin are disturbed at a nesting site, they usually fly around calling in alarm, behaviour that can often reveal a previously unknown territory. Once an observer has retreated to an appropriate vantage point, or a predator moves off, the Merlin settle down and usually return to the nest quickly. Searches and watches were therefore applied opportunistically as required.

3.2.2 Monitoring

Once a breeding territory had been identified, it was checked annually for occupancy, with visits made until the breeding status was clear. Occupancy was determined if Merlin were seen or heard, if fresh prey remains, pellets, whitewash or moulted feathers were found twice separated by at least a week, or if the signs indicated the presence of Merlin for at least that time (in comparison to other occupied territories). Confirmed breeding was recorded if courtship display such as a food delivery, and copulation or nest site scraping was observed (Feldsine and Oliphant 1985), if a used nest or eggs were found, or young seen or heard or fledgling down was found. Probable breeding was recorded if an accumulation of prey remains, pellets, whitewash and moulted feathers were found or if the behaviour of the Merlins indicated, that breeding was likely to have occurred. If confirmed or probable breeding was not recorded at an occupied territory, breeding was considered possible.

The western boundary of the study area largely adjoined other MGM (Figure 3.1) mostly in the county of Angus (Figure 14.1 in Appendix 8). Members of the Tayside Raptor Study Group (TRSG) surveyed and monitored the suitable Merlin breeding habitat in Angus (Downing 1996). The Aberdeenshire part adjoined Glen Tanar National Nature Reserve and information on breeding Merlin was exchanged between Scottish Natural Heritage (SNH) and the North-East Scotland Raptor Study Group (NESRSG) (section 14.6 in Appendix 8). Close co-operation with SNH, NESRSG and TRSG meant that I could map the neighbouring Merlin territories and record any nearby fluctuations.

3.2.3 The Fountain Forestry and Forestry Commission afforestation schemes

The Fountain Forestry (FF) and Forestry Commission (FC) schemes were entirely commercial with the maximum amount of suitable ground planted. The national forestry grant structure in the late 1970s to early 1980s encouraged this type of strategy (Chapter 1.8) with typical schemes composed of 90 to 95% plantations and 5 to 10% unplanted ground. The preparatory work involved burning virtually all the ground vegetation and deep ploughing the soil, and in the FF zone new hill roads, drains and culverts were installed. This created a massive amount of disturbance and nest sites for open-country birds were lost (e.g. Photographs 11 and 12, and see also Photograph 10 in Chapter 1).

Photograph 11. Merlin breeding territory number 5 in the Fountain Forestry zone before conifer afforestation. The area in the photograph also held other typical moorland birds, such as breeding Hen Harrier, Short-eared Owl, Red Grouse, Curlew, Snipe, Teal, Mallard, Skylark, Whinchat, Stonechat, Meadow Pipit and Wren (G. W. Rebecca).

Photograph 12. The same Merlin breeding territory as in photograph 11 after preparation for conifer afforestation. The shrub layer has been burnt off and drainage and deep ploughing completed (G. W. Rebecca).

In addition to the usual survey methods, all the unplanted ground was searched annually for signs of Merlin. A consequence of the redundant grouse moor management was that Carrion Crows were nesting in some of the scattered Scots Pine or Rowan *Sorbus aucuparia* trees (e.g. Appendix 7) and trees that were known to hold old crow nests were checked annually. Other trees were re-checked regularly for crow nests and nearby FC plantation edges were regularly checked for the presence of Merlin (e.g. Rebecca 1992, Appendix 7).

3.2.4 The Glen Dye Estate afforestation scheme

The Glen Dye Estate (GDE) scheme was originally planned similar to the FF and FC schemes. However, there was strong resistance to the GDE scheme and it was considerably amended in an attempt to maintain the viability of three Merlin breeding territories (full details in Appendix 5). I negotiated with the head forester on GDE that the recent sites where Merlin had previously nested were not to be planted (apart from an alternate nesting site in the FF zone at territory 7). The unplanted areas around the previous nests were approximately 40 to 45 hectares, and it was anticipated these territories would remain suitable for Merlin. Combined with the un-plantable ground the final scheme comprised of 70% new plantations, 27% open ground and 3% potential natural forest regeneration (Appendix 5). A forest design of these general proportions, and incorporating the knowledge of breeding Merlin, had not been attempted previously (Parr 1992, Petty 1995).

3.3 Results

3.3.1 General

The study area was fully surveyed by the end of 1982 when 17 breeding territories were identified, this increased to 25 by 2003 (Figure 3.3, Table 3.1). The distribution of all confirmed, probable and possible breeding records are shown in Figure 3.4, with breeding area polygons linking the records for each territory shown in Figure 3.5. The territories were well distributed apart from above 500 m (Figure 3.5). The annual distribution of the occupancy of territories during 1980 to 2003 is shown in Appendix 3 (a-x).

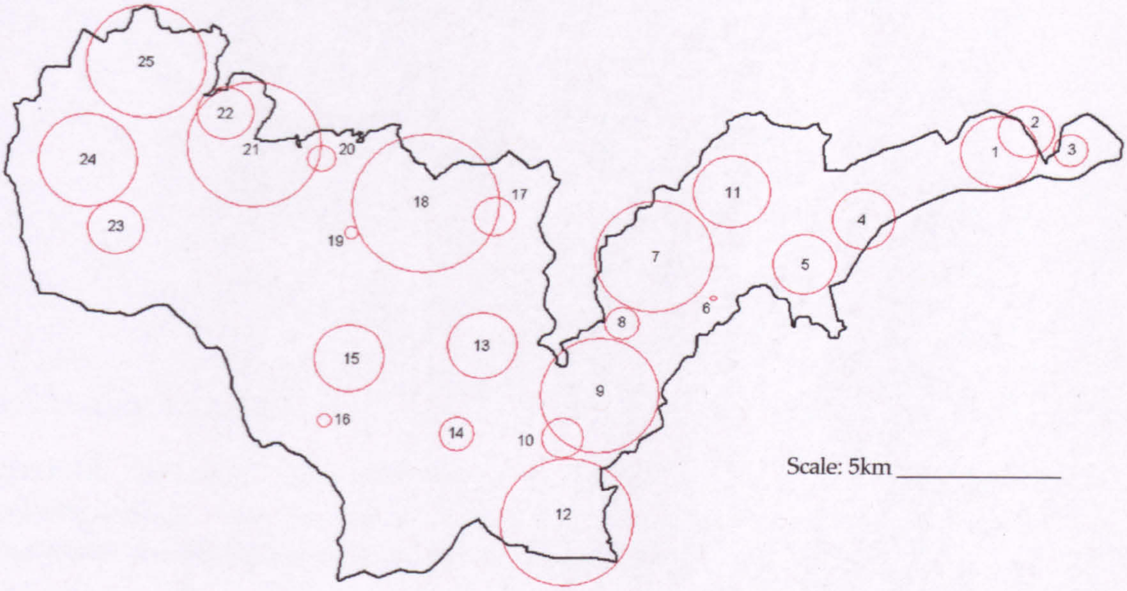


Figure 3.3 The lower Deeside Merlin study area and central location of breeding territories 1 to 25. The centre of a territory was determined by linking all confirmed, probable and possible breeding records to form breeding area polygons (see Figures 3.4 and 3.5) and then judging the approximate centre of the polygon. The size of circles represent the number of years the territories were occupied by confirmed or probable breeding pairs during 1982 to 2003, with one millimetre diameter representing one year (see also Table 3.1 for occupancy periods).

For example: I---I 5 years I------I 10 years I---------I 15 years I-------------I 20 years

After accounting for same year movements, a mean of 13.2 ± 0.4 standard error (SE) (~13, range 11 to 15) territories were occupied by confirmed, probable or possible breeding pairs during 1982 to 1992, and a mean of 9.8 ± 0.5 SE (~10, range 8 to 12) territories were occupied by confirmed, probable or possible breeding pairs during 1993 to 2003 (Table 3.1). This represented a highly significant decline in potential breeding pairs of 26% in the second 11-year period of study following full survey of the study area, $t_{20} = 5.03$, $P < 0.001$.

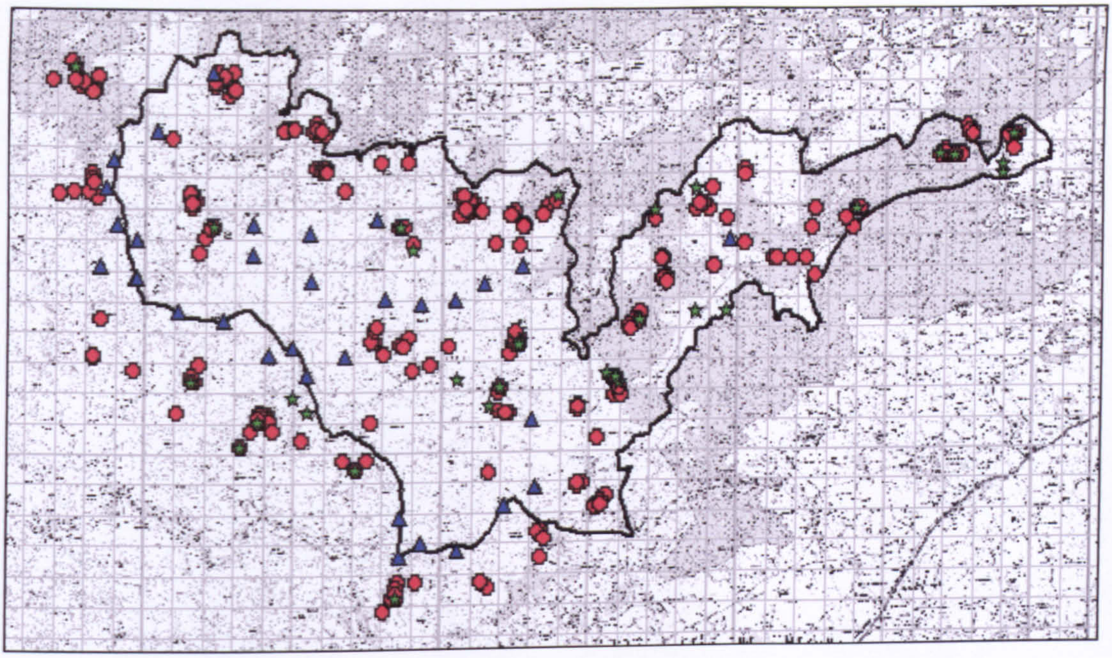


Figure 3.4 The lower Deeside Merlin study area and nearby, and all confirmed or probable breeding records ● and possible breeding ★ records during 1980 to 2003. Grid lines are 1 km squares and blue triangles ▲ are spot heights over 500 m. Scale: 5 km ___________

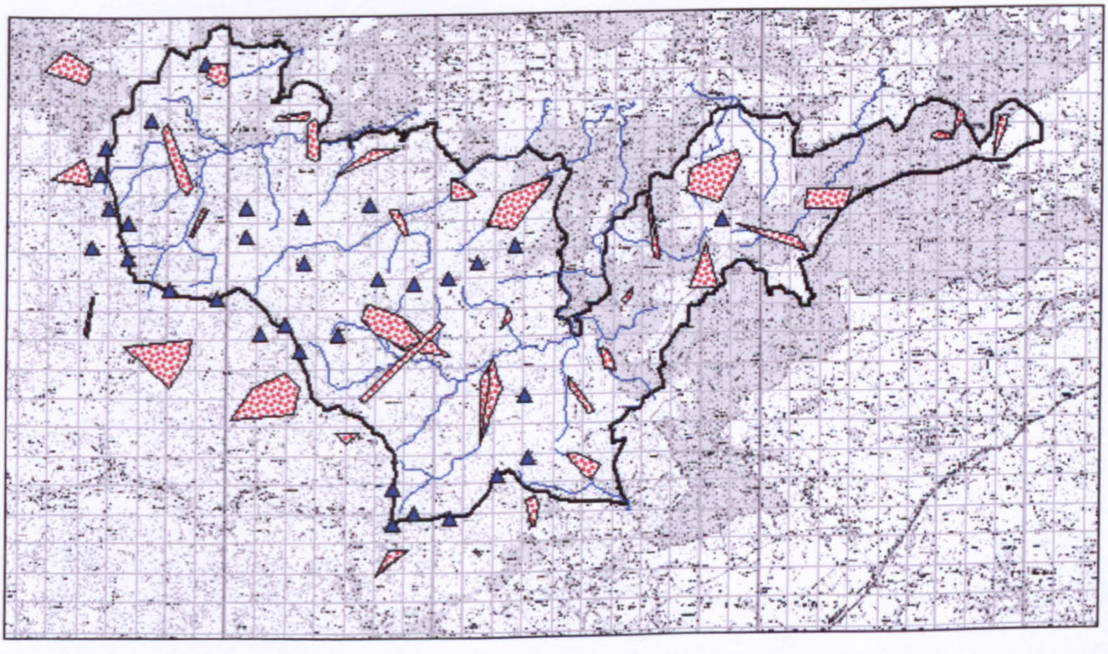


Figure 3.5 The lower Deeside Merlin study area and nearby, showing breeding area polygons in red linking all confirmed, probable and possible breeding records for each territory during 1980 to 2003. Grid lines are 1 km squares and blue triangles ▲ are spot heights over 500 m. Rivers and tributaries are in blue. Scale: 5 km ___________

Table 3.1 The number of occupied Merlin breeding territories in lower Deeside during 1980 to 2003 (see also Appendix 3 (a-x)).

FC = Forestry Commission zone, FF = Fountain Forestry zone, GDEF = Glen Dye Estate Forestry zone, Managed Grouse Moor = non afforested areas. Blank = not checked, - = not occupied, p = possible breeding, ? = breeding pair but outcome unknown, F = failed nest, S = successful nest.

Green type represents territories where the surrounding area was being prepared for afforestation or already afforested, blue type represents territories on degenerate moor or scrub and due for afforestation, and purple type represents territories on Managed Grouse Moor.

Year	FC	FF					GDEF			Managed Grouse Moor																Number of occupied territories (movements)
	3	1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
1980	p	S	-		S		S	-	S	-	-		?	S			S	S	-						S	10
1981	S	p	-		-	-	S	-	p	-	p	S	S	p	-	-	S	S	S	-	S	-			S	13
1982	F	S	F	F	-	-	F	-	S	-	-	S	S	S	-	-	F	S	p	-	S	-	S	-	F	15
1983	F	S	F	-	S	-	F	-	p	?	-	S	S	p	S	-	-	S	p	-	-	-	p	F	S	16 (9 to 10, 23 to 24)
1984	F	F	-	-	F	S	S	p	-	S	-	F	F	-	S	-	-	S	-	-	S	-	S	-	S	14
1985	F	S	F	p	-	p	S	-	F	S	-	S	F	-	F	-	-	S	F	-	S	-	-	F	F	16 (10 to 9, 13 to 10)
1986	S	F	S	F	-	-	S	-	F	-	-	S	p	-	p	-	-	S	S	-	S	S	-	?	S	15 (13 to 15)
1987	-	F	S	S	-	-	S	-	p	-	?	F	p	-	-	-	-	S	-	F	-	F	S	-	F	13 (1 to 2, 9 to 13)
1988	-	-	S	S	-	p	S	S	F	-	S	F	-	-	-	-	-	F	-	S	S	-	-	S	S	13
1989	-	-	S	F	-	-	F	F	S	-	?	-	F	-	-	-	-	F	-	-	S	-	-	F	S	11
1990	-	-	F	S	-	-	F	S	S	-	S	F	F	-	-	-	F	F	-	-	S	S	-	S	F	14
1991	p	F	-	S	S	-	F	S	F	-	-	F	-	-	-	-	-	F	-	-	S	S	-	F	S	13 (1 to 3)
1992	-	S	-	F	S	-	F	F	S	-	S	F	-	-	-	-	-	-	-	-	F	S	F	-	F	12
1993	-	S	-	-	S	-	F	-	F	S	-	S	-	-	-	-	-	S	-	-	S	-	-	-	F	9
1994	-	S	-	F	-	-	S	-	F	S	-	S	-	S	S	-	-	S	-	-	-	F	-	S	S	12
1995	-	S	-	-	F	-	F	-	F	S	-	S	-	-	F	-	-	S	-	-	S	S	-	F	S	12
1996	-	p	-	-	S	-	-	-	S	-	-	S	F	-	-	-	S	F	-	-	S	S	-	S	S	11
1997	-	-	-	-	S	-	-	-	S	-	-	S	S	-	F	-	F	S	-	S	S	-	-	S	S	11
1998	-	-	-	-	F	-	S	-	S	-	S	F	F	-	S	-	-	S	p	-	S	-	-	S	S	12
1999	-	-	-	-	-	-	-	-	S	-	S	-	-	-	F	S	-	S	-	S	S	-	-	F	-	8
2000	-	-	-	-	-	-	-	-	S	-	S	F	-	-	-	F	p	S	-	-	S	-	S	-	-	8
2001	-	-	-	-	-	-	-	-	S	-	S	F	-	F	-	-	-	S	-	-	S	-	S	S	-	8
2002	-	-	-	-	-	-	S	-	p	-	S	F	-	F	S	-	S	S	-	-	S	-	S	-	-	10 (9 to 7)
2003	-	-	-	-	-	-	S	-	-	-	S	-	S	S	F	-	S	S	-	-	S	-	S	-	-	9
Pairs in 1982-2003	5	11	8	9	9	1	17	5	17	6	11	19	10	5	10	2	6	21	2	4	19	8	8	14	17	

3.3.2 The Fountain Forestry and Forestry Commission afforestation zones

There were six Merlin breeding territories (numbers 1 to 6) in the combined FF and FC forestry zones (Figures 3.2 and 3.3) and they were afforested or ready for afforestation by 1985 (Table 3.1). The maximum number of confirmed or probable breeding pairs located in any year was four, in 1982, 1983, 1984 and 1986 (Table 3.1, Figure 3.6 a). There was then a steady decline in numbers to zero in 1999 to 2003 inclusive. This showed a highly significant negative correlation as the plantations were established and aged towards canopy closure (thicket stage) $r = -0.925$, $P < 0.001$ (Figure 3.6 a). Territory 5 was the last to be occupied by a breeding pair, and in 1997 and 1998 the nest was in an area of un-planted plateau moor (Figures 3.3, 3.4, 3.5 and Appendix 3 (r-s)). The pattern of the annual distribution of occupancy can be deduced from Table 3.1, Figure 3.3 and Appendix 3 (a-x).

3.3.3 The Glen Dye Estate afforestation zone and the Managed Grouse Moor zone

There were three Merlin breeding territories (numbers 7 to 9) in the GDE forestry zone (Figures 3.2 and 3.3). During 1980 to 1984, the nest at territory 7 was in an area of under-planted and naturally regenerating Scots Pine near to mature conifer plantation and semi-natural pinewood (Figures 3.1 and 3.3). Then, during 1985 to 2003, the Merlin at territory 7 moved, first to the edge of the FF forestry zone in 1985 to 1987 and then to the GDE forestry zone in 1988 to 2003 (Figures 3.2 to 3.5 and Appendix 3 (a-x)). During 1980 to 1986, territory 9 was still classed as MGM and then the area was afforested. Prior to the main period of afforestation in the GDE forestry zone numbers were relatively stable at 1 to 3 pairs (1982 to 1989), $r = 0.594$, $P = 0.12$, not significant (NS). In contrast, numbers declined significantly following the commercial afforestation in 1990 to 1994, from three pairs in 1990 to 1992 to one pair in the last five years under review, $r = -0.869$, $P < 0.001$ (Figure 3.6 c, Table 3.1).

There were 16 Merlin breeding territories (numbers 10 to 25) in the MGM zone (Figures 3.2 and 3.3) with a mean of 7.3 ± 0.2 SE (range 5 to 9) confirmed or probable breeding pairs during 1982 to 2003. The mode was eight pairs, found in nine years including 1982 and

2003 (Figure 3.6 b, Table 3.1). There was no major land-use change in the MGM zone and the population was relatively stable $r = 0.053$, $P = 0.815$ NS (Figure 3.6 b).

