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HOME RANGE AND HABITAT USE BY THE ENDANGERED GREY PARTRIDGE (*Perdix perdix*) IN THE IRISH MIDLANDS

Thesis submitted to the University of Dublin, Trinity College for the Degree of Doctor of Philosophy

By

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2001

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Dr. John Rochford, Department of Zoology, University of Dublin, Trinity College.
Declaration

This thesis has not been submitted as an exercise for a degree at any other University.

This thesis contains research based on my own work and the analysis of unpublished data from two previous Irish radio-tracking studies.

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SIGNED: E.C. O'Shea
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Most importantly, but for the encouragement, patience and support of my wife Klaudia and my family, I would not have completed this work.

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List of Abbreviations

General
BNM  Bord na Mona (Irish semi-state peat producing company)
BTO  British Trust for Ornithology
CAP  Common Agricultural Policy
NARGC National Association of Gun Clubs in Ireland

Data analysis
BTP  Biological Time Period
CL   Cluster Analysis
HM   Harmonic Mean Analysis
KL   Kernel Analysis
MCP  Multiple Convex Polygon

n    Sample size
sd   Standard deviation
se   Standard error

Pair identification
Pair 1 Male #2 and partner radio-tracked during the present Boora study
Pair 2 Male #6 and partner radio-tracked during the present Boora study
Pair A Birds #6&3 radio-tracked during the Lullymore study
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Page 1, top paragraph, bottom sentence
Add to the end of this sentence “but recent archaeological evidence (Tyrberg, 1998) indicates otherwise (see p.3)”.

Page 6, bottom paragraph and Appendix 1
Barley is *Hordeum*, not *Hordium*.

Page 21, third paragraph, second line
“Have” should be replaced by “has”.

Page 45, second paragraph and Chapter 8
“Pennychuik” should be “Pennycuick”.

Page 90, paragraph beginning Yarrell, six lines down
The incomplete sentence “In both Boora and” should be deleted.

Page 107, third paragraph, second line
Carroll’s work was in North Dakota, not New York.

Page 115, second sentence
The word “permanently” should be deleted.

Page 122, third paragraph down, fourth line
“Jenkin’s limitation” should be replaced by “Jenkin’s definition”.

Table 7.1 and 7.2
Table 7.1 is the estimated autumn population based on reported sightings of all birds, including single birds and pairs. Table 7.2 is an estimate of chick survival based on data from coveys containing 3 or more birds. The data in Table 7.1 indicates a large drop in population between autumn 1995 and autumn 1996. It is not clear whether this decline was a result of more reliable census estimates in 1996 and future years, (the conservation project began in May 1996, with full-time personnel on site), or low adult survival between years.

Page 130 bottom, page 131 top
The sentence “Only covey sizes of 3 or more birds were used to calculate the mean covey size” should be deleted.

Page 131, four lines up
The words “data that has not been recorded to date” should be replaced with “data that is presently unavailable”.

Page 163,
Reitz & Mayot, *in prep.* should be “IUBG” not “IUBG”.

CORRIGENDA
SUMMARY

In Ireland, an 86% decline in distribution was recorded for grey partridge (*Perdix perdix*) between 1968 and 1991 (Sharrock, 1976; Gibbons *et al*., 1993). By 1995, only two wild populations remained, in Boora, Co. Offaly and Lullymore, Co. Kildare (Kavanagh, 1992; 1998). Both areas contained a mosaic of cutaway bog and farmland, with evidence that pairs were breeding on cutaway bog (Kavanagh, 1992). Partridge traditionally breed on farmland (Potts, 1986; Birkan & Jacob, 1988) and similar declines in Britain and Europe have coincided with agricultural intensification (Potts, 1986; Tucker & Heath, 1994; Hagemeijer & Blair, 1997; Aebischer & Potts, 1998). Twenty three of the 27 other species of birds which live in grey partridge habitat in Ireland and Britain are declining (Gibbons *et al*., 1993) and hundreds of farmland plant and insect species have also declined (Firbank *et al*., 1991). Cutaway bog is an open, mostly barren habitat following industrial peat extraction. Recolonisation by a variety of plant communities occurs in subsequent years (Kavanagh, 1990; Egan, 1995). Cutaway bog has not been described in partridge studies outside Ireland.

In 1993, three partridge pairs were radio-tracked in Lullymore (J. Hearshaw, unpubl. data). Nesting sites were chosen in areas of recolonised cutaway bog, but in all cases the nest was predated. Since 1996, a combination of predation control and the provision of game crops has been the focus of conservation efforts in Boora, in an attempt to prevent further population declines (Kavanagh, 1998). Two pairs (one in 1997 and 1998) were radio-tracked in Boora during the conservation project. Both pairs bred successfully in an area of cutaway bog planted with game crops and young forestry.

Radio-tracking data collected in Lullymore and Boora were analysed. The data was separated into time periods based on individual changes in breeding biology (Church *et al*., 1980; Carroll *et al*., 1990), not on pre-determined calendar dates. Outside the breeding season, changes in movement pattern were used to separate data, rather than seasonal cues. A change in movement pattern was detected when a significant shift in home range had occurred, using Ranges V software (Kenward, 1996). Collectively, these time periods,
based on changes in breeding biology and movement patterns were defined as biological time periods (BTP). The partridge year was defined by the following BTPs: covey break-up, exploration, habituation, laying, incubation, brood rearing, primary and secondary covey movements. Home ranges were estimated using multiple convex polygons (MCP), harmonic mean, kernel and cluster analysis. Habitat preferences were calculated using compositional analysis.

Mean home ranges (MCP, +/- se) for each BTP were: covey break-up (234.8 ha, n=1), habituation (40.4 +/- 10.7 ha, n=5), laying (32.1 +/- 11.8 ha, n=5), incubation (11.4 +/- 7.3 ha, n=5), brood rearing (9.1 +/- 4 ha, n=2), primary covey movements (157.7 +/- 67.7 ha, n=4) and secondary covey movements (87.7 ha, n=1). Shifts in home range were less than 1 km during the breeding season, but varied from 0.2-6.1 km for other periods. Breeding attempts occurred within the cutaway bog area, but coveys moved to nearby private bog and cattle pastures between July and August. A second shift in home range between September and November was evident. In Boora, this shift was made to utilise winter stubbles on adjacent farmland. Birds returned to breeding sites within cutaway bogs the following spring. Movement patterns and habitat use were also described for 5 unpaired male partridge.

In Boora, the population continued to decline despite management. Traditional partridge breeding areas were lost when cutaway bog was reclaimed for other land uses, as part of the Lough Boora Parklands development. Analysis of autumn census data suggested that mean chick survival rates were unsustainable. Habitat improvements and future partridge research opportunities were outlined. The long-term future of grey partridge in Ireland rests with the commitment of the National Parks and Wildlife Service, Birdwatch Ireland and Bord na Mona.
Chapter 1

INTRODUCTION
1.1 The grey partridge

The grey partridge (*Perdix perdix*) is a member of the Order Galliformes, Family Phasianidae, Genus Perdix. It is currently found on farmland from west Russia across Europe south to Italy and Greece, north to lower regions of Scandinavia to the Atlantic seaboard in Ireland (Fig. 1.1). Over the last century the species has been introduced to North America where it has become established in many States (Cramp & Simmons, 1980). The biological features of the grey partridge clearly show it is a species strictly linked with open steppe type habitats. It is believed that the species was not, therefore, present in Western Europe before human cereals cultivation 5-8000 years ago (Hammer *et al.*, 1958; Matteucci, 1988).

The origin of this Gallinaceous bird is likely to be the Asiatic steppe (Hammer *et al.*, 1958) as indicated by the presence in the Eastern Palearctic region of the only other species of the *Perdix* genus. These are the similar but smaller, bearded or Daurian partridge (*Perdix daurica*) and the similar sized but differently coloured Tibetan or Ladakh partridge (*Perdix hodgsoniae*). This indicates an earlier speciation in that region which can be reasonably considered the spreading centre of the genus (Matteucci, 1988). Over thousands of years the clearance of woodland in Europe for agriculture, in particular grain production, would have created suitable new habitats. This would have lead to an increase in the geographical distribution of the grey partridge into Western Europe (Potts, 1986).

Partridge begin the winter in family parties called the covey. A typical covey consists of an adult male and female, their surviving young from the previous summer's breeding attempt and often one or more adults that failed to breed.
Figure 1.1 The European distribution of grey partridge as surveyed for the EBCC Atlas (Aebischer & Kavanagh, 1997)

- Qualitative data, possible breeding
- Qualitative data, confirmed and probable breeding
- Semi-quantitative data, possible breeding
- Semi-quantitative data, confirmed and probable breeding
In grey partridge there is usually a surplus of cocks amongst the adults in the covey because some hens are killed each year during incubation, typically by foxes (Potts, 1980). Pairing begins amongst old birds in the covey, with the young cocks leaving the covey to pair with non-siblings. Pairing and spring dispersal are usually completed by February/March (Cramp & Simmons, 1980).

The pair then selects a suitable nest site. Nesting material used depends on what is available nearby, but in most cases it is residual cover, typically the brown dead grass from the previous years growth. Female grey partridge use dead grass to cover their eggs during the laying period. An ideal nest location would be along the grassy bank of a well-managed hedgerow bordering a cereal field. The hen lays an average clutch size of 15 eggs over 21 days with incubation taking an average of 25 days in Britain (Potts, 1980; 1986). The chicks are precocial and nidifugous. They can walk and feed for themselves but cannot control their body temperature for the first 2 weeks after hatching (Offerdahl, 1985). The parents lead the chicks to areas of high insect density to feed. The chicks are brooded by both parents at intervals during the day and night. This 2 week period is a critical time for partridge breeding success as a combination of cold, wet weather and low insect density can lead to high chick mortality (Green, 1984; Rands, 1985; Enck, 1987; Dahlgren, 1987; 1990). Once the chicks develop thermo-regulation and flight the mobility of the covey increases. The proportion of insects in the chick diet decreases as plant matter increases. The covey stays intact until the following spring when dispersal and pair formation occurs.
1.2 History of the Grey Partridge in Ireland

*Perdix* fossils have been recorded at many cave deposit sites across the Palearctic region dating from the early to late Pleistocene. The Pleistocene began between 1.64 and 2.3 million years ago. *Perdix* fossils dating from the early Pleistocene were found at sites in Romania, Spain, and Ukraine. Those dating from the middle Pleistocene were found at sites in Austria, Azerbaijan, Czech Republic, France, Georgia, Germany, Hungary and Italy. These fossils may be of *Perdix paleoperdix*, believed to be a direct ancestor of *Perdix perdix* (Tyrberg, 1998). Late Pleistocene cave deposits contain *Perdix perdix* at 17 sites in Britain, dating from 42,200-9,300 years before present. In Ireland, *Perdix perdix* was recorded at 3 cave deposit sites, the Catacomb and Newhall caves in Co. Clare and Plunkett cave (also referred to as Keishcorran P cave) in Co. Sligo. These sites date from the Holocene (within the last 10,000 years), but the presence of common turkey (*Meleagris gallopavo*) bones at all 3 sites indicates a post 1492 AD date for some of the remains (Tyrberg, 1998).

Therefore, it is not known if the partridge remained in Ireland during the last ice age. If the species returned following the ice age, this would need to have occurred before the land bridge with Britain disappeared between 13,000-10,000 years before present (Mitchell & Ryan, 1997). There is a race of grey partridge (*Perdix perdix lucida*) in Eastern Europe, which migrates over hundreds of kilometres in response to severe winter weather (Cramp & Simmons, 1980). However, this is not the same as continuous flight over water. There are cases of partridge flying out over sea or estuaries when frightened and landing exhausted on water, apparently incapable of sustained flight greater than 0.5-2 km. (Paludan, 1963; Cramp & Simmons, 1980). It is
unlikely that the partridge could have reached Ireland naturally after the land bridge disappeared with Britain. Ireland was almost completely afforested before the arrival of man (Mitchell & Ryan, 1997). A species adapted to a steppe cereal ecosystem (Potts & Vickerman, 1974; Potts, 1991; 1997), would have difficulty surviving in such a landscape.

The first farmers crossed the sea from Britain to clear the totally afforested landscape for agriculture. This Neolithic culture was established in Ireland by 4000-3800 BC, managing arable as well as extensive pastureland, in organised fenced fields (Mitchell & Ryan, 1997). Archaeological excavations of human food remains at Irish sites have yielded valuable information of a selection of birds present in pre-history Ireland (Cabot, 1999). A *Perdix* coracoid bone was found in excavations at Newgrange (2500 BC). However, the smooth appearance of the bone indicated that it might be of more recent origin (Van Wijngaarden-Barkker, 1974). If the partridge was present in Ireland at the time of the building of Newgrange, it may have been local in distribution, given its absence in the early literature. The most suitable habitat would have been the grassland of the eskers and moraines of the midlands. If these populations existed, they would have gradually spread into the surrounding landscape, as tillage became widespread.

The first written record of Irish fauna is in the nature poetry and other literature of the early Christian monks from AD 600-800. Game birds mentioned were woodcock (*Scolopax rusticola*), snipe (*Gallinago gallinago*), red grouse (*Lagopus lagopus*) and duck (*Anas* sp.), (Cabot, 1999). The grandson of Henry I, Giraldus Cambrensis published Topographia Hiberniae in 1185 AD providing an account of twelfth century Ireland. This is the next record of Irish game birds with quail (*Coturnix coturnix*), capercaille (*Tetrao urogallus*) and
red grouse. Cambrensis commented on the absence of partridge (*Perdix & Alectoris* sp.) and pheasants (*Phasianus* sp.) at that time (O’Meara, 1951). The pheasant was not introduced to England until 1299 (Watters, 1853) and Ireland until at least the 1500’s (Kennedy *et al.*, 1954; Viney, 1997). Cambrensis’s conclusion about partridge indicates that the grey partridge may have also been introduced to Ireland. However he also wrote that the common frog (*Rana temporaria*) was absent; a view later contradicted with the finding of frog bones in 1901 at the Keishcorran caves, Co. Sligo, estimated to be 10,000 years old (Cabot, 1999).

The present partridge population in Ireland is most likely that established through translocated birds, provided as sport for the English estates in Ireland. One of the first written records of grey partridge in Ireland is in the 17th century when they were described as ‘plentiful’ by the Duke of Ormond (Whilde, 1993). The demesnes have been a dominant feature of the Irish landscape since medieval times and once occupied over 5% of the country. They have had a central role in the development of Irish agriculture, horticulture, sylviculture and field sport (Reeves-Smyth, 1997). While the grey partridge may have been plentiful in the midlands the same was not true everywhere. For instance the manager of the new Phoenix Park complained that “there’s scarcely a partridge left in these parts” owing to excessive poaching by the soldiers of Charles II’s army in the late 1600’s (MacLysaght, 1979).

In "*Ireland’s Naturall History*" (Boate, 1652) it was noted that “in Co. Meath and further northward on the top of the great hills and mountains, not only at the side and front of them, to this day the ground is uneven as if it had been ploughed in former times; the inhabitants affirm that their fore-fathers were
much given to tillage contrary to what they are now”. It is likely that partridge populations would have fluctuated in proportion to the changing acreage of tillage through the centuries in Ireland.

In Browne’s “A Catalogue of the Birds of Ireland” (1774) the partridge is included in the list. No indication is given of status. In the early 1800’s the extensive farming of wheat (*Triticum aestivum*) and potato (*Solanum tuberosum*) crops benefited the partridge. However, there was a noted decline in the species following the Great Famine and the widespread switch from tillage to pasture (Ussher & Warren, 1900). In “The Natural History of Birds of Ireland” (Watters, 1853) the partridge is described as occurring in smaller numbers than any of the other game birds and rarely seen in some localities where it was once abundant. The decline was most evident in Co. Meath where the partridge had become rare having been abundant 30 years previously. The partridge is described as ‘indigenous’ with other examples in this category being red grouse, quail, corncrake (*Crex crex*), song thrush (*Turdus philomelos*) and blackbird (*Turdus merula*). The Irish game laws of 1860 stated that no one earning less than £40 a year could shoot hares, grey partridge, pheasant, grouse or quail (Levinge, 1860).

From 1855 to 1901 cereal production showed a significant decrease; oats (*Avena sativa*) by 48.1 %, barley (*Hordeum vulgare*) by 90.4% and wheat by 28.7% (Bell & Watson, 1986). In 1900 the grey partridge is described as having an extensive range though unevenly distributed, being plentiful in Co. Tipperary, King’s County (Co. Offaly), Queen’s County (Laois), Co. Kildare and Co. Meath, but scarce in the west of Connaught and Donegal where moors and mountains prevailed (Ussher & Warren, 1900). On a 162 ha farm in Kilkenny, Seigne (1930) reported that the density of partridge had
decreased from 4-5 coveys to 1-2 coveys. This was attributed locally to a high level of poaching (Seigne, 1930). Nationally, the decline was so serious that by the early 1930’s numbers that new stocks were released and legislation prohibiting the shooting of grey partridge was introduced (Humphreys, 1937).

Following these measures an increase was noted from 1933 onwards and grey partridge had colonised areas in the west of Ireland where 20 years before they were unknown. However, in most counties the bird was still sparsely distributed with the birds more plentiful in Co. Carlow than any other county (Kennedy et al. 1954). Status in the 1960’s was similar to that given previously with no indication given as to the actual size of the population. Ruttledge (1966) noted that grey partridge were sparsely distributed and sometimes found in small-cultivated fields of desolate areas.

More recent survey work conducted by the British Trust for Ornithology and the Irish Wildbird Conservancy (now Birdwatch Ireland), has shown a drastic decrease in distribution since the late 1960’s (Fig. 1.2). The first survey collected data between 1968-1972. Of the 1,010 10km squares surveyed nation-wide, partridge were recorded breeding in 255 (25.2%) of these (Sharrock, 1976). In the second breeding survey (1988-1991) partridge occurred in only 35 (3.5%) squares (Gibbons et al. 1993). A winter survey (1981-84) showed partridge in 28 (2.8%) squares (Lack, 1986).

A national survey of partridge was conducted in 1991 when a questionnaire was distributed to gun clubs by the National Association of Regional Game Councils (NARGC). Any information relating to sightings of grey partridges in their localities was sought. Of 26 counties surveyed, 7 counties were identified where wild birds definitely still existed. In Galway farming was grassland
Figure 1.2 Change in the recorded distribution of the grey partridge in Ireland, illustrating contraction of range to the midlands.

Breeding Bird Atlas
Sharrock, 1976

Breeding Bird Atlas
Gibbons et al., 1993

Two remaining wild populations
Kavanagh, 1992
dominant, while tillage was important in Tipperary, Wicklow and Wexford. In Kildare, Offaly and Louth farming was mixed in a landscape containing large areas of cutaway and intact bogland. Seven other counties had release programmes with hand-reared stock. Three main populations were identified. One population in Co. Wexford was composed of mixed stocks of wild and released birds, while two populations in the Irish midlands were deemed to have completely wild stocks. These latter birds were found in areas containing cutaway bogland at Boora, Co. Offaly and Lullymore, Co. Kildare (Kavanagh, 1992).

1.3 Irish Grey Partridge Conservation Project

In the “Irish Red Data Book 2” (Whilde, 1993) the native grey partridge was described as “endangered” with less than 200 breeding pairs in Ireland. A number of release programmes were initiated on farmland in Kildare (1993) and Wexford (1994) but did not result in a successful wild breeding population (Kavanagh, 1998). Annual autumn surveys of the two remaining wild populations at Boora and Lullymore cutaway bogs have been conducted since 1991. In spring 1994 only 3-4 pairs of wild grey partridge remained in the population at Lullymore. In the absence of intervention, extinction of this population seemed imminent. In August 1994 & 1995 a release of reared partridge was conducted at Lullymore. Limited fox (Vulpes vulpes) and corvid control was also carried out at both the Boora and Lullymore sites. By 1995, surveys had indicated a total loss of 43.5% of known locations since 1991 (Kavanagh, 1998).

In 1995 wild grey partridge were removed as quarry from the list of Irish game species. There had previously been a voluntary moratorium in place but owing
to continued shooting, particularly in Lullymore, total protection was needed. Subsequently, the NARGC indicated that gun clubs that formerly released partridge would find it difficult to justify expenditure on a species now removed from the quarry list. The partridge release programme in Wexford was stopped in 1995.

The conservation project was focused on the Boora population in 1996 with European funding for 3 years. The aim of the project was to increase the partridge population by traditional methods. A gamekeeper was employed in May 1996 to control predator numbers. Nesting and brood-rearing habitat was provided in strips on cutaway bog areas known to contain partridge. In 1999 further funding was provided by the National Parks and Wildlife Service (NPWS) to continue the project, as numbers had still not increased.

1.4 Previous Grey Partridge Research

The world population of the Grey partridge has decreased dramatically over the past 40 years. By the mid-1980’s it was estimated that the world population had declined to 20% of its pre-1950s level (Potts, 1986). The stock of grey partridge in Europe is currently estimated at 3.5 million pairs. In the 1930s there were 20 million pairs. This represents a decline in breeding pairs of at least 83% (Tucker & Heath, 1994; Potts, 1997). Reports have been published in recent years on grey partridge population decline in various parts of the world, including Austria (Gossow et al., 1992), Denmark (Fog, 1988), France (Reitz, 1999), Finland (Pulliainen, 1984), Germany (Nosel, 1992), Greece (Thomaides & Papageorgiou, 1992) Italy (Matteucci, 1988), Poland (Pielowski, 1988) Britain (Aebischer & Kavanagh, 1997) and North America (Nelson, 1987). These rely on relative changes in game census and annual bag
records on partridge shoots from year to year (Tapper, 1992). The species is on the verge of extinction in Norway and Switzerland (Hagemeijer & Blair, 1997).

Several reasons are suggested as contributory factors for these declines. The increase in predators (Newton, 1993) and its impact on partridge numbers is documented (Reynolds & Tapper, 1996), as is the loss of nesting habitats such as hedgerows (Potts, 1980; Rands, 1986b) and the decline of mixed farming practices (Potts, 1970).

However the main reason for the decline in partridge numbers was owing to changes in the cereal ecosystem, through intensification. A combination of the increased use of insecticides, herbicides and the decline of undersowing cereals with grass have reduced the availability of five groups of insect food preferred by partridge chicks (Potts & Aebischer, 1991).

These are in order of preference:
1. small diurnal ground beetles (Carabidae)
2. sawfly and other caterpillars (Symphyta and Lepidoptera)
3. leaf beetles (Chrysomelidae) and weevils (Curculionidae)
4. plant bugs (Heteroptera) and leaf hoppers (Cicadellidae)
5. aphids (Aphidiae)

This has caused a decline in partridge populations through increased chick mortality. The combined use of herbicides and insecticides reduces insect densities in the cereal crop (Potts, 1997). Chicks use the cereal edge to feed and if the density of preferred insects is reduced, chick mortality increases (McCrow, 1980; Green, 1984; Rands, 1985; 1986a). Simulation modelling
shows that chick mortality rates greater than 80% would inevitably lead to the extinction of a partridge population (Potts, 1986).

In Ireland, local extinctions of partridge have occurred in all regions except those within cutaway bogs. This suggests that the modern agricultural landscape does not support stable partridge populations in Ireland. Cutaway bog is an open, mostly barren habitat following industrial peat extraction. Recolonisation by a variety of plant communities occurs in subsequent years (Kavanagh, 1990; Egan, 1995). The recolonised areas within cutaway bogs contain residual cover and rich herbaceous cover previously found in traditionally farmed tillage areas. Partridge breeding on cutaway bogs may have had higher chick survival than that possible on farmland, with the result that presently, populations are limited to these areas.

The grey partridge is one of the most widely studied species of Galliformes because of its economic importance as a game bird, especially in parts of Europe. There has been much research in Britain into the causes of the population decline at The Game Conservancy Trust at Fordingbridge in England. Of particular note is the long-term study of the partridge population in Sussex (Aebischer & Potts, 1998) and analysis of grey partridge bag records in Great Britain from 1793-1993 (Potts & Aebischer, 1995). One of the Game Conservancy’s roles is to use research to find ways of making the modern arable farming system compatible with grey partridge management.

A 333 ha arable grassland estate at Loddington in the English midlands is being managed in a partnership between the Allerton Research and Educational Trust and the Game Conservancy since 1993. This farm has demonstrated that profitable modern farming can include healthy wild game populations
Measures include predation control (Tapper et al., 1996), the provision of good nesting cover along hedgerows (Potts, 1986) and spraying of crop edges with selected herbicides and insecticides, termed "Conservation Headlands". Conservation Headlands minimise the impact of sprays on insect abundance and promote higher chick survival for pheasants and partridge whose broods feed along the crop edge (Sotherton, 1991). Other developments include "Wild Bird Cover" (additional brood rearing cover), "Beetle banks", (raised banks 2m wide and 0.5m high created across the centre of large fields as additional nesting cover) and winter cover based on kale (Brassica oleracea) or other Brassica species (Sotherton et al., 1994, cited in Boatman & Brockless, 1998). The breeding performance of grey partridge, red-legged partridge, pheasant and brown hares have improved since active management at Loddington began (Boatman & Brockless, 1998).

Generally partridge research has tended to focus on subjects relevant to management, for example the survival of game-farm releases (Paludan, 1963; Panek, 1988; Dowell, 1990; Putaala et al., 1997a; Kavanagh, 1998;), translocated wild birds (Church, 1993), and wild birds (Chlewski & Panek, 1988; Carroll, 1990; Panek, 1990; Birkan et al. 1992; Kobriger & Schulz, 1992; Reitz, 1992). Home range and habitat use by wild partridge has been less widely studied. Some studies used indirect research methods such as marked birds (Blank & Ash, 1956; Jenkins, 1961a;b) or transect counts (Dudzinski, 1988a,b; Nikiforov, 1992; Farago, 1998; Ruiz & Kilchenmann, 1998).

Radio-tracking is used frequently to provide accurate data on location, movement and behaviour of species, from which home range size and patterns of utilisation can be determined (Harris et al., 1990). Several grey partridge
studies have used this technique to investigate home range and habitat use
(McCrow, 1977; Church et al., 1980; Smith et al., 1982; Rands, 1986a;
Church & Porter, 1990; Birkan et al., 1992; Church, 1994; Goatee, 1998;
Kaiser, 1998; Thomaides, 1998; Reitz & Mayot, 1999). There has been little
research on partridge behaviour in the wild. Most of our knowledge stems
from field studies by McCabe & Hawkins (1946) in Wisconsin, and two
English studies (Blank & Ash, 1956; Jenkins, 1961a). This, and additional
data is summarised in Cramp & Simmons (1980), Potts (1986), Birkan &

1.5 Previous Irish research

Lullymore study
A radio-tracking study was carried out in Lullymore, Co. Kildare from 1992-94
(J. Hearshaw, unpubl. data). The aim of the study was to gain baseline
information on the ecology of the bird in Ireland. Of particular interest was an
investigation into:

a) the use of the cutaway bog, a novel habitat for breeding partridge,
b) the movement patterns and habitat use of birds

This was the first radio-tracking study of wild partridge in Ireland. Three wild
breeding pairs and one farm reared male/wild female pair were radio-tracked.
However, all four pairs suffered nest predation and no chicks were produced.

Previous Boora study
In 1995 a research assistant was employed for a period of one year to radio-
track partridge in Boora, Co. Offaly. Owing to predation and difficulties in
catching wild partridge a number of reared birds were released to pair with
wild birds. This had a second role as an experimental trial to see if wild and farm-reared pairings would breed successfully. The breeding attempts of two radio-tracked pairs (wild male/farm reared female and farm reared pair) were recorded. A wild unpaired male was also radio-tracked (F. Lester, unpubl. data) However neither pair reared chicks owing to nest abandonment and predation.

1.6 Aims of this thesis

During the latter half of the 20th century farmland birds declined in range across western Europe (Tucker & Heath, 1994). The Common Agricultural Policy (CAP) reforms of the 1990s were considered inadequate to address the ultimate causes of farmland bird declines in Britain (Potts, 1997). In Ireland, the grey partridge population had contracted in range to two populations by 1995 (Kavanagh, 1998), and a species specific management plan was implemented to prevent extinction of the Boora population in 1996. The ecology of the partridge is well defined within the cereal ecosystem in Britain (Potts, 1986, 1997). Twenty three of the 27 other species of birds which live in grey partridge habitat in Ireland and Britain are declining (Gibbons et al., 1993) and hundreds of farmland plant and insect species have also declined (Firbank et al., 1991).

Surveys in Lullymore and Boora suggested that partridge were breeding on cutaway bogs (Kavanagh, 1992; 1998; 2001). Cutaway bog has not been described in partridge studies outside Ireland. The Lullymore data gave evidence that railway lines were an important resource within the cutaway bog prior to nesting and that pairs moved several kilometres outside the breeding season (J. Hearshaw, unpubl. data). However, this data was based on
unsuccessful breeding pairs and may not have been typical. Further partridge research was needed, to gain an understanding of the relative importance of cutaway bog compared to other habitats.

Recovery programs for endangered species require concurrent research input (Cade & Temple, 1995). In 1996 conservation efforts were focused in Boora and a decision was made to radio-track wild partridge at this site. The hypothesis was that the population would benefit from the provision of game crops and predator control, as in Britain (Potts, 1986; Anon, 1992; Tapper et al., 1996; Aebischer, 1997; Boatman & Brockless, 1998). By monitoring the movements of birds in Boora, we would be able to identify key sites within the study area. The main aims of the thesis were as follows:

1. To test the hypothesis that partridge breed on cutaway bog and move to other areas outside the breeding season
2. To provide an explanation for these movements.
3. To provide management proposals based on this information

Note: References in the text to the three Irish radio-tracking studies follow the following format.

Previous Boora study: in reference to the previous study in Boora in 1995  
Lullymore study: in reference to the study in Lullymore from 1992-1994

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Chapter 2

STUDY AREA
2.1 Introduction

The Boora bogs

The present Boora study was focused in the Irish midlands where areas of raised bog were interspersed with ‘islands’ of mixed farmland, known to contain wild breeding grey partridge. It was situated in West County Offaly which is commonly referred to as the Boora ‘group of bogs’ (Fig. 2.1). This area can be found on the 1:50,000 Discovery series maps (maps 48 and 54), with a national grid reference N 180 197 for the Bord na Mona workshops. There is no townland of Boora but the area gets its name from an ancient lake (now drained) “Lough Boora” in the locality and the fact that Bord na Mona called its peat operation in the area “Boora Works” (Ganly, 1998). Tullamore is 15 km to the north-east and Birr 19 km to the south-west. The village of Kilcommac is 5 km south.

Mean annual rainfall (+/- se) recorded between 1951 and 2000 at the weather station in Boora Works was 849.0 +/- 14.1 mm (S. Ganly, unpubl. data). The mean monthly temperature for June, July and August from 1872-1998 at Birr weather station was 13.6, 15.1 and 14.8 °C, respectively. Winters are mild with a mean January temperature of 5.5 °C and an average of 10 days per year with air temperature below 0 °C. Weather details were provided by the Meteorological service. Given the importance of bog in the study area a brief description and history of the exploitation of this unique habitat is given below.
Figure 2.1 Boora Group of bogs (brown outlines) in West Offaly and location of the present Boora study area (green outline)
Brief introduction to bogs

It is estimated that 16.2% of the land surface of the island of Ireland is covered in peatlands. World-wide only Canada and Finland with 18.4% and 33.5% respectively, contain a higher proportion of peatland (Taylor, 1983). Peat is formed under waterlogged conditions when organic matter is produced by plants and deposited at a faster rate than it is decomposed. In Ireland the word bog (*bogagh* is soft ground in Gaelic) is used to describe a peatland area. The terms moor, mire or heath are used in England depending on the context (Feehan & O’Donovan, 1996). There are three major peatland types in Ireland, blanket bogs, fens and raised bogs.

Blanket bog covers many of the mountainous regions in Ireland and also some of the lowland areas of the wetter western seaboard. The wet climate of these areas combined with geological features and human interference has contributed to the growth of blanket bogs in Ireland. Clearance of woodlands by farmers thousands of years ago and the continued prevention of regeneration, allowed soil deterioration to set in. Water-logging and leaching, thus preparing the ground for the transition to bog as the climate changed (Feehan & O’Donovan, 1996).

Fens are shallow water-bodies found mostly in the low-lying midlands. These are supplied with an alkaline and mineral rich water source. The bottom of the fen contains a thin layer of peat with extensive reed and sedge beds around the edges. An example is Pollardstown Fen in Co. Kildare. Over thousands of years a fen can become enclosed and a raised bog may form (Bellamy, 1986).

