The ecology of Twite *Carduelis flavirostris* in Ireland

December 2009

Author: Derek McLoughlin BSc (Hons)

A thesis submitted to the Institute of Technology, Sligo for the degree of Doctor of Philosophy

Supervisor:

Dr Don Cotton

Senior Lecturer in Ecology

Department of Environmental Science

Institute of Technology, Sligo

Funding agency:

National Parks and Wildlife Service,

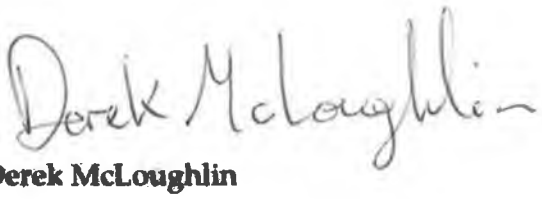
7 Ely Place,

Dublin 2

This is to certify that;

(i) **This thesis represents my own original work. Co-authors have been listed in each of the chapters.**

(ii) **Due acknowledgement has been made of all material referred to in the text.**



Derek McLoughlin

December 2009

Table of Contents

ABSTRACT

Title: The Ecology of Twite *Carduelis flavirostris* in Ireland

Author: Derek McLoughlin

Date: December 2009

The Twite *Carduelis flavirostris* is one of only three passerine species to appear on the red list of Birds of Conservation Concern in Ireland. It is also listed in The Irish Red Data Book of endangered species. Despite its unfavourable conservation status, no previous study has ever focused on this bird in Ireland. Data on Irish Twite has been sparse and largely anecdotal because it mainly relied upon the observations of birdwatchers. It also lacked ecological precision or information on demographics. Population surveys in this study found north county Mayo and west county Donegal to be the two breeding strongholds, accounting for a combined total of 40 pairs. Based on this data, and various verified records, it is estimated that the national population is between 54 and 110 breeding pairs with a minimum of 650-1,100 birds wintering here. Applying these figures to the IUCN Red Data Book criteria, Twite are 'Endangered' and can be considered at 'high risk of extinction in the wild' in Ireland. Nesting habitat for Twite in Ireland comprises good quality long Heather *Calluna vulgaris*, and occasionally Bracken *Pteridium aquilinum*. For foraging, Twite selected dry-humid acid grassland, saltmarsh and artificial surfaces such as small weedy roads and roadside verges. Twite targeted the seed of more than 20 plant species depending on their availability, particularly; *Taraxacum* agg., *Rumex acetosa*, *Stellaria media*, and *Plantago maritima*. Freshwater streams provide an important habitat for bathing, drinking, and picking up grit. It was found that foraging habitats were always within 2.5 km of the nest sites. Twite remain in their breeding areas from late April to September and generally over-winter within 30 km of their breeding areas. Winter flocks primarily forage for seed at cattle ring-feeders, saltmarshes, and sea drift lines. Overgrazing and changes in land use represent the main threats to Twite. Measures to conserve Twite as a breeding species in Ireland must include the maintenance and creation a heterogeneous mix of moorland, particularly long Heather, and avoid agricultural improvement (e.g. reseeds) in foraging areas.

ABBREVIATIONS

ANOVA	Analysis of Variance
ANCOVA	Analysis of Covariance
BDP	Biological Diversity Plan
BP	Brood Patch
BTO	British Trust for Ornithology
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CFP	Commonage Framework Plan
EU	European Union
EURING	European Union for Bird Ringing
FPS	Farm Plan Scheme
GFP	Good Farming Practice
GIS	Geographical Information System
JNCC	Joint Nature Conservation Council
IUCN	International Union for the Conservation of Nature
LINNET	Land Invested in Nature, Natural Eco-Tillage
MANOVA	Multivariate Analysis of Variance
MCP	Minimum Convex Polygon
NPWS	National Parks and Wildlife Service
REPS	Rural Environment Protection Scheme
RSPB	Royal Society for the Protection of Birds
SAC	Special Area of Conservation
SAP	Species Action Plan
SPA	Special Protection Area

Acknowledgements & Dedications

Firstly I am very grateful to Don Cotton for supervising this thesis and Chris Benson who so generously gave his time, expertise and patience throughout this study. Both of you have been a great inspiration. Thanks also to Aleksandra Borawska who assisted me in the field for four months in 2007.

Thank you to all the birdwatchers that submitted records to me over the past four years (many are acknowledged in the papers listed in Appendix B, Appendix C and Appendix E).

I thank David Cabot, who came up with the idea for this study, Tony Murray, Eoin McGreal, David Norriss, Dave Suddaby, John Wilson, Ken Perry, Steve Newton, James Kilroy, Oliver O'Cadhla, John O'Halloran, John Bartlett, Emer Magee, Mike Trewby, Irene O'Brien, Alyn Walsh, Lorcan O'Toole, Declan Manly, Eamonn O'Sullivan, Sabina Hiller, Dave Sowter and Andre Raine who were tremendously encouraging and supportive. Thanks to Eugene Archer who started a thread on Twite on the Irish Bird Network Internet forum that acted as a very useful starting point for my study and Brendan Kavanagh who also had a keen interest in Twite.

For help and advice on data analysis, thanks to Bryony Williams, Jessica Beaubier & Andrew Cameron, Elvira de Eyto, Barry Rourke and Brendan Cameron.

I am very grateful to Micheál Casey, Gillian Marsh TV and Liam McDevitt for many of the photos in this thesis.

I thank my wonderful family, and my good friends who also helped out: Conor, James, Robin, Liam, Anthony, Baz, Eoin, Lochlann, Bill & Iris.

Above all I thank my wife Sue, and mother of our newborn son Rowan, for her infallible patience, love and understanding of my four-year endeavour. I am a lucky man!

Finally, I sincerely thank the National Parks and Wildlife Service for generously funding this study.

I dedicate this thesis to my parents Kieran and Rita.

PREFACE

Rationale for study on Twite in Ireland

The lack of information on Twite in Ireland has been acknowledged by several authors over the past fifty years, e.g. Ruttledge (1966); Gibbons *et al.* (1993); Whilde (1993); Cabot (1999); Taylor & O'Halloran (1999); Lysaght (2002); Langston *et al.* (2006). The Twite is one of only a few resident bird species for which no systematic research has ever been carried out. Even the estimate of the national population status here was uncertain. Gibbons *et al.* (1993) estimated 3,500 breeding pairs based on extrapolation of British densities, while Coveney *et al.* (1993) estimated between 750 and 1,000 pairs. Cabot (2004) then revised this figure down to between 50 and 150 pairs. All of these estimates were made in the absence of specific Twite fieldwork. As the population status and distribution of a species was considered to be one of the first steps in establishing its ecological requirements, we were missing even the most basic of information on the Twite in Ireland. Concern over an unstudied and potentially declining Red listed population gave us the impetus to study Twite. The National Parks and Wildlife Service (NPWS) of the Department of Environment, Heritage and Local Government came on board at an early stage to fund this study.

OBJECTIVES AND SCOPE OF THIS STUDY

Knowledge of a species' population status, movement patterns, and habitat choice is a prerequisite for assessing its ecological requirements in order to plan successful conservation strategies (Brandt & Cresswell 2008). With this in mind, the primary objective of this study is to fill the some of the serious information gaps of the Twite's ecology in Ireland and provide a platform from which we can start to conserve Twite as a breeding species in Ireland.

The objectives of this study are as follows:

1) To collate all previous literature and information relating to Twite in Ireland.
2) To visit areas where Twite were previously found to breed in Ireland and determine whether or not Twite still breed there.
3) To determine the breeding and winter population status of Twite in Ireland based on fieldwork and data from other sources.
4) To establish the movement patterns and population dynamics of Twite in their breeding strongholds in Ireland.
5) To determine the wintering locations of Irish breeding Twite.
6) To analyse the breeding habitat requirements of Twite in Ireland.
7) To examine the habitat selection processes of Twite in their breeding strongholds using innovative equipment and software including, radio telemetry, RANGES7 software, and COMPOS+ software,
8) To compare Irish, Scottish, and English Twite, based on biometric data gathered through the study's ringing activities.
9) To summarise threats to the Twite in Ireland and propose conservation measures to conserve and enhance populations here.

Structure of thesis

This thesis follows a papers-based format with a general introduction (Chapter 1), and five papers intended for publication (Chapters 2-6). As a consequence of this format, there is some repetition between the methods and reference sections of the papers.

Paper one, entitled the Status of Twite in Ireland, assesses the status of breeding and wintering Twite *Carduelis flavirostris* in Ireland using our own data and data from various verified records from throughout the country. We also review literature relating to Twite populations in Ireland, dating from 1849 to present day. It has been published in *Irish Birds* journal (McLoughlin & Cotton 2008).

Paper two, entitled the movement patterns of two populations of Twite in Ireland, analyses the results of an intensive colour ringing programme on two populations of Twite. Using radio telemetry we also discuss the range size and structure of 11 birds in county Mayo. This paper is currently in press for publication in *Ringing and Migration*.

Paper three investigates the breeding habitat requirements of Twite in Ireland. We use a traditional transect method to determine the habitat use patterns of Twite during the months of April to September, in counties Mayo and Donegal. We also use innovative radio telemetry techniques to examine habitat selection on the Mullet Peninsula in county Mayo.

Paper four analyses Twite biometrics data gathered through our colour ringing activities. This is compared to Twite biometrics data from the Orkneys in Scotland and the South Pennines in England.

The final paper is entitled the conservation of Twite in Ireland and summarises findings of the previous papers, discusses possible conservation measures for Twite in Ireland, and suggests avenues for further study of aspects of the ecology of Twite in Ireland.

CHAPTER 1

Introduction

1. Origin of the name

The Twite *Carduelis flavirostris* (Linnaeus, 1758) is a small species of bird that belongs to the finch family (Fringillidae). *Carduelis* is thought to be derived from the Latin word *Carduus* meaning thistle (Anon 2003) (a targeted source of food for many species of finch including Twite). *Flavirostris* can be broken down to two other Latin words, *Flavi* meaning yellow and *rostris* translating as bill (Anon 2003). The common name, Twite, comes from the phonetic interpretation for its characteristic 'twveeeit' contact call. The Twite is still known by some as the Mountain Linnet, while in Scotland, many refer to Twite as Linties. The literal translation of its Irish name, An Gleoiseach Sléibhe, is the Mountain Chatterer (Dempsey & O'Clery 2002).

2. General biology and similar species

Within the finch family two sub-families occur, the Fringillinae (Chaffinches etc.), and the Carduelinae (Twite, Linnet, Greenfinch etc.). The Twite is a member of the Carduelinae, which are often referred to as Cardueline finches within which, Twite is most closely related to the Linnet *Carduelis cannabina*, Lesser Redpoll *Carduelis flammea cabaret* and the Common Redpoll *Carduelis flammea flammea*. The separation of these species in the field can sometimes be problematic for the untrained observer. Twite, have a 'warmer' appearance than the linnet, with a buff-coloured, unstreaked throat. They have a brown golden-streaked plumage. During the breeding season their bill is a similar grey colour to that of the Linnet, however between September and March it turns distinctively yellow. Linnet have a chestnut coloured back and a slate-grey head with some streaking on the throat. They have a white patch on their cheek, with a pale, whitish eyebrow. Twite do not have the black mark under their bill as both the Lesser and Common Redpoll species do. The

vocalisations of these species differ quite distinctly and allow identification when the bird cannot be identified on sight (Newton 1972, Mullarney *et al.* 1999).

The members of the Cardueline sub-family have evolved to become adept at clinging to twigs and stems and many have specialised bills to deal with particular seed-heads and cones. They live almost entirely on seed, unlike the Fringillinae sub-family, for which insects comprise a relatively large part of their diet. The young are fed by regurgitation of either seeds alone, or a mixture of both seeds and insects. As a result of their dependence on seed Cardueline finches tend not to defend large territories, in or out of the breeding season unlike insectivorous birds, but instead nest in loose colonies and forage throughout the year in flocks (Newton 1972).

Figure 1. A pair of Twite at breeding site on Ling Heather *Calluna vulgaris*.

3. Nesting biology

Twite nests are often found in Bracken *Pteridium aquilinum* and Ling Heather *Calluna vulgaris* (Fig. 1) usually less than 50cm above the ground (Orford 1973, McGhie *et al.* 1994). Nests have also been recorded in a wide variety of other habitats including rushes *Juncus* spp., stonewalls, Thistles *Cirisium* spp. (Brown *et al.* 1995), coniferous plantations (Nick Wilkinson pers. comm.) and cliff ledges with or without vegetation (Cramp 1998). The nests are generally built using grasses and plant stems and are almost invariably lined with wool, hair or feathers (Harrison & Castell 1998). As with the Linnet and Redpoll, it is the female that chooses the nesting location, constructs the nest, and incubates the eggs and young. The male generally 'stands guard' within approximately 20 metres of the nest, singing from a prominent perching point, e.g. a clump of Heather or Bracken, a rock, or cliff top position.

The Twite's mating system is apparently mainly monogamous with some examples of polygamy as noted by Marler & Mundinger (1975). Pair formation is said to occur in the spring flock (Cramp 1998). In Britain and Ireland, egg laying begins in mid- to late April and continues until August (Newton 1972). However, laying in northern Scotland is a little later with the first eggs in mid-May and the last in mid-August. Some of the Norwegian birds lay from early April to mid-August (Cramp 1998).

Twite tend to have two broods during the course of the breeding season with the average clutch sizes being between 5 and 6 eggs. The female generally lays an egg a day and probably commences incubation after the third or fourth egg. Incubation takes approximately 12 or 13 days and hatching may occur over a two or three day period. Both parents feed the young although

there are records of males taking no part in the provisioning of the chicks (Harrison & Castell 1998, Cramp 1998).

4. Distribution and population

Twite has a disjunct global population (Newton 1972, Brown *et al.* 1995) occurring in north western Europe and 2,500 km away in Central Asian (Fig. 2). Its European population stretches from Norway and Sweden, in a southwest direction, to Britain and Ireland (Vaurie 1956, Voous 1960, Cramp 1998, Langston *et al.* 2006). The Asian population occur in eastern Turkey and Iran, through northern Pakistan, Afghanistan and Tibet and into western China (Vaurie 1956, Voous 1960, Orford 1973). This Asian range extends northwards into Mongolia and Russian Siberia. The two populations appear to have been isolated for several thousand years, and Orford (1973) and Voous (1960) speculate that this is possibly since the retreat of the last major glaciation.

There is some confusion over the number of subspecies of Twite that occur throughout its global range. Vaurie (1956) points out, primarily based on morphology, that perhaps six subspecies of the nominate race *Carduelis flavirostris flavirostris* occur in Asia. *C.f. pipilans* and *C.f. bensonorum* are the subspecies said to occur in Britain and Ireland with the latter only noted from the Outer Hebrides. Ten different subspecies of the nominate race throughout its global range are listed by Cramp (1998), whilst Clements (2007) lists six subspecies of the nominate race throughout the world (Table 1). Although most of these suggested subspecies have not as of yet stood up to rigorous genetic taxonomic examination, Mathinsen *et al.* (2008) did find two well supported monophyletic groups when comparing the nominate *C.f. flavirostris* (Norway) with *C.f. rufostrigata* (Himalayas). *C.f. rufostrigata*, which occurs in

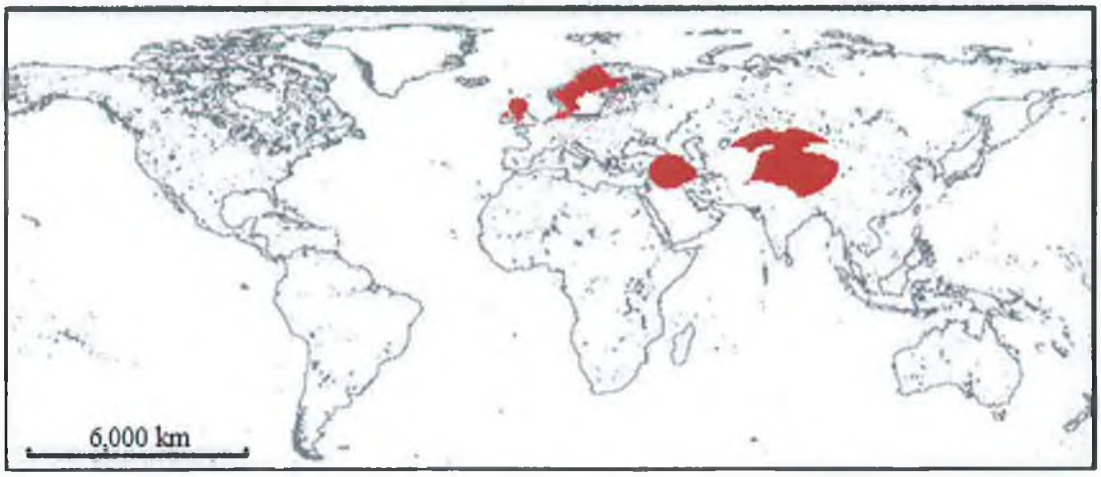
the Himalayas from Ladakh to southeast Tibet, has been classified as *C.f. miniakensis* in 2008 (Table 1; Clements 2008).

Table 1. Global distribution of the nominate race, and subspecies of Twite (Clements 2007).

Subspecies	Location
C.f. flavirostris (nominate)	Norway, Northern Sweden and Finland. Winters along the European low countries.
C.f. pipilans	Scotland (including northern and western isles), England, and Ireland.
C.f. brevirostris	Eastern Turkey and Caucasus to NW Iran.
C.f. korejevi	South Ural Mts. to Caspian Sea, Kirghiz steppes and Tien Shan Mts.
C.f. atlaica	Altai Mts. of Central Russia to NW Outer Mongolia.
C.f. montanella	Kyrgyzstan (Alai Mts.) to Pamirs and Western China (western Xinjiang).
C.f. miniakensis	Western China (east Xinjiang, Qinghai, and Gansu) to SE Tibet.

There is an estimated 100,000 breeding pairs in Norway where Twite are said to be one of the commonest coastal passerine (Birdlife International 2004). This brings the total European breeding population to somewhere around 130,000-150,000 pairs, which is less than half of the total global population (Cramp 1998). The population of the current 25 member state European Union is somewhere between 7,900 – 18,000 breeding pairs (Birdlife International 2004), of which an estimated 10,000 pairs breed in the UK (Langston *et al.* 2006).

Figure 2. Global distribution of Twite. The distinct separation between the northwest European and Asian populations is apparent. This map has been modified using a Birdlife International map.



Historically, Twite have been recorded in all Irish counties except those of the midlands (Ussher & Warren 1900, Holloway 1996), however, according to Sharrock (1976), Twite had become largely confined to the extremes of the western seaboard from Donegal to Kerry by 1970. Gibbons *et al.* (1993) estimated the Irish population to be in the region of 3,500 pairs. This estimate was based on an extrapolation of British breeding data, where densities were much higher than Ireland. However, most recently, Cabot (2004) somewhat reduces this estimate putting the Irish breeding population between 50 and 150 breeding pairs. The winter population in Ireland, according to recent estimates is thought to be somewhere between 400 – 600 birds (O'Sullivan 2005). Both of this estimates however lack any fieldwork data and are thus only informed opinions.

5. Habitat

Twite are found in tundra, boreal, and marginally temperate zones, extending north to about the July isotherm of 10°C. They tend to occupy terrain more or less free of trees and shrubs or bushy growth, in cool, windy, and often wet climates without much sun or warmth, often on stony, rocky, or hilly ground, including sea-cliffs and inshore islands (Cramp 1998).

In Scandinavia, Twite breed at high altitude on fjelds and on barren slopes near crags or precipices, with flocks later moving to newly mown fields, and in coastal regions to gardens. Many of these birds winter on saltmarsh along coastal areas of the low countries of Belgium, Holland, Germany and Poland (Bernhof-Osa 1965, Dierschke 1997). According to Cramp (1998), Twite fed on weeds on sites of destroyed buildings in wartime Germany. They have often been observed roosting on high buildings in some German cities. Generally throughout Europe winter populations gather in flocks at estuaries and saltmarshes (Lack 1986, Brown & Atkinson 1996, Dierschke & Bairlein 2004), or opportunistically take advantage of winter stubble and loose seed on coastal farmlands or other disturbed weedy coastal strips (Clarke and Sellers 1998).

In Britain and Ireland, Twite breed mainly in the far west on moorland in upland areas that is dominated by Heather and Bracken (Haworth & Thompson 1990, Ratcliffe 1990) and in open coastal grassland habitats (Ruttledge 1966, Sharrock 1976). The Irish breeding population are strongly associated with precipitous heathery cliffs (Ussher & Warren 1900) and coastal uplands. In the winter Twite can be found on saltmarsh and shorelines along the north and west coasts (Cabot 1999, O'Sullivan 2005).

6. Diet

Small seeds form the sole diet for most Twite throughout the year. Cramp (1998) surmises that the few birds in whose diet invertebrates have been found may have inadvertently pick them up in the course of foraging for seed. However, Bannerman (1953) gives an example where the diet of the young was said to be largely or wholly insects.

Throughout its Western Palaearctic range the foods selected are quite similar. During the breeding season, in all areas where they are available, Dandelion *Taraxacum* spp., Sorrel *Rumex* spp. and Chickweed *Stellaria* spp. (in order of preference) appear to be the favoured seed (Bub 1976, Marler and Mundinger 1975, McGhie *et al.* 1995 and Raine 2006). Orford (1973) noted that burnt Purple Moor-grass *Molinia caerulea* was very important to birds returning to their breeding grounds in the spring prior to the commencement of breeding. In the South Pennines in England between April and August, Annual Meadow-grass *Poa annua*, Marsh, Spear and Creeping Thistle *Cirisium palustre*, *C. vulgare* and *C. arvense*, and Autumn Hawksbit *Leontodon autumnalis* are the most important food plants (Raine 2006).

