Forestry Commission

Bulletin 118

Ecology and Conservation of Raptors in Forests

Steve J Petty

FORESTRY COMMISSION BULLETIN 118

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LONDON : The Stationery Office

ISBN 0 11 710344 6

Petty, Steve J. 1998. Ecology and Conservation of Raptors in Forests. Bulletin 118.
TSO, London. x + 45pp.

FDC 148.2 : 907.1 : 15 : (410)

KEYWORDS: Artificial nest sites, Biological diversity, Birds of prey, Clear-cutting, Food-supply, Forestry, Gamebirds, Habitat requirements, Population limitation, Predation, Wildlife management

Acknowledgements

For constructive comments on an earlier draft of this publication I would like to thank Nicola Crockford (RSPB), Fred Currie (FA), Simon Hodge (FCRD), David Jardine (FE), Dr Mick Marquiss (ITE), Dr Greg Mudge (SNH), Professor Ian Newton (ITE), Geoff Shaw (FE), Dr Des Thompson (SNH) and Richard Toleman (FE). I am also grateful to the Scottish Raptor Study Groups for allowing contact addresses to be included in Appendix 1.

Front cover: A spruce forest in Argyll with tree stands of various ages. S.W. PETTY
Inset: A buzzard at its nest with downy chicks. FOREST LIFE PICTURE LIBRARY

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Summary

Background information is provided on the status and ecology of raptors (birds of prey) in Britain and the legislation that gives them full protection. Based on this information, management techniques are proposed that will improve man-made conifer forests in the uplands for this spectacular group of birds, and the food webs upon which they are dependent.

The role of raptor predation is reviewed, and its importance in maintaining the fitness and health of prey populations is stressed. Contrary to widely held views, there is little evidence to support claims that raptors are responsible for the current declines in a number of bird species. In fact, the diversity and breeding performance of raptors in forests reflects the increasing variety of wildlife to be found within these man-made habitats.

Different raptors are capable of exploiting a wide range of forest habitats. Both young and old forests support more species than the thicket stage, and forest edges are important features. All raptors under consideration here are solitary breeders which exhibit regular spacing of breeding pairs in suitable habitats. Their densities are governed primarily by food-supplies. Secondary factors which may limit numbers include: shortage of nest sites, competition with other species for scarce resources, contamination with pollutants and illegal killing.

Management techniques for improving forests include: maintaining or enriching food-supplies through habitat management at the landscape scale, conserving and improving nest sites, and minimising disturbance. The transformation of even-aged conifer forests in the uplands into more complex habitats through small scale patch clear-cutting will diversify raptor populations and their food-supplies. Examples are given of how the size and spatial arrangement of clear cuts can affect the distribution of raptor species. At present, the lack of old trees within these relatively young habitats is limiting their potential for raptors and their prey. So, planning now for large areas of old trees will enable these forests to become even more important wildlife habitats in the future.

Ecologie et conservation des rapaces dans les forêts

Résumé

Cet article fournit des informations générales sur le statut et l'écologie des rapaces (oiseaux de proie) en Grande-Bretagne, ainsi que sur la législation qui leur donne entière protection. En s'appuyant sur ces informations, il propose des techniques de gestion qui amélioreront les forêts de conifères plantées sur les hautes terres pour ce groupe spectaculaire d'oiseaux et pour les réseaux alimentaires dont ils dépendent.

Le rôle joué par la prédation du rapace s'y trouve réexaminé en mettant en valeur son importance pour le maintien de populations de proies saines. Contrairement à une opinion très répandue, peu de faits viennent appuyer les conjectures voulant que les rapaces soient responsables du déclin actuellement connu par un certain nombre d'espèces d'oiseaux. En fait, dans les forêts, la diversité des rapaces et leurs performances reproductives reflètent la variété croissante de faune sauvage trouvée dans ces habitats artificiels.

Différents rapaces sont capables d'exploiter une grande variété d'habitats forestiers. Les forêts, jeunes et vieilles, abritent plus d'espèces que le taillis, et les lisières en sont des éléments importants. Tous les rapaces examinés ici sont des reproducteurs solitaires qui montrent un espacement régulier des couples reproducteurs au sein des habitats appropriés. Leur densité dépend surtout de l'abondance des ressources alimentaires. Parmi les facteurs secondaires pouvant limiter leur nombre figurent le manque d'emplacements pour faire les nids, la rivalité avec les autres espèces pour s'approprier des ressources peu abondantes, la contamination par des polluants et les mises à mort illégales.

Les techniques de gestion visant à améliorer l'état des forêts comprennent: le maintien ou l'enrichissement des ressources alimentaires par la gestion de l'habitat à l'échelle du paysage, la conservation et l'amélioration des emplacements abritant les nids et la réduction au minimum de toute perturbation. La transformation des forêts des hautes terres, plantées de conifères du même âge, en habitats plus complexes à l'aide des coupes rases effectuées par endroit et sur une petite échelle diversifiera les populations de rapaces et leurs ressources alimentaires. Des exemples sont donnés pour montrer dans quelle mesure la superficie et l'arrangement spatial des coupes rases peut affecter la distribution des espèces de rapaces. C'est présentement le manque de vieux arbres qui limite le potentiel présenté par ces habitats relativement jeunes pour les rapaces et leurs proies. Il s'ensuit donc qu'en prenant maintenant les dispositions nécessaires pour avoir à l'avenir de vastes superficie plantées de vieux arbres, on permettra à ces forêts de devenir dans le futur des habitats encore plus importants pour la faune sauvage.

Ökologie und Schutz von Greifvögeln in Wäldern

Zusammenfassung

Es werden Hintergrundinformationen zum Status und zur Ökologie der Greifvögel (Raubvögel) in Britannien, sowie zur Gesetzgebung, die ihnen vollen Schutz gewährleistet, gegeben. Es werden Bewirtschaftungsmethoden vorgeschlagen, die sich auf diese Informationen basieren und die für diese spektakuläre Vogelgruppe die Kulturforste in Höhenlagen, sowie die Nahrungsnetze, auf welche sie angewiesen sind, verbessern können.

Die Rolle der Raubvogelprädation wird untersucht und deren Wichtigkeit zum Erhalt von Fitneß und Gesundheit der Beutepopulation wird betont. Entgegen weit verbreiteter Meinungen, gibt es wenig Beweise dafür, daß Greifvögel für den momentanen Rückgang in einigen Vogelarten verantwortlich sind. In der Tat spiegelt die Diversität und die Brutleistung der Greifvögel in Wäldern, eine zunehmende Vielfalt des Wildbestandes in diesen, vom Menschen geschaffenen, Lebensräumen, wieder.

Verschiedene Raubvögel können eine große Auswahl von Waldlebensräumen nutzen. Sowohl Jung- als auch Altholz tragen mehr Arten als die Dickung und Waldränder sind wichtige Bestandteile. Alle Raubvögel, die hier betrachtet werden, sind solitäre Brüter, welche in geeigneten Lebensräumen, regelmäßige Abstände zwischen den Brutpaaren aufweisen. Deren Dichte wird vor allem vom Nahrungsangebot bestimmt. Sekundärfaktoren, die die Anzahl begrenzen können, sind unter anderem Nestplatzmangel, Wettbewerb mit anderen Arten um knappe Ressourcen, Verschmutzung und illegale Tötung.

Zu den Bewirtschaftungsmethoden zur Verbesserung der Forste zählen Erhalt oder Bereicherung des Nahrungsangebots durch Biotoppflege im Landschaftsumfang, Erhalt und Verbesserung der Nistplätze und minimale Störung. Durch kleinflächigen Plätzekahlschlag können gleichaltrige Nadelwälder in Höhenlagen zu komplexeren Lebensräumen umgewandelt werden, dies fördert die Vielfalt der Raubvogelpopulationen und deren Nahrungsquellen. An Beispielen wird gezeigt, wie die Größe und räumliche Verteilung der Kahlschläge die Verteilung der Raubvogelarten beeinflussen kann. Im Moment verringert der Mangel an alten Bäumen, in diesen relativ jungen Lebensräumen, ihr Potential für Raubvögel und Beute. Indem man heute große Gebiete mit alten Bäumen einplant, ermöglicht man es diesen Wäldern, in Zukunft noch wichtigere Lebensräume zu werden.

Chapter 1

Introduction

Historical background

Over the centuries, our native forests declined from being almost unbroken on all but the highest, most exposed and wettest areas, to mere modified remnants by the early 1900s (Harley and Lewis, 1984; Godwin, 1984). Man brought about this dramatic change, which has had a profound effect on wildlife, including the distribution and status of birds of prey (Newton, 1972; Brown, 1976; Newton, 1979). This extensive deforestation provided advantages and disadvantages; it benefited open-country raptors but led to the decline of many forest-dwelling species. Then, in the 19th century, man began to have a more direct effect on raptor populations through widespread killing, because of their perceived impact on gamebirds and livestock (Richie, 1920; Newton, 1972; Bijleveld, 1974; Newton, 1979). More recently (1950s–1970s), the insidious effects of persistent organochlorine pesticides led to dramatic population declines in bird-eating raptors (Newton, 1979). Now, following restrictions on the use of these chemicals, and with the emergence of more tolerant human attitudes, the fortunes of many species have improved, including the re-establishment of some that had ceased to breed on the British mainland (Newton, 1984).

Since 1920, policies recommending the extensive planting of conifer forests have brought about a major change in the British uplands (Holmes, 1979; Locke, 1987). Although these new forests are not replacements for those which existed prior to man's intervention, they nevertheless provide suitable habitats for a wide range of raptors, where they are largely free from persecution (Petty, 1996a). In this way, forests are providing safe refugia within otherwise hostile environments and many are large enough to sustain viable populations of certain raptors, and the prey species upon which they depend.

Objectives

The main aim of this Bulletin is to inform forest managers about the ecology of birds of prey in these new conifer forests and to offer practical advice on management techniques that will improve their attractiveness for this important group of birds. While the information and advice given concentrates on and relates to man-made forests in the uplands, many of the principles discussed are also relevant to raptors in other upland habitats, and in the lowlands. Many aspects will be of interest to the more general reader.

The species covered and national population trends

Throughout the text the term 'raptor' is used instead of 'birds of prey', and refers to 16 diurnal and nocturnal species in five families, the Accipitridae (true hawks), Pandionidae (ospreys), Falconidae (falcons), Tytonidae (barn owls) and Strigidae (other owls) (Table 1.1). Detailed descriptions of these species can be found in *The birds of the Western Palearctic*, volumes II and IV (Cramp and Simmons, 1980; Cramp, 1985), while Gibbons *et al.* (1993) give their breeding distributions in Britain and Lack (1986) their winter distributions.

Before looking at population trends it is useful to note raptors numbers in Britain. These range from 8–10 pairs of the recently re-established white-tailed eagle to 50 000–100 000 pairs for the

Table 1.1 Raptors which breed in upland forests. Many species have restricted distributions (Lack, 1986; Gibbons *et al.*, 1993).

Family	*Species*
Accipitridae	Honey buzzard *Pernis apivorus* Red kite *Milvus milvus* White-tailed eagle *Haliaetus albicilla* Hen harrier *Circus cyaneus* Goshawk *Accipiter gentilis* Sparrowhawk *Accipiter nisus* Buzzard *Buteo buteo* Golden eagle *Aquila chrysaetus*
Pandionidae	Osprey *Pandion haliaetus*
Falconidae	Kestrel *Falco tinnunculus* Merlin *Falco columbarius* Peregrine *Falco peregrinus*
Tytonidae	Barn owl *Tyto alba*
Strigidae	Tawny owl *Strix aluco* Long-eared owl *Asio otus* Short-eared owl *Asio flammeus*

ubiquitous tawny owl (Table 1.2), and some of the 16 species have populations of many thousands of pairs in the lowlands. Since the 1970s, population trends have shown an increase for 10 out of the 16 species. Two species, short-eared owl and long-eared owl, have populations that fluctuate mainly due to annual variations in rodent density. The golden eagle population is static, hen harrier population levels vary regionally, and only the kestrel and barn owl may be declining, although barn owl numbers appear to have stabilised recently (Table 1.2).

These increases in numbers are the result of a whole range of factors and influences. For example, reduction in illegal poisoning has helped the red kite and buzzard (Taylor *et al.*, 1988; Batten *et al.*, 1990); white-tailed eagle, red kite and goshawk have been re-established by releasing birds into areas from which they had become extinct (Marquiss and Newton, 1981; Love, 1983; Evans *et al.*, 1994; McGrady *et al.*, 1994); ospreys have naturally re-colonised Scotland (Dennis, 1987; Dennis, 1995); and declining levels of organochlorines in food chains have greatly helped the recovery of the bird-eating sparrowhawk, merlin and peregrine (Newton and Haas, 1984; Newton *et al.*, 1993; Ratcliffe, 1993). The goshawk, sparrowhawk, buzzard and tawny owl have benefited from the increasing area of forest allowing them to extend their distribution within the uplands (Table 1.2). So, prospects for most raptor species in Britain are at present encouraging.

The decline in many species was highlighted with the publication of the first Red Data List of birds (Batten *et al.*, 1990). It included 10 of the 16 raptors considered here (Table 1.3). This list has recently been revised by Gibbons *et al.* (1996) and now comprises three categories: Red, Amber, and Green. Red List species are those whose population or range is rapidly declining, recently or historically, and those of global conservation concern. Amber List species are those whose population is in moderate decline, rare breeders, internationally important and localised species, and those of unfavourable conservation status in Europe. All other species are on the Green List (Table 1.3).

Vagrants to the British Isles are excluded from consideration here, as are species which breed mainly in the lowlands such as the marsh harrier, Montagu's harrier, hobby and little owl. Montagu's harrier bred on upland moors and in young conifer plantations in the past, a habit which could occur again if the population continues to increase (Batten *et al.*, 1990).

Legislation

Legislation is effected in a variety of ways through national and European regulations. All raptors, and their occupied nests, are fully protected in Britain under the Wildlife and Countryside Acts 1981–1985 (WCA), with additional protection given to rarer species listed under Schedule 1 of the WCA (Table 1.3).

The latter includes special penalties for intentionally disturbing nesting birds. Nests are classed as occupied from the start of nest building until young disperse from the nesting area, not just when eggs and chicks are in the nest.

The interpretation of what constitutes disturbance is less clear, but a reasonable definition would be 'that which affects normal parental activity at a nest', including flushing the bird from the nest. Some types of disturbance can affect birds at a considerable distance from the nest (see Chapter 3).