Raised bog develops when the water source of a fen is cut off by the sealing layers of peat that build up over time. Gradual colonisation by *Sphagnum*
mosses occurs; these derive their inorganic nutrients and water supply entirely from rain. The metabolism of these mosses create acidic conditions. Peat layers build up from the partially decomposed remains of mosses and heather to create a domed profile raised 5-8 m above the surrounding countryside. The surface of the bog becomes a mosaic of pools and hummocks with large areas dominated by heather vegetation (Cabot, 1999). The Boora area was covered in a large lake, Lough Boora, in early post-glacial Ireland 10,000 years ago. This lake shrank in area as continual bog growth constricted it. Over thousands of years the lake developed into a fen and then raised bog, and as part of the Bog of Allen, dominated the landscape of the midlands (Mitchell & Ryan, 1997). Boora bog was one of the first raised bogs to be developed for peat extraction by Bord na Mona, and is now almost cut away (Feehan & O’Donovan 1996).

**Cutaway bog**

The edges of many raised bogs were cut by hand over the centuries to burn the peat (termed ‘turf’ in Ireland) as fuel. By the mid-twentieth century half the total area of the large midland bogs was cut by hand. A Turf Development Board was founded by the government to expand sod peat production in the 1930s. Bord na Mona (BNM) was set up as a semi-state body in 1946 and took over the responsibilities of peat production nationally. Milled peat production was developed in the 1950s. Boora bog, which had been prepared and drained to supply sod peat, was converted to milled peat production for Ferbane power station. It was drained by gravity with major excavations around and through the bog leading to the nearby river Brosna (Egan, 1999).

Once the surface vegetation was removed, the exposed peat layer was milled to a crumb structure using large purpose built machinery. The bog was
organised in sets of bays (11 per set) 15 meters wide, with one bay, usually the middle one, used for stacking the milled peat. Layers of peat were harvested each year (5-7 cm) over a large area (Plate 2.1). Temporary small-gauge railway lines were laid down along the stockpiles of peat. The dried peat could then be processed. Temporary lines were connected to permanent railway lines on a raised bank of marl and stone ballast leading to a nearby processing plant. The process continues in other raised bogs today but many of the bogs in the Boora group have been exhausted of extractable peat (Egan, 1999).

Once peat production ceases the resulting area is termed ‘cutaway’ bog. The residue remaining consists of a varying depth of basal fen peat overlying an undulating sub-peat mineral soil. The peat store is exhausted after 30-50 years depending on the peat depth. In parts of Boora, the peat removal process has exposed the bare surface as it was in post-glacial Ireland 10,000 years ago. In other parts a layer of peat of varying depth may be left behind. The cutaway bogs in the study area have been left idle for up to 20 years depending on when the extractable peat was exhausted (Egan, 1999).

**Recolonisation on the cutaway bog**

Re-colonisation by plant pioneer species occurs on the cutaway bog once it is left idle (Plate 2.2). A baseline ecological survey of cutaway bog was carried out at Turraun bog (Kavanagh, 1990). This is 2 km north of the study area (Fig 2.1). The vegetation covering the site was influenced by a number of factors such as the time since peat extraction ceased, the underlying substrate characteristics, the remaining peat depth (0.0-1.2m), water availability and characteristics of the seed bank present in the surrounding lands. This resulted in a mosaic of plant communities and animal species throughout the site.
The main conclusions determined from this survey were:

1. The deeper the remaining peat the lower the pH.
2. The pH level had a major role in determining the distribution of plant communities on the site.
3. The depth of peat influenced the moisture content of the soil.
4. Drier areas tended to support grassland vegetation.

During the survey, 157 plant species were recorded. A subsequent survey in the Turraun area in 1994 (Egan, 1995) recorded a further 48 plant species not found in the previous study. The cutaway bogs within the present Boora study area (Fig. 2.1) show many of the characteristics of re-colonisation described in these two surveys. This varied from uncolonised bare peat that was recently abandoned, through various colonising plant communities to 25 year old birch (*Betula* sp.) and willow (*Salix* sp.) woodland.

**Reclamation of the cutaway bogs**

In the 1970s the first attempt at reclamation on a cutaway within the study area was made adjacent to Spain’s Island (Fig. 2.1). The area was deep ploughed, mixing the underlying subsoil with the remaining peat. After several years approximately 40 hectares of cereals (spring wheat and barley) was sown annually. Another area at Turraun was also reclaimed for arable land. However the crop yields were unsatisfactory owing to small grain size. The crop was difficult to harvest in wet autumns. The crop range was then extended with winter wheat and barley, oilseed rape (*Brassica napus*) and sugar beet (*Beta vulgaris*). In the early 1980s a decision was made to convert all areas to grassland and experimentation with stocking densities were conducted. The land was subsequently sold as grassland to local farmers (Egan, 1997). By 1997, approximately 350 hectares were developed as
grassland and sold privately to 23 local farmers in varying lot sizes. A further 80 hectares are currently under development for grassland (Egan, 1998).

Not all of the cutaway area is suitable for grassland. Blocks of land ranging from several to hundreds of hectares have been planted with conifer woodland. Research has shown that some of the plantations have failed or were seriously understocked. The main causes of failure and poor growth rates were frost, competition from weed vegetation and nutrient deficiencies (Jones et al., 1998).

There are a number of experimental trial areas within the study area where a mixture of conifers and broad-leaved trees have been planted. In other places the residual peat/subsoil combination or hydrological condition is unsuitable for either grassland or forestry. Within the Boora bogs, a number of wetland sites have been created. These have a number of recreational uses including angling, bird-watching and walks. To date a total of 2225 hectares of cutaway bogs has been designated 'Lough Boora Parklands' with its mosaic of grassland, forestry and amenities. The Lough Boora Parklands project won the 1995-96 Ford Irish Conservation Award. Turraun, East Boora, Spain’s Island and Tumduff are the main areas incorporated within the parkland project. The study area for this project consists of the eastern part of the Lough Boora Parkland (Tumduff and Spain’s Island) and areas of farmland further east outside this zone.

**Farmland**

Farmland is found on "mineral islands"; areas of calcium rich moraine deposits, such as eskers, at an elevation slightly above that of the surrounding bog. Most of the townlands are between 50-60 m above sea-level. The townlands
consist of low-lying flat or undulating plain composed mostly of carboniferous limestone. Sir Charles Coote studied agriculture in the region in 1801, which was within the barony of Garrycastle. He described the area as “barren rock with scarcely a stratum of soil”. In his view Garrycastle was the least fertile of all the King’s County (Offaly) baronies. Crops grown at this time were wheat, potatoes, oats and flax (*Linum usitatissimum*). Peat was mixed with the soil and used as a nutrient in crop production. The heavy land near the bogs, with good soil depths and the damp climate were ideal for growing flax which was used in the linen industry. The lack of shelter made it inappropriate for the keeping of cattle (*Bos taurus*). Clover (*Trifolium* sp.) was abundant and native to the soil. Meadows were light and easily harvested with no lush growth. Two of the townlands in the area, Leabeg and Leamore get their name from the word ‘lea’ meaning small (beg) and big (Mor) grey meadows (Ganly, 1998).

The mineral soils in the region provide mainly for grassland usage because of impeded drainage. Tillage is not a common farming practice in the area. Grassland is grazed by sheep (*Ovis aries*), cattle or horses (*Equus* sp.) all year round, while some fields produce cuts of silage or hay during the summer months. Cereals grown are mostly winter wheat and spring oats and barley. Root crops are a mix of sugar beet, turnips (*Brassica rapa*), rape and potatoes.
2.2 Methods

Mapping of the study area took place from March 1997-November 1998 and was continuously updated as radio-tracked partridge moved into new areas. Field-notes were recorded in three A4 hardbound ledger books. All mapping details were noted such as boundary lines (drains, hedgerow or railway) plant community types on cutaway bog, grassland use (grazing, silage or hay), crop type (cereals or root crops) and any other relevant features.

Bord na Mona maps (1:10,000 scale, 1mm = 10m) of railway-lines and drain networks were used to take bearings within the Lough Boora Parklands. On private land, boundary lines from ordnance survey records were used to map more recent features. All details were transferred to larger scale 1-5000 maps (1mm = 5m). A3 graph paper was used with each page covering 2 km². Each box of the grid represented 5m². This proved invaluable for maintaining accuracy when mapping newer features. The position of a newly mapped area was calculated using compass bearings and distance to the nearest permanent feature.

All details were input into the software package Ranges V (Kenward, 1996). This is a widely used program for the analysis of radio-tracking data. In a radio-tracking study a background map or grid is required so that the location of radio-fixes can be inputted. Mapping data can be used to calculate the proportion of habitats available in a study area, or within a home range. This information is important when calculating habitat preferences. The map was inputted as a jigsaw of closed shapes. Each shape contained a number of coordinates, from a minimum of 4 to over 100 for some of the more complicated shapes. The habitat type of each shape was also input using a numbered
coding system (1=water, 2=grass, 3=cutaway bog, etc.). The original mapping data from the Lullymore and previous Boora study were re-examined so that the proportions of available habitats could be calculated using Ranges V.

2.3 Results

Mapping

In this study the final map consisted of a matrix of 397 shapes (3980 coordinates). This was exported from Ranges V with a "*.dxf" extension for graphical enhancement in the software package CorelDraw 3.0. Here each shape was colour coded with the habitat type designated to it. The resulting map (Fig. 2.2) covered an area of 18km². A red line encompasses a smaller area of 9.2 km² for the purpose of the radio-tracking study. This is referred to as the "study area" which is drawn as a Minimum Convex Polygon (MCP, see Chp. 5) around all the radio-tracking data collected over the two years fieldwork. By design it encompassed all areas used by the partridge followed during this study. This approach has been used in previous studies to define the study area of a radio-tracked species (Andelt & Andelt, 1981; Whiteside & Guthery, 1983; Jenkins & Starkey, 1984; Rolando & Cariso, 1999). It is a more realistic method of assessing the habitat available to the study species rather than an area determined by land ownership, road boundaries or some other non-biological criterion. The area of each habitat type within the MCP in Fig 2.2. was calculated using Ranges V and is presented in Table 2.1.
Figure 2.2 Boundary of the present Boora study area (in red) as determined by all radio-tracking data.

KEY TO HABITAT TYPES
- Cutaway Bog
- Private Bog
- Heather Top
- Young Forestry
- Other Tree Cat.
- Grassland
- Tillage
- Game Crop
- Edge
- Hedge Row
- Drain
- Building
- Wetland

1 km
Habitat designation in this study

From five major land use categories thirteen main habitat types were used to describe the present Boora study area for the purpose of computer analysis (Table 2.1). The designation of these habitat types was decided after the first year’s fieldwork was completed. As can be seen from Table 2.1 there were slight changes in the relative sizes of the habitat areas between years. For instance the lake shown within the MCP in Fig. 2.2 was created in 1998 and there were also small changes in the size of cutaway bog, edge, tillage and grassland between both years.

Table 2.1  The proportion of each habitat type available within the present Boora study area (outlined in red in Fig. 2.2.)

<table>
<thead>
<tr>
<th>Main Habitat Category</th>
<th>Study area in 1997</th>
<th>Study area in 1998</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hectares</td>
<td>%</td>
</tr>
<tr>
<td>Bogland</td>
<td></td>
<td></td>
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<tr>
<td>Cutaway bog</td>
<td>271.7</td>
<td>29.3</td>
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<tr>
<td>Private bog</td>
<td>80.6</td>
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<td>Trees</td>
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<td></td>
</tr>
<tr>
<td>Young forestry</td>
<td>17.6</td>
<td>1.9</td>
</tr>
<tr>
<td>Other tree cat.</td>
<td>95.0</td>
<td>10.3</td>
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<tr>
<td>Agricultural Land</td>
<td></td>
<td></td>
</tr>
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<td>Tillage</td>
<td>28.2</td>
<td>3</td>
</tr>
<tr>
<td>Linear habitats</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Game crops</td>
<td>14.5</td>
<td>1.6</td>
</tr>
<tr>
<td>Edge</td>
<td>39.2</td>
<td>4.3</td>
</tr>
<tr>
<td>Drains</td>
<td>49.2</td>
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<td>Hedgerow</td>
<td>11.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Others</td>
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<td></td>
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<tr>
<td>Buildings</td>
<td>2.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Wetlands</td>
<td>0.0</td>
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<tr>
<td>Total</td>
<td>926.7</td>
<td>100</td>
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</tbody>
</table>
The remainder of this section outlines the thirteen main habitat types chosen in
the present Boora study with a brief description of each. Some habitat types
were sub-divided for clarity, but only the main habitat type was used in
computer analysis.

Cutaway Bog (Plates 2.1 & 2.2), 28-29%.
During fieldwork some of the plant communities described for Turraun bog
(Kavanagh, 1990; Egan, 1995) were found here. These comprised pioneer
vegetation on younger cutaway areas, pioneer vegetation on older exposed
peat, wetland communities of drains and inundated peat, grasslands dominated
by wild flowers and grasses, grasslands dominated by purple moor grass
(Molinia caerulea), heather (Erica & Calluna sp.) dominated grasslands,
woodlands and rush (Juncus sp.) communities. In the present Boora study the
heather top areas, drains, wetlands and woodlands within the cutaway blocks
were assigned to separate habitat types. The remaining area classified as
cutaway bog had a patchy cover of vegetation with one community merging
into another over short distances.

Two subdivisions of cutaway bog were made for the purpose of the study.

A. Active peat extraction zones consisting of large areas of bare peat in
trenches with colonised areas limited to the drains.

B. Recently extracted areas with recolonisation by various plant communities
containing marsh arrow-grass (Triglochin palustris), rush, coltsfoot
(Tussilago farfara), horsetail (Equisetum sp.) and sedges (Carex sp.).

Private Bog (Plate 2.3), 8.7%.
Private bog areas were found along the outskirts of Bord na Mona property but
with different plant communities. Two sub-divisions were necessary as there
were differences between sites.

A. Areas where turf was cut privately by machine or hand and left stacked in large bare tracts with recolonisation around the edges, including heather, gorse (*Ulex europaeus*), purple moor grass, silverweed (*Potentilla anserina*) and tormentil (*Potentilla eracta*).

B. Idle areas where turf was once harvested privately and was recolonised by grasses including Yorkshire fog (*Holcus lanatus*) and fescue (*Festuca* sp.) and plants such as knapweed (*Centaurea nigra*), nettle (*Utrica dioica*) and bramble (*Rubus fruticosus*). Some areas were subject to occasional grazing.

**Heather Top (Plate 2.4), 2.3%**.

Areas of bog that were never harvested for peat and usually at a height of several metres above the surrounding land. As with private bog this habitat was distributed around the periphery of the cutaway bog. It was dominated by heather, with some purple moor grass and open willow, birch, and Scot’s pine (*Pinus sylvestris*). The features of this habitat were homogenous in the study area and there was no need for sub-divisions.

**Young Forestry (Plate 2.5), 1.9%**.

Young forestry was separated from areas containing trees as a main habitat type when it became evident that this was an important habitat for partridge. Conifer plantations comprise large areas of cutaway bog planted by the state forestry service Coillte. The most recent plantations were included in this habitat type. They contained sitka (*Picea sitchensis*) and Norway spruce (*Picea abies*) with some colonisation by willow and birch. There were also experimental plantations in strips on the cutaway bog. These contained a mix of broad-leaved trees and conifers. Those identified included sitka and
Norway spruce, lawson cypress (*Chamaecyparis lawsoniana*), European larch (*Larix decidua*), Scot’s pine, yew (*Taxus baccata*), downy birch (*Betula pubescens*) and silver birch (*Betula pendula*) and sessile oak (*Quercus petraea*).

A plantation was classified as being young forestry when the stand was less than 4 years old and where some trees had reached 2m but the majority were 0.5-1m. This resulted in an open canopy with many herbaceous plants growing between the trees. On wet ground, rushes and sedges tended to dominate. On higher dry ground there was a diversity of plants, including willowherbs (*Epilobium* sp.), coltsfoot, buttercups (*Ranunculus* sp.), clover, thistles (*Cirsium & Carduus* sp.), chickweed (*Stellaria media*), common mouse-ear (*Cerastium fontanum*), common groundsel (*Senecio vulgaris*), hawkweed (*Hieracium* sp.), cats-ear (*Hypochoeris radicata*) and many other members of the daisy family and various grass species.

**Other tree categories** (Plate 2.6), 10.3%.

Wooded areas other than young forestry were linked together as a main habitat type. Three sub-divisions were made:

A. Conifer plantations where the average height was over 2m and the canopy has become closed with either no ground vegetation or one dominated by soft rushes.

B. Naturally regenerated mixed willow and birch woods on cutaway bog.

C. Recently felled conifer plantations. These areas were adjacent to mature conifer plantations on the outskirts of the mapped area in Fig. 2.2

**Grassland** (Plate 2.7, 2.8), 32%.

Grassland was the largest available habitat in the study area. Permanent pastures were at an elevation above the raised bog and were undulating in
nature. Field boundaries were composed of hedgerow with or without drains. Grassland grazed only by sheep had a close sward of grass with few weeds where as fields containing cattle only, or mixed cattle and sheep tended to have poached ground (Plate 2.7) where chickweed and annual meadow grass (*Poa annua*) could grow. Grassland recently reclaimed from drained cutaway bog was laid out in large flat fields divided by drainage ditches and wire fencing (Plate 2.8).

Poached ground was more common on the new grassland as the top-soil was thin. During the summer months some fields yielded cuts of silage and hay. There were 3 sub-divisions based on management practices.

A. Unimproved grassland, patchy mixed grass cover with sow-thistles (*Sonchus* sp.), nettles, ragwort (*Senecio jacobaea*) and chickweeds. Tendency to flood periodically and occasionally grazed.

B. Improved grassland dominated by perennial ryegrass (*Lolium perenne*) and clover. Grazed with cattle and sheep. Cattle-grazing tears the turf providing bare soil for chickweed and annual meadow grass.

C. Grassland from which silage or hay is extracted in summer and is then grazed by sheep or cattle during the winter.

**Tillage** (Plate 2.9), 3%.

This was a diverse habitat with many crop types and rotations. It was however, decided to limit the number of sub-divisions to three.

A. Spring sown oats and barley with stubbles left over the winter. Diversity of common arable weeds around edges of some of the fields and in stubble such as meadow grass, *Polygonum* sp., nettles, chickweed, hemp-nettle (*Galeopsis tetrahit*), thistles and buttercup.

B. Winter wheat.
C. Root crops such as sugar beet, turnips, fodder rape and potatoes. Redshank (*Polygonum persicaria*) and knotgrass (*Polygonum aviculare*) common at edges and after harvest.

**Game crops** (Plate 2.10), 1.6%.

As part of the partridge conservation efforts in Boora a number of cutaway bog areas along railway lines were planted with a mix of nesting and brood rearing cover. Oats, wheat, barley, white clover (*Trifolium repens*), and lucerne (*Medicago sativa*) were provided as brood rearing cover. Partridge nesting cover consisted of a grass mix of cocksfoot (*Dactylis glomerata*), timothy (*Phleum pratense*), red fescue (*Festuca rubra*) and reed canary grass (*Phalaris arundinacea*). Downy birch and goat willow (*Salix caprea*) saplings tended to colonise along the edge of the game crops after the first year. Colonisation by various plant communities (as for cutaway bog section) was common on the brood rearing cover after the first year. No subdivisions were assigned as both nesting cover and brood rearing cover were seeded in sections next to each other.

**Edge** (Plate 2.11), 4.3%.

There were three subdivisions in this habitat type based on management. Edge was defined as:

A. The ungrazed and unploughed areas on farmland including wide strips along the edge of drains and fence-lines, often with dense grass cover or nettles.

B. Roadways in Boora contain a wide diversity of plants along the edges and centre strip. These include many members of the daisy and parsley family, bramble, ribwort plantain (*Plantago lanceolata*) and bracken (*Pteridium aquilinum*).
C. Narrow gauge railways used by Bord na Mona have a verge of vegetation similar to that of roads. These railways often contain the only plants in an otherwise barren bare peat landscape. The railways are only found on cutaway bog areas where as roads pass through bog and farmland. Purple moor grass is often dominant along the railway verge with common daisy (*Bellis perennis*), milkworts (*Polygala* sp.) and common bird’s foot trefoil (*Lotus corniculatus*) between the tracks.

**Drains** (Plate 2.8), 5.3%.

With the development of the cutaway bog many deep drains were dug to lower the water table for peat extraction. Recolonisation of cutaway bog often had its starting point from seeds carried along these drains (Kavanagh, 1990). The drains also allowed reclamation for grassland. Newly created grasslands contained a complex of fenced drains along which a diversity of herbaceous plants were protected from grazing (Plate 2.8). Drains were also common on the original farmland. Where a hedgerow was growing on both sides of a drain it was defined as hedgerow. The width of the drains varied between 5-10m. Drains measured a total length of 98.4 km in the 9.3km² study area (10.6 km drains per km²).

**Hedgerow** (Plate 2.12), 1.2%.

Hedgerows were only found on the original farmland surrounding the cutaway bog. No hedgerows had developed on the farmland reclaimed from cutaway bog. However gorse and willow bushes were developing along several roads and railways by the end of the study. Many of the hedgerows on farmland were managed and comprised hawthorn (*Crataegus monogyna*) with occasional larger trees such as common ash (*Fraxinus excelsior*) and sycamore (*Acer pseudoplatanus*). Gorse and willow were common in some of the
hedgerows near the bog. Hedgerows averaged 5m in width. The total length of hedgerow was calculated as 22.6 km in the 3.2 km$^2$ of farmland in the study area (7.1 km hedgerow per km$^2$).

**Buildings** (Plate 2.13), 0.3%.
There were a number of barns and dwelling houses within the study area. Several of the dwelling houses were abandoned and derelict. Given the very different physical nature of these areas and the possibility that they might play a significant factor in the distribution of partridge they were included as a main habitat type.

**Wetlands** (Plate 2.14), 0.0-0.6%.
A number of lakes were created in Boora, Tumduff and Turraun for public uses such as angling, walks and birdwatching. Grasses were seeded along the edges of these lakes with high abundance of clover and plantains (*Plantago* sp.). Only one lake was within the perimeter of the study area. This was an area of flooded cutaway bog created in the winter of 1997/98. This lake accounted for 0.6% of the study area in 1998.
Plate 2.1  Cutaway bog during the peat removal process with an electricity generating power station in the background.

Plate 2.2  Cutaway bog exhausted of harvestable peat, with early recolonisation on the shallow depth of peat remaining.
Plate 2.3  Private bog with a diversity of herbaceous cover and sods of peat scattered throughout the area.

Plate 2.4  Heather top illustrating a height difference with the reclaimed grassland below
Plate 2.5 Young forestry planted by Coillte on cutaway bog illustrating the diversity of herbaceous cover between the rows of trees.

Plate 2.6 Maturing conifer plantation with a closed canopy and a lack of ground cover.
Plate 2.7  Permanent pasture with exposed areas of soil allowing weed species to grow

Plate 2.8  Drain with residual cover following silage cutting in the adjacent reclaimed grassland
Plate 2.9  Harvesting of spring sown cereals

Plate 2.10  Game crop planted on cutaway bog containing oats to provide partridge brood rearing cover
Plate 2.11 Area of railway line used to transport peat to the electricity generating power station

Plate 2.12 Hedgerow
Plate 2.13 Disused farm buildings

Plate 2.14 Wetland created by Bord na Mona by flooding an area of cutaway bog
Lullymore and previous Boora study

Comparison will be made in later chapters with the analysis of radio-tracking data from the Lullymore study and to a lesser extent the previous Boora study. Colour coded habitat maps similar to that of Fig. 2.2 were produced (Figs. 2.3 & 2.4) based on the original radio-tracking data collected, to illustrate habitat availability during these studies. These maps are presented for the first time here. Note that there are fewer habitat designations because mapping by the researchers was less detailed than in the present study.

Lullymore study area (Fig. 2.3)

The Lullymore study area was 52 km² in size as defined by the MCP (outer edges of map illustrated in Fig. 2.3) of all radio-tracking data collected. Five main habitat types were defined, cutaway bog (54.7%), private bog (7 %), heather top (7.7%), agriculture (22.3%) and woodland (8.3%).

It should be noted that in Lullymore peat was removed by the ‘sod’ peat process, which is different to the ‘milled process’ in Boora. Drainage is achieved by digging parallel trenches, about 250m apart, through the peat. These trenches may be up to 3m deep. Peat is then cut by a machine along two face banks, one on each side of the trench, and deposited on the bog surface to dry. Once all the top layer has been removed, the peat is dried out on the large areas between the trenches. If there is still a sufficient depth of peat remaining, the whole process may be repeated. It was noted that the primary difference between the two processes was that more rapid vegetation re-generation was possible on “sod” peat cutaway bogs (J. Hearshaw, pers. com.).
In Lullymore small-scale mapping was conducted on an area of cutaway bog in Lodge (see Fig. 2.3 for map reference). The distribution of seven habitat categories were recorded during fieldwork from June-August 1993. This bog was approximately 2 km$^2$ in area. The results are summarised because they were not available as raw data for re-analysis or illustration in this thesis. bare ground (91.8%) covered the majority of Lodge, consisting of no vegetation, except isolated tufts of rushes. Heather dominated vegetation comprised 0.7% of the study area. Some areas were dominated by horsetails (2.4%). Railway comprised 1.8% of the bog. Plant communities with willow and birch were defined as “trees” (1.3%). Undefinable plant communities were included as “sparse” (1%) and “other” (1%) areas.

As explained earlier, many of the non-bog type habitats in the present Boora study were the result of recent reclamation from cutaway bog. However, cutaway bog still comprised a significant proportion of the study area as a whole. The bare areas recorded in Lodge bog were not as extensive as on cutaway bog in Boora. Colonisation of existing bare areas was possible within a period of months. In Boora it was deemed more relevant to include railway with road and other edge type habitats as ‘edge’. Given these categories, it was felt that dividing cutaway bog into sub-habitats would not have aided interpretation of partridge habitat utilisation.
Figure 2.3 Study area in Lullymore, Co. Kildare from 1992-94 as calculated from original radio-tracking data

KEY TO HABITAT TYPES

- CUTAWAY BOG
- PRIVATE BOG
- HEATHER TOP
- AGRICULTURAL LAND
- WOODLAND
Previous Boora study area (Fig. 2.4)

During the previous Boora study habitat availability was not fully recorded. For the purpose of analysis habitat availability was calculated for some areas using BNM maps. The red boundary of the study area in Figure 2.4 marks the outer limits of the radio-fixes recorded (MCP) and enclosed an area of 19km². Four main habitat types were defined during this study: bogland, agricultural land, woodland and edge (road & railway). The Lough Boora Parklands initiative had just begun in 1995. Therefore the habitat map of Boora in 1995 (Fig. 2.4) was quite different from that in the present Boora study (Fig. 2.2) and a higher proportion of forestry plantations would have been defined as ‘Young Forestry’. There were fewer reclaimed grasslands than at present and the lake development had only just begun.

Comparison of habitat availability between all study areas (Table 2.2) was possible for 3 habitat groups: bogland, agricultural land and trees. Availability of trees was similar between studies. Bogland habitats were three times more abundant than agricultural land in Lullymore while the reverse was the case in the previous Boora study.

Table 2.2 A comparison of the percentage availability of bogland, agricultural land and trees in Lullymore, the previous and the present Boora study areas

<table>
<thead>
<tr>
<th></th>
<th>Lullymore Study %</th>
<th>Previous Boora Study %</th>
<th>Present Boora Study %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogland</td>
<td>69.4</td>
<td>21.6</td>
<td>40</td>
</tr>
<tr>
<td>Agricultural land</td>
<td>22.3</td>
<td>62.6</td>
<td>36</td>
</tr>
<tr>
<td>Woodland</td>
<td>8.3</td>
<td>15.8</td>
<td>12.2</td>
</tr>
</tbody>
</table>
Figure 2.4 Previous Boora study area (red boundary) in 1995 as calculated from original radio-tracking data.
Chapter 3

BIRD CAPTURE AND TRANSMITTER ATTACHMENT
3.1 Introduction

Marks and devices used in field studies of behaviour and ecology of birds are diverse. Leg attachments include metal rings, colour rings, tape, thread, streamers, strips, flags, flipper bands, toe bands and web tags. Other examples are back tags, neck tags, neck collars, nasal marks and dyes (Calvo & Furness, 1992). For the research of movements, activities and behaviour of birds using these study tools, visual observation is required. This may be difficult with mobile and inconspicuous wildlife species and radio-transmitters are often utilised in these cases (Amstrup, 1980).

The advantage of a radio-transmitter is that the tracked animal can not only be identified individually but be located at any time. A radio-transmitter may be attached to a bird on its neck, back, wing or tail feathers. Methods of attachment include collars, cords, straps, harnesses, ponchos and glue depending on the area of attachment and the species being radio-tracked.

3.2 Methods

Bird capture

In this study, grey partridge were captured so that a transmitter could be attached. Trapping and lamping of partridge were the two methods of capture used. A walk-in cage trap with a funnel entrance was used to catch partridge (Fig. 3.1, Plate 3.1) from spring to early summer. Female farm-reared partridge (obtained from a game-farm in Co. Longford) were used as decoys to attract wild male birds to the trap. The trap design was provided by the Game
Conservancy, England (K. Blake, pers com.). The trap consisted of 3 compartments each with its own hinged door in the roof. The roof consisted of a soft plastic 1mm mesh to reduce head injuries, with chicken wire on the sides and floor. The middle compartment contained the hen while the outer two compartments had an entrance consisting of a tapered funnel of chicken wire. Both entrances were baited with grain. Partridge, attracted by the calls of the female, would enter the large funnel opening but be unable to return through the smaller opening on the inside. The trap was surrounded by an electric fence to guard against fox predation.

Lamping was the second capture method (Drewien et al., 1967). Birds were captured at night with a net and lamp as they roosted on the ground. A tape recording of a tractor engine allowed a closer approach to roosting birds (W. Kaiser, pers com.). Birds were dazzled by the light and the net placed quickly over their heads for capture. The net was 1 metre in diameter, attached to a 2.5 metre pole. The 500,000 candlepower lamp had a 30 cm hood of cardboard secured around it to narrow the beam. Partridge were lamped in the spring and early summer if they were found roosting in the periphery of the trap. In autumn lamping attempts were made on members of radio-tracked coveys.

Only male partridge were fitted with radio-transmitters. British Trust for Ornithology (BTO) metal leg rings were attached to any female birds caught to identify any individuals recaptured. Birds were weighed and in several cases feather and blood samples taken for future DNA analysis (see Chp. 7). Birds were removed to a nearby vehicle for processing.
Figure 3.1 Schematic diagram of the walk-in trap
The radio-necklace

The transmitter was attached around the neck with a cord (Plate 3.2, note that this is a female farm reared partridge photographed for illustrative purposes). A knot was tied in the cord at the required fit and super-glue applied to this knot. The transmitter sat snugly against the feathers of the upper chest and the whip antennae extended behind the bird's head.

The transmitter was a TW-3 10g model from Biotrack Ltd., England. It had a ground-ground range of 1-3km and a transmitting life of 7-12 months depending on the model used. The longer lasting models produced a slower pulse rate and had a shorter range. A signal was emitted continuously from the moment the battery was connected to the circuitry. This was achieved by joining two protruding wires and soldering them together. The bond was subsequently sealed with epoxy resin. This took at least an hour to harden sufficiently. Transmitters were prepared in advance of a capture attempt.
Plate 3.1  Walk-in cage trap surrounded by an electric fence to prevent fox predation of the decoy hen and any partridge captured

Plate 3.2  Photograph illustrating the necklace attachment method of the radio-transmitter
3.3 Results

Nine male birds were captured and fitted with radio-transmitters, five (male #1-#5) in 1997 and four (male #6-#9) in 1998 (Table 3.1). Six of the birds were caught in spring/early summer as the catching effort was most intense at this time.

Male #1 remained unpaired for the duration it was tracked. Chapter 6 outlines the movement patterns of unpaired birds. Male #2 and his mate bred successfully to produce eight juveniles. Male #2 and his mate are henceforth referred to as “pair 1” or with young as “covey 1”. Two juvenile male partridge, members of covey 1, were fitted with transmitters in October. However, the remains were found several days after release. Parts of the birds had been eaten (probably by a fox) but it is not known if they were predated or had died and subsequently been scavenged. Male #5, an adult member of a non-breeding covey was also captured in October, but was found buried by a fox three weeks later. No further attempt was made to capture partridge until the following spring.