During the winter time Twite using saltmarsh habitats particularly target: Glassworts *Salicornia* spp., Seablite *Suaeda* spp., Sea Lavender *Limonium* spp., and Sea Thrift *Armeria maritima* (Brown and Atkinson 1996, Atkinson 1998). Dierschke & Bairlein (2004) observed that Twite wintering on saltmarshes of the German Wadden Sea prefer areas with Glassworts *Salicornia europaea* in late autumn and *S. stricta* throughout the winter. Rock Samphire *Crithmum maritimum* and Sea Aster *Aster tripolium* are also important food plants (Davies 1988). In Scotland, Clark & Sellers (1998) note the importance of weedy Turnip *Brassica rapa* fields, Rape *Brassica napus* and Rape stubbles,

other stubbles especially barley, pasture and other farmland, waste ground, saltmarsh and beaches and the strandline. Wintering Twite in Ireland have been observed feeding on the seeds of Daisies *Bellis perennis*, Charlock *Sinapis arvensis*, and Dandelion (Cabot 1999).

Table 2. Summary of food plants most commonly targeted by Twite during the breeding and winter seasons as per the authors referred to above.

	Common name	Scientific name
Breeding season	Dandelion	*Taraxacum* spp.
	Sorrel	*Rumex* spp.
	Thistle	*Cirisium* spp.
	Common Chickweed	*Stellaria media*
	Autumn Hawksbit	*Leontodon autumnalis*
	Annual Meadow-grass	*Poa annua*
Winter season	Glasswort	*Salicornia* spp.
	Sea blite	*Suaeda* spp.
	Sea Lavender	*Limonium* spp.
	Sea Thrift	*Armeria maritima*
	Rock Samphire	*Crithmum maritimum*
	Sea aster	*Aster tripolium*
	Turnip	*Brassica rapa*
	Rape	*Brassica napus*
	Charlock	*Sinapsis arvensis*

7. Movements

As with many passerine species (Werham *et al.* 2002), some Twite remain less than 20 kilometres from their breeding areas throughout the year, while others will move many hundreds of kilometres between breeding and wintering sites (Brown & Atkinson 2002). Very little is known about the movements of the Asian Twite populations, but it is thought they make altitudinal movements, leaving their breeding areas to winter on lower ground (Cramp 1998).

Ringing studies have shown that up to 50% of the Scandinavian breeding population winters on the saltmarshes of the Danish, German, and Dutch Wadden Sea (Bernhof-Osa 1965, Dierschke 1997). Bub (1976) notes that many of these over-wintering birds on the Wadden Sea will move 50 km from a good feeding site and return to it within a day. Despite a large ringing effort in Norway (Bernhof-Osa 1965), there have been no Scandinavian ringed birds recovered in either Britain or Ireland (Brown & Atkinson 2002). In total, only seven continental-ringed Twite have been recovered in Britain. Five of these birds were ringed in the Netherlands and two in France, with all of them being initially ringed and retrapped during the winter (BTO database).

Ringing in the South Pennines in Britain has shown that a large proportion of the breeding population winter on the coasts of Lincolnshire and Kent (Atkinson 1999, Brown & Atkinson 2002, Raine *et al.* 2006. A small amount of winter recoveries have also been recorded from the Wadden Sea, which illustrates a winter range overlap with the Norwegian-breeding birds.

On the coast of Lancashire and Cumbria, Raine *et al.* (2006) observed that despite a distance of only 55 kilometres from the closest South Pennines breeding colony, none of the 700+ birds ringed on the northwest coast during the winter bred there. Birds ringed in winter on the northwest coast of England were resighted during the breeding season along the western Isles of Scotland from Islay to South Uist.

Clark and Sellers (1998a) tentatively identified three migration routes in Scotland based on field observations, seasonal population variations and ringing recoveries. Amongst these routes they consider that some breeding Twite of the West Highlands and Western Isles winter in Ireland. However, Brown and Atkinson (2002) suggest that much of the Twite population of

Ireland and Scotland is sedentary, based on a small amount of ringing, and also population distribution data from Lack (1986). Lack (1986) suggests that the number of Twite wintering in Ireland is not indicative of a large influx. This concurs with informed opinion of many that Twite in Ireland are sedentary (Barrington 1900, Kennedy *et al.* 1954, Whilde 1993, Werham *et al.* 2002).

There are two previous ringing recoveries to show the occurrence of migration between Ireland and Scotland. These recoveries include a bird ringed in Co. Down in April, which was retrapped 73 km away on the Mull of Kintyre, Scotland one month later. Also a bird ringed on Longay Island off the Isle of Skye, Scotland in August was found the following February in Co. Derry (BTO database). These are most likely the two ringing recoveries referred to by Hutchinson (1989).

8. Conservation Status and relevant legislation

Based on key populations in Norway (100,000 pairs) and Turkey, Twite populations are considered stable, and their conservation status is listed as 'secure' in Europe (Hagenmeijer & Blair 1997, Birdlife International 2004). It is therefore of least conservation concern in Europe. In contrast however, in Britain and Ireland, where serious range contraction, and population decline has taken place over the past number of decades, they have been listed as a Red Data species, along with being red listed in the Birds of Conservation Concern, in Ireland (Whilde 1993, Lynas *et al.* 2007), and in Britain (Batten *et al.* 1990, Gregory *et al.* 2002).

Twite are not listed in Annex I to the EU Birds Directive, however, they are afforded some protection under Article 4.2 to the EU Birds Directive and

Appendix III to the Berne Convention. Through the United Nations Convention on Biological Diversity (CBD), which Ireland became a signatory to in 1996, a national Biological Diversity Plan (BDP) was put in place. The BDP is the route taken to put in place Species Action Plans (SAP), which are species specific plans designed to propose and implement measures to conserve species of conservation concern (National Parks and Wildlife Service 2005). Many county councils throughout Britain have written SAPs for Twite and Environment and Heritage have prepared one (based on Twite recommendations from England) for Northern Ireland (Anon 2006; Appendix I) but as of yet there has not been any written for Twite in the Republic of Ireland (with the exception of a draft plan composed by BirdWatch Ireland in 2005, D. Suddaby pers. comm.).

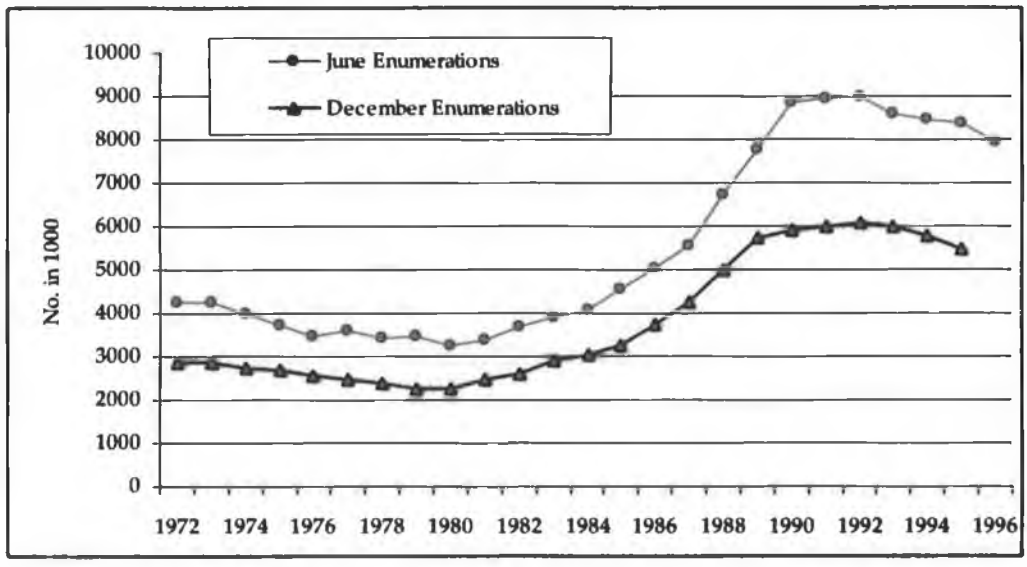
9. Threats to the Twite

The primary threat to Twite in Britain, and main reason for its decline, is considered to be a reduction in the food supply through the loss of hay meadows used during the breeding season and a loss of salt marsh used during the winter (Atkinson 1998, Newton 2004). Agricultural intensification resulting in reseeding of fields with Perennial Rye Grass *Lolium perenne*, earlier cutting dates, and more intensive grazing, is widely considered to be the main cause of the loss of suitable foraging habitat in the breeding season (Newton 2004, Raine 2006). The threat of climate change to Twite populations is unclear and difficult to ascertain (Norris *et al.* 2004).

Large-scale agricultural intensification has also taken place over the past four decades in Ireland, largely as a consequence of the European Union's Common Agricultural Policy (CAP). CAP has been linked to a decrease in bird populations throughout the European Union for the same period

(Donald *et al.* 2002). One of the manifestations of this agricultural intensification in Ireland was the increase in sheep populations on the uplands from 3.3 million in 1980 to 8.9 million in 1992 (The Heritage Council 1999, Walsh *et al.* 2001; Figure 4). This gave rise in many western areas to serious overgrazing of upland areas and a subsequent decrease in upland biodiversity (Bleasdale & Sheehy Skeffington 1992, The Heritage Council 1999, Walsh *et al.* 2001, Geerling *et al.* 2002). Large-scale plantations of coniferous forestry possibly represent a threat to Twite nesting habitat in upland areas in Ireland. In addition, genetic drift due to population fragmentation and isolation may also pose a further threat to populations.

Figure 4. Total Sheep Numbers in Ireland from 1972 to 1996 (The Heritage Council 1999).



The populations of many other species of farmland bird in western Europe that share some aspects of the Twites' habitat requirements have also suffered as a result of agricultural changes (Taylor & O'Halloran 2002). The list of species to have undergone severe population decline includes: Grey Partridge *Perdix perdix*, Stock Dove *Columba oenas*, Yellowhammer *Emberiza citrinella*,

and Corn Bunting *Miliaria calandra*, which is now thought to be extinct as a breeding species in Ireland (Taylor & O'Halloran 2002).

10. Agri-Environment initiatives relevant to Twite in Ireland

Ireland's agri-environment scheme REPS (Rural Environmental Protection Scheme) was revised in June 2004 and re-launched as REPS 3 (Anon 2000). REPS 3 included enhanced biodiversity measures in relation to grassland management (including options for Traditional Hay Meadows and Species-Rich Grassland), retaining wildlife habitats (including options for creation of a New Habitat and Nature Corridors), tillage crop production (Management of Straw and Stubble and Establishment of an Uncultivated Margin with options including Green Cover Establishment, Environmental Management of Setaside and Increased Arable Margins) and a Supplementary Measure: LINNET (Land Invested in Nature, Natural Eco-Tillage) habitats. REPS 4, which develops the options available in REPS 3, was launched in 2007 and will run until 2013 (Anon 2007). Although these schemes may benefit Twite none are specifically aimed at Twite.

The Chough *Pyrrhocorax pyrrhocorax* occurs throughout much of the west and south coasts of Ireland, including many Twite breeding areas. As the Chough is listed as an Annex I species under the 1979 *EU Birds Directive*, Special Protection Areas have been designated to protect Chough and their preferred habitat. Management activities in their preferred foraging habitat include heavy grazing regimes to give tight sward grassland (National Parks and Wildlife Service 2006). This raises a potential conflict in conservation interests as Twite require long Heather for nesting and traditional hay meadows for foraging.

11. Recent research on Twite in Britain

Up until the mid 1990's, only a small amount of quantitative research work had been done on Twite in Britain. McGhie *et al.* 1994 and Brown *et al.* 1995, focused on the population status and aspects of the breeding biology of Twite in the South Pennines. As part of his PhD study, Atkinson (1998) developed the knowledge of the link between the South Pennines breeding birds and winter Twite on the southeast coast of England through a small amount of colour ringing. He then targeted the wintering habitat associations and ecology of Twite on the southeast coast, looking particularly at the causes and consequences of habitat loss. The first comprehensive national survey of Twite in Great Britain took place in 1999 (Langston *et al.* 2006). In 2003, a second PhD focused on the breeding ecology of Twite and the effects of agricultural intensification in the uplands (Raine 2006). This study also primarily focused on the South Pennines population but also ran a colour-ringing programme on the Cumbrian coast (Raine *et al.* 2006; 2006a). In 2004 and 2005 the Royal Society for the Protection of Birds (RSPB) investigated nesting and feeding distribution, breeding success and nestling diet of Twite on South Uist and Harris in the Outer Hebrides of Scotland (Wilkinson & Wilson in press).

REFERENCES

Anon, (2000) *Rural Environment Protection Scheme: Farmer's Handbook for REPS 3*, Dept. Agriculture & Food.

Anon (2003) *Latin Concise Dictionary*, HarperCollins, New York.

Anon (2005) Interim Review of the Implementation of the National Biodiversity Plan 2002-2006.

Anon (2006) Site Synopsis: West Donegal Coast SPA.

Anon (2006) *Northern Ireland Species Action Plan - Twite Carduelis flavirostris*, Environment and Heritage, N.I.

Anon, (2007) *Rural Environment Protection Scheme: Farmer's Handbook for REPS 4*, Dept. Agriculture & Food.

Atkinson, P.W. (1998) The wintering ecology of the Twite *Carduelis flavirostris* and consequences of habitat loss, PhD thesis, University of East Anglia.

Bannerman, D.A. (1953) *The Birds of the British Isles*. Vol. 1. Oliver and Boyd, Edinburgh and London.

Barrington, R.M. (1900) *The Migration of Birds as Observed at Irish Lighthouses and Lightships*, R.H. Porter, London.

Batten, L.A., Bibby, C.J., Clement, J., Elliott, G.D. & Porter, R.F. (1990) *Red Data Birds in Britain*, T. & A.D. Poyser, UK.

Bernhoft-Osa, A. (1965) Om Birgiriksens *Carduelis flavirostris* trekk, *Stavanger Museums Arbok* **35**: 109-118.

Birdlife International, (2004) *Birds in Europe*, Birdlife International, Cambridge, UK.

Bleasdale, A. & Sheehy Skeffington, M. (1992) The influence of agricultural practices on plant communities in Connemara. *Environment and Development in Ireland* (ed J. Feehan), pp. 331-336. University College Dublin, Dublin.

Brandt, M.J. & Cresswell, W. (2008) Breeding behaviour, home range and habitat selection in Rock Firefinches *Lagonosticta sanguinodorsalis* in the wet and dry season in central Nigeria, *Ibis* **150:** 495-507.

Brown, A.F. & Atkinson, P.W. (1996) Habitat associations of coastal wintering passerines. *Bird Study* **42:** 188-200.

Brown, A.F., Crick, H.Q.P., Stillman, R.A. (1995) The distribution, numbers and breeding ecology of Twite *Acanthis flavirostris* in the south Pennines of England, *Bird Study* **42:** 107-121.

Brown, A.F. & Atkinson, P.A. (2002) Twite. In The Migration Atlas: Movements of the Birds of Britain and Ireland (eds Wernham, C.V., Toms, M.P. Marchant, J.H., Clark, J.A., Siriwardena, G.M. & Baillie, S.R.), pp 657-659. T. & A.D. Poyser, London.

Bub, H. (1976) Flügelmaße und Gewichte des Berghänflings (*Carduelis f. flavirostris), Ornithologosche Mitteilungen* **27:** 6-12.

Cabot, D. (2004) *Irish Birds*, Collins, London.

Cabot, D. (1999) *Ireland*, Collins, London.

Clarke, H and Sellers, R.M., (1998) Winter Habitats of Twites in Scotland, *Scottish Birds* **19:** 262-269.

Clarke, H and Sellers, R.M., (1998a) Movements of Twites in Scotland, *Scottish Birds* **19:** 270-279.

Clements, J.F. (2007) *The Clements Checklist of the Birds of the World*, Cornell University Press, USA.

Clements, J.F. (2008) *The Clements Checklist of the Birds of the World: December Taxonomy Update*, Cornell University Press, USA.

Coveney, J., Merne, O., Wilson, J., Allen, D. & Thomas, G. (1993) *A Conservation Strategy for Birds in Ireland*, Irish Wildbird Conservancy, Dublin.

Cramp, S. (1998) *The Birds of the Western Palearctic*, on CD-ROM, Disk 3. Oxford Univ. Press, Oxford, UK.

Davies, M. (1988) The importance of Britain's Twite, *Royal Society for the Protection of Birds Conservation Review* **2:** 91-94.

Dempsey, E., & O'Clery, M. (2002) *The Complete Guide to Ireland's Birds*, Gill & Macmillan, Dublin.

Dierschke, J. (1997) The status of the Shorelark *Eremophila alpestris*, Twite *Carduelis flavirostris* and Snow Bunting *Plectrophenax nivalis* in the Wadden Sea. *Wadden Sea Ecosystem No.* 4., Common Wadden Sea Secretariat, Wilhelmshaven: 95-114.

Dierschke, J. & Bairlein, F. (2004) Habitat selection of wintering passerines in salt marshes of the German Wadden Sea, *Journal of Ornithology* **145** (1): pp 48-58, Springer Berlin, Heidelberg.

Donald, P.F., Pisano, G., Rayment, M.D. & Pain, D.J. (2002) The Common Agricultural Policy, EU enlargement and the conservation of Europe's farmland birds, *Agriculture, Ecosystems and Environment*, **89** (3): 167-182.

Geerling, G.W., van Gestel, C.B.L., Sheehy Skeffington, M., Schouten, M.G.C., Nienhuis, P.H. & Leuven, R.S.E.W. (2002) Blanket bog degradation in river catchments in the west of Ireland. *Application of Geographic Information Systems and Remote Sensing in River Studies* (eds R.S.E.W. Leuven, I. Poudevigne & R.M. Teeuw), pp. 25-40. Backhuys Publishers, Leiden.

Gibbons, D.W., Reid, J.B. & Chapman, R.A. (1993) *The New Atlas of Breeding Birds in Britain and Ireland:* Poyser, London.

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

Hagenmeijer, W.J.M., Blair, M.J. (1997) *The EBCC Atlas of European Breeding Birds*, Poyser, London.

Harrison, C. & Castell, P. (1998) *Bird Nests, Eggs and Nestlings of Britain and Europe*, HarperCollins, London.

Haworth, P.F. & Thompson, D.B.A. (1990) Factors associated with the breeding distribution of upland birds in the south Pennines, England. *J. Appl. Ecol.* **27**: 562-577.

Holloway, S. (1996) *The Historical Atlas of Breeding Birds in Britain & Ireland: 1875-1900*, T & A.D. Poyser, London.

Hutchinson, C.D. (1989) *Birds in Ireland*, T & A.D. Poyser, Carlton.

Kennedy, P.G., Ruttledge, R.F. & Scroope, C.F. (1954) *The Birds of Ireland*, Oliver & Boyd, Edinburgh, Scotland.

Lack, P. (1986) *The Atlas of Wintering Birds in Britain and Ireland.* Poyser, Carlton.

Langston, R.H., Smith, T.H., Brown, A.F. & Gregory, R.D. (2006) The status of Twite *Carduelis flavirostris* in the UK. *Bird Study* **53**: 55-63.

Lynas, P., Newton, S.F., Robinson, J.A. (2007) The status of birds in Ireland: an analysis of conservation concern 2008-2013, *Irish Birds* **8** (2): 149-166.

Lysaght, L. (2002) *An Atlas of Breeding Birds of the Burren and Aran Islands*, BirdWatch Ireland, Dublin.

Marler, P. & Mundinger, P.C. (1975) Vocalisations, social organisation and breeding biology of the Twite, *Acanthis flavirostris*, *Ibis* **117**: 1-17.

Mathinsen, G., Wennerberg, L., Lifjeld, J.T. (2008) Low support for separate species within the redpoll complex (*Carduelis flammea-hornemanni-cabaret)* from analyses of mtDNA and microsatellite markers, *Molecular Phylogenetics and Evolution* **47:** 1005-1017.

Mullarney, K., Svensson, L., Zetterstrom, D., & Grant, P.J. (1999) *Collins Bird Guide,* Harper Collins, UK.

McGhie, H.A., Brown, A.F., Reed, S., Bates, S.M. (1994) *Aspects of the Breeding Ecology of Twite in the South Pennines,* English Nature Research Reports, No. 118, Peterborough.

Newton, I. (1972) *Finches,* Collins, London.

Newton, I. (2004) The recent declines of farmland bird populations in Britain: an appraisal of causal factors and conservation actions. *Ibis* **146:** 579-600.

Norris, K., Atkinson, P.W., Gill, J.A. (2004) Climate change and coastal waterbirds populations - past declines and future impacts, *Ibis* **146** (1): 82-89.

Orford, N. (1973) Breeding distribution of the Twite of central Britain, *Bird Study* **20:** 51-62 and 121-126.

O'Sullivan, O. (2005) Concern over Twite drop, *Wings* **36:** 6-7.

Raine, A.F. (2006) The breeding ecology of Twite *Carduelis flavirostris* and the effects of upland agricultural intensification. PhD thesis, University of East Anglia.

Raine, Andre F., Sowter, David, J., Brown, Andrew F., Sutherland, William J., (2006) Migration patterns of two populations of Twite *Carduelis flavirostris* in Britain. *Ringing and Migration* **23:** 45-52.