Table 1.2 Breeding populations of raptors in Britain, with an indication of recent population trends and the effects of afforestation. Only species that breed in the uplands are included, although the number of breeding pairs is for the whole of Britain (updated from Petty 1996a).

Species	*Breeding pairs*			*Recent population trend (source)*	*Effects of afforestation (a) (source)*
	Number	*Year*	*Source*		
Honey buzzard	10–30	1994	1, 2	slight increase (1, 2)	+
Red kite	136*	1994	1	increasing (1, 2, 22)	= (21, 22)
White-tailed eagle	8–10	1994	1	slow increase (1)	=
Hen harrier	Scotland 570±150 (95%CI) England & Wales 60	1988–89	3	varies regionally (3)	- (3, 23, 24)
Goshawk	400	1994	4	increasing (1, 4, 11, 44)	+ (4, 25, 45)
Sparrowhawk	*c.* 32 000	1988–91	12, 36	increasing (12, 13)	+ (12, 26, 36)
Buzzard	12 000–17 000	1983	6	increasing (6)	+ (27)
Golden eagle	422	1992	42	static (7, 42)	- (28, 43)
Osprey	95	1994	1, 40	increasing (1, 2, 40)	=
Kestrel	*c.* 50 000	1988–91	1	fluctuates/decreasing (1, 14)	= (14, 33)
Merlin	550–650	1983–84	8	increasing (15, 16, 17)	= (5, 29, 31, 41, 46)
Peregrine	1 200	1991	9, 37	increasing (9, 37)	= (9)
Barn owl	4 400–9 000**	1968–72	10	decreasing/fluctuates (10, 18, 19, 36, 38)	= (19, 30)
Tawny owl	50 000–100 000	1968–72	10	increasing (10, 20)	+ (20)
Long-eared owl	2 200–7 200**	1988–91	36	fluctuates (10, 36)	= (32, 33)
Short-eared owl	1 000–3 500**	1988–91	36	fluctuates (10, 36)	- (34, 35, 39)

(a): + beneficial, - detrimental, = neutral
* excludes re-established population which in 1994 totalled 22 pairs in England and 11 pairs in Scotland
** estimated breeding population in Britain and Ireland

References:

1 = Ogilvie *et al.*, 1996
2 = Batten *et al.*, 1990
3 = Bibby and Etheridge, 1993
4 = Petty, 1996b
5 = Petty, 1995
6 = Taylor, K. *et al.*, 1988
7 = Dennis *et al.*, 1984
8 = Bibby and Nattrass, 1986
9 = Ratcliffe, 1993
10 = Sharrock, 1976
11 = Marquiss, 1981
12 = Newton, 1986
13 = Newton and Haas, 1984
14 = Village, 1990
15 = Haworth and Fielding, 1988
16 = Ellis and Okill, 1990
17 = Little and Davison, 1992
18 = Shawyer, 1987
19 = Taylor, I.R. *et al.*, 1988
20 = Petty, 1992
21 = Newton *et al.*, 1981
22 = Newton *et al.*, 1996
23 = Watson, 1977
24 = O'Flynn, 1983
25 = Petty, 1989a
26 = Newton, 1991
27 = Newton *et al.*, 1982
28 = Watson, 1992
29 = Bibby, 1986
30 = Taylor and Shaw, 1992
31 = Parr, 1994
32 = Village, 1981
33 = Village, 1992
34 = Lockie, 1955
35 = Village, 1987
36 = Gibbons *et al.*, 1993
37 = Crick and Ratcliffe, 1995
38 = Taylor, 1994
39 = Shaw, 1995
40 = Dennis, 1995
41 = Orchel, 1992
42 = Green, 1996
43 = McGrady *et al.*, 1997
44 = Marquiss and Newton, 1981
45 = Toyne, 1994
46 = Little *et al.*, 1995

Even with good planning, occupied nests of protected species are occasionally disturbed or even destroyed by felling because their presence was unknown. Such an event is not an offence under the WCA providing that the landowner, 'shows that the act was the incidental result of a lawful operation *and could not reasonably have been avoided*'. However, it is the landowner's responsibility to ensure that such incidents do not happen.

Unoccupied nests are not legally protected. So, for instance, a tree with an osprey nest could be felled outside the breeding season, or in the breeding season if it was unoccupied, but good practice often rules out such action.

Finding and monitoring nests are essential parts of the management of raptor populations. Licences may be issued by the statutory nature conservation bodies (Countryside Council for Wales, English Nature and Scottish Natural

Table 1.3 Legislation under which raptors are protected in Britain, and those listed as Red Data species.

Species	*Wildlife & Countryside Acts 1981–85*	*Wildlife & Countryside Acts 1981–85 Schedule 1*	*EC Wild Birds Directive Annex 1 (1994)*	*Red Data Species**
Honey buzzard	■	■	■	□ (A)
Red kite	■	■	■	□ (R)
White-tailed eagle	■	■	■	□ (R)
Hen harrier	■	■	■	□ (R)
Goshawk	■	■		□ (G)
Sparrowhawk	■			(G)
Buzzard	■			(G)
Golden eagle	■	■	■	□ (A)
Osprey	■	■	■	□ (R)
Kestrel	■			(A)
Merlin	■	■	■	□ (R)
Peregrine	■	■	■	□ (A)
Barn owl	■	■		□ (G)
Tawny owl	■			(G)
Long-eared owl	■			(G)
Short-eared owl	■		■	□ (G)

* = Red Data species in Batten *et al.*, 1990; (G) = green list species, (A) = amber list species, and (R) red list species in Gibbons *et al.*, 1996.

Heritage, see Appendix 1) for visits to nests of Schedule 1 species for scientific, conservation or photographic purposes. Such a licence does not confer the right of entry onto land and licensees are always advised to seek the landowner's consent. Landowners or their agents also need a licence if they are to knowingly disturb a Schedule 1 species near its nest. Most management techniques advocated in this Bulletin do not need to be licensed, and where they do, this is noted.

Persons holding Schedule 1 licences who apply to forest managers to visit raptor nests should be carefully vetted annually to ensure that nest visits are justified and not duplicated by other people or groups. Nests of raptors not on Schedule 1 (Table 1.3), although legally protected, can be visited or photographed without a licence, but the landowner's permission should still be sought.

The WCA implements legislation given to scarce and particularly threatened raptors under European Union (EU) legislation (Table 1.3), the most important being the EU Wild Birds Directive. This requires that species listed in Annex 1 (EEC Directive 79/409 on Conservation of Wild Birds, as amended), 'shall be the subject of special conservation measures concerning their habitat in order to ensure their survival and reproduction in their area of distribution'. Most species of raptors listed on Schedule 1 of the Wildlife and Countryside Acts also appear in Annex 1. There are three exceptions, the goshawk and barn owl are listed only on Schedule 1 and the short-eared owl only in Annex 1. The Berne Convention and Bonn Convention give additional protection to the habitats of listed species (Tucker and Heath, 1994).

Chapter 2

Ecology of raptors

The role of raptor predation

We often take for granted that predation is an important factor in maintaining the fitness of wildlife populations (Crawley, 1992). While this Bulletin is concerned with raptors, it should be remembered that predation is a natural process influencing virtually every trophic level, apart from a few species at the top of food webs, and that many predators, including raptors, are at times subject to predation themselves (Mikkola, 1976, Newton, 1979).

Does predation regulate prey numbers?

Raptors have to kill to survive, but this does not mean they have adverse effects on prey species. Generally, the abundance of prey influences the abundance of raptors, not vice versa. Healthy wildlife populations produce far more offspring each year than is necessary to replace adult losses. In stable populations this surplus is reduced by a number of factors. For example, when predators are absent, density dependent starvation is often the overriding factor in controlling numbers. But with predators present, predation can sometimes account for most of these losses, and in such cases is often 'compensatory' (replacing other forms of mortality) rather than 'additive' (adding to other mortality) (Newton, 1993). The reduction in prey numbers often occurs over winter, and ensures that only fit individuals survive to breed and contribute to the next generation. This process helps to ensure that populations of many species hold healthy individuals.

Predation is more likely to have adverse effects on any prey species if its population is already declining rather than stable or increasing. In such cases mortality from predation is often additive. However, many declines are ultimately related to a reduction in the carrying capacity of the habitat due to changes in land-use or other factors, rather than predation. Declining populations of prey species often lack the pool of non-breeding adults which buffer healthier populations against predation. Thus, predation may hasten population reduction to a new lower carrying capacity, or to extinction if the habitat becomes totally unsuitable. Whether predation is involved in bringing about this reduction depends on how vulnerable a rare or declining species is to specific predators. In the absence of predation, other factors, such as starvation and disease, are involved in reducing numbers.

Are raptors responsible for declines of some bird species?

There is little evidence to support the notion that raptors have been the main cause of declines in many bird populations over the last 20 years. Two examples are used here. First, it is sometimes said that the decline in black grouse numbers in many upland forests is the result of increasing predation by crows, foxes and raptors. In fact such declines have often coincided with the loss of vast areas of ericaceous vegetation (upon which black grouse largely depend for food and shelter), as young trees in new forests shade out ground vegetation around the time of canopy closure (Cayford, 1993). Second, increasing numbers of sparrowhawks are often claimed to be the cause of declining songbird numbers, particularly on farmland. Yet all the scientific evidence links these declines instead to changes in agricultural practices, such as the widespread use of pesticides, drainage, reseeding, the change from spring-sown cereals to autumn-sown cereals, and hedgerow removal. One way or another these changes have reduced insect and plant food-supplies of birds and also the amount and quality of nesting cover (Evans *et al.*, 1995; Evans, 1997; Potts, 1997; Tucker, 1997).

Prey switching and the influence of predation on community structure

While raptors are unlikely to have a long-term detrimental effect on most wild prey species, they do have the capacity to temporarily reduce prey numbers. Within any habitat a raptor will concentrate on the easiest prey it can catch. Abundance and availability of prey species varies throughout the year, so raptors tend to concentrate on few prey species at any one time, until they become unprofitable to hunt either because they become less numerous or more difficult to catch. Raptors will then switch onto the next most profitable species, so allowing numbers in the first group to recover (Crawley, 1992; Newton, 1993; Caughley and Sinclair, 1994).

This prey-switching behaviour has the potential to reduce peak populations of some of the most abundant species, and so stabilise prey numbers. If any raptor reduced the overall amount of prey available to it, its own numbers would then decline due to lack of food. This would lessen predation pressure and so lead to an increase in prey numbers over time. There are few published cases of raptors permanently limiting prey populations below the carrying capacity of a habitat, but it is theoretically possible (Newton, 1993; Caughley and Sinclair, 1994).

Some studies suggest that, collectively, predation may permanently lower or regulate the abundance of some vertebrate species. But it is often difficult or impossible to isolate the impact of raptors from other forms of predation. Newton (1993) considered that some species had the potential to occur at two quite different densities, depending on whether predators had a regulatory effect or not. Some species, that were particularly vulnerable to predation, could have their populations permanently depressed by constant heavy predation, and so live in a 'predation trap'. This is most likely to occur in landscapes with a varied assemblage of generalist predators, that can switch onto vulnerable species as soon as they increase in the environment, and then back onto other species once they become scarcer. Interestingly, Wesolowski and Tomialojc (1995) suggested this might be one reason for the low densities and poor breeding success of many bird species in the primeval Bialowieza Forest in Poland, one of the few habitats in Europe with a near full assemblage of raptors and mammalian predators. In addition, Erlinge *et al.* (1983 and 1988) and Hanski *et al.* (1991) considered that the lack of multi-annual cycles in vole populations in southern Sweden could be the result of predation. In such fragmented habitats, generalist predators were abundant. These fed on alternative prey when voles were scarce, but increased their predation on voles, once voles started to increase, to the point where numbers then decreased. In this way they kept voles at a fairly stable level and so prevented the development of multi-annual cycles. In contrast, in northern Scandinavia with pronounced 3–5 year vole cycles, generalist predators were scarce or absent, and vole numbers were able to increase rapidly from the low point in the cycle, because there was little predation (Hanski *et al.*, 1991; Korpimäki and Norrdahl, 1989; Korpimäki and Norrdahl, 1991). Only when voles became abundant did specialist predators (such as weasel, short-eared owl and kestrel) start to exploit them and reduce their numbers.

Predation within conifer forests in Britain

Man-made conifer forests in Britain are dynamic habitats with food resources and predator populations continually changing with the cycle of felling and replanting. As forests move into second and subsequent rotations, and become even more diverse, it is unlikely that predation pressure will be evenly spread, either between or within habitats. Instead there will be some patches where predation is low, due for instance to dense ground vegetation providing cover against avian predators. Here prey species will produce more offspring than is necessary to replace losses (source areas), and so provide potential colonists for elsewhere. Meanwhile prey populations in other parts of the forest will be

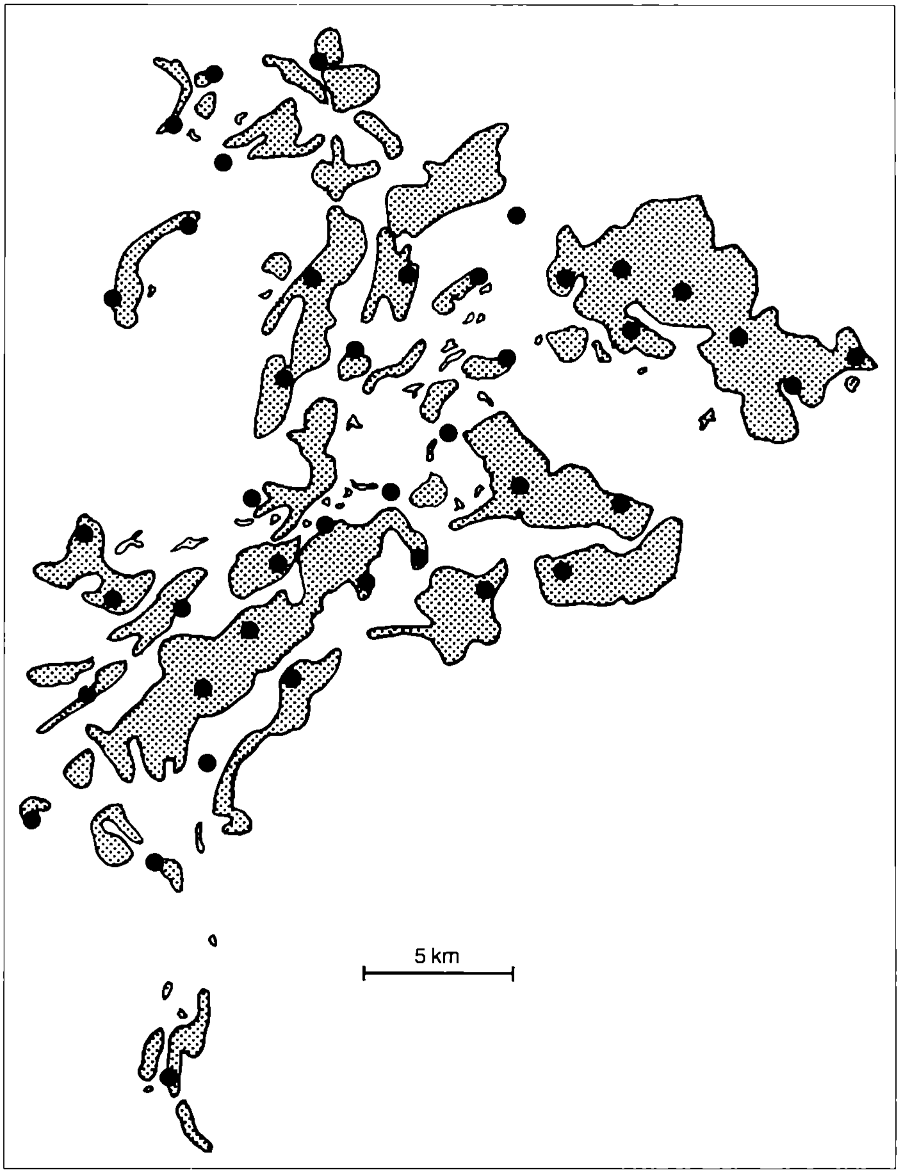

Figure 2.1 *The regular spacing of sparrowhawk nesting areas (spots) in Upper Speyside, Inverness-shire. Areas of woodland are shaded (adapted from Newton* et al., *1977).*

subject to heavy predation (sink areas) and these would decline without immigration from source areas. The balance between source and sink areas will be dynamic, too, resulting in an overall decline of some species and the increase of others.