From spring to early summer four male partridge were captured. A new longer lasting transmitter (12 months) was used so that recapture would not be necessary during autumn/winter. Male #6 and his mate bred successfully to produce ten juveniles. Male #6 and his mate are henceforth referred to as “pair 2” or with young as “covey 2”. Male #7 was lamped at the end of March but contact was lost within 3 weeks. Male #8 was lamped in April but was killed by a peregrine falcon after several days. Male #7 was re-captured in the trap in April. It was discovered that contact loss in this case was caused by disconnection of the battery owing to breakage in the solder. The bird was
released with a new transmitter but contact was lost after 8 days. Male #9 was trapped in June and contact was lost to unknown reasons after two and a half weeks. In all cases where contact was lost signal readings were taken from high vantage points around the periphery of the mapped area (Fig 2.2) for several days.

Thus, nine partridge were captured (male #7 twice) during the study (Table 3.1). Of these 10 bird captures 40% were lamped and 60% trapped. Contact was lost in 40% of cases within the first week following capture.
Table 3.1 Capture date, method, weight, fate and tracking time of all birds caught during the present Boora study

<table>
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<th>Capture date</th>
<th>Method</th>
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<th>Fate</th>
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<tbody>
<tr>
<td>Adult male#1</td>
<td>09-Apr-97</td>
<td>Trap</td>
<td>410</td>
<td>Unpaired, joined unpaired bird and barren pair in autumn</td>
<td>Transmitter life ended 30/11/97, bird visually observed for several days</td>
<td>8 mths</td>
<td>178</td>
</tr>
<tr>
<td>Adult male#2</td>
<td>10-Apr-97</td>
<td>Trap</td>
<td>420</td>
<td>Paired several days after release</td>
<td>Found buried by fox on private bog on 23/1/98</td>
<td>10 mths</td>
<td>196</td>
</tr>
<tr>
<td>Juvenile male#3</td>
<td>11-Oct-97</td>
<td>Trap</td>
<td>406</td>
<td>Member of male#2 covey, adult hen also trapped</td>
<td>Remains found on grassland, eaten by fox on 14/10/97.</td>
<td>3 days</td>
<td>2</td>
</tr>
<tr>
<td>Juvenile male#4</td>
<td>11-Oct-97</td>
<td>Trap</td>
<td>425</td>
<td>Member of male#2 covey, adult hen also trapped</td>
<td>Radio-collar found on drain edge beside chewed feathers between 14-16/10/97</td>
<td>3 days</td>
<td>4</td>
</tr>
<tr>
<td>Adult male#5</td>
<td>15-Oct-97</td>
<td>Lamp</td>
<td>430</td>
<td>Member of male#1 covey, adult hen also caught</td>
<td>Found buried by fox along fenceline in stubble field on 6/11/97</td>
<td>3 wks</td>
<td>10</td>
</tr>
<tr>
<td>Adult male#6</td>
<td>09-Mar-98</td>
<td>Lamp</td>
<td>396</td>
<td>Caught roosting near funnel trap on handcut bog</td>
<td>Radio-collar found on drain edge with chewed feathers on 2/11/98</td>
<td>7 mths</td>
<td>199</td>
</tr>
<tr>
<td>Adult male#8</td>
<td>01-Apr-98</td>
<td>Lamp</td>
<td>416</td>
<td>Caught roosting at trap remained at trap site for several days</td>
<td>Killed by pergrine falcon (<em>Falco peregrinus</em>) near trap site on 4/4/98</td>
<td>3 days</td>
<td>3</td>
</tr>
<tr>
<td>Adult male#9</td>
<td>13-Jun-98</td>
<td>Trap</td>
<td>385</td>
<td>Bird unpaired during tracking time</td>
<td>Signal lost on 29/6/98</td>
<td>2.5 wks</td>
<td>14</td>
</tr>
</tbody>
</table>
3.4 Discussion

Capture data from previous Irish studies

In the Lullymore study 12 birds were captured and fitted with radio-necklaces (J. Hearshaw, unpubl. data). Five of the twelve birds captured were female. Five birds were recaptured (two twice). Of the 21 bird captures 81% were lamped and 19% trapped. 14% of captures resulted in mortality in the first week.

In the previous Boora study 6 wild birds were captured and fitted with radio-necklaces (F. Lester, unpubl. data). All birds were trapped. Of these birds, 4 were found eaten by foxes, transmitter life expired for one bird and radio-contact was lost with another bird. No other capture details were available from this study.

Short term effects on mortality

In a review by Kaiser (1999) it is suggested that capture and handling itself, rather than other factors had the most important impact on mortality during the first week. Data has been reported in a number of partridge studies and the percentage mortality is variable between researchers (Table 3.2). Known cases of mortality in the first week after release in Irish studies were 14% (3 birds, n=21) in Lullymore and 30% (3 birds, n=10) in the present Boora study.
Table 3.2  Mortality in the first week after release for grey partridge fitted with radio-transmitters.

<table>
<thead>
<tr>
<th>Source</th>
<th>Location</th>
<th>% Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Putaala et al., 1997a</td>
<td>Finland</td>
<td>12</td>
</tr>
<tr>
<td>Kaiser, 1999</td>
<td>Germany</td>
<td>12</td>
</tr>
<tr>
<td>J. Hearshaw, unpubl. data</td>
<td>Ireland</td>
<td>14</td>
</tr>
<tr>
<td>Serre et al., 1989</td>
<td>France</td>
<td>22</td>
</tr>
<tr>
<td>Present Boora study</td>
<td>Ireland</td>
<td>30</td>
</tr>
<tr>
<td>Carroll, 1990</td>
<td>North Dakota, USA</td>
<td>34</td>
</tr>
</tbody>
</table>

Carroll (1990) stated that the effects of researchers on partridge survival were difficult to assess because it was difficult to obtain controls to compare survival rates.

Birds can become injured during the catching process. With trapping, birds risk damaging their wings and head against the wire mesh. With lamping there is a risk that the rim of the net can strike the bird during capture. Handling wild birds will cause stress. The longer it takes to process the bird the greater this stress is likely to be. Trapping may cause greater stress than lamping because the birds see the researcher approaching them and they panic having been in the trap for up to several hours. In contrast with lamping the birds are processed within 20 minutes of capture. However stress and injuries only contributed to mortality in some birds. In the present Boora study one bird (male #1) had been badly pecked on the head by a second bird (male #2), both birds having been captured in the same compartment of the trap. Despite a serious injury this bird survived for 8 months. A similarly injured juvenile male bird caught in the Lullymore study was found eaten by a fox after 21 days. In contrast, birds with no obvious injuries were found as intact corpses (no suggestion of predation) or found as eaten remains within days.
The data sets in Lullymore, the previous Boora study and the present Boora study were too small to make any conclusive analysis on whether trapping technique (trapping/lamping), sex (male/female), time of year or age class (juvenile/adult) had a significant impact on short term survival. Given that the grey partridge is endangered in Ireland (Whilde, 1993), it would be desirable to reduce capture related mortality in future radio-tracking studies. The most important guideline is not to use trapping as a capture method if possible owing to the longer processing time. Birds can be attracted to an area using a decoy farm-reared female bird as for trapping, but the trap openings should be closed. Birds can then be lamped at night as they roost on the ground nearby.

**Effect of the radio-transmitter**

There have been many bird studies that utilised radio-transmitters. In a recent review (Calvo & Furness, 1992) of 171 papers, effects described include initial discomfort shown as an increase in preening activity and pulling at the device. Other physical problems include skin abrasion due to the attachment, feather wear or loss, external and internal injuries, impaired movement and weight loss.

Backpack attachment designs were shown to lead to weight loss in captive grey partridge held in outdoor pens compared to untagged controls (Schulz & Upgren, 1977). In a study comparing the effects of ponchos and backpacks on grey partridge it was found that both contributed to mortality, mainly by raptors, in the first week after release (Carroll, 1990).

In an English study female grey partridge radio-tracked using a backpack attachment method were twice as likely to be killed by foxes while incubating compared to females without a radio-backpack (Reynolds et al., 1992). It is
suggested by the authors that the backpack may have caused the release of
more scent from the bird by breaking up the outline of the back feathers, thus
leading the fox to the sitting female.

The necklace attachment method used in the present Boora study has been
used in other partridge studies (Birkan et al., 1992; Bro et al., 2001; Kaiser,
1998) and on other game-birds (Willebrand, 1988; Marcstrom, 1989; Taylor et
al., 2001; Marjalkangas & Oils, in prep; Pereira et al., in prep).

When radio-backpacks, radio-necklaces and leg ringing were compared on
pheasants (Marcstrom et al., 1989), radio-backpacks resulted in greater
mortality than radio-necklaces. No difference in mortality was found between
pheasants with necklaces and leg-rings. Similarly no difference in mortality
was found between black grouse with necklaces and leg-rings (Willebrand,
1988). Taylor et al. (2001) found that northern bobwhite wearing radio-
necklaces had higher survival than those wearing radio-backpacks during the
breeding season. Also, nest success and brood production rates were
significantly higher for females wearing radio-necklaces than those wearing
radio-backpacks.

Kaiser (1999) assessed if radio-necklaces increased mortality, after the
partridge had got used to them, by analysing the data for partridge with and
without radio-necklaces in 27 coveys in a previous study (Kaiser, 1998).
Results showed that 27% (n=86) mortality for radio-tracked individuals was
significantly higher than 17% (n=169) mortality of non-radio-tracked birds in
the same coveys. Putaala et al. (1997b) suggested that the additional weight of
the radio-necklace may have made the bird more vulnerable to predation. This
could be owing to diminished acceleration and manoeuvring capabilities. For
instance, a bird less willing to fly or with a slow escape flight when approached by a fox will be more vulnerable to fox predation, a bird less capable of manoeuvring in flight would be more vulnerable to raptor predation.

Pennychuik et al. (1989) suggested that the acceptable ratio mass of radio-transmitters for birds should be expressed as a fraction of the food load mass they can carry, not as a percentage of the body mass. An examination of 429 partridge crops revealed the heaviest to be 18.3g (Middleton & Chitty, 1937). Therefore a 10g radio-necklace would be a maximum 54% additional weight to the food mass carried.

Hill & Robertson (1987) suggested that transmitters should weigh less than 5% of the weight of a small bird, but Kaiser (1999) showed reduced survival for partridge in coveys wearing a transmitter weighing less than 2% body weight. The weight of the radio-necklace in the present Boora study was less than 3% of the mean body weight of the 9 male partridge tracked (407g +/- 6.2 SE).

A study on willow grouse used brightly coloured back-mounted transmitters to make recognition of the birds easier if the transmitter failed (Erikstad, 1979). There was no difference in number of clutches of eggs hatched compared with the untagged control group. However, subsequent chick survival was lowered in the tagged group. It is believed that the transmitter may have attracted the attention of grey crows (Corvus corone cornix). In the Lullymore study; it is possible that the aerial of the radio-necklace was visible to corvids such as the grey crow and magpies (Pica pica). In the present Boora study it was observed that the aerial tended to shine in bright sun. Four nests were predated by corvids in the Lullymore study. Since female birds had transmitters
attached, this may have led to predation of the nest if she was noticed leaving and returning to the nest site to feed (Hammond & Forward, 1956).

Radio-transmitters, regardless of design, have some effects on the birds wearing them. As discussed earlier, the radio-necklace design has the least adverse effects of designs available at present. However, the additional weight of the radio-necklace has been shown to affect survival of partridge (Kaiser, 1999). Therefore, partridge studies using the radio-necklace will tend to overestimate mortality rates. The purpose of the present Boora study was to investigate home range and habitat use of the birds. The radio-necklace was deemed not to have an adverse affect on this aspect of research.

Loss of contact with birds

Loss of contact occurred for 5 birds in the Lullymore study, 1 bird in the previous Boora study and 2 birds in the present Boora study. The possible reasons for loss of contact are signal failure, birds moving out of the study area and predation.

The best way of eliminating the risk of signal failure is to use the more expensive magnetic-switch transmitter. The connection between the battery and the transmitter is regulated by a magnetic switch, removing the risk of solder breakage. The transmitter can be switched on by simply removing a small magnet taped to the outside of the transmitter. There would be no need, therefore, to prepare a transmitter in advance of a capture attempt.

A total of 5 birds in Lullymore, 4 birds in the previous Boora study and 5 birds in the present Boora study were suspected to be predated by foxes (remains found eaten or buried). These were cases where the carcass was discovered
with the transmitter still functioning. It is possible that other birds were predated with the radio-necklace being damaged in some way, such as the aerial being chewed off or bite marks to the transmitter. In Lullymore the leg ring of one bird where contact had been lost was found in a fox scat several months later. Some of the predated birds had been buried which reduced the tracking range to a few hundred metres. These would not have been recovered if the bird had been in an unfamiliar area (for the researcher) when predated.

Disproportionate mortality of female partridge during the breeding season leads to a surplus of male partridge the following spring (Potts, 1980; Potts & Aebischer, 1989). At North Farm in the south-east of England, foxes killed almost a quarter of incubating hens (Potts, 1986). In France, the mortality of 1009 female partridge, across 10 study sites, were monitored on a daily basis (Bro et al., 2001). Mortality was highest in May, June and July when females were laying and incubating. The mortality rate of females during breeding was higher than 50% in some regions. Predation was the main (73%) proximate cause of female mortality. Ground carnivores were responsible in 64% of cases (Bro et al., 2001). A consequence of such high mortality on a radio-tracking study is that a significant proportion of hens will be lost during the breeding season. However, in Lullymore and Boora no radio-tracked females, or females paired to a radio-tracked male, were lost between May and July. During the Lullymore study fox control was carried out locally by the gun clubs (B. Kavanagh, pers. com.), while in Boora fox control was intensive as part of the partridge conservation project. In England, experiments showed that predation control can significantly reduce hen predation during the breeding season (Tapper et al., 1996).
In Lullymore, temporary signal loss was noted for a number of radio-tracked pairs ranging from 3 to 18 days before the birds were relocated within the study area. It is suggested that the birds had made exploratory movements outside the study area to an unknown location and out of range of the receiver. It is therefore possible that in cases where loss of contact was permanent that the birds simply did not return. In Lullymore, 4 of the 5 birds lost were male and losses occurred from November to April. In the previous Boora study one male partridge disappeared in spring. In the present Boora study all radio-tracked birds were male and loss of contact occurred from March to June. In spring, male partridge are known to range over several kilometres in search of mates (Jenkins, 1961a; Weigand, 1977; Aufradet, 2001). Therefore, loss of contact owing to emigration is more likely with male birds during this time (see Chp. 6).

Lack (1954) used the formula $2-m/2m$ (where $m = \%$ annual mortality), to calculate the average expectation of further life for an animal. This can be applied to any time period such as days, weeks or months, for which mortality data is available. In a study of a partridge population in Montana (Weigand, 1980, cited by Carroll, 1993), this calculation gave an average expectation of further life of 0.9 years for immature males, 0.8 years for immature females and 1.8 years for adults. The maximum age recorded for a partridge in Montana was 4 years. In Denmark (Paludan, 1963) the maximum age recorded for a farm reared partridge in the wild was 5.2 years.

The 27 wild partridge radio-tracked in the three Irish studies were followed for varying time periods. The fate of many of these birds after loss of contact were unknown, as discussed earlier. This data can be used to provide a conservative estimate of the average length of further tracking (as opposed to
"life") time expected for each bird using Lack's (1954) method. For the purpose of the radio-tracking data, loss of birds during each month of tracking gave equivalent mortality figures. In this analysis mortality did not mean death for the bird, but it represented death for the research, as no further data could be collected. Thus, the average expectation of further tracking time was calculated (Fig. 3.2). All birds were at least 5 months old when captured. The average expectation of further tracking time for a partridge was 2.9 months after capture. From a total of 27 birds only 3 birds (11%) were followed for more than a year. Aebischer et al. (1993) recommended a sample size of 30 for the analysis of radio-tracking data. Therefore, under Irish conditions 273 radio-tracked partridge would have been needed to follow 30 birds for a period greater than one year. In autumn 1995, the total Irish population was estimated to be 148 birds (Kavanagh, 2001).

![Graph](image)

**Figure 3.2** Expectation of further tracking data from capture onwards for 27 partridge radio-tracked in Ireland
Summary

In the present Boora study it was hoped that at least 3-4 male birds would be caught each year and that these would pair, breed successfully and be radio-tracked for as long as possible. Owing to the loss of birds for various reasons described earlier, eventually only one pair in each year was radio-tracked through the breeding season. However, both these pairs bred successfully providing vital information for the first time on this stage of the life cycle of grey partridge in Ireland, as will be discussed in later chapters. This can be attributed mainly to predation control in the study area, because only male birds were radio-tracked, and no attempts were made to locate nests during the study. Increased risk of mortality was a result of capture and radio-tracking. However, I believe that the positive outcome of the knowledge gained in relation to management of the population in the long-term, outweighed any short-term losses.
Chapter 4

CALCULATION OF THE BIOLOGICAL TIME PERIODS
4.1 Introduction

Radio-tracking utilises very high frequency radio (VHF) with wavelengths between 1 and 10 metres. Crystal-controlled transmitters can be made with fewer than 10 components and weigh less than 1 gram. In the simplest system the biologist tracks the animal using a hand-held directional antenna, a receiver and headphones. Radio-tracking was introduced as a research tool in the early 1960s. It has since become widely regarded as a useful technique to provide the type of data suitable for home-range analysis (Harris et al., 1990). Workers once manufactured their own transmitters based on various published designs (Kenward, 1987) but nowadays the majority of researchers purchase them from specialist companies.

Radio-tracking can provide information in a number of ways. Movements provide information on how animals use the environment such as migration patterns, dispersal and activity patterns. Home range estimates quantify the area used by the animal. Habitat use studies provide information on habitat preferences. Survival studies give estimates of mortality rates. Population estimation studies calculate the number of animals in a population (White & Garrot, 1990). The purpose of radio-tracking in this study was to provide information on movement patterns, home range and habitat use.

Radio-tracking enables the researcher to monitor the movements of an animal over time. Each radio-fix is a sample. As sampling intervals become shorter, successive observations for an individual grow closer until at the shortest interval possible they are continuous. Continuous radio-tracking studies are uncommon used because they require an automated system of recording movements. Therefore most studies involve dis-continuous radio-tracking and
the frequency of sampling is important. The greater the number of radio-fixes collected, the more detail can be obtained on movement patterns. However, for each animal tracked one radio-fix should be statistically independent from the next. Autocorrelation means that the position of the subject at time t, influences its position at time t+1. (Swihart & Slade, 1985a;b). This correlation is particularly important for probabilistic methods of home range analysis. To avoid autocorrelation it should be theoretically possible for the animal tracked to move from one end of its home range to the other, in the time elapsed between radio-fixes. This time will vary between studies (White & Garrot, 1990).

In many radio-tracking studies the initial aim is to calculate the area of land that the animal uses. This can vary from several hundred m² for the Malayan wood-rat *Rattus tiomanicus* (Buckle *et al.*, 1997) to several hundred km² for the African elephant *Loxodonta africana* (Thouless, 1996). Depending on the life span of the transmitter, animal radio-tracked and the nature of the research, the time period will vary greatly from several days to several years. Therefore, the timing and length of the time period will be fundamental to the definition of a home range (Morris, 1980). This chapter describes the time periods used in this study of the grey partridge in and therefore serves as an introduction to Chp. 5.
4.2 Methods

Field-work

The signal from the radio-transmitter was detected on a Mariner 57 receiver with a hand-held Yagi 3-element aerial. At each radio-fix the date, time, weather, habitat type, location and other relevant details were recorded. Radio-fixes were made from an all-terrain vehicle or on foot. Visual observations were often possible from a vehicle.

When the accuracy of a fix was undetermined between two habitat types a closer approach was necessary or triangulation was used (Heezen & Tester, 1967; Springer, 1979). Sometimes the area was searched for droppings the following day after the bird had left to determine the exact location. During the breeding season care was taken to minimise disturbance owing to the risk of observer-initiated corvid predation (Hammond & Forward, 1956; Dwernychuck & Boag, 1972; Jones & Hungerford, 1972; MacInness & Misra, 1972; Erikstad et al., 1982). All radio-fixes were calculated by triangulation during this time.

For long-term radio-tracking studies where man-power is limited, a frequency of 1 or 2 radio-fixes per individual a day is recommended (Swihart & Slade, 1985b). This was considered a realistic goal. Consistency is important and it was decided not to take more than 2 radio-fixes a day per partridge. Otherwise, a situation could arise whereby sampling was unequal. For example, 5 radio-fixes taken in one day would be less representative than 1 radio-fix each day for 5 days. The movements of the first radio-tracked bird were observed closely. It was soon determined that the most practical way of monitoring partridge was to record a radio-fix in the morning and one later in
the day. An effort was made to vary the times of these radio-fixes. Often only one radio-fix was recorded for logistical reasons. The minimum interval between radio-fixes was 5 hours. In this study it was assumed that radio-fixes 5 hours apart were independent of one another. This was considered a sufficient time interval for partridge to move between all available habitat types and has been used in previous partridge studies (Church & Porter, 1990; Church, 1994).

The co-ordinates of each radio-fix were calculated using the background map of the study area as illustrated in Fig. 4.1. The co-ordinates and the corresponding habitat code on which the fix occurred, were input to Ranges V software package (Kenward, 1996) for analysis. During radio-tracking the sightings of other birds was noted and an estimate of the location and number of nesting pairs was made in the total mapped area each year. Counts were also made of the number of birds comprising each covey.

No partridge radio-tracking study outside Ireland was found which had attempted to define movement patterns of grey partridge through a complete year. Using information from 2 previous radio-tracking studies (Church et al. 1980; Carroll et al. 1990) and information gained from analysis of the Irish data, a number of time periods were used to describe the partridge year. These have been coined ‘Biological Time Periods’ (BTP) as they are based on breeding behaviour and movement patterns of the birds being followed as opposed to calendar periods chosen by the researcher.
Figure 4.1 Radio-fix co-ordinates (see Appendices) were calculated from grid references on the map of the present Boora study area. Grid = 1km²

For example the coordinates for the radio-fix above (X) would be (7820, 10915)
Breeding biology

In the present Boora study it was necessary to calculate the starting date of laying and incubation to determine the timing of BTPs for individual birds during the breeding season. The obvious method would be to locate the nest during laying and back-calculate the onset of laying from the number of eggs found in the nest at that time. An average of one egg is laid every 1.4 days in Britain (Potts, 1986). On discovering 5 eggs in a nest the researcher would calculate that nest initiation began 7 days (5*1.4) prior to this. However, this method entails finding nests. No attempt was made to find nests in this study owing to the risk of disturbance and predation, given the endangered status of the species. All radio-fixes were taken from a distance by triangulation. Therefore, indirect methods were used to calculate the date of laying by back-calculation from the hatching date (Carroll et al., 1990). The hatching date was known from observation of the young brood and estimation of the age of the chicks. In the Lullymore study, the location of the nest site and the initiation date for incubation were known, as females wore radio-transmitters.

The average clutch size of the grey partridge in Finland is at 19 (Pulliainen, 1971), the highest of any bird species in the world. Clutch size can vary between 10-20 eggs (Potts, 1986; Carroll, 1993). Lack (1947) illustrated that partridge clutch size increases geographically from south to north (i.e. 15 eggs in Britain, 16-18 eggs in Norway) and from west to east (i.e. 15 eggs in Britain, 14-16 eggs in Belgium, 16-20 eggs in central Germany). In North American studies the average clutch size is 16.1 eggs (Church, 1984), similar to that found in Eastern Europe, from which the majority of partridge were translocated (Lack, 1947). Based on this data, partridge in Ireland (which is further west than Britain) may have an average clutch size less than 15 eggs. However, in the absence of Irish data, it was deemed reasonable to use the
British data for analysis in this study. Incubation can vary in length from 21-26 days, but 25 days is considered the average in North America (McCabe & Hawkins, 1946, cited in Carroll et al., 1990) and in Britain (Fant, 1953; Potts, 1980; 1986). An incubation length of 25 days was used in this study, which was confirmed by field observations.

Movement patterns

The term ‘movement pattern’ in this study refers to the displacement from one radio-fix to the next. This can be represented by lines linking one radio-fix to the next. This method gives the researcher an index of the movements of the partridge themselves, but does not strictly refer to actual movements of the birds. This would require continuous radio-tracking (White & Garrott, 1990).

Outside the breeding season, a change in the movement pattern was used to determine a switch from one BTP to another. A change in movement pattern could be observed visually when a bird moved away from an area previously used (Fig. 4.2). The point at which a new BTP was designated (separating one set of radio-fixes from the next), was calculated using Ranges V (Kenward, 1996). The area enclosed by a set of radio-fixes can be calculated using a range of home range analysis methods (Chp. 5). For each method, successive radio-fixes can be plotted against the area enclosed (incremental area analysis). The area enclosed increases in increments until an asymptote is reached, when additional radio-fixes do not result in a subsequent increase in area. At this point, the area enclosed represents stabilisation of the home range, as defined by the radio-fixes collected (White & Garrot, 1990; Kenward, 1996). The number of radio-fixes required to reach an asymptote will vary between methods and individuals (Harris et al., 1990). When there is a significant change in the movement pattern (i.e. when a radio-tracked animal moves to a
Figure 4.2 Designation of a new biological time period (BTP) from a change in the displacement of radio-fixes

1 → 23 Radio-fixes within first BTP.

24 → 45 Radio-fixes within second BTP.
new area), this is detected by further increments in area above the previous asymptote reached. The point at which this occurs separates the set of radio-fixes recorded in one BTP, from the next BTP. Spatially, there may be some overlap during the shift in home range (Fig. 4.2) with a number of radio-fixes recorded during the new BTP, occurring within the area enclosed during the previous BTP. Designation of BTPs using this method were independently validated by differences in home range size and habitat utilisation between BTPs (Chps. 5&6).
4.3 Results

Radio-tracking in the present Boora study was conducted for 19 months (April 1997 - October 1998). The radio-tracking effort was equally distributed between months (Fig. 4.3). Data was collected for a mean number of 18 days (se=0.8, n=19, min=12, max=23) per month. For 347 radio-tracking days, one radio-fix per day was recorded in 67% cases, 2 radio-fixes in 33% of cases. Sufficient data for detailed analysis was obtained of the movements and habitat use of three birds. The three partridge, two paired (one pair in each year) and one unpaired male, were tracked for a period of between 8-10 months each.

Figure 4.3. Monthly radio-tracking effort during this study
Calculation of the laying, incubation and hatching dates

Pair 1 (1997). Male#2 was flushed in the young forestry strip on the 28 June. He flew alone into the grasslands, which indicated that the hen was still incubating the eggs. On 4 July when male#2 was flushed he did not fly immediately but ran a few steps and then flew a short distance. The female was also spotted and she was calling and feigning a broken wing. This indicated that the period of incubation was over and that chicks had hatched (Bewick, 1976) at some stage between 29 June - 3 July. A mean hatching date was calculated midway between these dates as 1 July. Therefore the date incubation was initiated was calculated as 25 days (average incubation length) prior to the hatching date. This date was the 6 June. It takes 21 days for a hen partridge to lay 15 eggs (Potts, 1980; 1986). The initiation date for egg laying was estimated by back calculating 21 days to 16 May.

Pair 2. (1998). Chicks belonging to pair 2 were first spotted on 26 June on a ridge of marl on cutaway bog. The parents were flushed and landed a few feet away, one bird feigning a broken wing. The chicks were then heard and seen scattering into the cover of horsetails. It was estimated that the chicks (10-12 in number) were between 8-10 days old (K. Buckley pers. com.). Backdating gave a hatch date between 16-18 June. Field-notes record that on the 23 June male#6 was approached to within 2m and did not fly and was suspected to be brooding chicks at the time. On the 18 June, male#6 was flushed and flew by himself indicating that the hen was still incubating. Therefore the hatch date occurred soon after this date. The 20 June was chosen as the most likely hatch date. Backdating 25 days gives incubation beginning on 26 May. In fact field records for this date show that male#6 was flushed and flew by himself, thus confirming that the female was indeed incubating. Backdating 21 days from 26 May gives 4 May as the beginning of the laying period.
Table 4.1  Dates calculated for the onset of laying, incubation and brood rearing BTPs for pairs 1 & 2 in the present Boora study

<table>
<thead>
<tr>
<th>Initiation date</th>
<th>BTP</th>
<th>Pair 1</th>
<th>Pair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laying</td>
<td>16-May</td>
<td>04-May</td>
<td></td>
</tr>
<tr>
<td>Incubation</td>
<td>06-Jun</td>
<td>26-May</td>
<td></td>
</tr>
<tr>
<td>Brood rearing</td>
<td>01-Jul</td>
<td>20-Jun</td>
<td></td>
</tr>
</tbody>
</table>

Calculation of BTPs using movement patterns

Male #2 and male #6 were captured in Spring of 1997 and 1998 respectively. Following release, each bird rejoined his mate. For a number of days there was no distinct pattern of movement. This period of exploration ended when movements were limited to an area in which the eventual nest site was located, the onset of what was termed the habituation BTP. This period ended when the female began laying. The laying and incubation BTPs began and ended on individually calculated dates based on breeding biology as explained earlier. The brood rearing BTP began on the hatching date. Movements were limited to a small area as the young chicks fed on insect matter and developed thermoregulation. When movements of the family covey suddenly expanded beyond this area a new BTP had begun, described in this study as the primary (1°) covey movements BTP. A distinct area was used during this BTP. The secondary (2°) covey movements BTP began when a second migration was made by the covey away from one area to a new location. The initiation dates of these BTPs are presented in Table 4.2.
Table 4.2  Dates calculated for the onset of habituation, $1^\circ$ and $2^\circ$ covey movement BTPs for pairs 1 & 2 in the present Boora study

<table>
<thead>
<tr>
<th>Initiation of:</th>
<th>Pair 1</th>
<th>Pair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habituation</td>
<td>16 April</td>
<td>24 March</td>
</tr>
<tr>
<td>$1^\circ$ covey mov.</td>
<td>20 August</td>
<td>27 July</td>
</tr>
<tr>
<td>$2^\circ$ covey mov.</td>
<td>12 November</td>
<td>28 Sept</td>
</tr>
</tbody>
</table>

Note that an initiation date for exploration could not be calculated as the birds were captured during this BTP. Drawing a line from one radio-fix to the next, with a different coloured line for each BTP, illustrated the movement patterns of the birds during tracking. The movement patterns for pairs 1 and 2 are presented in Fig. 4.4.

Therefore the BTPs recorded for breeding pairs in the present Boora study were exploration, habituation, laying, incubation, brood-rearing, primary and secondary covey movements. These were based on and coincided with changes in the movement patterns and breeding biology of the individual birds radio-tracked. As can be seen from Fig. 4.4 there were similarities in the pattern of movement between years. In both years the male bird wearing the transmitter died (probable fox predation) during the secondary covey movements BTP and therefore radio-contact was lost with the covey. Contact was lost with covey 2 before a clear pattern of movement was evident (Fig. 4.4). However visual sightings of covey 2 following male#6’s death confirmed that many of the same areas were used by this covey as for covey 1 the previous winter (S. Leonard, pers com.).
Figure 4.4 Movement patterns from one radio-fix to the next recorded for pair 1 & 2 in the present Boora study

Start of tracking
Finish of tracking

**Pair 1**
Tracking time: 10 April 1997-22 Jan 1998

**Pair 2**
Lullymore study

Long-term radio-tracking information (7-14 months) was collected for six birds in Lullymore (J. Hearshaw, unpubl. data). Three pairs of wild partridge were radio-tracked. The radio-tracking data was analysed, divided into BTPs using the same methods as previously and is presented here in Figs. 4.5-4.7. Note that the same scale is used in Fig. 4.4 (present Boora study) and Figs. 4.5-4.7 (Lullymore study). These highlight the significantly larger distances travelled by birds in Lullymore. In Figs. 4.6 & 4.7 some distances between successive radio-fixes were so large that they needed to be cut with a 2 km and 3 km break respectively to fit on the A4 page. There was less similarity in movement patterns between pairs, compared to Boora.