Raine, Andre F., Sowter, David, J., Brown, Andrew F., Sutherland, William J. (2006a) Natal philopatry and local movement patterns of Twite Carduelis flavirostris, *Ringing and Migration* **23:** 89-94.

Ratcliffe, D.A. (1990) *Bird life of mountain and upland*. Cambridge University Press, Cambridge.

Ruttledge, R.F. (1966) *Ireland's Birds*, H.F. & G. Witherby Ltd., London.

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

Taylor, A.J. & O'Halloran, J. 1999. *The Decline of the Corn Bunting (Miliaria calandra) in the Republic Of Ireland, With Reference to Other Seed Eating Birds*, The Heritage Council, Co. Kilkenny, Ireland.

Taylor, A.J. & O'Halloran, J. (2002) The Decline of the Corn Bunting *Miliaria calandra* in the Republic of Ireland. *Biology and Environment: Proceedings of The Royal Irish Academy*, Vol. 102b, **3:** 165–175.

The Heritage Council (1999) *Impact of Agricultural Schemes and Payments on Aspects of Ireland's Heritage*, The Heritage Council, Co. Kilkenny, Ireland.

Ussher, R. J. & Warren, R. (1900) *The Birds of Ireland*, Gurney and Jackson, London.

Vaurie, C. (1956) Systematic Notes on Palaearctic Birds. No. 19 Fringillidae: the Genera Fringilla, Serinus, Carduelis, and Acanthis, *American Museum Novitates* **1775**: 1-26.

Voous, K.H. (1960) *Atlas of European Birds,* Newton, London.

Walsh, M., Collins J.F., Guinan L., Clavin D.J. & Nixon D. (2001) *Evaluation of impact of livestock on the hill environment – soil, water and vegetation in western Ireland,* End of Project Reports Sheep Series No. 16, Project No. 4359, Teagasc Agriculture and Food Development Authority, Sheep Research Centre, Athenry.

Werham, C., Toms, M., Marchant, J., Clark, J., Siriwardena, G., Baille, S. (2002) *The Migration Atlas: Movements of the Birds of Britain and Ireland,* T & A.D. Poyser, London.

Whilde, A. (1993) *Threatened Mammals, Birds, Amphibians and Fish in Ireland,* Irish Red Data Book 2, HMSO, Belfast.

Wilkinson, N.I. & Wilson, J.D. (In press) Breeding ecology of Twite *Carduelis flavirostris* in a crofting landscape. *Bird Study.*

CHAPTER 2

The status of Twite *Carduelis flavirostris* in Ireland

McLoughlin, D. & Cotton, D. (2008) The Status of Twite *Carduelis flavirostris* in Ireland 2008. *Irish Birds* 8: 323-330.

Overview

Assessing the population status and distribution of a species is a fundamental step in establishing conservation priorities for that species. This paper presents the results of breeding and winter season population surveys from the west and northwest of Ireland. Some of these results have been used to inform Birds of Conservation Concern in Ireland (Lynas *et al.* 2007) and this paper has been published in *Irish Birds* journal (McLoughlin & Cotton 2008).

The status of Twite *Carduelis flavirostris* in Ireland 2008

Derek McLoughlin*[1] & Don Cotton[2]

**Correspondence author derekmcloughlin@eircom.net*

[1] Loughloon, Westport, County Mayo.

[2] School of Science, Institute of Technology, Sligo.

In this paper an assessment of the current status of breeding and wintering Twite in Ireland is drawn using our own data and data from various verified records from throughout the country. We present the results of a Twite breeding population survey for north County Mayo and west County Donegal along with additional data gathered through other fieldwork. The peak number of either probable or confirmed breeding from 2005 to 2008 was 44 pairs in the study area, and the breeding population for the whole of Ireland is estimated at between 54 and 110 breeding pairs. The winter population for the same period is estimated at between 650 and 1,100 birds. Based on the best available evidence, breeding Twite can be categorised as being 'Endangered' using the IUCN criteria for the categorisation of Red List species and are thus considered to be facing a 'very high risk of extinction in the wild' in Ireland.

Introduction

Twite *Carduelis flavirostris* is a member of the finch family that breeds and winters in Ireland. It has a disjunct world population, being found on the coastline and mountains of northwest Europe, and over 2,700 km away, in the uplands of Central Asia, from eastern Turkey to Tibet and western China. It is the only avian Tibetan faunal element found in Europe (Voous 1960, Orford 1973). Twite breeding in Ireland and Britain are regarded by some as a distinct race, *C.f. pipilans*,

Plate 87. Twite, Termoncarragh, County Mayo (Micheál Casey).

from the nominate *C.f. flavirostris,* which occurs in Scandinavia (Marler & Mundinger 1975, Brown *et al.* 1995). They were assumed to be sedentary in Ireland (Barrington 1900, Whilde 1993), however now it appears that some migrants from Scotland augment numbers in winter (Brown & Atkinson 2002, McLoughlin 2008, unpublished PhD data).

In Ireland and Britain, Twite breed on heather and bracken dominated moorland in upland areas (Haworth & Thompson 1990, Ratcliffe 1990). Their diet is thought to consist entirely of seeds (Newton 1972) and, like many other seed-eating birds, Twite require low intensity, species rich semi-natural grasslands to provide food in spring, summer, and autumn (McGhie *et al.* 1994). Winter populations generally gather in flocks where they feed at estuaries, saltmarshes (Lack 1986), and in Ireland, semi-natural grasslands in coastal areas (pers. obs.).

Twite is one of only three passerine species to be listed on the Red list of Birds of Conservation Concern in Ireland (Lynas *et al.* 2007). Despite its unfavourable conservation status, no all-Ireland survey has been carried out and previous population figures have been extrapolated from Breeding and Wintering Bird Atlas works (Sharrock 1976, Lack 1986, Gibbons *et al.* 1993); this is the first study to focus on Twite in Ireland.

Historical status of Twite in Ireland: Pre-1968

In the 19th century, Twite although not abundant were said to occur in all coastal counties in Ireland (Thompson 1849, Ussher & Warren 1900). The earliest documented references to their distribution suggested that they were locally common in coastal areas of Counties Kerry and Cork with several 'samples' being obtained from County Kerry by Thompson (1849). In County Sligo, Warren (1890) found a nest with five eggs on a heathy bank, at Lough Talt, near the Ox Mountains. In Counties Mayo and Galway, Twite are said to have bred in most coastal areas including Killala Bay, and on Achill Island, Clare Island, and Inishturk (Ussher & Warren 1900, Ussher 1912). Ruttledge (1957) notes that they were still present as a breeding species on Inishturk, County Mayo in the late 1950s. Barrington (1900) refers to records from Copeland Island where winter flocks were observed coming in off the sea. On the southeast coast of Ireland, Ussher and Warren (1900) describe breeding Twite in County Waterford in the late 1800s. Although it appears that Twite were never common along the east coast of Ireland, they did breed in the Dublin and Wicklow Mountains, possibly until the 1950s. According to Hutchinson (1989), they had ceased breeding there by the late 1960s. Kennedy *et al.* (1954) largely agrees with Ussher and Warren's account of Twite's distribution in Ireland, but adds "it is tolerably certain that the bird does not breed in Clare." However, others observed breeding at the Cliffs of Moher at least into the 1960s (F. King pers. comm.).

In County Donegal, bird observatory reports from the 1960s suggest that less than three pairs of Twite bred on Tory Island at least until 1966 (Pettitt 1960, 1962, 1967). Malin Head reports imply that autumn flocks may be composed of local breeders but does not confirm breeding there. Flocks of up to 200 Twite were recorded in September 1964 and 1965 near Malin Head Bird Observatory (Devlin & Merne 1966).

1968-2005

The 1968-1972 Breeding Bird Atlas, (Sharrock 1976) recorded Twite in 127 10 km squares, mainly along the west and north coasts of Ireland. This was the first population estimate to relate to Ireland, which gave a total population of between 20,000-40,000 pairs for Ireland and Britain. Although no population figures existed prior to the Breeding Bird Atlas, Sharrock (1976) alluded to an apparent long-term decrease in the population in Ireland. This is possibly due to the very low numbers, or absence, of birds in the south and east of the country. Twenty years later, in the 1988-1991 Atlas, Gibbons *et al.* (1993) recorded a 53% decline in the number of occupied 10 km squares. Based on an extrapolation of British Twite densities, the Irish population was estimated to be 3,500 pairs. *The Irish Red Data Book* (Whilde 1993), in which Twite's status is listed as 'Indeterminate', estimated the Irish population at less than 1,000 pairs. Following a targeted breeding survey in Northern Ireland in 1999, the estimated minimum population was believed to be around 10 pairs (Langston *et al.* 2006), these being concentrated between Carrick-a-Rede and Ballintoy, and on Rathlin Island (McDowell 2004, D. Allen (pers. comm.)).

By the mid-1990s the only notable breeding season records outside of Counties Antrim, Donegal, Mayo, and Kerry, relate to a probable breeder and two sightings in northwest County Clare (Lysaght 2002), and a female that was ringed in Waterford in August (O'Meara 1999). Outside of the north and northwest of Ireland, winter numbers are generally in the single figures. The most recent breeding season estimate comes from Cabot (2004) who dramatically reduces the previous estimate to between 50-150 breeding pairs. O'Sullivan (2005) puts the winter population estimate somewhere between 400-600 birds.

These estimates all potentially involve a large degree of error and are often only informed opinions. However, the limited evidence of the previous populations of Twite in Ireland indicates serious declines here over the past 100 years. It appears now that their breeding distribution has shrunk to a few restricted areas along the west and north coasts. For this reason, Twite is listed on the red list of Birds of Conservation Concern in Ireland (Lynas *et al.* 2007).

A declining population is evident in Britain, where Twite is also red listed on their Birds of Conservation Concern (Gregory *et al.* 2002). There was a significant loss of range in Scotland and northern England during the 20th century (Orford 1973, Sharrock 1976, Gibbons *et al.* 1993). Following the first national Twite survey in 1999, the estimated breeding population for Britain is 10,000 pairs (Langston *et al.* 2006). Despite these declines in Ireland and Britain, populations in Norway (100,000 pairs) and Turkey are stable and hence its conservation status is listed as 'secure' in Europe (Birdlife International 2004).

These population declines appear to be occurring in a number of other bird species such as Red Grouse *Lagopus lagopus,* Yellowhammer *Emberiza citrinella*, and Corn Bunting *Miliaria calandra* (now extinct in Ireland), which share some aspects of the Twite's ecological requirements. Reasons for the declines in these species are thought to include the intensification of agriculture, the change of harvesting hay over to making silage, decline in tillage farming, overgrazing of hillsides and the planting of upland moorland with coniferous forestry (Taylor & O'Halloran 1999, Allen *et al.* 2005, Raine 2006).

Present status

Between 2005 and 2008, we collated breeding and winter records from throughout Ireland. This data was augmented by breeding season fieldwork in two focus areas of the country where Twite were previously observed to breed. This work forms part of a PhD study on the general ecology of Twite in Ireland (D. McLoughlin, in prep.). Data from this PhD (e.g. ringing data) has also been used in this paper to estimate breeding and winter populations.

Based on recent historical records, Counties Mayo (north) and Donegal (west) were identified as Twite strongholds. These areas were surveyed following adapted methods of Langston *et al.* (2006) and Gilbert *et al.* (1998) to establish a better estimate of its population status there. To achieve this, we conducted systematic surveys of suitable habitat in the study area between 2005 and 2008. In addition, occupied tetrads in eighteen out of sixty 10 km squares found to have Twite present in the 1988-1991 Breeding Atlas were surveyed. Following the 2005 survey, intensive fieldwork focused primarily on tetrads that were known to have breeding Twite.

Evidence of breeding was determined using the criteria of Gilbert *et al.* (1998) for probable/confirmed breeding. Possible breeding was considered to be a bird observed during May, June or July within 3 km of suitable nesting habitat (bracken or heather). The absence of Twite in suitable habitat could be confirmed by conducting 90-minute 'effort' watches, as studies in Britain suggest that they return to the nest every 15 to 40 minutes (McGhie *et al.* 1994, Brown *et al.* 1995, Raine 2006).

In addition, to establish an estimate of their current status, anecdotal breeding and wintering records were obtained from throughout the country through correspondence with various birdwatchers.

Breeding population estimates

County Mayo

Between May 2005 and July 2008, breeding Twite were found along the northwestern coastline from Erris Head, on the Mullet Peninsula to Belderg in the east. Although full 2x2 km tetrads were not completed east of Belderg, the coastline was searched for suitable nesting habitat, of which little or none was found. Many small villages and hamlets between Belderg and Kilcummin Head were also searched for feeding Twite and, although Linnet *Carduelis cannabina* were observed on many occasions, no Twite were found.

Both Achill Island and Clare Island were found to be absent of Twite, despite considerable survey coverage of both areas over the study duration, and none were recorded from Inishturk (E. McGreal, pers. comm.)

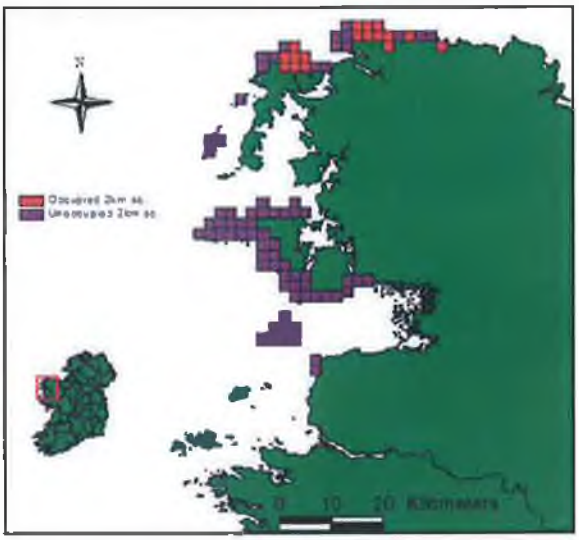


Figure 1. 2x2 km tetrads visited between May 2005 and July 2008. Occupied tetrads include all sightings in May, June or July.

The total number of pairs of Twite is shown in Table 1. A fluctuation in the number of breeding pairs can be seen from 2005 to 2008. This is most likely a result of varied effort in the two areas through nest finding, and colour-ringing.

West County Donegal

Twite were found in a total of five 2x2 km tetrads in the west Donegal study area. Confirmed breeding was only noted in three of these tetrads. The two occupied tetrads to the

Table 1. Number of probable and confirmed breeding Twite for the North Mayo mainland and the Mullet Peninsula.

Survey area	2005	2006	2007	2008
North Mayo mainland	13	8	10	15
Mullet Peninsula	6	7	13	13
Total no. of pairs	19	15	23	28

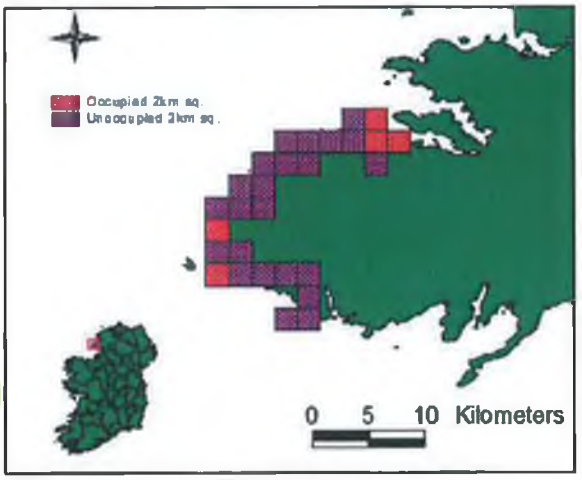


Figure 2. 2x2 kilometres tetrads visited between May 2005 and July 2007. Occupied tetrads include all sightings in May, June or July.

Table 2. Number of probable and confirmed breeding Twite for the West Donegal study area. This area was not visited in 2008.

Survey area	2005	2006	2007
Total no. of pairs	7	9	11

southwest of Figure 2, (below) had either juvenile birds, a post breeding flock, or was a casual sighting (fly-over).

Breeding was confirmed on the northeast slopes of Slievetooey, near Maghera village. No birds were detected between these colonies and Glencolumbkille to the southwest of Maghera. Although breeding was suspected near Malin Beg to the southwest of the study area, this could not be confirmed.

Other counties

In 2005 and 2006, two possible breeding pairs were recorded in County Galway (Table 3). Generally the presence of Twite flock(s) during the winter months indicates a breeding population within 30 km (pers. obs.), especially when they occur on an annual basis. Therefore it is estimated that less than ten pairs combined breed in the Counties of Galway and Kerry where a regular wintering flock comprising of less than ten birds each occur. The only other probable breeding during the study years was of two pairs on Rathlin Island, County Antrim in 2007 (Table 3).

Plate 88. Twite, Termoncarragh, County Mayo (Micheál Casey).

Table 3. Breeding season records of note from 2005 to 2007.

Date	Location	County	Grid ref	No. of birds	Observer	Comment
9th May 2005	Ox Mountains	Sligo	G3615	1 pair	Ken Perry	This site was visited on a number of occasions subsequent to this sighting but no Twite were observed. Twite are not thought to breed in this area now.
12th July 2005	Termoncarragh	Mayo	F6535	1 female	Dave Suddaby	'Possible breeding'
30th July 2005	Killary Harbour	Galway	L7564	1 bird	Aonghus O'Donnaill	'Possible breeding'
10th May 2006	Maam Cross	Galway	L9946	1 pair	Chris Benson	'Possible breeding'
June-July 2007	Rathlin Island	Antrim	D1350	≥2pairs	Eugene Archer	'Probable breeding'

Breeding population estimate

Estimating the national Twite population in Ireland, in the absence of a full systematic survey of all suitable areas, is problematic. However, national population estimates, based on the best available knowledge of a species are very important in taking steps towards the conservation of that species.

Combining the peak breeding numbers for north Mayo and west Donegal with possible breeding records from all other areas, for the study period of 2005-2008, gives a total of 48 breeding pairs. Excluding the 'possible breeders', from this figure gives a total of 44 breeding pairs recorded for Ireland. It is likely that some breeding birds were overlooked through the logistical constraints of covering such a potentially large area. With this in mind, the all-Ireland Twite population is estimated at a minimum of 54 breeding pairs with a maximum of 110 breeding pairs (Table 4).

In terms of population change since the 1988-1991 Breeding Atlas, only nine of the eighteen 10 km squares covered in this study were found to have Twite present.

Table 4. Current breeding and winter population estimate.

County	Breeding population (pairs)	Winter population	Source
Donegal	15 - 30	200 - 250	1
Sligo	0	10 - 50	2
Mayo	30 - 50	250 - 300	1
Galway	2 - 5	5 - 30	1
Clare/Limerick	0	5 - 10	3
Kerry	2 - 5	10 - 20	4, 5
Cork/Waterford/Wexford	0	0 - 10	6, 7
Wicklow/Dublin/Meath	0	0 - 10	8
Louth	0	20 - 70	9
Down	0	50 - 100	10
Antrim	5 - 20	50 - 100	10, 11
Derry	0	50 - 150	10
Total	**54 - 110**	**650 - 1100**	

1 Derek McLoughlin, unpublished PhD material
2 Don Cotton and Micheal Casey pers. comm.
3 Rattigan and Murphy, 2008
4 McLoughlin, 2008
5 O'Clery, 2008
6 Cork Bird Report Editorial Team
7 Tony Murray pers. comm.
8 Coombes and Murphy, 2004
9 Enda Flynn and John Gallagher, pers. comm.
10 Northern Ireland Birdwatchers Association
11 Dave Allen and Eugene Archer pers. comm.

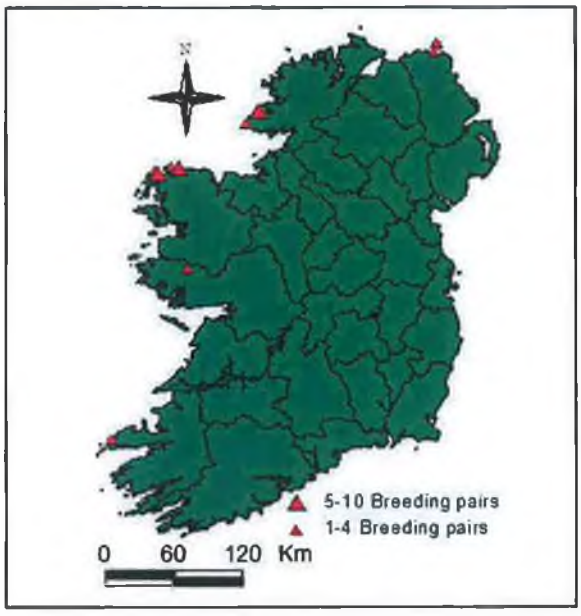


Figure 3. Twite breeding distribution 2005 – 2008.

Wintering population estimate

As with the breeding population, the vast majority of wintering Twite occur in the northern quarter of Ireland, north of Achill Island in the northwest and north of Strangford Lough in the northeast (Figure 4).

As Twite are particularly mobile in winter, and can travel over 400 km from their breeding sites (Raine *et al.* 2006), it is possible to encounter them during the winter season at any coastal location in Ireland. However, based on colour-ringing studies, wintering birds in Ireland tend to occur near, and be associated with, known breeding areas e.g. in north Mayo and west Donegal. However, flocks of over 100 are recorded most winters on the shores of Lough Foyle, County Derry and further along the coast of Antrim towards Belfast Lough. These may be augmented by birds from Scotland where previous ringing recoveries, albeit only four, have shown the link between Scottish breeding birds and birds wintering on the coastline, from County Mayo to County Antrim (Brown & Atkinson 2002, McLoughlin 2008, unpublished PhD material). It should also be noted that Rathlin Island, where Twite were confirmed breeding in 2007, is only 25.5 km from the Mull Of Kintyre, Scotland; a relatively short distance.