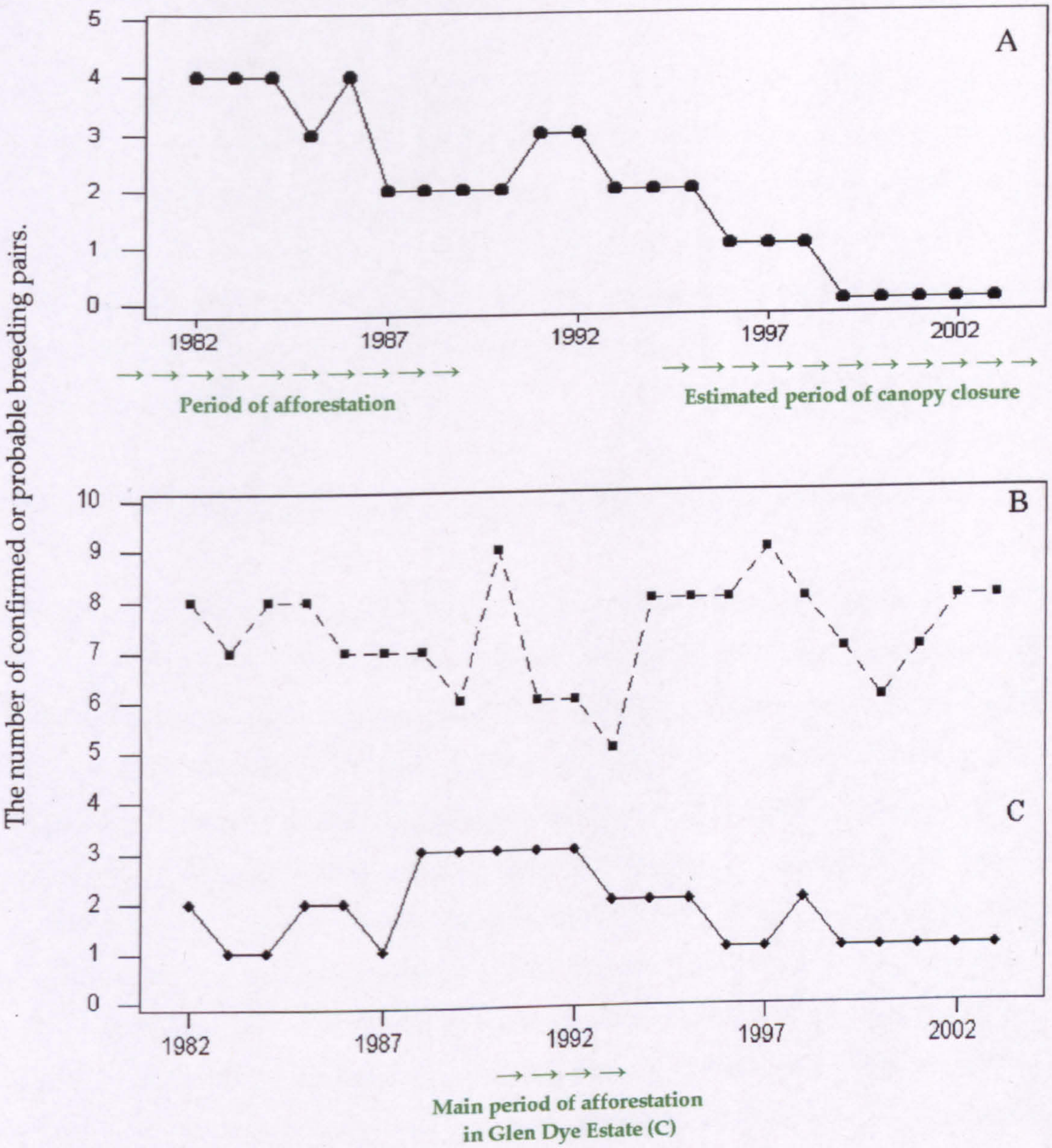


Figure 3.6 The number of confirmed or probable breeding pairs of Merlin in the three study zones in the lower Deeside study area during 1982 to 2003. **A)** The Fountain Forestry and Forestry Commission forestry zones combined ●. These zones were commercially afforested during 1980 to 1989. **B)** The Managed Grouse Moor zone ■. This zone did not have any major land-use change during the study period. **C)** The Glen Dye Estate forestry zone ◆. This zone was commercially afforested during 1990 to 1994 (Figure 3.2). In the Glen Dye Estate forestry zone, territory 7 was affected by natural regeneration and under-planting of Scots Pine during the late 1970s and territory 9 was still classed as managed grouse moor during 1982 to 1986 (see text and Table 3.1).

3.4 Discussion

3.4.1 The Managed Grouse Moor zone

The MGM zone was fully surveyed by 1982 with ten breeding territories known, and a further five were located by 1999. Territories 23 and 24 were alternate sites within the same territory until 2001 when two pairs were located (Table 3.1). This gave 16 discrete areas in the MGM zone where Merlin had bred during the study period (Figures 3.3 and 3.5). The population was relatively stable and seven or eight breeding pairs could be regarded as the annual normal (mean 7.3 and mode 8 breeding pairs between 1982 to 2003) with one or two additional pairs in a high occupation year.

3.4.2 The Fountain Forestry and Forestry Commission afforestation zones

The FF and FC forestry zones were also fully surveyed by 1982, with territories 1, 3 and 5 occupied at least once in the 1970s. Numbers were relatively constant during the early years of afforestation and then declined to zero as the plantations reached canopy closure. The territories were generally abandoned in chronological order following afforestation (Figure 3.2, Table 3.1, Appendix 3 (a-x)). All breeding attempts, apart from a repeat nest at territory 4 in 1991 that was in mature plantation (Appendix 3 l, Rebecca 1992) were in places considered un-plantable or in small areas of heather that had not been burned (e.g. see Appendix 7 for details at territories 1 to 3). The nest site at territory 1 in 1992 to 1995 was an artificial crow nest, which possibly extended the duration of occupancy and probably improved the breeding success (Appendix 7). There were some unexpected patterns of occupancy as the plantations were established and then aged. For example, territories 4 and 5 were alternative sites in the same territory until both were occupied by breeding pairs in 1991 and 1992. During 1993 to 1998, only one pair was present in these areas, with the nest at territory 5 gradually moving to an unplanted plateau area as the surrounding plantations reached the thicket stage. Further, the occupation at territory 6 was difficult to interpret with breeding only confirmed once and it may have been an alternative site to territories 8, 9 or 11 but this could not be confirmed.

The proximity of plantations to moorland can increase predation on nearby ground nesting birds (e.g. Nature Conservancy Council 1986) and this could be part of the reason for the abandonment of territories in the FF and FC zones (e.g. Appendix 7). There was certainly an increase in Carrion Crows in the zones during the early 1980s. In addition, larger raptors such as Eurasion Sparrowhawk and Common Buzzard were evident at territories 1 to 5 by the late 1980s (and a pair of Golden Eagle bred near territory 8 during the mid-to-late 1990s). These raptors are generally regarded as competitors of Merlin (Newton 1979).

Trees planted at high density are classed as thickets at around 15 to 20 years (Nature Conservancy Council 1986, Petty and Avery 1990). At the thicket stage, or canopy closure, conifer plantations are largely impenetrable. The abandonment of territories 1 to 5 (6 not assessed as it was possibly an alternative site for elsewhere) occurred at 17, 11, 2, 13 and 16 years respectively after afforestation (Table 3.1). In the last five years of the study, no Merlin were located at territories 1 to 5. During that period, the plantations were essentially all at the thicket stage. The second hypothesis for the thesis predicted that ***Merlin breeding territories in the FF and FC forestry zones would show reduced occupancy and eventually be abandoned as the plantations aged.*** The results show clearly this happened and the hypothesis is upheld.

In the FF zone the plantations around territories 1 and 2 were restructured in 1997 under a FC administered Woodland Grant Scheme. A considerable amount of poor growing Lodgepole Pine was felled to waste, and some of the area was replanted with native broadleaves. The remaining unplanted ground was left as potential Merlin hunting habitat, in an effort to attract Merlin back into the area (Appendix 7), but this had not happened by 2003. This area should be monitored further to establish if Merlin re-occupy the territories.

3.4.3 The Glen Dye Estate afforestation zone

The GDE forestry zone was fully surveyed by 1980, with territories 7 and 9 occupied for at least three years during the 1970s. Numbers were relatively stable prior to the commercial afforestation and then they declined significantly, even before canopy closure. It was anticipated that the unplanted areas at the previous nests sites would maintain their suitability for nesting Merlin and that the overall proportions of habitat mix would keep the territories viable. The third hypothesis for the thesis stated that ***Merlin breeding territories within the GDE forestry zone would remain suitable for Merlin as the plantations aged and be occupied at a similar level to those in the un-forested parts of the lower Deeside study area.*** The territories were used after the afforestation but only one was occupied during the last five years of study implying that the overall area may have been capable of only supporting one pair of Merlin in the later years. The hypothesis is therefore refuted since the decrease was significant compared to the stability in the MGM zone. However, a further period of study, until the plantations reach canopy closure, is necessary to establish if any of the territories are used again.

3.4.4 General

Some breeding territories showed a remarkable consistency of occupancy, particularly in the MGM zone, where the overall habitat and land-use changed little. For example; breeding pairs were found at territory 18 in 23 out of 24 years, at territories 12 and 21 for 20 out of 23 years and at territories 23 + 24 combined for 21 out of 22 years. A breeding pair occupied territory 25 in 1979 and then for a further 19 years to 1998 (Table 3.1). A large amount of disturbance occurred at territory 25 in spring and early summer 1999 and it has not been occupied since 1998 (Appendix 8). Further, a breeding pair occupied territory 7 for 16 consecutive years. These regularly occupied territories could be described as high quality or core areas. In contrast, territories 16 and 19 were only occupied by breeding pairs in two and three years respectively out of 23 (Table 3.1). These, and other less well-occupied territories could be described as poor quality or satellite areas. The 'core' territories with breeding pairs in at least 10 years during 1982 to 2003 (numbers 1, 7, 9, 11, 12, 13, 15, 18, 21, 23 + 24 and 25) were well spaced throughout the study area. These territories often had infrequently occupied 'satellite' territories adjacent to them (Figure 3.3). Indeed, some nesting places were judged as alternative sites in the same territory until two pairs occupied them, such as at territories 9 and 10 until 1993 (and 23 and 24, and 4 and 5 discussed earlier). Conversely, territories 1 and 2 were discrete until 1988, and then only one pair was present until 1995. Similarly, territories 7 and 9 were discrete but were judged as alternative sites during 1999 to 2003 (Table 3.1, Appendix 3 (t-x)). The previous two examples are explained by the plantations nearing or reaching canopy closure (discussed earlier). Presumably, when satellite or poor quality territories are occupied other conditions are favourable, such as over-winter survival or spring prey availability (e.g. Mearns and Newton 1982, Wiklund 2001).

Assessing the occupancy at breeding territories is straightforward if the Merlins are using a previously used area. However, if they are not using a known area (and the nearest neighbouring territory is occupied) it can be difficult deciding if the territory is actually unoccupied or if the nearest neighbour is an alternative site. Deciding on the latter is open to subjective assessment (see Appendix 8). Problems arise when two pairs nest closely for only one or two years, and these territories are counted as separate thereafter (see previous paragraph). By defining a study area, the number of pairs in the area can be compared on an annual basis to give a more realistic assessment of occupancy (I Newton *personal communication*). This assumes there are no alternative breeding sites outside the study area, and that all pairs are found within it. For the lower Deeside study area, none of the neighbouring Merlin territories to the south and west were believed to be alternatives and these were monitored by TRSG, SNH and NESRSG allowing annual and cumulative assessment (Figures 3.4 and 3.5, Appendix 3 (a-x)).

3.5 Conclusions

- There was a highly significant decrease in the occupancy of Merlin breeding territories in the lower Deeside study area during the course of the study. The decline in territory occupancy, and hence local status, occurred when the overall Merlin population in north-east Scotland was considered relatively stable (Rebecca *et al* 1992, Rebecca 1993, Cosnette and Rebecca 1997) and the British population increased (Rebecca and Bainbridge 1998 and reproduced as Appendix 6).
- The abandonment of breeding territories in the commercially afforested areas was the main cause of the decline and there is no doubt that the combined forestry schemes have negatively affected the Merlin population on lower Deeside.

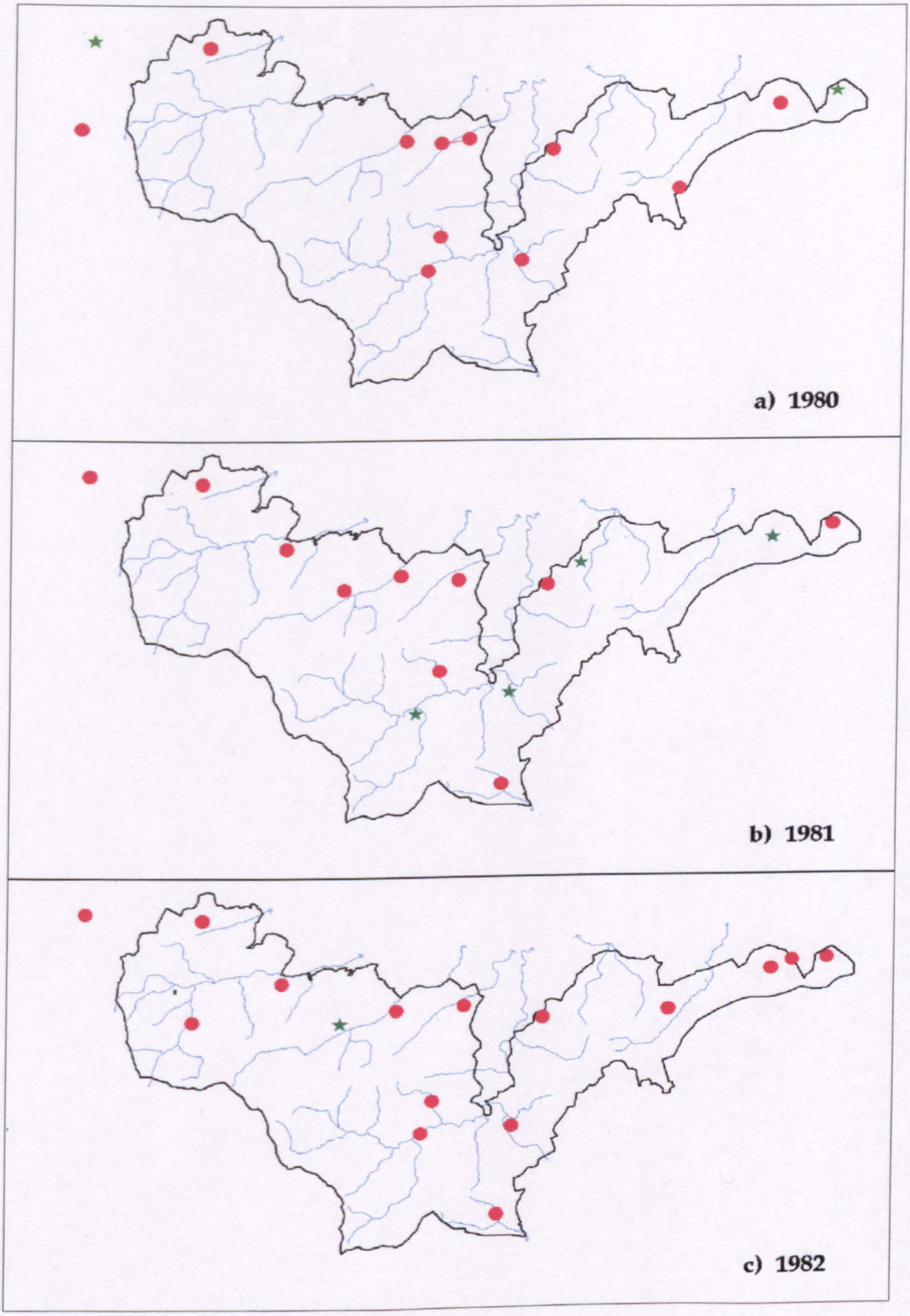
- The main reason for the abandonment of breeding territories was probably because the plantations were at, or approaching canopy closure (the thicket stage). This would have reduced the potential hunting area for Merlins and rendered the majority of prey difficult to catch.
- There was some evidence of the Merlins probably hunting the forest canopy (Appendix 9). This was a repeat breeding attempt and therefore later in the season. The number of Barn Swallows *Hirundo rustica* taken was unusually high and low numbers have been recorded since then (see Chapter 5 later). This did demonstrate that Merlins were adaptable, but thicket plantations are unlikely to attract insect eaters such as hirundines in spring, the critical period when Merlins are establishing their breeding sites.
- The installation of an artificial crow nest probably extended the occupation at territory 1 and almost certainly improved breeding success (Appendix 7).
- The unplanted ground around territories 7 to 9 also extended the occupancy at these areas, since the vegetation was originally planned to have been completely burned and the ground ploughed and afforested.
- A further period of study (until all the plantations reach canopy closure) is necessary to assess occupancy in the GDE forestry and MGM zones. Final judgement on the suitability of the habitat structure for Merlin in the GDE forestry zone should be reserved until then.

3.6 Postscipt

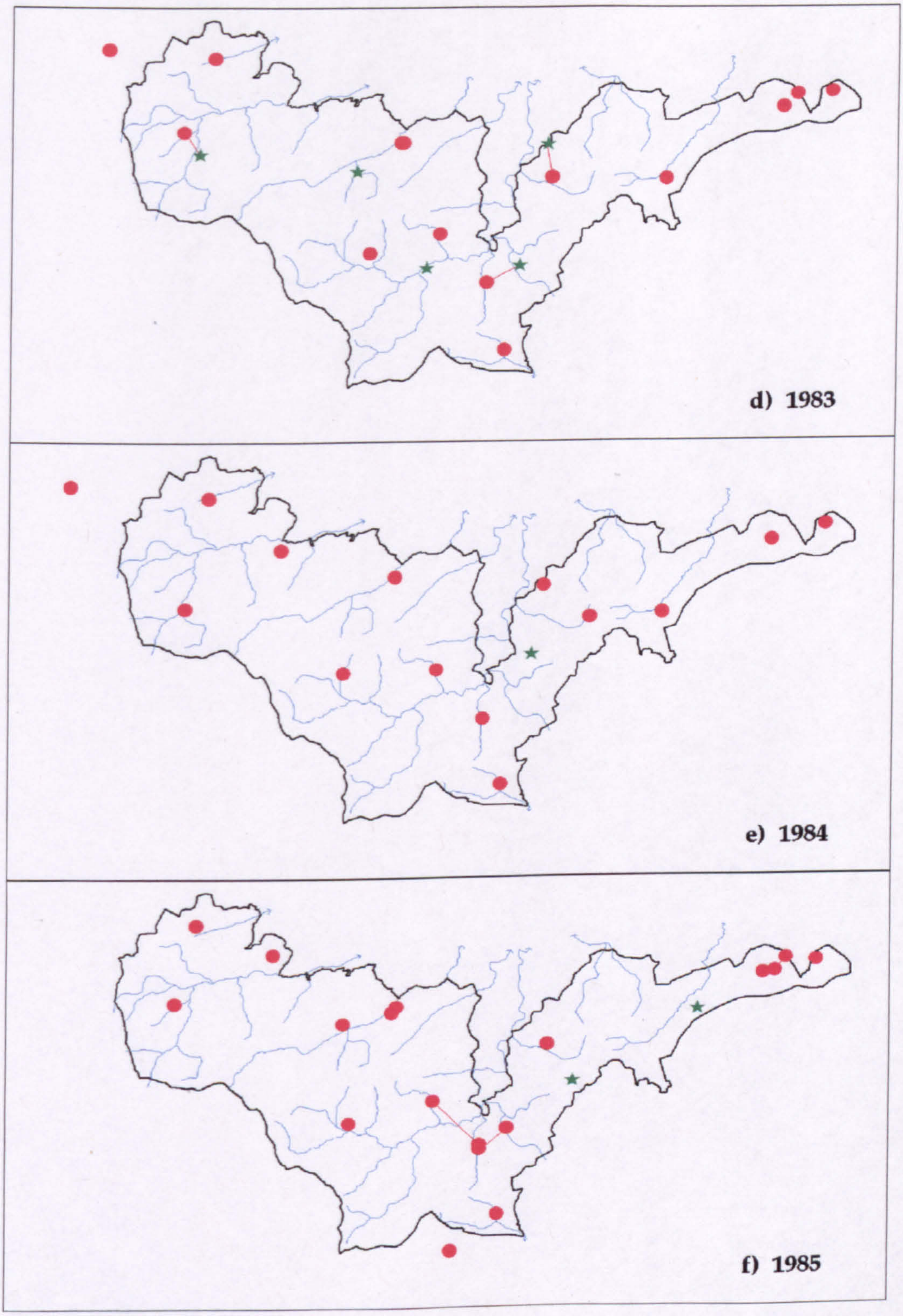
In 2004 and 2005, no Merlin breeding territories were occupied in the FC, FF or GDE afforested zones. In the MGM zone, eight confirmed breeding pairs were located in 2004, and five in 2005 plus two territories were occupied by apparently single Merlin.