Given the above observations, it is important to realise that wildlife communities in man-made conifer forests are continually changing, but largely through successional changes rather than predation. However, predation may assist in bringing about some of these habitat-driven population changes. Such fluxes in the density of individual species and assemblages may be greater than in less dynamic habitats. For instance, on moorlands, habitat structure and wildlife communities remain similar over many years because successional changes are arrested by regular burning and grazing, although even here the number of individual species can fluctuate between years. For example, some small herbivores (field voles, red grouse and blue hares) exhibit cyclic changes in abundance.

Table 2.1 Main (■) and occasional (□) foods of raptors in the uplands (adapted from Petty, 1996a).

Species	*Songbird*	*Larger bird*	*Small mammal*	*Lagomorph*	*Squirrel*	*Carrion (mammal)*	*Fish*	*Invertebrate*
Honey buzzard	□							■
Red kite	■	■	■	■		■		□
White-tailed eagle		■		■		■	■	
Hen harrier	■	■	■	■				
Goshawk	□	■		■	□			
Sparrowhawk	■	□						
Buzzard	■	■	■	■		■		□
Golden eagle		■		■		■		
Osprey							■	
Kestrel	□		■					
Merlin	■							□
Peregrine	■	■						
Barn owl			■					
Tawny owl	□	□	■	□				□
Long-eared owl	□		■					
Short-eared owl			■					

Population limitation in raptors

Most raptors in Britain are solitary breeders. Spatial separation of pairs of the same species is maintained by various forms of territorial behaviour (Newton, 1979). For example, sparrowhawks defend an area surrounding their nest, while the rest of their home range overlaps with that of other sparrowhawks (Newton, 1986). In contrast, tawny owls and buzzards strongly defend the whole of their territory from adjacent pairs (Southern, 1970; Hirons, 1985; Tubbs, 1974).

In suitable habitats, breeding pairs of raptors are often regularly spaced, rather than dispersed in clumps or at random (Figure 2.1). While the distance between pairs is often maintained by some form of territorial behaviour, density can be influenced by the following factors.

Food-supply

Where raptors are not illegally killed, their breeding densities are primarily governed by food-supply (Newton, 1979). So when prey are abundant, pairs breed closer together than when food is scarce (Figure 2.2). Birds and mammals provide the most important main foods of raptors in Britain, while invertebrates and fish are exploited heavily by relatively few species (Table 2.1).

There are many more species of birds in Britain than mammals. Raptors that hunt birds often have a more consistent food-supply from year to year. This is because, while the numbers of individuals in any bird species may fluctuate, they do so out of phase with one another, so that collectively bird prey exhibits relatively little annual variation in abundance. Hence, bird-eating raptors such as sparrowhawks, peregrine and merlin are noted in many areas for their year-to-year stability in breeding density and breeding performance (Newton, 1986; Ratcliffe, 1993). Sometimes, though, the gross abundance of bird prey can be more variable, particularly in large conifer forests. Petty *et al.* (1995b) recorded that numbers and breeding performance of sparrowhawks increased substantially following winters with bumper cone crops, because sparrowhawks switched to feeding on the vast numbers of crossbills and siskins attracted by the abundance of conifer seed.

Many larger raptors are also noted for their year-to-year stability in breeding pairs and

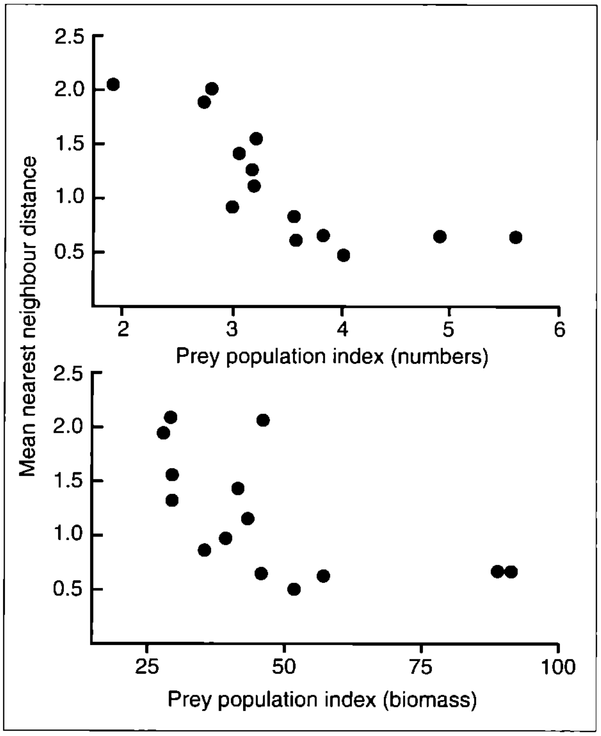

Figure 2.2 *Spacing of sparrowhawk nesting areas in relation to the abundance of bird prey in 14 different areas in Britain (adapted from Newton, 1986). Breeding density increases (nearest neighbour distances decrease) as prey become more abundant.*

reproduction. These include golden eagles, buzzards and red kites which are generalist predators feeding on a wide range of birds and mammals, including carrion, particularly during winter and early spring. Buzzards and kites also eat many earthworms.

In contrast, there are many fewer species of small mammals, whose abundance levels can fluctuate synchronously both within and between years, so making them a much less predictable food-supply than birds. Thus, raptors that depend on small mammals employ a range of different tactics to live through food shortages in years when small mammals are scarce. For example, short-eared owls have mobile populations capable of tracking high vole numbers, that settle and breed wherever food is most abundant. Voles have 3–5 year cycles of abundance that can be spatially synchronised over large geographical areas (Chitty, 1952; Hanski *et al.*, 1991; Korpimäki, 1992). Short-eared owls settling to breed at the peak of a rodent cycle defend smaller territories, and have larger clutch and brood sizes than pairs breeding in years on either side of the peak (Lockie, 1955; Village, 1987). This owl is often completely absent from areas in years between rodent peaks. Other raptors that concentrate on voles in the uplands, such as kestrel and long-eared owl, also have higher population densities and breeding productivity when voles are abundant (Village, 1981; 1982; 1986; 1990). In contrast, the tawny owl adopts a different strategy. It is a highly territorial species, but unlike some more mobile species, it is adapted poorly for sustained flight; so it remains on the same territory year after year but ceases to breed in poor rodent years (Southern, 1970; Petty, 1989b; Petty, 1992).

Nest sites

Of the natural factors that disrupt the usual regularity of spacing between pairs of raptors, the most important appears to be the availability of suitable nest sites (Newton, 1979). If these are scarce then breeding density may be below the level that food would permit.

In British landscapes that have been so altered by human activities, the major component missing is old trees, particularly in the uplands. These not only provide large cavities for hole-nesting species but substantial crowns for raptors that build large stick nests (Plate 2.1). Shaw and Dowell (1990) demonstrated that a lack of large nesting cavities prevented barn owls from breeding in low elevation conifer forests in SW Scotland, where rodent prey was abundant. In upland landscapes lacking good crag ledges, such as parts of the Southern Uplands, the breeding range of golden eagles could well be more widespread if there were more large trees in suitable locations for nesting (McGrady *et al.*, 1997).

Persecution

Widespread killing has had its greatest impact on larger species, because these have the lowest breeding densities and reproductive rates

(Newton, 1979). They were also relatively easy to shoot, trap or poison, making it possible to eradicate some species over large areas (red kite, buzzard and golden eagle), and even from the whole of Britain (goshawk, white-tailed eagle, osprey) (Newton, 1972). Killing raptors was most intense from the middle of the last century until the Second World War, and so had an additional impact on raptor communities that had already been drastically modified by deforestation.

Today, persecution of raptors is much reduced, due to fewer gamekeepers and a more enlightened attitude among many that remain. However, illegal killing appears still to be restricting the breeding range of hen harrier, goshawk, red kite and golden eagle; and probably that of peregrine and buzzard (Elliot and Avery, 1991; Bibby and Etheridge, 1993; Ratcliffe, 1993; Green, 1996; Petty, 1996b). The illegal taking of eggs and young by egg collectors and falconers can locally affect the breeding success of some species, but except in the case of very rare species, seldom has an impact on breeding density.

Pesticide contamination

During the late 1950s and early 1960s, dramatic declines in bird-eating raptors were subsequently linked to the use of organochlorine pesticides in agriculture. The worst affected species were sparrowhawk, peregrine and merlin (Newton, 1979; Newton, 1986; Ratcliffe, 1993), but carrion-eating golden eagles were affected too, through the use of organochlorines in sheep dips (Lockie *et al.*, 1969).

Soon after the Second World War, the organochlorine DDT became widely used as a general insecticide. This led to the contamination of many birds, and subsequently of raptors that ate them. High levels of DDT resulted in reduced productivity from egg-shell thinning, egg breakages and increased embryonic mortality (Ratcliffe, 1967; Newton, 1979). However, the final blow to raptors came with the introduction of cyclodiene compounds, such as aldrin and dieldrin. These organochlorines were more toxic than DDT, and resulted directly in the deaths of many adult raptors (Newton, Bogan and Rothery, 1986).

The widespread use of these chemicals in agriculture was withdrawn progressively from 1962 to 1986 (Newton, 1986), but because of their persistent nature, it has taken many years for them to decline in food chains. So, only recently have we been able to witness the spectacular recovery of sparrowhawk and peregrine falcon populations in eastern parts of the country. Recovery stabilised in the west in the 1960s, where usage of cyclodienes was lowest, and spread to the east by the 1980s (Newton and Wyllie, 1992; Ratcliffe, 1993).

Interspecific competition

Competition between different species of raptors can influence distributions, with the largest and most aggressive displacing and even killing smaller species (Mikkola, 1976; Newton, 1979). For instance, when nesting crags are scarce this may result in golden eagle displacing peregrine, and peregrines displacing kestrel or merlin. Within European forests, eagle owls are at the top of the forest food chains and influence the abundance and distribution of smaller raptors, in a similar way to golden eagles in more open upland habitats. However, golden eagles achieve this effect largely by physical displacement of smaller raptors and some predation, whereas the eagle owl does it almost entirely by predation (Mikkola, 1976). Viewed in a more holistic way, such complete assemblages of raptors appear to result not only in more diverse raptor communities, but in more diverse prey populations too. There is some evidence from pristine habitats that species diversity declines as top predators are progressively removed, so enabling the next best fitted to monopolise resources, because this last group can then exist at much higher densities (Paine, 1966; Terborgh, 1988). For example, removing top predators, such as wolves from temperate and boreal forests and large cats from tropical rainforests, often leads to a dramatic increase in ungulate numbers which then overgraze the ground vegetation. This not only results in a loss of species dependent on this vegetation layer but eventually to a complete change in the composition of the forest because fewer browse-resistant tree species are able to regenerate successfully .

Widespread killing has led to raptors of buzzard size and larger being eliminated from large tracts of the British countryside. The outcome has been that small raptors, such as the sparrowhawk and kestrel, are probably more abundant today than they would have been in the presence of relatively high densities of buzzards, red kites, and goshawks. These larger raptors would have overlapped on food requirements, competed for nesting space, and been potential predators of smaller species, and may have been a factor in limiting their breeding densities. The ranges of buzzards, red kites and goshawks are still limited by persecution, but this is slowly changing.

Habitat requirements

Raptors have evolved to exploit a wide range of habitats and the prey they contain. For instance, merlins with long wings and a short tail are designed to catch songbirds in fast chases in open conditions, whereas the sparrowhawk's long tail and short wings enable it to catch similar-sized songbirds but in short, agile flights in woodland.

Raptors have large home ranges or territories which often encompass a wide range of habitats. Therefore, it is not always easy to associate individual species with a specific habitat, particularly as breeding and foraging may require quite different areas. Goshawk and honey buzzard breed in old forest but can spend considerable time hunting over open country and edge habitats (Cramp and Simmons, 1980; Kenward and Widén, 1989). On the other hand, short-eared owls hunt and breed only in open conditions. Traditionally this was largely on moorland, but clear-felled patches within forests are increasingly being used (Shaw, 1995).

Using the forest growth stages defined by Ratcliffe and Petty (1986), it is possible to show broad habitat associations of the different species for breeding and foraging (Table 2.2). The thicket stage supports fewest species, while pre-thicket stages and old forest are the richest. Although thickets hold good songbird densities (Moss, 1979; Moss *et al.*, 1979; Patterson *et al.*, 1995), these birds are relatively secure from avian predators because of the dense nature of this habitat. Edges, particularly those between old trees and young tree crops or open areas, provide additional hunting and breeding opportunities.

Table 2.2 Main breeding and foraging habitats of 16 species of raptor in upland forests (adapted from Petty, 1988, 1996a).