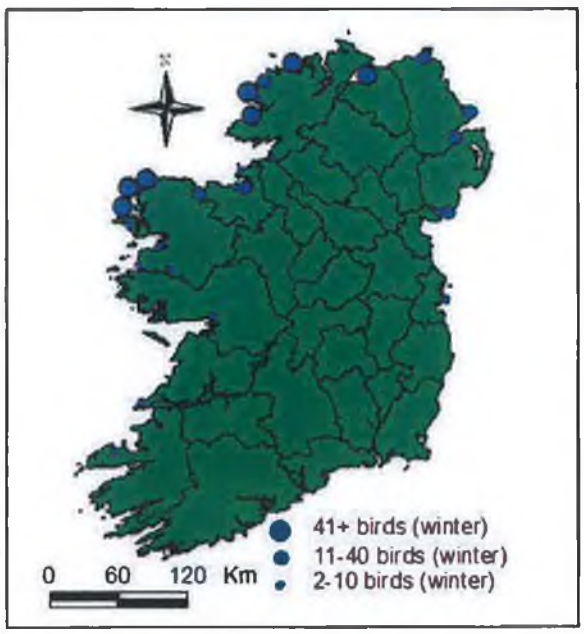


Figure 4. Twite winter distribution 2005 – 2008.

As with many bird species, migration patterns can be dependent on the severity of the weather during the winter season (Newton 1972). It is probable that fluctuating numbers of winter migrants occur each year. Therefore estimating the wintering population of Twite is difficult, however the estimated all-Ireland winter population for the study years is between 650 and 1,100 birds (Table 4).

Discussion

Twite is a small brown bird that can be difficult to detect when it breeds in relatively low densities, as it does in Ireland. Kennedy *et al.* (1954) notes that "on account of their resorting to mountains and high bogs, and by reason of their drab appearance, they may be easily overlooked." Twite researchers in Britain have also alluded to the problematic nature of surveying Twite in the breeding season and the difficulties in identifying a breeding bird from a non-breeding bird (e.g. Langston *et al.* 2006). In addition, under-recording of breeding Twite can often occur due to their similarity to other closely related finch species such as Linnet and Lesser Redpoll *Carduelis flammea*, as well as the sparse number of observers in areas where Twite occur and the potentially isolated places where they breed. The population figures presented are estimates; however they do correspond with those quoted by Cabot (2004) and O'Sullivan (2005). As a considerable proportion of research fieldwork time was carried out in the north Mayo and west Donegal study areas, the number of pairs observed most likely represents the vast majority of breeding Twite. With little or no breeding season sightings from outside these areas, this suggests that the number of breeding pairs estimated is reasonably accurate.

Using ringing data during the study period allowed us to develop a picture of the number of birds during the winter season in the study areas. The numbers ringed at each site tended to be at least two to three times higher than the maximum flock size. For example, our initial estimate of wintering birds for the winter of 2006/7 on the Mullet

Peninsula was 80-100 birds. However, over 200 were ringed during this period and well over 30 were still observed to be unringed. This clearly shows the potential for underestimating their wintering population; taking this into account the wintering numbers presented are a conservative estimate.

Twite is listed as 'Indeterminate' in the Irish Red Data (Whilde 1993). This category status was allocated due to the lack of information on Twite in Ireland. Based on the findings of this study they would meet the International Union for the Conservation of Nature and Natural Resources (IUCN) criteria for an 'endangered' (EN B1ab(ii, iii); C2a(i)) species, and are thus considered to be facing a very high risk of extinction in the wild (IUCN 2001).

Twite have clearly declined since the 19th Century and their breeding range contracted to two main areas. Population declines and range contractions have also been occurring amongst bird species such as Red Grouse, Yellowhammer, Tree Sparrow *Passer montanus* and Corncrake *Crex crex* that share some of the habitat requirements of Twite. The Corn Bunting, which was once common in Ireland, got pushed to the extremes of the coastal areas by the late 1960s and by 1998 was thought to be extinct as a breeding species in Ireland (Taylor & O'Halloran 1999). This contraction of range and restriction to the west coast has been mirrored by a number of species of Bumblebee (e.g. *Bombus distinguendus*), which are also associated with flower-rich open grassy habitats. Fitzpatrick *et al.* (2007) suggest that the widespread replacement of hay with silage in the agricultural landscape results in earlier and more frequent mowing and a reduction of late summer wildflowers. This intensification of agriculture, along with overgrazing of heather hillsides appears to be a contributor to the decline of Twite in Ireland. In Britain, this agricultural intensification has been linked to declines in population and productivity through the reduction of available seeds for Twite (McGhie *et al.* 1994).

Further investigations on the movement patterns, habitat requirements and general ecology of Twite in Ireland are currently in progress in order to inform land management practices and species policy in an effort to prevent further decline or possible extinction in Ireland.

Acknowledgements

We thank the National Parks and Wildlife Service for providing funding for this study. For support and advice, thank you to Chris Benson, Alex Borawska, David Cabot, Sue Callaghan, Eoin McGreal, Tony Murray, Steve Newton, David Norriss, John O'Halloran, Ken Perry, Dave Suddaby, and Mike Trewby,

Thank you to the many landowners who permitted us access to their lands throughout the country.

We are grateful to the following for their records and assistance in the field: Joe Adamson, Dave Allen, Eugene Archer, Robin Barry, John Bartlett, Michael Bell, Dermot Breen, Philip Buckley, Cape Clear Bird Observatory, Cameron Clotworthy, Derek Charles, Alex Copland, Jill Crosher, Miriam Crowley, Tom Cuffe, Sinead Cummins, Eric Dempsey, Dave Duggan, Jean Dunleavy, Wilton Farrelly, Seamus Feeney, Dara Fitzpatrick, John Gallagher, Tim Gordon, Nick Gray, Niall Hatch, Paul Hillis, Harry Hussey, Brendan Kavanagh, James Kilroy, Frank King, Ken Kinsella, Paul Lynas, Liam Lysaght, Sean Lysaght, Stephen McAvoy, Emer McGee, Philip McGinnity, Cóilín MacLochlainn, Mike McLaughlin, Peter McNally, Declan Manley, Stephen Meaney, John Milroy, Gerry Murphy, Tony Nagle, Northern Ireland Birdwatchers Association, Irene O'Brien, Oliver Ó Cadhla, Michael O'Clery, Aonghus O'Donnaill, Ger O'Donnell, Michael O'Keeffe, Éamon O'Sullivan, Oran O'Sullivan, Chris Peppiat, Peter Phillips, David and Hillary Poole, Russell Poole, Noel Raftery, Nicola Reddy, James Ryan, Derek Scott, Lorraine Shelley, Ralph Sheppard, Pat Smiddy, Wendy Stringer, Gareth Thompson, Matthew Tickner, Michael and Eithna Viney, Alyn Walsh, Micheál Walsh, Dave Watson, Nick Wilkinson, John Wilson, Steve Wing, Julian Wyllie and the late Willie McDowell.

Special thanks are due to Dave Suddaby for his efforts in improving an earlier script, David Cabot for the impetus to study Twite and giving me access to his library, and the editor for also improving the script. Sincere apologies to anybody who has been inadvertently left out.

References

Allen, D., Mellon, C., Mawhinney, K., Looney, D. & Milburne, J. 2005. The status of Red Grouse *Lagopus lagopus* in Northern Ireland 2004. *Irish Birds* 7: 449-460.

Barrington, R.M. 1900. *The Migration of Birds as Observed at Irish Lighthouses and Lightships.* R.H. Porter, London

BirdLife International. 2004. *Birds in Europe – Population estimates, trends and conservation status.* BirdLife International Conservation Series No. 2, Cambridge.

Brown, A.F. & Atkinson, P.A. 2002. Twite. In *Wernham, C.V., Toms, M.P. Marchant, J.H., Clark, J.A., Siriwardena, G.M. & Baillie, S.R (eds). The Migration Atlas: Movements of the Birds of Britain and Ireland. pp 657-659.* Poyser, London.

Brown, A.F., Crick, H.Q.P. & Stillman, R.A. 1995. The distribution, numbers and breeding ecology of Twite *Acanthis flavirostris* in the south Pennines of England. *Bird Study* 42: 107-121.

Cabot, D. 2004. *Irish Birds.* Harper Collins, London.

Coombes, R.H. & Murphy, D.F. 2004. *Irish East Coast Bird Report 2001.* BirdWatch Ireland, Wicklow.

Cork Bird Report Editorial Team. 2004. *The Cork Bird Report 1996-2004.* Privately published, Cork.

Devlin, T.R.E. & Merne, O.J. 1965. *Malin Head Bird Observatory Report 1961-1964.*

Devlin, T.R.E. & Merne, O.J. 1966. *Malin Head Bird Observatory Report 1965.*

Fitzpatrick, U, Murray, T.E., Paxton, R.J., Breen, J, Cotton, D., Santorum, V. & Brown, M.J.F. 2007. Rarity and decline in bumblebees – A test of causes and correlates in the Irish fauna. *Biological Conservation* 132, 4, 185-194.

Gilbert, G., Gibbons, D.W. & Evans, J. 1998. *Bird Monitoring Methods.* RSPB, UK.

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

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

Haworth, P.F. & Thompson, D.B.A. 1990. Factors associated with the breeding distribution of upland birds in the south Pennines, England. *Journal of Applied Ecology* 27: 562-577.

Kennedy, P.G., Ruttledge, R.F. & Scroope, C.F. 1954. *The Birds of Ireland.* Oliver & Boyd, Edinburgh.

Lack, P. 1986. *The Atlas of Wintering Birds in Britain and Ireland.* Poyser, Calton.

Langston, R.H., Smith, T.H., Brown, A.F. & Gregory, R.D. 2006. The status of Twite *Carduelis flavirostris* in the UK. *Bird Study* 53: 55-63.

Lynas, P., Newton, S.F. & Robinson, J.A. 2007. The status of birds in Ireland: an analysis of conservation concern 2008-2013. *Irish Birds* 8: 149-166.

Lysaght, L. 2002. *An Atlas of Breeding Birds of the Burren and Aran Islands.* BirdWatch Ireland, Monkstown, County Dublin.

Marler, P. & Mundinger, P.C. 1975. Vocalisations, social organisation and breeding biology of the Twite, *Acanthis flavirostris. Ibis* 117: 1-17.

Mc Dowell, W.M. 2004. *A History of the Birds of Northern Ireland.* [CD ROM]

McGhie, H.A., Brown, A.F., Reed, S. & Bates, S.M. 1994. Aspects of the Breeding Ecology of Twite in the South Pennines. *English Nature Research Reports, No. 118.* Peterborough.

McLoughlin, D. 2008. Dingle Peninsula Twite Survey, 2006. *The Dingle Peninsula Bird Report* 2005-2007: 72-74.

Newton, I. 1972. *Finches.* Collins, London.

Northern Ireland Birdwatchers' Association. 2004. *Northern Ireland Bird Report* 2002, Vol. 15. Northern Ireland Birdwatchers' Association, Belfast.

Northern Ireland Birdwatchers' Association. 2008. *Monthly Report, August 2008.* Northern Ireland Birdwatchers' Association, Belfast.

Orford, N. 1973. Breeding distribution of the Twite of central Britain. *Bird Study* 20: 51-62, 121-126.

O'Clery, M. 2008. *The Dingle Peninsula Bird Report 2005-2007.* Corca Dhuibhne Branch, BirdWatch Ireland.

O'Meara, M. 1999. Twite *Carduelis flavirostris* at the Kilbarry Bog, Waterford City, 1999. *Irish Birds* 6: 430-431.

O'Sullivan, O. 2005. Concern over Twite drop. *Wings* No. 36: 6-7.

Pettitt, R.G. 1960. *Report of the Tory Island Bird Observatory, 1958 and 1959.*

Pettitt, R.G. 1962. *Third Report of the Tory Island Bird Observatory, 1961.*

Pettitt, R.G. 1967. *Sixth Report of the Tory Island Bird Observatory, 1965.*

Raine, A.F. 2006. The breeding ecology of Twite *Carduelis flavirostris* and the effects of upland agricultural intensification. PhD thesis, University of East Anglia.

Raine, A.F., Sowter, D.J., Brown, A.F. & Sutherland, W.J. 2006. Migration patterns of two populations of Twite *Carduelis flavirostris* in Britain. *Ringing and Migration* 23: 45-52.

Ratcliffe, D.A. 1990. *Bird life of mountain and upland.* Cambridge University Press, Cambridge.

Rattigan, J. & Murphy, J.N. *Clare Bird Report 2007.* Clare Branch of BirdWatch Ireland.

Ruttledge, R.F. 1963. Migrant and Other Birds of Great Saltee, Co. Wexford. *Proceeding of the Royal Irish Academy,* Vol. 63, Section B, No. 4.

Ruttledge, R.F. 1966. *Ireland's Birds.* H.F. & G. Witherby Ltd., London.

Ruttledge, R.F. 1957. The Birds of Inishbofin, Co. Galway. *Bird Study* 4: 71-80.

Ruttledge, R.F. 1994. *Birds in Counties Mayo and Galway.* IWC, Dublin.

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

Taylor, A.J. & O'Halloran, J. 1999. *The Decline of the Corn Bunting* (Miliaria calandra) *in the Republic Of Ireland, With Reference to Other Seed Eating Birds.* The Heritage Council, Kilkenny.

Thompson, W. 1849. *The Natural History of Ireland.* Vol. I. Birds, Reeve, Benham, & Reeve, London.

Ussher, R.J. 1912. Clare Island Survey. Aves. *Proceedings of the Royal Irish Academy* 31: 1-54

Ussher, R. J. & Warren, R. 1900. *The Birds of Ireland.* Gurney & Jackson, London.

Voous, K.H. 1960. *Atlas of European Birds.* London.

Warren, R. 1890. Ornithological notes from Mayo and Sligo. *Zoologist* (3) 14: 273-274.

Whilde, A. 1993. Threatened Mammals, Birds, Amphibians and Fish in Ireland. *Irish Red Data Book 2.* HMSO, Belfast.

IUCN 2001 web: www.iucnredlist.org.info/categories_criteria2001.html

CHAPTER 3

The movement patterns of two populations of Twite *Carduelis flavirostris* in Ireland

McLoughlin, D., Benson, C., Williams, B. & Cotton, D. (in press) *Ringing and Migration.*

Overview

Having identified the core breeding areas in Ireland, we then focused our study on investigating the movement dynamics of these birds. Only very small numbers of Twite have previously been ringed in Ireland. The birds that were ringed in Ireland were trapped using a tape lure in north county Mayo and north county Down. Consequently, no data has ever been generated on the local movement patterns of Twite here. To address this dearth of knowledge we used colour ringing to investigate the local movement patterns of two populations of Twite in counties Mayo and Donegal between January 2006 and July 2008. This paper has been accepted for publication by *Ringing and Migration* journal and appears herein as a proof.

Ringing & Migration (2009) **24**, **–**

The movement patterns of two populations of Twites *Carduelis flavirostris* in Ireland

DEREK McLOUGHLIN[1]*, CHRIS BENSON[2], BRYONY WILLIAMS[3] and DON COTTON[1]
[1]*Department of Environmental Science, Institute of Technology, Sligo, Ireland* [2]*Cornfield, Hollymount, Co. Mayo, Ireland* [3]*Applied Ecology Unit, Centre for Environmental Science, National University of Ireland, Galway, Ireland*

The Twite *Carduelis flavirostris* is one of only three passerines included on the red list of Birds of Conservation Concern in Ireland. As part of a study on its ecology, we investigated the local movement patterns of two populations of Twites in Counties Mayo and Donegal between January 2006 and July 2008. The breeding populations studied comprised over 40 of an estimated 54–110 breeding pairs in Ireland. Colour ringing was used to identify individual Twites in the field. In the course of this study, 492 birds were ringed, of which 480 were caught outside the breeding season; 57 (12%) were resighted on their breeding grounds. The breeding birds spent most of the winter season within 28 km of their breeding areas. We also describe the size and structure of the home ranges of 11 Twites radio tracked over four periods – March, May, June and August – on the Mullet Peninsula, County Mayo, in the northwest of Ireland. The results of this study suggest that Irish Twites are mainly sedentary and that their populations appear to be augmented by Scottish breeding birds during the winter months.

The Twite *Carduelis flavirostris* has a disjunct world distribution, being found on the coastline and mountains of northwest Europe and, over 2,700km away, in the uplands of Central Asia from eastern Turkey to Tibet and western China (Newton 1972). Twites breeding in Ireland and Britain are regarded by some as a distinct race, *C.f. pipilans*, from the nominate *C.f. flavirostris*, which occurs in Scandinavia (Marler & Mundinger 1975). Twites are listed as a Red Data species, along with being red listed in the Birds of Conservation Concern, in Ireland (Whilde 1993, Lynas *et al* 2007) and in the UK (Eaton *et al* 2009). Their population in Ireland is estimated at between 54 and 110 breeding pairs, which are mainly found along the northwest coast of Ireland (McLoughlin & Cotton 2008).

Ringing studies in Britain have shown that a considerable proportion of the South Pennines breeding population winter on the southeast coastline (Atkinson 1998, Raine *et al* 2006a). Raine *et al* (2006a) also noted that most of the birds that winter on the Cumbrian and Lancashire coasts appear to originate on the west-coast islands of Scotland. Based on field observations, data showing seasonal population variations and ring recoveries, Clark & Sellers (1998) tentatively identified three migration routes in Scotland. Amongst these routes they consider that some breeding Twites of the West Highlands and Western Isles winter in Ireland. However, Brown & Atkinson (2002) suggest that much of the Twite population of Ireland and Scotland is sedentary, based on a small amount of ring recoveries and population distribution data shown by Lack (1986). Conversely, almost 50% of the Scandinavian breeding population moves south in winter to the saltmarshes of the Wadden Sea (Bernhoft-Osa 1965, Dierschke 1997).

As no data exist on local movements of Twites in Ireland, studies on local movement patterns are important for informing conservation strategies. This investigation is part of a wider study on the ecology of Twites in Ireland. Two wintering populations in the west and northwest of Ireland, on the Mullet Peninsula in Co. Mayo and Sheskinmore National Nature Reserve (NNR) in west Co. Donegal, were targeted as part of a colour-ringing programme. Some post-breeding birds were also ringed near known breeding colonies in Counties Donegal and Mayo. These areas are the strongholds for breeding Twites in Ireland with approximately 40 pairs of the 54–110 pairs estimated to breed in Ireland (McLoughlin & Cotton 2008). The local movement patterns of Twites in these areas are presented in this paper.

Although colour ringing is a very useful tool in determining movement patterns, accurately identifying range size and structure using this means, for example during the breeding season, can be problematic. Twite range size has previously been estimated based on field observations of ringed birds (*eg* Dierschke & Bairlein 2002). The primary limitation of this method is the inability to track an individual bird in the field (particularly

* Correspondence author
Email: derekmcloughlin@eircom.net

a small brown passerine). Radio telemetry overcomes this problem by allowing the observer to identify an animal's location continuously, or at regular intervals. This gives the observer an accurate spatio-temporal picture of the animal's movements and activity for the life span of the transmitter (Kenward 2001, 2004). Location data can then be analysed to gain knowledge of range size and structure, which are crucial elements in determining the ecological requirements of a species at a given time of the year (Johnson 1980). For a small and inconspicuous bird such as Twite, radio tracking is the most effective means of locating the study animal and, therefore, determining its range structure and size.

Although wildlife radio-tracking technology has been used since the early 1960s (Kenward 2001), it is only recently that lightweight transmitters suitable for Twites have become available. Raine (2006) was the first to use radio telemetry on Twites. Through his research he assessed habitat use by Twites in the South Pennines, England, including details of the distance travelled from the breeding colony. In this paper, we present the size and structure of the ranges of 11 birds, which were radio tracked on the Mullet Peninsula during 2007 and 2008. Ongoing work is aimed at investigating the reasons for resource selection, which give rise to the range size and structure. This is the first time that such information has been presented for the Twite.

METHODS

Study area

Winter flocks of Twites at Termoncarragh on the Mullet Peninsula, Co. Mayo (54°15'N 10°04'W), and Sheskinmore NNR, Co. Donegal (54°49'N 8°28'W), were trapped for ringing at artificial feeding stations between October and April from January 2006 to June 2008. During the breeding season, birds were ringed near breeding colonies at Maghera, Co. Donegal (54°45'N 8°31'W), and Glenlara on the Mullet Peninsula (54°17'N 9°59'W) (Figs 1 & 2).

Twite movements

The birds trapped at these locations were fitted with colour rings, which enabled identification in the field. The first 30 birds were given a cohort colour combination. However, on account of the relatively small number of wintering birds in Ireland (the minimum winter population is estimated at 650–1,100 birds: McLoughlin & Cotton 2008), it was decided to mark each bird with unique colour-ring combinations. These birds wore two colours on the left leg with a third colour above or below a metal BTO ring on the right leg. Birds were trapped at feeding stations provisioned with Niger *Guizotia abyssinica* seed using a whoosh net and drop-trap as described by Redfern & Clark (2001). A mist-net and tape lure were used at the other sites to target post-breeding flocks.