3.7 Appendix 3 (a-x)

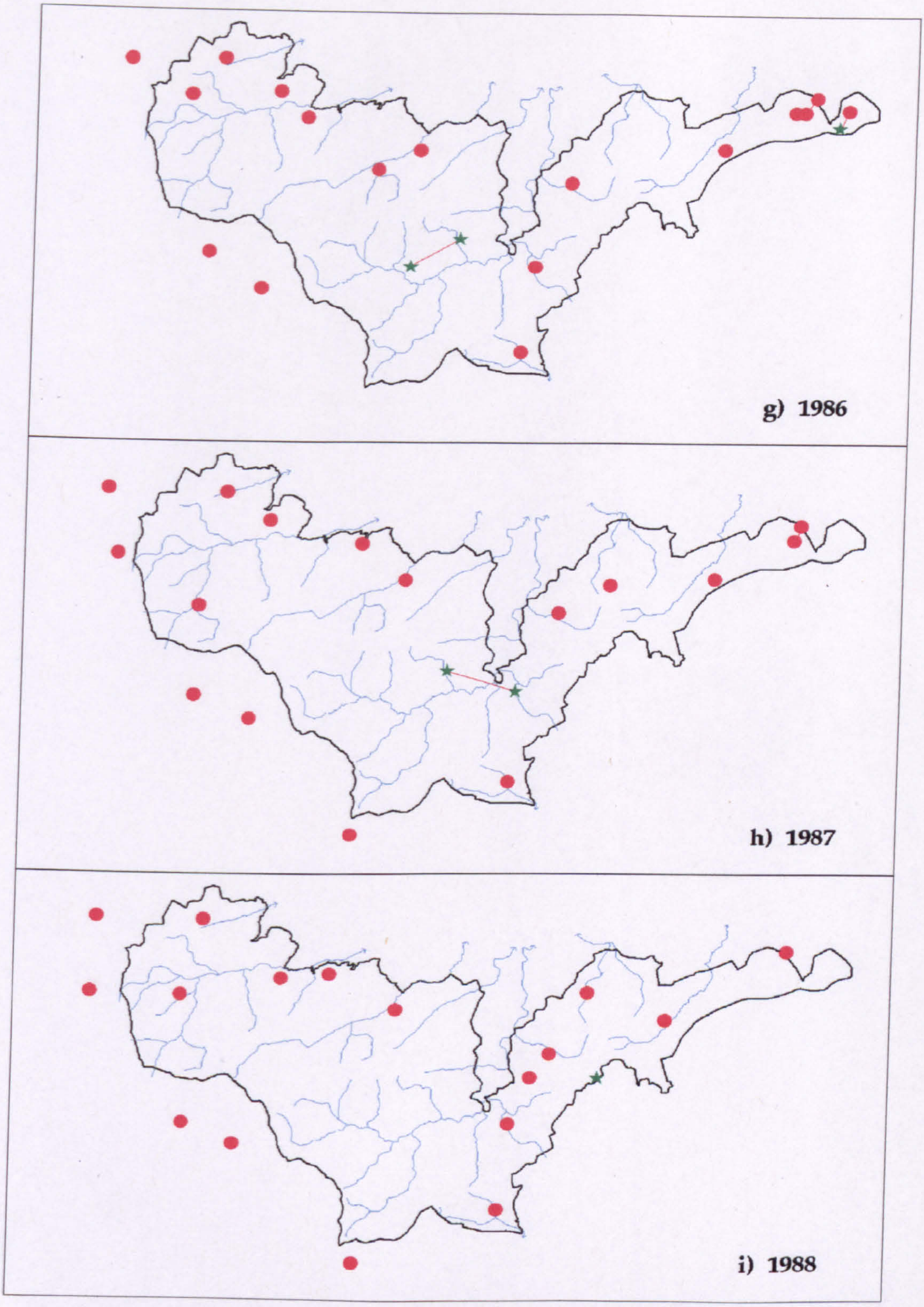
The annual distribution of confirmed, probable and possible breeding sites in the lower Deeside study area and nearby in 1980 to 2003 (pages 86 to 93).



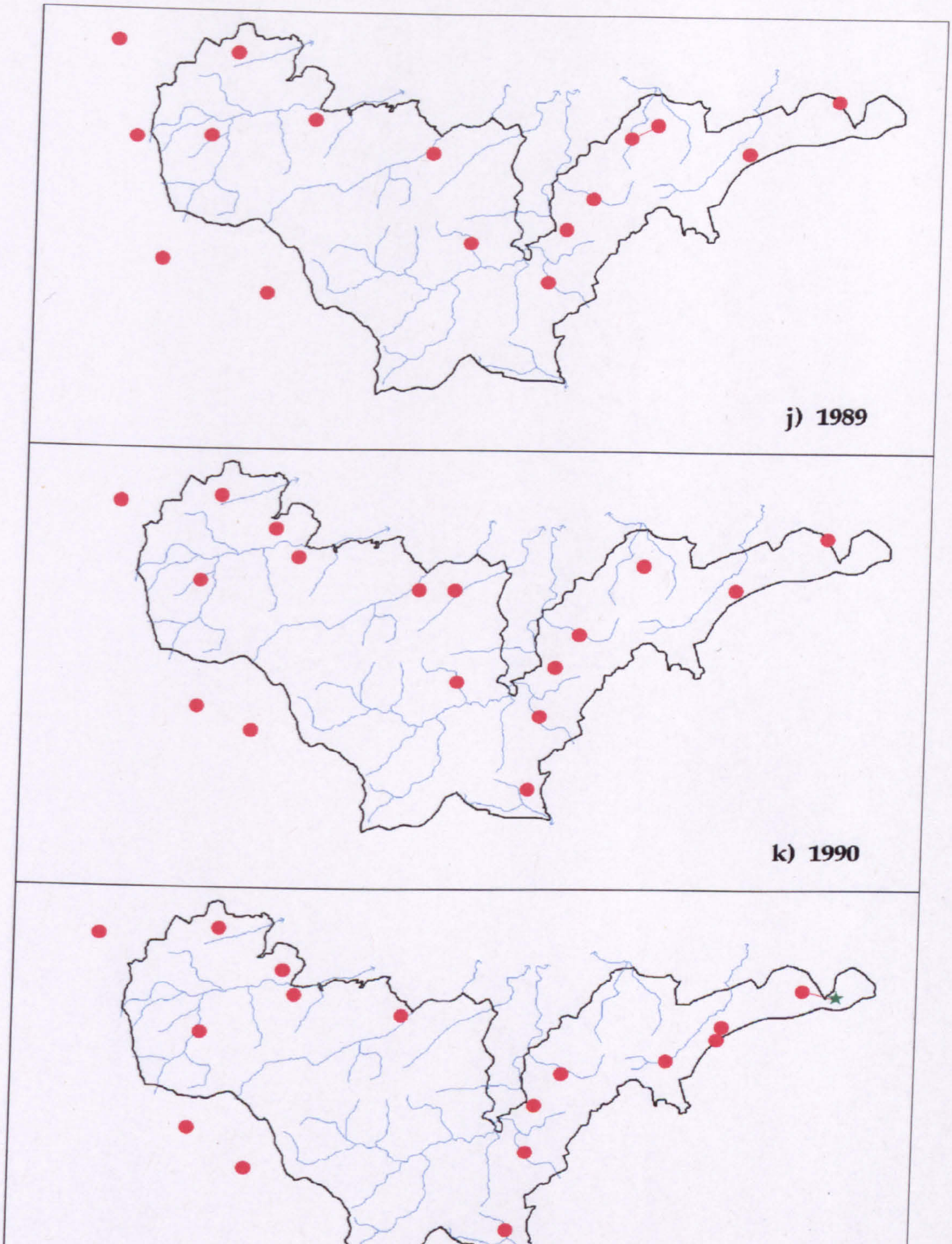
Appendix 3 (a-c) The lower Deeside Merlin study area and nearby, showing confirmed or probable ● and possible ★ breeding sites in 1980 to 1982. Red lines joining sites were repeat breeding attempts or movements and blue lines are rivers. Scale: 5 km ________



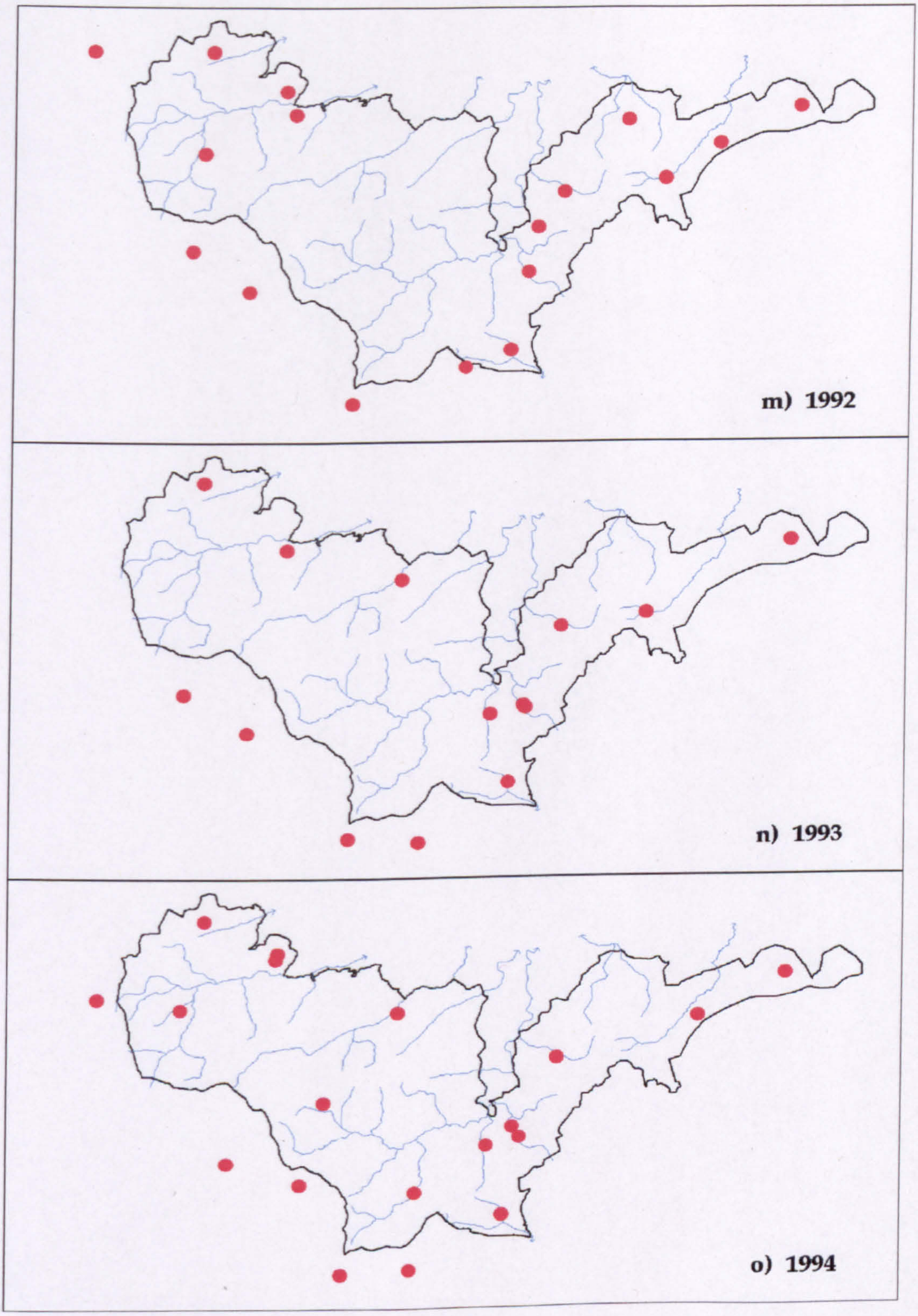
Appendix 3 (d-f) The lower Deeside Merlin study area and nearby, showing confirmed or probable ● and possible ★ breeding sites in 1983 to 1985. Red lines joining sites were repeat breeding attempts or movements and blue lines are rivers. Scale: 5 km ________



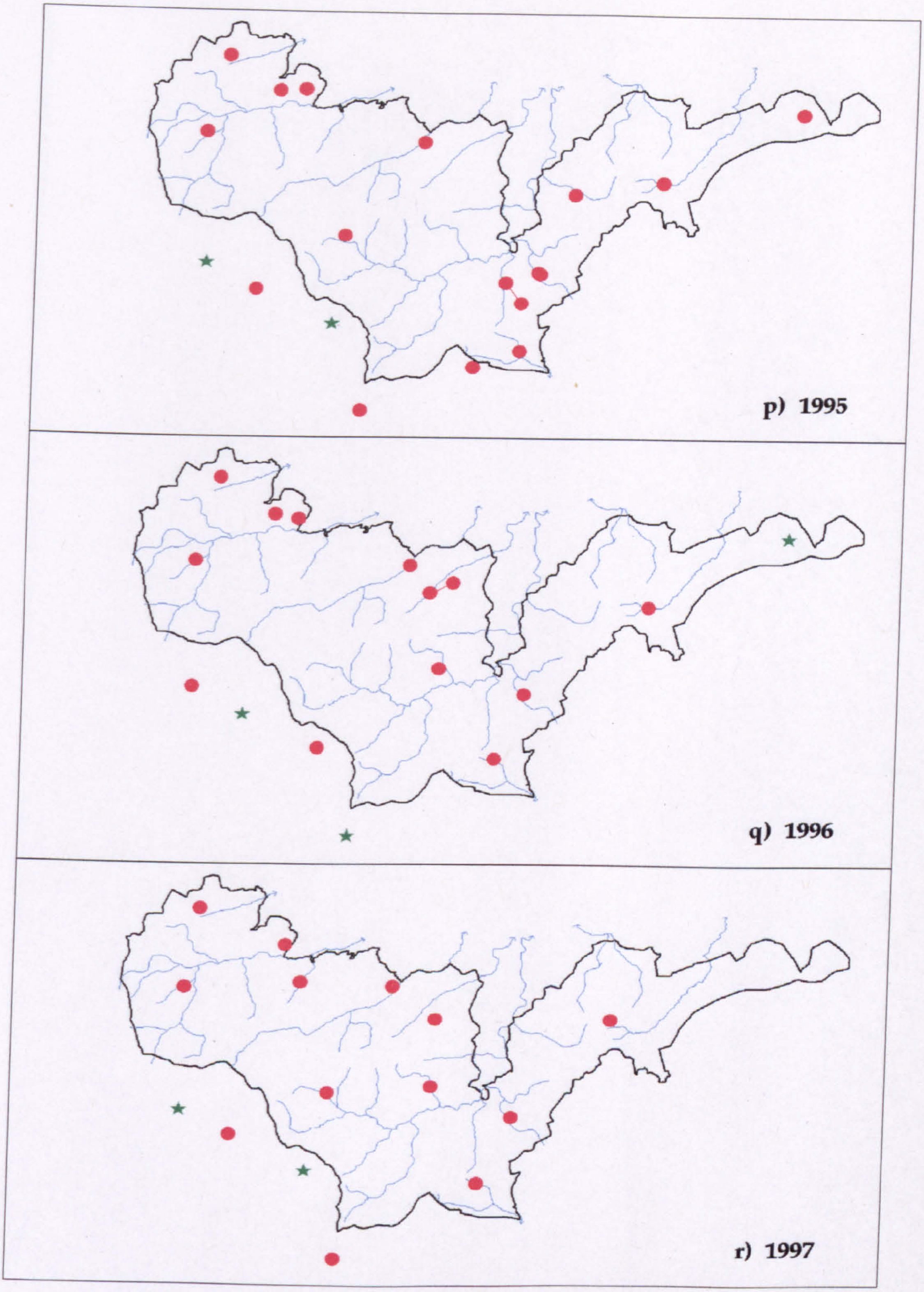
Appendix 3 (g-i) The lower Deeside Merlin study area and nearby, showing confirmed or probable ● and possible ★ breeding sites in 1986 to 1988. Red lines joining sites were repeat breeding attempts or movements and blue lines are rivers. Scale: 5 km ________



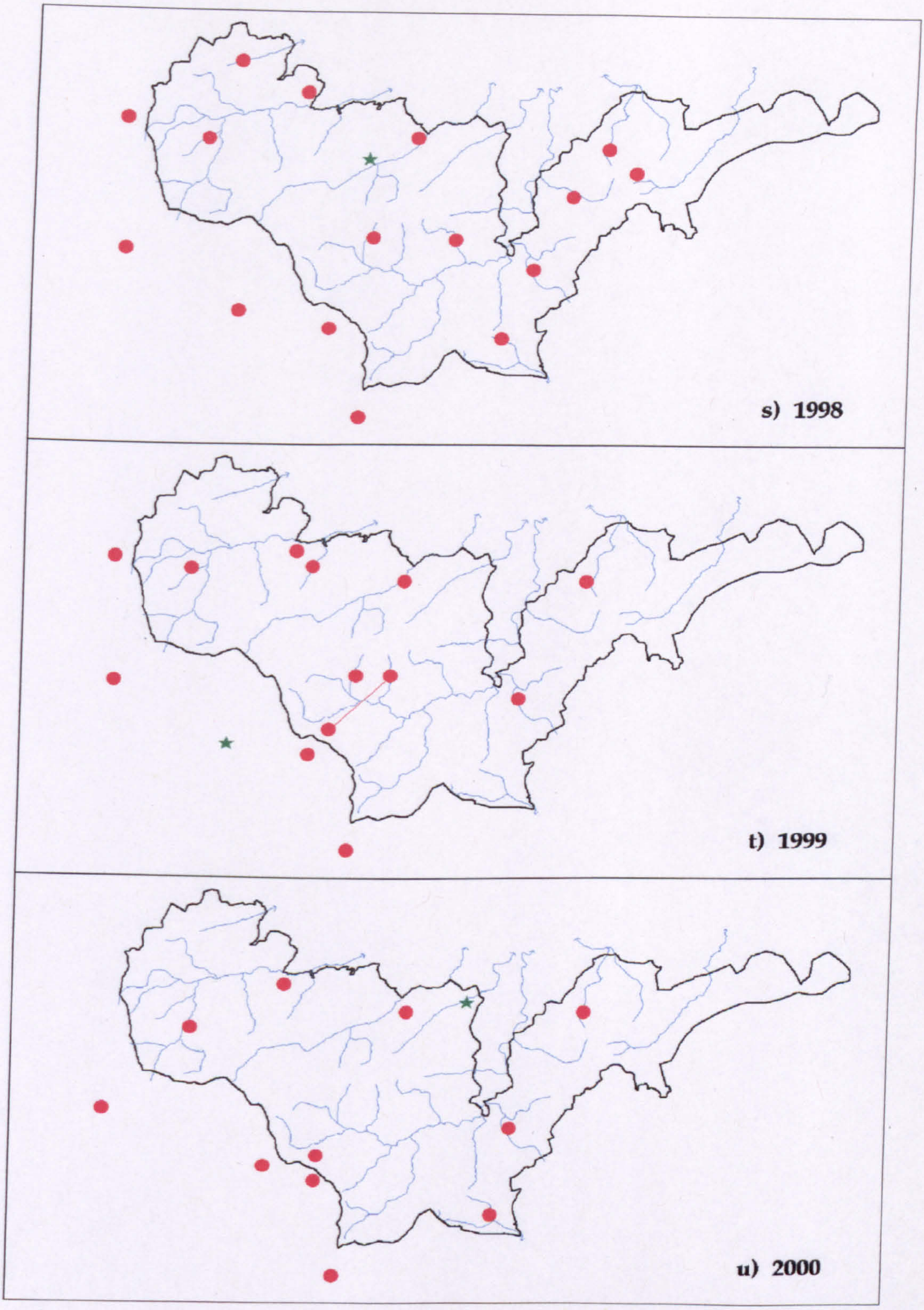
Appendix 3 (j-l) The lower Deeside Merlin study area and nearby, showing confirmed or probable ● and possible ★ breeding sites in 1989 to 1991. Red lines joining sites were repeat breeding attempts or movements and blue lines are rivers. Scale: 5 km ________



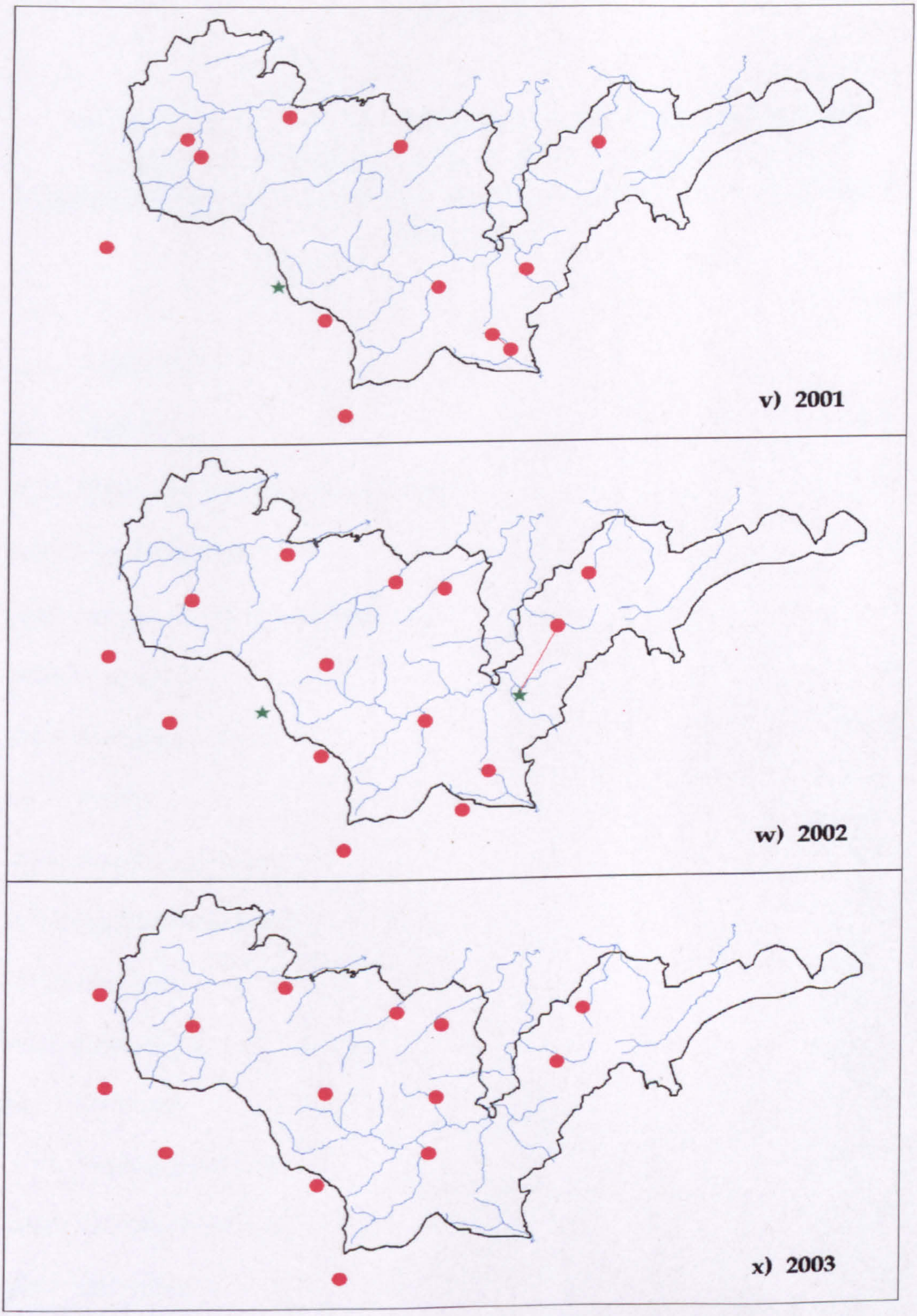
Appendix 3 (m-o) The lower Deeside Merlin study area and nearby, showing confirmed or probable ● and possible ★ breeding sites in 1992 to 1994. Red lines joining sites were repeat breeding attempts or movements and blue lines are rivers. Scale: 5 km ________