In Lullymore all three nests and one re-nesting attempt showed evidence of corvid predation. One pair produced chicks but it was suspected that a grey heron (*Ardea cinerea*) predated these shortly after hatching (B. Kavanagh, pers. com.). An unpredictable period of movement after predation (termed post nest predation, or post-clutch loss) was evident. In the Lullymore study 1° and 2° movement patterns were evident. These were also referred to as 1° and 2° covey movements but with the absence of young this referred to the pair and any other adults that may have joined the group. In two cases (Fig. 4.6 & 4.7) the tracking period continued through the winter (both radio-tracked males in the present Boora study were lost to predation at this time).

Pairs A & C were followed through to the end of 2° covey movements in late winter. From January pairs are formed or re-formed and coveys begin to break up. For both pair A and C a change in movement pattern corresponded with this period. This BTP was defined as covey break-up. Data for pair A indicated that covey break up was followed by an exploratory phase termed
Figure 4.5 Movement patterns from one radio-fix to the next recorded for pair A in the Lullymore study from 1992-93

Pair A
Tracking time: 18 Nov 92 - 14 Jul 93

- S: Start of tracking
- F: Finish of tracking
Figure 4.6 Movement patterns from one radio-fix to the next recorded for pair B in the Lullymore study in 1993

Pair B
Tracking time: 20 Feb 93 - 27 Nov 93

- Start of tracking
- Finish of tracking
- Known nest location

Legend:
- Exploration
- Habituation
- Laying & Incubation
- Post nest predation
- Re-lying attempt & Incubation
- Post nest predation
- 1st covey movements
- 2nd covey movements
Figure 4.7 Movement patterns from one radio-fix to the next recorded for pair C in the Lullymore study from 1993-1994

Pair C
Tracking time: 20 Apr 93 - 15 Feb 94
exploration. The male partner of both pairs radio-tracked in the present Boora study had been captured during this exploratory phase.

Table 4.3 Dates calculated for the initiation of BTPs for three wild breeding pairs radio-tracked in Lullymore, 1993-94.

<table>
<thead>
<tr>
<th>B.T.P.</th>
<th>Pair A Fig. 4.4</th>
<th>Pair B Fig. 4.5</th>
<th>Pair C Fig. 4.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covey break-up</td>
<td>7 Feb</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Exploration</td>
<td>21 Apr</td>
<td>-</td>
<td>27 Apr</td>
</tr>
<tr>
<td>Habituation</td>
<td>2 May</td>
<td>24 Feb</td>
<td>24 May</td>
</tr>
<tr>
<td>Laying</td>
<td>15 May</td>
<td>10 May</td>
<td>28 Jun</td>
</tr>
<tr>
<td>Incubation</td>
<td>5 June</td>
<td>31 May</td>
<td>18 Jul</td>
</tr>
<tr>
<td>Brood rearing</td>
<td>-</td>
<td>-</td>
<td>12 Aug</td>
</tr>
<tr>
<td>Post predation</td>
<td>-</td>
<td>3 Jun</td>
<td>13 Aug</td>
</tr>
<tr>
<td>Relaying</td>
<td>-</td>
<td>16 Jun</td>
<td>-</td>
</tr>
<tr>
<td>Incubation</td>
<td>-</td>
<td>28 Jun</td>
<td>-</td>
</tr>
<tr>
<td>Post predation</td>
<td>30 Jun</td>
<td>19 Jul</td>
<td>-</td>
</tr>
<tr>
<td>1° covey mov.</td>
<td>-</td>
<td>27 Jul</td>
<td>19 Aug</td>
</tr>
<tr>
<td>2° covey mov.</td>
<td>-</td>
<td>24 Sep</td>
<td>10 Oct</td>
</tr>
<tr>
<td>Covey break-up</td>
<td>-</td>
<td>-</td>
<td>29 Jan</td>
</tr>
</tbody>
</table>

Legend: "-" in a column denotes that the corresponding BTP did not apply.

The Partridge Year

Previous studies and data analysis for pairs 1 & 2 in the present Boora study and pairs A,B & C in the Lullymore study were used to provide a model of the BTPs that can be applied to Irish partridge during the year. These are summarised below for a typical breeding pair in the absence of predation. Fig. 4.8 presents the BTPs in a pie chart with an estimated duration for each BTP from information gathered to date.

Covey break-up: male birds leave the covey to find potential partners or reform with a pair of the previous breeding season (Jenkins, 1961a). Once a
pair bond is formed there may be a period of isolation (Church et al, 1980) followed by the period of exploration. An isolation period was not observed in Ireland to date.

**Exploration:** first described by Church et al. (1980), when radio-tracking pre-nesting pairs in Wisconsin. A similar movement pattern was observed in the Lullymore and in the present Boora study. It involved large (1-2 km) movements across the study area by the newly formed or reformed pair with no obvious centre of activity.

**Habituation:** began when movement patterns of a pair became more restricted to an area in which the eventual nest site was initiated. Church et al. (1980) described similar movement patterns.

**Laying:** the hen is laying eggs on the nest. At this time the hen is only present at the nest for 2% of the time all visits being during the day (Fant, 1953). An average of one egg is laid every 1.4 days over 21 days (Potts, 1980; 1986). The onset of laying varies between birds depending on the date of pairing and partridge are persistent renesters when a nest is destroyed, with as many as 4 nests initiated in a single season (Carroll, 1993).

**Incubation:** this time period referred to the duration the hen was incubating the clutch of eggs. At this time the hen is present at the nest for 90% of the time, all absences being during the day (Fant, 1953). The cock calls the hen off the nest to feed (G.R. Potts, pers com.).

**Brood-rearing:** begins when the chicks hatch. The movements of the parents and brood were restricted in the present Boora study until the chicks reached
5-7 weeks. A number of studies have investigated movements during this BTP. (Church, 1980; Green, 1984; Rands, 1986a, Carroll et al., 1990).

**Primary covey movements:** this BTP began with a sudden movement by the covey out of the brood rearing area in the late summer.

**Secondary covey movements:** this BTP began with a sudden movement out of the previous areas used to a new area in which the covey remained through the winter.

![Figure 4.8](image.png)

**Figure 4.8** Sample duration (in days) of each BTP in the partridge year as estimated from available Irish radio-tracking data

The data collected for an unpaired wild male in the present Boora study, were divided into 5 distinct BTPs based on movement patterns during 8 months radio-tracking. These were unrelated to the time periods used for the breeding pairs. As only one unpaired male was tracked for this length of time it is not known if these time periods are typical or variable from one individual to the next. See Chp. 6 for more details.
It should be noted that changes in the movement patterns of the birds in Lullymore and the present Boora study appeared to be unrelated to any obvious changes in the landscape. The study areas (Fig. 2.2 & 2.3) were largely bogland type habitats with agricultural land being grassland dominant. In most other partridge studies farming activity is the main emphasis in study areas, in particular with large areas of tillage in autumn being ploughed at the same time, drastically altering the landscape.
4.4 Discussion

Many partridge radio-tracking studies have used time periods based on pre-determined calendar dates for the purpose of investigating home range and habitat use. These dates are often chosen by the researcher rather than being influenced by changes in the requirements of individual partridge. It is my opinion that these researchers could have defined biological time periods (BTP) for each radio-tracked individual based on breeding biology and changes in movement patterns where appropriate. Then the data could be analysed, for example by comparing home range and habitat use for each individual during the BTP (such as laying, incubation etc.).

By choosing arbitrary dates for a time period and then looking for trends between individuals within this time frame, there is the risk that much variation will be included in the data. Carroll et al. (1990) discussed how many researchers had ignored reproductive status of individual birds (egg laying, incubation, brood rearing) when defining time periods, because they pooled the radio-tracking data into a 'summer' period. For example, some birds may have finished laying while others may be still searching for a nest site at the start of a randomly chosen date in the summer. These birds will have different requirements, which would affect their home range and habitat use. By pooling this kind of data from different stages of a life cycle there lies the potential to mask otherwise obvious trends. For the Irish data, defining BTPs was useful in identifying when movement patterns changed dramatically. However, the sample size was low and application may be limited to the interpretation of Irish data only.
The following studies used pre-determined calendar dates.

**Monthly time periods**

McCrow (1977) radio-tracked 3 partridge. The time periods used were September–November, December-January, July and August. Smith *et al.* (1982) radio-tracked 46 partridge. Bi-monthly time periods, from December to August were used over a two-year study. Reitz & Mayot (1999) investigated movement patterns of 85 radio-tracked partridge in 4 study areas from late summer (August) to the following spring. Monthly intervals were the time periods used.

**Seasonal time periods**

Birkan *et al.* (1992) radio-tracked 20 partridge using a Spring-Summer (May-August) time period to compare home range and habitat use. Church (1994) used a summer time period (May-September) to compare data collected for 23 radio-tracked partridge over two years. The author stated that the data were too limited for separate analysis by behaviour or breeding status and only described general patterns in habitat use. Church & Porter (1990a) compared habitat use of translocated partridge and established partridge. A winter and a springtime period were selected to compare the radio-tracking data. Kaiser (1998) investigated habitat use for 33 partridge coveys using an autumn (August-October) and a winter (November-January) time period. Thomaides *et al.* (2001) calculated winter (October-January) home ranges of 17 coveys.
The following studies have used biological time periods as opposed to calendar dates.

**Pre-nesting pairs**
Church *et al.* (1980) investigated movements and habitat use of 9 partridge from the date of known pairing to 30 April in 1979. They discovered three distinct BTPs, isolation exploration and habituation for these pre-nesting movement patterns.

**Breeding season**
Rands (1986a) radio-tracked 9 broods for the first 21 days after hatching, to investigate the effect of pesticides on survival and movement patterns. Thomaides *et al.* (2001) used the period from egg laying to hatching to calculate home ranges for 12 pairs. Carroll *et al.* (1990) calculated home ranges, habitat use and movements of radio-tracked partridge during several stages of the nesting and brood-rearing season.

**Post-breeding interval**
Primary and secondary covey movements were defined for the present Boora and Lullymore data. This replaced the use of terms such as “autumn” and “winter” time periods, which are based on calendar dates. The observed change in movement patterns that resulted in the definition of these BTPs, may of course be unique to Irish populations. Only one or possibly several BTPs may be needed to define this time interval in other populations. However, if partridge radio-tracking studies continue to use pre-determined dates over the autumn-winter period this question will remain unanswered. As a final comment, the BTP from covey break-up to when pairs are formed or reformed should be referred to as ‘covey break-up’ not ‘spring’. This is because spring
can refer to any time from March up to the end of May when some female partridge could even be incubating!

**Summary**

The BTPs described in this study are the first known attempt to define the movement patterns of grey partridge throughout the year. These BTPs were useful in interpreting radio-tracking data collected for partridge in cutaway bog areas. The limitation of the study is that a sample size of five wild breeding pairs was extremely small and no bird was followed for a complete 365-day period. However, the designation of these BTPs highlighted the influence of habitat availability on movement patterns in Chps. 5 & 6. The BTPs defined will also aid future assessment of survey data in Boora.

It is unlikely that other researchers will re-analyse their published data for each individual bird radio-tracked. However, I would recommend that future studies with large data sets should consider this approach, rather than using calendar dates to separate sets of radio-fixes. It is possible that changes in movement patterns for Irish partridge were easier to detect, compared to other studies where the distance between suitable breeding and wintering habitats are smaller. The purpose of this chapter was to introduce the reader to the BTPs defined in the study. Home range analysis, habitat use and preferences within each BTP, are the subjects of the following chapter.
Chapter 5

CALCULATION OF HOME RANGES AND HABITAT PREFERENCES
5.1 Introduction

A home range consists of a restricted area within which an animal moves when performing its normal activities. Blank & Ash (1956) studied movement patterns of partridge individually marked with plastic tabs. The authors pointed out that the strict definition of territory as "any area defended against members of the same species", was not strictly applicable to partridge. Based on sightings of birds within a distinct time period (pairs in spring and coveys in autumn and winter), shapes of various shapes and size were drawn on a map. Each shape represented the area used by a marked bird and contained all sightings for that bird within it. This is the first illustration of home range for partridge that appears in the literature. Since the 1960's radio-transmitters have been the most commonly used method of obtaining location data on animals for the purpose of home range analysis, although other location methods can also be used (Voigt & Tinline, 1980).

The internal home range or core areas, illustrate where activities of the animal may be centred. A wide variety of methods have been published on the estimation of core areas (Kenward, 1987; Harris et al., 1990; White & Garrot, 1990; Wray et al., 1992a,b; Casaer et al., 1998; Robertson et al., 1998). In this study the software package Ranges V (Kenward, 1996) was used and the methods that were available for home range analysis and those chosen to calculate habitat preferences are described in the next section.
5.2 Methods

Home range analysis

The purpose of analysis was twofold. The overall area of land used by partridge during a BTP was estimated. Within this home range the location of core areas were estimated. Radio-fixes collected for pair 1 were used to illustrate how the methods available within the Ranges V program produce different results for the same data set (Fig. 5.1). For all methods except concave polygons, home ranges were defined by utilisation distributions. These are lines of equal probability termed “isolines” (Kenward, 1996). The outer home range is defined by the 100% isoline (or 99% depending on analysis options) with internal home ranges defined by smaller percentages. In Fig. 5.1 these are illustrated in 5% decrements. For example the 95% isoline delimits the area in which there is a 95% probability of finding the animal based on that sample of radio-fixes.

In this study the core area was measured as the concentration of activity within the home range. This was based on the spatial distribution of radio-fixes recorded (Wray et al., 1990b). Core areas were calculated by plotting percentage of area against percentage of fixes at each 5% isoline. The core area was defined as the point where the gradient of this plot changes. Even for the same data set, estimates of core area locations and size will be different depending the method used.

Each home range analysis method available in the Ranges V package is briefly explained, within the context of this study.
Figure 5.1 Home range analysis of a radio-tracking data set (pair 1 radio-fixes, n=196) using Ranges V methods.

a Multiple Convex Polygon
100% = 383 ha
Core area is 90% = 178 ha

b Concave Polygon
Set at 0.2*max. range width
100% = 200 ha
No core area calculated

c Ellipses
99% = 508 ha
Core area is 95% = 330 ha

d Harmonic Mean Analysis
Contours modelled on fix density
with unmodified fixes, edge detection
99% = 663 ha
Core area is 95% = 262 ha

e Kernel Analysis
Core weighting, modelling on fix density, edge detection and rescaling, Smoothing factor = 1
99% = 198 ha
Core area is 95% = 152 ha

f Cluster Analysis
Nearest neighbour joining priority
100% = 383 ha
Core area is 95% = 48 ha
Fig. 5.1a. The minimum convex polygon (MCP) defines a home range consisting of straight lines with angles greater than 180° joining radio-fixes at the periphery of the data set. A polygon is thus formed containing all the radio-fixes in that time period. It was first described by Mohr (1947) and refined by Southwood (1966). Both the outermost (100%) area and shape will be strongly influenced by these outermost fixes. Isolines (5 - 95%) can be defined (Rolando & Cariso, 1999; Pereira et al., 2001) but some of the other methods below are more commonly used to calculate these in radio-tracking studies. For the example data set (Fig. 5.1a) the core area was defined by the 90% isoline.

Fig 5.1b. The Concave polygon method (also described as "restricted edge polygons") is useful in eliminating large areas where radio-fixes were not recorded from the home range (these would have been included using 100% MCP). Lines are only drawn between edge fixes if they are shorter than a selected fraction of the range width. This makes the range concave where there are large gaps between edge fixes (Kenward, 1996), thus removing the influence of the outermost fixes. Suppose radio-fixes occurred on both sides of a wetland. The MCP method would include wetland as a habitat within the home range. For grey partridge, water is not a habitat typically used (Potts, 1986). The concave method would produce a home range that did not include such a habitat within its boundary. As this situation did not arise during any BTP the concave method was not necessary.

The concave method does not include the option of producing isolines. Instead, the width fraction used to set the minimum edge length will determine the area of the home range and by varying these values the shape most suited
to the terrain can be produced. For the example (Fig. 5.1b) this was set at 0.2 times the maximum range width.

Fig 5.2c Ellipses (Jenrich & Turner, 1969) produce contoured isolines because they predict a normal distribution of radio-fixes. For this study the method did not define range shape well. Its advantage is that it requires few radio-fixes to calculate a maximum area estimate. It is therefore useful for estimating habitat available to animals radio-tracked infrequently and was not used in this study.

Fig 5.1d Harmonic mean analysis (Dixon & Chapman, 1980) estimates the fix density distribution (equivalent to the probability of encountering the animal) at intersections of an arbitrary grid. When calculating ranges there are a number of analysis options with each combination affecting the shape of the contours. Contours may be fitted to fixes or modelled on the fix density alone. Within these two parameters there is a choice of fixes centred between grid intersections or unmodified fixes. It is the researcher who decides which of the combinations is most appropriate to use. For this study contours were modelled to fix density, with fixes unmodified and with edge detection and rescaling. This combination consistently produced the smallest home range estimate. It should be noted that when contours are modelled to fix density, the outermost isoline is 99% not 100%. For the example data set (Fig. 5.1d) the core area was defined by the 95% isoline.

Fig 5.1e Kernel analysis (Worton, 1989) is a mathematical modification of the harmonic mean approach. It provides more consistent results because it is less grid dependant than harmonic mean analysis (Kenward, 1996). Again, there are a number of analysis options. In this study core weighting with contours modelled on fix density, and edge detection with rescaling gave the lowest
home range estimates with the outermost isoline set at 99%. Variation in home range calculation also depends on the smoothing factor (0.1 to 2.0) used. For the options chosen, a smoothing factor of 0.1 estimated a home range of 130 ha, a factor of 1 estimated 198 ha and 2 estimated 335 ha for the male #2 data set. A smoothing factor of 1 gave the best result. For these parameters the core area was defined by the 95% isoline for the data set in Fig. 5.1e.

Fig. 5.1f Cluster analysis (Kenward, 1987) is very useful in identifying several core areas in a home range. This can occur where an animal used several discrete areas that might not be identified using the previous methods. The closest two fixes in the data set with a nearest 3\textsuperscript{rd} fix are identified as the first cluster. Formation of a second and subsequent clusters depends on the relative distances of these to surrounding fixes. Once all clusters are defined convex polygons are drawn around them. There are two analysis options, nearest neighbour priority and centroid rule. Nearest neighbour priority identified more core areas than the centroid rule option. For the male #2 data set (Fig. 5.1f) the core area was defined by the 95% isoline. Cluster analysis was used to identify key areas used by partridge in the study site. The shape of the core areas calculated is more representative visually of radio-fix density than either harmonic mean or kernel analysis. Overlaying the core area polygons calculated by cluster analysis on a map of the study area serves to highlight these regions. The researcher can visit these areas for further assessment and comparison with other sites known to contain partridge.

Fig. 5.1 illustrates that the range size calculated depends very much on the initial parameters set, and that varying estimates of range size can be obtained from the same set of raw data. This makes comparison of home ranges between studies difficult for all methods except the MCP. While many studies
state the percentage isoline at which internal home ranges were defined (for example, home range defined by harmonic mean analysis 90% isoline in Birkan et al., 1992), analysis options chosen within the method are not. This difficulty is compounded by the fact that a variety of computer packages can be used for home range analysis. These may use different processing algorithms and number of cells within the analysis grid (Harris et al., 1990). Therefore, owing to its simple methodology only the MCP is directly comparable between studies and should always be included with results from other methods.

Harris et al. (1990) recommend the use of several methods to calculate core areas, because of differences in results between techniques. In this study, MCPs were used to calculate outer home ranges and core areas were calculated using harmonic mean analysis, kernel analysis and cluster analysis. The results of these methods are frequently published in radio-tracking papers (Wray et al., 1992b). Concave and ellipse analysis were not used in this study for reasons explained earlier. In summary, home ranges were analysed using the following methods and parameters.

1. Multiple Convex Polygons (MCP), outer 100% polygon only.
2. Harmonic Mean Analysis (HM) core areas. Using contours modelled on fix density with unmodified fixes and edge detection and rescaling.
3. Kernel Analysis (KL) core areas. Using core weighting, contours modelled on fix density, smoothing factor of 1, and edge detection and rescaling.
For each data set to be analysed it was necessary to plot the number of fixes against the range size until an asymptote was reached, i.e. additional radio-fixes recorded in the data set should not significantly increase the size of the home range. Estimates for individual home ranges reached asymptotes at different values ranging from 10 to 40 radio-fixes, depending on movement patterns and range size for each data set. If an asymptote is not reached this could indicate that the animal was radio-tracked during a migratory stage (i.e. exploration BTP), that too few radio-fixes were recorded or that radio-tracking was for an insufficient time period (i.e. loss of radio-contact with covey 2 at the beginning of the 2° covey movements). An estimation of area used at that point can be made but this should not be defined as the home range of the animal tracked. Therefore, it was not possible to calculate home ranges areas for every BTP.

The shift in home range between successive BTPs can be measured as the distance between the centres of each home range (Dudzinski, 1988b; Reitz & Mayot, 1999; Church & Porter, 1990). The arithmetic mean is a single point defined as the centre of the home range, based on the spatial distribution of the radio-fixes (Harris et al., 1990; Kenward, 1996; Reitz & Mayot, 1999). Thus, the distance measured between the arithmetic mean for successive BTPs gave an index of the shift in home range.

**Habitat use**

Habitat use in each BTP was calculated from the proportion of radio-fixes recorded in each of the habitat types discussed in Chp. 2. These calculations give an estimate of the time spent in each of the habitats types in the study area. For any one habitat this can vary from 0-100%. However it should be noted that the habitat type containing the majority of radio-fixes may not
always be the most crucial one. This will depend on the relative availability of habitats. Thus, while an examination of habitat use in itself is important, one must also consider habitat preferences.

**Habitat preference**

A common aim of radio-tracking studies is to determine how a species uses the habitats available to it. If certain habitats are preferred, this may effect species movement patterns and therefore, influence the home range. A number of methods have been widely used to calculate habitat preferences.

The chi-squared statistic tests whether usage of habitats is in proportion to their availability. Where a significant difference is recorded, a Bonferroni-z-statistic is applied to identify which habitats are used more and less than expected (Neu et al., 1974, revised by Byers et al., 1984). A great source of error is in the pooling of data, where every radio-fix recorded for each animal is given equal weight. Thus, the data set can be influenced significantly by unequal sampling of radio-fixes between animals in a study, particularly in the case of aberrant behaviour by one frequently located individual (Aldridge & Ratti, 1986; 1992). Another weakness is non-independence of proportions (habitat proportions sum to 1 over all categories). This entails that preference for one category automatically leads to avoidance of all others, therefore absolute preferences cannot be truly calculated. The existence of the unit sum constraint also means that techniques such as those of Friedman (1937) and Quade (1979) cannot be used (Aebischer et al, 1993).

Johnson (1980) used rankings of preference in relation to rankings of availability. Aldridge & Ratti (1992) tested this method with simulated field data and found that three out of a possible four habitat types were ranked as
equally preferred, whereas in fact two of these were used twice as much as would be expected from availability, with the third used as expected.

Habitat preferences in this study were analysed using Compositional Analysis (Aitchison, 1986; Aebischer & Robertson, 1992; Dowell et al., 1992; Aebischer et al., 1993). With this method each animal tracked is a sample unit, and the number of animals tracked in the same time period is the sample size. The proportion of habitat available to the animal is compared with habitat selected. Given D habitat types, an individual’s proportional habitat use is described by \( x_1, x_2, \ldots, x_D \), where \( x_i \) is the proportion of the individual’s trajectory or home range in habitat \( i \). Such a set of components summing to one is a composition (Aebischer et al. 1993). Aitchison (1986) showed that for any component \( x_j \) of a composition, the log ratio transformation \( y_i = \ln(x_i/x_j) \), \((i=1, \ldots, D, i \text{ not equal to } j)\) renders \( y_i \) linearly independent. Therefore, transforming the habitat proportions into log ratios renders each proportion independent from the rest (Aebischer et al., 1993).

A matrix of log ratio differences is produced for each sample (Table 5.1). The mean and standard error are calculated over all samples, for each element of the matrix. Analysis of the data produces a ranking system from most preferred to least preferred habitats. However, as outlined by Aebischer et al. (1993), a minimum of six birds in each time period is needed to test for statistically significant results, with a sample size of 30 recommended to make inferences about population trends. Given the endangered status of the grey partridge in Ireland (Whilde, 1993), the minimum sample size was not reached and the results were treated on an individual basis. Therefore, ranks were calculated from the relative values of the log ratio differences. In the worked example (Table 5.1) ranks are produced from the matrix elements for
illustrative purposes, but in practice the same ranks result from the row of log ratio differences when samples are analysed individually. For example, in Table 5.1, comparing habitats in the home range (MCP) with availability in the study area, cutaway bog with a log ratio difference of 1.739, was the highest value (rank 12). By contrast, tree categories with a log ratio difference of –6.869, was the lowest value (rank 0).

As recommended (Aebischer & Robertson, 1992), partridge habitat preferences were calculated in two stages, first by examining selection of a home range from within the study area, and second by examining use of particular types of habitat within that home range.

1. MCP versus STUDY AREA (Home range selection). The proportion of habitat types contained within the home range, as defined by the MCP, were compared with the proportion available in the study area. The study area was defined by the MCP for all radio-fixes recorded for all partridge (see Chp 2). This analysis investigates whether selection of the home range is preferential to the availability of particular habitat types.

2. USE versus MCP (Habitat selection). The proportion of radio-fixes recorded in each habitat type, compared with the proportion available within the home range as defined by the MCP. This analysis investigates whether some habitats are being used preferentially within the home range.

Ideally, all habitat types are available to and used by each bird. In practice however, the MCP may not contain some habitat types that were available in the study area, or no radio-fixes may be recorded in some habitat types that were available within the MCP. Therefore, the corresponding proportion is
Table 5.1. Worked example of Compositional Analysis for pair 2 (1998) habitat preferences, during primary covey movements in the present Boora study

Ranking is determined by the number of positive integers (zero value omitted) calculated for each habitat type
In this example the proportions of habitat in the MCP were compared with the proportion of habitats available in the study area

<table>
<thead>
<tr>
<th>MCP vs STUDY AREA</th>
<th>Cutaway bog</th>
<th>Private bog</th>
<th>Heather top</th>
<th>Young forestry</th>
<th>Other tree cat</th>
<th>Grass</th>
<th>Tillage</th>
<th>Game crop</th>
<th>Edge</th>
<th>Hedgerow</th>
<th>Drain</th>
<th>Building</th>
<th>Wetland</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP</td>
<td>0.268</td>
<td>0.016</td>
<td>0.004</td>
<td>0.101</td>
<td>0.490</td>
<td>0.019</td>
<td>0.011</td>
<td>0.032</td>
<td>0.009</td>
<td>0.000</td>
<td></td>
<td></td>
<td>0.049</td>
</tr>
<tr>
<td>Study area</td>
<td>0.287</td>
<td>0.087</td>
<td>0.023</td>
<td>0.019</td>
<td>0.103</td>
<td>0.316</td>
<td>0.033</td>
<td>0.016</td>
<td>0.043</td>
<td>0.012</td>
<td>0.053</td>
<td>0.003</td>
<td>0.006</td>
</tr>
<tr>
<td>InR MCP</td>
<td>0.000</td>
<td>-2.818</td>
<td>-4.205</td>
<td>-0.976</td>
<td>-7.894</td>
<td>0.603</td>
<td>-2.647</td>
<td>-3.193</td>
<td>-2.125</td>
<td>-3.394</td>
<td>-1.699</td>
<td>-7.894</td>
<td>-7.894</td>
</tr>
<tr>
<td>InR Study area</td>
<td>0.000</td>
<td>-1.194</td>
<td>-2.524</td>
<td>-2.715</td>
<td>-1.025</td>
<td>0.096</td>
<td>-2.163</td>
<td>-2.887</td>
<td>-1.898</td>
<td>-3.175</td>
<td>-1.689</td>
<td>-4.561</td>
<td>-3.868</td>
</tr>
<tr>
<td>DIFF</td>
<td>0.000</td>
<td>-1.625</td>
<td>-1.681</td>
<td>1.739</td>
<td>-6.869</td>
<td>0.507</td>
<td>-0.484</td>
<td>-0.306</td>
<td>-0.227</td>
<td>-0.219</td>
<td>-0.010</td>
<td>-3.333</td>
<td>-4.026</td>
</tr>
</tbody>
</table>

Young forestry (Rank = 12) was calculated to be the most preferred habitat type
Table 5.1 (cont.)

Ranking is determined by the number of positive integers (shaded boxes) calculated for each habitat type. In this example, the proportions of radio-fixes in each habitat (habitat use) were compared with the proportion of habitats available in the MCP.

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>USE</th>
<th>MCP</th>
<th>InR Use</th>
<th>InR MCP</th>
<th>DIFF</th>
<th>RANK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutaway bog</td>
<td>0.224</td>
<td>0.268</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>5</td>
</tr>
<tr>
<td>Private bog</td>
<td>0.016</td>
<td>0.016</td>
<td>-7.714</td>
<td>-2.818</td>
<td>-4.896</td>
<td>2</td>
</tr>
<tr>
<td>Heather top</td>
<td>0.004</td>
<td>0.004</td>
<td>-7.714</td>
<td>-4.205</td>
<td>-3.510</td>
<td>4</td>
</tr>
<tr>
<td>Young forest</td>
<td>0.104</td>
<td>0.019</td>
<td>-0.312</td>
<td>-0.976</td>
<td>-0.664</td>
<td>7</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.448</td>
<td>0.490</td>
<td>0.693</td>
<td>0.603</td>
<td>0.664</td>
<td>6</td>
</tr>
<tr>
<td>Tillage</td>
<td>0.060</td>
<td>0.101</td>
<td>-7.714</td>
<td>-0.004</td>
<td>-5.068</td>
<td>1</td>
</tr>
<tr>
<td>Game crop</td>
<td>0.104</td>
<td>0.009</td>
<td>-1.317</td>
<td>-0.016</td>
<td>-1.358</td>
<td>9</td>
</tr>
<tr>
<td>Edge</td>
<td>0.149</td>
<td>0.032</td>
<td>-0.767</td>
<td>-0.011</td>
<td>-5.068</td>
<td>8</td>
</tr>
<tr>
<td>Hedgerow</td>
<td>0.049</td>
<td>0.049</td>
<td>-7.714</td>
<td>-7.714</td>
<td>-7.714</td>
<td>3</td>
</tr>
<tr>
<td>Drain</td>
<td>0.000</td>
<td>0.000</td>
<td>-7.714</td>
<td>-7.714</td>
<td>-7.714</td>
<td>0</td>
</tr>
</tbody>
</table>

Game crop (Rank = 9) was calculated to be the most preferred habitat type.
positive in its availability but zero in its selection. This implies that selection was so low it was undetected (one must keep in mind that radio-fixes are only a sample of actual use). Since a zero value cannot be used in the log ratio transformation, the solution is to remove the zero value and substitute a small positive value that is less than the smallest recorded non-zero proportion (Aebischer et al., 1993).
5.3 Results

Home range analysis

Home ranges were calculated in each BTP for pairs 1 & 2 in the present Boora study (Table 5.2) and pairs A, B & C in the Lullymore study (Table 5.3). MCP calculations gave an indication of the maximum area used while the other three methods estimated the size of core areas used. For MCP analysis, the home range was defined by the 100% isoline. Core areas were calculated using harmonic mean, kernel and cluster analysis, defined by isolines that varied between 85-95% (Table 5.2 & 5.3). An estimate of total home range was calculated for each bird using all radio-fixes recorded during fieldwork. This area (mean MCP +/- se) was variable, but was significantly larger in Lullymore (1632.1 +/- 191.8 ha, n=3), compared to Boora (291.8 +/- 91.8 ha, n=2), t3=5.218, p<0.05, owing to large home range shifts between BTPs in Lullymore. Shifts in home range were less than 1 km during the breeding season (habituation-laying, laying-incubation, incubation-brood rearing), but varied from 0.15-6.05 km between other time periods (Table 5.4).