Range size and structure

Range size and structure were estimated using radio telemetry. Twelve Twites were fitted with a Biotrack Pip transmitter with Ag317 cells weighing 0.5 g. The battery life was approximately 18 days. Birds were trapped using the same method as for colour ringing. Radio tags were glued to the base of the central tail feathers, taking care to avoid the preen gland, and secured by tying dental floss around the tag and feather shaft. The antennae protruded beyond the tip of the tail feathers. The previous radio-tracking study on Twites by Raine (2006), along with our own observations of tagged birds, found no adverse affects on any aspect of the behaviour of the birds. They were observed to fly at the same speed, perform the same territorial displays, and forage in the same manner as the untagged birds.

Data analysis

Analysis and graphical presentation of data were made using Ranges7 (Anatrack, UK), ArcGIS Desktop (ESRI, USA), Excel (Microsoft, USA) and SPSS (SPSS Inc., USA). Range size was estimated using Minimum Convex Polygon (MCP) analysis for each individual as this method is widely used to give a broad estimate of animal ranges (*eg* Aebischer *et al* 1993). As these polygons often include large areas unvisited by tracked individuals (Kenward 2001), we used concave polygon analysis to minimise the unused areas. Cluster analysis was used to estimate range patchiness (Kenward 2001). Range span, the distance between the two furthest locations in an individual's range, was also estimated.

RESULTS

Twite movements

A total of 492 new birds were colour ringed between January 2006 and June 2008, of which a considerable proportion (26%) were either trapped or resighted at least 7 km from the original point of ringing (Table 1).

County Donegal

For the breeding-season ringing area at Maghera we ringed three juveniles and nine pulli from two broods in one of the three breeding colonies shown in Fig 1 between June 2006 and July 2007. As pulli were given a cohort colour combination, it was not possible to identify individuals. However, a minimum of two from each brood were noted approximately 6 km to the north at Sheskinmore NNR throughout the winters of 2006/07 and 2007/08. All of the three juveniles colour ringed at Maghera were controlled at

Table 1. Total number of Twites colour ringed (new birds); the number of retraps; and the number of controls for the four ringing sites from January 2006–June 2008.

Site	2006			2007			2008		
	New birds	Retraps	Controls	New birds	Retraps	Controls	New birds	Retraps	Controls
Co. Mayo									
Termoncarragh	172	101	77	89	45	43	13	5	2
Glenlara	95	39	6	41	25	7	3	5	15
Co. Donegal									
Sheskinmore	11	0	1	56	15	2	0	0	0
Maghera	8	0	0	4	0	9	0	0	0
Total	286	140	84	190	85	61	16	10	17

the feeding station at Sheskinmore NNR during the winter of 2006/07. Of the total of eight pairs confirmed to breed in the Maghera area, six individuals (38%) were found to have been colour ringed at the Sheskinmore site.

At the winter ringing site at Sheskinmore NNR, a total of 67 birds were colour ringed over six ringing days between November 2006 and March 2007. Six (9%) were observed to breed near Maghera at one of the breeding colonies indicated in Fig 1. One bird was later sighted and photographed at Machrihanish Bird Observatory, Mull of Kintyre, Scotland (see Discussion).

County Mayo

There were two ringing sites (Termoncarragh and Glenlara – both of which are on the Mullet Peninsula) and eight known breeding colonies in Co. Mayo (Fig 2). Fourteen percent of birds ringed in Co. Mayo were resighted at breeding colonies within 30 km of the ringing site (Table 2).

With 33 (87%) of the Twites observed to breed on the Mullet Peninsula in 2007 and/or 2008 being ringed or controlled at Termoncarragh, it is clear that the birds that bred on the Mullet Peninsula spent much of the winter within approximately 7 km of their breeding area. Forty percent of the breeding birds observed in the 21–25km distance interval, and 25% in the 26–30km band were ringed at Termoncarragh (Fig 2). This shows that a large proportion of the breeding Twite in north Co. Mayo spent much of the winter season on the Mullet Peninsula.

From a total of 139 Twites ringed at Glenlara during the breeding season, 64 (46%) were controlled 7 km to the southwest, at Termoncarragh, during the winter season. These included 15 (11%) individuals that bred at one of the colonies on the Mullet Peninsula. In the breeding seasons of 2007 and 2008, 38 breeding birds were observed on the Mullet Peninsula, of which 33 were colour ringed either as juveniles at Glenlara or during the

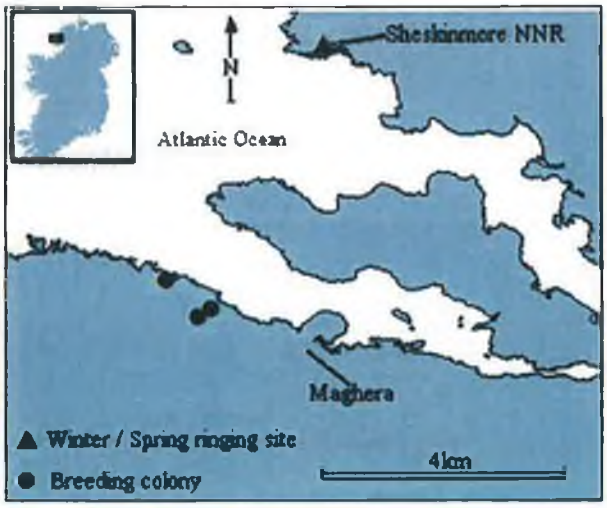


Figure 1. West Co. Donegal: the Sheskinmore NNR winter site, Maghera breeding season site, and known breeding colonies where colour-ringed birds were observed.

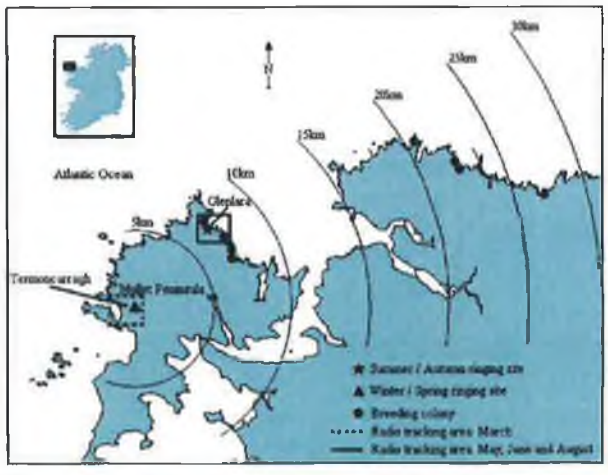


Figure 2. North Co. Mayo study areas with 5-km distance intervals from the winter ringing site at Termoncarragh and all known Twite breeding colonies in Co. Mayo. Also shown are both radio-tracking study areas at Termoncarragh and Glenlara for all tracking periods.

Table 2. Total number of recoveries in each 5 km distance interval of birds that were either ringed or controlled at Termoncarragh. A total of 274 birds were ringed at Termoncarragh between January 2006 and April 2008. The proportion of the estimated breeding population that were colour (cr) ringed in that distance interval is also given.

Distance from ringing site (km)	No. of recoveries from breeding site (% of total ringed)	Proportion of estimated population cr-ringed
0–5	0	0
6–10	28 (10%)	74%
11–15	0	0
16–20	0	0
21–25	10 (3%)	40%
26–30	2 (<1%)	25%
Total	40 (14%)	56%

winter season at Termoncarragh. No movements were observed between Counties Mayo and Donegal during the study period.

Site fidelity

At Termoncarragh between January 2006 and January 2008, 274 Twites were ringed over a total of 13 ringing days. Thirty-six percent (73) of these birds were retrapped a number of times (>30 days after ringing) throughout the winter, indicating that they use this area for much of the winter season. Seventeen (8.5%) of the birds ringed at Termoncarragh between January 2006 and April 2007 were resighted or retrapped during the following winter, indicating a degree of site fidelity. Twelve (18%) of the total ringed at Sheskinmore were retrapped at least once, a minimum of 30 days after ringing.

Range size and structure

Eleven birds were radio tracked in two study areas in Co. Mayo to develop a picture of their home-range size and structure (Fig 2). In 2007, one male and one female were tracked in March, three males were tracked in May and three different males were tracked in June. One of the birds tracked in June lost its transmitter on the first day and thus has not been included in the analysis. Only males were tracked during the breeding season as females might have been incubating and would thus have spent long periods on the nest. In 2008, four unsexed juveniles were tracked in August, however, we failed to pick up a signal for one of these birds after the second day. All radio-tracked birds were also individually colour ringed.

The two birds tracked in March had range sizes of 75 and 112 ha. Range patchiness was very low showing that the birds concentrated their activity in a small number of feeding sites. This low range patchiness is also evident in the differences between their concave and convex range sizes (Table 3). These feeding sites were invariably associated with haylage[1] supplementary feed for cattle on machair habitat (pers. obs.). We recorded multiple resightings of colour-ringed birds that used these same feeding sites from October to April each year. The associated flock size in which the birds moved varied between approximately eight and 70 individuals. Both birds roosted in the same flock throughout the study period, but were seldom observed to use the same feeding site simultaneously.

During the breeding season (May and June), all five tracked birds showed a near-triangular range shape with the apex being the nest site to the east of the range. The notable differences between range-size estimates based on convex and concave polygons indicated that a large proportion of the ranges were not used (Table 3). This is supported by the low range-patchiness estimates (3–13 location clusters per individual). It is important to note that these birds' nests were situated in heather *Calluna vulgaris* on sea-cliffs. The minimum distance travelled from nest to foraging area was 1.06 km with a maximum distance of 1.49 km.

Although four juveniles were tagged in August (Table 3), we failed to pick up the signal of one of the birds after the second day of tracking. Data for the other three birds showed relatively small range sizes of between 24.7 and 30 ha. They were much more widely dispersed within these ranges (*eg* Fig 3), which are illustrated by the small difference between the convex and concave polygon area estimates. As would be expected from such a case, the range patchiness was high for these three birds, which were tracked for eight days.

The radio-tracking duration (*ie* the number of days and locations recorded) varied between individuals (Table 3) as an effect of variations in cell life and the success of tag attachment. The number of locations is confounded with the number of days, so it was appropriate to test for an effect on range size for only one of these two variables. Spearman rank correlation tests indicated that the number of locations affected range size for concave ($n = 11$, $P = 0.04$, correlation coefficient = 0.609) but not convex ($n = 11$, $P = 0.14$, correlation coefficient = 0.473) polygon range-size estimators. This indicates that a longer sampling period would result in a larger concave range size but would not affect the convex range size.

DISCUSSION

Ringing of Twites in Ireland

The resighting and ringing effort was concentrated in specific locations (baited ringing stations and nesting

[1]Haylage is a cut forage grass, stored in an airtight plastic wrap, with a moisture content between that of hay and silage.

Table 3. Range-size and structure data for individuals 1 to 11, which were tracked in four separate periods.

Individual	Month	Breeding status	Minimum convex polygon (ha)	Concave polygon (ha)	Span (m)	Range patchiness	No. of days	No. of locations
1	March	Pre-breeding	74.5	29.8	1,752	6	12	3,408
2	March	Pre-breeding	112.2	81.4	1,739	8	12	2,513
3	May	Breeding	48.8	31.3	1,448	7	10	168
4	May	Breeding	29.5	3.6	1,246	12	10	243
5	May	Breeding	25.4	3.7	1,224	3	10	55
6	June	Breeding	70.5	17.3	2,242	13	7	123
7	June	Breeding	45.3	26.8	1,436	7	7	119
8	August	Post-breeding	3.8	2.9	381	4	2	19
9	August	Post-breeding	24.8	24.7	716	21	8	328
10	August	Post-breeding	26.2	25.1	712	21	8	295
11	August	Post-breeding	31.7	30.0	756	29	8	314

colonies) and, due to logistical constraints, very few confirmed records could be obtained from outside these areas. However, as fewer than 25 Twites had been ringed in Ireland in the 35-year period prior to 2005, the results of this study represent a large contribution to the knowledge of Twites in Ireland.

Movement of Twites between Ireland and Scotland

Many of the Twites observed around the coast of Ireland during the winter are thought to be of Scottish origin. This view is based on the proximity of the Mull of Kintyre to the north coast of Co. Antrim (c 25 km) combined with the relatively large Scottish breeding population and the small number of breeding records in Northern Ireland (c 10 pairs: Langston *et al* 2006). The results of this study, together with data from Clark & Sellers (1998), support this view. The confirmed, photographed resighting of a Twite which had been colour ringed at Sheskinmore at Machrihanish Bird Observatory on the Mull of Kintyre highlights the link between Scottish and Irish Twites. The two previous Irish–Scottish movements of Twites were between Longay, an island east of the Isle of Skye, and Lough Foyle, Co. Derry, and between north Co. Down and the Mull of Kintyre (BTO database). Hutchinson (1989) appears to have referred to these movements as being from Inverness to Co. Donegal and north Co. Down to Strathclyde.

In addition to these three known movements, we also know of a probable fourth Ireland–Scotland movement. A colour-ringed bird ringed at Termoncarragh on 18 November 2006 was retrapped there on 24 March 2007. Twelve days later a bird wearing the same colour-ring combination was observed in the field at Kilchoman Dunes, Islay, Scotland.

The timing of these movements between Ireland and Scotland suggests that these birds bred in Scotland and spent part or all of the winter season in Ireland. This concurs with the statement by Clark & Sellers (1998) that Twites that breed in Scotland have been known to migrate to Ireland for the winter. As the breeding areas of 88% of the 492 Twites ringed in the study areas are unknown, this suggests that a potentially large proportion of wintering Twites in Ireland may be Scottish breeders. It is important to note that some of these birds will not have survived to breed or may have bred in unknown Irish breeding colonies. Considering the very low Twite ringing effort in Ireland and along the west coast of Scotland, and the relative isolation of their breeding and wintering areas, the three confirmed and one probable movements between Ireland and Scotland are noteworthy.

The movement of Twites in the Irish study areas

Twites breeding in the Irish population strongholds appear to be generally sedentary, with many wintering within 28 km of their breeding areas. A relatively large proportion of breeding birds along the north Co. Mayo coastline spent much of the winter on the Mullet Peninsula. It is important to note that some birds may have moved much further than 28 km from their breeding areas, but due to limited observer effort were not resighted. Although considerably fewer resighting data were generated from Co. Donegal due to a lower ringing effort, a strong link was apparent between breeding birds at Maghera and the winter ringing sites 6 km north at Sheskinmore NNR.

The movement patterns of Irish breeding birds appear to be in contrast with those of the South Pennines and many of the Western Isles of Scotland (Raine *et al* 2006a), but concur with the view of Brown & Atkinson (2002) that

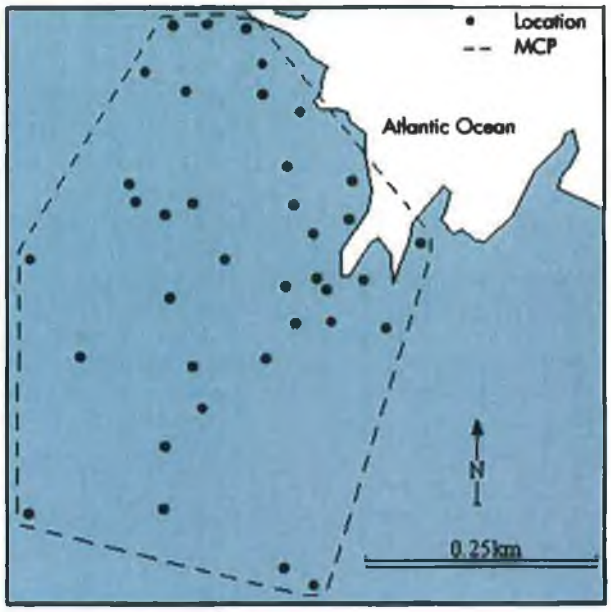


Figure 3. Sample location data and the Minimum Convex Polygon (MCP) for 100% of the locations (n = 295) of Individual 10, which was tracked on the Mullet Peninsula, Co. Mayo, in August 2008.

Irish birds are sedentary. Population data in McLoughlin & Cotton (2008) show that large flocks are observed each winter on the Mullet Peninsula and in the environs of Sheskinmore, but seldom outside these areas (with the exception of Northern Ireland). This too provides evidence for the sedentary nature of the Twites in the study areas, which account for 40 of the 54–110 breeding pairs estimated for Ireland.

Site fidelity

Twites at the Termoncarragh site showed a degree of fidelity to the winter study area. Atkinson (1998) and Raine *et al* (2006b) also found a degree of fidelity to their wintering sites in the southeast and northwest coasts of England. Ring recoveries in the German Wadden Sea indicate that some individuals show high while others show low winter site fidelity (Dierschke & Bairlein 2002).

Range size and structure

The highly mobile nature of Twites during the winter season has been well documented (*eg* Atkinson 1998, Raine 2006). Bub (1976) notes that birds wintering in Germany may move over 50 km from a good feeding site and return to it within a day. In this context, the two birds that were tracked in March showed a remarkably small range size of less than 150 ha. Although most feeding areas were common to both birds, they generally did not share the same one simultaneously. The low range patchiness for these birds, in addition to their small concave polygon area, shows the use of only a small number of feeding sites within their range. High densities of seed surrounding cattle ring-feeders is mostly likely responsible for focusing the birds in this relatively small number of feeding locations. General observations of Twites in this area showed that the majority of wintering birds also used these feeding locations for much of the winter.

During the breeding season, a large proportion of the area within flying distance of the breeding colonies was open ocean, and therefore unavailable to passerines. This most likely influenced the size and triangular shape of the range of these birds. This range shape is however typical for Irish Twite as all of the known breeding colonies in Ireland are coastal, occurring on steep, heather-dominated slopes within 100 m of the sea.

The relatively small foraging distance from nest sites in the study area (min 1.06 km, max 1.49 km) reflects the availability of suitable foraging habitat. In the South Pennines, Raine (2006) determined the minimum distance travelled of eight radio-tracked Twites from nest to foraging area to be 1.31 km with a maximum of 3.54 km. It is probable that Irish breeding Twites would also travel this distance from their nest site where necessary.

The juveniles tracked in August remained at feeding areas throughout the tracking period and subsequently had smaller range sizes than the breeding birds. The relatively high range patchiness demonstrates the dispersion of birds within their range and reflected the relatively abundant food resources in this area, which was also the main foraging area for breeding birds.

Information from this radio-tracking study shows that Twites on the Mullet Peninsula, which account for up to 15 breeding pairs (McLoughlin & Cotton 2008), use only relatively small areas for foraging and nesting between late April and September. This study would, however, benefit from a larger sample size with greater representation of age, sex and individuals that use alternative breeding and wintering areas. As the number of locations gathered affects the concave range size, a longer tracking duration would be preferable in future studies. Labour and financial constraints limited the sample size in this study; however, knowledge gained on the ecology of Irish Twite should be invaluable in informing national Twites conservation strategies. In addition, this new information and the combination of methods presented provide a pilot study for similar research studies in the future.

Conservation implications

A key finding from this study is that much of the Irish Twite breeding population spent the winter season within 28 km of their breeding area. In their winter range on the Mullet Peninsula, a large proportion of individuals appeared to use an area of less than 150 ha, including their roost site,

for much of the winter. From late April to late August radio-tracked birds used an area of less than 75 ha. From a conservation perspective, this leaves Twite populations very vulnerable to changes in land use and farm management practices. However, if adequate conservation measures were put in place within 28 km of breeding areas, this would benefit these populations of Twites during both the breeding season and throughout the winter. These areas must form the core of a targeted action plan for the conservation of Twites in Ireland.

ACKNOWLEDGEMENTS

Thanks to the National Parks and Wildlife Service for funding this study. We are most grateful to the farmers in the study areas for granting us permission to access their lands. For support, advice and assistance in the field we thank Aleksandra Borawska, David Cabot, Sue Callaghan, Declan Clarke, Cameron Clotworthy, Sarah Ingham, Liam McDevitt, Eoin McGreal, Clive McKay, Emer Magee, Eddie Maguire, Declan Manley, Tony Murray, Steve Newton, David Norriss, Irene O'Brien, John O'Halloran, Eamonn O'Sullivan, Lorcan O'Toole, Ken Perry, André Raine, Nicola Reddy, Dave Sowter, Wendy Stringer, Dave Suddaby, Sean Walls and Alyn Walsh. Thanks also to Chris Redfern and two anonymous reviewers whose comments improved an earlier draft of the manuscript.

REFERENCES

Aebischer, N.J., Robertson, P.A. & Kenward, R.E. (1993) Compositional analysis of habitat use from animal radio-tracking data. *Ecology* **74**, 1313–1325.

Atkinson, P.W. (1998) *The wintering ecology of the Twite* Carduelis flavirostris *and the consequences of habitat loss*. PhD thesis, University of East Anglia.

Bernhoft-Gaa, A. (1965) Om bergirisken (*Carduelis flavirostris*) trekk. *Stavanger Museums Årbok* **38**, 109–118.

Brown, A.F. & Atkinson, P.W. (2002) Twite. In *The Migration Atlas: movements of the birds of Britain and Ireland* (eds Wernham, C.V., Toms, M.P., Marchant, J.H., Clark, J.A., Siriwardena, G.M. & Baillie, S.R.), pp 657–659. T. & A.D. Poyser, London.

Bub, H. (1976) Flügelmaße und Gewichte des Berghänflings (*Carduelis f. flavirostris*). *Ornithologische Mitteilungen* **27**, 6–12.

Clark, N. & Sellers, R.M. (1998) Movements of Twites in Scotland. *Scottish Birds* **19**, 270–279.

Dierschke, J. (1997) The status of the Shorelark *Eremophila alpestris*, Twite *Carduelis flavirostris* and Snow Bunting *Plectrophenax nivalis* in the Wadden Sea. *Wadden Sea Ecosystem* **4**, 95–114. Common Wadden Sea Secretariat, Wilhelmshaven.