Appendix 3 ***(p-r)*** The lower Deeside Merlin study area and nearby, showing confirmed or probable ● and possible ★ breeding sites in 1995 to 1997. Red lines joining sites were repeat breeding attempts or movements and blue lines are rivers. Scale: 5 km ________



Appendix 3 (s-u) The lower Deeside Merlin study area and nearby, showing confirmed or probable ● and possible ★ breeding sites in 1998 to 2000. Red lines joining sites were repeat breeding attempts or movements and blue lines are rivers. Scale: 5 km ________



Appendix 3 (v-x) The lower Deeside Merlin study area and nearby, showing confirmed or probable ● and possible ★ breeding sites in 2001 to 2003. Red lines joining sites were repeat breeding attempts or movements and blue lines are rivers. Scale: 5 km ________

CHAPTER 4

HABITAT RELATED AND SPATIAL VARIATION IN MERLIN BREEDING PHENOLOGY, EGG SIZE, CLUTCH SIZE AND PRODUCTIVITY ON DEESIDE, NORTH-EAST SCOTLAND DURING 1980 to 2003

HABITAT RELATED AND SPATIAL VARIATION IN MERLIN BREEDING PHENOLOGY, EGG SIZE, CLUTCH SIZE AND PRODUCTIVITY ON DEESIDE, NORTH-EAST SCOTLAND DURING 1980 to 2003

4.1 Introduction

In natural ecosystems habitats change under the influence of global weather patterns (Morris *et al* 1993). Plants and animals respond to habitat change by adapting, often through evolutionary natural selection (Darwin 1888) or by moving range. If habitat change is rapid or extreme, as following earthquake or volcanic eruption, species can become temporarily absent or extinct (e.g. Winchester 2004). Habitats can therefore vary in structure in space and time, and can broadly be described as optimal, suitable, marginal or inappropriate when considering individual species.

After the formation of the Forestry Commission in Britain in 1919, large areas of the uplands were afforested with conifers (e.g. Nature Conservancy Council 1986, and details in Chapter 1.8 and Figure 1.7). The avifauna of commercially afforested moorland changes as open-country develops into plantations, with typical open-country birds decreasing and typical woodland birds increasing (Jessop 1982, Petty and Avery 1990). Such extensive land-use change can negatively affect territory quality in certain open-country birds. For example, decreases in Raven and Golden Eagle in south-west Scotland were believed to be caused by a loss of foraging habitat following afforestation (Marquiss *et al* 1978, 1985).

With regard to Merlin breeding habitat in Britain, it was reasoned that Merlin adapted to ancient natural forest clearance by colonising the successional moorland (Chapter 1.8). More recently, Merlin adapted to commercial conifer plantations in Wales (Parr 1991, 1994), north-east England (Little and Davison 1992, Little *et al* 1995) and south-west Scotland (Orchel 1992, Shaw 1994). However, Merlins were not utilising conifer plantations on a similar scale throughout their British breeding range (Chapter 2) and in north-east Scotland, a local population declined to zero following the commercial afforestation of former grouse moor (Chapter 3). The transition from moorland to dense conifer plantation could affect certain aspects of Merlin breeding biology. For example, by changing prey composition and possibly prey availability (Chapter 5) or by influencing breeding phenology, and egg and clutch sizes and productivity. The timing of breeding by some birds is determined by the body condition of individual females (Perrins 1970), for example, food availability was shown to influence egg-laying date and clutch size in the Kestrel *Falco tinnunculus* (Dijykstra *et al* 1982, Meijer *et al* 1990).

Following the decline of Merlin in the lower Deeside forestry (LDF) zone (Chapter 3), it could be expected that any changes to factors influencing breeding success would be detrimental. To explore this theory, I compare first egg-laying date from first clutches, egg volume per clutch, clutch size and productivity from the LDF zone and lower Deeside and mid and upper Deeside managed grouse moor (MGM) zones, and examine temporal trends where relevant. This chapter therefore addresses part of the fourth hypothesis for the thesis, which was ***"Merlin breeding in the afforested zone will have a different diet and breeding phenology, have different egg and clutch sizes and different productivity from those Merlin breeding in the managed grouse moor zones of the lower Deeside and mid and upper Deeside study areas".***

4.2 Methods

4.2.1 Study areas, survey and monitoring

The separation of north-east Scotland into Merlin study areas is shown in Figure 4.1. The lower Deeside study area was detailed in Chapter 3 Figure 3.1, with the LDF zone highlighted in Figure 3.2. In the LDF zone, the habitat prior to afforestation at three territories was either degenerate moor or scrub due for afforestation (5 nests at 2 territories) or MGM (4 nests at 1 territory) (see Chapter 3, Table 3.1). The five nests on degenerate moor or scrub due for afforestation were within 400 metres (m) of extensive post-thicket conifer plantations (see Chapter 3, Figures 3.1, 3.2 and 3.5). There was a strong possibility that the surrounding mature plantations (and current new plantations) would have an influence on breeding success at these nests. For example, conifer plantations are known to harbour potential predators of Merlin and their nests (e.g. Nature Conservancy Council 1986, Chapter 3.4.2, Appendix 7). Because of this, and as the land-use was fundamentally different from MGM I included the data from these nests in the LDF zone. In addition, the data from the four nests on MGM were included in the LDMGM zone. The mid and upper Deeside (MUD) MGM zone encompassed the majority of the remaining apparently suitable Merlin breeding habitat within the River Dee catchment. The survey and monitoring methods were detailed in Chapter 3, sections 3.2.1 and 3.2.2.

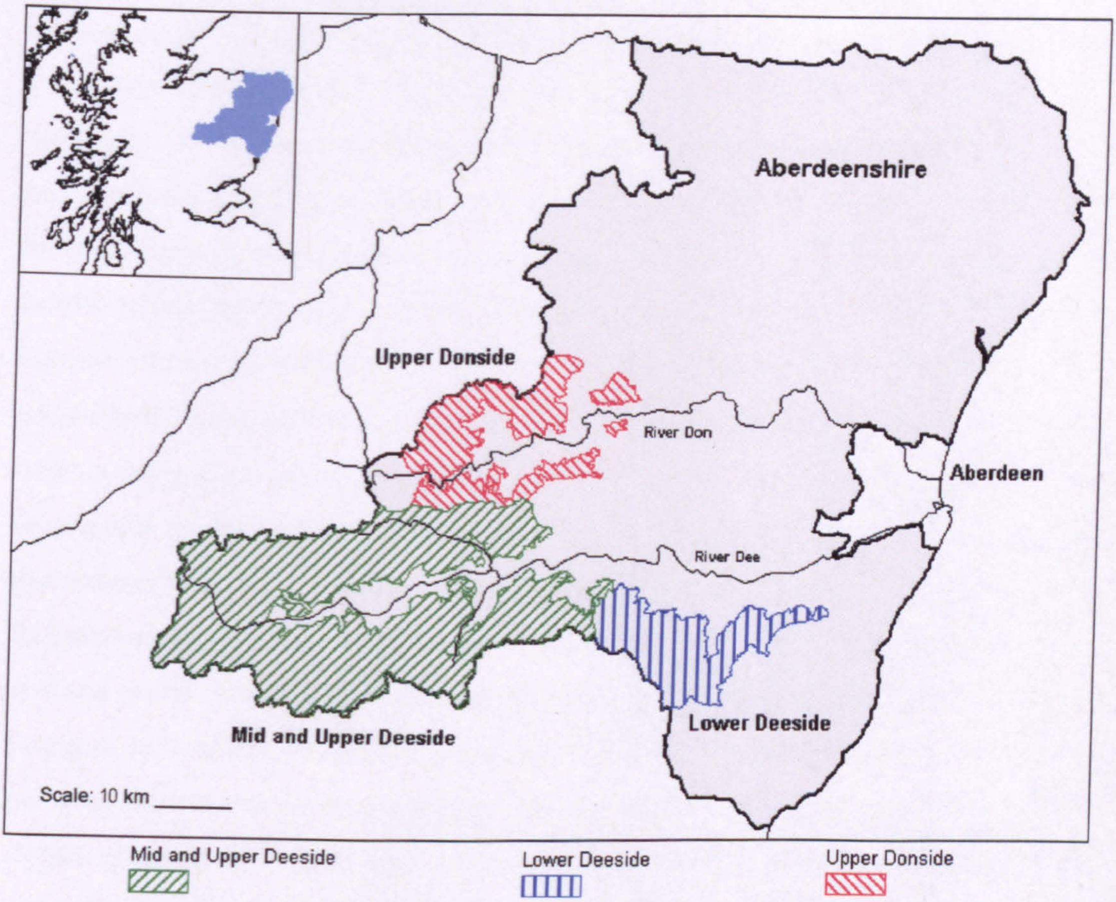


Figure 4.1 Separation of the Merlin breeding range in north-east Scotland into three study areas, for comparing territory occupancy and productivity in 1993 to 1996 (Cosnette and Rebecca 1997). Lower Deeside and mid and upper Deeside were used for this Chapter and Chapter 5. The lower Deeside study area was detailed in Chapter 3, Figures 3.1 and 3.2.

4.2.2 Egg laying dates

Merlin clutch size is usually three to five eggs, laid at two-day intervals and incubation normally begins on the second last egg (Chapter 2). The incubation period is usually 28 to 29 days per egg and the young fledge at 28 to 30 days (BWP 1980, Picozzi 1983, Dickson 2003). Using this knowledge the dates of the first egg laid was calculated using the following criteria. **The laying-in period:** This was when a nest was located with a partial clutch. If an egg was wet or had a feather stuck to it, it was judged as laid that day. Otherwise, the last egg was presumed laid the previous day. By counting back two days per egg for the remainder of the clutch, the first egg-laying date was estimated to within a day. **The hatching stage:** This was when the eggs were starred or chipping and the furthest developed was judged to hatch that day, or in 1 to 2 days. If a chick was wet, or dry and its size equivalent to egg volume, it would have hatched that day. If the chicks were about twice egg volume they were estimated to be 2 to 3 days. By counting back 29 days from the calculated hatch date of the oldest chick and as for the laying-in period, the first egg date could be estimated to within 1 to 3 days. **The ringing stage**: In 1987, Keith Brockie produced sketches from my photographs of known age chicks (Figure 4.2). For broods where the laying-in period or hatching stage was not known, their age was estimated from the sketches and by comparing their development with measurement graphs from Merlin in Orkney (Picozzi 1983). The oldest chick could then be identified and back counting done, giving an estimated first egg date to within 2 to 3 days. **The fluttering or recently fledged stage**: Before young Merlin fledge, they can flutter or fly short distances at 24 to 28 days (Dickson 2003 and see Photograph 4 in Chapter 1). At that stage, they occasionally allow a close approach or can be viewed with binoculars to assess down loss and feather development. Comparison can then be made with other recently fledged young of known age and back counting done. Although probably not as accurate as the previous criteria, this method estimated the first egg date to within 2 to 4 days. If the fledged young are confident flyers, it is not reliable to assess their age, as they can remain dependant on their parents for around 2 to 3 weeks after fledging. The accuracy of the calculations therefore varied between 1 to 4 days (or a maximum of ± 1.5 days) depending on the criterion used. This variation was not considered critical when assessing temporal trends or spatial variation as the same methods were used in all study zones. For presentation purposes, the mid point was plotted when the first-egg date could have been either of two, three or four days.

Based on a recommendation to standardise methods across European ornithology (Flegg and Zink 1973), Vaisanen (1977) attempted to limit bias on the timing of breeding of waders by defining the main egg-laying period as the shortest group of 5-day intervals in which 80% of clutches were started, with 10% dropped from the distribution ends. He believed this described breeding phenology more accurately than means, standard deviations (SD) and ranges, largely as it tried to eliminate repeat or unusually early clutches. For the Deeside study, any proven or highly probable repeat clutches (judged by the behaviour and signs left by the Merlins) were not included in the phenology analysis. This was considered appropriate as it reduced potential bias linked to study zone predation levels and there has been much recent interest in the timing of first clutches of birds in relation to global climate change (Crick *et al* 1997, Crick and Sparks 1999).

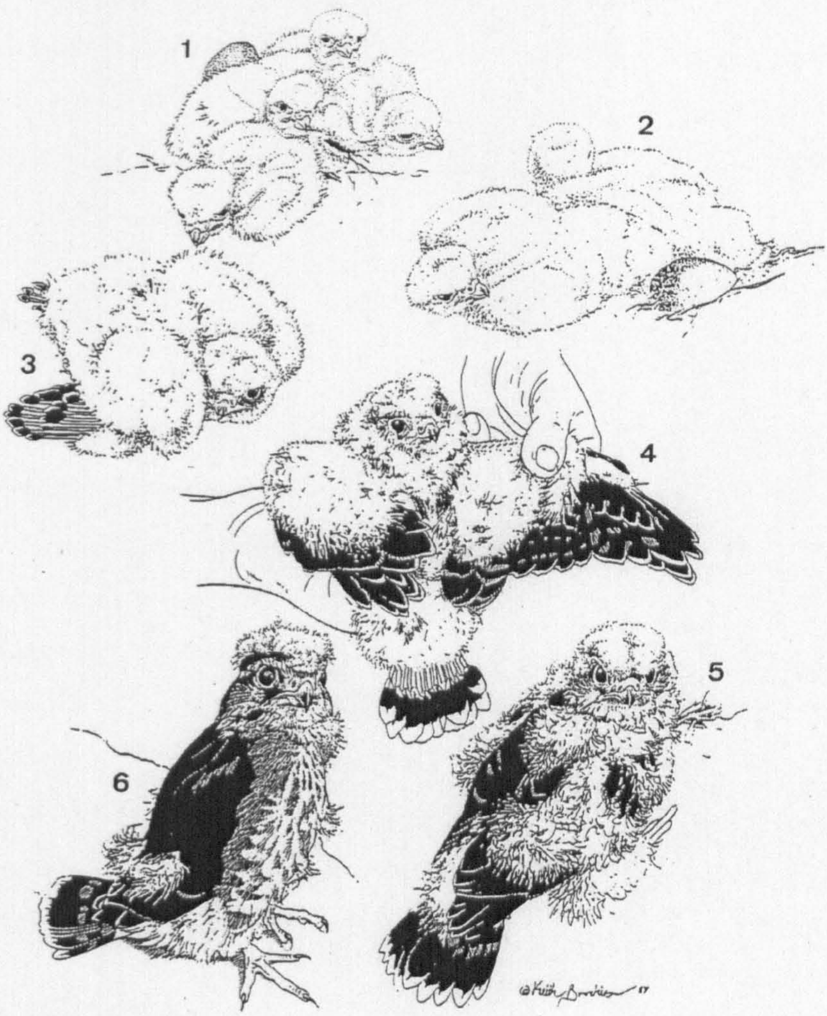


Figure 4.2 Sketches of nestling Merlin of known age by Keith Brockie. **1** = 3 to 5 days, short white down, egg tooth still present. **2** = 6 to 7 days, longer greyish down, no egg tooth. **3** = 11 to 15 days, primaries and tail sprouting, can be ringed but sexing sometimes difficult. **4** = 17 to 18 days, easy to handle and ring, sexing reliable, males <200 grams, females >200 grams. **5** = 21 to 22 days, rapid down loss and feathers forming well, males usually ~200 grams, females usually >220 grams. **6** = 24 to 26 days, capable of short flights.

4.2.3 Clutch size, egg size and egg volume

Clutch size was determined if the nest was visited at least twice during incubation, or if the signs on the first visit indicated that incubation had begun and depletion was not suspected. After incubation starts, moulted body feathers from adults can attach to vegetation around the nest. As incubation progresses the adults start to moult primary, secondary and tail feathers and these can be found at the nest or at nearby plucking or perching sites. Further, at ground nests, the adults nibble through many heather stalks. These clues all confirm that incubation has begun. From 1982, the length, and breadth at the widest point, of most eggs was measured to the nearest 0.1 millimetre (mm) using dial callipers. Egg volume in cm^3, was calculated using the formula $el \times eb^2 \times K$ where *el* represented egg length and *eb* egg breadth, with *K* the constant 0.51, as devised by Hoyt (1979).

4.2.4 Productivity

The number of recently fledged young and young believed to have fledged was used to measure breeding performance. Most nests were previously visited to ring the young, when they were between 2 and 3½ weeks old. When the expected number of fledged young were not seen or heard, the nest and surrounding area was searched for casualties or signs of a predator (Rebecca 1992, Rebecca *et al* 1992). If no evidence of depredation was found the number of young ringed, or expected to fledge, was taken as the fledged total (see also Chapter 2.1 for similar methods used at other Merlin studies in Britain). Mean annual productivity per study zone was determined by dividing the total number of young fledged or expected to fledge, by the number of confirmed or probable breeding attempts, including nests that had failed earlier.

4.2.5 Statistical analyses

To compare first egg-laying date from first clutches, egg volume per clutch, clutch size and productivity between the two study areas (lower Deeside and mid and upper Deeside) and land-use (commercial afforestation and managed grouse moor) I used a MIXED procedure model in SAS v 9 (SAS 2001). The commercial afforestation category included years prior to planting, when the habitat was either degenerate moor or scrub due for afforestation (see 4.2.1 earlier) or was being prepared for planting (e.g. see Photograph 10 in Chapter 1 and Photograph 12 in Chapter 3). I tested for differences in relation to land-use and study area using first egg-laying date from first clutches, egg volume per clutch, clutch size and productivity as dependant variables, with territory and year as random class variables. I also examined temporal patterns from each study zone for the same dependent variables with territory as a random class variable. Finally, for the LDF zone I tested for the effects of the age of the plantations for the same dependent variables with year and territory as random class variables. Denominator degrees of freedom were calculated in the model using Satterthwaite's formula (Littell *et al* 1996). This formula controls for, or attempts to limit bias through pseudo-replication, with each error stratum and each test in the model contributing to the total of residual degrees of freedom (see Preface). Descriptive statistics were done using Minitab software, version 13 (Minitab 2001).

4.3 Results

4.3.1 Breeding phenology

The first egg-laying date was calculated for 360 nests during 1980 to 2003, a mean of 15 per year, range 7 to 22 (Table 4.1). There were 70 nests from the LDF zone, 139 from the LDMGM zone and 151 from the MUDMGM zone. The first egg-laying range covered 43 days, from the 24 to 25 of April to 5 June (Figure 4.3). Ten definite and ten probable repeat nests were recorded but are not considered further (explained in Methods, section 4.2.2).

The mean first egg-laying dates, SD and first and third inter-quartile ranges for first clutches were similar for each study zone (Table 4.2) and there was no significant difference between study areas ($F_{1,42}$ = 0.15, P = 0.698) or land-use types ($F_{1,39}$ = 0.25, P = 0.623). There was no significant temporal change in the first egg-laying date for first clutches in either study zone (LDF, $F_{1,49}$ = 0.03, P = 0.873, LDMGM, $F_{1,128}$ = 0.04, P = 0.843 and MUDMGM, $F_{1,129}$ = 0.08, P = 0.784). There was also no significant relationship in the LDF zone between first egg-laying date for first clutches and the age of the plantations ($F_{1,50}$ =

0.02, $P = 0.885$). Combining the data for all of Deeside gave a mean first egg-laying date for first clutches of 8 May ± 5.5 days SD (n 340) with the first and third inter-quartile ranges covering the 4 to 5 May to 11 May (Table 4.2).

Table 4.1 The number of Merlin breeding attempts on Deeside, north-east Scotland where the first egg-laying date was calculated during 1980 to 2003.