Mean home ranges (MCP, +/- se) for each BTP were: covey break-up (234.8 ha, n=1), habituation (40.4 +/- 10.7 ha, n=5), laying (32.1 +/- 11.8 ha, n=5), incubation (11.4 +/- 7.3 ha, n=5), brood rearing (9.1 +/- 4 ha, n=2), primary covey movements (157.7 +/- 67.7 ha, n=4) and secondary covey movements (87.7 ha, n=1). A complete set of data for covey break-up and 2° covey movements were only available for pair A and pair C. For pairs 1 & 2, and pairs A & B, estimates of area used up to the date of contact loss were provided for 2° covey movements. The largest home range in any one BTP was for pair C, 1° covey movements (MCP = 357 ha).
Table 5.2. Home ranges calculated for pairs 1 and 2 from 1997-1998, in the present Boora study

<table>
<thead>
<tr>
<th>BTP</th>
<th>Fixes</th>
<th>Days</th>
<th>Start</th>
<th>Finish</th>
<th>MCP 100% ha</th>
<th>HM 95/90% ha</th>
<th>KL 95/90% ha</th>
<th>CL 95/90% ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habituation</td>
<td>27</td>
<td>30</td>
<td>16-Apr-97</td>
<td>15-May-97</td>
<td>80.7</td>
<td>40.3</td>
<td>39.4</td>
<td>*6.9</td>
</tr>
<tr>
<td>Laying</td>
<td>21</td>
<td>21</td>
<td>16-May-97</td>
<td>05-Jun-97</td>
<td>8.2</td>
<td>1.6</td>
<td>2.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Incubation</td>
<td>26</td>
<td>25</td>
<td>06-Jun-97</td>
<td>30-Jun-97</td>
<td>5.5</td>
<td>3.0</td>
<td>2.9</td>
<td>*0.8</td>
</tr>
<tr>
<td>Brood rearing</td>
<td>41</td>
<td>50</td>
<td>01-Jul-97</td>
<td>19-Aug-97</td>
<td>5.1</td>
<td>5.7</td>
<td>3.5</td>
<td>3.0</td>
</tr>
<tr>
<td>1° covey mov.</td>
<td>50</td>
<td>79</td>
<td>20-Aug-97</td>
<td>06-Nov-97</td>
<td>77.4</td>
<td>*42.3</td>
<td>*34.2</td>
<td>*16.8</td>
</tr>
<tr>
<td>2° covey mov.</td>
<td>28</td>
<td>77</td>
<td>07-Nov-97</td>
<td>22-Jan-98</td>
<td>91.9</td>
<td>69.2</td>
<td>*92.2</td>
<td>*14.4</td>
</tr>
<tr>
<td>All radio-fixes</td>
<td>196</td>
<td>288</td>
<td>10-Apr-97</td>
<td>22-Jan-98</td>
<td>383.3</td>
<td>262.2</td>
<td>152.1</td>
<td>49.9</td>
</tr>
<tr>
<td>Pair 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habituation</td>
<td>35</td>
<td>41</td>
<td>24-Mar-98</td>
<td>03-May-98</td>
<td>19.5</td>
<td>9.2</td>
<td>16.2</td>
<td>9.8</td>
</tr>
<tr>
<td>Laying</td>
<td>17</td>
<td>21</td>
<td>04-May-98</td>
<td>25-May-98</td>
<td>20.4</td>
<td>10.3</td>
<td>*13.9</td>
<td>5.0</td>
</tr>
<tr>
<td>Incubation</td>
<td>26</td>
<td>25</td>
<td>26-May-98</td>
<td>19-Jun-98</td>
<td>6.7</td>
<td>3.9</td>
<td>3.7</td>
<td>3.4</td>
</tr>
<tr>
<td>Brood rearing</td>
<td>31</td>
<td>37</td>
<td>20-Jun-98</td>
<td>26-Jul-98</td>
<td>13.0</td>
<td>*4.2</td>
<td>8.5</td>
<td>1.1</td>
</tr>
<tr>
<td>1° covey mov.</td>
<td>67</td>
<td>63</td>
<td>27-Jul-98</td>
<td>27-Sep-98</td>
<td>68.1</td>
<td>48.0</td>
<td>39.8</td>
<td>*32.3</td>
</tr>
<tr>
<td>2° covey mov.</td>
<td>16</td>
<td>18</td>
<td>28-Sep-98</td>
<td>15-Oct-98</td>
<td>84.3</td>
<td>*17.6</td>
<td>81.6</td>
<td>*24.2</td>
</tr>
<tr>
<td>All radio-fixes</td>
<td>200</td>
<td>220</td>
<td>10-Mar-98</td>
<td>15-Oct-98</td>
<td>200.2</td>
<td>89.9</td>
<td>62.9</td>
<td>54.7</td>
</tr>
</tbody>
</table>

MCP 100% = Multiple Convex Polygon, area defined by 100% isoline
HM 95/90% = Harmonic Mean Analysis, area defined by 95 or 90% isoline
KL 95/90% = Kernel Analysis, area defined by 95 or 90% isoline
CL 95/90% = Cluster Analysis, area defined by 95 or 90% isoline

NOTE: 2° covey movements for both birds were not completed due to bird loss. Therefore area calculation is an estimate to that date, and not a home range.
<table>
<thead>
<tr>
<th>BTP</th>
<th>Fixes</th>
<th>Days</th>
<th>Start</th>
<th>Finish</th>
<th>MCP 100% ha</th>
<th>HM 95% ha</th>
<th>KL 95% ha</th>
<th>CL 95/90% **85% ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2° covey mov</td>
<td>65</td>
<td>108</td>
<td>18-Nov-92</td>
<td>06-Feb-93</td>
<td>109.2</td>
<td>68.8</td>
<td>66.1</td>
<td>52.4</td>
</tr>
<tr>
<td>Covey break-up</td>
<td>62</td>
<td>73</td>
<td>07-Feb-93</td>
<td>20-Apr-93</td>
<td>234.8</td>
<td>66.6</td>
<td>43.3</td>
<td>14.3</td>
</tr>
<tr>
<td>Habituation</td>
<td>15</td>
<td>14</td>
<td>02-May-93</td>
<td>14-May-93</td>
<td>38.9</td>
<td>5.7</td>
<td>16.0</td>
<td>3.1</td>
</tr>
<tr>
<td>Laying</td>
<td>22</td>
<td>21</td>
<td>15-May-93</td>
<td>04-Jun-93</td>
<td>51.7</td>
<td>15.0</td>
<td>48.5</td>
<td>**9.5</td>
</tr>
<tr>
<td>Incubation</td>
<td>26</td>
<td>25</td>
<td>05-Jun-93</td>
<td>29-Jun-93</td>
<td>3.0</td>
<td>0.7</td>
<td>1.7</td>
<td>1.9</td>
</tr>
<tr>
<td>All radio-fixes</td>
<td>202</td>
<td>268</td>
<td>18-Nov-92</td>
<td>14-Jul-93</td>
<td>1532.9</td>
<td>445.7</td>
<td>564.5</td>
<td>111.0</td>
</tr>
</tbody>
</table>

| Pair B       |       |      |             |               |             |           |           |                  |
| Habituation  | 75    | 75   | 24-Feb-93   | 09-May-93     | 25.5        | 20.6      | 17.9      | 5.5             |
| Laying       | 29    | 21   | 10-May-93   | 30-May-93     | 11.8        | 7.9       | 6.8       | 0.4             |
| Relaying     | 13    | 12   | 16-Jun-93   | 27-Jun-93     | 43.4        | 14.9      | 14.4      | 3.1             |
| Incubation   | 19    | 21   | 28-Jun-93   | 18-Jul-93     | 1.1         | 0.7       | 0.9       | 0.4             |
| 1° covey mov | 38    | 59   | 27-Jul-93   | 23-Sep-93     | 128.4       | 92.7      | 65.4      | **22.3          |
| 2° covey mov | 35    | 65   | 24-Sep-93   | 27-Nov-93     | 273.5       | 180.4     | 108.9     | **12.8          |
| All radio-fixes | 232   | 281  | 20-Feb-93   | 27-Nov-93     | 2002.7      | 1217.1    | 1306.9    | 182.9           |

| Pair C       |       |      |             |               |             |           |           |                  |
| Habituation  | 41    | 35   | 24-May-93   | 27-Jun-93     | 37.4        | 22.7      | 14.6      | **3.4           |
| Laying       | 24    | 20   | 28-Jun-93   | 17-Jul-93     | 68.2        | 23.4      | 61.6      | **19.4          |
| Incubation   | 24    | 25   | 18-Jul-93   | 11-Aug-93     | 40.5        | 15.6      | 9.5       | **3.1           |
| 1° covey mov | 36    | 52   | 19-Aug-93   | 09-Oct-93     | 357.0       | 152.9     | 269.9     | 41.2            |
| 2° covey mov | 48    | 111  | 10-Oct-93   | 28-Jan-94     | 87.7        | 59.3      | 54.0      | **6.1           |
| All radio-fixes | 211   | 302  | 20-Apr-93   | 15-Feb-94     | 1360.8      | 689.8     | 549.7     | 87.8            |

MCP 100% = Multiple Convex Polygon, area defined by 100% isoline
HM 95% = Harmonic Mean Analysis, area defined by 95% isoline
KL 95% = Kernel Analysis, area defined by 95% isoline
CL 95/90/85% = Cluster Analysis, area defined by 95, 90 or 85% isoline

NOTE: 2° covey movements for pair A and B were not completed due to bird loss. Therefore area calculation is an estimate to that date, and not a home range.
Core areas calculated using cluster analysis gave consistently lower home range estimates than harmonic mean analysis or kernel analysis (Table 5.2 & 5.3). The location of these core areas shifted between BTPs in the present Boora study (Fig. 5.2 & 5.3) and the Lullymore study (Figs. 5.4-5.6). For BTPs during the breeding season, the relative size of the core areas were compared (Fig. 5.7). In the present Boora study, core areas declined in size from habituation through to brood rearing, (with the exception of an increase in size during brood rearing for pair 1). In Lullymore, results were variable and larger core areas during laying were evident for pair A & C, compared to either habituation or incubation.

Table 5.4  Home range shift (m) between successive BTPs for pairs 1&2 (1997-98) in the present Boora study and pairs A, B & C (1993-94) in the Lullymore study

<table>
<thead>
<tr>
<th></th>
<th>Sec. covey mov.</th>
<th>Covey breakup</th>
<th>Habituation</th>
<th>Laying</th>
<th>Re-laying</th>
<th>Incubation</th>
<th>Brood rearing</th>
<th>Prim. covey mov.</th>
<th>Sec. covey mov.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>36</td>
<td>73</td>
<td>42</td>
<td>528</td>
<td>1181</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 2</td>
<td>1966</td>
<td>5320</td>
<td>122</td>
<td>300</td>
<td>152</td>
<td>704</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair A</td>
<td>179</td>
<td>935</td>
<td>135</td>
<td>6045</td>
<td>1352</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair B</td>
<td>247</td>
<td>256</td>
<td>466</td>
<td>1594</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

83
Habitat use

Habitat use in the present Boora study varied between BTPs and between pairs (Fig. 5.8). The majority of radio-fixes for pair 1 during the breeding season BTPs were recorded in a young forestry belt. Core areas for pair 1 during incubation suggested that the nest was located within this young forestry belt (Fig. 5.2). Habitat use for pair 2 the following year was more variable with 51-65% of radio-fixes in young forestry during habituation and laying respectively. Cutaway bog was the most used habitat during incubation. Core areas for pair 2 during incubation suggested that the nest was located near a game crop (Fig. 5.3). During brood rearing, pair 2 moved into the same forestry belt as used the previous year by pair 1.

Habitat use changed dramatically during 1° covey movements in both cases (Fig. 5.8). Over 40% of radio-fixes recorded for both coveys 1 & 2 were in nearby grassland. Use of tillage (stubble fields and beet) was first evident during 2° covey movements. As illustrated in Figs. 5.2 & 5.3 use of tillage required a substantial shift of up to 1km from core areas previously used. Visual sightings of the covey 2 following the death of male #6 suggested that the same areas of pasture were used later in the BTP, as covey 1 had used the year previously.

Habitat use in the Lullymore study is illustrated in Fig. 5.9. During the breeding season BTPs, all radio-fixes for the three pairs were recorded on cutaway bog. Habitat use during 1° covey movements was mainly cutaway bog (one radio-fix on heather top) for pair B, while pair C used cutaway bog, private bog, heather top and agricultural land. Pair B moved to adjacent private bog, heather top and agricultural land during 2° covey movements but use of cutaway bog was still significant (49 %). Pair C habitat use during 2°
covey movements was mainly private bog with several radio-fixes recorded on agricultural land. Radio-tracking of pair A began during the latter part of 2° covey movements with habitat use limited to only cutaway bog. A shift in core areas during covey break-up corresponded with a switch in habitat use to mainly private bog (several radio-fixes recorded in heather top and one in cutaway bog and woodland).

Habitat preferences

As explained earlier, habitat preferences were obtained by comparing selection with availability on two levels. A combination of radio-fixes and the outline of the MCP for each BTP is given for pair 1 (Fig. 5.10) and pair 2 (Fig. 5.11) in the present Boora study for visual interpretation. This was not necessary for the Lullymore pairs, as the mapping was less detailed.

The data set for habitat availability (study area and each MCP) and habitat use in each BTP can be consulted in Appendices 2 & 3 for the present Boora study and Lullymore study, respectively. Appendix 4 (using data for pair 2, 1° covey movements) illustrates how habitat preferences were ranked using compositional analysis. The results are presented for the present Boora study in Table 5.5 and for Lullymore in Table 5.6. These were colour coded to the maps for ease of interpretation. The remainder of this section describes relevant details from these rankings.

Pair 1 (Table 5.5)

MCP versus STUDY AREA: Young forestry was the highest ranked habitat in all BTPs except during 2° covey movements, when the home range contained a high proportion of tillage (18%) compared to the study area (3%). This was the most preferred habitat during this period.
USE versus MCP: Edge was ranked highest during laying and 1° covey movements. In the first case, during laying this was based on a single radio-fix on a road at the edge of the home range, when all other radio-fixes had been recorded in young forestry (Fig. 5.10). Cutaway bog was highest ranked for 2° covey movements. This was also based on one radio-fix in the corner of the MCP. During this BTP tillage was ranked second highest with 43% use compared to 18% availability.

Pair 2 (Table 5.5)
MCP versus STUDY AREA: Young forestry was ranked highest for all BTPs except incubation and 2° covey movements. During incubation game crop was most preferred, while tillage was highest ranked for 2° covey movements.
USE versus MCP: Game crop was highest ranked for three BTPs. During habituation this was based on only one radio-fix however. Young forestry was most preferred for laying and brood rearing. During 2° covey movements edge was the most preferred habitat.

Pair A (Table 5.6)
Covey break-up was the only BTP where habitats other than cutaway bog were included in the home range.
MCP versus STUDY AREA: Private bog was ranked highest.
USE versus MCP: Private bog the most preferred habitat within the home range.

Pair B (Table 5.6)
More than one habitat was used in 1° and 2° covey movements.
MCP versus STUDY AREA: For 1° covey movements cutaway bog was ranked higher than heather top, as only 0.2% of the MCP contained heather
top. During $2^\circ$ covey movements, in a home range containing all 5 habitat types, heather top was highest ranked.

USE versus MCP: For $1^\circ$ covey movements, the single radio-fix in heather top in a corner of the MCP gave heather top a higher rank than cutaway bog. During $2^\circ$ covey movements agricultural land was most preferred.

**Pair C (Table 5.6)**

More than one habitat was used in $1^\circ$ and $2^\circ$ covey movements.

MCP versus STUDY AREA: During $1^\circ$ covey movements a high proportion of the home range (16%) consisted of heather top compared to the study area (8%) giving this habitat the highest rank. For $2^\circ$ covey movements private bog had the highest rank.

USE versus MCP: Agricultural land was most preferred during $1^\circ$ covey movements while private bog was highest ranked for $2^\circ$ covey movements.
Summary of results

A larger area of land was encountered by birds in Lullymore compared to Boora. This was because pairs in Lullymore tended to move large distances between successive BTPs outside the breeding season. During the breeding season, birds in both studies remained within cutaway bog areas. In Lullymore, only cutaway bog was used during this time. In Boora, a number of habitats were used but a preference for young forestry plantations on former cutaway bog was evident. Birds in both studies moved away from cutaway bog areas outside the breeding season. This is reflected by a greater diversity of habitats included in these home ranges, and an associated change in habitat use. In Boora, habitat use switched to mainly grassland during 1° covey movements and a combination of tillage and grassland during 2° covey movements. In Lullymore, a switch in habitat use to private bog and agricultural land was evident in most cases.

For both studies the calculation of habitat preferences gave insight into the potential importance of other habitats. In Boora edge and game crops were preferred habitats in some BTPs. In Lullymore heather top was sometimes selected. While note was taken for preferences based on only one radio-fix, this may have as much to do with the methodology as selection by the birds.
Figure 5.2 Core areas used by pair 1 (1997-98) in the present Boora study calculated using Cluster Analysis, 90% or 95%.

Key to Core Areas

- **T** Trap site
- **H** Habitation: 6.9 ha*
  - 16 Apr-15 May, N=27
- **L** Lay: 1.4 ha
  - 16 May-5 Jun, N=21
- **I** Incubation: 0.8 ha*
  - 6 Jun-30 Jun, N=26
- **B** Brood rearing: 3 ha*
  - 1 Jul-19 Aug, N=41
- **1st** covvy movements: 16.8 ha*
  - 20 Aug-6 Nov, N=50
- **2nd** covvy movements: 14.4 ha*
  - 7 Nov-22 Jan, N=28
  - Contact lost with covvy before completion of BTP

Key to Habitat Types

- **CUTAWAY BOG**
- **PRIVATE BOG**
- **HEATHER TOP**
- **YOUNG FORESTRY**
- **OTHER TREE CAT.**
- **GRASSLAND**
- **TILLAGE**
- **GAME CROP**
- **EDGE**
- **HEDGEROW**
- **DRAIN**
- **BUILDING**
- **WETLAND**

1km
Figure 5.3 Core areas used by pair 2 (1998) in the present Boora study calculated using Cluster Analysis, 90% or 95%.

Key to Core Areas

- **T** Trap site
- **E** Habituation; 9.8 ha
  - 24 Mar-3 May, N=35
- **L** Lay; 5 ha
  - 4 May-25 May, N=17
- **I** Incubation; 3.4 ha
  - 26 May-19 Jun, N=25
- **B** Brood rearing; 1.1 ha
  - 20 Jun-26 Jul, N=31
- **VC** Covey movements; 32.3 ha*
  - 27 Jul-27 Sep, N=67
- **V** Covey movements; 24.2 ha*
  - 28 Sep-15 Oct, N=16
  - Contact lost with covey before completion of BTP

**Key to Habitat Types**

- **CUTAWAY BOG**
- **PRIVATE BOG**
- **HEATHER TOP**
- **YOUNG FORESTRY**
- **OTHER TREE CAT.**
- **GRASSLAND**
- **TILLAGE**
- **GAME CROP**
- **EDGE**
- **HEDGEROW**
- **DRAIN**
- **BUILDING**
- **WETLAND**

1 km
Figure 5.4 Core areas used by Pair A (1992-93) in the Lullymore study calculated using Cluster Analysis, 85% or 95%.

Key to Core Areas

- **2° covey movements**: 52.8 ha
  18 Nov-6 Feb, N=65
- **Covey break-up**: 14.3 ha
  7 Feb-20 Apr, N=62
- **Habituation**: 3.1 ha
  2 May-14 May, N=15
- **Laying**: 9.5 ha*
  15 May-4 Jun, N=22
- **Incubation**: 1.9 ha
  5 Jun-29 Jun, N=26
  Chicks lost shortly after hatching

KEY TO HABITAT TYPES

- **CUTAWAY BOG**
- **PRIVATE BOG**
- **HEATHER TOP**
- **AGRICULTURAL LAND**
- **WOODLAND**

1 km
Figure 5.5  Core areas used by Pair B (1993) in the Lullymore study calculated using Cluster Analysis, 85**, 90* or 95%.

KEY TO HABITAT TYPES

- CUTAWAY BOG
- PRIVATE BOG
- HEATHER TOP
- AGRICULTURAL LAND
- WOODLAND

Key to Core Areas

- Habituation: 5.5 ha
  24 Feb-9 May, N=75
- Laying: 0.4 ha
  10 May-30 May, N=29
- Relaying: 3.1 ha
  16 Jun-27 Jun, N=13
- Incubation: 0.4 ha
  28 Jun-18 Jul, N=19
- 1st covey movements: 22.3 ha*
  27 Jul-23 Sep, N=38
- 2nd covey movements: 12.8 ha**
  24 Sep-27 Nov, N=35
  Contact lost with covey before completion of BTP
Figure 5.6 Core areas used by Pair C (1993-94) in the Lullymore study calculated using Cluster Analysis, 85**, 90* or 95%.

Key to Core Areas

- **Habituation**: 3.4 ha*  
  24 May-27 Jun, N=41
- **Laying**: 19.4 ha**  
  28 Jun-17 Jul, N=24
- **Incubation**: 5.1 ha**  
  18 Jul-11 Aug, N=24
- **1° covey movements**: 41.2 ha  
  19 Aug-9 Oct, N=36
- **2° covey movements**: 6.1 ha**  
  10 Oct-28 Jan, N=48

KEY TO HABITAT TYPES

- CUTAWAY BOG
- PRIVATE BOG
- HEATHER TOP
- AGRICULTURAL LAND
- WOODLAND

1 km
Figure 5.7  Comparison in the size of core areas (CL 90/95%) used by pairs during the breeding season BTPs in the present Boora study and Lullymore study.
Figure 5.8  Habitat use recorded in each BTP for pairs 1&2 from 1997-1998 in the present Boora study

**Pair 1**

**Pair 2**
**Figure 5.9** Habitat use recorded in each BTP for Pairs A, B & C from 1992-1994 in the Lullymore study
Figure 5.10 Illustration of habitat use compared with habitat availability for pair 1 (1997-98) in the present Boora study. Radio-fixes with MCPs for each BTP.

KEY TO MCPs

- Trap site
- Radio-fix, N=193
- Habituation: 80.7 ha
  16 Apr-15 May, N=27
- Lay: 8.2 ha
  16 May-5 Jun, N=21
- Incubation: 55 ha
  6 Jun-30 Jun, N=26
- Brood rearing: 5.1 ha
  1 Jul-19 Aug, N=41
- 1st covey movements: 77.4 ha
  20 Aug-5 Nov, N=50
- 2nd covey movements: 91.9 ha
  7 Nov-22 Jan, N=28

KEY TO HABITAT TYPES

- Cutaway Bog
- Private Bog
- Heather Top
- Young Forestry
- Other Tree Cat.
- Grassland
- Tillage
- Game Crop
- Edge
- Hedgerow
- Drain
- Building
- Wetland

1 km
Figure 5.11 Illustration of habitat use compared with habitat availability for pair 2 (1998) in the present Boora study. Radio-fixes with MCPs for each BTP.

KEY TO MCPs

- Trap site
- Radio-fix, N=191
- Habituation: 19.5 ha
  24 Mar-3 May, N=35
- Lay: 20.4 ha
  4 May-25 May, N=17
- Incubation: 6.7 ha
  26 May-19 Jun, N=25
- Brood rearing: 13 ha
  20 Jun-26 Jul, N=31
- 1st covey movements: 68.1 ha
  27 Jul-27 Sep, N=67
- 2nd covey movements: 84.3 ha
  28 Sep-15 Oct, N=16

KEY TO HABITAT TYPES

- CUTAWAY BOG
- PRIVATE BOG
- HEATHER TOP
- YOUNG FORESTRY
- OTHER TREE CAT.
- GRASSLAND
- TILLAGE
- GAME CROP
- EDGE
- HEDGEROW
- DRAIN
- BUILDING
- WETLAND

1km
Table 5.5 Habitat preferences* calculated for pairs 1&2 from 1997-1998 in the present Boora study

* habitat types ranked from most preferred to least preferred

Note: information for secondary covey movements is incomplete

<table>
<thead>
<tr>
<th>Pair 1</th>
<th>MCP vs Study area</th>
<th>Use vs MCP</th>
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<tr>
<td>Habituation</td>
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<th>MCP vs Study area</th>
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**KEY TO HABITAT TYPES**
- Cutaway bog
- Private bog
- Heather Top
- Young forestry
- Other tree categories
- Grassland
- Tillage
- Game crops
- Edge
- Hedgerow
- Drains
Table 5.6 Habitat preferences* calculated for pairs A, B & C from 1992-1994 in the Lullymore study

* habitat types ranked from most preferred to least preferred

**Note:** information for Pair A&B secondary covey movements is incomplete

### Key to Habitat Types
- Cutaway bog
- Private bog
- Heather Top
- Woodland
- Agricultural land

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<th>MCP vs Study area</th>
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5.4 Discussion

The sample size of 5 pairs is extremely low. Therefore, no statistical confidence can be placed on the results of this study. This is particularly the case when interpreting the results of habitat selection. In some cases the highest ranked habitat may be based on only one or two radio-fixes in the periphery of a MCP. Sometimes this contains a small area of a habitat not otherwise available within the MCP. For example, if two out of 40 radio-fixes were in this habitat (Use = 5%) and the area of the habitat contained within a 60 ha MCP was 0.2 hectares (MCP = 0.33 %); the difference between use and availability (15 times greater use than availability) would be likely to give this habitat the highest ranking. With a large sample of birds, one could investigate whether the result was statistically significant or not. It could be due to a once-off event, or birds could be consistently moving to the edge of their home range to utilise an uncommon habitat, but were only detected in this area rarely when sampled by radio-tracking.

In Boora, one pair was tracked each year and both successfully bred. In Lullymore, three pairs tracked simultaneously all failed to breed. This lack of replication accentuates the difficulties of meaningful interpretation of the results. Due to variations in home range size and habitat utilisation, the results must be regarded as 5 individual radio-tracking histories. The information is useful in providing baseline data on the ecology of partridge within cutaway bogs. However, as the landscape continues to be altered, with cutaway bog being transformed to other land uses (Egan, 1997; 1998; 1999), this radio-tracking data may have no practical application in the future. The ecology of the grey partridge has been widely studied in Britain, Europe and North
America. This prior knowledge is compared with the information gathered to date in Ireland.

**Partridge on bogs: a historical perspective**

Grey partridge have been known to breed on farmland surrounding the Boora bogs since the turn of the century, as they were frequently shot along with red grouse along the edges of the bog until recent times (V. Touher, pers. com.). In the Burdette Estate (some of which included the lower portion of the Boora group of bogs) a tally of game killed there in sport between 1888 and 1896 totals 312 partridge (Trodd, 1997). No partridge shoots now exist in the area.

Yarrell (1843) observed that in some heath-land districts in Surrey such as the Hurtwood and Bagshot heath, partridge were seldom seen to frequent the "corn-lands" but instead "lived apon the heath itself". It is suggested that they subsisted on the heath and hurtle-berries. These birds were not confused with the red grouse as they are described as "not so white in the flesh when dressed as others and have some of the flavour of the grouse". In both Boora and Bannerman & Lodge (1963) reported that in Suffolk partridge were adapted to the heath and were never observed to move off it. In Lullymore, radio-tracked birds occasionally used the heather top habitat. Partridge in Boora were frequently observed flying to nearby heather top for temporary refuge when flushed. The partridge in Surrey and Suffolk may have used heather in the same manner.

At the end of the 19th century a clearly differentiated dark subspecies, *Perdix perdix sphagnetorum*, known as the moor partridge, was described (Altum, 1894; Peus, 1929, cited in Potts 1986). It was reportedly confined to the lowland heaths in the Netherlands and north-west Germany. In a 1970s
survey, approximately 5500 pairs were counted in Drente in the Netherlands. The known range extends south and west into the flood plains of north and east into Schleswig Holstein (Kelm, 1979; Teixeira, 1979; Knolle & Heckenroth, 1985, cited in Potts, 1986). In light of this historical information, it is tempting to consider the birds in Boora and Lullymore as a relict population of heathland partridge. Realistically, it is more likely that they are descendants of partridge that once bred on nearby farmland.

Partridge occurring near the edge of the largely intact raised bog may have occasionally found suitable nesting sites in areas being hand-cut for fuel. As parts of cutaway bog became colonised by suitable vegetation, some birds may have begun breeding in this habitat. The absence of herbicides and pesticides on cutaway bog has allowed once common arable weeds to colonise (Kavanagh, 1990; Egan, 1995). In Britain the primary factor influencing post-hatching chick survival was the availability and abundance of certain insect groups (Chp. 1). In the modern farmland habitat the combined use of herbicides and pesticides reduce insect densities in the cereal crop (Potts, 1997). The cereal edge is used by the chicks to feed and if the density of preferred insects is reduced, chick mortality increases (McCrow, 1980; Green, 1984; Rands, 1985; 1986a).

Therefore, while the populations of Irish partridge breeding on farmland gradually became extinct (owing to low breeding success on modern farms), the species contracted in range to cutaway bog areas. These populations occur at densities of less than 1 pair per km² (Kavanagh, 1992). Since the 1980s partridge have been observed by Bord na Mona workers breeding on the Boora and Lullymore cutaway bogs.
Below, I have provided some explanations for the low density of pairs occurring on cutaway bogs:

1. **Limited availability of suitable breeding habitat.** Nesting cover on the cutaway bog is patchy and only in certain conditions does vegetation suitable for nesting and brood-rearing cover occur naturally alongside one another.

2. **Succession.** If unmanaged, the recolonised areas develop into scrub (Kavanagh, 1990; Egan, 1995). This means that they become unsuitable as breeding sites for partridge within a few years.

3. **Predation.** Corvid predation of eggs was a major problem as noted in Lullymore (J. Hearshaw, unpubl. data). Anecdotal evidence suggests a higher density of hares (Lepus timidus hibernicus) within cutaway bog areas. Foxes are known to be attracted to areas containing high density of hares (Goszczynski, 1991). One fox was observed foraging in the vicinity of lapwing (Vanellus vanellus) nests. When subsequently shot its stomach contents contained three lapwing chicks (K. Buckley pers. com.). Foxes are likely to encounter partridge frequently, especially given the patchy nature of the cover (this makes it easier for foxes to find nests). Predation can have a major impact on breeding success (Tapper *et al.*, 1996).

**Dispersal of pairs: exploration**

At the end of the covey break-up period the re-formed or newly formed pairs begin an exploratory phase (see Figs. 4.3-4.6). This involved unpredictable movements of up to several km per day. In both Irish studies, radio-contact was lost for several days at a time. In some cases this contact loss was
permanent (Chp. 3). In Britain the period from covey break-up to nesting is considered to have the highest rate of local natural population loss (Middleton, 1935; Jenkins, 1961; Blank & Ash, 1962).

Church et al. (1980) radio-tracked 9 pairs from the date of known pairing. The authors found that pairing occurred within the females’ winter ranges between February and April. Following a period of isolation immediately after pair formation, an exploratory period was observed. The distance between the two furthermost radio-fixes was used as an index to compare exploratory movements between pairs. These distances ranged between 0.9 – 9.6 km ($X = 2.2 \text{ km } +/- 0.4 \text{ SE}$). The average length of this period was 25 days. This exploratory period was considered to be a form of density dependant dispersal, with pairs prospecting for a potential area to settle in. Carroll & Crawford (1991) observed pairs moving up to 25 km where there was limited nesting cover. The distance moved during the dispersal period may also be related to partridge density with larger movements in areas of lower density (Church et al. 1980; Reitz & Mayot, 1999).

In Ireland the exploratory period took place between February and May. Both pairs in Boora and pair B in Lullymore were captured during this period. For pair A & C the exploration lasted a total of 12 to 27 days respectively. During exploration in Lullymore and Boora, pairs travelled across both agricultural and bog type habitats. Pairs may find the unmanaged residual grassy cover along the network of drains, access roads and railway lines within the cutaway bogs more attractive compared to that available on agricultural land. Nest sites in Britain occur mainly in linear and permanent cover, with the most important cover type being hedgerow surrounding agricultural fields (Potts, 1980, 1986). Hedgerow density and the availability of residual cover at the
hedgerow base were identified as important factors affecting nest site quality (Rands, 1986b). In north-west Bavaria, Germany (W. Kaiser, unpubl. data) partridge strongly selected permanent structures (field margins, road-sides & hedgerow) in spring but not at other times of the year. Results also indicated that partridge survival was significantly lower in a control area with fewer permanent structures.

Familiarity with cutaway bog is another factor to be considered. Previous research has shown that partridge prefer to breed in locations they were raised in, or bred in the previous year (Church, 1984; Kugelschafter et al., 2001). The Irish data has also indicated the presence of traditional breeding sites, with evidence of partridge breeding in the same areas from year to year. The majority of these sites have been within cutaway bog areas. Given this evidence, there are likely to be several generations of partridge that have bred on cutaway bog, each generation returning to breed in a familiar environment.