Dierschke, J. & Bairlein, F. (2002) Why did granivorous passerines wintering in Wadden Sea salt marshes decline? In *The avian calendar: exploring biological hurdles in the annual cycle*. (eds Both, C. & Piersma, T.) Proc. 3rd Conf. European Orn. Union, Groningen, August 2001. *Ardea* **90**, 471–477.

Eaton, M.A., Brown, A.F., Noble, D.G., Musgrove, A.J., Hearn, R.D., Aebischer, N.J., Gibbons, D.W., Evans, A. & Gregory, R.D. (2009) Birds of Conservation Concern 3: the population status of birds in the United Kingdom, Channel Islands and Isle of Man. *British Birds* **102**, 296–341.

Hutchinson, C.D. (1989) *Birds in Ireland*. T & A.D. Poyser, Calton.

Johnson, D.H. (1980) The comparison of usage and availability measurements for evaluating resource preference. *Ecology* **61**, 65–71.

Kenward, R.E. (2001) *A Manual for Wildlife Radio Tagging*. Academic Press, London.

Kenward, R.E. (2004) Radio-tagging. In *Bird Ecology and Conservation a handbook of techniques* (eds Sutherland, W.J., Newton, I. & Green, R.E.). Oxford University Press, Oxford.

Lack, P. (1986) *The Atlas of Wintering Birds in Britain and Ireland*. T. & A.D. Poyser, Calton.

Langston, R.H.W., Smith, T.W., Brown, A.F. & Gregory, R.D. (2006) Status of breeding Twite *Carduelis flavirostris* in the UK. *Bird Study* **53**, 55–63.

Lynas, P., Newton, S.F. & Robinson, J.A. (2007) The status of birds in Ireland: an analysis of conservation concern 2008–2013. *Irish Birds* **8**, 149–166.

Marler, P. & Mundinger, P.C. (1975) Vocalisations, social organisation and breeding biology of the Twite, *Acanthis flavirostris*. *Ibis* **117**, 1–17.

McLaughlin, B. & Cotton, D. (2008) The status of Twite *Carduelis flavirostris* in Ireland 2008. *Irish Birds* **8**, 323–330.

Newton, I. (1972) *Finches*. Collins, London.

Raine, A.R. (2006) *The breeding ecology of Twite* Carduelis flavirostris *and the effects of upland agricultural intensification*. PhD thesis, University of East Anglia.

Raine, A.R., Sowter, D.J., Brown, A.F. & Sutherland, W.J. (2006a) Migration patterns of two populations of Twite *Carduelis flavirostris* in Britain. *Ringing & Migration* **23**, 45–52.

Raine, A.R., Sowter, D.J., Brown, A.F. & Sutherland, W.J. (2006b) Natal philopatry and local movement patterns of Twite *Carduelis flavirostris*. *Ringing & Migration* **23**, 89–94.

Redfern, C.P.R. & Clark, J.A. (2001) *Ringers' Manual*. BTO, Thetford.

Whilde, A. (1993) *Threatened Mammals, Birds, Amphibians and Fish in Ireland*. Irish Red Data Book 2. HMSO, Belfast.

(MS received 8 February 2009; accepted 24 August 2009)

CHAPTER 4

Habitat selection by Twite *Carduelis flavirostris* during the breeding season in Ireland

Derek McLoughlin, Bryony Williams & Don Cotton

Overview

In the previous paper, we identified some of the movement dynamics of Twite between the Irish breeding strongholds and important wintering grounds for these birds. We then focused on the breeding population on the Mullet Peninsula and determined the patterns (range size and structure) of their movements within their breeding home ranges. Our next step was then to examine the reasons for these patterns and to determine the habitat requirements for Irish Twite in general. In this paper we investigate breeding season habitat use and selection of Twite between April and September using transect and radio tracking methods. We systematically visited all areas within 2 km of all known colonies throughout the breeding season in counties Mayo and Donegal to assess habitat use of the birds on a large scale. These results are representative of the habitat requirements for all Twite in Ireland. The radio tracking study focuses in more detail on the habitat selection of the birds tracked on the Mullet Peninsula in the previous chapter.

ABSTRACT

A detailed knowledge of a species' habitat requirements is fundamental to conservation strategies for that species. In Ireland and Britain a decline in many granivorous birds has been noted over the past number of decades. Many of these declines have been linked with agricultural intensification. The Twite *Carduelis flavirostris* is one such granivorous bird that breeds and winters in Ireland and Britain. Despite its declining population, now estimated at between 54 and 110 breeding pairs, no previous study has investigated the habitat requirements of Twite in Ireland. In this paper we present the results from an investigation into the habitat requirements of the Twite between April and September using radio tracking and transect methods. The study focuses on the two largest populations that are situated in counties Mayo and Donegal and that account for over 40 breeding pairs. Foraging Twite selected lower saltmarsh habitats in west county Donegal and dry-humid acid grassland habitats in north county Mayo, where lower saltmarsh did not occur. Wildflowers along tracks and roads were important in both areas in April and early May. Of 72 nest sites found between 2005 and 2008 in Donegal and Mayo, 68 occurred in long Heather *Calluna vulgaris* with only four using patches of Bracken *Pteridium aquilinum*. Freshwater streams were also an important habitat in the home range of breeding Twite. We highlight the importance of maintaining and increasing the extent of long heather adjacent to breeding colonies and the importance of grazing in the foraging habitat during the breeding season to maintain suitable sward height.

INTRODUCTION

For many species it is believed that population decline and even extinction is partly caused by habitat deterioration and loss (The Heritage Council 1999). For many farmland granivorous birds in Ireland and Britain, this link has been well documented (e.g. Siriwardena *et al.* 2001, Buckingham *et al.* 2006). The Twite *Carduelis flavirostris* is one such granivorous bird that has undergone long-term decline and range contraction (Brown *et al.* 1995, Langston *et al.* 2006). Twite are listed as a Red Data Book species, along with being Red Listed in the Birds of Conservation Concern, in Ireland (Whilde 1993, Lynas *et al.* 2007) and in Britain (Batten *et al.* 1990, Gregory *et al.* 2002). Declines in Twite populations in Britain have largely been attributed to a reduction in food supply, which is a consequence of the loss of hay meadows used during the breeding season, and a loss of saltmarsh used during the winter (Atkinson 1998, Newton 2004). Agricultural intensification resulting in reseeding of fields with Perennial Rye Grass *Lolium perenne*, earlier cutting dates and more intensive grazing, is widely considered to be the main cause of the loss of suitable foraging habitat during the breeding season (Newton 2004, Raine 2006).

In Ireland the estimated breeding population of Twite is between 54 and 110 pairs, which are found in only a few coastal locations on blanket bog in the north and northwest of the country (McLoughlin & Cotton 2008). The breeding strongholds, which comprise approximately 40 pairs of the estimated national population, occur in small coastal colonies in the extreme west of counties Mayo and Donegal.

Large-scale agricultural intensification has taken place in Ireland over the past number of decades, primarily as a consequence of the European Union's

Common Agricultural Policy (CAP). CAP has been linked to a decrease in bird populations throughout the European Union for the same period (Donald *et al.* 2002). One of the manifestations of this agricultural intensification in Ireland was the large increase in sheep populations on the hillsides in the 1980s and 1990s (Walsh *et al.* 2001). This gave rise to serious overgrazing of blanket bog, which predominates the west of Ireland, and a subsequent decrease in upland biodiversity (Bleasdale & Sheehy Skeffington 1992, The Heritage Council 1999, Walsh *et al.* 2001, Geerling *et al.* 2002). Large-scale plantations of coniferous forestry represent a further threat to blanket bog in Ireland. However, as no work has previously been done on the habitat associations of Twite in Ireland, the extent of these impacts on their population is not known. Anecdotal evidence suggests that this intensive grazing on blanket bog has seriously reduced suitable nesting habitat, along with deterioration of foraging habitats through other intensive agricultural activities (Bleasdale & Sheehy Skeffington 1992). As the Irish Twite population appears to be in serious decline, it is imperative that we identify the habitat requirements of our known remaining breeding populations in order to inform future management and conservation efforts.

In this paper we analyse habitat selection of Twite in their remaining breeding strongholds in the northwest of Ireland with respect to the following:

- We test the hypothesis that habitat use by Twite is random during April to September;
- We compare habitat selection for the two main breeding populations in Ireland;
- We show changes in the patterns of habitat use patterns and targeted food plants in the breeding season over the study period.

Based on our findings from this study, we make recommendations for the conservation of Twite.

METHODS

Study areas

Based on data gathered by McLoughlin & Cotton (2008), populations in north county Mayo and west county Donegal were selected for study (Fig. 1a). Within these areas six breeding colonies were identified; two near Glenlara on the Mullet Peninsula (54°17'N 09°59'W), and another two near the villages of Portacloy and Porturlin (54°18'N 09°43'W), Co. Mayo (Fig. 1b); and two near Maghera (54°45'N 08°31'W), Co. Donegal (Fig 1c). Each breeding colony formed the hub of a 2 km circle, which overlapped between colonies. A 2 km radius was chosen because published literature for Britain suggests that Twite feed within 1-2 km of their nest site (Orford 1973, Reed 1995). Information from Chapter 3 also added credence to the area of use. The study areas comprised a total of approximately 3,250 ha.

Figure 1a. Study areas of north county Mayo and nest county Donegal in Ireland.

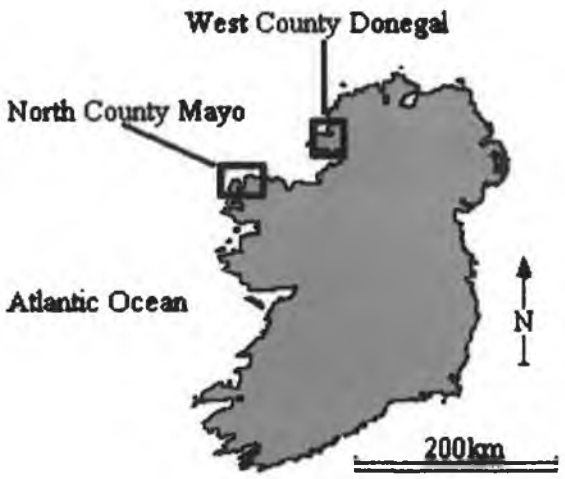


Figure 1b. Transect study areas in north county Mayo.

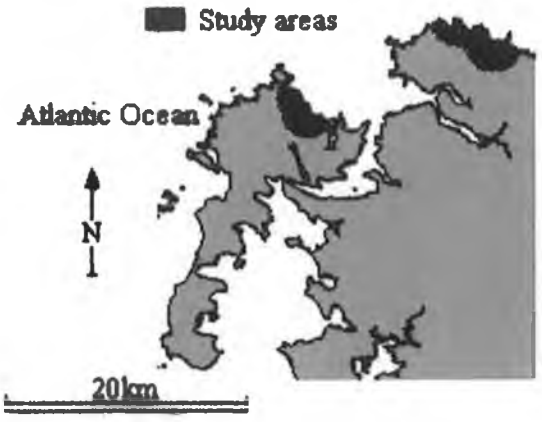


Figure 1c. Transect study areas in west county Donegal

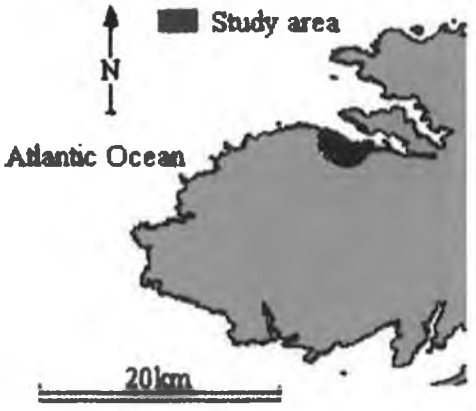


Figure 1d. Radio tracking study area on the Mullet Peninsula, north county Mayo.

Two methods were used to gather habitat selection data; (i) transects of each study area shown in Figures 1b and 1c, and (ii) radio tracking in the study area outlined in Figure 1d. The study site for the radio tracking study was also one of the colonies surveyed using the transect method at Glenlara on the Mullet Peninsula, Co. Mayo, which also consisted of a 2 km radius around the nest sites.

Transects

One hundred metre-wide transects were walked covering all areas within a 2 km radius of each of the known breeding colonies once every two weeks from April to September 2007 (Appendix F). However, where topography and vegetation cover allowed a clear view of either side of the transect line, the width of transect increased up to 200 metres. When Twite were observed during transects, the number of birds and their activity were recorded. Where Twite were observed foraging, the location was marked on an aerial photo along with the habitat type and targeted food source (where identification was possible). If birds were observed in enclosed fields (i.e. fenced off fields as opposed to open moorland), sward height and the presence/absence of sheep or cattle were recorded.

Radio tracking

Birds were trapped at feeding stations provisioned with Niger *Guizotia abyssinica* (L.f.) seed using a whoosh net and drop-trap as described by Redfern & Clark (2001). Each bird was colour ringed with a unique colour combination to enable the identification of individuals in the field. Ten of these Twite were then fitted with Biotrack Pip transmitters weighing 0.5 g and with a battery life span of up to 18 days. Radio tags were fitted to the base of the central tail feathers with the antennae protruding beyond the tip of the tail feathers.

In 2007, three males were tracked in May and three different males were tracked in June. Only males were tracked during the breeding season as females may have been incubating and would thus spend long periods on the nest. In 2008, four unsexed juveniles were tracked in August. One of the birds tracked in June lost its transmitter on the first day and thus has not been included in the analysis. Sample radio tracking data is listed in Appendix G.

Habitat classification

Ecological studies generally use standard habitat classification schemes such as those by the Joint Nature Conservancy Council (JNCC; 1990) in Britain, and Fossitt (2000) in Ireland, both of which are botanically orientated. Both of these are referred to in this study. However, previous work on Twite indicates that such factors as the condition of particular habitat type may be an important factor in habitat selection, e.g. height of Heather *Calluna vulgaris*. For this reason and based on previous studies by Raine (2006) and McGhie *et al.* (1994), we classified all parts of the study areas into one of eight of our own habitat categories. We refer hereafter to these categories as 'Twite study habitat categories' (Table 1).

Table 1. Description of Twite study habitat categories in the study area and the equivalent classification using the Fossitt classification system.

Habitat category	Description	Fossitt classification
Heather < 0.3 m	Heather cover < 0.3 m	Peat bog, Wet heath
Heather > 0.3 m	Heather cover > 0.3 m	Peat bog, Wet heath
Garden	Garden property adjacent to house, with or without trees	Built land, Disturbed ground
Grassland < 0.03 m	Grassland along the coastal fringes that have been subjected to intense grazing with a sward < 0.03 m	Semi-natural grassland, Salt marsh
Improved	Pastures or re-seeded land	Improved grassland
Meadow	Flower-rich, semi-natural grassland	Semi-natural grassland
Road / track	Tarred or gravel vehicular road or track	Built land, Disturbed ground
Rough grazing	Fields, generally with a long sward that tends to be occasionally grazed by cattle. Often containing, Purple Moor-grass, Rushes, Thistles, and / or Sorrel.	Peat bog, semi-natural grassland

Enclosed fields were sub-divided into three sub-categories using sward height; short (≤10cm), medium (11-25cm) and long (>25cm).

The habitat categories and classes listed in Table 1 were mapped with the aid of colour ortho-corrected aerial photography and digitised using Geographical Information Systems (GIS). Analysis and graphical presentation of data were made using ArcGIS Desktop (ESRI, USA), Ranges7 (Anatrack, UK), Excel (Microsoft, USA) and SPSS (SPSS Inc., USA).

Home range and habitat selection analysis

We estimated home ranges for individual Twite that were radio tracked using Minimum Convex Polygons (MCPs). MCPs are widely used as a broad estimate of an animal's home range (e.g. Aebischer *et al.* 1993) and are produced simply by linking the outermost location records. Tracking resolution, which depends on the accuracy of the radio tracking (Kenward 2001), used to estimate the MCP was 50 metres. We estimated the habitat content of the study areas used for both transect and radio tracking. Radio tracking data also enabled us to estimate the habitat content of ranges for individual Twite and habitat use at location.

Habitat selection was then tested using weighted compositional analysis (Compos Analysis V.6.2+, Smith Ecology Ltd, UK). Proportions of habitat use were compared with those available, using Wilks' lambda (Λ) test (multivariate analysis of variance; MANOVA). Transect data from each 2 km plot around the colony was combined and analysed, to compare proportions of habitats used at location with those available in the study area. The sample size was the number of transects followed and values were weighted by the total number of birds observed during each combined transect.

The radio tracking data enabled us to analyse data at two levels based on selection levels identified by Johnson (1980) (Appendix E):

(i) Broad: Comparing proportions of habitats present within each range with those available in the study area.

(ii) Detailed: Comparing proportions of habitats used at location with those available within individual ranges.

Data for each individual bird were weighted by the number of useable locations. It is unlikely that habitat use and available percentage data follow a multivariate normal distribution, hence randomisation tests were used to evaluate the significance of Λ and t values (Aebischer *et al.* 1993).

The use of the terms habitat 'use' and 'selection' are sometimes used inconsistently (Jones 2001). In this paper we use the term habitat 'use' as the pattern of presence or absence of birds in the study area. Habitat 'selection' is the hierarchal process by which birds select one particular habitat over another one, which, in our case, compares the proportions used with those available (Johnson 1980).

RESULTS

Habitat classification

A total of 19 habitats following Fossitt (2000) classification, and eight habitats using the Twite study habitat classification system were recorded in the study areas (Tables 1 and 2). These equate to 18 habitats in the JNCC classification (both including two habitat mosaics; Table 2).

Table 2. Habitats found in the study areas using the Irish and equivalent UK system of classification.

Habitat name and code			
Fossitt classification (Ireland)	Code	Joint Nature Conservancy Council (UK)	Code
Lowland blanket bog	PB3	Wet modified bog	E1.7
Wet heath / Lowland blanket bog (mosaic)	HH3 / PB3	Wet dwarf shrub heath-Semi-improved acid grassland	D2 - B1.2
Eroding blanket bog	PB5	Bare peat	E4
Semi-natural dry-humid acid grassland	GS3	Semi-improved acid grassland	B1.2
Semi-natural dry-humid acid grassland / lowland blanket bog (mosaic)	GS3 / PB3	Wet modified bog - Semi-improved acid grassland	E1.7 - B1.2
Cutover bog	PB4	*Wet modified bog*	E1.7
Rocky sea cliffs	CS1	Hard cliff (Maritime cliff and slope)	H8.1
Buildings and artificial surfaces (incl spoil & bare ground)	BL3	Buildings (also 'Other habitat (track)')	J3.6
Dense bracken	HD2	Bracken-continuous	C1.1
Fixed dunes	CD3	Dune grassland	H6.5
Machair	CD6	Coastal grassland	H8.4
Improved grassland	GA1	Improved grassland	B4
Acid oligotrophic lakes	FL2	Standing water - oligotrophic	G1.3
Dune scrub and woodland	CD4	Dune scrub	H6.7
Upper salt marsh	CM2	Saltmarsh - dense/continuous	H2.6
Upland river	FW1	Running water - oligotrophicG	2.3
Semi-natural wet grassland	GS4	Marsh/marshy grassland	B5
Dry siliceous heath	HH1	Dry dwarf shrub heath	D1
Lower salt marsh	CM1	Saltmarsh - scattered plants	H2.4

Habitat availability

Lowland blanket bog was the most dominant habitat in all of the study areas although proportions of this and other habitats varied between study areas. Not all habitats occurred in all study areas (Table 3a). Short Heather was the dominant habitat type in county Mayo using the Twite study habitat classification (both transect and radio tracking areas) and long heather was dominant in county Donegal (Table 3b).

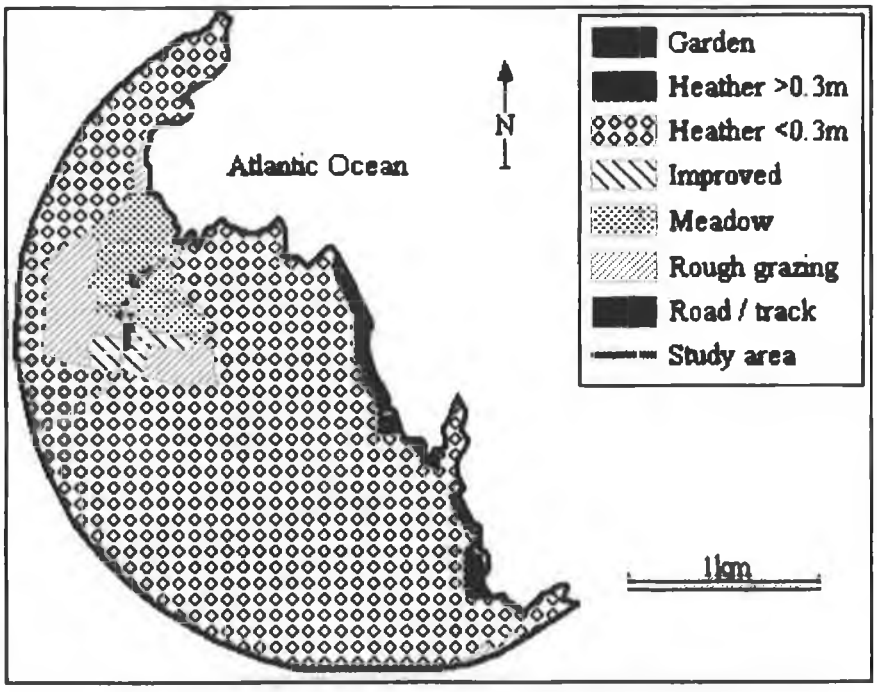
Table 3. Habitat availability for study areas following; (a) Fossitt (2000) and; (b) Twite study habitat classification system. Habitats are listed in descending order of area for the combined areas.