	Successional stages from moorland to old forest				
Species	*Moorland*	*Pre-thicket*	*Thicket*	*Tall forest*	*Old forest*
Honey buzzard	■	■		□■	□■
Red kite	■	■		□	□■
White-tailed eagle	□■	□■			□
Hen harrier	□■	□■			
Goshawk	■	■		□■	□■
Sparrowhawk	■	■	□■	□■	□■
Buzzard	□■	□■		□■	□■
Golden eagle	□■	□■			□■
Osprey				□	□
Kestrel	□■	□■	□	□	□■
Merlin	□■	□■	□	□	□■
Peregrine	□■	□■			
Barn owl	□■	□■	□		□■
Tawny owl		■	□	□■	□■
Long-eared owl	□■	■	□	□■	□■
Short-eared owl	□■	□■			

□ = breeding habitat, ■ = foraging habitat

Therefore, raptor diversity will be greatest in forests comprising a patchwork of different-aged patches of forest, particularly when the forest is intermixed with farmland and/or moorland.

The use of raptors as bio-indicators

Because raptors are at the top of many different food webs, they can be used to indicate the health of the environment in which they live (Furness and Greenwood, 1993). Studies on raptors were the first to detect the insidious effects of organochlorine contamination of prey populations (Ratcliffe, 1967). Since then raptors have increasingly been used to monitor the levels of a range of chemicals in the environment (Newton, 1986; Newton and Galbraith, 1991; Newton and Wyllie, 1992; Furness, 1993; Newton *et al.*, 1993). For instance, recent studies have shown that DDT and cyclodiene compounds have declined in many food chains, whereas PCBs have not.

There has been less work on the use of raptors as indicators of biological diversity, but it is likely to be a fruitful area for future research. There are two ways in which raptors could be used.

First, the diversity of raptor species is likely to be related to that area's biological complexity, providing other factors such as illegal killing are not limiting raptor numbers. For example, an extensive newly afforested area will have few raptor species compared to the same area 70 years later if, in the meantime, it has been subjected to patch clear-cutting to create a mosaic of different-aged forest stands suitable for a wider range of species (Table 2.2). However, if the same area was clear-felled over a short time period, raptor diversity would probably be similar to that soon after the initial planting.

Second, the breeding density and productivity of individual raptor species is directly related to their food-supply. For instance, the breeding performance of tawny owls can be used to estimate the abundance of woodland rodents (Southern, 1970; Petty, 1992; Petty and Fawkes, 1997), and the breeding density of sparrowhawk reflects the density and biomass of bird prey present in an area (Figure 2.2). Using raptors to indicate changes in the abundance of different foods depends on an understanding of: (a) the diet of raptors in the area to be surveyed, and (b) the period over which monitoring needs to be done.

The breeding cycle

Species vary greatly in the timing of breeding and length of the breeding season (Figure 2.3). Generally, the larger the species the earlier breeding starts, because more time is needed for each part of the breeding cycle. Between raptors of the same body size, those feeding on small mammals breed earlier than those feeding on birds. Small mammals are much easier to catch in early spring before the growth of ground vegetation provides them with cover from avian predators, whereas bird prey are most vulnerable later in the season when large numbers of fledglings provide easy pickings in May–July. The breeding season can be divided into four distinct phases (Figure 2.3), namely:

Pre-laying

The pair increasingly spend more time together. Courtship displays occur which involve nest site selection, nest building and copulation. During this period the female reduces her hunting effort and becomes more reliant on the male to provide food. Females have to substantially increase their body weight to initiate the hormonal changes that lead to egg laying. Becoming heavier results in less agility, so females become even more dependent on males to provide food. If the male is unable to provision the female sufficiently, either because prey densities are low or he is a poor hunter, the breeding attempt may fail before eggs are laid, or soon afterwards. Prior to the first egg being laid the female spends increasing amounts of time on the nest, rearranging nest material or forming the cup for the eggs.

Laying and incubation

Eggs are laid at 2–4 day intervals depending on species. Females remain at the nest after the first egg is laid, but do not start incubating properly until after the second or third egg. This results in asynchronous hatching, with 2–3 chicks hatching together and the remainder following in a staggered sequence. In raptors that lay large clutches, such as short-eared owls, this results in great variation in chick size. Such an adaptation allows brood size to be adjusted to food-supply at the time of hatching, with the smallest chicks surviving only when food is abundant. In raptors, the incubation period is considerably longer that in passerines because the chicks are more advanced when they hatch. Incubation periods range from around 25 days in the small falcon to 45 days in golden eagles. During incubation, the female is totally dependent on the male to provide food. In most species the male will cover the eggs while the female is off the nest eating the food he has supplied, but this is variable. In the tawny owl and sparrowhawk there is little evidence of males covering eggs at all, but in falcons the males may incubate for up to one-third of daylight hours.

Nestling period

Newly hatched chicks require constant attention from the female. They need small portions of food at regular intervals. So in some species there is often surplus food in the nest to ensure that chicks survive periods of bad weather when the

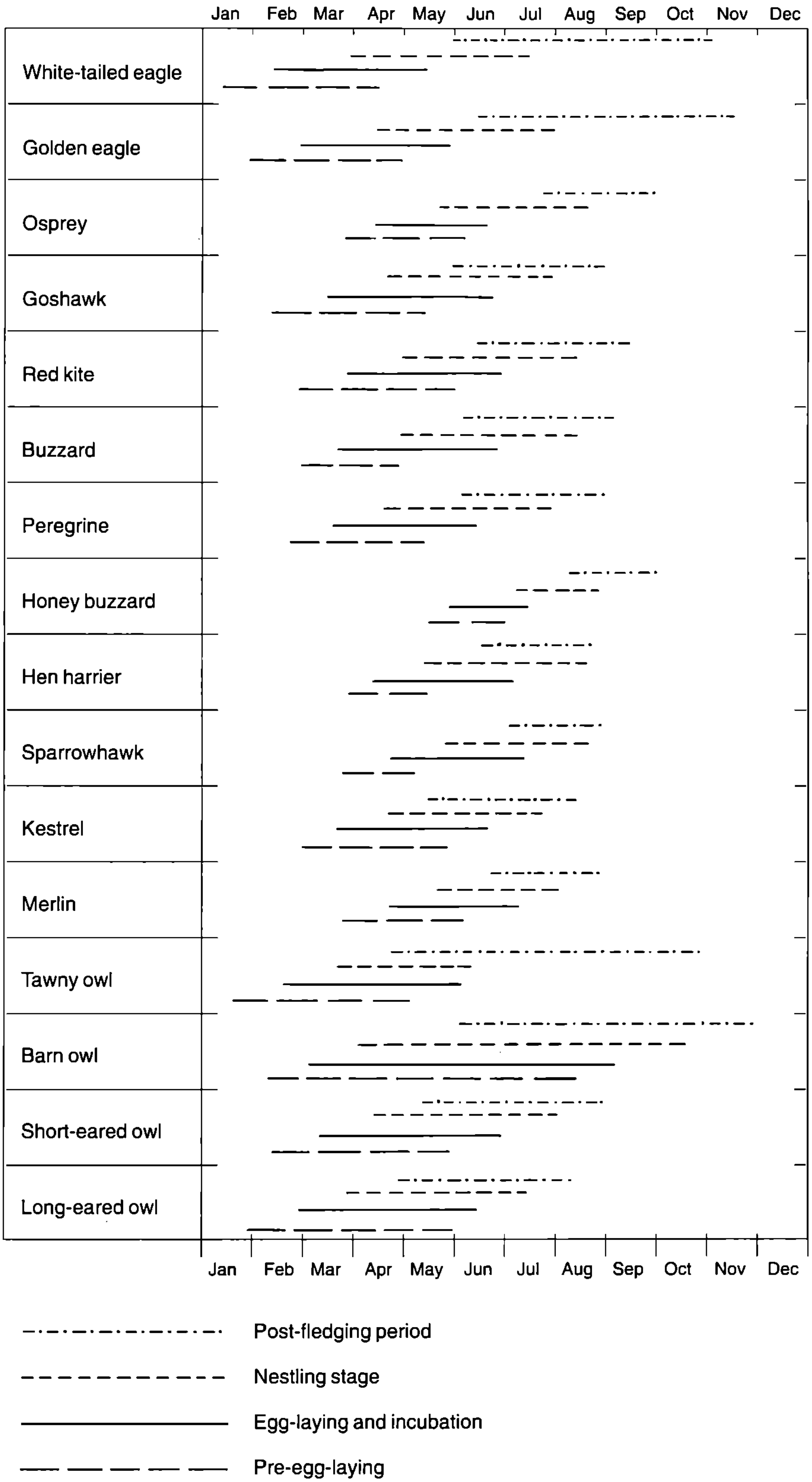

Figure 2.3 *The breeding seasons of 16 species of raptors in upland forests, divided into four stages; pre-laying, laying and incubation, nestling period, and post-fledging period. The bar for each stage includes the normal span over which egg-laying occurs and the time taken to complete that stage. Barn owls have a potentially longer breeding season than golden eagles because they lay eggs over a much longer period of time (from early March to the end of August compared to a six-week window for golden eagles) and are the only British raptor to sometimes raise two broods a year.*

male is unable to hunt. Young chicks cannot regulate their own body temperature, so are dependent on the female to keep them warm in cold weather by brooding them, and cool in hot weather by shading them. If brood reduction occurs, it invariably happens by starvation when chicks are small. Nothing is wasted during periods when food is scarce, so chicks that die are often torn apart by the female and fed to the remaining chicks or eaten by the female. As chicks grow, the female gradually spends less time at the nest, although she can often be located nearby. Chicks start to regulate their own temperature once feather growth is well advanced, so allowing females to hunt again. By the time the chicks fledge, the female may be contributing more food to the family than the male.

Post-fledging

After leaving the nest, the chicks remain in the vicinity, fed by their parents where they develop their aerial and hunting skills. Noisy chases take place between siblings, both close to the ground and in high aerobatics as they learn to use air currents above the nesting area. Parents often bring unplucked food into the site, and fledglings are encouraged to chase after them before the prey is eventually handed over for them to pluck. The time spent in the vicinity of the nest after fledging varies between species, but is at least 3–4 weeks. After this, the juvenile's area of activity gradually expands, and in some species a fairly rapid dispersal from the natal territory occurs. In more sedentary species, juveniles can remain in the natal territory for a considerable time; for up to two months after fledging in tawny owls and even longer in golden eagles.

Effects of afforestation on moorland raptors

Afforestation of moorlands has the potential to reduce the distribution of raptors that are adapted to hunt in these open conditions, due to a reduction in foraging habitat. Most concern has been expressed for the golden eagle, hen harrier, merlin and short-eared owl (Thompson *et al.*, 1988). All have substantial populations in the uplands that are important in either a national or European context (Dennis *et al.*, 1984; Bibby and Nattrass, 1986; Batten *et al.*, 1990; Bibby and Etheridge, 1993; Green, 1996).

Merlin and short-eared owl populations appear little affected by current levels of afforestation. Merlins have managed to maintain substantial breeding populations in areas with extensive forests, such as parts of Wales, Northumberland and Galloway (Parr, 1991; Orchel, 1992; Parr, 1994; Little *et al.*, 1995; Petty, 1995; Petty *et al.*, 1995b; Shaw, pers. comm.). While merlins in these areas are still dependant on moorland songbirds for food during most of the breeding season, they have adapted well to the presence of forests. In particular, they have reverted to breeding in tree nests, where they are safer from mammalian predators. This habit has allowed them to exploit lower elevation grass moors which previously lacked nest sites, and woodland songbirds now form an important part of their diet in early spring.

Short-eared owls will breed on vole-rich clear-cut patches within forests (Shaw, 1995). With clear-cutting increasing in the future,around 15% of forests may be suitable for short-eared owls at any one time. This will provide a substantial resource for this species, considering that vole densities can be far higher on felled areas than on heavily grazed moorland. So both merlin and short-eared owl appear little threatened by current levels of afforestation.

The position with the hen harrier is quite different. Afforestation since the last war has been an important factor in its recolonisation of the British mainland (Newton, 1972; Watson, 1977). Since then populations in Northumberland, Galloway and Ireland have declined as forests have matured (Watson, 1977; Galloway and Meek, 1978; O'Flynn, 1983), and there has been no widespread return to breed on restocked sites which now comprise a large proportion of older forests where the initial colonisation occurred (Petty and Anderson, 1986). This suggests there may be subtle differences between afforested and restocked sites in either food availability or competition from forest-based raptors. The limited amount of data available suggests that food-supply differences may not apply as some restocked sites can have similar or higher densities of songbirds compared to afforested sites (Leslie, 1981; Patterson *et al.*, 1995), and field voles can form a substantial part of the small mammal community (Petty, 1992). However, restocked sites often lack larger prey, such as red grouse and lagomorphs, that are so important for successful breeding by harriers on some moorlands and newly afforested areas. So, in the long term, afforestation may lead to a permanent loss of breeding habitat for this species. This is not to say that older forests are unimportant for harriers, because restocked sites can be heavily used by wintering harriers, particularly when vole numbers are high (Shaw, pers. comm.).

Effects of forestry on golden eagles will be different to those on hen harriers. Substantial parts of many golden eagle territories are at higher elevations, where climatic and economic factors limit the expansion of forestry, so ensuring that large open areas remain suitable for foraging. Golden eagles with their soaring flight are well adapted to exploit extensive moorland and mountain habitats where prey densities are low. Those golden eagle territories most at risk are low lying ones, where a substantial proportion of the available ground can be planted (Watson, 1992; McGrady *et al.*, 1997).

To conserve substantial populations of moorland raptors, it is important to maintain a balance between the ratio of moorland to forest in the environment. This can be explained using a simplistic model (Figure 2.4) which uses three raptors as examples; the golden eagle, which is dependent on moorland, the tawny owl which is dependent on various growth stages within forests, and the goshawk which breeds in forests but forages on agricultural land, moorland and in forests (Table 2.2). The greatest species richness is likely to occur when around half of any given area is planted, particularly as forestry is usually restricted to the lower and mid elevations. S-shaped or sigmoid curves used here often describe decreasing and increasing population trends better than linear functions (Begon and Mortimer, 1981; Moss *et al.*, 1982; Begon *et al.*, 1986). An important point to note is that substantial habitat changes can occur before any species is affected, but once a certain point is reached, changes (increases or declines) are then rapid.