**Habituation**

In Wisconsin (Church et al. 1980) movements during habituation were confined to 4 ha (MCP) for 9 pairs. This is smaller than in Ireland (mean MCP= 40.4 ha, n=5). The availability of residual cover in the Wisconsin study was estimated at 2.5%. Residual cover was found to be the most preferred habitat type (contained 52% of all radio-fixes), compared to ploughed fields, tame hayfields, corn-fields and miscellaneous habitats. This reflected a dependence by pairs on residual cover for nesting.

The pair will remain within, or in the vicinity, of the habitat offering the best nesting and feeding opportunity. Female quail show a preference for high protein food in the period prior to breeding, which is related to egg production.
(Combreau & Guyomarc’h, 1992). In Boora, birds were observed feeding on a variety of plants species previously recorded in partridge diets (Middleton & Chitty, 1937; Potts, 1986) such as clover, redshank, chickweed and annual meadow grass.

During the habituation period, birds have the opportunity to assess the suitability of a habitat in more detail. The presence of adequate chick-rearing habitat, frequency of disturbance, or vulnerability to predation, are examples of factors that may need to be considered. The pair may also have to engage in territorial disputes with other pairs that come to enter the chosen habitat (Jenkins, 1961). Blank & Ash (1956) considered the formation of a pair territory prior to nesting as having four requirements: (1) an area of ground that they come to know intimately, (2) a known reliable source of food, (3) an adequate nesting site and (4) some escape (from predators) cover.

**Laying**

The Irish data indicates that home ranges during laying were higher in Lullymore (mean MCP=43.9, n=3) than in Boora (mean MCP=14.3, n=2). This probably reflects differences in the availability of food plants between study areas. As cover and food tend to be linked (Blank & Ash, 1956), the birds in Lullymore may have been more visible to corvids, (through less cover) thus having larger movements compared to Boora. In North Dakota, a mean MCP of 11.5 ha was calculated for 10 pairs during laying (Carroll et al. 1990).

**Incubation**

During incubation the male movements were centred on the vicinity of the nest site, while the hen sits at the nest incubating the eggs. Carroll et al. (1990) found that MCP calculations for incubation were lowest compared to other
time periods with a mean home range of 1.7 ha for 11 pairs. Calculations of MCP for the Irish data varied from 1.1-40.5 ha. This variation reflected occasional movements outside the smaller core areas used. In North America, the male partridge typically stays within 30-50m of the nest during incubation.

**Brood rearing**

During brood rearing, movements of the parents will be limited by the mobility of the chicks, particularly in the first 2-3 weeks after hatching. Partridge undergo a complete body moult (apart from the outer two primaries) in the period after the chicks have hatched (Potts, 1986). In Boora, brood rearing lasted 37 and 50 days for pairs 1 and 2 respectively. The juvenal plumage is not complete until 6 weeks (42 days) after hatching (McCabe & Hawkins, 1946, cited in Carroll, 1993).

Rands (1986a) calculated MCPs for 9 partridge broods radio-tracked in Hampshire, England during the first 21 days after hatching. Home range size ranged between 0.3-2.9 ha. In North Dakota, home range for 5 broods during the first 2 weeks after hatching gave a mean size of 8.2 ha using MCP (Carroll et al., 1990). Also reported was a mean home range of 19.7 ha for early brood rearing in Wisconsin (Church, 1980, cited in Carroll et al. 1990). In fact, home range size during brood rearing in Boora showed a clear distinction between the first 2-3 weeks and the remainder of the brood rearing period (Table 5.7).
Table 5.7 Home ranges during early and late brood rearing in the present Boora study

<table>
<thead>
<tr>
<th>Pair</th>
<th>Time period (days)</th>
<th>MCP (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>1-18</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>19-50</td>
<td>5.1</td>
</tr>
<tr>
<td>Pair 2</td>
<td>1-11</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>12-37</td>
<td>2.0</td>
</tr>
</tbody>
</table>

These results indicate that home ranges during early brood rearing in Britain above are closer in size to the Irish data, compared to the American data. However, with minimal sample sizes conclusions are tentative.

In Britain, the main mortality period for partridge chicks is known to occur during the first 3 weeks after hatching, with variability in chick survival thought to be primarily related to the availability of arthropods (Potts, 1980, 1986; Green, 1984; Rands, 1985, 1986a). The chicks cannot thermoregulate completely until development of juvenile plumage is completed, which takes at least 2 weeks (Offerdahl & Fivizzani, 1987).

Radio-tracking work by Green (1984) and subsequently by Rands (1986a) revealed that partridge chick survival was negatively related to the distance travelled by a brood between successive roost sites. Green (1984) indicated that long distance movements were stimulated by poor feeding conditions. Enck (1990) investigated vegetation characteristics of roost sites for 2 broods in New York state. It was suggested that thermal protection might be an important function of roost sites, as chicks less than 2 weeks old were at greater risk of hypothermia.
Activity near pairs during the breeding season in Boora was minimised, to reduce the risk of disturbance. Brood roost sites in Boora were not examined and clutch size and number of chicks at hatching were not available. Chicks belonging to pair 1 were first counted when 7 weeks old and numbered 8 juveniles. For pair 2, 10-12 chicks were first counted when 6 days old, with 10 juveniles counted at 7 weeks.

In North America, mean brood size (+/- se) at hatching varied between studies, with 16.5 +/- 5.5 chicks in North Dakota (Carroll et al., 1990), 14.7 +/- 1.2 chicks in Wisconsin (Church, 1980, cited in Carroll et al., 1990), 14.3 chicks in Montana (Weigand, 1980, cited in Carroll, 1993) and 12.5 chicks in a different Wisconsin study (Gates, 1973). In Britain, mean brood size (+/- se) at hatching was remarkably constant at 13.8 +/- 0.1 chicks, based on data from 1907-1984 from over 200 study areas with predation control (Potts, 1980; 1986). In the absence of Irish data it is reasonable to use the comprehensive British data as the mean brood size at hatching in Boora. This figure would give a chick survival rate to 7 weeks of 58 and 72% for pair 1 and pair 2 respectively. In the pre-pesticide era in Britain, mean chick survival rate (+/- se) to 6 weeks was 48.6 +/- 2.8%, based on data from 1903-1952 (Potts & Aebischer, 1995).

The majority of partridge studies in Britain and Europe report partridge broods favouring the edge of cereals (Potts, 1986). In America, cereals and row crops are mainly used, but also roadsides and shelter belts (Carroll, 1993). In Ireland, birds have been breeding in a novel habitat, the cutaway bog, in preference to the surrounding agricultural land, which includes cereals. The fact that populations on farmland have largely died out was already discussed. Relatively good chick survival was recorded for pair 1 and 2 broods and
autumn counts from 1993-2000 have indicated mean covey sizes ranging from 4 to 9 birds (Kavanagh, 1992). Successful breeding is possible within cutaway bogs, though chick survival in the 1990s may not be high enough to maintain a stable population (see Chp. 7). Contraction in range and numbers in recent years indicates that the population has continued to decline (Kavanagh, 1998). The following two sections consider the attributes of the habitats that were used by radio-tracked partridge in Lullymore and Boora during the breeding season.

**Additional habitat research in Lullymore**

An investigation of partridge habitat selection within cutaway bog was carried out in Lullymore based on small scale mapping in Lodge bog (Chp. 2). The original data for this research was not available for analysis, which is the reason why the previously unpublished results (J. Hearshaw, unpubl. data) are presented in this section.

Pair B & C nested in Lodge bog in 1993 (see Fig. 2.3 for location of Lodge bog on map, and Fig. 5.5 & 5.6 for core areas used within this area). Radio-fixes recorded for pair B & C during habituation and laying were combined and habitat use was analysed against availability for habitat preferences. Of the seven sub-habitats, railway was most used by the pairs, containing 59% and 48% of radio-fixes for pair B & C respectively. Comparing habitat use with availability in Lodge (1.5%) gave railway the highest rank using compositional analysis (J. Hearshaw, unpubl. data).

Railway was also found to contain the highest plant species diversity compared to the other sub-habitats within Lodge. It was felt that railway was preferred during the habituation-laying period because it offered both food and cover in
closer proximity than within the other sub-habitats. Being at an elevation above the surrounding areas, it was also considered that railways made it easier to detect the approach of predators. In Wisconsin, partridge spent much time in herbaceous cover during the habituation stage, close to where the eventual nest was located (Church et al., 1980). In Lullymore, railway was a preferred habitat prior to nesting, but pair B & C nest sites were within recolonised patches on the cutaway bog. This discrepancy was attributed to disturbance by traffic, consisting of trains carrying peat, tractors driving along the edge of the railway, and people with dogs (J. Hearshaw, pers. com.). However, there was no supporting evidence of traffic disturbance in Lullymore, and partridge successfully nest along busy roadsides in North America (Carroll, 1993) Britain (Lynn-Allen & Robertson, 1956) and the Czech Rep. (pers. obs.).

The importance of railways as a breeding site was documented for may species of birds and mammals in the former Czechoslovakia and along one 314km section of railway 197 (0.63 birds per km) partridge were recorded (Havlin, 1987). Seigne (1930) describes an estate in the south of England that was divided by a railway line passing through a long and deep chalk cutting. The sides were sloped, but not unduly steep with sparse cover. The south facing bank was described as a preferred nesting site with up to 20 partridge nests along its length. In Boora, railway line was included as a sub-habitat within ‘edge’. During two years field-work, birds were only observed using railway on 2 occasions with the majority of radio-fixes occurring on road. Roads pass through both agricultural land and cutaway bog. Radio-fixes occurring on roads were mostly within a grassland mono-culture. Railway only passed through cutaway bog. In Boora, railway and cutaway bog appeared to have a comparable vegetation cover. There were few roads in Lullymore and railway
was described as the only area within Lodge bog containing green vegetation during winter and spring (J. Hearshaw, pers. com.). This could explain the greater use of railway in Lullymore compared to Boora. In both study areas roads and railway were considered to be an obvious source of grit (B. Kavanagh, pers. com.). This is ingested by partridge to aid the breakdown of vegetable matter for digestion (Pulliainen, 1984).

As no chicks were produced in Lullymore a complete record of breeding was limited to the present Boora study.

**Overview of suitable breeding habitats in Boora**

Both pairs in Boora settled in Tumduff (see Fig. 2.2 for map ref.) following the exploratory phase. As explained in Chp. 2 much of the non-bog habitats mapped in Boora were recently reclaimed from cutaway bog. The ridge of heather top and areas of private bog in Figs. 5.2 & 5.3 delimit the edges of the Tumduff bog, with original agricultural land found beyond these borders. Habitat selection during the breeding season was dominated by three habitats: young forestry, cutaway bog and game crops. Both young forestry and game crops were planted on cutaway bog, in areas with a thin layer of remaining peat. These habitats were colonised by many of the same plants recorded on recolonised cutaway bog (Kavanagh, 1990; Egan, 1995). In Lullymore, young forestry and game crops were not present as habitat types during field-work (1992-94). Since then, young forestry was planted in Lullymore and there has been anecdotal evidence of partridge breeding in this habitat (B. Kavanagh pers. com.).
Young forestry

The grey partridge is a bird of open landscape and forestry is not a habitat type generally associated with partridge use (Potts, 1986). In a study of data from 17 estates in Britain from 1961-1978, partridge recruitment was lower than expected when there were greater than 10 trees per km of linear cover (Rands, 1982). In Germany, goshawk (*Accipiter gentilis*) predation was found to be significantly higher within 70m of trees (Doring & Helfrich, cited in Potts, 1986). Partridge avoidance of trees is believe to be an adaptation to protect against raptor predation. In Boora, preference for young forestry during the breeding season was an unexpected result.

Young forestry as opposed to mature trees, may offers a good breeding habitat with the aerial cover of small trees, nesting materials in the form of grasses, and areas of open ground between the rows with rich herbaceous cover. Habitat use by broods is believed to be mainly influenced by arthropod food availability and vertical habitat structure (Green, 1984; Enck, 1987). In a study of partridge habitat selection in Hungary, a preference for forest belts was most evident from March-May over a three year period (Farago, 1998). In a separate Hungarian study (Farago, 1997) the microclimate of brood rearing habitats was investigated. Forest belts were found to have the most stable temperature and humidity values relative to other habitats such as cereals, banks of ditches and roads, mown grassland, rape and onion (*Allium vineale*) plots. A stable microclimate was considered desirable for newly hatched chicks. In Hungary, it was concluded that partridge established their nests in or near forest belts partly because of their advantageous micro-climatic conditions (Farago, 1997). Both pairs in Boora used young forestry during brood rearing. Movements during early brood rearing for pair 1 were limited to the eastern side of a young forestry strip. Interestingly, in Hungary the
microclimate in forestry belts was most favourable within the eastern and medium parts (Farago, 1997). Pair 2 were recorded on cutaway bog during the initial brood rearing period (see next sub-section), subsequently moving to young forestry. Two farm-reared pairs, released during the previous Boora study were recorded nesting along the edge of young forestry in 1995 (F. Lester, unpubl. data). In 1999 a pair with chicks was seen along the edge of a forestry plot in Boora (K. Buckley, pers. com.).

However, the suitability of young forestry for breeding is temporary. Within a few years the canopy closes and ground vegetation becomes dominated by rushes. As the trees mature they have the potential to become barriers to partridge movements between cutaway bogs.

**Cutaway bog**

During the habituation period for pair 1 in Boora, another pair was observed on occasion within the young forestry strip. On several evenings territorial disputes were overheard. Despite spending the majority of the habituation period in this young forestry strip, pair 2 were believed to have nested on nearby cutaway bog. It is possible that pair 2 were excluded from the young forestry site by another pair. During incubation, movements of the male bird indicated the nest to be within, or in the vicinity of a game crop and a linear mound of marl (spoil from the creation of drains on cutaway bog). Chicks were first sighted on the mound itself. Subsequently, the young family moved to the nearby young forestry strip (note location of core areas for brood rearing in Fig. 5.3). The reason for this movement is unknown. It could have been owing to disturbance, caused by Coillte workers. It could also have been opportunistic. There was no evidence that the pair previously occupying the young forestry produced chicks. It is possible that pair 2 moved their chicks to
a better brood rearing environment. In West Boora cutaway bog (see Fig. 2.1), a pair was sighted with chicks nearby a marl mound on cutaway bog in 1999. A young family had also been sighted in this area the year previously, with several partridge chicks found flattened by a tractor (K. Buckley, pers com.).

In Lullymore, recolonised areas of cutaway bog were used for all known nesting attempts. The fact that all nesting attempts except one were unsuccessful, may be an indication that the available nesting cover was insufficient to provide adequate protection from corvids. The fact that females wore radio-transmitters may also have contributed to corvid predation (see Chp. 3). In Boora, predation control would have reduced the likelihood of nest predation (Tapper et al., 1996).

Game crops
In Britain wild partridge shooting is a commercial industry and successful partridge breeding can now be incorporated into the modern farming environment when certain measures (Conservation headlands, beetle banks, hedgerow management, winter stubbles and feeding cover etc.) are in place. The results of decades of game research on such measures by the Game Conservancy in Britain is put into practice on a privately owned farm in Loddington, England (see Boatman & Brockless, 1998 for details). Seed mixes for partridge nesting and brood rearing cover are now provided by commercial seed companies. These game crops were planted on cutaway bog in Boora to increase the availability of suitable partridge breeding habitats.

During the present Boora study, pairs were sighted on occasion within game crops. The grassy strips provided green vegetation during the spring when newly planted, with residual cover for nesting the following season. The
provision of cereals provided suitable aerial cover for broods similar to that available in young forestry and recolonised cutaway bog. The cereal strips were not sprayed or commercially harvested and they provided weed cover the following year. Colonisation of a variety of food plant (as for cutaway bog) species occurred in the cereal strips, with aerial cover provided by willowherb vegetation. It is suspected that at least one brood (a non-radio-tracked pair) was raised within a game crop in Boora. However, many game crops became rank and unsuitable breeding sites in their third year in the absence of management.

The future availability of suitable breeding habitat in Boora

There is evidence of partridge breeding successfully on three habitats related to cutaway bog. These are recolonised areas on the cutaway bog, with young forestry and game crops planted on former cutaway bog. The suitability of these sites for breeding is temporary and with alternative land uses taking shape on cutaway bog, it will be vital to maintain suitable breeding habitat for partridge within the new landscape. These aspects are discussed further in Chp. 7.

Primary and secondary covey movements

A large shift in home range (0.7-1.6 km) was observed between primary and secondary covey movements with the initiation dates varying between birds. No other partridge studies were known which identified specific time periods between the end of brood rearing and covey break-up the following spring. Other studies refer to a single autumn or winter period.

Home ranges (MCP) in South Dakota during autumn (Hupp, 1980, reported in Carroll, 1993), varied from 16 to 310 ha for 4 coveys. In Lullymore home
range calculation was of a comparable scale for pair B (Jul-Sep, MCP=128.4 ha) and pair C (Aug-Oct, MCP=357 ha) in covey movements. In Poland (Dudzinski, 1988b), the mean distance of partridge movements between covey sites in autumn and the centre of their winter home ranges was 209m. For 40% of the coveys, their autumn site was within the winter home range. Ussher & Warren (1900) considered partridge in Ireland to "become very wild and uncertain in their places of resort" in the month of October. Is it possible that the authors were referring to a similar movement away from known breeding sites as recorded in Lullymore and Boora?

A second historical reference to partridge movements in Ireland was in the form of a letter to the Zoologist (O’Cannon, 1893). It reads as follows: "Have any of your readers observed partridges migrating? In 1889 there was an unusual number of coveys here. I left a full stock, hoping for an increase the following year. Late in 1889 about November 31st, I saw on a road near here a very large number of partridges. They went off towards the hills to the south-west. About 2 miles further on the same road I saw another pack, which flew in the same direction as the others. Since then I have had very few. In 1889 several coveys appeared in my fields which were certainly not there at the beginning of the season, and which I believe must have come from a distance."

Seasonal migrations have been described in various parts of Russia (Nikiforov, 1992, *et al.*) and may be related in part to periods of severe weather conditions. Nikiforov cited Russian literature indicating that migrant coveys formed as a result of two or several family coveys joining together, sometimes forming groups of up to 100-150 birds in times when environmental conditions were worsening. In a transect and questionnaire study Nikiforov documented
covey sizes varying from 2 to 48 birds in Belorussia from 1982-86. Non-migrant coveys were small (mean covey size (+/- se) = 9.69 +/- 0.01, n=98) and inhabited restricted territories of 30-120 ha, while migrant coveys were larger (mean covey size (+/- se) = 26.30 +/- 0.46, n=8) and were not locally fixed but moved on to other places.

Home range (MCP) calculations for the winter period (Nov-Jan) include 0.1-5.6 ha in Montana (Weigand, 1980, cited in Carroll, 1993), 4.9-34.4 ha in North Dakota (Schulz, 1980) and estimated up to 20 ha in England (Blank & Ash, 1956). In Poland (Dudzinski, 1988b), the mean winter home range (using transects) of coveys varied from 24.4 ha in snowy winters to 33.1 ha in winters with little snow. Data that coincided with these winter months for 2° covey movements in Ireland were: pair 1 (Nov-Jan, MCP=91.9) in Boora and pair A (Nov-Feb, MCP=109.2) and pair C (Oct-Jan, MCP=87.7) in Lullymore. The Irish data gave considerably larger figures compared to these studies.

However, Church and Porter (1990) calculated core areas used for 7 coveys during winter in New York. This averaged 105 ha using HM 95%, which was larger than that calculated for the three Irish results (mean = 65.8 for HM 95%). In North Dakota, a mean winter home range (MCP) of 116.6 ha was recorded for 17 coveys (Smith et al. 1982) while in New York, winter home range (MCP) ranged from 105 to 392 ha for 31 coveys (Carroll, 1989).

The literature suggests much variation in the size of home ranges from the end of brood rearing to covey break-up. Variation between studies could in part be explained by different methods, habitat availability and weather conditions. However there is also much unexplained variation in home range size between different groups within studies. Clearly this time period needs further research
with greater attention paid to individual covey movement patterns rather than using predetermined calendar dates to compare results.

During 1° covey movements birds in Boora and Lullymore gradually moved away from central cutaway bog areas to the edges and surrounding habitats. In Lullymore this was mainly private bog, in Boora it was grassland. No clear explanation, as regards food availability, can be found to explain why cutaway bog would be less favourable in the autumn. For instance, in Boora parts of the cutaway bog contained areas of 100m² and more of redshank cover. In Lullymore, similar types of vegetation were used by birds within private bog as was found on cutaway bog. Ploughing of grain-rich autumn stubble fields has been found to lead to autumn dispersal of coveys (Potts, 1980). In Ireland no definitive man-made changes in habitat availability could account for 1° covey movements.

In Lullymore, predators were not suggested as a potential factor in autumn (J. Hearshaw, unpubl. data). In Boora, is it coincidental that as sightings of partridge on the cutaway bog decreased, sightings of hen harriers (Circus cyaneus) increased? A nationally important harrier breeding site is found in the Slieve Bloom mountains, 12 km south of Boora (Coveney et al., 1993). During July birds begin to appear more frequently on the cutaway bogs (pers. obs.). Up to 4 birds have been seen flying to communal roosts within forestry plantations in Boora (K. Buckley, pers. com.). Hen harriers have also been personally observed attempting to hunt partridge. In one case during 1998, a harrier had to be frightened away from a partridge brood it was attacking. In autumn, the approach of a harrier would result in the covey emitting a series of excited calls (McCabe & Hawkins, 1946, cited in Carroll, 1993) and running or flying to available heavy cover. The gorse areas found at the edge of the
cutaway bog were the most frequently used escape cover (5 observations) while heather top was used as an escape cover on one occasion. Perhaps it is encounters with hen harriers that leads to coveys moving to the edges of the cutaway bog where suitable cover is readily available.

During 1° covey movements in Boora, the majority of radio-fixes were in grassland. Several studies indicated that partridge avoided meadows. (Church, 1980, cited in Carroll et al., 1993; Weigand, 1980, cited in Carroll, 1993; Birkan et al., 1992; Kaiser, 1998). Reasons suggested for this avoidance were that birds were disturbed by cattle and because meadows held moisture. In Boora, coveys frequently used pastures containing cattle. Birds were observed travelling along the 'cattle paths' (bare trackways through the grass) and feeding in larger areas of poached ground where chickweed and annual meadow grass were growing (Plate 2.7). Coveys were never observed using fields containing sheep only, the grass sward being closely grazed and with no bare areas for weed species to colonise. Edge habitats were preferred during 1° covey movements, with roadways offering a greater diversity of food plants than grassland.

In Lullymore, a shift in home range after the breeding season was evident, but there was no obvious change in the pattern of habitat use between 1° and 2° covey movements, with varying proportions of cutaway bog, private bog, heather top and agricultural land used. This could be related to the fact that these coveys consisted of unsuccessful breeding pairs. Constraints on food availability would be less important for a small group of birds. Perhaps it is more important for the birds to find other groups to join up with. When partridge are feeding, one bird is always on guard for potential threats (Jenkins, 1961; pers. obs.). As outlined by Potts (1986), for a pair this behaviour
represents 50% of a pair's time budget, but only 8% for a covey of 12 birds. Therefore, if there are constraints on food availability, partridge in a small group may be more vulnerable to starvation and predation than in a larger group.

The switch in home range from 1° to 2° covey movements in Boora appeared to be related to the use of cereal stubbles. Following the cereal harvest of spring sown cereals partridge will feed on waste grain among the stubbles. A variety of weed seeds such as knotgrass, black-bindweed (*Fallopia convolvulus*) and common hemp nettle are also eaten. Where cereals are not available or stubbles ploughed in, partridge will be found on pastures, where grasses, clover and weeds such as dandelions (*Taraxacum officinale*) are eaten (Potts, 1986). Cereal stubbles have previously been identified as a preferred winter habitat for partridge in other studies (McCrow, 1977; Schulz, 1980; Church & Porter, 1990; Kaiser, 1998).

**Covey break-up**

In Lullymore, pair A was radio-tracked as a member of a covey during the winter, subsequently leaving the covey during covey break-up when core areas were on private bog (Fig. 5.4). Home ranges from February-April in New York averaged 82 ha (HM 95%) for 5 partridge (Church & Porter, 1990), compared to 66.6 ha (HM 95%) for pair A. Following a period of exploration, pair A migrated to a breeding site within cutaway bog (Fig. 5.4). In Boora, following loss of radio-contact with both coveys in Boora during 2° covey movements, anecdotal evidence suggested that coveys remained in the same areas until January/February. In January and February, though sometimes as late as March or April, birds began to appear again within the cutaway bog. It
is not known if the coveys broke up on the farmland and returned as pairs/individuals to the cutaway bog, or if complete coveys returned during late winter/early spring, with covey break-up then taking place.

We are not yet certain why the birds leave the cutaway bog areas after breeding. Two provisions were planned in Boora for 1999. Firstly, to provide root crops for feeding cover during the late summer/autumn. There is evidence that such non-linear cover can provide protection from harriers (Reitz & Mayot, in prep.). Secondly, given the preference for winter stubbles during 2° covey movements, winter stubbles could be provided within the cutaway bog. If birds subsequently remained in the area during the winter, it would be easier to monitor and protect the population. Further details of these experiments are given in Chp.7.
Chapter 6

UNPAIRED MALE PARTRIDGE
6.1 Introduction

Grey partridge spend the winter in coveys. These usually comprise the family unit of parents and young of the previous breeding season and one to several other adult birds that failed to breed or lost their partner during the year (Potts, 1980). Covey break-up begins in late December, continues throughout January, and is most rapid in early February. Pairing is intensified by mild weather during these months (Blank & Ash, 1956, Bishop et al. 1977). If both members of a pair survive to the following spring they usually reform. Siblings do not pair and young males leave the covey to attract females from other coveys (Jenkins, 1961a). Single males seeking a mate, approach coveys and can provoke aggressive responses from remaining male members of a covey. The female is the active bird in mate selection and usually chooses an older bird as a partner. The female is responsive both to direct display and to dominance established by one male over others in their presence (Cramp & Simmons, 1980).

There is an imbalance in sex ratios of adults owing to greater female mortality from the previous breeding season (Potts, 1980). The proportion varies from year to year, depending on the age of the population, mortality of nesting hens, incidence of shooting and disease. Competition amongst males for females will inevitably occur. Frequently there is much changing of mates before a pair settles down. One male is known to have finally bred after five changes of hen (Blank & Ash, 1956). There was a reported incident of one particularly aggressive paired female which killed another paired female, copulated with the latter’s mate but then deserted him and her own mate, to rejoin and breed with a mate of the previous nesting season (Cramp & Simmons, 1980). Some females may remain unpaired for periods of time during the pairing up period,
but eventually find mates (Aufradet, 2001). A surplus of unpaired males occurs when most pairing has been completed at the end of February.

The monogamous pair bond of the grey partridge is subject to sporadic interference from unpaired males. The movement patterns and behaviour of these birds is different to that of the paired male. Unpaired males tend to show no territorial behaviour and may wander over considerable distances (Jenkins, 1961a). Presumably this is in search of a female partner. Since all hens are by now paired, the unpaired male must approach pairs in an attempt to find a mate. Usually he will be driven away. Much calling occurs during disputes. Unpaired males use what is known as the ‘rusty gate’ or ‘kee-uck’ call to which paired males will respond, typically in the evenings (Carroll, 1993).

In observations of an individual pair in England, an unpaired male was noted being driven away by a marked male on 8 occasions during the day. This was when the unpaired male approached within 30 yards of the pair. In some cases an unpaired male is tolerated and may remain in the vicinity of a pair for several weeks at a time. Should the paired male be killed during this time the hen either remains in the territory with the available male or moves to a new area (Blank & Ash, 1956).

A pair may often be subject to interference by a succession of unpaired males and the defending male can become exhausted from these disputes. Occasionally unpaired males can become dominant over the paired male and replace him as the hen’s new partner. Females have been recorded changing mates even after laying 13 eggs (Cramp & Simmons, 1980).
During the three Irish partridge studies a number of unpaired birds were radio-tracked. The information gathered on movement patterns, behaviour and habitat use is presented in this section.

6.2 Methods

The methods used for the capture and radio-tracking of the unpaired males are the same as described earlier. Calculations of habitat use and preferences are also identical to those in the previous chapter. Designation of biological time periods (BTPs) was based on the same principals of movement patterns and biological considerations. For unpaired males the definitions were different because these birds did not find a pair while being radio-tracked.
6.3 Results

Of the 27 birds radio-tracked in the three Irish studies, 5 were unpaired males (Table 6.1). Radio-contact was permanently lost with 4 of the unpaired males while they were searching for a partner. One bird was radio-tracked for 8 months, from April-November 1997. This provided information on the movement patterns, habitat use and social interactions of an unpaired male before, during and after the breeding season. Home range calculations are summarised for all unpaired males in Table 6.2.

Table 6.1. Proportion of radio-tracked partridge that were defined as unpaired males in the three Irish partridge studies to date

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Study Area (km²)</th>
<th>Birds radio-tagged</th>
<th>Unpaired males</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lullymore</td>
<td>1992-94</td>
<td>52</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>Boora</td>
<td>1995</td>
<td>19</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Boora</td>
<td>1997-98</td>
<td>9</td>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 6.2 Radio-tracking data recorded for unpaired males

<table>
<thead>
<tr>
<th>Unpaired male</th>
<th>BTP</th>
<th>No. fixes</th>
<th>Days</th>
<th>Start</th>
<th>Finish</th>
<th>MCP 100%</th>
<th>HM 95%</th>
<th>KL 95%</th>
<th>CL 95-90, 95%*90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lullymore (1994) Mate search</td>
<td>6</td>
<td>18</td>
<td>29-Jan</td>
<td>15-Feb</td>
<td>Too few fixes recorded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boora (1995) Mate search</td>
<td>47</td>
<td>57</td>
<td>27-Feb</td>
<td>25-Apr</td>
<td>309.9</td>
<td>118.7</td>
<td>216.9</td>
<td>*3.9</td>
<td></td>
</tr>
<tr>
<td>male #1 (1997) Mate search</td>
<td>62</td>
<td>69</td>
<td>09-Apr</td>
<td>16-Jun</td>
<td>104.3</td>
<td>66.2</td>
<td>64.4</td>
<td>**6.8</td>
<td></td>
</tr>
<tr>
<td>1° mov. pat. Isolation</td>
<td>29</td>
<td>32</td>
<td>19-Jul</td>
<td>18-Jul</td>
<td>89.4</td>
<td>49.9</td>
<td>73.1</td>
<td>**2.8</td>
<td></td>
</tr>
<tr>
<td>2° mov. pat. 3rd mov. pat.</td>
<td>29</td>
<td>46</td>
<td>21-Aug</td>
<td>05-Oct</td>
<td>137.4</td>
<td>60.9</td>
<td>44.6</td>
<td>*34.4</td>
<td></td>
</tr>
<tr>
<td>All fixes</td>
<td>178</td>
<td>208</td>
<td>09-Apr</td>
<td>30-Nov</td>
<td>492.3</td>
<td>353.1</td>
<td>350.4</td>
<td>76.2</td>
<td></td>
</tr>
<tr>
<td>male #7 (1998) Mate search</td>
<td>13</td>
<td>40</td>
<td>01-Apr</td>
<td>10-May</td>
<td>155.3</td>
<td>Too few fixes recorded</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>male #9 (1998) Mate search</td>
<td>14</td>
<td>12</td>
<td>15-Jun</td>
<td>26-Jun</td>
<td>99.5</td>
<td>Too few fixes recorded</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mate search

All movements of unpaired males from covey break-up to the end of June were described as the "mate search" period. During this time the unpaired male would still have a remote possibility of finding a female and producing young. Subsequent time periods recorded for one bird (male #1 in the present Boora study) were related to changes in movement patterns.

Lullymore study (1994, J. Hearshaw, unpubl. data)

In Lullymore the migration of an unpaired male was recorded as it left a covey during the first two weeks of February (Fig. 6.1). A small home range of 22 ha (MCP) was used from 6 December 1993 to 28 January (as the member of a covey), followed by a displacement of over 7 km in an 18 day period when the bird left the covey. Radio-contact was subsequently lost.

Previous Boora study (1995, F. Lester, unpubl. data)

Within the previous Boora study area (Fig. 2.4), an unpaired male was radio-tracked for a two month period in spring, 1995 (Fig. 6.2). The home range of 309 ha (MCP) contained a number of core areas (Cluster analysis 90%) where activity was centred. These core areas occurred within young forestry areas and along the edges of cutaway bog. Radio-contact was subsequently lost with this bird.
Figure 6.1 Movement patterns recorded for an unpaired male in Lullymore from 1993-1994.