The criteria used to calculate the dates were: 1) An incomplete clutch. 2) Eggs starred or chipping, chicks just hatched or 1 to 3 days old. 3) Brood weighed and measured and compared to graphs (Picozzi 1983) and sketches of known age chicks (Figure 4.2). 4) Recently or nearly fledged young. Further details in the Methods (section 4.2.2).

	Incomplete clutch	Hatching eggs or chicks 1-3 days	Biometrics, graphs and sketches	Recently or nearly fledged young
1980			7	
1981	3	2	3	
1982	6	3	3	
1983	3	2	3	
1984	10	3	2	
1985	7	9	3	
1986	9	2	7	
1987	5	3	4	
1988	8	5	2	1
1989	2	1	7	1
1990	9	5	3	3
1991	9	3	4	1
1992	10	2	5	1
1993	8	1	7	1
1994	6	3	6	
1995	5	2	6	1
1996	3	2	8	1
1997	12		5	
1998	13		5	1
1999	6	2	7	
2000	4	2	9	1
2001	2	2	10	
2002	1	1	14	
2003	1	2	19	
Totals	142	57	149	12

Table 4.2 Mean first egg-laying dates, SD and inter-quartile ranges of first clutches of Merlins at three study zones on Deeside, north-east Scotland during 1980 to 2003. For the annual spread of dates see Figure 4.3. Day one represented 24 April.

Study zone	Number of clutches	Mean first egg-laying day and date (standard deviations)	Inter-quartile range
LDF	65	15.78 (5.32) ~ 16 = 9 May (4-14 May)	5-6 to 12-13 May
LDMGM	130	14.94 (5.54) ~ 15 = 8 May (2-14 May)	4-5 to 11-12 May
MUDMGM	145	14.95 (5.54) ~ 15 = 8 May (2-14 May)	4-5 to 11 May
All Deeside	340	15.01 (5.49) ~ 15 = 8 May (2-14 May)	4-5 to 11 May

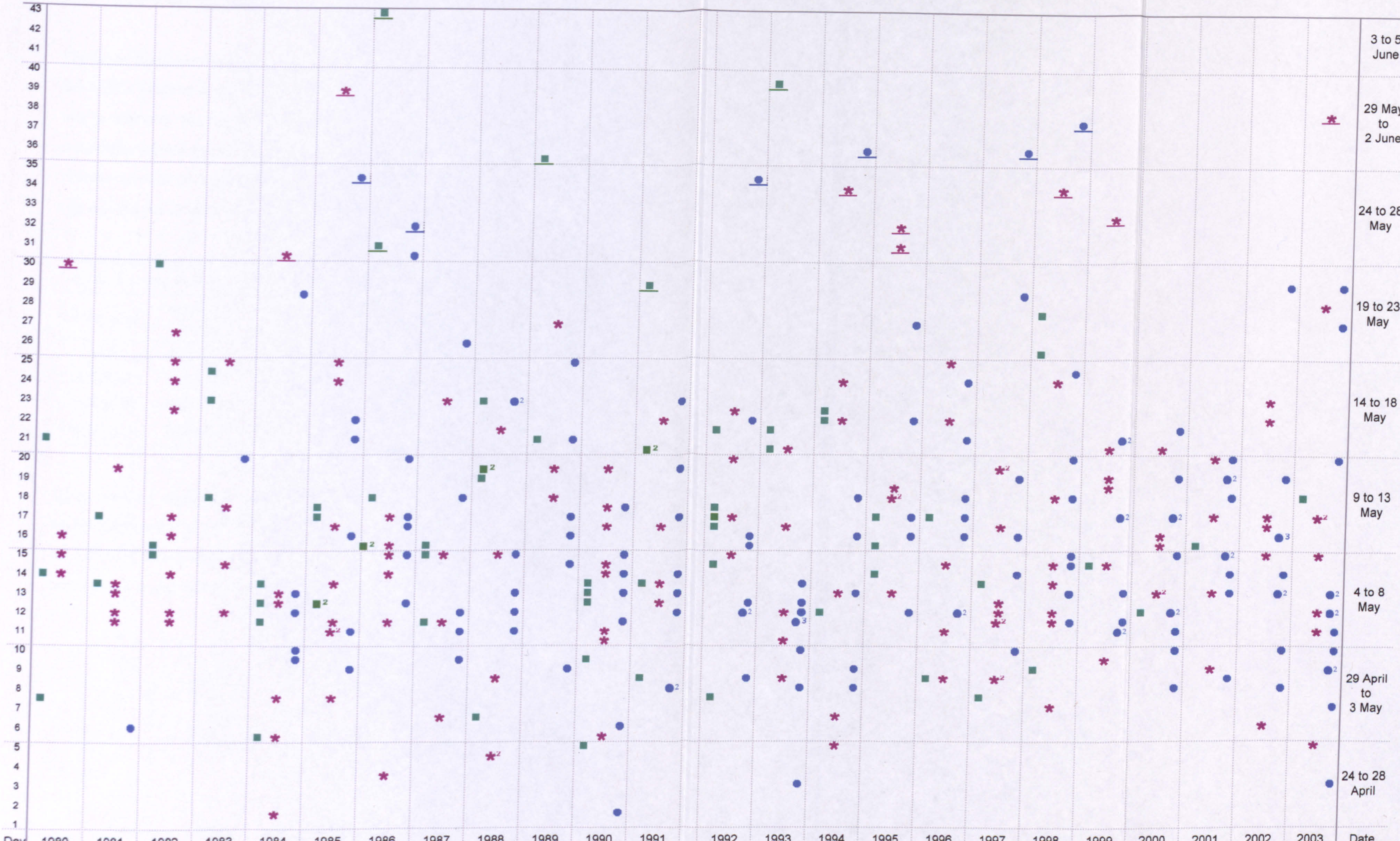


Figure 4.3 Calculated first egg-laying date from all clutches of Merlins on Deeside, north-east Scotland during 1980 to 2003. The criteria used are shown in Table 4.1 and are detailed in the Methods, 4.2.2. ■ Represents lower Deeside forestry. ✱ Represents lower Deeside managed grouse moor. ● Represents mid and upper Deeside managed grouse moor. Day 1 represents 24 April. Superscript numbers [2,3] represent the number of clutches started that day. There was 10 definite and 10 probable repeat nests (judged by behaviour or movements) and these are underlined.

4.3.2 Egg size and egg volume

The mean measurements of egg length and breadth, and egg volume (cm³) per clutch from 281 Merlin clutches at the three study zones in 1982 to 2003 are shown in Table 4.3. There was a tendency for eggs to be smaller in lower Deeside but the difference was not statistically significant ($F_{1,45} = 3.7$, $P = 0.061$). There was also no significant difference in egg volume between land-use types ($F_{1,36} = 2.09$, $P = 0.157$). Combining all of Deeside the mean egg volume per clutch was 20.1 cm³ ± 1.3 SD.

Table 4.3 Mean egg length and breadth (mm) and egg volume (cm³) per clutch ± SD of Merlin from three study zones on Deeside, north-east Scotland during 1982 to 2003.

Study zone	Mean egg length	Mean egg breadth	Number of eggs	Mean egg volume per clutch	Number of clutches
LDF	39.6 ± 1.5	31.3 ± 1.0	229	19.8 ± 1.7	54
LDMGM	40.0 ± 1.3	31.4 ± 0.9	527	20.1 ± 1.3	123
MUDMGM	40.0 ± 1.6	31.5 ± 0.9	463	20.3 ± 1.1	104
All Deeside	39.9 ± 1.5	31.4 ± 0.9	1219	20.1 ± 1.3	281

There was no significant temporal change in mean egg volume per clutch in the MUDMGM zone ($F_{1,98} = 1.07$, $P = 0.303$) or LDF zone ($F_{1,52} = 1.03$, $P = 0.314$) but there was in the LDMGM zone (Figure 4.4). There was no significant relationship within the LDF zone between mean egg volume per clutch and the age of the plantations ($F_{1,52} = 1.53$, $P = 0.222$).

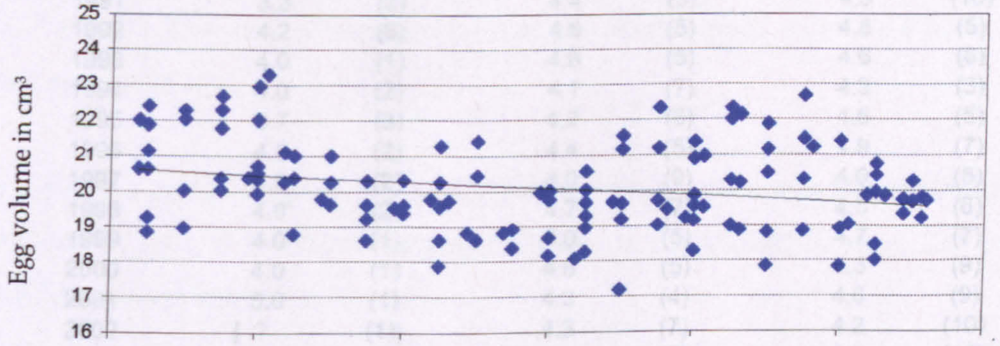


Figure 4.4 The mean egg volume per clutch (cm³) of Merlin in the lower Deeside managed grouse moor zone, north-east Scotland during 1982 to 2003. If the data points overlapped considerably, they were moved ± 0.25 years. The negative temporal trend was highly significant ($F_{1,119} = 8.88$, $P = 0.004$) with potential pseudo-replication controlled for in the model (see Methods).

4.3.3 Clutch size

Mean annual clutch sizes, and total means ± 95% confidence intervals, from the three study zones in 1980 to 2003 are shown in Table 4.4. There was no significant difference in overall clutch size between study areas ($F_{1,49}$ = 1.59, P = 0.213) or land-use types ($F_{1,45}$ = 0.20, P = 0.654) giving a mean for all of Deeside of 4.4 ± 0.6 SD per clutch (n 342). There was also no significant temporal change in clutch size in the LDMGM zone ($F_{1,133}$ = 0.3, P = 0.588) and MUDMGM zone ($F_{1,103}$ = 0.18, P = 0.674) but there was in the LDF zone (Figure 4.5). However, there was no significant change in clutch size in the LDF zone in relation to the age of the plantations ($F_{1,49}$ = 1.22, P = 0.275).

Table 4.4 Mean annual clutch sizes, and total means ± 95% confidence intervals, of Merlin from the three study zones on Deeside, north-east Scotland during 1980 to 2003. Sample sizes are within brackets.

Years	Study zones and mean clutch sizes					
	LDF	(n)	LDMGM	(n)	MUDMGM	(n)
1980	5.0	(2)	4.7	(3)	4.5	(2)
1981	4.0	(2)	3.8	(5)	-	-
1982	4.3	(4)	4.1	(9)	4.0	(1)
1983	4.3	(3)	3.8	(4)	4.0	(4)
1984	4.3	(3)	4.2	(5)	4.0	(4)
1985	4.7	(3)	4.8	(8)	4.6	(5)
1986	5.0	(3)	4.8	(5)	4.1	(7)
1987	4.7	(3)	4.3	(4)	4.5	(8)
1988	4.6	(5)	4.4	(5)	4.6	(8)
1989	4.0	(1)	4.8	(4)	4.8	(5)
1990	4.2	(5)	4.1	(7)	4.3	(7)
1991	3.3	(3)	4.4	(5)	4.3	(10)
1992	4.2	(6)	4.6	(5)	4.6	(5)
1993	4.0	(1)	4.6	(5)	4.6	(6)
1994	4.0	(2)	4.1	(7)	4.3	(3)
1995	3.7	(3)	4.2	(6)	4.6	(5)
1996	4.5	(2)	4.4	(5)	4.9	(7)
1997	4.0	(2)	4.0	(9)	4.0	(5)
1998	4.0	(2)	4.7	(7)	4.5	(6)
1999	4.0	(1)	4.0	(5)	4.7	(7)
2000	4.0	(1)	4.6	(5)	4.3	(9)
2001	5.0	(1)	4.3	(4)	4.6	(9)
2002	[?	(1)]	4.3	(7)	4.2	(10)
2003	4.0	(1)	4.4	(7)	4.4	(14)
1980-03	4.3 ± 0.2	(59)	4.3 ± 0.1	(136)	4.4 ± 0.1	(147)

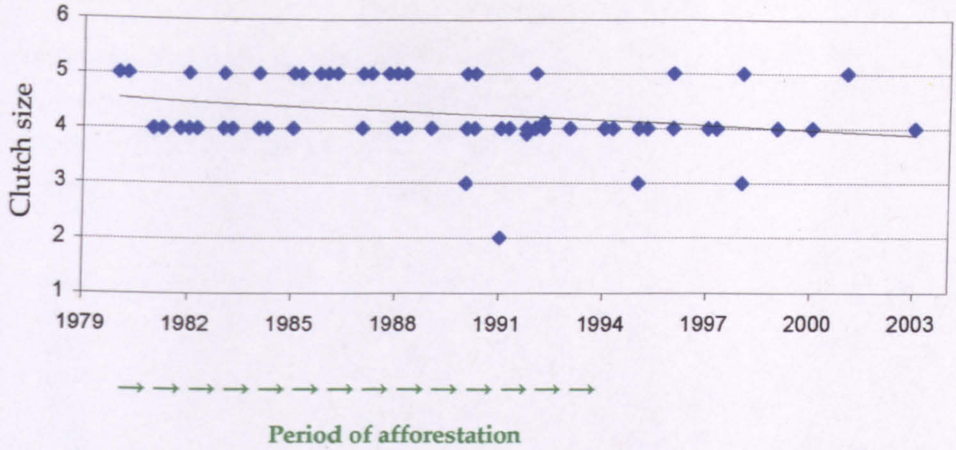


Figure 4.5 Clutch size of Merlin in the lower Deeside forestry zone, north-east Scotland during 1980 to 2003. If the data points overlapped considerably, they were moved ± 0.25 years and sample sizes are in Table 4.4. The negative temporal trend was significant ($F_{1,57}$ = 4.0, P = 0.05) with potential pseudo-replication controlled for in the model (see Methods).

4.3.4 Productivity

Mean annual productivity, and total means ± 95% confidence intervals, from the three study zones in 1980 to 2003 are shown in Table 4.5. There was a significant difference in productivity between study areas ($F_{1,37}$ = 6.73, P = 0.014) but not between land-use types ($F_{1,38}$ = 1.27, P = 0.268). There was a highly significant positive temporal change in productivity in the MUDMGM zone (Figure 4.6) whereas there was no significant temporal change in productivity in the LDMGM zone ($F_{1,167}$ = 0.78, P = 0.378) and LDF zone ($F_{1,79}$ = 0.53, P = 0.47). This gave a mean productivity for all of Deeside of 2.4 ± 1.8 SD fledged young per pair (n 464).

The difference in the complete failure rate between study zones was almost statistically significant ($F_{1,39}$ = 3.15, P = 0.084) ranging from 25% in the MUDMGM zone, 31% in the LDMGM zone and 42% in the LDF zone.

Table 4.5 Mean annual productivity, and total means ± 95% confidence intervals, of Merlin from the three study zones on Deeside, north-east Scotland during 1980 to 2003. Sample sizes are within brackets.

Years	Study zones and mean productivity					
	LDF	(n)	LDMGM	(n)	MUDMGM	(n)
1980	3.3	(3)	3.5	(4)	1.5	(2)
1981	2.0	(2)	2.6	(7)	2.0	(1)
1982	0.8	(5)	2.4	(9)	1.5	(2)
1983	1.4	(5)	2.8	(5)	2.1	(7)
1984	1.0	(4)	1.7	(7)	2.9	(9)
1985	1.5	(4)	1.4	(9)	1.9	(12)
1986	2.2	(5)	3.0	(7)	2.1	(10)
1987	3.7	(3)	1.0	(6)	2.4	(10)
1988	2.8	(5)	2.6	(7)	3.0	(10)
1989	1.2	(5)	1.8	(5)	1.9	(10)
1990	1.4	(5)	1.7	(9)	2.7	(11)
1991	1.5	(6)	1.2	(6)	2.3	(12)
1992	0.8	(6)	0.8	(6)	2.8	(9)
1993	1.8	(4)	2.0	(5)	2.0	(11)
1994	1.5	(4)	3.0	(7)	2.8	(9)
1995	1.0	(4)	2.8	(8)	3.0	(7)
1996	3.0	(2)	2.5	(8)	3.7	(7)
1997	3.5	(2)	2.0	(9)	1.8	(9)
1998	1.7	(3)	2.4	(8)	3.3	(8)
1999	1.0	(1)	1.7	(7)	2.5	(10)
2000	4.0	(1)	2.8	(6)	3.6	(11)
2001	5.0	(1)	2.1	(7)	2.8	(10)
2002	[>1.0	(1)]	2.9	(8)	3.8	(13)
2003	3.0	(1)	3.5	(8)	2.9	(15)
1980-03	1.8 ± 0.4	(81)	2.3 ± 0.3	(168)	2.7 ± 0.2	(215)

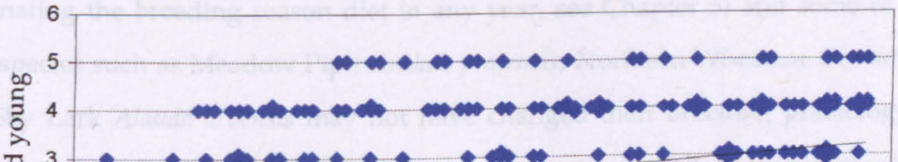


Figure 4.6 Number of fledged young of Merlin in the mid and upper Deeside managed grouse moor zone, north-east Scotland during 1980 to 2003. If the data points overlapped considerably, they were moved ± 0.25 years and sample sizes are in Table 4.5. The positive temporal trend was highly significant ($F_{1,148}$ = 9.04, P = 0.003) with potential pseudo-replication controlled for in the model (see Methods).

4.4 Discussion

4.4.1 Breeding Phenology

Contrary to one prediction from my fourth hypothesis, there was no significant difference in breeding phenology between the LDF and the two MGM zones. Nor was there any significant difference between the two study areas. Between 1971 and 1995 many British birds advanced their breeding cycle in response to warmer springs linked to global climate change (Crick *et al* 1997). In the analysis by Crick *et al* (1997) birds showing a significant trend towards earlier egg-laying were not confined to any one ecological or taxonomic group and comprised of waders, resident and migrant insectivores, corvids and seed-eaters. These included species regularly taken as Merlin breeding season prey in north-east Scotland, such as Wren *Troglodytes troglodytes*, Common Starling *Sturnus vulgaris*, Willow Warbler *Phylloscopus trochilus*, Common Chaffinch *Fringilla coelebs* and Greenfinch *Carduelis spinus* (see Chapter 5 later). Merlins are dependent on bird prey, some of which can be influenced by climatic conditions. A trend towards earlier egg-laying in the later years of this study may therefore have been expected. However, there was no significant temporal change in Merlin first egg-laying dates from first clutches from either study zone.

The apparent lack of response to climate change by Merlin in north-east Scotland could be due to several factors. For example, Merlin are generalist predators (with 4 to 7 birds dominating the breeding season diet in any year, see Chapter 5) and some of their main prey species such as Meadow Pipit *Anthus pratensis*, Northern Wheatear *Oenanthe oenanthe* and Sky Lark *Alauda arvensis* may not have changed their breeding phenology. Even if Merlin prey are breeding earlier it does not automatically follow that migrants returned early, or if they did, that they were available for Merlin. Other environmental conditions could be just as, or more important than temperature in regulating Merlin breeding phenology. For example, precipitation or fog-days can affect Merlin hunting efficiency and males provide for the females for around a month prior to and during egg-laying (e.g. BWP 1980). The duration of the study, in climate change terms, may not have been adequate to assess changes, particularly as there was large non-correlated annual variation in first egg-laying date (Figure 4.3), indicating that other factors may have been controlling

Merlin phenology in north-east Scotland. It is plausible to suggest that phenology was influenced by female body condition in winter and spring (e.g. Dijykstra *et al* 1982) linked to the male's hunting efficiency in the pre-egg-laying period.

As there was no significant difference in first egg-laying dates of first clutches or temporal trends, from either study zone, the data were combined to set a baseline for future comparison, and for possible comparison with other studies. However, such data from other Merlin studies in Britain are either not being collected or have not been published (Merlin study group co-ordinators *personal communications*). This may change if raptor ecologists are made more aware of the possible effects of global warming. The publications by Crick *et al* (1997) and Crick and Sparks (1999) have alerted conservationists to the correlations between advanced breeding in many birds and the phenomenon of global warming, but it may need a specific request to Raptor Study Groups for them to record qualitative and quantitative data on Merlin egg-laying dates.

4.4.2 Egg size and egg volume

Merlin egg volume was not significantly different between study zones. However, the temporal pattern of egg volume in the LDMGM zone was interesting, in that it decreased during the mid 1980s to mid 1990s and then increased again. A possible reason for this could be that habitat quality changed during that period. The primary land management in the LDMGM zone throughout the study period was aimed at increasing Red Grouse for sport shooting (Chapters 1.9 and 3.1). However, on Glen Dye Estate (the largest estate in the lower Deeside study area) in the mid 1980s to mid 1990s there was also a targeted attempt to promote Red Deer. This was an attempt to further diversify the business interest on the estate (see Appendix 5 for forestry diversification on Glen Dye Estate). The scheme was described as "Red Deer farming" by Peter Gladstone and Archie Dykes, the game manager and head game-keeper respectively on Glen Dye Estate. The main management techniques, as far as I observed and could decipher, were to reduce the cull on hinds and calves (to build up a large stock). Then, fence large areas of moorland and annually capture, coral and cull wild deer in autumn, keeping some as corralled breeding stock. Finally, provide winter feed and shelter for the remaining wild population and retain large numbers of prime breeding age animals.