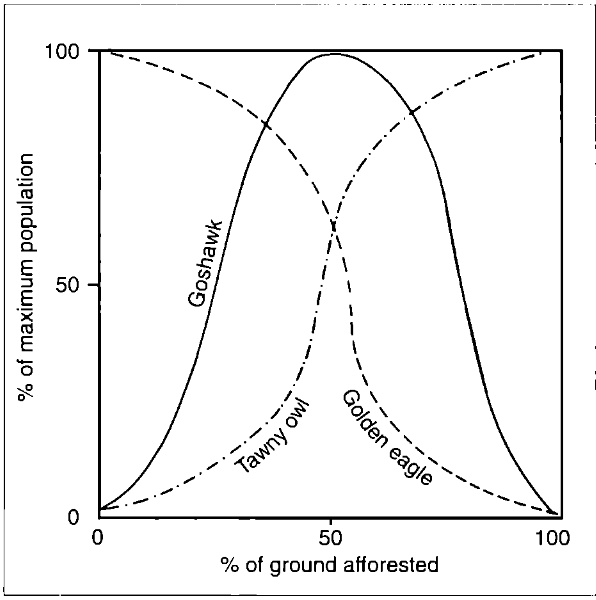

Figure 2.4 *Model demonstrating possible population changes in a raptor of moorland (golden eagle), woodland (tawny owl), and both habitats (goshawk), with differing levels of afforestation (adapted from Petty and Avery, 1990).*

Chapter 3

Management of forests for raptors

The concept of managing habitats to enhance raptor populations has developed over the last 20 years, after the existence of many species was threatened by the insidious effects of organochlorine pesticides. Many simple techniques can increase or stabilise populations under pressure from environmental change; these have been reviewed by Olendorff (1980) and Giron Pendleton *et al.* (1987). Other publications have covered particular aspects of raptor conservation and management (Geer, 1978; Newton, 1979; Petty, 1988).

Raptors are not easily conserved under existing legislation. Although legally protected, their low densities make it difficult to protect the habitat of large numbers of pairs, either in nature reserves or sites of special scientific interest (SSSIs), as is sometimes possible with localised populations of scarce plants, invertebrates or birds with small ranges or clumped distributions. Therefore, it should be seen as an important responsibility of forest managers to safeguard, and if possible increase, the potential of the land under their control for raptors, which in turn will have beneficial effects on other organisms. The needs of raptors should be incorporated into the Forest Design Planning Process. The following sections explain how this can be achieved.

Locating nests

Locating nests is a crucial part of raptor management. For example, nests need to be found so that disturbance can be minimised, and to determine which species are present within a forest and how abundant they are. Locating nests often causes some disturbance, for which a licence is required for Schedule 1 species (Table 1.3).

Building up a database

Many raptors have a helpful habit of returning to breed in sites (nesting areas) that they have used before, although different nests may be used. Most species can have alternative nesting areas within their territory, so not all will be occupied every year.

Gradually building up a database with the locations of these traditional sites, and the species that use them, is an essential first step to learning more about the distribution of raptors within your forest. As it is impossible to 'manage' raptors without this information, it is strongly recommended that managers make the resources available to create this database.

Known nesting areas should be checked each spring to see if they are occupied, and nesting areas located for the first time need to be added to the database.

When information is needed on the breeding success of individual home ranges, the most important data to collect and record in the database are:

- Whether or not a home range is occupied, taking care to check alternative nesting areas.
- Whether or not pairs in occupied home ranges successfully rear chicks.
- The number of chicks produced per successful pair.

With training and experience, these data can be collected for most species with 2–3 visits each year to the nesting territory, often without close inspection of the nest. Unless detailed population studies are being undertaken, it is not necessary to collect data on clutch size, the number of chicks hatching, or to ring chicks.

Finding nests

Finding new nest sites requires experience and the motivation to search large areas of suitable terrain. Sometimes there are no alternatives to a lot of legwork. If experience is lacking, raptor enthusiasts working with local Raptor Study Groups may be able to help. Much of upland Britain is now covered by a network of these groups (Appendix 1). Raptor Study Groups can sometimes provide training for well motivated but inexperienced individuals, often by helping with existing projects.

It is useful to follow up repeated sightings of birds in areas containing a suitable nesting habitat, with a more thorough search on foot for signs of occupancy. Prior to egg laying, females spend increasing periods of time loafing in the vicinity of nests between bouts of courtship, nest building and feeding. In open habitats, some species can even be watched from a distance as they deliver nesting material to a nest. Once incubation commences, and during the nestling period, activity around nests becomes far less obvious. Another peak in activity occurs soon after chicks leave the nest, when they can be very noisy and visible. However, observations at this time reveal only successful nests, as some nests will have inevitably failed earlier.

Raptors leave signs around their nesting areas that can be used to confirm if sites are occupied and to indicate where the active nest is situated. Such signs include:

- Pellets and white faeces from adults that accumulate under favourite perches (Plate 3.1).
- Moulted feathers from adults are found under perches, beneath the nest or on flight lines between perches and the nest. Most species moult throughout the breeding cycle, and because the female is confined to the nesting area for a period prior to egg laying until the nestlings are at least half grown, most of the feathers found belong to her rather than the male. Moulted feathers can also be used to identify the species occupying the nest site (Petty, 1989a; Brown *et al.*, 1992).
- Remains of prey on 'plucking posts' or under perches (Plates 3.2, 3.3 and 3.4). Remains comprise feathers or fur, plucked from the prey by the adults before being eaten, or skeletal remains too large to eat (Plate 3.4). Remains collected from nest sites can be used to identify (from a reference collection or experience) and to quantify prey taken by the adults.

Initially, it can be more profitable to look for these signs to confirm that a site is occupied than to spend time looking for the nest. When some or all of the above signs are found, it can be assumed that the site is occupied and further searching will locate an active nest, but an appropriate licence is then needed when this involves disturbing a Schedule 1 species (Table 1.3).

Within occupied nesting areas, there can be numerous old nests or nest ledges that have been used in the past. The active nest can be identified from:

- White down around the rim of the nest. In most species females start to moult from the beginning of incubation (Plate 3.5).
- White faeces on the ground beneath the nest. Chicks defecate over the side of the nest, resulting in a gradual build-up of deposits during the nestling period (Plate 3.6).

Are there risks associated with finding nests?

Visits to locate nests or to monitor breeding performance should be in good weather and limited to 30 minutes or less. This level of disturbance will have no detrimental effects on the number of chicks reared providing care is taken. Experience is needed though, because individual species react differently to disturbance from short-duration nest visits.

Tawny owls provide one extreme example of problems that can be encountered. Some individual females will desert after being flushed from the nest just once during incubation, but they are not adversely affected by visits after hatching (Petty, 1992). Therefore, plan to visit tawny owl nests post-hatching. However, care is then needed because some individual females are dangerous. Attacks are often silent and directed to the observer's head, and usually happen while chicks are being handled. People have been blinded by such attacks, so it is essential that goggles are worn for all visits to tawny owl nests with chicks. In contrast, sparrowhawks and barn owls are far more tolerant, and clutch and brood sizes can be obtained with no risk of causing a desertion, or of being attacked by the adults (Newton, 1986; Taylor, 1991).

There are often more risks associated with visiting nests of ground-nesting raptors. Short-eared owls and hen harriers have white eggs, and once the incubating bird has been flushed, their eggs (and small chicks) are highly visible to potential nest robbers such as crows. There is also some evidence to suggest that human scent trails might be used by mammalian predators to locate nests (Whelan *et al.*, 1994). So for these species try and obtain brood counts when chicks are well grown, and avoid visits during the incubation and early nestling stages.

Conserving natural nest sites

Many raptors use nesting areas which often have a long history of usage. Many golden eagle and peregrine nest ledges known to egg collectors last century are still in use today (Plate 3.7). Therefore, measures taken to conserve nesting areas will be of long-term value. Nevertheless, it is important to realise that raptors require areas to hunt in as well as to nest. This means areas rich in potential prey. So conserving nest sites alone is unlikely to be a successful strategy.

Crag nests

Inappropriate forestry has the potential to restrict or limit the use of crags by a range of species (Table 3.1). Crags with well-sheltered ledges provide nest sites for golden eagle, peregrine, buzzard and kestrel, while steep heathery banks and small crags are used by merlin. Crags with large fissures may provide the only nest sites for barn owls in areas lacking large tree cavities or suitable buildings.

In any area, the use of crags depends on both the availability of alternative crags and the raptor species present. When crags are plentiful, such as in parts of the Scottish Highlands, then each species may have numerous alternatives, leading to a low proportion being occupied in any one year. Where crags are scarce, such as in Northumberland, parts of mid Wales and southern Scotland, then most good ledges are occupied every year, sometimes by different species.

Crag nests will continue to be used successfully after afforestation, providing a few simple precautions are taken. Planting too close to crags may eventually lead to sites being abandoned as flight access becomes restricted by tree growth. Therefore, an unplanted area needs be left around each crag, particularly on the downhill side, so that at the end of the rotation the crag is still open. The proximity of planting depends on adjacent landform, with low crags needing relatively more unplanted ground below them than high ones. At restocking, the opportunity arises to open up crags where the previous crop was planted too close (Plate 3.8).

Species such as golden eagle and peregrine need large, well-sheltered ledges on which to nest, and it is sometimes possible to excavate an existing ledge to make it more suitable.

Tree nests

Substantial tree nests built by large raptors should be retained wherever possible, as trees with suitable crotches or whorls of branches in

Table 3.1 Main nest sites of raptors in upland Britain (adapted from Petty, 1996a).

Species	*Nest sites*	*Builds own nest of twigs and branches*
Honey buzzard	tree	yes
Red kite	tree	yes
White-tailed eagle	tree, cliff ledge	yes
Hen harrier	ground	yes
Goshawk	tree	yes
Sparrowhawk	tree	yes
Buzzard	tree, cliff ledge	yes
Golden eagle	cliff ledge, tree	yes
Osprey	tree	yes
Kestrel	tree nest, cliff ledge, building	no
Merlin	tree nest, cliff ledge, ground	no
Peregrine	cliff ledge	no
Barn owl	building and large cavity in tree or cliff	no
Tawny owl	tree nest, tree cavity, building, ground	no
Long-eared owl	tree nest	no
Short-eared owl	ground	no

which replacement nests can be built are not always available. This particularly applies to eagle and osprey nests which, because of their scarcity, are usually safeguarded by special measures. However, old nests of buzzards and goshawks provide sites in which small falcons and owls breed. They can even be used by pine martens for sleeping and breeding. So, whenever possible, large nests should be left during thinning operations.

Goshawks often commence breeding in crops towards the end of commercial rotations, when nests are then prone to accidental felling. This can be prevented by extending the rotation length in nesting areas, but this requires a knowledge of the location of nesting areas, and a commitment to leave a minimum of 5 ha around each nest up to a maximum area determined by the nearest wind-firm edge (Petty, 1989a; Petty, 1996c). Honey buzzards also breed in older stands of trees and are very site faithful, but are much scarcer than goshawks. So, whenever possible, all nesting stands used by this species should be retained.

Smaller stick nests, particularly those of crows and magpies, are also important nest sites for a group of smaller falcons and owls that do not build their own nests (Table 3.2). If crows and magpies are shot at nests as part of a properly justified control programme, it is important to flush and identify the nest occupant first. This avoids shooting a nesting raptor accidentally or ruining a nest that may be used by a raptor in the future.

If forests are clear-felled in the sequence in which they were planted, there will be periods when nesting opportunities are limited for raptors that breed in forest interiors and along edges of older stands. When nesting habitat is not limited, many species exhibit a regular spacing between pairs (Figure 2.1). Therefore, the restructuring of upland forests at the end of the first rotation to create a mosaic of different-aged patches (Hibberd, 1985) will ensure that breeding habitat is available for the greatest range of species, providing this incorporates the retention of patches of old forest. It then becomes less necessary to refrain from felling blocks with nests, providing that cutting is done outside the breeding season.

Table 3.2 Raptors that use artificial nests.

Species	*Building own nest*	*Nest box*	*Platform*	*Artificial crow nest*	*Improved crag ledge*
Honey buzzard	*				
Red kite	*				
White-tailed eagle	*		■(1)		
Hen harrier	*				
Goshawk	*		■(1,11)		
Sparrowhawk	*		■(1)		
Buzzard	*		■(1)		
Golden eagle	*		■(1)		■
Osprey	*		■(1,2)		
Kestrel	+	■(3,4)		■(5)	■(12)
Merlin	+			■6,7)	
Peregrine	+				■
Barn owl	+	■(8,9)			
Tawny owl	+	■(10)		■(6)	
Long-eared owl	+	■(4)		■(5)	
Short-eared owl	+				

* Species which build their own nests of sticks and branches.
+ Species which do not build nests but form a scrape for their eggs in some existing substrate.

References:

1 = Saurola, 1978	7 = Rebbeca *et al.*, 1991
2 = Dennis, 1987	8 = Taylor, 1994
3 = Canham, 1992	9 = Shaw and Dowell, 1990
4 = Riddle, 1992	10 = Petty, 1987
5 = Village, 1983	11 = Petty, 1989a
6 = Little and Davison, 1992	12 = Village, 1992

Artificial nest sites

In conifer forests and semi-natural woodlands, nest sites for some species may be absent, in short supply or of poor quality. These factors may limit distribution or affect productivity, and may occasionally warrant the use of artificial nests. Even so, artificial nests are only a short-term solution, and a strategy should be developed whereby forests of the future provide ample nesting opportunities. For example, barn owls require large cavities in which to nest (Taylor, 1994). So in the short term nest boxes can be used. But, in the long term, it is desirable that tree species capable of producing large cavities are incorporated in broadleaved patches, where they can develop until biologically mature (Shaw and Dowell, 1990; Petty *et al.*, 1994). Ash, sycamore and common alder are particularly

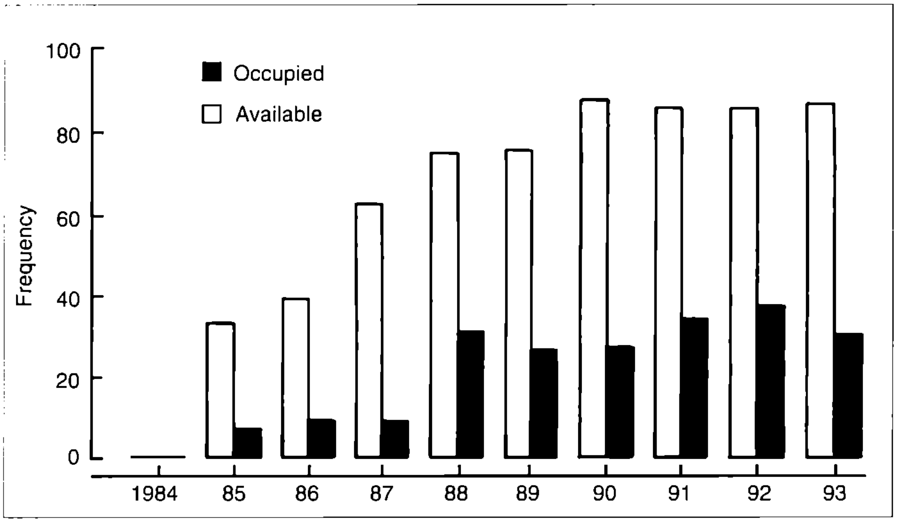

***Figure 3.1** Number of nest box sites available and number occupied by barn owls in Galloway. Nest boxes were first available in 1985, prior to this 3–6 pairs bred in the area. The population has subsequently stabilised at 30–40 pairs (adapted from Petty* et al., *1994).*

valuable in this respect, and well suited to many upland sites (Low, 1986).