(a)		Transects						Radio tracking	
		Mayo		Donegal		Combined			
Habitat classifcation	Abbreviated name	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Lowland blanket bog	bl. bog	932.7	38.6	675.3	70.7	1608.0	47.7	358.0	65.3
Wet heath / Lowland blanket bog (mosaic)	w. heath / bl. bog	365.0	15.1	14.6	1.5	379.6	11.3	11.4	2.1
Eroding blanket bog	eroding bog	313.8	13.0	0	0	313.78	9.31	16.0	2.9
Semi-natural dry-humid acid grassland	acid gr.land	258.6	10.7	47.5	5.0	306.1	9.1	45.8	8.4
Semi-natural dry-humid acid grassland / lowland blanket bog (mosaic)	acid gr.land / bl. bog	206.4	8.5	51.1	5.4	257.5	7.6	6.9	1.3
Cutover bog	cutover bog	147.4	6.1	0	0	147.38	4.37	58.3	10.6
Rocky sea cliffs	cliff	105.0	4.3	31.0	3.3	136.0	4.0	21.7	4.0
Buildings and artificial surfaces (incl. spoil & bare ground)	bdgs.& art. surf.	41.2	1.7	7.3	0.8	48.52	1.44	3.4	0.6
Dense bracken	bracken	5.5	0.2	27.4	2.9	32.9	1.0	3.4	0.6
Fixed dunes	dunes	0	0	27.4	2.9	27.4	0.8	0	0
Machair	machair	0	0	25.6	2.7	25.6	0.8	0	0
Improved grassland	imp. gr.land	25.7	1.1	0	0	25.74	0.76	16.0	2.9
Acid oligotrophic lakes	acid lake	6.9	0.3	11.0	1.1	17.9	0.5	5.7	1.0
Dune scrub and woodland	dune scrub	0	0	11.0	1.1	11.0	0.3	0	0
Upper salt march	upper saltmarsh	0	0	11.0	1.1	11.0	0.3	0	0
Upland river	u.river	5.5	0.2	1.8	0.2	7.3	0.2	1.1	0.2
Semi-natural wet grassland	wet gr.land	0	0	3.7	0.4	6.9	0.2	0	0
Dry siliceous heath	dry heath	0	0	7.3	0.8	7.3	0.2	0	0
Lower salt marsh	saltmarsh	0	0	1.8	0.2	1.8	0.1	0	0
	Total	2413.7	100	954.5	100	3371.4	100	547.9	100

(b)		Transects						Radio tracking	
		Mayo		Donegal		Combined			
Habitat classifcation	Abbreviated habitat	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Heather (< 0.3 m)	short heather	1879.2	81.1	259.1	28.0	2138.3	66.0	453.2	83.8
Heather (> 0.3 m)	long heather	45.5	2.0	444.7	48.1	490.2	15.1	13.8	2.6
Rough grazing	rough grazing	128.4	5.5	106.6	11.5	235.0	7.3	29.9	5.5
Meadow	meadow	169.4	7.3	49.6	5.4	219.0	6.8	32.2	6.0
Grassland (< 0.03 m)	short grassland	31.9	1.4	14.7	1.6	46.6	1.4	0	0
Sand dunes	dunes	0	0	44.1	4.8	44.1	1.4	0	0
Improved	improved grassland	35.1	1.5	0	0	35.1	1.1	8.1	1.5
Road / track	road / track	13.2	0.6	3.7	0.4	16.9	0.5	1.2	0.2
Garden	garden	14.1	0.6	1.8	0.2	15.9	0.5	2.3	0.4
	Total	2316.8	100	924.3	100	3241.1	100	540.6	100

Figure 2. Twite radio tracking study area habitat classification following (a) Twite study classification and (b) Fossitt's classification

(a)



(b)

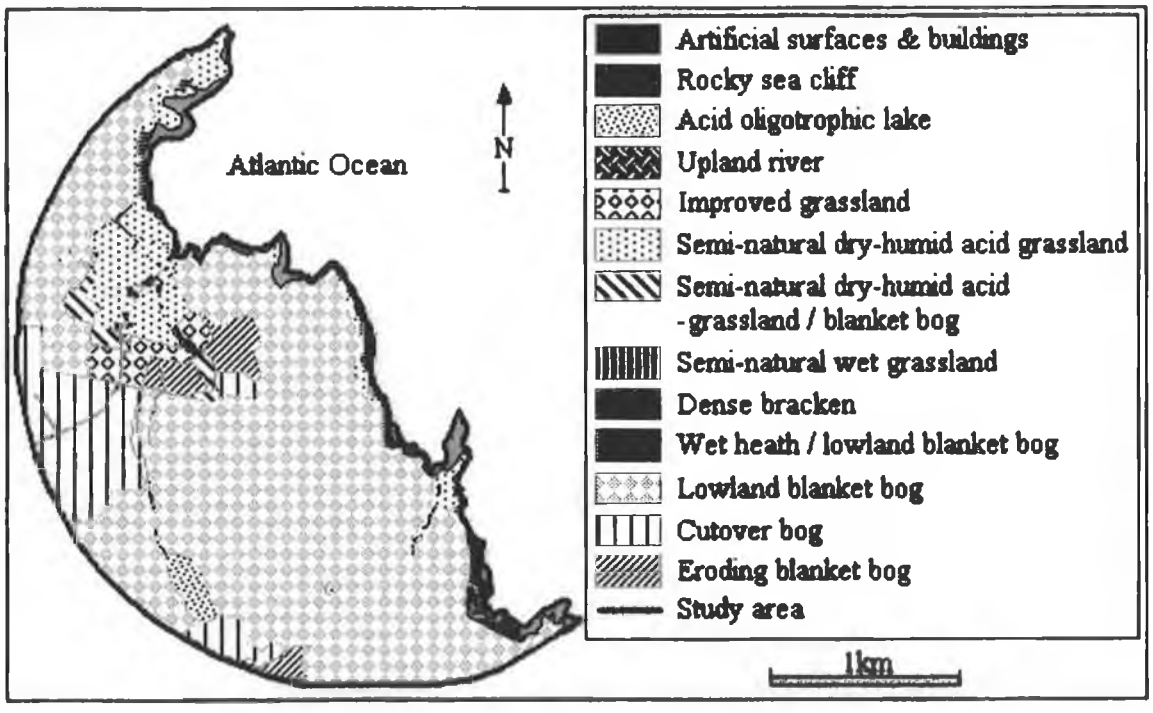
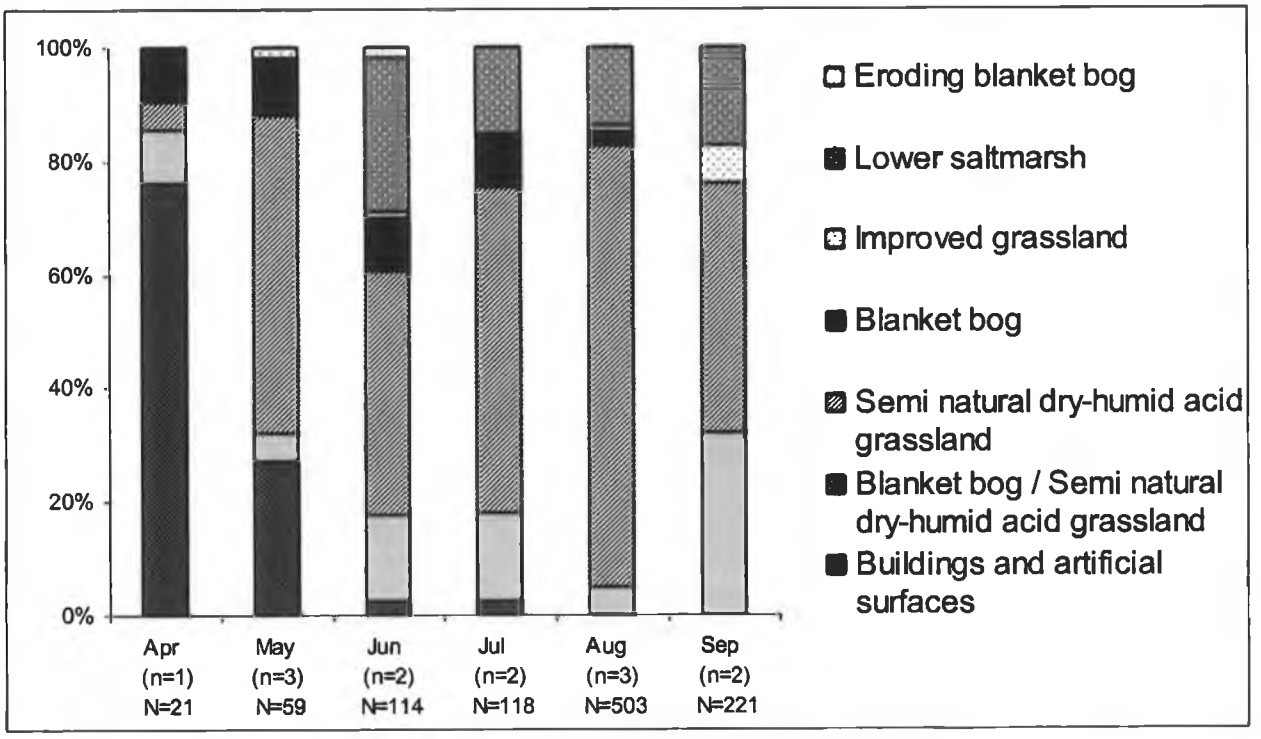
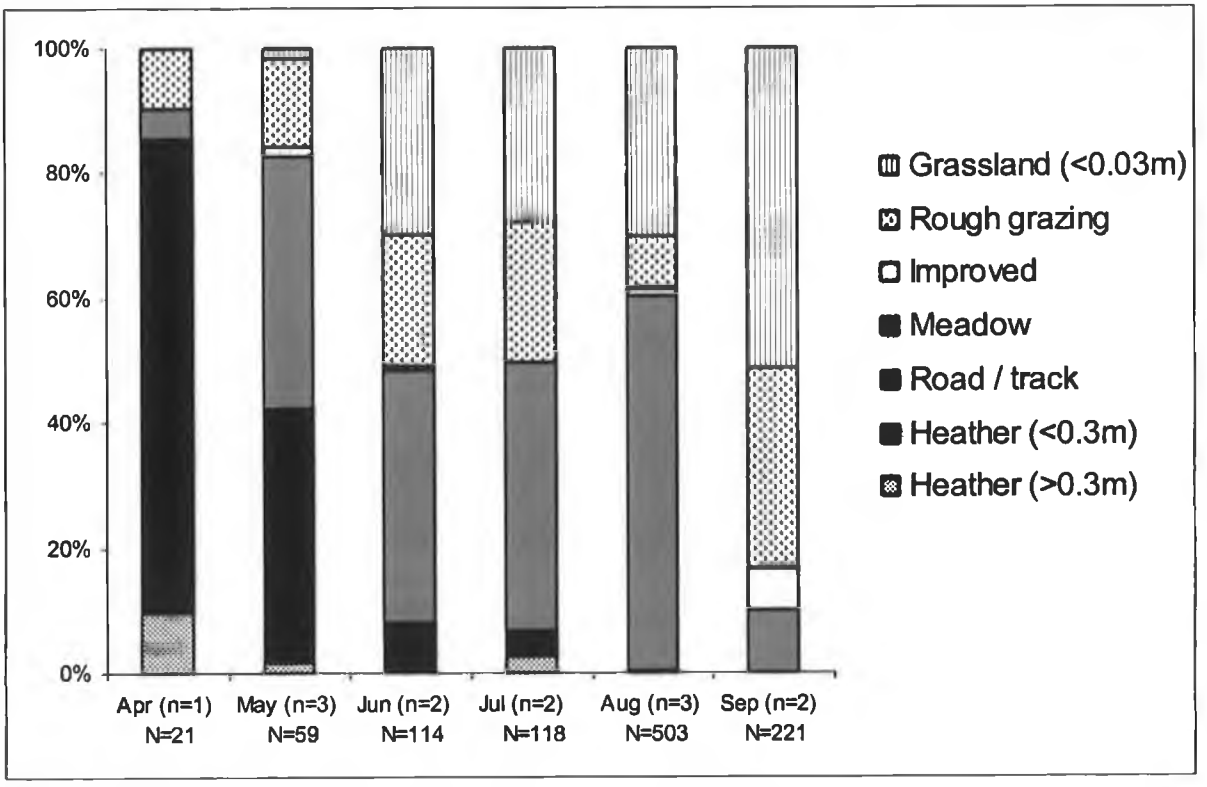


Figure 3. Monthly foraging habitat use patterns based on transect data recorded April – September 2007 using; (a) Fossitt (2000) and; (b) Twite study habitat classification system. N = total number of birds observed. n = the number of combined transects in that month (i.e. no. of visits to each study area).

(a)



(b)



Habitat use and selection

Transect data

The total length of transects walked per visit (one visit every two weeks) was approximately 180 km, covering an area of 3,371 ha within 2 km of known breeding colonies.

Buildings and artificial surfaces (i.e. tracks and roads) was the most used habitat in April, with semi-natural dry-humid acid grassland (dry-humid acid grassland) being the most used habitat during the May to September transects (Fig. 3a). Despite lower saltmarsh occurring in just 0.1% of the available area, 14 to 27% use by Twite was recorded June to September. A similar trend was noted for road/track and grassland (<0.03 m) using our Twite study classification system, when combined, constituted less than 2% of the total area available (Fig. 3b). Observations of the targeted food plants for the same time period (Figure 4) are consistent with the habitat use findings presented in Figure 3. Dandelion *Taraxacum* spp., Common Sorrel *Rumex acetosa* and Annual Meadow Grass *Poa annua* were the most used plant species in April, May and early June. Throughout the rest of the summer, birds used a much wider variety of food plants particularly, Common Chickweed *Stellaria media*, Sea Thrift *Armeria maritima*, Autumn Hawksbit *Leontodon autumnalis* and Sea Plantain *Plantago maritima*.

April to September, the primary foraging habitats in the vicinity of Twite breeding colonies were roads/tracks, meadows and short grassland using the Twite study classification system. These habitats correspond to buildings and artificial surfaces, spoil and bare ground, dry-humid acid grassland and lower saltmarsh in the Fossitt system.

Habitat selection was significant for all 14 tests based on transect data (all $P<0.05$, of which 13 tests were $P<0.01$; Table 3). Foraging Twite preferred short grassland and meadows using the Twite study habitat classification (Table 4), and dry-humid acid grassland using Fossitt's system (Table 3). In west Donegal, lower saltmarsh was the most selected habitat ahead of dry-humid acid grassland, which was the most selected habitat in north Mayo where lower saltmarsh did not occur.

When all Twite behaviour activities are included in the compositional analysis (Table 3) for the two study areas combined, lower saltmarsh and dry-humid acid grassland were also the most selected habitats. Upland rivers also emerged as an important habitat for Twite using Fossitt's classification.

The test for sward height (Table 3) showed a significant departure from random use (Wilk's Lambda $P<0.01$) with a short sward selected significantly more than medium or long swards (Wilk's Lambda $P<0.05$).

Figure 4. Targeted food plants of Twite observed during transects. 'n' = number of observations of birds feeding on those plants.

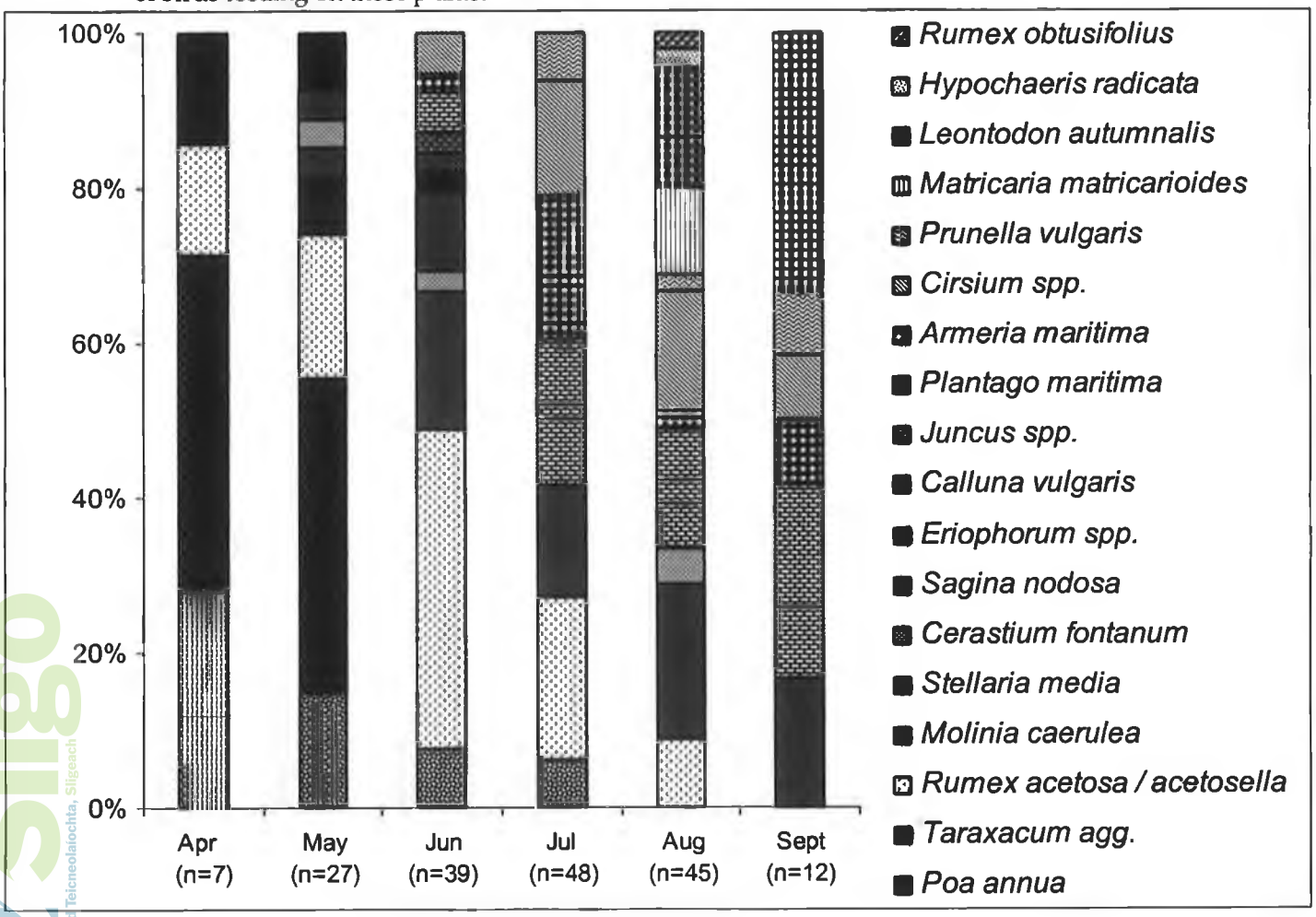


Table 3. Tests for random habitat use by Twite based on transect data following Fossitt (2000), the Twite study habitat classification system, and preferred sward heights. In cases where a habitat type was not used or was not present in a study area, this habitat was omitted as it prohibited analysis. The symbol '>>>' denotes a significant difference between two consecutively ranked habitats at the 5% level. Habitats are presented using their abbreviated names. A total of 12 combined transects were carried out in west Donegal with 13 in north Mayo. n = number of birds observed.