Red deer numbers were generally high on Deeside during the 1980s and this new management technique increased numbers such that large herds of 800 to 900 were regularly seen throughout Glen Dye Estate and neighbouring estates. It is possible that the increasing Red Deer population altered the quality of the moorland habitat for some of the Merlin's prey species. For example, by increased trampling of nests of birds such as Meadow Pipit and Sky Lark and by increased grazing of heather. Archie Dykes (*personal communication*) believed that such large numbers of Red Deer were negatively affecting Red Grouse numbers, by trampling nests and small young and by overgrazing the heather, the main food plant of Red Grouse. There was much debate between the land-managers on Glen Dye Estate regarding the merits or otherwise of Red Deer farming (Archie Dykes and Frank Sheridan, head forester on Glen Dye Estate [see Appendix 5] *personal communications*). The enterprise was abandoned in the late 1990s following issues concerning the catching and corralling of the deer and winter mortality of the breeding stock.

There has been considerable debate within avian studies when assessing the advantages or otherwise of larger or smaller than average eggs (reviewed in Williams 1994). Many studies concluded there was a positive link between larger eggs and chick survival, and hence breeding success (e.g. Amundsen and Stokland 1990 and Clutton-Brock 1991, both in Williams 1994). Other authors have theorized and produced plausible evidence that large eggs are linked to habitat quality (Evans *et al* 2005) or parental quality, particularly of female size and condition (e.g. Bolton 1991, Magrath 1992, both in Williams 1994). It has also been suggested for some species that variation in avian egg size may simply be inherited (Moss and Watson 1982, Flint *et al* 2001). Assessing parental quality or analysing genetic structure of adults was outwith the scope of this Chapter, since the main aim was to compare breeding parameters across study zones, one of which had undergone radical habitat change.

However, there is evidence from ringing recoveries and controls, of a good genetic mix in British Merlin (Mead 1973, Heavisides 2002). Further, the switching of breeding areas, and movements from birthplace to breeding place of Merlins is regular between the Deeside study zones, and Donside study area in Aberdeenshire (Figure 4.1) and from studies in the neighbouring regions of Morayshire and Tayside (Rebecca 1987 a, Rebecca *et al* 1992, Appendices 6 and 7). These movements also indicate that there is probably a good genetic mix within Merlin populations in central and north-east Scotland. This being the case, it is more likely that habitat quality is influencing Merlin egg size in north-east Scotland since the largest eggs were found in the MGM zones, both of which produced more young on average than the LDF zone.

4.4.3 Clutch size

There was no significant difference in clutch size between study areas or land-use types. There was also no significant temporal change in the LDMGM and MUDMGM zones. However, this was not the case for the LDF zone, where there was a significant decrease in clutch size during the study period. It has been suggested, and confirmed experimentally for the Magpie, that territory quality is the most important factor in determining the optimum clutch size in territorial birds (Hogstedt 1980). This implies that birds occupying high quality territories lay larger than average clutches and birds with poor territories lay smaller clutches. The occupancy of breeding territories in the LDF zone had declined to zero by 2004 and 2005 indicating that the habitat was unsuitable for Merlin (Chapter 3). The temporal decrease in clutch size in the LDF zone suggests that the overall area became a poorer habitat for breeding Merlin over time, providing further evidence that commercial conifer plantations are an inappropriate breeding habitat for Merlin in north-east Scotland.

4.4.4 Productivity

There was a significant difference in productivity between study areas, but not land-use. This was a result of the productivity in the LDMGM zone being intermediate and influencing both explanatory variables in the model. There was no significant temporal change in productivity the LDF and LDMGM zones. In contrast, there was a highly significant increase in productivity in the MUDMGM zone during the study period. By the mid 1990s, Merlin in Britain had generally recovered from the worst effects of pollutants (Newton *et al* 1999, and details in Chapter 1.5) and breeding success improved over time during 1937 to 1989 (Crick 1993). Assuming that the effects of pollutants occurred evenly across study zones on Deeside, the lower complete failure rate in the MUDMGM zone, in comparison to both lower Deeside zones, was probably the main reason for the temporal increase in productivity in the MUDMGM zone. This indicates that some aspects of territory quality in the MUDMGM zone were better for Merlin than in the lower Deeside zones, and that the LDMGM zone was better for Merlin than the LDF zone. The higher complete failure rate in the LDF zone could reflect an increased predation risk associated with commercial afforestation (e.g. Nature Conservancy Council 1986). Further work to test these theories should include quantifying game-keeper quality and intensity, quantifying Merlin prey and potential Merlin predator abundance, assessing Merlin nest-site quality and identifying land-management priorities.

In an assessment of productivity and Merlin population status, a minimum of 2.0 fledged young per pair per year was the figure reasoned to maintain relative stability (Petty 1995 and see Chapter 2.1). Below that figure, it was predicted that Merlin would decrease, if emigration and immigration for a study area were similar. The poor overall productivity from the LDF zone, at an average of 1.8 fledged young per pair per year, supports the theory from Petty (1995) since the Merlin population there declined significantly during the study period and was zero in 2004 and 2005 (Chapter 3).

4.5 Conclusions

- The first-egg laying dates from first clutches were similar in different land-use and spatial study zones, and there was no temporal trend evident at either study zone.
- Egg volume was smaller, but not significantly so, in the commercially afforested zone. Egg volume decreased in the LDMGM zone, possibly linked to a change in land management, involving an increase in Red Deer numbers

- There was no significant difference in overall clutch size in the different land-use and spatial study zones. However, clutch size decreased significantly in the commercially afforested zone over time.
- Productivity was lower in the commercially afforested zone compared to both MGM zones, with the difference being significant between study areas. Further comparison would be desirable but this is unlikely due to the lack of breeding pairs in the afforested zone. The MUDMGM zone was by far the most productive, and both 'grouse moor' zones produced enough young, based on previous assessment, to maintain stability at least. In contrast, the commercially afforested zone produced less young than necessary to maintain numbers.
- The fourth hypothesis for the thesis predicted that ***certain breeding parameters in the lower Deeside forestry zone would be different from those in the lower Deeside managed grouse moor zone and mid and upper Deeside managed grouse moor zone.*** The hypothesis is rejected for breeding phenology, is inconclusive for egg and clutch size and is upheld for productivity.
- There was no long-term biological benefit to Merlin in north-east Scotland following the commercial afforestation of previously suitable moorland breeding habitat. Egg and clutch sizes may have been negatively affected by such land-use change and productivity was below the baseline assessed to maintain stability in numbers. These factors combine to confirm that breeding habitat quality decreased in the afforested zone over time and that 'grouse moors' were more suitable habitats for Merlin in north-east Scotland during 1980 to 2003.

CHAPTER 5

MERLIN BREEDING SEASON DIET FROM DEEESIDE, NORTH-EAST SCOTLAND IN RELATION TO TIME, AREA AND LAND-USE CHANGE DURING 1980 to 2003

MERLIN BREEDING SEASON DIET FROM DEEESIDE, NORTH-EAST SCOTLAND IN RELATION TO TIME, AREA AND LAND-USE CHANGE DURING 1980 to 2003

5.1 Introduction

The breeding season diet of the Merlin has been well reported from some areas of Britain, such as Shetland (Ellis and Okill 1990), Orkney (Meek 1988), the Lammermuir Hills in south-east Scotland (Heavisides *et al* 1995), Galloway in south-west Scotland (Watson 1979, Orchel 1992), Northumbria in north-east England (Newton *et al* 1984, Petty *et al* 1995) and Wales (Bibby 1986, Roberts and Jones 1999). These studies provide a representative view from widely separated areas within the Merlin breeding range (see Chapter 2, Figure 2.1). The most important prey species from these studies, from over 15000 items, are show in Table 5.1.

At the beginning of the Merlin study in north-east Scotland, one of the aims was to identify and quantify the breeding season diet. At that time, there was still a belief within certain game-keeping circles in north-east Scotland that Merlins were a threat to Red Grouse (Rebecca *et al* 1992, Cosnette and Rebecca 1997). In addition, in 1980, part of the lower Deeside Merlin study area began to be afforested with commercial conifers (Chapter 3). This potentially provided an opportunity for a comparative diet study in an area of changing land-use with the remainder of the lower Deeside study area and from mid and upper Deeside. Part of the fourth hypothesis for the thesis predicted that ***certain aspects of Merlin breeding ecology, such as prey composition, would be different in the afforested zone on lower Deeside compared to the managed grouse moor (MGM) zones in lower Deeside and mid and upper Deeside.*** This Chapter addresses this question by assessing and comparing the Merlin breeding season diet during April to July, the main period when territories are occupied, from the lower Deeside forestry (LDF), lower Deeside MGM (LDMGM) and mid and upper Deeside MGM (MUDMGM) land-management zones over similar study periods, and examines temporal trends where relevant.

Table 5.1 The top five avian prey species in percent numbers and percent weight (where available) of Merlins from various breeding season studies throughout Britain in the 1970s to 1990s. * Classed as woodland or scrub species with the remainder classed as open-country species. Insects and other prey were considered unimportant by weight at all studies.

Area, years and sample size.	[1]Shetland 1984-87 1248		[2]Orkney 1981-87 845		[3]Lammermuirs 1984-94 2040		[4]Galloway 1973 161		[5]Galloway 1977-80 152		[6]Northumbria 1974-82 2001		[7]Northumbria 1991-92 880		[8]Wales 1981-84 6366		[9]Wales 1973-89 1645	
Species	% no.	% wt.	% no.	% wt.	% no.	% wt.	% no.	% wt.	% no.	% wt.	% no.	% wt.	% no.	% wt.	% no.	% wt.	% no.	% wt.
Red Grouse						5												
Dunlin	5	8																
Common Snipe						8	2											
Common Cuckoo							2											
Sky Lark	27	32	21	25	9	11	24		6		12	16	8		3	5		
Meadow Pipit	16	10	39	26	63	38	45		47		56	37	59		61	52	48	
Whinchat															3		6	
Common Stonechat									2									
Northern Wheatear	39	34	6	6	6	5	4		7		2				5	5	5	
Fieldfare			2	6							2	7				5		
Common Starling			2		3	6	14				4	9			3	9		
House Sparrow	4	4	18	17													8 *	
Common Chaffinch*					5				3		6	5	12		8	7	6	
Siskin*													4					
Common Crossbill*													4					
% Totals	91	88	88	80	86	73	91		65		82	74	87		83	83	73	

[1] Ellis and Okill 1990, [2] Meek 1988, [3] Heavisides *et al* 1995, [4] Watson 1979, [5] Orchel 1992, [6] Newton *et al* 1984, [7] Petty *et al* 1995, [8] Bibby 1986, [9] Roberts and Jones 1999. Latin names in Table 5.2.

5.2 Study areas and methods

5.2.1 Study areas, and survey and monitoring of breeding territories

Study areas and the three land-management zones were as described in Chapters 3 and 4 (Figures 3.1, 3.2 and 4.1). The methods for survey, and monitoring of occupied breeding territories were also detailed in Chapters 3 and 4 (sections 3.2.1, 3.2.2 and 4.2.1).

5.2.2 Locating, identifying and quantifying prey remains

Merlin hunting techniques of surprise power attack and their large hunting range ruled out direct observations as a method for studying breeding season diet (Bengston 1975, Trimble 1975, Brown 1976, Newton 1979, Watson 1979, BWP 1980, Becker and Sieg 1987, Rebecca *et al* 1990).

In Britain, Merlins pluck and prepare prey near to their eventual nest, with small birds predominating during the breeding season (BWP 1980, Table 5.1). They also produce regurgitated pellets of indigestible material, but pellet analysis was not considered practical for Merlin diet study because the feather remains are difficult to identify (Ian Newton *personal communication*) and it is not possible to determine whether insect remains were from insects taken by the Merlin or their prey (Newton *et al* 1984). It is generally regarded that remains at plucking sites is the most practical method for assessing Merlin breeding season diet. Although this method is believed to under-represent insects, any possible bias was negligible because such prey was regarded as unimportant in terms of prey weight (e.g. Newton *et al* 1984, Bibby 1987, Meek 1988, Ellis and Okill 1990, Heavisides *et al* 1995). I therefore focussed on prey remains at or near nests as the method for assessing Merlin breeding season diet for this study.

During April to July, perching and plucking sites were located at occupied breeding territories and searched for prey remains. These were often distinct boulders, hummocks, shooting butts, fence posts, dead trees or stumps, vehicle tracks, scree or bare areas of ground, such as recently burnt patches of heather. Initially prey remains were collected and bagged for each site, noting the date and territory, and then dried. Feathers, fur or wings from moths were then separated and assigned to an anticipated species. Species identification was confirmed or otherwise by comparing with taxidermy specimens at Aberdeen University Department of Zoology Museum, or from literature keys or photographs (Yalden 1977, Watson and Whalley 1983, Brown *et al* 1987). An ongoing reference collection of samples, in particular wings and tails, of actual and potential Merlin prey species was compiled. With these aids, virtually all prey remains could be identified.

To quantify numbers from each plucking site, diagnostic primary, secondary or tail feathers or moth wings were counted, giving a minimum number of individuals for any species (Watson and Whalley 1983, Bibby 1987, Brown *et al* 1987). Once my reference collection was comprehensive, most remains were identified and quantified on site and buried. To determine if afforestation may have influenced prey selection, woodland/scrub and open-country species were categorised and separated as in previous Merlin studies from north-east England, Wales and south-east Scotland (Newton *et al* 1984, Bibby 1987, Heavisides *et al* 1995 respectively).

5.2.3 Prey weights for biomass calculations

The weights of prey species (biomass) were estimated following those used in other British breeding season Merlin studies (Ian Newton *personal communication* for Northumbria, Meek 1988 for Orkney, Ellis and Okill 1990 for Shetland and Heavisides *et al* 1995 for south-east Scotland) and are detailed in Table 5.2. When the remains of partly grown grouse or waders were found their size was estimated as: downy chick (c), about ¼ grown (q), about ⅓ grown (t) about ½ grown (h) and about ¾ grown (tq) and the weights calculated accordingly. For passerines, fledglings (fl) and nestlings (n) were estimated at ½ and ¼ of the adult weight respectively.

5.2.4 Statistical analyses

To assess differences in the number of open-country and woodland/scrub prey between study zones (LDF, LDMGM and MUDMGM) I used a Generalised Linear Mixed Model (glimmix) with a binomial error structure and logit link function in SAS v 9 (SAS 2001). I tested for differences in relation to land-management (commercial afforestation and moorland managed for Red Grouse) and study area, using the proportion of open-country prey as the dependent variable. I included both categories of land-use and study area as explanatory variables, and year and territory as random variables. Denominator degrees of freedom were calculated in the model using Satterthwaite's formula (Littell *et al* 1996). This formula controls for, or attempts to limit bias through pseudo-replication, with each error stratum and each test in the model contributing to the total of residual degrees of freedom (see Preface).

5.3 Results

5.3.1 General

A total of 11225 prey items were recorded during 1980 to 2003 (Table 5.2). This comprised of 10657 birds from 59 species, 547 moths, mainly from two species and 21 other items covering small mammals, butterflies, dragonflies, ground beetles and a frog. The annual and study zone totals are shown in Table 5.3. There were only two years when less than 100 items were recorded, in 1980 when the study was still at the early stage and 1993 when I was concentrating on survey coverage for the first year of the national Merlin survey. There were 1924 (17%) items from the LDF zone, 5474 (49%) from the LDMGM zone, and 3827 (34%) from the MUDMGM zone.

Overall, birds accounted for 94.9% and 99.5%, and moths 4.9% and 0.5% of items and biomass respectively (Table 5.2). The insects and other prey were therefore insignificant in biomass terms and are not considered further in this analysis. The same five bird species made up 83% and 79% of numbers and biomass respectively from the bird totals. These were, Meadow Pipit (65.5% and 52.4%), Northern Wheatear (6.7% and 8.2%), Common Starling (2.4% and 8.9%), Common Chaffinch (6.0% and 6.1%) and Sky Lark (2.3% and 3.9%) (Table 5.2). A further nine bird species each accounted for >1% of items or biomass. These were Barn Swallow, Pied Wagtail, partly grown Red Grouse, Common Snipe, Goldcrest, Whinchat, Willow Warbler, Siskin and Linnet (Table 5.2).

Table 5.2 Prey species of breeding Merlin from Deeside north-east Scotland, during April to July in 1980 to 2003. Weights from Ratcliffe 1980, BWP 1980 and Ian Newton (*personal communication*) and detailed in the Methods. + represents chicks or partly grown juveniles only and * classed as woodland or scrub species following Newton *et al* 1984, Bibby 1987 and Heavisides *et al* 1995. Calculation of weights of partly grown juveniles (c, q, h, tq, fl,n) explained in the Methods. Birds with >1% in numbers or biomass from bird totals, **in blue** and **red,** respectively.

Species	Latin name	Weight (grams)	Number	> 1%	Biomass (grams)	> 1%
Red Grouse +	*Lagopus L. scoticus*	c 50 q 100	44c 30 q = 74		5200	2.2
Black Grouse * +	*Tetrao tetrix*	c 50 q 150	9 c 8 q = 17		1650	
Grey Partridge	*Perdix perdix*	150	1		150	
Oystercatcher +	*Haematopus ostralegus*	500	1h		250	
European Golden Plover	*Pluvialis apricaria*	200, c 50 h 100	2, 5 c 1 h = 8		750	
Northern Lapwing +	*Vanellus vanellus*	c 50 q 75 h 100	16 c 3 q 1 h = 20		1125	
Eurasian Curlew +	*Numenius arquata*	c 50 q 170	2 c 2 q = 4		440	
Common Redshank	*Tringa totanus*	150	8		1200	
Common Sandpiper	*Actitis hypoleucos*	66	6		396	
Common Snipe	*Gallinago gallinago*	106, tq 80	24, 3 tq = 27		2784	1.2
Stock Dove *	*Columba oenas*	300	1		300	
Feral Rock Dove	*Columba livia*	350	4		1400	
Common Cuckoo	*Cuculus canorus*	115, tq 80	1, 1 tq = 2		195	
Wryneck *	*Jynx Torquilla*	80	1		80	
Sky Lark / fledgling	*Alauda arvensis*	37	242/4 = 246	2.3	9028	3.9
Sand Martin	*Riparia riparia*	15	24		360	
Barn Swallow	*Hirundo rustica*	20	210	2.0	4200	1.8
House Martin	*Delicton urbica*	18	2		36	
Meadow Pipit	*Anthus pratensis*	20	5368]	65.5	107360]	52.4
M P fledgling / nestling	*Anthus pratensis*	fl10 n5	1290/319 = 1609]	/	14495]	/
Grey Wagtail	*Motacilla cinerea*	17	21		357	
Pied Wagtail / fledgling	*Motacilla alba*	21	147/10 = 157	1.5	3192	1.4
Dipper	*Cinclus cinclus*	64	1		64	
Wren *	*Troglodytes troglodytes*	9	58		522	
Hedge Accentor *	*Prunella modularis*	21	7		147	
Robin *	*Erithacus rubecula*	18	38		684	
Bluethroat *	*Luscinia svecica*	18	1		18	
Common Redstart *	*Phoenicurus phoenicurus*	14	6		84	
Whinchat / fledgling	*Saxicola rubetra*	18	122/7 = 129	1.2	2259	1.0
Common Stonechat	*Saxicola torquata*	15	2		30	
Northern Wheatear / fledgling	*Oenanthe oenanthe*	27	689/27 = 716	6.7	18968	8.2
Ring Ouzel / fledgling	*Turdus torquatus*	100	21/1 = 22		2150	
Blackbird *	*Turdus merula*	96	13		1248	
Fieldfare	*Turdus pilaris*	110	4		440	
Song Thrush *	*Turdus philomelus*	74	22		1628	
Redwing	*Turdus iliacus*	67	2		134	
Mistle Thrush *	*Turdus viscivorus*	118	15		1770	
Willow Warbler* / fledgling	*Phylloscopus trochilus*	9	123/2 = 125	1.2	1116	
Goldcrest *	*Regulus regulus*	6	220	2.1	1320	
Spotted Flycatcher *	*Muscicapa striata*	15	3		45	
Long-tailed Tit *	*Aegithalos caudatus*	9	3		27	
Coal Tit *	*Parus ater*	9	27		243	
Blue Tit *	*Parus caeruleus*	11	49		539	
Great Tit *	*Parus major*	18	23		414	
Eurasian Treecreeper *	*Certhia familiaris*	9	8		72	
Common Starling	*Sturnus vulgaris*	80	258	2.4	20640	8.9
House Sparrow *	*Passer domesticus*	30	20		600	
Common Chaffinch *	*Fringilla coelebs*	22	642	6.0	14124	6.1
Brambling *	*Fringilla montifringilla*	22	3		66	
Greenfinch *	*Carduelis chloris*	28	69		1932	
Goldfinch *	*Carduelis carduelis*	17	11		187	
Siskin *	*Carduelis spinus*	14	125	1.2	1750	
Linnet * / fledgling	*Carduelis cannabina*	18	126/1 = 127	1.2	2277	1.0
Common Redpoll *	*Carduelis flammea*	13	2		26	
Common Crossbill *	*Loxia curvirostra*	41	5		205	
Bullfinch *	*Pyrrhula pyrrhula*	24	18		432	
Snow Bunting	*Plectrophenax nivalis*	34	2		68	
Yellowhammer *	*Emberiza citrinella*	26	53		1378	
Reed Bunting	*Emberiza schoeniclus*	20	3		60	
Budgerigar	*Melopsittacus undulatus*	25	1		25	
unidentified fledgling / nestling		fl10 n5	5/8 = 13		90	
Total birds (%)			**10657**	**(94.9)**	**232730**	**(99.45)**
Emperor	*Saturnia pavonia*	2	232		464	
Northern Eggar	*Lasiocampa quercus*	2	314		628	
Kentish Glory	*Endromis versicolora*	2	1		2	
Total moths (%)			**547**	**(4.9)**	**1094**	**(0.47)**
Small Tortiseshell	*Aglias urticeae*	2	4		8	
Field Vole	*Microtus agrestis*	20	2		40	
Shrew spp.	*Sorex aroneus / minutus*	10	1		10	
unidentified small mammal	*Microtus - Sorex*	15	7		105	
Dragonfly/Ground Beetle	*Anisoptera/Carabidae*	2/1	3/3 = 6		9	
Frog	*Rana temporaria*	20	1		20	
Total other (%)			**21**	**(0.2)**	**192**	**(0.08)**
Grand total			**11225**		**234016**	

These 14 bird species could therefore be considered important in sustaining the Merlin population in north-east Scotland during the study period. Although Red Grouse figured in this list, there is no justification for game-keepers to be concerned over grouse stocks. There was only 74 partly grown juveniles, an average of three per year, and these were not confined to any study zone or particular breeding territories (Appendix 4 a-c).