A wide range of species will accept artificial nests, but the justification for their use should be carefully considered beforehand, and may involve seeking specialist advice (Appendix 1). Man-made structures for nesting include nest boxes, nesting platforms and artificial crow nests.

Nest boxes

Nest boxes can be used by raptors which do not build their own nests (Table 3.2). For these species, boxes may provide better quality sites than natural ones, and this may lead to enhanced breeding success. Nest boxes, rather than open nests, can give better protection to occupants in prolonged wet spells and from potential predators of smaller raptors such as goshawk and buzzard. The three species below regularly breed in boxes in Britain, and long-eared owls have occasionally bred in nest boxes in southwest Scotland (Riddle, 1992) and in The Netherlands (Cave, 1968).

1. *Barn owl.* Barn owls can be present during the early growth stages of a forest, when they frequently inhabit old buildings, some of which lack a suitable ledge for a nest. Taylor (1994) gives a design of box which is suitable for use in these sites.

   In Galloway in southwest Scotland, attempts were made to encourage barn owls to nest within forests, particularly on newly afforested and restocked sites that lacked traditional nest sites (Shaw and Dowell, 1990; Petty *et al.*, 1994). Eighty-litre plastic drums were attached vertically and horizontally to trees at heights of about 4–6 m in pairs (Plate 3.9). The drums had a square hole cut near the top with a rough piece of wood bolted below to facilitate entry. Drainage holes were drilled in the bottom and a layer of sawdust was added. The results have been encouraging, with 30–40 pairs now established in an area that previously held 3–6 pairs (Figure 3.1). There was no evidence that adults switched from traditional farmland sites to these drums. The success of this project was related to: (1) the presence of a good food-supply in the young forest and adjacent farmland, (2) a nearby source of recruits. Similar results may not be possible where food or barn owls are scarce.

2. *Tawny owl.* This owl starts to colonise conifer forests towards the end of the first rotation, and although normally considered a cavity nester it will breed in a wide range of natural sites (Petty, 1992). They will even breed on the ground, usually between the buttresses of a tree (Plate 3.10). Nest boxes are readily used (Plate 3.11), and may encourage the existing population to switch from natural sites (Figure 3.2). In conifer forests, the entire population can switch to breeding in boxes, but

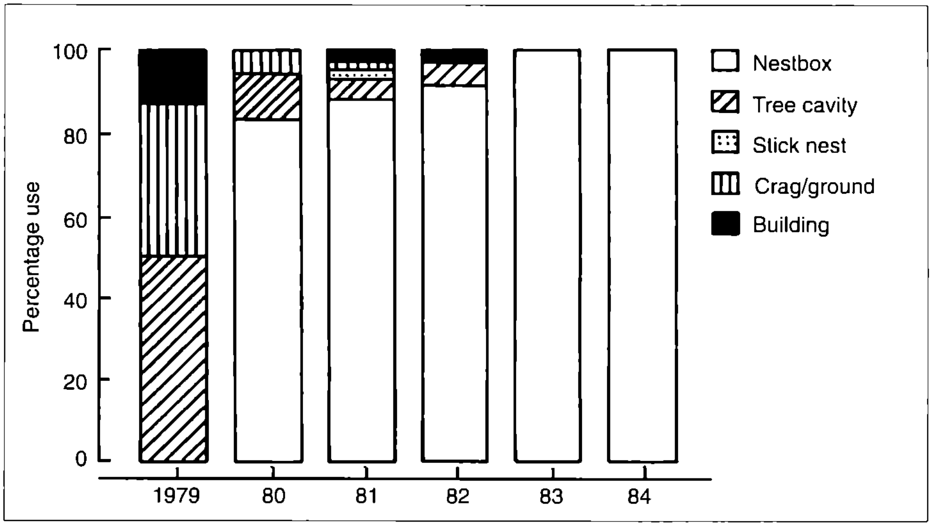

Figure 3.2 *Nest site choice by tawny owls before and after the erection of nest boxes in Kielder Forest, Northumberland (adapted from Petty, 1992). Nest boxes were first erected during the 1979/80 winter. By 1983, all pairs had abandoned their traditional nest sites for boxes.*

in lowland broadleaved woods with many natural cavities the response can be less dramatic (Southern, 1970; Petty, 1992; Petty *et al.*, 1994). Tawny owls will use smaller tree cavities than barn owls because the nestling period is far less (30 days instead of 60 days) and brood size is on average smaller (Southern, 1970; Petty, 1992; Taylor, 1994). Therefore, while nest boxes can greatly assist with a population study of tawny owls, they are often unnecessary as a conservation measure; in contrast to the situation with barn owls.

3. *Kestrel.* Nest boxes have been widely advocated for kestrels since the spectacular increase in density resulting from the use of boxes in the Dutch polders where there were no natural nest sites (Cave, 1968). However, trials undertaken with boxes in a newly afforested site in mid-Wales where natural sites were lacking, and around clear-fells in Northumberland where kestrels bred in old crow nests, were both unsuccessful because kestrels did not use the boxes provided in Wales or switch from crow nests in Northumberland (Petty, 1985). There may be specific instances when nest boxes can be advantageous for kestrel, such as on crags which do not contain good ledges, on buildings, in patches of trees lacking crow nests around new clear-cuts, or even on poles in open country (Plate 3.12) (Village, 1990; Canham, 1992; Riddle, 1992). However, once forests start to mature there is usually an abundant supply of disused nests of other species for kestrels to use. When these are scarce or absent, then the use of artificial crow nests may be more successful than boxes, and easier and cheaper to make and erect (see pages 22–23).

Nesting platforms

Nesting platforms can be made of branches or wood which are wired or nailed onto supporting branches to provide the nest base for raptors, such as eagles, goshawks and ospreys, which build substantial tree nests (Table 3.2) (Saurola, 1978).

Dennis (1985; 1987) describes the construction and successful use of platforms by ospreys in Scotland. About one-third of the population now use artificial nests or natural ones which have been artificially rebuilt. Platforms are built on top of a dominant tree, usually one with the top cut out (Figure 3.3). Dennis (1985) recommends erection of artificial nests for ospreys throughout Scotland and northern England where the following requirements are met:

- adequate fishing areas available;
- sympathetic landowner with suitable trees;
- secluded localities away from the public.

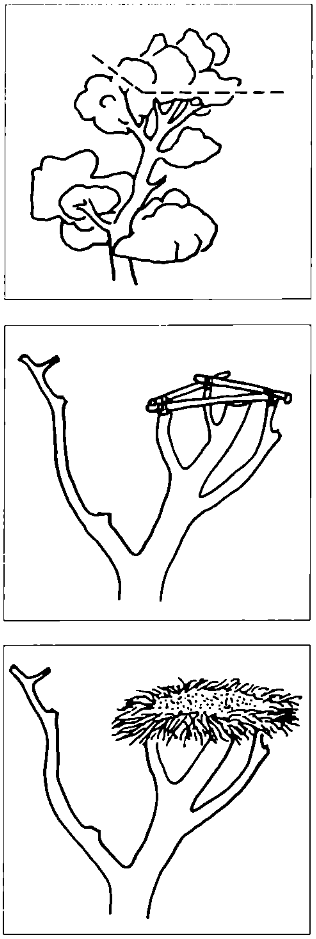

Figure 3.3 *Stages in the construction of a nesting platform for ospreys (redrawn from Dennis, 1987).*

Many upland forests contain such sites. The presence of platforms can attract passing migrants and sub-adult ospreys into new areas. Platforms can also be used to move ospreys from nests which are being robbed or grossly disturbed into safer areas up to 2 km away.

A similar approach works for goshawks (Petty, 1989a; unpublished data). Platforms may encourage birds to stay and breed in areas where they have previously been seen prospecting. They need to be built on a strong whorl of branches just below the green canopy of a conifer (Figure 3.4). They can also be used to move goshawks from nests which are being disturbed or robbed, or from areas scheduled for felling.

Golden eagles have also nested on platforms to replace tree nests that had blown out, or to move them from grossly disturbed crag nests (Petty, unpublished data). The use of platforms in trees for white-tailed eagles could become more widespread as the population in western Scotland increases.

Artificial crow nests

Disused crow (and magpie) nests provide nest sites for small falcons and owls that do not build nests themselves (Table 3.2 and Plate 3.13). Crows may sometimes be absent during the afforestation phase, even when old shelter belts are present, and in these circumstances the use of artificial crow nests may be justified. However, once forests start to mature, crows invariably colonise suitable habitat, thus providing an abundance of old nests for certain raptors. In forests, crows build a new nest each year, so within each crow's territory there is often a cluster of 1–5 old nests.

Four raptors regularly use nests of other birds (particularly those of crows and magpies) for breeding (Table 3.1), and artificial crow nests have been used by these with varying degrees of success.

1. *Kestrel.* Artificial nests successfully increased the breeding density of kestrels in a newly afforested area in southern Scotland (Village, 1983). These were sited in old shelter belts lacking crow nests. Long-eared owls used these artificial crow nests too (Village, 1981). This may be a more successful technique for manipulating kestrel numbers than nest boxes, but it depends on some trees being present.
2. *Merlin.* In Northumberland, breeding success was more successful in crow nests in trees compared to ground nests (Newton, Meek and Little, 1986). Following these findings, around 200 artificial nests were sited along the forest/moorland edge in Kielder Forest. These nests were made of wire netting to form a bowl, into which was woven heather or willow branches (Plate 3.14). An upturned peat sod was placed in the bottom for the birds to scrape a nest cup. They were slightly larger than natural crow nests, and were wired on to a

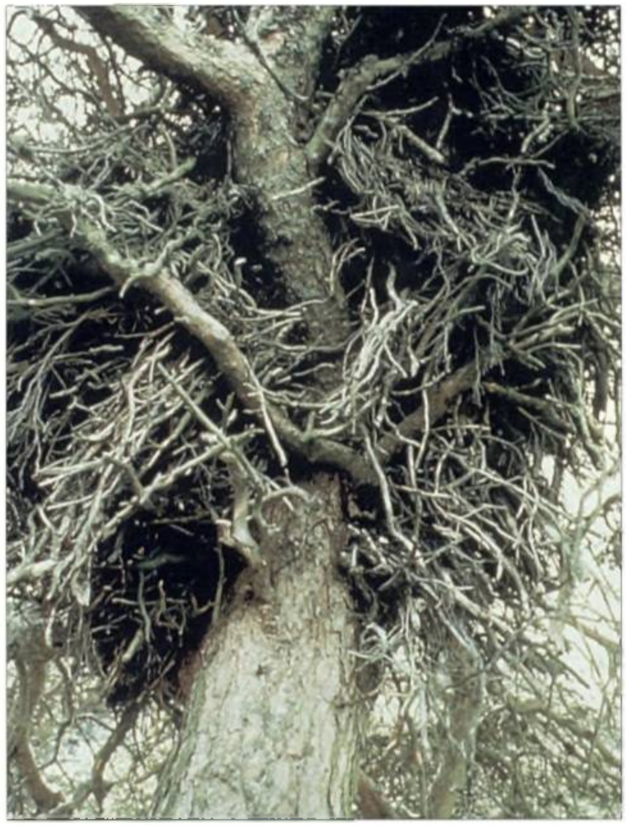

Plate 2.1 *A golden eagle nest in an old pine tree. Such nests become massive structures after being used for many years.* FOREST LIFE PICTURE LIBRARY

Plate 3.1 *Windthrown tree used as a perch by a sparrowhawk. The accumulation of faeces and pellets indicates there is an occupied nest nearby.* S.J. PETTY

Plate 3.2 *Plucking post of a merlin on a boulder top near to a nest in deep heather. Merlin and sparrowhawk plucking posts can be similar, and care is needed to correctly identify the occupant, particularly along forest edges.* S.J. PETTY

Plate 3.3 *Plucking post of a goshawk on a windthrown root plate strewn with feathers from a woodpigeon. Sparrowhawks kill woodpigeons too, but they are unable to lift them onto elevated sites to pluck them.* S.J. PETTY

Plate 3.4 *Skeletal remains of bird prey collected from beneath perches in an occupied goshawk nesting area.* S.J. PETTY

Plate 3.5 *An incubating female goshawk. Females start to moult around the time of egg laying, resulting in an accumulation of white down around the nest rim which is visible from the ground with binoculars.*
M.J. RICHARDS

Plate 3.6 *White faeces beneath the nest indicates that it contains nestlings.*
S.J. PETTY

Plate 3.7 *Golden eagles require a large, well-sheltered ledge for nesting. These are often scarce, even in mountainous areas, and will have been used by many generations of eagles.*
FOREST LIFE PICTURE LIBRARY

Plate 3.8 *Clear-cutting can expose nesting crags that have become overgrown by conifers. Buzzards used this crag in the first breeding season after clear-cutting.*
S.J. PETTY

Plate 3.9 *A barn owl nesting barrel. Barrels should be erected in pairs with 20–40 m between each, as earlier-nesting tawny owls may use one. Barrels should be sited in valley bottoms, adjacent to unimproved farmland or clear-fells where rodent prey abounds.*
S.J. PETTY

***Plate 3.11** Tawny owls will readily switch from natural nest sites to breed in nest boxes.* S.J. PETTY

***Plate 3.10** Tawny owls prefer dry tree holes for nesting, but they are adaptable, and will nest on the ground when nothing else is available. This nest is typical of ground nests in conifer forests.* S.J. PETTY

***Plate 3.12** A nest box fixed to a fence post extension. Kestrel will sometimes use these in newly afforested areas that lack natural nest sites.* M. CANHAM

Plate 3.14 *An artificial crow's nest made of wire netting with willow (or heather) branches woven into the netting. After fixing to a tree, an upturned peat sod should be placed in the centre. These can be used by kestrels, and occasionally by long-eared owls and tawny owls.* S.J. PETTY