- 15 Dec 93-2 Feb 94, MCP=22.4 ha, N=20
- 3 Feb-15 Feb 94, Displacement of 7 km before loss of radio-contact
Figure 6.2 Home range (MCP) with several core areas (CL 90%) for an unpaired male in the previous Boora study from 27 Feb-25 Apr 1995.

100% MCP = 309 ha, N = 47

CL 90% = 4 ha, N = 47
During the present Boora study three unpaired males were radio-tracked, male #1 in 1997 and male #7 and male #9 in 1998 (numbers refer to capture sequence in Chp. 3).

**Male #7 (1998)**

Radio-contact was lost with male #7 after 2 weeks due to signal failure. Following recapture in May radio-contact was lost after 5 days. Radio-fixes recorded during this time are illustrated (Fig. 6.3). Male #7 was observed temporarily in the company of other partridge, on 1 April, with 3 females, and a single female on 4 April. Interaction with pair 1 was observed on several occasions. Of the 13 radio-fixes recorded, 8 were on cutaway bog, 4 within game crops and one on a road (edge).

**Male #9 (1998)**

Male #9 was recorded on grassland in the vicinity of a known pair for several days before a displacement of over 1 km on 25 June (Fig. 6.3). Radio-fixes were subsequently recorded in young forestry in the vicinity of the pair 1, which had young chicks at this time. Radio-contact was lost on 29 June.

**Male #1 (1997)**

From 9 April to 16 June male #1 was actively searching for a mate and was heard calling in the vicinity of known pairs in the evenings. One of these pairs was pair 1. Several aggressive interactions between male #1 and pair 1 were observed. Analysis of radio-tracking data during the male #1 mate search period illustrates core area overlap between male #1 and pair 1 home ranges during this time (Fig. 6.4).
Figure 6.3 Radio-fixes recorded for unpaired males #7 & #9 in 1998 in the present Boora study

**Male #7**
- 13 radio-fixes
  - 1 Apr-10 May
- Area outlined = 155.3 hectares
- Trap site

**Male #9**
- 14 radio-fixes
  - 15 Jun-26 Jun
- Area outlined = 99.5 hectares
- Trap site

KEY TO HABITAT TYPES

- CUTAWAY BOG
- PRIVATE BOG
- HEATHER TOP
- YOUNG FORESTRY
- OTHER TREE CAT.
- GRASSLAND
- TILLAGE
- GAME CROP
- EDGE
- HEDGEROW
- DRAIN
- BUILDING
- WETLAND

1 km
Figure 6.4 Core area (90% CL) overlap between an unpaired male (male #1, 62 radio-fixes) and a breeding pair (pair 1, 61 radio-fixes) radio-tracked from 9 April to 16 June in the present Boora study in 1997.

- Unpaired male core areas: 16 ha
- 90% Cluster Analysis

- Breeding pair core areas: 10 ha
- 90% Cluster Analysis

Male #1 core areas calculated for the mate search BTP occurred within cutaway bog, young forestry and game crops. There was evidence of a pair of partridge breeding within these game crops, though no interactions were observed. During the mate search period the majority of radio-fixes (64.5%) were recorded on cutaway bog, with a preference shown for young forestry. Core areas used by male #1 during mate search and subsequent time periods are illustrated in Fig. 6.5. Habitat use (Fig. 6.6), habitat preferences (Table 6.3) and home range shifts (Table 6.4) were calculated. Percentage habitat use and availability can be consulted in Appendix 4.

Rest period

The mate search time period ended in mid-June when male #1 moved away from the cutaway bog to silage and hay fields 1 km away. The area contained no known breeding pairs. This was termed the rest period because male #1
Figure 6.5 Core areas used by male #1 (1997) in the present Boora study using Cluster Analysis, 80 or *90%
Figure 6.6  Habitat use recorded in each BTP for male #1 (1997) in the present Boora study

Table 6.3  Habitat preferences recorded in each BTP for male #1 (1997) in the present Boora study

* habitat types ranked from most preferred to least preferred
ceased to call in the evenings, no interaction with other birds was observed, and he sometimes remained in one field for several days before moving to another one. Breeding partridge moult their feathers in the period after the chicks have hatched (Potts, 1986). As the rest period began in June during the peak hatching period, it must be presumed that male #1 was also undergoing a body moult at this time. Habitat use was dominated by grassland (55.2%), with a lesser preference for nearby game crops. Subsequent BTPs were described as 1°, 2° and 3° movement patterns, with the end of each time period related to a major shift in home range (Table 6.4) and habitat use (Fig. 6.6). Interestingly, these shifts in home range also coincided with social interactions with other partridge.

**Primary movement pattern**

On 16 July male #1 was observed in the company of another unpaired male. Shortly afterwards both birds moved to new regions of the study area. This BTP was termed the “1° movement pattern”. Whereas previously much time was spent in the long grass of silage and hayfields, male #1 used permanent pastures containing cattle during this BTP. 78.1% of radio-fixes were recorded in grassland. The home range contained a high proportion of young forestry (10.5%) compared to availability in the study area (1.9%). Game crops were the most preferred habitat used.

**Secondary movement pattern**

From 21 August new regions in the study area were frequented and coincided with a change in the group size from 2 to 3 birds. It is presumed that this was the result of a third bird (of unknown sex) joining the two unpaired males. Another shift in home range was evident during the 2° movement pattern. Two core areas, separated by 1 km were used, with the covey moving between both
areas on a day to day basis. Home range selection indicated a preference for private bog (14.2% in MCP compared to 8.7% in study area). Habitat use was equally distributed between grassland and private bog but a preference was shown for game crops.

**Tertiary movement pattern**

A 3° movement pattern began on 6 October with the group of three birds now reduced to the two unpaired males. Discovery of partridge remains (plucked primaries) within 10m of a radio-fix taken during the previous BTP, indicated raptor predation. Within the new home range these two males joined or were joined by, a pair with no young. This pair was known to have bred unsuccessfully in a nearby silage field. One of the male birds in this new grouping was captured on 15 October (see Chp. 3, Table 3.1), so that the covey now contained two birds wearing radio-transmitters, male #1 and male #5. However, male #5 was found buried by a fox on 5 November. No shift in home range was detected in the 3 weeks after the loss of male #5 from the group. Radio-contact was lost with the group after 30 November, when the battery on the radio-collar worn by male #1 expired. Habitat use up to this point was dominated by grassland (76.9%), but tillage (green stubble fields) was the preferred habitat.

**Table 6.4** Home range shift (m) between successive BTPs for male #1 (1997) in the present Boora study

<table>
<thead>
<tr>
<th>Mate search</th>
<th>Rest period</th>
<th>Primary mov. pat.</th>
<th>Secondary mov. pat.</th>
<th>Tertiary mov. pat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male #1</td>
<td>855</td>
<td>853</td>
<td>1014</td>
<td>1370</td>
</tr>
</tbody>
</table>
6.4 Discussion

There is potential for confusion over use of the term "covey" in the literature. In the traditional sense this refers to the pair and its young in the autumn and winter (Potts, 1986). However any grouping of more than two birds after the breeding season can be referred to as a covey (Nikiforov, 1992). In Chp. 5, I referred to 1° and 2° covey movements to define the time periods following breeding. In Boora this referred to the pair and young, while in Lullymore this was the unsuccessful pair and any other birds that had joined them. As discussed in Chp. 5 it is not known if the larger area used in Lullymore, compared to Boora, were primarily the result of an absence of young. In this section I have referred to 1°, 2° and 3° movement patterns as opposed to "covey movements" because an unpaired male, not a pair was the focal point. Further radio-tracking studies of unpaired males and pairs would be needed to address if this distinction was necessary.

Movements and habitat use by the unpaired males during the mate search period took place within the cutaway bog areas, where pairs were known to breed. Outside this period we only have data for one bird, male #1 in Boora. Therefore, it is not known if the pattern of habitat use between BTPs is representative of unpaired males. A preference for tillage was indicated for the male #1 group during the 3° movement pattern. At the same time of year, the covey consisting of pair 2 and juveniles were using stubble fields at the eastern edge of the study area (Fig. 5.3, 5.11). This indicates that the availability of stubble fields is important for partridge in Boora, regardless of social mix. During the complete radio-tracking period male #1's home range was 492 ha, larger than for breeding birds male #2 (383 ha) and male #6 (200 ha) radio-
tracked for a similar length of time. Male #1 moved widely through the study area (Fig. 6.5), with large home range shifts (0.8-1.4 km) between BTPs.

An excess of males in the population at covey break-up is a feature of grey partridge (Potts, 1980). At a study site in Hampshire, Jenkins (1961a) estimated that 10% of the spring population consisted of unpaired males. In Montana (Weigand, 1977), an excess of males was found in the late winter, with 16% more males than females in the trapped population and 11% greater in the observed population. In a French study (Aufradet, 2001) 12% of marked partridge were observed as unpaired males. During the three Irish studies 19% of the radio-tracked birds were unpaired.

Weigand (1977) suggested that this excess led to movement of males, particularly juveniles, to remote winter ranges for mate selection. Weigand regarded a winter density of one bird per 20-42 ha as a very low density when compared to Jenkins’ (1961a) limitation of greater than or equal to one bird per 2 ha for low density. Within the Boora study area, the density of birds in autumn 1998 was one bird per 225 ha, which compared to these two studies would be regarded as a very low density. Weigand (1977) proposed that the movement of unpaired males was one of a number of factors preventing in-breeding in a low density population. The movement of unpaired males may contribute to genetic flow between cutaway bogs, which can be separated by several kilometres. Radio-contact was lost with 4 of the 5 unpaired males during the mate search BTP in Ireland. It is possible that these birds moved to new areas outside radio-receiver range in search of mates. In Boora in August 1999, a bird wearing a radio-transmitter was observed in a non-breeding covey with three other adults in Boora. This bird was either male #1, #7 or male #9, as all other radio-tracked males were known to have died.
Aufradet (2001) observed unpaired males from February to July 1986-88. Thirteen of these males left the study area, 10 paired with a hen that had lost its mate and 6 remained unpaired and joined a covey. By moving from one pair to another, an unpaired male can be available to a hen in the event that her mate is predated. This is beneficial to the female. In some cases unpaired males will dominate the resident male and displace him and where a pair is attended by a succession of males the resident male may become totally exhausted through continuous vigilance (Blank & Ash, 1956).

In a small partridge population on the verge of extinction, such as in Ireland presently, it would be hugely beneficial if this proportion of males could be used to contribute to the breeding stock. When extra females were provided by the release of hand-reared pairs in France they paired with the surplus males and bred only 11% less successfully than the wild pairs (Potts, 1980). This could become a management option in Boora. However, sometimes an unpaired male is not driven away by the resident male (Cramp & Simmons, 1980) and remains in the vicinity of a pair for several weeks (Fig. 6.4).

This raises an intriguing question: Is it possible that the unpaired male may sometimes sneak a mating opportunity with a paired female? Mixed genetic paternity of broods due to copulations with additional males, termed “extra-pair copulations”, is proving to be more common in birds than previously thought (Westneat et al., 1990). In the case of the grey partridge this has yet to be researched. If proven, it could explain for instance, why some unpaired males join family groups (vested interest) while others choose to join other unpaired males and unsuccessful breeders. Further radio-tracking of unpaired males coupled with DNA analysis of a sample of nests in a partridge population would address this speculation.
7.1 Introduction

The analysis of 5 years radio-tracking data (1992-94, 1995, 1997-8) presented in this volume represents the first detailed study of wild grey partridge in Ireland. Time periods based on breeding biology and changes in movement patterns were used to interpret home ranges and habitat use. These were termed biological time periods (BTP). This was deemed to be a novel and more informative method than using pre-determined calendar dates. Mean home ranges (MCP, +/- se) in each BTP were: covey break-up (234.8 ha, n=1), habituation (40.4 +/- 10.7 ha, n=5), laying (32.1 +/- 11.8 ha, n=5), incubation (11.4 +/- 7.3 ha, n=5), brood rearing (9.1 +/- 4 ha, n=2), primary covey movements (157.7 +/- 67.7 ha, n=4) and secondary covey movements (87.7 ha, n=1).

Shifts in home range were less than 1 km during the breeding season (habituation-laying, laying-incubation, incubation-brood rearing), but varied from 0.15-6.05 km between other time periods. Breeding attempts occurred within the cutaway bog area. In Lullymore recolonised areas were used, while in Boora game crops and young forestry plantations were preferred. Coveys moved outside cutaway bog areas between July and August to feed on nearby cattle pastures. A second shift in home range between September and November was evident. In Boora, this shift was made to utilise winter stubbles on farmland. Birds returned to breeding sites in the cutaway bog area the following spring.

Due to variations in home range size and habitat utilisation between birds, the results should be regarded as 5 individual radio-tracking histories. The information was useful in providing baseline data on the ecology of partridge.
within cutaway bogs. In Ireland, partridge need suitable breeding sites within cutaway bogs to produce young. The availability of root crops and stubble fields may influence the movement of partridge outside cutaway bog areas. However, as the landscape continues to be altered, with cutaway bog being transformed to other land uses (Egan, 1997; 1998; 1999), this radio-tracking data may have no practical application in the future.

7.2 Population dynamics

Decline of a species
The grey partridge was most likely introduced to Ireland between the 16th and 17th century, based on current archaeological and historical evidence (Chp. 1). Grey partridge were widely distributed in lowland areas up to the mid-19th century. A long-term decline in abundance was reported from this period, up to the 1960s. This trend was attributed to a reduction in grain growing, increase in predators and unregulated shooting (Watters, 1853; Ussher & Warren, 1900; Kennedy et al., 1954; Ruttledge, 1966). Since the 1960s an 86% decline in distribution was recorded by BTO/Birdwatch Ireland breeding bird surveys (Sharrock, 1976; Gibbons et al., 1993). By 1991 this had resulted in a range contraction to the Irish midlands (Kavanagh, 1992).

The grey partridge has also declined outside Ireland (Chp. 1). A population decline of between 80-90% has occurred in most parts of Western Europe. These declines have been accompanied by a contraction in range (Tucker & Heath, 1994). Across Western Europe range contractions have occurred away from mountainous areas. Grey partridge are believed to be extinct in Portugal and Norway, and close to extinction in Switzerland. Local extinctions have
been recorded in northwest Spain, northern Finland and Sweden, southern Italy and Greece, and western Britain. (Hagemeijer & Blair, 1997). Population estimates based on reliable quantitative data giving the number of breeding pairs are available from France (900,000), Britain (140,000-150,000), Denmark (20,000-30,000), Netherlands (20,000-25,000), Moldova (5,500-7,000), Greece (3,150), Switzerland (30-50) and Norway (0). There are an estimated 1-2 million breeding pairs in Russia (Tucker & Heath, 1994; Hagemeijer & Blair, 1997).

Modelling

The decline of a population may have more than a single external cause, expressed in density dependant and independent factors that individually or collectively can cause changes in population size. Conservation projects seek to identify the most effective methods of restoring the endangered population. However, since even stable populations can remain so, with a range of survival and recruitment rates it may often be far from obvious which factors have changed to cause a shift from stability to decline (Green, 1995).

In partridge populations brood production rates (proportion of paired females in spring that survived to successfully produce chicks) and over-winter survival (proportion of females present in autumn that are paired in spring, as influenced by mortality, immigrations and emigrations) are density dependent factors. Chick survival (proportion of hatched chicks surviving to the age of 6 weeks) is density independent (Potts, 1980; 1986; Potts & Aebischer, 1989; 1991). Potts & Aebischer (1995) examined the population dynamics of grey partridge in Britain using bag records and autumn count data from a variety of sources, including information from an estate with records dating from 1793. Long term data (1903-1993) on chick survival rates to 6 weeks were analysed.
The mean chick survival rate (+/- se) from 1903-1952 (49 +/- 3%) was significantly higher than from 1962-1993 (32 +/- 1%). Herbicides were introduced in Britain after 1952, and became widespread by 1962. On a study area in Sussex, spring density declined from 21 pairs/km$^2$ in 1968 to 4 pairs/km$^2$ in 1993, with a mean chick survival rate of 28% through the period (Potts & Aebischer, 1995).

Potts & Aebischer (1995) used modelling to illustrate that adjustment in the rate of chick survival could significantly alter the demographic parameters of partridge populations. Demographic data was obtained from the literature for 36 partridge populations from 9 countries. Using this data, stable populations were shown to decline and declining populations were made stable by adjusting mean chick survival rate to post-herbicide and pre-herbicide rates. The authors noted that while a decline in mean chick survival rate would result in a lower post-breeding population, whether or not this extended through to spring stocks would be determined by the compensatory mechanisms in the density dependent factors. They found that where non-chick mortality was high, a population became more vulnerable to decline (Potts & Aebischer, 1995). In Britain, the abundance of predators has increased and gamekeeper numbers have decreased. Remaining gamekeepers have been forced to concentrate on pheasant rearing, rather than predation control (Tapper, 1992). Modelling by Potts & Aebischer (1995) illustrated that partridge stocks collapsed with a post-herbicide chick survival rate and the reduction of predation control.

In France, reducing shooting pressure did not halt recent declines in partridge stocks (Reitz, 1999). This raised concerns about the future conservation and harvesting of the species, and it was suggested that the decline could be
attributable to a decrease in hen survival rate during breeding. To test this hypothesis 1009 hen partridge were radio-tracked at 10 contrasting sites over 3 years (Bro et al., 2000). The parameters directly investigated were hen survival rate during the first nesting attempt, hatching rate of clutches, brood size at hatching, re-nesting rate, chick survival to 6 weeks, hen survival rate after nesting, and hen survival during laying and incubation of replacement clutches. Over-winter survival rate was estimated by comparing December and mid-March count data. Increasing a single demographic variable in a declining population upward to that of a stable population did not have a stabilising effect. A stable population could only be produced by improving four parameters simultaneously: over-winter survival rate, hen survival rate during breeding, hatching rate of first clutches and chick survival rate (Bro et al., 2000). This result contrasts with the British model (Potts & Aebischer, 1995), where chick survival rate alone could stabilise the majority of declining populations. However, in both studies the proposed remedy is the same, legal seasonal control of predator species responsible for losses, the provision of nesting and winter cover, and management of field margins to enhance chick survival.

The exact cause of the partridge decline in Ireland is not known, but it may also be linked to agricultural changes, given that the remaining populations have been breeding in a non-agricultural landscape of naturally re-colonised cutaway bogs. Historically, Irish partridge have been less economically important a game bird, compared to Britain (Tapper, 1992; Corbally et al., 1997). Intensive control of predators has never been widespread in Ireland. Furthermore, the partridge decline has only received attention in this country for the past decade (Kavanagh, 1992). The decline has been characterised by regional extinctions and a contraction in range to the Irish midlands (Fig. 1.2).
Autumn census data

The study site mapped in Boora with Tumduff cutaway bog at its core (Fig. 2.2), is part of a wider area of cutaway bogs in the region (Fig. 2.1). Conservation efforts have focused on Tumduff since 1996 but partridge are found in other areas within the Boora group of bogs and Lullymore (Kavanagh, 1992, 1998). A one-day autumn survey is carried out in Boora each year, with the help of locals. However, this is largely a public relations exercise as the area is large and it is difficult to flush partridge coveys from the heavy cover found on the bog. In both 1997 and 1998 the radio-tracked coveys were not located during the survey. The date of the survey varies between years and if it occurs after September coveys that have moved off the bog to farmland (during primary covey movements) will be missed. Autumn census data in Boora and Lullymore has relied mainly on casually reported sightings recorded by peat workers and farmers (Table 7.1).

Table 7.1. Estimated autumn partridge population in Lullymore and Boora, based on reported sightings from 1993-2000 (Kavanagh, 2001)

<table>
<thead>
<tr>
<th>Year</th>
<th>Lullymore 65 km²</th>
<th>Boora 54 km²</th>
<th>TOTAL 119 km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>26</td>
<td>38</td>
<td>64</td>
</tr>
<tr>
<td>1994</td>
<td>23</td>
<td>79</td>
<td>102</td>
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<tr>
<td>1995</td>
<td>41</td>
<td>107</td>
<td>148</td>
</tr>
<tr>
<td>1996</td>
<td>17</td>
<td>42</td>
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</tr>
<tr>
<td>1997</td>
<td>15</td>
<td>55</td>
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<td>24</td>
<td>32</td>
</tr>
<tr>
<td>1999</td>
<td>2</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>2000</td>
<td>1</td>
<td>22</td>
<td>23</td>
</tr>
</tbody>
</table>

Most sightings comprise only an approximate number of birds flushed, without details of sex and age. The location of these sightings may of course be biased towards the seasonal distribution of peat workers rather than reflect the actual population of partridge each year. Sightings are often several weeks to months...
apart and double counting of the same pair/covey is likely given the large
distances traveled by radio-tracked birds. However, taken as an index, the
data indicates an overall population decline since 1993, with the Lullymore
population close to extinction (Table 7.1).

In Britain, the provision of nesting and brood rearing habitat, combined with
predation control are proven to benefit partridge populations (Potts, 1986;
Anon, 1992; 1994; Tapper et al., 1996; Aebischer, 1997). In 1996, 14.5
hectares of game crops were planted along railway lines within Tumduff
cutaway bog (Fig. 2.2). Between February and August each year, American
mink (Mustella vison), stoats, rats, grey crows and magpies were trapped in a
9km² area around Tumduff from February to August. A special section 42
license was obtained under the national 1976 Wildlife Act, to allow control of
stoats. Foxes and feral cats (Felis catus) were shot all year round in a 20 km²
area around Tumduff. However, despite these measures the number of spring
pairs in Tumduff fell from 6 in 1996 to 1 in 2000 (Fig. 7.1), while the
population based on sightings continued to decline (Table 7.1).

Chick survival rate
Potts & Farago (1999) estimated chick survival rates from autumn census data
collected at the Esterhazy estate in Hungary, from 1922-33. As for the Irish
data, the autumn census consisted only of the number of birds in each covey,
without details of age and sex. The authors examined detailed data collected in
Damerham, England (1947-1960) during which time annual chick survival
rates were determined directly. The correlation between mean covey size in
autumn and mean chick survival rate was very high ($r^2 = 0.94, p<0.001$). The
mean covey size in autumn ($x$) could be used to reliably estimate the mean
chick survival rate ($y$), using the equation, $y = 7.41x-25.25$. Only covey sizes
Figure 7.1. Estimated location of breeding pairs in the Boora study area from 1996-2000

- 1996: 6 pairs
- 1997: 4 pairs
- 1998: 4 pairs
- 1999: 2 pairs
- 2000: 1 pair
of 3 or more birds were used to calculate the mean covey size. The mean number of chicks at hatching in Damerham was 13.5, with a mean number of 3.4 adults per covey. Therefore, for a mean covey size of 3.4, mean chick survival rate would be 0%, while a mean covey size of 16.9 gave an estimated chick survival rate of 100%. The number of chicks at hatching in Hungary at this time was 13.2, based on data from two other estates in Hungary. This value was not significantly different from 13.5, the number observed at Damerham. The mean number of 3.4 adults per covey observed in Damerham was assumed the same for Hungary. Control of predators was intensive at the Esterhazy estate. Reference to results of the six year Salisbury plain experiment in England (Tapper et al., 1996) showed that the relationship between mean covey size and chick survival rate was not affected by the presence or absence of predation control (Potts & Farago, 1999). Using this equation, Potts & Farago (1999) estimated a mean chick survival rate (+/- se) of 74.8 +/- 1.7% at the Esterhazy estate from 1922-33. This high value was attributed to small field size, high crop diversity and the absence of pesticides.

The number of partridge shot at the estate rank among the highest on record in the world.

In Ireland, the mean covey size (3 or more birds) was estimated from autumn count data collected in Boora and Lullymore from 1993-2000 (B. Kavanagh, unpubl. data). The equation used by Potts & Farago (1999) to estimate mean chick survival rate was applied to the Irish data (Table 7.2). One should be cautious about the results, as this equation assumes 13.5 chicks at hatching and 3.4 adults per covey in Ireland, data that has not been recorded to date. Also, unsuccessfully breeding pairs and unpaired birds have occasionally been recorded in groups of 3 and 4, which could lead to errors. The estimated mean chick survival rate (+/- se) between 1993-1998 was 26.5 +/- 3.8%, which is
within the same range as the mean chick survival rate (32 +/- 1%) which lead
to the population decline in Britain (Potts & Aebischer, 1995). Therefore,
while individual pairs may have had high breeding success (i.e. pairs 1&2)
within cutaway bogs, it would appear from this data that the habitat has not
supported a stable population in the last decade. In 1999 and 2000, the
estimated chick survival rate was less than 5%. It is possible that only one pair
may have bred at all in the last 2 years, as all other sightings were of groups
numbering between 3-5 birds, some of which were reported to be all adults.

Table 7.2. Mean autumn covey size in Ireland (3 or more birds) from 1993-
2000 (B. Kavanagh, unpubl. data) and estimated mean chick
survival rate

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean covey size</th>
<th>SD</th>
<th>N</th>
<th>Mean chick survival rate %*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>5.11</td>
<td>2.34</td>
<td>9</td>
<td>12.62</td>
</tr>
<tr>
<td>1994</td>
<td>7.00</td>
<td>1.09</td>
<td>10</td>
<td>26.62</td>
</tr>
<tr>
<td>1995</td>
<td>7.38</td>
<td>3.28</td>
<td>13</td>
<td>29.44</td>
</tr>
<tr>
<td>1996</td>
<td>6.63</td>
<td>3.74</td>
<td>8</td>
<td>23.88</td>
</tr>
<tr>
<td>1997</td>
<td>9.00</td>
<td>3.56</td>
<td>7</td>
<td>41.44</td>
</tr>
<tr>
<td>1998</td>
<td>6.75</td>
<td>3.83</td>
<td>4</td>
<td>24.77</td>
</tr>
<tr>
<td>1999</td>
<td>4.00</td>
<td>0.89</td>
<td>6</td>
<td>4.39</td>
</tr>
<tr>
<td>2000</td>
<td>4.20</td>
<td>1.79</td>
<td>5</td>
<td>5.87</td>
</tr>
</tbody>
</table>

*Calculated using the equation \( y = 7.41x - 25.25 \) (Potts & Farago, 1999), where
\( y \) = mean chick survival rate and \( x \) = mean covey size in autumn

A number of authors have provided evidence that climatic conditions are
correlated with the size of the post-breeding population (Mitchell, 1977;
Meriggi et al. 1990; Milanov, 1998; Stoyanov et al., in prep.). Monthly
rainfall was recorded in Boora (Appendix 5). No significant correlation was
found between the estimated autumn population in Boora and rainfall in June
\( (R=0.688, df=6, P=0.131) \), July \( (R=0.294, df=6, P=0.571) \), August \( (R=0.027,
df=6, P=0.602) \), or total rain from June-Aug \( (R=0.539, df=6, P=0.27) \), using
Spearman’s correlation analysis. Therefore, fluctuations in summer rainfall did not have an effect on the estimated post-breeding population. The impact of poor weather on chick survival will depend on insect abundance and suitable brood rearing cover (Potts, 1986). Therefore breeding success will be low in studies where there is a combination of poor weather and unsuitable brood rearing habitats. In upland areas of northern England a wetter climate was found to be a limiting factor for partridge breeding success (D. Baines, unpubl. data). It has been suggested that the population decline in Ireland has been more pronounced than in Britain due to a relatively wetter summer climate (Potts, 1986), thereby exacerbating the effect of poor brood rearing habitat on chick survival rates.

7.3 Effect of habitat

Game crops
Habitat provision has been inadequate when compared to continued loss of breeding sites. The game crops (14.6 ha) planted on cutaway bog in Boora in 1996, represented 1.1% of the mapped area (Fig. 2.2). However, 27.6 ha of cutaway bog within the same area had been lost to wetland development by 1998. Game-crops were provided along railway lines as these had been identified as a preferred habitat for two breeding pairs in Lullymore (Chp. 5). However, in Boora older conifer plantations occurred close to many of the sites chosen along railway lines (Fig. 2.2). Self-sustaining pheasant populations are widespread in Boora, most notably within the maturing conifer plantations. Pheasants were observed flying from nearby plantations to feed in the game crops and several pheasant nests were discovered within the crops during fieldwork. Radio-tracked partridge were also recorded using game crops and
this was a preferred habitat within some BTPs. However, the value of the game crops as a breeding site may have been negated somewhat by the presence of pheasants. Pheasant parasitism of partridge nests appears to increase with pheasant density and many cases are known where such parasitized nests are abandoned (Westerskov, 1990). A study at a rearing field in Stirlingshire, Scotland (D. Tompkins unpubl. data) provided evidence that parasite transfer was possible between pheasants and partridge, with pheasants better able to cope with the parasite load.

**Forestry plantations**

In the short-term, the planting of young forestry on cutaway bog may have benefited the partridge population, as young forestry was a suitable brood rearing site for pair 1 & 2 (Chp. 5). In the early 1990s hundreds of hectares of young forestry were planted in large blocks in West and East Boora and in the north of Tumduff (see Fig 2.1 for map refs.). By the mid 1990s, many of these young forestry areas had become unsuitable for partridge breeding owing to canopy closure and replacement of herbaceous cover with rushes (B. Kavanagh, pers. com.). Forestry plantations are not viable as a long term partridge breeding habitat in Boora. In fact, as the stands mature they may become a major barrier to partridge dispersal between the adjoining cutaway bogs (Fig. 2.1). Use of short rotation forestry for biomass production could become an alternative management option (S. Jones, pers. com.).

**Grassland**

Some cutaway areas have been reclaimed as grassland. After the first year’s growth, grass is harvested as silage. Some birds returning to traditional breeding sites will be attracted to nest in these fields. Several pairs were reported without chicks in the vicinity of such fields. It is likely that the chicks
were lost through hypothermia during wet weather as the thick grass sward is devoid of drying out areas. It is likely that other birds lost nests or chicks during mowing. Two cases were reported of partridge chicks being rescued during mowing in Boora (K. Buckley pers. com.). Permanent pasture grazed by cattle is used by partridge coveys to feed from autumn to spring. Sheep pastures are of little value to partridge as feeding sites owing to a closely grazed sward with no poached soil areas available to weed species.

Tillage

Radio-tracked partridge were recorded using winter stubbles. The movement of coveys away from the cutaway bog appears to be linked to the availability of these tillage areas. However, anecdotal evidence suggests that pheasant shooting (which begins in November) in some of these tillage areas has lead to increased disturbance, with birds moving to nearby permanent pastures for the remainder of the winter.

Additional habitat

Cutaway bog continued to be reclaimed for alternative uses by Bord na Mona from 1996-1998. The partridge population had continued to decline. By 1998, it became evident that management of the remaining cutaway bog was of paramount importance for the future survival of partridge in Ireland. In 1999, 70 hectares of cutaway bog within the Tumduff area were obtained on a temporary lease from Bord na Mona. Management guidelines for partridge in Britain (Aebischer, 1997) recommend a 2m high hedgerow along a 1.3m wide grassy bank as a good nesting habitat. The hedgerow is maintained at this height and is free of tall trees that can provide lookout perches for avian predators. The banks are cut every 2-3 years on a rotational basis to avoid scrub encroachment while promoting nesting cover. During fieldwork in Boora
it was noted that the marl mounds along drains on the cutaway bog offered good nesting cover (Plate 7.1). These marl mounds were created as a process of drain creation, with the marl and peat spoil dumped as a ridge parallel to the drain. Subsequent colonisation by grasses and willows saplings produced a favourable partridge nesting habitat with adjacent recolonised areas of cutaway bog providing brood rearing cover. During radio-tracking, pair 2 bred successfully near one of these mounds. The chicks were first sighted on the side of the mound. In West Boora, a pair with young chicks was sighted adjacent to a similar marl mound in 1998 and 1999.

In spring 1999, a survey was carried out within the newly acquired conservation site. Six locations were identified where provision of additional marl mounds was possible (Fig. 7.2). Instead of digging a drain however, the nesting banks were created by scraping a quantity of the marl/peat substrate from both sides into a linear pile. These were seeded with recommended grass species in autumn 1999 (Plate 7.2). Brood-rearing cover was provided on both sides of these nesting banks and winter crops were planted in three blocks nearby. A number of partridge remained in the vicinity of the crops during winter 1999/2000 (K. Buckley, pers. com.). It is hoped that the nesting banks will provide suitable breeding sites from spring 2001 onwards.