Table 5.3 Annual totals of prey of breeding Merlin from the three land-management study zones; lower Deeside forestry (LDF), lower Deeside managed grouse moor (LDMGM) and mid and upper Deeside managed grouse moor (MUDMGM) in north-east Scotland during 1980 to 2003. Percent in brackets.

Year	LDF			LDMGM			MUDMGM			All Deeside			Totals
	Birds	Moths	Other*	Birds	Moths	Other*	Birds	Moths	Other*	Birds	Moths	Other*	
1980	17	1		59	14					76	15		91
1981	29	3	1	157	5	1				186	8	2	196
1982	16	2		102	6					118	8		126
1983	63	2	1	152	14	1	10			225	16	2	243
1984	113	10	2	248	8	2	129			490	18	4	512
1985	149	27		501	135	2	313	59	1	963	221	3	1187
1986	220	9	2	447	58	1	217	5	2	884	72	5	961
1987	107	8	2	160	8		124			391	16	2	409
1988	91	11		219	16		78	1		388	28		416
1989	109	12		54	6		32	2		195	20		215
1990	56	2		66			94	2		216	4		220
1991	127	22		39	4		34	2		200	28		228
1992	64	3		27			123			214	3		217
1993				13			42			55			55
1994	56			60			147			263			263
1995	93	16		238	4		192	2		523	22		545
1996	77			359	5		171			607	5		612
1997	74	3		377	5		179	5		630	13		643
1998	115	6		425	10		286		1	826	16	1	843
1999	64			355			301	4	1	720	4	1	725
2000	57			326	2	1	319			702	2	1	705
2001	50			300	9		387			737	9		746
2002				290	8		358	2		648	10		658
2003	26	6		174	1		200	2		400	9		409
Totals	1773	143	8	5148	318	8	3736	86	5	10657	547	21	11225
%	(92.2)	(7.4)	(0.4)	(94.0)	(5.8)	(0.2)	(97.6)	(2.3)	(0.1)	(94.9)	(4.9)	(0.2)	
	1924 (17%)			5474 (49%)			3827 (34%)						

* other: 2 vole, 1 shrew, 7 unidentified small mammal, 4 butterfly, 3 dragonfly, 3 ground beetle, 1 frog.

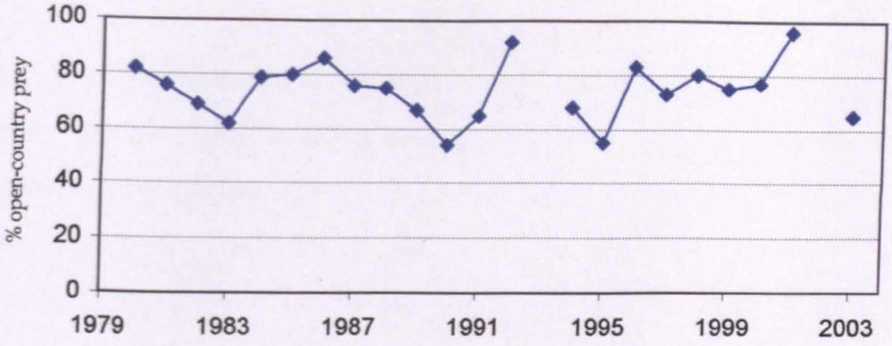
5.3.2 Comparison of Merlin diet between study areas and land-management zones.

The Merlin breeding season diet for the three land-management zones is shown in Appendix 4 (a-c), with the proportion of open-country and woodland/scrub species shown in Table 5.4. There was a highly significant difference in the proportion of open-country prey across study areas ($F_{1,44}$ = 13.99, P = 0.0005) with fewer open-country prey found in lower Deeside. There was also a highly significant difference in the proportion of open-country prey across land-management zones ($F_{1,40}$ = 10.1, P = 0.0028) with fewer open-country prey found in the LDF zone.

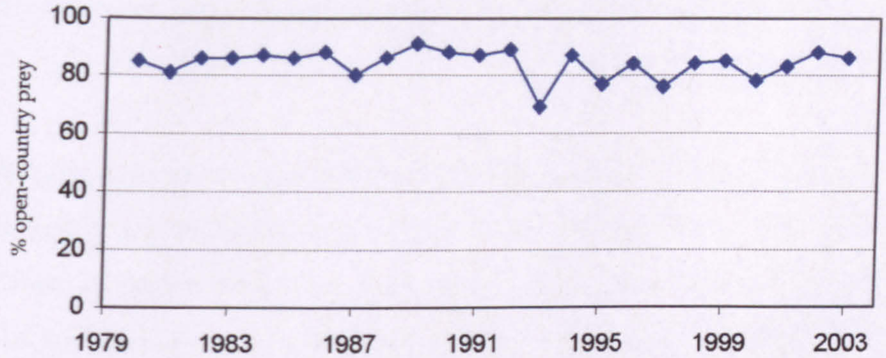
Table 5.4 The number of open-country and woodland/scrub prey of Merlin from three land-management zones on Deeside, north-east Scotland during 1980 to 2003. LDF represents lower Deeside forestry, LDMGM represents lower Deeside managed grouse moor and MUDMGM represents mid and upper Deeside managed grouse moor. Percent in brackets.

Study area	Prey type			
	open-country		woodland/scrub	
LDF	1322	(75%)	451	(25%)
LDMGM	4299	(84%)	849	(16%)
MUDMGM	3324	(89%)	412	(11%)
All Deeside	8945	(84%)	1712	(16%)

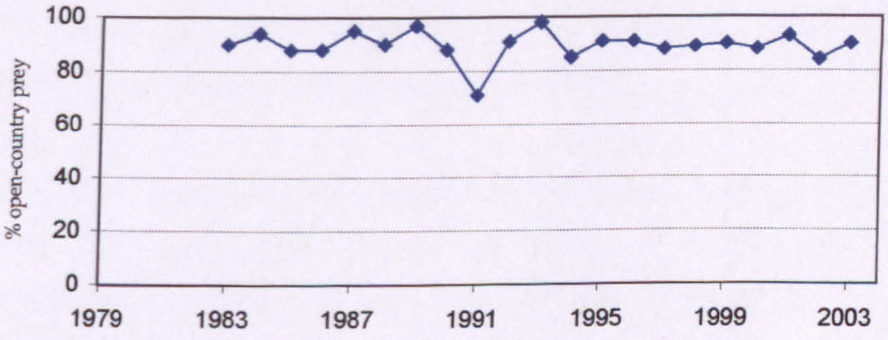
There was no significant temporal change in the proportion of open-country prey at either land-management zone (LDF, $F_{1,58}$ = 1.72, P = 0.194, LDMGM, $F_{1,146}$ = 0.86, P = 0.356 and MUDMGM, $F_{1,139}$ = 3.16, P = 0.079), although there was a tendency for such prey to decrease in the MUDMGM zone (Figure 5.1). There was also no significant change in the proportion of open-country prey in the LDF zone in relation to the age of the plantations ($F_{1,44}$ = 2.25, P = 0.141).



Lower Deeside forestry



Lower Deeside managed grouse moor



Mid and upper Deeside managed grouse moor

Figure 5.1 The percentage of open-country prey of Merlins in three land-management zones on Deeside, north-east Scotland in 1980 to 2003. Top graph represents lower Deeside forestry, middle graph represents lower Deeside managed grouse moor, and bottom graph represents mid and upper Deeside managed grouse moor. Sample sizes are in Table 5.3 and species numbers and categories are detailed in Appendix 4, a-c.

5.4 Discussion

As was typical for Merlin breeding season diet in Britain, small birds were the most important prey for numbers and biomass in north-east Scotland. Five species made up 80% of the biomass, similar to the composition found at other areas in Britain (Table 5.1). The vast majority of prey was classed as open-country species with woodland/scrub species accounting for 11 to 25% of prey at the different land-management study zones. Part of the fourth hypothesis for the thesis predicted that prey composition would be different in the LDF zone compared to the LDMGM and MUDMGM zones. There was significantly less open-country prey recorded for the afforested zone on lower Deeside in comparison to the two managed grouse moor zones, and this part of the hypothesis is upheld.

Merlins have been shown to utilise prey broadly in proportion to their abundance in the surrounding environment (Baker and Bibby 1987). Although it was not measured in this study, there is proportionally less commercial afforestation within the Merlin breeding range in mid and upper Deeside compared to lower Deeside. Further, mid and upper Deeside is more mountainous than lower Deeside (e.g. see Photographs 5, 6 and 7 in Chapter 1) with much more land above 550 metres (Buckland *et al* 1990). These environmental factors result in there being vastly more potential open-country foraging area for Merlins in mid and upper Deeside, and is probably the main reason why proportionally more open-country prey was taken there.

In the LDF zone, the abundance of potential Merlin prey did not measurably differ from that in the LDMGM or MUDMGM zones (G. W. Rebecca *unpublished counts*). As expected, bird diversity in the LDF zone changed from a predominance of open-country species to woodland/scrub species over time (G. W. Rebecca, B. L. Cosnette and L. D. Steele *unpublished observations*, and similar to previously reported for afforested moorland in Britain e.g. Petty and Avery 1990). However, the Merlins occupying this zone appeared not to respond fully to the change. In the LDF zone, an area where Merlins declined to zero during 1990 to 2004 (Chapter 3), the ratio of open-country prey to woodland/scrub prey was 3:1. This implies that the Merlins which continued to occupy the LDF zone either, hunted the remaining unplanted areas such as roads and verges, rides, riparian zones, un-plantable areas and plateau moor (e.g. Chapter 1.9, sections 3.2.3 and 3.2.4) or foraged further afield. It also implies that the new woodland/scrub prey resource was not fully utilised, possibly because such prey was unavailable to the Merlins. It is plausible to suggest that the majority of the woodland/scrub prey resource may have been unavailable because the density of trees at commercial conifer plantations, particularly at or near the thicket stage, provides much additional cover for potential Merlin prey (e.g. Nature Conservancy Council 1986, Avery and Leslie 1990, Petty and Avery 1990).

This study did not have the resources to examine these suggestions, for example by applying extensive long-time vantage point watches or radio telemetry of adults. In two previous Merlin studies at commercial conifer plantations, breeding males were believed to primarily hunt open areas during the nestling and early fledging periods (Watson 1979, Parr 1992). In the first study, at a mix of young conifer plantation and moorland in south-west Scotland, males returned to two nests under review, from the direction of moorland, in 88% and 99% of prey deliveries (n = 58 and 73 hunts respectively). In the second study, at mixed age conifer plantations, moorland and farmland in north Wales, a radio tagged male primarily hunted grass-dominated moorland, and to a lesser extent hunted heather-dominated moorland and 15 to 20 year old Sitka Spruce plantation. This male largely avoided hunting over farmland and > 40 year old Sitka Spruce plantation (Parr 1992).

It was expected that small birds would be the most important component of Merlin breeding season diet in north-east Scotland (Table 5.1 references) and that typical open-country species would predominate, particularly at open habitats. It was also expected that Red Grouse numbers would be minimal, as had been found at other Merlin study areas in Britain (Table 5.1 references) and was generally believed to have been the case across the rest of the British Merlin breeding range (e.g. Brown 1976, Newton 1979, BWPC 1990, Ratcliffe 1990). Game-managers on Red Grouse moors have therefore no legitimate reason to be concerned over breeding Merlin. Further, the majority of adult and juvenile Merlins are usually off the breeding moors in autumn and winter (BWPC 1990, Rebecca 1990), the period when game-keepers complain about raptors disturbing Red Grouse shoots.

5.5 Conclusions

- Small birds, weighting 20 to 80 grams, were by far the major component of Merlin breeding season diet on Deeside, north-east Scotland. Five species made up around 80% of the bird diet in both numbers and biomass. These were Meadow Pipit, Northern Wheatear, Common Starling, Common Chaffinch and Sky Lark.

- Game birds, such as Red Grouse were unimportant, comprising of less than 1% of bird numbers.

- Typical open-country species composed of 84% the bird diet, with the remainder classed as woodland or scrub species.

- Significantly more woodland or scrub species were found at a study zone that had been commercially afforested with conifers.

5.6 Appendix 4 a-c (pages 129 to 131)

Appendix 4 (a). Bird prey numbers and biomass of Merlin, from the lower Deeside forestry zone in north-east Scotland, during April to July in 1980 to 2003. Weights and other criteria in Table 5.2. + represents chicks or partly grown juveniles only and * classed as woodland or scrub species.

Species	Number	>1%	Biomass	>1%
Red Grouse *	4c/5q = 9		700	1.7
Oystercatcher *	1h		250	
European Golden Plover	2/1c = 3		450	1.1
Northern Lapwing *	3c		150	
Common Redshank	1		150	
Common Snipe	6		636	1.5
Feral Rock Dove	2		700	1.7
Sky Lark /fl	52/2 = 54	3.0	1961	4.6
Sand Martin	5		75	
Barn Swallow	68	3.8	1360	3.2
House Martin	1		18	
Meadow Pipit	733]	52.7	14660]	39.2
Meadow Pipit fl/n	169/33 = 202]	"	1855]	"
Grey Wagtail	5		85	
Pied Wagtail /fl	25/2 = 27	1.5	546	1.3
Wren *	12		108	
Robin *	9		162	
Common Redstart *	1		14	
Whinchat /fl	19/1 = 20	1.1	351	
Northern Wheatear /fl	96/4 = 100	5.6	2646	6.3
Ring Ouzel	2		200	
Blackbird *	8		768	1.8
Fieldfare	1		110	
Song Thrush *	8		592	1.4
Mistle Thrush *	5		590	1.4
Willow Warbler *	22	1.2	198	
Goldcrest *	60	3.4	360	
Spotted Flycatcher *	2		30	
Long-tailed Tit *	1		9	
Coal Tit *	9		81	
Blue Tit *	10		110	
Great Tit *	4		72	
Eurasian Treecreeper *	2		18	
Common Starling	72	4.1	5760	13.7
House Sparrow *	9		270	
Common Chaffinch *	163	9.2	3586	8.5
Greenfinch *	18	1.0	504	1.2
Goldfinch *	5		85	
Siskin *	40	2.3	560	1.3
Linnet *	36	2.0	648	1.5
Common Redpoll *	1		13	
Common Crossbill *	1		41	
Bullfinch *	4		96	
Yellowhammer *	21	1.2	546	1.3
Reed Bunting	1		20	
unidentified nestling	6		30	
Totals	**1773**		**42174**	

Appendix 4 (b). Bird prey numbers and biomass of Merlin, from the lower Deeside managed grouse moor zone in north-east Scotland, during April to July in 1980 to 2003. Weights and other criteria in Table 5.2. + represents chicks or partly grown juveniles only and * classed as woodland or scrub species.

Species	Number	>1%	Biomass	>1%
Red Grouse +	22c/5q = 27		1600	1.4
Black Grouse + *	8c/2q = 10		700	
Grey Partridge	1		150	
European Golden Plover +	2c		100	
Northern Lapwing +	9c/4q = 13		775	
Eurasian Curlew +	1q		170	
Common Redshank	6		900	
Common Snipe	10/2tq = 12		1220	1.1
Stock Dove *	1		300	
Feral Rock Dove	2		700	
Common Cuckoo	1/1tq = 2		195	
Wryneck *	1		80	
Sky Lark /fl	114/2 = 116	2.3	4255	3.8
Sand Martin	9		135	
Barn Swallow	108	2.1	2160	1.9
House Martin	1		18	
Meadow Pipit	2599]	65.7	51980]	52.8
Meadow Pipit fl/n	616/167 = 783]	*	6995]	*
Grey Wagtail	9		153	
Pied Wagtail /fl	78/7 = 85	1.7	1712	1.5
Wren *	24		216	
Hedge Accentor *	3		63	
Robin *	18		324	
Bluethroat *	1		18	
Common Redstart *	2		28	
Whinchat /fl	89/6 = 95	1.8	1656	1.5
Common Stonechat	1		15	
Northern Wheatear /fl	260/11 = 271	5.3	7169	6.4
Ring Ouzel	2		200	
Blackbird *	4		384	
Fieldfare	1		110	
Song Thrush *	11		814	
Redwing	2		134	
Mistle Thrush *	9		1062	1.0
Willow Warbler /fl *	65/2 = 67	1.3	594	
Goldcrest *	110	2.1	660	
Long-tailed Tit *	1		9	
Coal Tit *	7		63	
Blue Tit *	31		341	
Great Tit *	11		198	
Eurasian Treecreeper *	6		54	
Common Starling	146	2.8	11680	10.5
House Sparrow *	10		300	
Common Chaffinch *	315	6.1	6930	6.2
Brambling *	3		66	
Greenfinch *	39		1092	
Goldfinch *	6		102	
Siskin *	48		672	
Linnet /fl *	77/1 = 78	1.5	1395	1.2
Common Crossbill *	3		123	
Bullfinch *	11		264	
Yellowhammer *	19		494	
Reed Bunting	2		40	
Budgerigar	1		25	
unidentified nestling	2		10	
Totals	**5148**		**111603**	

Appendix 4 (c). Bird prey numbers and biomass of Merlin, from the mid and upper Deeside managed grouse moor zone in north-east Scotland, during April to July in 1980 to 2003. Weights and other criteria in Table 5.2. + represents chicks or partly grown juveniles only and * classed as woodland or scrub species.

Species	Number	>1%	Biomass	>1%
Red Grouse +	18c/20q = 38	1.0	2900	3.7
Black Grouse * +	1c/6q = 7		950	1.2
European Golden Plover +	2c/1h = 3		200	
Northern Lapwing +	4c		200	
Eurasian Curlew +	3q		510	
Common Redshank	1		150	
Common Sandpiper	6		396	
Common Snipe	8/1tq = 9		928	1.2
Sky Lark	76	2.0	2812	3.6
Sand Martin	10		150	
Barn Swallow	34		680	
Meadow Pipit	2036]	71.2	40720]	58.6
Meadow Pipit fl/n	505/119 = 624]	"	5645]	"
Grey Wagtail	7		119	
Pied Wagtail /fl	44/1 = 45	1.2	935	1.2
Dipper	1		64	
Wren *	22		198	
Hedge Accentor *	4		84	
Robin *	11		198	
Common Redstart *	3		42	
Whinchat	14		252	
Common Stonechat	1		15	
Northern Wheatear /fl	333/12 = 345	9.2	9153	11.6
Ring Ouzel /fl	17/1 = 18		1750	2.2
Blackbird *	1		96	
Fieldfare	2		220	
Song Thrush *	3		222	
Mistle Thrush *	1		118	
Willow Warbler *	36	1.0	324	
Goldcrest *	50	1.3	300	
Spotted Flycatcher *	1		15	
Long-tailed Tit *	1		9	
Coal Tit *	11		99	
Blue Tit *	8		88	
Great Tit *	8		14	
Common Starling	40	1.1	3200	4.0
House Sparrow *	1		30	
Common Chaffinch *	164	4.4	3608	4.6
Greenfinch *	12		336	
Siskin *	37	1.0	518	
Linnet *	13		234	
Common Redpoll *	1		13	
Common Crossbill *	1		41	
Bullfinch *	3		72	
Snow Bunting	2		68	
Yellowhammer *	13		338	
unidentified fledgeling	5		50	
Totals	**3736**		**79194**	

CHAPTER 6

GENERAL DISCUSSION

GENERAL DISCUSSION

6.1 Main conclusions

The main aim of this Open University study was to provide further information on the relationship between breeding Merlin and commercial afforestation in Britain. The results from detailed and accountable studies are regarded as credible within the statutory and non-statutory conservation agencies in Britain. As such, the various methods applied throughout the study were designed so the results would be useful and applicable for nature conservation planning. For example, it is anticipated that the results and conclusions could be used by state and private foresters when planning new forests or re-designing existing commercial conifer plantations. It is also anticipated that conservation advisers and planners in Scottish Natural Heritage (SNH), the Royal Society for the Protection of Birds (RSPB) and the Scottish Wildlife Trust (SWT) will utilise the results and conclusions when responding to requests for comments on new and re-designed forestry schemes.