Plate 3.13 *A long-eared owl nesting in an old crow's nest. Kestrels, merlins and tawny owls also breed in disused stick nests of other species, particularly those of crows.* P.N. JOHNSON

Plate 3.15 *In good vole years, newly afforested areas are noted for the abundance of short-eared owls, long-eared owls and kestrels. Hen harriers often colonise lower elevation sites attracted by the abundance of songbirds and red grouse.* S.J. PETTY

Plate 3.16 *Once extensive areas of first generation forest pass into the thicket stage, raptor numbers decline. These crops hold good songbird numbers, but these are relatively inaccessible to raptors.* S.J. PETTY

Plate 3.17 *Felling coupes separated by older crops are beginning to create a patchwork of varied growth stages in many upland forests. These provide a much greater range of habitats for a wider range of wildlife, including raptors.* S.J. PETTY

Plate 3.18 *Trees or groups of trees with sturdy horizontal branches provide good perches for raptors on clear cuts. Here, groups of Scots pine have been left in a large clear cut.* S.J. PETTY

Plate 3.19 *Golden eagle feeding on the remains of a red deer. Carrion is an important winter food of eagles, buzzards and red kites.* FOREST LIFE PICTURE LIBRARY

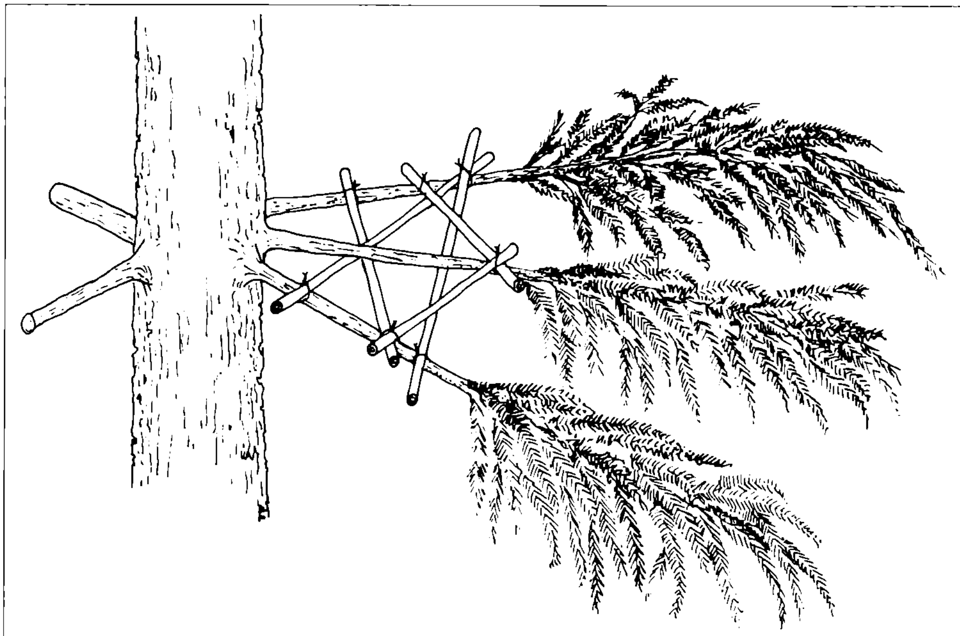

Figure 3.4 *Artificial nesting platform for goshawks (from Petty, 1989a). A strong whorl of branches should be selected to which the supporting sticks are tied with string or wire.*

whorl of branches in the upper crown of young spruce or pine trees. During a five-year trial, long-eared and tawny owls bred in the nests but not merlins. Wiklund and Larsson (1994) obtained similar results in Sweden, and concluded that merlin numbers were limited by food-supply and not lack of nest sites. So in forests, there is little justification for using artificial crow nests for merlins unless crows have been eliminated by control measures. But on moorlands they have been used successfully in isolated broadleaved trees that lacked crow nests (Rebecca *et al.*, 1991).

3. *Long-eared owl.* Artificial crow nests have been used (Village, 1981), but there has been no trial to fully evaluate their usefulness to long-eared owls. In most forests, disused stick nests of squirrel, crow, magpie and sparrow-hawk are far more abundant than long-eared owls. Therefore it is unlikely that a lack of nest sites would limit the breeding density of long-eared owls.
4. *Tawny owl.* Artificial crow nests are used occasionally, but tawny owls prefer more sheltered nest sites (Petty, 1987; Petty *et al.*, 1994).

Improving food-supplies

Food availability is a major factor determining the density and distribution of raptors, and their prey (Newton, 1979; Staines *et al.*, 1987). Therefore it is prudent to consider ways of improving, or at least conserving, the existing food-supply in upland forests.

The most sensible approach to increasing the food-supply is through habitat improvement. It has already been shown that the most important feeding (and breeding) habitats for raptors are unplanted moorland, the early and late growth stages of a forest, and forest edges (Table 2.2). The poorest feeding areas are thicket stage plantations.

Newly afforested areas are often extensive and planted over a short period of time. This leads to dramatic changes in wildlife communities as forests pass from one growth stage to the next (Ford *et al.*, 1979; Petty *et al.*, 1995a; Petty, 1996a). Prior to canopy closure, spectacular raptor assemblages can congregate as food-supply increases following the removal of domestic stock and the corresponding growth of ground vegetation (Plate 3.15). As forests move into the thicket stage (Plate 3.16), food-supply becomes less accessible to raptors and numbers and species decline.

These dramatic changes in the composition of wildlife communities over large areas of forest can be substantially modified by gradually restructuring forests from the start of clear-cutting (Patterson *et al.*, 1995; Petty *et al.*, 1995a). Such a policy will produce more diverse and sustainable raptor (and wildlife) communities in forests of the future.

Restructuring forests

There are some habitat similarities between the establishment phase following both afforestation and restocking, although the latter areas are usually smaller and surrounded by forest. In northern England and Scotland, many restocked sites that are heavily grazed by deer develop grassy vegetation.

However, the composition of raptor communities that develop in second generation forests may be quite different to that following afforestation. Newly afforested areas are noted for their abundant short-eared owls, kestrels and occasionally hen harriers and merlins. Whereas restocked sites provide good hunting areas for forest-breeding species such as the tawny owl, buzzard, sparrowhawk and goshawk. In addition, kestrels will hunt over clear-fells and short-eared owls will nest on them when field voles are abundant (Shaw, 1995).

Restructuring aims to gradually create a mosaic of different-aged felling coupes of varying sizes, each coupe being much smaller in size than the original planting, and with the greatest amount of spatial and temporal separation from other coupes (Hibberd, 1985; Ratcliffe and Petty, 1986; Petty and Avery, 1990). This is achieved by both reducing and increasing rotation lengths around the optimum of 45–55 years for economic timber production. Habitat mosaics offer many advantages to raptors, mainly because few species can obtain all their requirements from just one growth stage (Table 2.2; Plate 3.17). Therefore it is important not to fell blocks in the same sequence in which they were planted to avoid re-creating extensive even-aged forests.

Reducing rotation lengths will lead to a greater proportion of the forest in the pre-thicket stage. Such areas provide important habitat for rodents, and are therefore particularly important for the eight raptors which are dependent on small mammals for food (Table 2.1). The older growth stages and forest edges provide higher densities of songbirds (Moss, 1979; Patterson *et al.*, 1995) and better access for raptors which feed on forest birds.

Size and distribution of felling coupes

The size of felling coupes will have an important influence on both the distribution of raptors and their prey. Fine-grained mosaics, created by small clear-cuts, will benefit raptors that depend on older trees for nesting but forage on clear-cuts or edges between clear-cuts and older trees; examples are buzzard, goshawk, sparrowhawk and tawny owl. Coarse-grained mosaics, created by larger clear-cuts, are likely to benefit raptors that are adapted for hunting over large-scale open habitats, such as short-eared owls and long-eared owls, and possibly merlin and hen harrier. There are few records at present of hen harrier nesting on restocked sites, but they regularly hunt over them outside the breeding season, particularly in good vole years.

Therefore, a strategy that combines the use of large and small clear-cuts is likely to benefit the greatest range of raptors. Hibberd (1985) gave an account of restructuring in Kielder Forest. Here the forest was grouped into three windthrow zones based on elevation: low, medium and high risk. The felling coupe size for the low risk zones was 5–25 ha, for the medium risk zones 25–50 ha, and for the high risk zones 50–100 ha.

Subsequent research on raptors is beginning to support this approach. In upland areas, the breeding distribution of tawny owls is along valley bottoms rather than at higher elevation (Petty, 1992). In Kielder Forest, the highest productivity of tawny owl was achieved when clear-cuts were around 8–9 ha, and the highest breeding density in areas with the greatest amount of forest edge created by clear-felling (Petty, 1989b). Thus, tawny owl requirements corresponded well with the 5–25 ha coupe size recommended for low elevation sites. It appears possible to manipulate tawny owl density by varying felling coupe size; fine-grained mosaics would result in high tawny owl densities whereas coarse-grained mosaics would give much lower densities.

In contrast, short-eared owls prefer to breed on larger clear-cuts. Shaw (1995) demonstrated in Galloway that no short-eared owls bred on clear-cuts under 50 ha, but they did breed on most clear-cuts in the range 64–174 ha. This again corresponded well with Hibberd's recommended coupe size at higher elevations, and these sites are the ones most likely to be colonised by short-eared owls.

Provision of perches on clear-cuts

Many raptors regularly hunt from exposed perches. But many clear-cuts although rich in foods such as rodents and songbirds, are often devoid of standing trees (Reinert, 1984). In Sweden, Widén (1994) tested whether the lack of perches on clear-cuts limited foraging by raptors. He selected 22 clear-cuts, and on half erected 6 m poles with crossbars at a density of 2 ha^{-1}. Foraging raptors used clear-cuts with perches significantly more than clear-cuts lacking perches, and raptor utilisation changed accordingly when the control and experimental areas were switched. This work indicated that a lack of perches on large clear-cuts can restrict the foraging activity of raptors.

Rather than using man-made perches, the retention of small patches of trees may be the best way of improving restocked sites for hunting raptors (Plate 3.18). Trees with good horizontal branches are particularly favoured. On exposed sites where the risk of windthrow is high, the retention of large dead trees may be more appropriate.

Clear-cuts away from forest edges and with dense ground vegetation may be productive habitats (source areas) for a range of prey species such as black grouse and field voles. The use of perches may well increase raptor use, but they could also turn them into sink areas for some species (Chapter 2). These observations suggest that some clear-cuts should be cleared of all standing trees. In this context it would be more valuable to target areas with, for instance, good black grouse numbers, and larger rather than smaller clear-cuts, as a greater proportion of the area is then away from older trees around the edge.

Artificial feeding

This is the supply of food directly to raptors. The most notable examples within Europe are the winter feeding stations established for white-tailed eagles in Sweden (Helander, 1978; Helander, 1985) and for vultures in the Pyrenees and Massif Central (Terrasse, 1985; Terrasse *et al.*, 1994).

A number of studies in the British uplands have shown the importance of carrion, particularly that of domestic sheep, for red kite (Davis and Davis, 1981) and buzzard (Newton *et al.*, 1982) in Wales, and for golden eagle (Plate 3.19) (Brown and Watson, 1964; Lockie, 1964; Marquiss *et al.*, 1985) and white-tailed eagle in Scotland (Love, 1983).

Surprisingly, there have been few attempts to measure the response of raptors to regular supplies of carrion in Britain. Petty (unpublished data) established feeding stations over two winters (1977/78 and 1978/79) in the Galloway uplands, primarily for ravens. They were little used by ravens or carrion-eating raptors. Crows and foxes were the main species attracted to these sites, the former wintering in the area from which they were normally absent. During one four-month period, when a time lapse camera took over 29 000 photographs at one feeding site, a golden eagle was recorded on 157 frames (0.53%) and raven on 274 (0.93%), compared to 5 488 (18.62%) for crows. However, the number of raptors that could potentially feed on carrion in this area was low, with only two pairs of golden eagles present during the winter.

It would be useful to undertake a similar trial in other areas holding a better population of carrion-feeding raptors, particularly where a major change in land-use is likely to affect the quantity of carrion available. At present it is a technique that cannot be recommended for general use, because it has to be sustained, and limited evidence indicates that it may lead to increases in foxes and crows instead of carrion-feeding raptors.

A number of raptors are attracted to artificially high food resources, such as ospreys

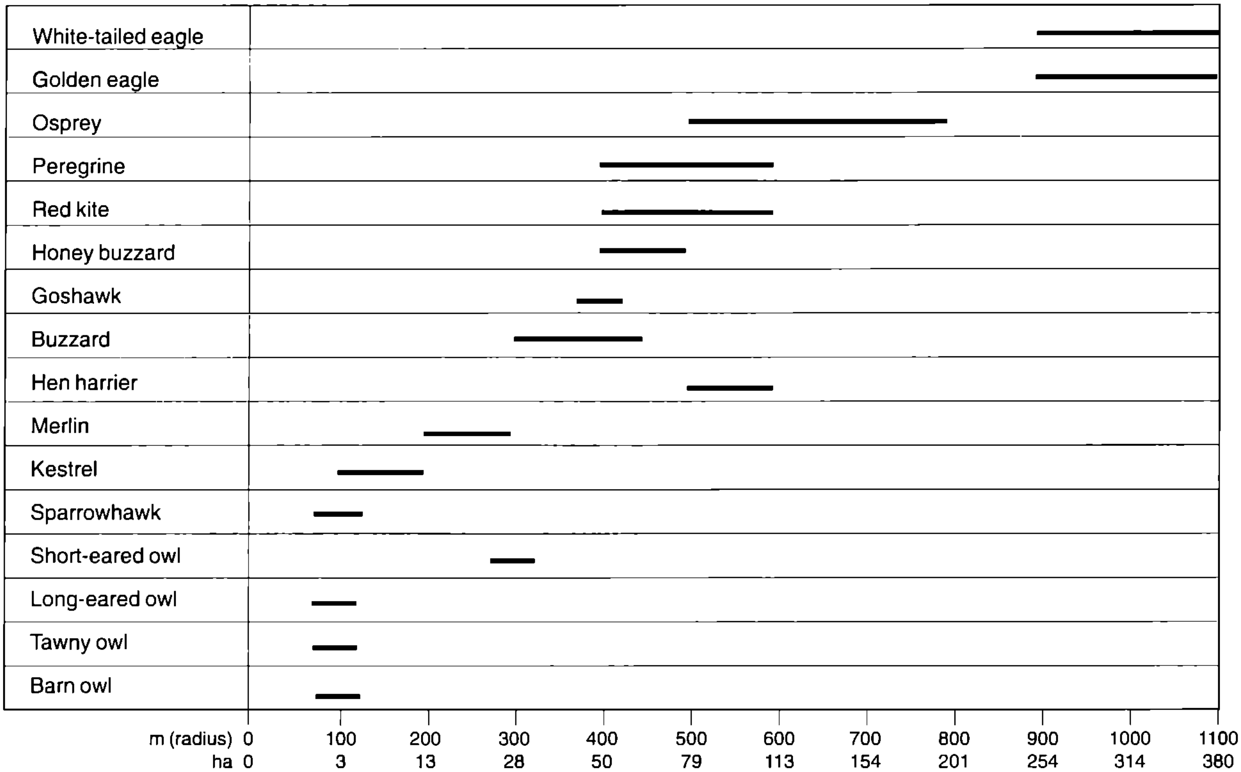

Figure 3.5 *Recommended disturbance-free zones around occupied raptor nests (March to July inclusive, but see Figure 2.3). The bars give the radius of zones for closed habitat (woodland) at the left end of the bar, and for open habitats (moorland and very open forest) at the right end of the bar. These distances are intended as a guide and will vary depending on topography and habitat, and stage of the breeding cycle. It is sometimes possible to decrease the radius of zones by 25%–50% once chicks are present (for example, see Petty (1996c) for goshawks), but this varies between species. If in doubt, use the distances in the above figure and seek advice.*

at fish farms and heavily stocked waters, and goshawks and other raptors to pheasant release pens. However, a considerable change of attitude from those involved in fish or gamebird management would be needed if these were to be considered of benefit to raptors; at present they often lead to greater persecution of raptors (Anon, no date).