**Lough Boora Parklands**

The development of Lough Boora Parklands has altered the landscape from a bleak cutaway bog to a visually pleasing mosaic of wetlands, forestry and grassland. Exploitation of the raised bogs for fuel on an industrial scale has provided local employment since the 1950s. Lough Boora Parklands is being promoted as a flagship model for alternative land uses, illustrating the potential for other areas of cutaway bogs which have become exhausted of peat (Egan,
The plan provides other means of local employment once all the peat is gone. This takes the form of tourism, farming and forestry. Funding is obtained from a European cutaway bog regeneration fund (see Acknowledgements). However, any land development that could have a negative impact on a nationally endangered species needs to be assessed.

With adequate planning it may be possible to combine partridge conservation with future land development. Bord na Mona management have been informed of the negative impact that present land developments could have on the remaining partridge. A number of measures have been suggested to them, such as replacing electric fences with hedgerows, leaving small blocks of cutaway bog within new grasslands and avoiding further forestry plantations in the area. However, subsequent developments indicate that the plight of the partridge is not high on the agenda. Use of the 70 ha conservation site is temporary and this land will eventually become grassland. The remaining cutaway bog south of the conservation site in Tumduff was planted with experimental forestry in 1999 and further plantations are planned.

The local community has been highly supportive of the partridge project and with funding, suitable partridge habitat could be incorporated within the surrounding farmland. Modern farming and partridge conservation can be compatible (Anon., 1992). The number of suitable nesting sites that could be provided within the mapped area of Boora is considerable for any one of the linear habitats available (Table 7.3). This data is based on a maximum of one nesting site for every 200m of linear cover (after Potts, 1986). Such wide-scale measures may not be costly if they are incorporated into the Lough Boora Parklands plan.
Plate 7.1 Marl mound on cutaway bog with grasses, herbaceous cover and willow saplings

Plate 7.2 Nesting bank within the conservation site in Tumduff
Figure 7.2. Habitat key to partridge conservation site in Tumduff, with positions of nesting banks, brood rearing cover and winter crops

LOCATION WITHIN MAP

KEY TO CONSERVATION SITE

- Nesting bank
- Brood rear. cover
- Winter crop
- Peat pile
- Cutaway bog
- Young forestry
- Grassland
- Drains
- Road & railway

Nesting banks with brood rearing cover (n=6): 888m
Other nesting banks (n=4): 435m
Winter crops (n=3): 1.6 ha
Peat piles (n=5): 745m
Table 7.3  Potential number of nest sites within the mapped area of Boora (1,823 ha), based on one nest site per 200m linear cover (Potts, 1986)

<table>
<thead>
<tr>
<th>Linear habitat</th>
<th>Length (km)</th>
<th>Potential nest sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway</td>
<td>9.1</td>
<td>45</td>
</tr>
<tr>
<td>Edge</td>
<td>13.2</td>
<td>66</td>
</tr>
<tr>
<td>Hedgerow</td>
<td>19.6</td>
<td>98</td>
</tr>
<tr>
<td>Road</td>
<td>21.2</td>
<td>106</td>
</tr>
<tr>
<td>Drain</td>
<td>44.9</td>
<td>224</td>
</tr>
</tbody>
</table>

7.4 Extinction risks

Population size
Regional decline of a species can often accompany habitat fragmentation, as no species has its individuals homogeneously and evenly distributed through its range. At some scales there will always be aggregations. Therefore a species decline that involves the loss of distinct populations may not be related to why the loss is occurring or what dynamics maintained the species prior to the contraction in range. Therefore the isolation of populations may be only a symptom of the decline, not the actual cause. The exact cause of a specific extinction will often be elusive. Several negative factors working in tandem or a series of disasters can often produce the final demise (Simberloff, 1995). Quammen (1996) describes a hypothetical event, where one of the last female owls of an endangered species chokes on a mouse. Partridge broods are sometimes killed by farm machinery, but the overall effect on the population is small (Carroll et al., 1990). In 1998, 5 chicks in west Boora were killed on cutaway bog by a tractor, and a similar accident was reported (but not confirmed) in 1999. With the Irish population at such a low level, the effect of
these normally insignificant events is amplified (Quammen, 1996). Currently
the Irish partridge is limited to two populations that are considered to be
isolated from one another due to distance (Fig. 1.1). Small population size and
concentration into a few sites can be considered as increasing the risk of
extinction for a species (Green, 1995).

Therefore, should we be concerned about the future viability of the species in
Ireland? Estimates for minimum viable populations vary between studies. A
species number of 500 individuals is considered an order of magnitude
necessary to maintain 90% of genetic variability over 100 generations
(Franklin, 1980 cited in, Clout & Craig, 1995). The risk of extinction rapidly
increases in sub-populations smaller than 20 reproductive units (Quinn &
Hastings, 1988, cited in Opdam et al., 1995). Local extinction is frequent in
forest bird populations below the size of five pairs (Van Noorden, 1986, cited
in Opdam et al., 1995). Some suggest that as populations go below a certain
minimum viable size, that they are subsequently doomed and that conservation
efforts should focus elsewhere (Soule, 1983, cited in Quammen, 1996). In
Costa Rica, officials were going to abandon saving jaguars (Panthera onca)
and harpy eagles (Harpia harpya) because they were told that a population
reduced to fewer than 50 individuals would go extinct (Quammen, 1996).
However, some populations persist for long periods despite the risks. For
example, the Sorocco Island Hawk (Buteo jamaicensis socorroensis) has
persisted at around 20 pairs for many generations and possibly for its whole

The Mauritius kestrel (Falco punctatus) and the Rodrigues fody (Foudia
flavicans) are examples of birds that have recovered from potentially doomed
bottleneck events. The Mauritius kestrel increased from what was believed to
be two surviving pairs in nature to more than 60 pairs through a range of management efforts (Jones et al., 1995). The Rodrigues fody was reduced to 5-6 pairs in 1968, due to forest destruction, but a recent survey estimated a minimum breeding population of 334 pairs (Impey, 2000). However, these recoveries are not common and adaptability of the species, sufficient habitat available for expansion and within dispersal distance of the species are important factors following a bottleneck event. In Lullymore, there may be no breeding partridge left, while in Boora there remains a maximum of 8 pairs (Kavanagh, 2001). What are the risks of inbreeding in Boora? The most extreme case of inbreeding in game birds was for a group of pheasants collected in China in 1864 (Potts, 1986). Two females and a male were ancestors to a population of 600 in the 1980s. Some birds had lost the ability to mate owing to low fertility, but the majority were unaffected. Mating between brothers and sisters or parents and young has not been observed in wild partridge, and the risk of extreme inbreeding is regarded as low, owing to separate dispersal of the sexes during covey break-up (Potts, 1986). Local extinction may be more likely, (when birds simply cannot find a suitable mate or breeding site), before any effects of inbreeding depression take effect (Stewart & Hutchings, 1996).

Home range analysis has shown that Irish partridge can cover up to 20 km² (Table 5.2 & 5.3) of land, from one breeding season to the next. Contact was lost with several radio-tracked birds in spring, and dispersal to other areas up to 6 km away (Table 5.4) is possible. Are the partridge in Tumduff (Fig. 2.2) part of the larger Boora population or a meta-population? A meta-population is perceived to exist as a series of sub-populations, linked by migration between them. However, the rate of migration is limited, such that the dynamics of the meta-population should be seen as the sum of the dynamics of the individual
sub-populations (Begon, *et al*., 1996). There is no dichotomy of populations. All may go extinct occasionally and all may serve as sources for the establishment of other populations. The Boora bogs encompass an area of 54km² and given the large movements of birds, should be considered as one population. The number of spring pairs in Tumduff may have declined during management partly because any benefit to breeding success resulted in additional birds to other cutaway areas. Estimated mean chick survival rates are low (Table 7.2). At some stage birds may become locally extinct in Tumduff, but be potentially re-colonised by birds from adjacent cutaway bogs.

Instead of regarding Tumduff as a refuge for remaining partridge it may be necessary to regard all the Boora cutaway bogs as playing a role preventing the extinction of the Irish grey partridge. It may be too late to save the Lullymore population. Reserves have an important role to play in conservation but their creation leads to the perception that any land-use can occur on the periphery (Wiens, 1995). Population processes in for example Turraun may be equally important to those in Tumduff. If the flux of individuals between cutaway bogs reaches zero, then each isolated area will become more vulnerable to demographic stochasticity (Quammen, 1996). Habitat fragmentation could have this effect.

**Habitat fragmentation**

Habitat fragmentation includes four components as summarised by Opdam *et al*. (1995).

1. A general loss of habitat area in the landscape (note: habitat loss does not always go together with fragmentation, but it often does; conversely fragmentation usually includes habitat loss.
2. A decrease in the size of habitat remnants.
3. An increase in the distance between patches.
4. An increase in the resistance to dispersal movements of organisms between fragments (due to the disappearance of small landscape elements which facilitate dispersal; or to the introduction of barriers such as wetlands or forestry)

Habitat fragments are open to influences from the surrounding landscape, with these effects possibly more important than those occurring within the fragment. Habitat fragmentation as a process can be defined as a disruption of habitat continuity. As the amount of habitat in an area is reduced there may be an abrupt threshold at which diffusion of individuals among patches is sharply reduced. The effect of habitat fragmentation depends on the scaling used. An area broken into 1 ha blocks of forest and clear-cut may represent fragments of suitable versus unsuitable habitat to an individual with a small home range less than 1 ha. The same landscape would be perceived as a fine-grained mixture of small patches by an individual with a larger home range of several km$^2$ (Wiens, 1995).

Partridge in Boora find breeding sites on the cutaway bog and wintering sites on pastures/cereal stubbles. Habitat loss can have an effect on bird populations for both losses of breeding and wintering grounds. Loss of wintering areas leads to concentration in remaining areas which could increase density dependant mortality (Simberloff, 1995). The ability of populations to adapt to loss of wintering areas may depend on genetics and cultural determination. For partridge, which spend winter in family groups and move from breeding areas on a local scale compared to migratory birds, the cultural influence may be dominant. In Boora, partridge home range shifts were related to the availability of cereal stubbles. Changes in the availability of cereal stubbles may effect the subsequent distribution of coveys during the winter. The large movements observed between breeding and wintering areas may
make grey partridge vulnerable to predation, but there is no evidence of this at present. Severe winter weather can effect mortality, when ice and heavy snow reduces availability of food (Potts, 1986; Panek, 1990; Carroll, 1993). In New York State, daily movements of up to 1.6 km were reported for coveys during the severe winter of 1981/2 (Church, 1980, cited by Potts, 1986). The sub-species *Perdix perdix lucida* in Eastern Europe migrates over hundreds of kilometers in response to severe winter weather (Cramp & Simmons, 1980).

Corridors are widely thought to reduce the vulnerability of isolated populations to chance extinction and to enhance the re-colonisation of empty habitat patches, thereby fostering species persistence. However, evidence that species do depend on corridors for their movement is limited (Hobbs, 1992). In Lullymore, railways were perceived to provide a link between cutaway bog areas as they provided a suitable cover of vegetation for birds to walk along, because many bird sightings occurred on railway and it was a preferred habitat during certain time periods (J. Hearshaw, pers. com.). Unfortunately, there was no direct radio-tracking evidence of birds moving along railways or roadways in either Lullymore or Boora. This would require evidence from continuous radio-tracking data or frequent observations of marked birds during a dispersal period. Therefore, it is not known if corridors are important for dispersal of Irish partridge between cutaway bogs in the spring or at any other times of the year.

It is possible that the plantation of forestry and the creation of wetlands as part of the Lough Boora Parklands initiative could increase the resistance to dispersal between remaining cutaway areas. Dispersal distance can vary as a function of habitat. For example, median dispersal distances of young nuthatches (*Sitta europaea*) were twice as great in a more heavily forested area
in Germany (Wiens, 1995). The Irish data indicates that partridge are capable of moving up to 6 km between time periods (Table 5.4), but these movements have been recorded in an open flat terrain and the effect of perceived barriers cannot be predicted. The dispersal distance of a species will determine whether part of a population becomes isolated. Strong effects of area as well as distance between heath-land areas were evident for the black grouse (*Tetrao tetrix*), a species confined to heath-lands in the Netherlands and northern Belgium. Spatial analysis suggested that re-colonisations over distances exceeding 10 km do not occur (Reijnen & Celada, unpubl. data, cited by Opdam et al., 1995). The combined effect of increased distance and dispersal resistance between habitat fragments would be to reduce the chance of a deserted habitat site being re-colonised, thereby decreasing the probability that local dispersers could rescue sub-populations from local extinction.

7.5 Future partridge conservation in Boora

There are many remaining gaps in our knowledge regarding the processes affecting grey partridge in the Irish midlands. A common outcome of intensive management is that it addresses proximate as opposed to ultimate causes of endangerment. Long term security can be ensured only if rescue efforts are coupled with efforts to address ultimate problems that are usually the result of landscape changes. These complimentary approaches need to be co-ordinated closely through a planning process, which aims to restore a population and remove threats to it (Cade & Temple, 1995). The balance of conservation action is gathering detailed and convincing evidence of the causes of the decline in the long term and applying present knowledge to the most promising remedies (Green, 1995).
Radio-tracking of individuals in this study has provided information on the relative use of habitats available within cutaway bogs and farmland. Recovery programmes need input from several disciplines all at once, e.g. education, public relations, fund-raising, biology, ecology, behaviour, population dynamics, modelling and environmental politics (Cade & Temple, 1995). Assessing the effects of present and future habitat changes in Boora on population dynamics will require detailed and systematic census data coupled with close monitoring of habitat change.

Several spatial concepts for designing landscapes with fragmented habitat are available. Examples include two basic types of network (Opdam et al., 1995).

1. One big core area allowing a near zero local extinction risk and supporting small sites in the surrounding landscape with dispersers
2. A network of small patches in which local populations frequently go extinct and reappear, so that patches though not sustainable on their own, form a spatial network in which the species can find a long term sustainable equilibrium.

Big and small are subjective terms. The total home range (MCP) for pair 1 and 2 in the Boora landscape were 3.8 and 2 km² respectively, which includes breeding and part of their wintering areas. This gives a mean value of 2.9km² per pair that could be considered the minimum area needed by a successfully breeding pair in 1997/8 in Tumduff. The mapped area of Tumduff (Fig. 2.2, 7.1) is 18km² which could be considered a “big” area for a pair using a 2.9km² portion. In 1996, there were 6 spring pairs (Fig. 7.1). This would not support the condition of “zero” extinction risk in case 1, but quite the opposite, studies discussed earlier predict this sub-population to be at a high risk of extinction. This is happening, with only one spring pair known in 2000. Therefore, the
Tuinduff area should be seen as case 2, a patch within a network, the network being the Boora group of bogs, a mosaic of breeding and wintering grounds. However, the autumn census data (Table 7.2) does not suggest a sustainable equilibrium, rather an overall decline. The objective should be to prevent further declines.

The present approach of focusing only on Tuinduff may be futile in the long term. However, this suggests an impossible situation presently, because resources only allow for intensive management in one cutaway bog. Cade and Temple (1995) discussed the "single species" approach versus the more holistic "ecosystem" approach. They suggest that an already threatened species often requires special efforts directed to its particular needs, in order to be restored to a viable population within the larger ecological context. The particular needs of the partridge require more resources and in-depth discussions with Bord na Mona (who own the breeding sites on cutaway bogs), and farmers (owners of some breeding sites and all the wintering sites). A detailed analysis will be needed of the area of land within the Boora group of bogs, that can be realistically managed in a way that is compatible with partridge requirements. This could be a lengthy undertaking and would require large-scale mapping (or an aerial survey) and the involvement of other interest groups. There are several other vulnerable and endangered species that are known to occur on the cutaway bogs. These species could be linked to an integrated action plan, thereby giving it more political power and funding. Examples of species that have been recorded in the Boora bogs include corncrake, quail, lapwing, hen harrier, merlin (*Falco columbarius*), nightjar (*Caprimulgus europaeus*) Irish hare and the Marsh fritillary butterfly (*Euphydryas aurinia*). Therefore the "ecosystem" approach may hold the key
to the partridge’s long-term survival, requiring modifications to the Lough Boora Parklands initiative.

7.6 Further partridge research

Roost sites
During the course of fieldwork partridge roost sites were recorded intermittently during the year. These were additional radio-fixes taken at night that were not used in previous analysis (Table 7.4). In most cases a radio-fix taken previously in the day was also available and it was possible to measure the distance from this radio-fix to the roost site. It was also of interest to note any differences in habitats used as roost sites.

There was considerable variation in the distance (mean +/- sd) between the radio-fix taken during the day and the roost radio-fix (male #1, 534 +/- 512 m, n=11; pair 1, 305 +/- 180 m, n=17; pair 2, 270 +/- 131 m, n=5). Possible sources of variation were time of previous radio-fix, time of year and the number and social mix of birds. Birds did not leave their home range to roost, as in all cases the roost site was within the home range (MCP) for that time period. The majority of roost sites recorded were within grassland (male #1: 83%, male#2: 66%, male #6: 100% of roosts), despite the fact that during the day grassland may not have been used throughout an entire time period. This was typically permanent pasture grazed by cattle.

Previous research involving partridge roost sites has focused on selection by partridge broods (Enck, 1990) or for the purpose of faecal collection (Green, 1984; Rands, 1985, 1986a; Moreby, 1987). The only exception found was a study by Dudzinski (1988a). The author studied partridge wintering grounds in
Table 7.4 Roost site data collected for male #1 and pairs 1 & 2 in Boora

<table>
<thead>
<tr>
<th>DATE</th>
<th>Time of previous radio-fix</th>
<th>Habitat for previous radio-fix</th>
<th>Time recorded at roost</th>
<th>Habitat for roost site</th>
<th>Distance between radio-fixes (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male #1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23-May-97</td>
<td>17.05</td>
<td>Cutaway bog</td>
<td>23.15</td>
<td>Cutaway bog</td>
<td>356</td>
</tr>
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Poland. It was found that partridge did not use the same roosting bowl twice. It was suggested that this was because frozen piles of old faeces did not allow them to use the same site roosting bowl twice. By comparing habitat use during the day with that of roost sites it was found that open crop fields were more preferred at night than during the day. The author felt that coveys roosted in open winter crops because this protected them to some degree against predators, but that to create a suitable roosting bowl mostly shallow depressions within this habitat were selected. This was because they accumulated a depth of 7-10 cm of snow (enabling a roost bowl to be formed, even during light snowfall). Given the relatively mild Irish winters (mean January temperature of 5.5 °C) it is likely that different parameters are influencing partridge roost site selection in winter. Moreover, grassland was recorded as a roost site in all months except February and during brood rearing. Why grassland is usually selected is not known and would require further research. In Lullymore, of the 15 attempts to catch birds at night, birds were observed roosting on bare areas of cutaway bog 9 times and 6 times in heather top habitat.

Clearly there is scope for further research in this area. I would suggest for instance an intensive study where three radio-fixes a day are recorded, one in the morning, afternoon and prior to dusk, followed by location of the roost site. This would be carried out for one week every month for one year for a sample of birds.

**Diet and food availability**

In Ireland, cutaway bog was identified as a preferred breeding habitat to the present modern farm environment where partridge populations have become extinct. However, given the low density and estimated chick survival of birds,
cutaway bog must be considered a poor substitute for breeding partridge when compared to the traditional tillage habitat of the 1950's. In this context, it would have been enlightening to survey plant and insect diversity/density within the various cutaway bog plant communities, (particularly during the brood rearing period) and to compare the results with those available from previous partridge studies on farmland. This could become an informative future research area. An extensive collection of adult partridge droppings sampled during all months of the year was collected during fieldwork in the present Boora study and these are available for analysis.

**Tape playback**

Tape playback of partridge calls have been used in previous studies as a means of surveying partridge populations (Moyles & Lester, 1987; Beani et al, 1988; Schoppers, 1996). During the present Boora study, a tape call was obtained of a farm-reared female. This was useful in locating unpaired males, but response by pairs was unpredictable. During a preliminary study in spring 1997, the efficiency of tape playback (2 x 30 sec playback followed by 1 min wait, after Moyles & Lester, 1987) was tested at locations known to contain pairs. These took place after dusk in calm conditions in spring 1997. Of 40 separate playback events, only 10 playbacks resulted in a response from the pair. Therefore, lack of a response to a tape call did not imply that no birds were present, indicating that the tape call was an unreliable way of estimating pair locations. However, personal observations of unpaired males would suggest that use of a tape call using the call of a wild unpaired male may be more likely to elicit a response from a pair. With further research this method could provide a useful management tool in the estimation of spring pair densities.
Chapter 8

REFERENCES


BROWN, P. 1774. A catalogue of the birds of Ireland, whether natives, casual visitors or birds of passage, taken from observation and disposed according to Linnaeus. The Gentleman’s and London Magazine: or, Monthly Chronologer. 1774: 385-387.


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POTTS, G.R. 1980. The effects of modern agriculture, nest predation, and game management on the population ecology of partridges (*Perdix perdix* and *Alectoris rufa*). Advances in Ecological Resources. 11:2-79.


Pimlico, London.

Biology. 1: 198-208.


RANDS, M.R.W. 1985. Pesticide use on cereals and the survival of grey partridge chicks:

RANDS, M.R.W. 1986a. The survival of gamebird chicks in relation to pesticide use on
cereals. Ibis. 128: 57-64.

RANDS, M.R.W. 1986b. Effect of hedgerow characteristics on partridge breeding


REITZ, F. 1992. Adult survival and reproductive success in abundant populations of grey
partridge (*Perdix perdix*) in North Central France, in: M. Birkan, G.R. Potts, N.J. Aebischer
& S. Dowell (eds.), *Perdix VI*, First International Symposium on Partridges, Quails and
Francolins, Gibier Faune Sauvage, 9: 313-324.


end of summer to the next spring: a comparative study, in: S. Farago (ed.), Perdix VIII

REITZ, F. & MAYOT, P. (in prep.) Effects of habitat characteristics on the predation risk

REYNOLDS, J.C., DOWELL, S., BROCKLESS, M., BLAKE, K. & BOATMAN, N.


ROLANDO, A. & CARISIO, L. 1999. Effect of resource availability and distribution on
autumn movements of the Nutcracker *Nucifraga caryocatactes* in the Alps. Ibis. 141: 125-
134.


Appendix 1. List of common names (Latin in brackets) for amphibians, birds, crops, grasses, insects, livestock, mammals, plants, and trees/shrubs used in this thesis.

Note: Where the common names of amphibians, birds, crops, grasses, insects, livestock, mammals, plants, and trees/shrubs first appear in the thesis, the scientific name follows in brackets. Subsequent use of the same common name is not presented with scientific text.

Amphibians
Common Frog (*Rana temporaria*)

Birds
Blackbird (*Turdus merula*)
Black grouse (*Tetrao tetrix*)
Capercaillie (*Tetrao urogallus*)
Corncockle (*Crex crex*)
Duck (*Anas sp.*)
Goshawk (*Accipiter gentilis*)
Grey Crow (*Corvus corone cornix*)
Grey Heron (*Ardea cinerea*)
Harpy eagle (*Harpia harpya*)
Hen-harrier (*Circus cyaneus*)
Lapwing (*Vanellus vanellus*)
Magpie (*Pica pica*)
Mauritius kestrel (*Falco punctatus*)
Merlin (*Falco columbarius*)
Nightjar (*Caprimulgus europaeus*)
Nuthatch (*Sitta europaea*)
Partridge
  Daurian (*Perdix dauica*)
  Grey (*Perdix perdix*)
  Tibetan (*Perdix hodgsoniae*)
Peregrine Falcon (*Falco peregrinus*)
Pheasant (*Phasianus colchicus*)
Quail (*Coturnix coturnix*)
Red Grouse (*Lagopus lagopus*)
Rodrigues Fody (*Foudia flavicans*)
Scops Owl (*Otus scops*)
Snipe (*Gallinago gallinago*)
Song thrush (*Turdus philomelos*)
Sorocco Island Hawk
  (*Buteo jamaicensis socorroensis*)

Birds (cont.)
Woodcock (*Scolopax rusticola*)

Crops
Barley (*Hordeum vulgare*)
Flax (*Linum usitatissimum*)
Kale (*Brassica oleracea*)
Oats (*Avena sativa*)
Oilseed rape (*Brassica napus*)
Onion (*Allium vineale*)
Potato (*Solanum tuberosum*)
Sugar beet (*Beta vulgaris*)
Turnips (*Brassica rapa*)
Wheat (*Triticum aestivum*)

Grasses
Annual Meadow (*Poa annua*)
Cocksfoot (*Dactylis glomerata*)
Fescue
  Red (*Festuca rubra*)
  Sheep (*Festuca ovina*)
  Tall (*Festuca arundinacea*)
Perennial rye (*Lolium perenne*)
Purple moor grass (*Molinia caerulea*)
Reed canary (*Phalaris arundinacea*)
Timothy (*Phleum pratense*)
Yorkshire fog (*Holcus lanatus*)

Insects
Marsh Fritillary Butterfly
  (*Euphydryas aurinia*)

Livestock
Cattle (*Bos taurus*)
Horse (*Equus sp.*)
Sheep (*Ovis aries*)
## Appendix 1 (cont.)

### Mammals
- African Elephant (*Loxodonta africana*)
- American mink (*Mustela vison*)
- Feral Cat (*Felis catus*)
- Fox (*Vulpes vulpes*)
- Irish Hare (*Lepus timidus hibernicus*)
- Rat
  - Brown (*Rattus norvegicus*)
  - Malayan Wood (*Rattus tiomanicus*)
- Stoat (*Mustela erminea*)

### Plants
- Black-bindweed (*Fallopia convolvulus*)
- Bracken (*Pteridium aquilinum*)
- Bramble (*Rubus fruticosus*)
- Buttercup
  - Bulbous (*Ranunculus bulbosus*)
  - Creeping (*Ranunculus repens*)
  - Meadow (*Ranunculus acris*)
- Cats' ear (*Hypocheris radicata*)
- Chervil
  - Rough (*Chaerophyllum temulentum*)
- Chickweed (*Stellaria media*)
- Clover
  - Red (*Trifolium pratense*)
  - White (*Trifolium repens*)
- Coltsfoot (*Tussilago farfara*)
- Common bird's-foot-trefoil (*Lotus corniculatus*)
- Common daisy (*Bellis perennis*)
- Common groundsel (*Senecio vulgaris*)
- Common hemp nettle (*Galeopsis tetrahit*)
- Common mouse-ear (*Hieracium pilosella*)
- Heather
  - Bell (*Erica cinerea*)
  - Cross-leaved (*Erica tetralix*)
  - Ling (*Calluna vulgaris*)
- Horsetail
  - (Equisetum avene)
- Knapweed (*Centaurea nigra*)
- Knotgrass (*Polygonum aviculare*)
- Lucerne (*Medicago sativa*)
- Milkwort
  - Common (*Polygala vulgaris*)
  - Heath (*Polygala serpyllifolia*)
- Mouse-ear (*Hieracium pilosella*)
- Nettle (*Urtica dioica*)
- Parsley
  - Cow (*Anthriscus sylvestris*)
  - Upright hedge (*Torilis japonica*)
- Plantain
  - Hoary (*Plantago media*)
  - Ribwort (*Plantago lanceolata*)
  - Ragwort (*Senecio jacobaea*)
- Redshank (*Polygonum persicaria*)
- Rush
  - Bulbous (*Juncus bulbosus*)
  - Jointed (*Juncus articulatus*)
  - Sharp flowered (*Juncus acutiflorus*)
  - Soft (*Juncus effusus*)
  - Toad (*Juncus bufonius*)
- Sedge
  - Bottle (*Carex rostrata*)
  - Carnation (*Carex panicea*)
  - False fox (*Carex obturata*)
  - Glaucous (*Carex flacca*)
  - Greater tussock (*Carex paniculata*)
  - Star (*Carex echinata*)
- Silverweed (*Potentilla anserina*)
- Sowthistle
  - Prickly (*Sonchus asper*)
  - Smooth (*Sonchus oleraceus*)
- Thistle
  - Creeping (*Cirsium avene*)
  - Meadow (*Cirsium dissectum*)
  - Marsh (*Cirsium palustre*)
  - Spear (*Cirsium vulgare*)
  - Welte (*Carduus acanthoides*)
Appendix 1 (cont.)

Plants (cont.)

Tormentil (*Potentilla erecta*)

Willowherb
- Broad leaved (*Epilobium monatum*)
- Great (*Epilobium hirsutum*)
- Marsh (*Epilobium palustre*)
- Rosebay (*Epilobium angustifolium*)
- Short fruit (*Epilobium obscurum*)
- Small flowered hairy (*Epilobium parviflorum*)

Trees & Shrubs

Birch
- Downy (*Betula pubescens*)
- Silver (*Betula pendula*)

Common Ash (*Fraxinus excelsior*)

European Larch (*Larix decidua*)

Gorse (*Ulex europaeus*)

Hawthorn (*Crataegus monogyna*)

Lawson Cypress (*Chamaecyparis lawsoniana*)

Sessile Oak (*Quercus petraea*)

Scots Pine (*Pinus sylvestris*)

Spruce
- Norway (*Picea abies*)
- Sitka (*Picea sitchensis*)

Sycamore (*Acer pseudoplatanus*)

Willow
- Bay (*Salix pentandra*)
- Creeping (*Salix repens*)
- Eared (*Salix aurita*)
- Goat (*Salix caprea*)
- Sallow (*Salix atrocinerea*)

Yew (*Taxus baccata*)
## Appendix 2. Habitat use (% radio-fixes in each habitat) and habitat availability (% habitats in Study area & MCP) in each BTP for pairs 1 & 2 from 1997-1998 in the present Boora study

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<th>Other tree cat.</th>
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<th>Tillage</th>
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Appendix 3. Habitat use (% radio-fixes in each habitat) and habitat availability (% habitats in MCP) in each BTP for Pair A, B & C from 1992-1994 in the Lullymore study

<table>
<thead>
<tr>
<th>Study area habitats 1992-94</th>
<th>Cutaway bog</th>
<th>Private bog</th>
<th>Heather top</th>
<th>Agriculture</th>
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<tr>
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<td>54.7</td>
<td>7</td>
<td>7.7</td>
<td>22.3</td>
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</table>

| Pair A | 2° cov.mov | USE | 100 |
|        |            | MCP | 100 |
|        | Covey break-up | USE | 1.6 | 88.7 | 8.1 | 1.6 |
|        |              | MCP | 40.6 | 34.7 | 23.9 | 0.7 |
|        | Habitation   | USE | 100 | |
|        |              | MCP | 100 | |
|        | Laying       | USE | 100 | |
|        |              | MCP | 100 | |
|        | Incubation   | USE | 100 | |
|        |              | MCP | 100 | |

| Pair B | Habituation | USE | 100 |
|        | Laying      | USE | 100 |
|        | Re-lying    | USE | 100 |
|        | Incubation  | USE | 100 |
|        |              | MCP | 100 |
|        | 1° cov.mov  | USE | 97.4 | 2.6 |
|        |              | MCP | 99.8 | 0.2 |
|        | 2° cov.mov  | USE | 48.6 | 5.7 | 28.6 | 17.1 |
|        |              | MCP | 68.7 | 5.2 | 19.9 | 1.1 |

| Pair C | Habituation | USE | 100 |
|        | Laying      | USE | 100 |
|        | Incubation  | USE | 100 |
|        |              | MCP | 100 |
|        | 1° cov.mov  | USE | 38.8 | 33.3 | 5.6 | 22.2 |
|        |              | MCP | 67.4 | 9.8 | 16.1 | 6.3 |
|        | 2° cov.mov  | USE | 89.6 | 3.2 | 10.4 |
|        |              | MCP | 35 | 3.2 | 61.8 |
### Appendix 4. Habitat use (% radio-fixes in each habitat) and habitat availability (% habitats in study area & MCP) in each BTP for male #1 (1997) in the present Boora study

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Study Area Habitats 1997</th>
<th>Mate Search USE</th>
<th>Mate Search MCP</th>
<th>Isolation USE</th>
<th>Isolation MCP</th>
<th>1st mov. Pat. USE</th>
<th>1st mov. Pat. MCP</th>
<th>2nd mov. Pat. USE</th>
<th>2nd mov. Pat. MCP</th>
<th>3rd mov. Pat. USE</th>
<th>3rd mov. Pat. MCP</th>
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<td>8.1</td>
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<td>31</td>
<td>10.5</td>
<td>37.9</td>
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<td>9.7</td>
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Appendix 5. Rainfall recorded in June, July and August at Bord na Mona Works in Boora from 1993-2000 (courtesy of S. Ganly, BNM)

<table>
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<th>Year</th>
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