Merlins in Britain declined seriously in numbers and range during most of the 20th century, with the negative effects of organochlorine pesticides and other pollutants prevalent during the 1960s to 1980s (Chapter 1). The British Merlin breeding population in 1993 and 1994 was estimated at 1300 ± 200 pairs following a partial survey and calculated extrapolation of the remaining suitable habitat (Appendix 6). This population estimate reflected a recovery in British Merlins, and breeding productivity in 1993 and 1994, at an average of 2.25 fledged young per pair was indicative of a stable or increasing population (Chapter 2). The well known association of heather with breeding Merlin in Britain was re-affirmed, with 88% of breeding territories in 1993 and 1994 centred on heather moor or mixed grass-heather moor. Dense coniferous plantation was the habitat where 9% of breeding territories were centred, with their locations almost all in either south-west Scotland, north-east England or Wales, areas where this phenomenon had previously been reported (Chapter 2).

In part of a delimited study area in north-east Scotland, Merlin territory occupancy gradually decreased to zero. This followed extensive land-use change, from heather moorland previously managed for the production of wild Red Grouse to commercial conifer plantations. The abandonment of Merlin breeding territories largely coincided with the plantations reaching the thicket stage, or canopy closure (Chapter 3). In one private forestry scheme, contingency plans to retain breeding Merlin, by leaving traditional nesting areas unplanted and ensuring a net unplanted area of approximately 30%, were not successful. However, the decline in this area was slower, in comparison to the remainder of the afforested zone, and Merlins did use the unplanted traditional nesting areas. It is suggested that a further trial, with approximately 50% of open habitat could be tried and tested at another new forestry scheme (Chapter 3, Appendix 5).

In the afforested areas, where Merlin decline to zero breeding pairs, the mean first egg-laying date and mean clutch size were similar to comparable adjacent and further afield Merlin study areas, where there was no or little change in habitat management. However, overall productivity as measured by fledged young per pair, was significantly less in the afforested zone. It was concluded that commercially afforested moorland was an inappropriate breeding habitat for Merlin in north-east Scotland (Chapter 4). Merlin breeding season diet was assessed by identifying and quantifying prey remains found at or near nests. In total, small birds accounted for 95% of items and 99% of biomass from 11225 items, with five species accounting for 83% and 79% of bird numbers and biomass respectively. Typical open-country species composed of 84% of the bird prey, with significantly more woodland or scrub species found at the afforested zone (Chapter 5).

6.2 Site designation, nature conservation planning and the Royal Society for the Protection of Birds.

Within the European Community (ECo), member states have a responsibility to adhere to legal Directives. For example, the 1979 ECo Directive (79/409/EEC) on the Conservation of Wild Birds requires members to "preserve, maintain or re-establish a significant diversity of area of habitats for all species referred to in Annex 1". Throughout this study, the Merlin was included as an Annex 1 species under this Directive. In 1992, further European nature conservation legislation included the ECo Directive (92/43/EEC) on the

Conservation of Natural Habitats and of Wild Fauna and Flora. Under these Birds and Habitats Directives, member states are expected to establish and protect a representative series of the best areas for designated species and habitats, called ***Natura 2000 areas*** (see Chapter 2, page 64). Within this framework in the United Kingdom (UK), Special Protection Areas (SPA) for birds and Special Areas of Conservation (SAC) for other fauna and flora represent the Natura 2000 areas. English Nature, the Countryside Commission for Wales, the Environment and Heritage Service and SNH are the government organisations responsible for ensuring that an adequate number of such sites are designated in England, Wales, Northern Ireland and Scotland respectively. Non-government organisations (NGOs) such as the RSPB and SWT can advocate for appropriate areas to be designated as SPA or SAC. They can also object or express concerns if important species or habitats are under threat from inappropriate development or land-use change. NGOs usually have their own priority species lists and in Britain, they often pool their knowledge with government and voluntary organisations to produce "Red Lists" with specific objectives, and responsibilities devolved to individual organisations. This co-operative approach is seen as a progressive step towards achieving joint aims using the best available resources (e.g. Batten *et al* 1990, Avery *et al* 1994, Gibbons *et al* 1996). The need for a SPA/SAC network in Britain was necessary following human activities that increasingly damaged or changed natural habitats to their detriment, resulting in some species declining in both national and international terms. When a species is deemed rare or endangered, it is often necessary to verify the accuracy of the assessment before applying criteria to redress the decline (e.g. Green and Hirons 1991).

Within the RSPB, it is desirable to have up-to-date information on the population status and breeding ecology of Annex 1 species to be in a position to influence conservation planning issues. Conservation planning in the RSPB covers four main areas. 1) ***Nature Reserve acquisition*** : Where land is purchased or management agreements established. 2) ***Nature conservation site designation recommendations*** : Involves contributing data and lobbying for Natura 2000 sites (discussed earlier). 3) ***Casework responses*** : Involves commenting on scoping papers and planning applications for new developments. Includes objecting to inappropriate applications. 4) ***Providing advice*** : For example, to the Forestry

Commission (FC) regarding forest design plans, or to SNH, private estates and planning authorities on all aspects of ornithology.

This study aimed to produce results that would be useful within the conservation planning structure of the RSPB. I also aim to ensure that the results are available for wider use. Amongst other things, the study attempted to address three high priority actions identified in the RSPB Species Action Plan for Merlin (Elliot and Crockford 1993). These were: 1) "To investigate the effects of forestry on Merlins in Scotland". 2) "To promote techniques of moorland and forestry management to owners and managers of suitable and potentially suitable habitat for Merlins". 3) "To seek redirection of inappropriate afforestation away from Merlin breeding and hunting areas by influencing forestry policy at national, regional and site level".

6.3 Merlins and conifer plantations in Britain.

In 1992, I was responsible for planning the second Merlin breeding survey in Britain (Chapter 1.5). The survey was carried out in 1993 and 1994 and quantified the breeding population more thoroughly than previously, indicating that regional populations had either increased or remained stable (Appendix 6). This gave the first reasonably accurate status figure for Merlin in Britain and provided the focus for the first area of study for the thesis. The nest record forms from the survey provided a unique opportunity to determine the extent of conifer plantation nesting by Merlin from around 60% of their recent breeding range. Assessing nest-site selection on such scale over the same period had not been possible previously. However, there are large areas of north and west Scotland that are not monitored regularly for Merlin, but this situation is unlikely to change. Even if it was economically feasible to survey these areas for Merlins, it is highly unlikely that enough qualified field-staff could be found to complete the task. Conservationists and planners therefore have to accept what is known, and not stall over making decisions on what might hypothetically be there. The recent publications on breeding Merlin and communication with local experts complemented the field-based data, giving credibility to the overall assessment of the number of plantation nesting Merlin in surveyed areas (Chapter 2).

In the areas where conifer plantation nesting by Merlins was widespread (Wales, north-east England and south-west Scotland) the surrounding moorland had been largely over-grazed. Whereas, in most of the rest of the Merlin breeding range there was still abundant mature heather moorland, much of it managed for the production of Red Grouse.

6.4 Long-term population and ecological study of Merlins on Deeside, north-east Scotland.

When I initiated the Merlin study on Deeside in 1980, I visualised two main components developing. 1) Monitoring of the occupancy of territories and subsequent breeding performance at a widespread scale sufficient to reveal relevant trends. 2) Detailed ecological research on breeding behaviour in a smaller defined area, or number of pairs. Both areas of study have developed with component one being the most practical in relation to resources I could source (summarised in Chapter 1.1, 1.2 and 1.4).

The value of long-term population and ornithological study was reviewed following a British Ornithologists Union conference on "long-term studies of birds" (Ibis 1991, volume 133, supplement I). There was much debate as to the respective merits of the long-term approach to population ecology and short-term experimental approach to understand mechanisms effecting ecology (e.g. Krebs 1991, Pienkowski 1991). A general view was that most ecologists favour long-term studies and that they were necessary for two main conservation purposes: "monitoring of population parameters" and "defining habitat requirements to set targets for conservation action" (Pienkowski 1991). Another argument was that both approaches were important in achieving ecological understanding (Krebs 1991).

Perhaps fortuitously, part of the lower Deeside Merlin study area began to be afforested at the beginning of the study. Field-survey in the late 1970s had established that Merlins were breeding in the areas due for afforestation. This presented an opportunity to monitor the effects of typical commercial afforestation on the breeding ecology of the Merlin at the same time as the national debate over forestry and open-country birds raged on (Chapter 1.9). I was then able to influence the forest design in the Glen Dye Estate section of the overall afforestation schemes (Appendix 5). The value of having good base-line data was obvious when applying a comparative before and after aspect to this part of the study (Chapters 3, 4 and 5).

6.4.1 Afforestation on lower Deeside, north-east Scotland

As predicted, breeding Merlin gradually decreased to zero in the afforested areas where no contingency plans were made for them (Chapter 3, section 3.3.2). Initially, they continued to nest on the ground in unplanted or un-plantable areas, then switched to old crow nests in trees or an artificial nest that I installed (Appendix 7). By the time the last pair were occupying the area the majority of the surrounding habitat could have been described as "closed forest". Carrion Crows had declined, and the Merlins had moved to a small plateau area of moorland where they reverted again to ground nesting.

In the Glen Dye Estate forestry zone, a similar pattern ultimately developed (Chapter 3, section 3.3.3). However, the Merlins that continued to occupy the area did use the traditional breeding sites that had been left unplanted as part of the plan to retain them. These areas were still judged as "suitable for ground nesting" in 2004 and 2005 yet they were un-occupied. At that time the surrounding plantations were either at, or approaching the thicket stage, but the planned open-moorland had remained as moorland with no noticeable regeneration of trees. As a result, the overall habitat proportions at the scheme in 2004 and 2005 were still approximately 70% plantations and 30% open-country. These habitat proportions therefore were not in the order to maintain the Merlin occupancy and the experiment ultimately failed. However, there were precedents learned which could be applied to other similar scenarios if there is a desire to repeat this type of study (see later).

6.4.2 The effects of afforestation on Merlin breeding ecology.

Merlin territory quality obviously decreased in the afforested zones on lower Deeside over time, correlating with the plantations ageing towards the thicket stage (Chapter 3). It was therefore expected that key factors of the Merlin's breeding ecology would also be negatively affected. However, there was no area or temporal effect on breeding phenology

(Chapter 4). Further, although clutch size did decrease significantly in the afforested zones over time, the overall effects on egg and clutch size were inconclusive in comparison to the other study area and land-management type. The main, and arguably the most important breeding parameter directly or indirectly affected by the conifer afforestation was productivity. This was considerably lower in the afforested zones, particularly in comparison to the mid and upper Deeside Merlin study area, and was below the estimated figure reasoned to maintain population stability. Sample sizes from the afforested zones in the later years of the study were small, and it is unlikely that further comparison will be possible.

The Merlins that continued to use the afforested zones still relied on open-country prey species for the majority of their breeding season diet, despite the surrounding habitat largely changing from open-country to closed woodland (Chapter 5). Young and thicket stage conifer plantations in south-west Scotland held substantially more potential Merlin prey than nearby grass-heather moorland (Moss *et al* 1979). Similarly, on Deeside, potential Merlin prey was not significantly different at Merlin territories in the afforested zone and both managed grouse moor study zones (G. W. Rebecca *unpublished data*). Paradoxically, most of the increased prey resource usually associated with young plantations (e.g. Moss *et al* 1979, Petty and Avery 1990) was presumably unavailable for Merlins in the lower Deeside afforested zones. Otherwise, it could have been expected that Merlins would have occupied breeding territories at a similar level to that in the remainder of the lower Deeside study area, and switched to a diet of mainly woodland and scrub species (see Baker and Bibby 1987).

6.5 Implications for conservation and management.

The results from the 1993 to 1994 British Merlin survey provide a reasonably robust population figure with confidence limits (Appendix 6). This should ensure that the population estimate is accepted within the conservation and forestry environment in Britain. If so, commercial foresters cannot realistically claim that Merlin numbers are still underestimated, and that the respective percentage numbers at local site level are exaggerated (as happened in the past). Similarly, when the results from Chapter 2 are published, there should be less suggestions that there could be, or are, many hundreds of pairs of Merlins breeding in plantations in the highlands of Scotland, and are "just waiting to be discovered" (as has also happened in the past!). The speculation as to the extent of conifer plantation nesting by Merlin, away from Wales, north-east England and south-west Scotland should cease, or at least be more guarded.

The results from lower Deeside also demonstrate that previously typical afforestation methods and scale were indeed detrimental to Merlin, even in an area where contingency plans were tried in an attempt to retain them. The results from lower Deeside did at least show that Merlins will use artificial nests (as had been previously known from other areas in Scotland (Rebecca *et al* 1991) but not in England (Little and Davison 1992)) and continue to occupy unplanted areas, whether these were planned for Merlin or not. The lower Deeside results also showed that habitat proportions of around 30% open-country and 70% plantations, were not suitable for retaining Merlins once the plantations neared the thicket stage. These results can be used on a minimalist level to recommend measures to foresters and conservation planners that may be more successful in retaining Merlins in a commercially afforested landscape. I therefore recommend the following management suggestions to this aim. The guidelines are formulated largely from my experiences on lower Deeside, but also include information and ideas that I have collected from Merlin breeding areas throughout Britain, and from discussion with many other Merlin enthusiasts.

6.6 Recommended guidelines for retaining breeding Merlin within commercial afforestation schemes in Britain.

1) Assemble all historical Merlin breeding data for the area. It would be desirable to have 3 to 4 years of recent information. If this data was not available undertake at least two years full monitoring of the area using generic methods to identify Merlin breeding habitat and locate breeding pairs. I recommend the following publications for this purpose:

The Birds of the Western Palearctic. 1980. Editors, S. Cramp and K.E.L. Simmons, volume 2, pages 308-316, Oxford University Press, Oxford.

The breeding status of the Merlin *Falco columbarius* in Britain in 1993-94. G.W. Rebecca and I.P. Bainbridge. Bird Study 1998, 45 : 172-187.

Bird Monitoring Methods, a manual of techniques for key UK species. 1998. Editors, G. Gilbert, D. W. Gibbons and J. Evans. RSPB, Sandy.

Additionally, if there are any regional publications on Merlin breeding biology or behaviour these should be consulted and area specific methods also considered.

2) To identify the breeding area within a Merlin territory map all breeding records and link them using the polygon method as used in Chapter 3 (e.g. see Figure 3.5), then draw a 500 metre (m) border around the polygon. This area can then be described as the 'potential nesting area and buffer' (PNAB). If any particular PNAB was small, for example if there were few breeding records or the nest site did not switch much between years the area should be extended to around 100 hectares (equivalent to 1 km^2). A PNAB should not be planted or burned to ensure future rank or scrub vegetation. If any PNAB has existing commercial forestry, or mature native woodland, the equivalent amount of open-country should be added to it.

3) Establish an open, unplanted riparian zone of around 200 m, approximately 100 m either side of rivers and tributaries. Within this zone encourage a small scattering of native broadleaved trees or small copses of Birch, Rowan, Alder *Alnus glutinosa* and Willow *Salix*. This should attract passerines (important for future Merlin prey) and will provide future potential nest sites for crows and artificial nests. Any existing trees of these species or isolated Scots Pine should be retained.

4) Establish a 500 m unplanted area adjacent to crags that were considered suitable for Merlin to nest in. The relative importance of crags would depend on the topography of the scheme and number of crags. One or two crags per Merlin territory would be suitable.

5) In areas where altitude may be considered a planting constraint, for example, where trees would be susceptible to wind-blow, the plateau should be left unplanted and not burned.

6) After taking account of recommendations 2 to 5 the overall area of unplanted open-country should be made up to around 50%. This figure should be regarded as an experimental minimal amount of open-country in an effort to retain Merlin. Previous suggestions of the proportions of habitat to keep Merlins were 60% open-country and 40% plantations from south-west Scotland (Orchel 1992) and 70 to 80% open-country and 20 to 30% plantations from Wales (Parr 1992). These figures may be more appropriate and they all need trying if there are areas and schemes willing to participate. Other crucial factors could be linked to the density of open-country prey and proximity to farmland. These factors would need to be accounted for in any subsequent trials.

7) Merlins will hunt low-density woodland (e.g. BWP 1980) and it would be helpful if the forest edge was less densely planted for around 50 to 100 m and interspersed with native broadleaved species. The aims of this would be to increase the potential Merlin prey availability and diversity (e.g. Petty and Avery 1990).

8) Where possible one or two artificial crow nests should be installed, following the design and layout that had previously been successful (Rebecca *et al* 1991, Dewar and Shawyer 1996, Appendix 7). These should be situated in or as near to the PNAB as practical.

9) Most forestry schemes in Britain are grant-aided through the FC and are now encouraged to contain an environmental component. As part of any grant package, a period of environmental monitoring could be made conditional. The period of monitoring could be assessed in relation to the conservation status of the Merlin at that time and the location of the scheme. For example, it may be feasible to invite raptor group members to undertake the conditional monitoring. If this was the case, it is likely that a longer period of monitoring would be possible in comparison to what commercial ornithological consultants would achieve for the grant allocation. Any local raptor group members are also likely to have the relevant experience and local knowledge.

6.7 Future Merlin studies in north-east Scotland.

The value of long-term ornithological study to population ecology has been endorsed by many eminent ornithologists and ecologists (Ibis 1991, volume 133, supplement 1). It is therefore important that the long-term Merlin studies in north-east Scotland continue. The following is an example of how existing sections of study could continue with some additional elements for consideration.

1) Continue to monitor an appropriate sample of territories in lower Deeside, mid and upper Deeside and Donside. Ensure that all the historical territories in the lower Deeside forestry zone are monitored until the plantations are thinned or re-structured, probably for at least another 10 to 12 years. This could be tedious, but negative records are also important and necessary as sceptics could claim that Merlins might be, or are, using the mature plantations. Basic monitoring should be for 1 to 3 visits. First to check for occupancy, second to locate the nest or ring the young and third, to ring the young or assess productivity.

2) Further investigation into factors influencing occupancy and productivity.

a) Assess occupancy in relation to previous productivity on an annual basis per territory.

b) Assess productivity in relation to territory quality. This could include prey counts, and detailed habitat analysis of PNAB and land-use over a wider area.

c) Assess productivity in relation to nest site quality. This could include categorising predation risk, and measuring vegetation depth.

3) Assess and quantify mate and territory fidelity in relation to productivity.

a) I tried individual colour ringing of the young in 1996 to 1998, in an attempt to locate them later without using intrusive methods such as catching. Subsequent sightings were few (two on breeding sites and one on the coast in winter) and this method was not considered suitable for Merlin.

b) I also initiated collaboration with Nottingham University Department of Genetics, who had a team studying the microsatellite DNA profiling of birds, leading to the Deeside Merlins being part of their study. The study incorporated the profiling of individual Merlins, using cast adult feathers from Deeside from 1980 to 2000 and blood and feathers from nestlings from 1997 to 2000 (Marsden 2002, Appendix 10). The Nottingham University study is now finished but I continued to collect feathers during 2001 to 2005.

There is an opportunity for another University collaboration to analyse these feathers. The cumulative results would be interesting when combined with earlier ringing recoveries and controls (e.g. Rebecca 1987 a, Rebecca *et al* 1992, Appendix 10) and related to aspects of breeding biology, such as productivity.

c) A recent technical development to identify individual Merlin was piloted in Yorkshire (Peter Wright *personal communication,* Wright 1997). This involves catching adults at the nest, under licence, and fitting specially made stainless steel split rings. The rings have a passive integrated transponder (PIT) tag with a unique code. An electronic loop, placed around the nest, activates the transponder when a ringed bird returns to the nest, and the code is recorded on a data logger positioned 25 m from the nest (Wright 1997, 2005). This method would be suitable for Merlins in north-east Scotland as most nests are on the ground. The main benefit of this system is that adults only need to be caught once and the rings can be applied to young just before fledging (Wright 2005).

The necessity for future work would be dependant on the Merlin's status. For example, the species is now on the Amber list of Birds of Conservation Concern in the UK (Gregory *et al* 2002) and technically not rare. It is possibly not so crucial to attempt to secure every pair under threat. However, it is still interesting and necessary for some studies to continue as the Merlin's status might change again. Being more common might enable some of the more intrusive of studies, such as the initial PIT tag catching and ringing, to be more acceptable. This could provide important data on aspects of the Merlins population dynamics that have previously been little known, such as adult survival, mate and site fidelity and movements between populations.

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