What do our current forests lack?

It is worth considering how food-supplies and the provision of nest sites for raptors can be further improved. The present policy of restructuring at the end of the first rotation is certainly a major step forward. But inspection of Table 2.1 shows that some important prey groups are either largely inaccessible to raptors or scarce.

Carcasses of large mammals (mostly sheep and deer) are an important food for raptors in moorland habitats. In forests, deer are a potential source of carrion, but many that die often do so in dense tree cover where they are inaccessible to raptors. Medium-sized herbivores such as black grouse, capercaillie, rabbits and hares are scarce in many upland forests, although rabbits can be locally abundant in some forests in the eastern Highlands. The scarcity of these herbivores may in part be related to the impact of high deer densities, and the shading effect of dense tree cover on ground vegetation. Deer remove a substantial part of the vegetation that would otherwise be eaten by smaller herbivores.

Medium-sized herbivores and carrion might well be more abundant and available to raptors if much larger areas of old forest were present. Old forest in this context means crops of twice the normal rotation age, or older. Ground vegetation provides both food and shelter for woodland grouse and lagomorphs, and becomes well developed under older trees (Moss and Picozzi, 1994). Deer carrion may well be more visible to raptors in these open stands, and the openness would facilitate more effective deer control.

Most older forests provide ample nesting opportunities for raptors. However, there are two categories of nest sites which are scarce in our relatively young forests, and planning should aim to alleviate this in the future. These are: (a) large tree cavities which more readily form in broadleaves than in conifers, and (b) patches of old forest that, in the right topographical situation, would provide nesting opportunities for raptors, such as eagles, that build large nests (McGrady *et al.*, 1997). In this latter example, old conifers, in particular Scots pine, are better than broadleaves because they provide more protection to the nest from severe weather in early spring, a better branch structure to support a large nest, and more easily broken twigs and branches for nest building.

Controlling disturbance

Disturbance to raptors can be caused directly through forestry operations or recreational activities in the vicinity of nest sites. It can also be caused by carelessly advertising the presence of rare breeding species, which may then lead to disturbance from bird watchers or the theft of eggs and chicks by egg collectors and falconers.

Forestry operations

Most forestry operations, such as planting, harvesting, road building and maintenance, and recreational activities can lead to desertions if these are undertaken too close to occupied nests. It is illegal to cause intentional disturbance to Schedule 1 species, and undesirable to disturb other raptors. While most raptors will accept short, infrequent nest visits, few will accept more persistent disturbance. The worst type of disturbance is when a sudden change occurs in the nesting environment, such as the start of a harvesting operation. Raptors can sometimes become conditioned to more regular disturbance. Pairs will occasionally nest close to busy main roads or recreation areas, but in these cases disturbance was present from the start of nesting.

The levels of disturbance which are tolerated vary, and depend on a number of factors including species, food-supplies and stage of breeding. Golden eagle, buzzard and tawny owl are very sensitive to disturbance and some individuals will easily desert during incubation if flushed from the nest, sometimes after only one visit.

Within the same species, desertions are more frequent when food is scarce, either in poor food years or when parents are inexperienced. There is also a trend for desertion to be more frequent early in the breeding cycle, when birds are nest building or incubating, compared to later on when large chicks are in the nest (Newton, 1979; Petty, 1996c).

Disturbance may also cause other problems apart from desertions. If the adult is kept off the nest, eggs may become chilled which can lead to reduced hatching success due to embryonic deaths. Small chicks (which cannot regulate their own body temperature) may die as a result of either chilling or overheating (Fyffe and Olendorff, 1976; Giron Pendleton *et al.*, 1987), or the nest contents can be predated by crows.

To avoid these problems birds should not be flushed from occupied nests and disturbance-free zones around known nests should be observed for all potentially disturbing activities during the breeding season (Figure 3.5).

Harvesting operations occasionally result in the accidental felling of a raptor nest. If the nest contains eggs then little can be done. If the nest contains unharmed chicks then remedial action is often successful. This involves building an artificial nest in a nearby tree and placing the chicks in it. Providing all disturbance ceases immediately, there is a good chance that the parents will continue to care for the chicks.

These problems can be avoided if areas to be thinned or clear-felled during the breeding season (March–July inclusive) are searched for signs of active nests before operations commence.

Security of information

Forest managers need to know the nesting locations of at least the rarer raptors within their forests if these sites are to be effectively safeguarded. Therefore, it is helpful if those licensed to work on raptors, such as members of Raptor Study Groups, provide forest managers with nest locations. For this process to be successful, forest managers need to show that such information is treated confidentially and used in an effective way. Nest locations of Schedule 1 raptors should be the responsibility of one person within each forest who will ensure that other staff are informed only when necessary. They should not be included on design plans which are widely circulated, either within or outside the forest, but must be included in the design planning process.

Re-establishing populations

It is not the purpose of this Bulletin to encourage the translocation of raptors by foresters to re-establish populations that have become locally or nationally extinct. Nevertheless, such schemes do have an important place in raptor conservation, because they provide a relatively quick way of re-establishing extirpated populations (Temple, 1978; Newton, 1979; Cade *et al.*, 1988). However, they need to be led by the relevant conservation agency (Appendix 1).

Most species of raptors are slow colonists, because juveniles return to the vicinity where they were reared to establish a territory for themselves. The method used to overcome this strong site fidelity is to take chicks from nests, move them into aviaries or artificial nests in totally new areas, and then let them fledge naturally. During this process food is provided but human contact is minimised to prevent imprinting problems. The chicks then treat the release site as their natal area and eventually return there to breed.

Table 3.3 Criteria to evaluate re-establishment proposals (IUCN, 1987).

- There should be good historical evidence of former natural occurence.
- There should be clear understanding of why the species was lost to the area. In general, only those lost through human agency and unlikely to recolonise naturally should be regarded as suitable candidates.
- The factors causing extinction should have been rectified.
- There should be suitable habitats of sufficient exent to which the species can be re-established.
- The individuals taken for re-establishment should be from a population as close as possible to that of the native population.
- Their loss should not prejudice the survival of the population from which they were taken.

The current programme to re-establish red kites in England and Scotland has been highly successful (Evans *et al.*, 1994; McGrady *et al.*, 1994). While red kites might eventually have recolonised Scotland unaided, this was unlikely to have happened until well into the next century, and was by no means certain. Some success has been achieved with re-establishing white-tailed eagles. Although birds are now breeding in the wild, the population has been slow to increase (Love, 1983; Evans *et al.*, 1994; Green *et al.*, 1996). They need more time than red kites because of their low reproductive rates, and in the meantime the release of more birds from Norway has commenced.

The only other raptor to have been successfully re-established in Britain following extinction is the goshawk (Marquiss and Newton, 1981; Petty, 1996b). In contrast to the two previous examples, this was done by falconers in a relatively uncontrolled manner. But it did succeed, largely because releases (each of a few birds) occurred in many locations throughout Britain over about a 10-year period. Some populations quickly went extinct but many succeeded. By 1994 the population had grown to over 400 pairs. These are still increasing, and could eventually result in a national population numbering several thousand pairs (Petty, 1996b).

There is still scope for more re-establishment programmes with raptors in Britain. Work will

Table 3.4 Suggestions for improving the design of pheasant release pens to reduce avian predation (P. Kirk, pers. comm.).

- Avoid siting release pens in woods close to nesting raptors such as goshawk and buzzard.
- Makes pens large enough for the number of pheasants being confined (allow at last 1 m of perimeter fence per poult).
- Aim for pens to include a minimum of 20% shrub cover and 30-40% herb cover. Ensure sufficient light is available to establish understory/ground cover. Quick-growing plants such as willow can be used in suitable sites with annual coppicing to provide additional cover. In large pens with sufficient light it may be possible to establish cover crops such as kale.
- In pens with poor cover, acclimatise poults quickly and get them out of the pen as soon as possible.
- Release poults as early as possible in the year to try and avoid the main dispersal period of newly independent raptors (mid-August to mid-September).
- Use deterrents such as plastic sacks and glitter bags hung from trees on the perimeter and from thin horizontal wires strung across the pen. Tailors' dummies dressed to look like humans, flashing lights (more useful for tawny owls) and scare bangers may prove useful. Most predators become used to deterrents, so move them around and change the type used.

continue on red kites to establish more release sites in other areas (Wray, 1996). The establishment of osprey populations around lowland reservoirs has already started, with the translocation of nestlings from Scottish nests to Rutland Water in 1996. However, it is vital that such programmes are fully vetted by the relevant conservation bodies, including a period for consulting other organisations and land-owners who might be affected, and this is where forest managers can make a contribution. The IUCN guidelines should form the basis for any re-establishment project (Table 3.3).

Gamebird management

Pheasants

The rearing of pheasants in release pens provides a great attraction to certain raptors that can kill poults (Kenward, 1977; Kenward *et al.*, 1981). This can result in raptors being illegally killed in the hope that such losses will be reduced. Unfortunately, one raptor can be quickly replaced by another, so killing raptors at pens can lead to depletion of the raptor population over a much larger area. Evidence of illegal killing of raptors should be reported to the nearest police station or RSPB office.

If poult rearing is to be practised, then everything possible must be done to reduce predation by improving rearing techniques (Lloyd, 1976; Hill and Robertson, 1988) (Table 3.4). Ultimately some losses of young pheasants to raptors may have to be accepted. After all, some estimates put the pheasant as one of the commonest breeding birds in Britain.

Where pheasant shooting is practised then ideally woodland habitats should be improved for wild-bred pheasants (Robertson, 1992), which are far more challenging to shoot.

Grouse management

Woodland grouse (capercaillie and black grouse) populations are declining in Britain and throughout most of Europe. While some of the larger raptors do kill woodland grouse, there is no evidence to link their population decline in Britain to raptor predation (Cayford, 1993; Moss and Picozzi, 1994). Declining habitat quality, largely through overgrazing and overburning, appears to be one of the main factors involved. In particular, high deer densities overgraze dwarf scrubs that are such an important food for adult grouse (woodland grouse and red grouse), and a source of invertebrates for their chicks (Baines *et al.*, 1994; Baines, 1996).

Forests often contain large areas of ericaceous moorland with the capacity to hold substantial red grouse and black grouse populations. The normal practice of strip and patch burning to maximise grouse production on moorland may not be the best way of managing moors in close proximity to forests and potential grouse predators. Patch and strip burning was developed as a grouse management technique earlier this century (Watson and Miller, 1976; Hudson, 1986; Hudson, 1992), when intense keepering substantially reduced mammalian and avian predators. There are fewer keepers today, and more foxes and crows which can be legally killed (Tapper, 1992). Raptors have also increased, including those that kill grouse, such as golden eagle, hen harrier, peregrine, buzzard and goshawk, but these are legally protected.

Adopting a non-burning regime for heather moors close to forests reduces the risk of fires accidentally spreading into forests, and may provide a far better habitat for grouse, providing heather is not then overgrazed by deer or domestic stock (Baines *et al.*, 1994; Baines, 1996). Unburnt heather stands reach maturity when 20–40 years of age and then start to collapse. Regeneration occurs in these gaps, and through time tends to produce an uneven-aged mosaic. These mosaics often comprise other ericaceous species that are eradicated by burning. Blaeberry, which grows in the shade of tall heather, is an important food plant for adult grouse and provides a rich supply of insects for grouse chicks (Cayford, 1993; Baines *et al.*, 1994; Moss and Picozzi, 1994; Thompson *et al.*, 1995).

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Appendix 1

Useful addresses

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**English Nature (EN)*
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Hawk and Owl Trust, c/o Zoological Society
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Lothian and Borders Raptor Study Group
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North-east Scotland Raptor Study Group
(Chairman; Jon Hardey)
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(UK and England)
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Royal Society for the Protection of Birds (Scotland)
17 Regent Terrace, Edinburgh EH7 5BN

Royal Society for the Protection of Birds (Wales)
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Scottish Ornithologists' Club
21 Regent Terrace, Edinburgh EH7 5BT

Scottish Natural Heritage (SNH)
12 Hope Terrace, Edinburgh EH12 9AS

**Scottish Natural Heritage*
2 Anderson Place, Edinburgh EH6 5NP

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Principal's Office, Culzean Country Park, Maybole
Ayrshire KA19 8LE

Tayside Raptor Study Group
(Chairman; Keith Brockie)
Iolair, Dron Farm, by Invergowrie
Perthshire DD2 5LH

Uist Raptor Study Group
(Chairman; Bill Neill)
Rannachan, Askernish, South Uist HS8 5SY

* Apply to the Licensing Officer at these addresses for a licence to disturb Schedule 1 species.

Raptor Study Groups are being formed in England and Wales. A contact address for the group in your area can be obtained through your local EN, CCW or RSPB office.

Printed in the United Kingdom for The Stationery Office
J44741 C15 4/98

Bulletin 118 Ecology and Conservation of Raptors in Forests

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