(i) Habitat selection for foraging

Twite study classification

Location	Lambda	P =	Habitat Ranking (most > least used)	n =
West Donegal	0.097	0.01*	short grassland > meadow > road / track >>> rough grazing >>> long heather	223
North Mayo	0.071	0.006**	meadow > short grassland > rough grazing > road / track > improved grassland > long heather >>> short heather	825
Combined	0.039	0.001**	short grassland > meadow >>> rough grazing > road / track > improved grassland >>> long heather > short heather	1048

Fossitt

Location	Lambda	P =	Habitat Ranking (most > least used)	
West Donegal	0.046	0.007**	saltmarsh > acid gr.land > bdgs.& art. surf. > wet gr.land >>> bl. bog	223
North Mayo	0.081	0.003**	acid gr.land >>> acid gr.land / bl. bog > imp. gr.land > bdgs.& art. surf. > bl. bog > eroding bog	825
Combined	0.027	0.001**	acid gr.land > saltmarsh > acid gr.land / bl. bog > imp. gr.land > bdgs.& art. surf. > bl. bog > eroding bog	1048

(ii) Habitat selection for all activities

Twite study classification

Location	Lambda	P =	Habitat Ranking (most > least used)	
West Donegal	0.006	0.001**	short grassland > meadow > road / track >>> long heather > rough grazing >>> short heather	224
North Mayo	0.093	0.008**	meadow > short grassland > rough grazing > long heather > road / track > improved grassland >>> short heather	902
Combined	0.008	0.003**	short grassland > meadow >>> rough grazing > road / track > improved grassland > long heather >>> short heather	1126

Fossitt

Location	Lambda	P =	Habitat Ranking (most > least used)	
West Donegal	0.021	0.003**	saltmarsh > acid gr.land > w. heath / bl. bog > bdgs.& art. surf. > u.river >>> acid gr.land / bl. bog > bl. bog	246
North Mayo	0.021	0.002**	acid gr.land > u.river > acid gr.land / bl. bog > imp. gr.land > bdgs.& art. surf. > bl. bog >>> eroding bl. bog > w. heath / bl. bog	967
Combined	0.021	0.006**	acid gr.land > saltmarsh > u.river > acid gr.land / bl.bog > imp. gr.land > wet gr.land > bl. bog > bdgs.& art. surf. > w.heath / bl. bog > eroding bl. Bog	1178

(iii) Preferred sward height for enclosed fields

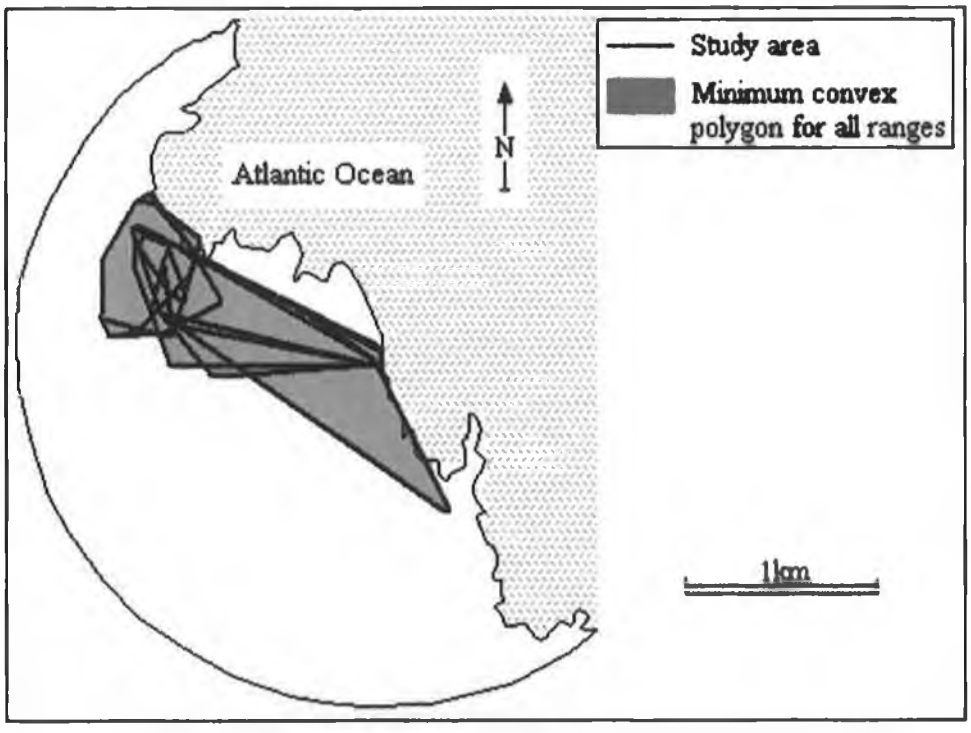
	Lambda	P =	Sward height selection ranking	
Combined areas	0.356	0.003**	Short >>> Medium > Long	875

Table 4. Tests for random habitat selection by nine radio tracked Twite at broad and detailed selection levels for both Fossitt (2000) and the Twite study habitat classification. In cases where a habitat type was not used, this habitat was omitted as it prohibited selection analysis. MCP = Minimum Convex Polygon, used to estimate ranges. Habitat ranking in parenthesis show non-significance.

Dataset	Lambda	*P*	Habitat ranking (most used > least used)	No. of locations	% of total locations
(a) Broad level	MCP v's Study area				
Fossitt	0.001	0.075	(river > acid gsld >>> bdgs & art. surf. > imp. gsld >>> cliff > blkt bog > acid gsld / blkt bog > eroding bog > w.heath / blkt bog)	1,638	98.5
Twite study category	0.015	0.008 **	meadow >>> road/track >>> garden > short heather > rough grazing > long heather > improved grassland	1,624	97.6
(b) Detailed level	Locations v's MCP				
Fossitt	0.001	0.048 *	w.heath / bl. bog > river > acid gsld / blkt bog > bdgs & art. surf. > acid gsld >>> imp. gsld > cliff > blkt bog > eroding bog	1,651	99.3
Twite study category	0.022	0.518	(long heather > road / track > meadow > rough grazing > improved grassland > short heather > garden)	1,640	98.6

[a]MCP = Minimum Convex Polygon, used to estimate home ranges

Figure 5. Combined home ranges of nine Twite estimate using Minimum Convex Polygons (MCP).



Radio tracking data

Nine birds were successfully tracked and home ranges were estimated using Minimum Convex Polygons (MCP; Fig. 5). The mean range size was 34ha (min 3.8ha, max 70.5) with considerable range overlap between individuals.

At the broad selection level, resource selection was significant using the Twite study habitat classification system (Wilks' $P<0.01$) and non-significant using the Fossitt system (Table 4a). Meadows were selected significantly more than roads and tracks (Wilks' $P<0.05$), which were selected significantly more than all other habitats present (Wilks' $P<0.05$). Meadows accounted of 6% of the radio tracking study area with roads and tracks accounting for 0.2%.

The reverse was the case at the detailed selection level with significant resource selection in the Fossitt classification but not the Twite study classification (Table 4b). Wet heath/lowland blanket bog, upland river, and dry-humid acid grassland/lowland blanket bog were the most selected habitats.

Nest site selection

During the breeding season of 2007 the nest sites of 19 pairs of Twite were located and all of these were observed to nest in long heather. Through the course of other fieldwork during the period of 2005 to 2008 (e.g. McLoughlin & Cotton (2008) and unpublished work), the nest sites of 72 pairs of Twite were located in the study areas of north county Mayo and west county Donegal. Sixty-eight (94%) of these nests were in long heather, with the remaining four in Bracken *Pteridium aquilinum*. All Twite nests observed were sited on steep slopes facing between north and northeast within 200 m of the sea.

DISCUSSION

Habitat selection

Transect data

Despite dry-humid acid grassland comprising 9.1%, and saltmarsh comprising 0.1% of the study area using Fossitt's classification system, these were the two most selected habitats in the study areas. Upland river, which was ranked third most selected habitat were generally used for drinking and bathing, however, we cannot rule out the presence of seed in dry

patches of river bed. Twite were only observed using shallow (<0.01 m deep) gravel-substrate riffle sections, and pools. Streams or rivers were not included as a category in the Twite study classification and therefore could not appear in the rank sequence. Using the Twite study classification system, short grassland and meadows were the most selected habitats. These two habitat types comprise a mixture of Fossitt's dry-humid acid grassland and saltmarsh. The 'short grassland' category generally had a short sward of Sea Plantain (<0.03 m), which had colonised heavily grazed patches within 100 m of sea cliffs in the study area. Saltmarsh was also contained in this category on which, Sea Plantain and Sea Thrift were the primary food sources. The selection of habitats during the study period tended to correspond with the most commonly observed food source (pers. obs.).

Although roads and tracks did not rank in the top three selected habitats, it is clear that they provide a very important habitat in April and early May, which marks the beginning of the breeding season. The roads and tracks where Twite were observed to feed tended to be third class roads, carrying less than 50 vehicles per day, and gravel tracks. These primarily provided Dandelion and Sea Plantain seeds for feeding, but also grit and occasionally puddles for bathing (pers. obs.).

The selection of a short sward height in the study area appears to be in contrast to Raine (2006) who found Twite preferentially use enclosed fields of medium (11-30 cm) sward height. This may be explained by easier assess to low growing seed plants such as Sea Plantain, and Chickweed associated with habitats in our study area. However, short sward fields were almost invariably grazed by sheep that avoided Thistles on which Twite were

observed to feed during July, August and September. The Thistle height was generally >30 cm.

Radio tracking data

At the broad selection level, which compares the proportions of the habitats present in the range of each bird with what is available in the study area, meadows and roads/tracks were the most selected habitats using the Twite study classification. In contrast, resource selection was non-significant using the Fossitt system. This may be due to a low statistical power of test on account of the nine habitat categories used in the test for Fossitt, as oppose to seven in the Twite study system.

Conversely, resource selection level was significant using the Fossitt system but non-significant using the Twite study classification at the detailed selection level. This level compares the proportion of habitats used at location with those available in an individuals' range. The two most selected habitats were wet heath/lowland blanket bog mosaic and upland river. As with the broad selection, it is unclear exactly why selection was significant for one habitat classification but not for the other. However, as illustrated in Figure 5 these birds have already made a distinct selection as to their home range using the Twite study classification in the broad analysis. Overall, possible explanations for the discrepancies between the two datasets include the suitability of the habitat classification systems in terms of Twite use, and the influence of the tracking resolution in the analysis of the location data.

Tracking resolution, which in this study was 50 m, is used to set the width of the boundary strip that is included in the MCP edges and areas. As the boundary strip is half the tracking resolution value, the boundary strip in

this study was 25 metres. MCP estimations given in this study include the boundary strip of 25 m. This leads to the inclusion of some habitats in the habitats ranking that Twite avoided, e.g. gardens being ranked third at the broad selection level. The major benefit of using the tracking resolution in the analysis it accounts for the location of the bird through triangulation rather than an exact visual and thus takes potential inaccuracies of locations into account.

Habitat use and selection methods

The two techniques used in this study to analyse habitat section are largely complimentary. Radio tracking allowed us to gather detailed information on single individuals in the study area and generate large amounts of data even in inclement weather conditions. Nesting and roosting sites of the individual can be detected relatively easily. Radio tracking also allows the recording of the locations of an individual without disturbing the bird. However, as radio tracking gives us detail on an individual within its home range, to get a picture of habitat selection of Twite over a large area, a much larger sample size would be required. This would involve a large extra effort in trying to trap birds to radio tag. In contrast, the transect method gathers a large amount of data on a large number of individuals, but does not relate to a single individual. Therefore, it is possible to cover large areas over a wide range of habitats and can be more representative of the requirements of Irish Twite breeding population.

In addition to increasing the sample size of radio tracked birds, transects should also be done over several years to account for potential annual variation in targeted habitat and food.

Nesting habitat

In Britain Twite also predominantly nest in Heather and Bracken (McGhie *et al.* 1994, Raine 2006), although Bracken does not appear to be as important for nesting Twite as in Ireland. However, we have observed flocks of up to 80 Twite roosting in Bracken in autumn and early winter in county Donegal and its importance for Twite in Ireland should not be overlooked.

Habitat classification methods

The Fossitt habitat classification system (Fossitt 2000) is widely used in ecological studies in Ireland. The purpose of Fossitt's *Guide to Habitats of Ireland* is to provide a standard classification of habitats throughout Ireland by a wide range of users. Its use in this paper is to present the habitat preferences of Twite in Ireland in the context of this widely used classification system. Although Twite often use 'micro-habitats' that differ from the predominating habitat (e.g. a 2 x 2 m area of exposed gravel in a 1 ha field of semi-improved grassland), the Twite's statistically significant resource selection in this study shows a relatively close relationship between the Fossitt's classification and the habitat required by Twite in the study areas.

The Twite study habitat classification was used to take such factors as height of Heather into account in the analysis. As with the Fossitt classification, the statistically significant resource selection of this habitat classification demonstrates the importance of these categories in the assessment of Twite habitat. In future studies, however, we recommend an extra category for freshwater stream and number and density of grazers.

Context of habitat requirements of Irish Twite

The habitat requirements of Twite in the breeding season in Ireland do not appear to differ markedly from populations in England, Scotland and Norway. In the South Pennines, flower-rich meadows are preferentially used, with roadside verges, dam overspills and open moorland also forming part of the targeted foraging area (McGhie *et al.* 1994, Raine 2006). Twite in England show a strong preference for Heather and Bracken as nesting sites (McGhie *et al.* 1994). In the Western Isles of Scotland, Twite feed on farmland, particularly machair grassland and cultivated fallows and nest mainly in Heather dominated moorland and, in the Uists, the young conifers of small shelter-belt plantations (N. Wilkinson pers. comm.).

Norwegian Twite *C. f. flavirostris* also forage in meadows and roadside verges, where they target plants such as Dandelion, Common Sorrel, Chickweed and other similar food plants to Ireland and Britain. Many birds nest on rock ledges on steep cliffs that may be either completely bare or vegetated by Heather and low shrubs (Marler and Mundinger 1975).

Conservation implications

During the breeding season Twite require long Heather for nesting and suitable foraging habitat within 2-3 km. In the case of Twite in Ireland, birds in county Mayo predominantly selected dry-humid acid grassland or meadows as their preferred foraging habitat. In county Donegal, lower saltmarsh and dry-humid acid grassland habitats were the most selected. It is important to note that this is a combination of all data from April to September; roads and tracks provided an important food source in April and early May. An extension to this study with sufficient sample sizes to

enable habitat selection analysis by month could provide further invaluable information.

One of the main threats to Twite populations in Ireland and elsewhere is a change in land management practices within the ranges of breeding Twite colonies. The removal of heather through sheep overgrazing has been a major problem in the breeding colonies in county Mayo resulting in a dramatic decline in the number of suitable nesting sites. Breeding colonies only occur in long heather on steep cliff sides in areas largely inaccessible to sheep. This type of heather occurs in only 2% of the total study area in county Mayo. In county Donegal, although overgrazing of blanket bog is not a threat in the study area, other blanket bog areas in the west of the county have been seriously affected by overgrazing (McLoughlin & Cotton, 2008). Conversely, recent (and current) agricultural policy is encouraging wide-scale destocking of sheep from many hillsides along the west and northwest of Ireland (Warner 1999), (e.g. Commonage Framework Plan). If this greatly reduced grazing pressure relates to all western seaboard blanket bog. Where the heather has not been completely degraded this would result in larger areas of long Heather and suitable Twite nesting habitat (Thompson *et al.* 1998).

One of the effects of destocking sheep in the west of Ireland is that farming in some areas is being discontinued. This may give rise to land abandonment, which is of increasing concern across Europe. Land abandonment has a damaging effect on many habitats (Bignal & McCracken 1996) and would impact Twite through the subsequent loss of some of the targeted food plants, particularly on dry-humid acid grassland and meadows. The reseeding of traditionally species-rich fields with Perennial Rye Grass represents a loss of foraging habitat for Twite. Although in this

study Twite were occasionally observed feeding in these improved agricultural grasslands, they invariably targeted damp areas with large concentrations of Common Chickweed or Pineappleweed *Matricaria matricarioides* within the improved grassland areas.

Recommendations

To promote the conservation of Twite populations, we recommend the following management prescriptions are implemented:

- Maintain grassy tracks and roadside verges within proximity of the areas adjacent to breeding season foraging areas to encourage wildflowers such as Dandelion, Common Sorrel, Sea Plantain and Thistle.
- Increase areas of long heather in the Mayo study area to enlarge suitable nesting areas and provide an important cover to recently fledged young. This should be achieved by establishing a suitable grazing regime in selected heather-dominated areas.
- Cease reseeding land for agricultural improvement within 3 km of Twite colonies.
- Continue grazing Twite foraging areas as this is an essential tool in maintaining desirable plant species assemblages.

REFERENCES

Aebischer, A.E., Robertson, P.A. & Kenward, R.E. (1993) Compositional analysis of habitat use from animal radio-tracking data, *Ecology* **74:** 1313-1325.

Atkinson, P.A. (1998) The wintering ecology of the Twite *Carduelis flavirostris* and consequences of habitat loss. PhD thesis, University of East Anglia.

Batten, L.A., Bibby, C.J., Clement, J., Elliott, G.D. & Porter, R.F. (1990) *Red Data Birds in Britain*, T. & A.D. Poyser, UK.

Bignal, E.M. & McCracken, D.I. (1996) Low-intensity farming systems in the conservation of the countryside, *Journal of Applied Ecology* **33:** 413-424.

Bleasdale, A. & Sheehy Skeffington, M. (1992) The influence of agricultural practices on plant communities in Connemara. *Environment and Development in Ireland* (ed J. Feehan), pp. 331-336. University College Dublin, Dublin.

Brown, A.F., Crick, H.Q.P. & Stillman, R.A. (1995) The distribution, numbers and breeding ecology of Twite *Acanthis flavirostris* in the south Pennines of England, *Bird Study* **42:** 107-121.

Buckingham, D.L., Peach, W.J. & Fox, D.S. (2006) Effects of agricultural management on the use of lowland grassland by foraging birds, *Agriculture, Ecosystems and Environment* **112** (1): 21-40.

Donald, P.F., Pisano, G., Rayment, M.D. & Pain, D.J. (2002) The Common Agricultural Policy, EU enlargement and the conservation of Europe's farmland birds, *Agriculture, Ecosystems and Environment* **89** (3): 167-182.

Fossitt, J.A. (2000) *A Guide to Habitats in Ireland.* The Heritage Council, Kilkenny.

Geerling, G.W., van Gestel, C.B.L., Sheehy Skeffington, M., Schouten, M.G.C., Nienhuis, P.H. & Leuven, R.S.E.W. (2002) Blanket bog degradation in river catchments in the west of Ireland. *Application of Geographic Information Systems and Remote Sensing in River Studies* (eds R.S.E.W. Leuven, I. Poudevigne & R.M. Teeuw), pp. 25-40. Backhuys Publishers, Leiden.

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

Johnson, D.H. (1980) The comparison of usage and availability measurements for evaluating resource preference. *Ecology* **61:** 65-71.

Joint Nature Conservancy Council. (1990) *Handbook for Phase 1 Habitat Survey: a Technique for Environmental Audit.* Joint Nature Conservation Committee, UK.

Jones, J. (2001) Habitat selection studies in avian ecology: A critical review, *The Auk* **118:** 557–562.

Kenward, R.E. (2001) *A Manual for Wildlife Radio Tagging,* Academic Press, London.

Langston, R.H., Smith, T.H., Brown, A.F. & Gregory, R.D. (2006) The status of Twite *Carduelis flavirostris* in the UK. *Bird Study* **53:** 55-63.

Lynas, P., Newton, S.F. & Robinson, J.A. (2007) The status of birds in Ireland: an analysis of conservation concern 2008-2013, *Irish Birds* **8** (2): 149-166.

Marler, P. & Mundinger, P.C. (1975) Vocalisations, social organisation and breeding biology of the Twite, *Acanthis flavirostris*, *Ibis* **117:** 1-17.

McGhie, H.A., Brown, A.F., Reed, S. & Bates, S.M. (1994) *Aspects of the Breeding Ecology of Twite in the South Pennines*, English Nature Research Reports, No. 118, Peterborough, PE1 1UA.

McLoughlin, D. & Cotton, D. (2008) The Status of Twite *Carduelis flavirostris* in Ireland 2008. *Irish Birds* **8:** 323-330.

Newton, I. (2004) The recent declines of farmland bird populations in Britain: an appraisal of causal factors and conservation actions. *Ibis* **146:** 579-600.

Orford, N. (1973) Breeding distribution of the Twite of central Britain, *Bird Study* **20:** 51-62 and 121-126.

Raine, A.F. (2006) The breeding ecology of Twite *Carduelis flavirostris* and the effects of upland agricultural intensification. PhD thesis, University of East Anglia.

Redfern, C.P.F. & Clark, J. A. (2001) *Ringers' Manual*. BTO, Thetford, Norfolk, UK.

Reed, S. (1995) Factors limiting the distribution and population of twite (*Carduelis flavirostris*) in the Pennines. *Naturalist* **120:** 93-102.

Siriwardena, G.M., Baillie, S.R., Crick, H.Q.P. & Wilson, J.D. (2001) Changes in agricultural land-use and breeding performance of some granivorous farmland passerines in Britain, *Agriculture, Ecosystems & Environment* **84** (3): 191-206.

The Heritage Council, (1999) Impact of Agriculture Schemes and Payments on Aspects of Ireland's Heritage, The Heritage Council, Kilkenny.

Thompson, D.B.A., MacDonald, A.J. & Hudson, P.J. (1998) Upland moors and heaths. In *Managing Habitats for Conservation,* ed. Sutherland, W.J. & Hill, D.A. pp. 292-325, Cambridge University Press, Cambridge.

Walsh, M., Collins J.F., Guinan L., Clavin D.J. & Nixon D. (2001) *Evaluation of impact of livestock on the hill environment – soil, water and vegetation in western Ireland,* End of Project Reports Sheep Series No. 16, Project No. 4359, Teagasc, Athenry, Galway.

Warner, P. (1999) Proceedings of the 1999 Teagasc REPS Conference, Wexford, Ireland.

Whilde, A. (1993) *Threatened Mammals, Birds, Amphibians and Fish in Ireland,* Irish Red Data Book 2, HMSO, Belfast.

CHAPTER 5

The biometrics of Twite *Carduelis flavirostris pipilans* in Ireland, England and Scotland

Derek McLoughlin, Jessica Beaubier, Chris Benson, David Sowter, Colin Corse, Andre Raine, Alan Draper & Don Cotton

Overview

As a product of our intensive colour ringing programme to investigate the movement patterns of Twite in Chapter 3, we gathered a large amount of biometric data on Twite in Ireland. Similar ringing studies in Britain that are currently in progress or recently completed have also gathered Twite biometrics data. On foot of this, we collaborated with our British colleagues, with the aim of identifying similarities and differences between the respective populations. This paper compares Twite biometric data from ringing studies in Ireland, England and Scotland.

ABSTRACT

In this paper we analyse and compare biometric data of Twite from Ireland, England and Scotland. We use a data verification process to eliminate any birds that may have been incorrectly sexed in the field. Male Twite in Scotland had a significantly longer wing length than Irish and English Twite ($P<0.0001$), which did not differ from one another. There were no inter-country differences in the wing lengths of female Twite. Scottish male Twite were significantly heavier than Irish male Twite ($P<0.0001$), which were heavier than English male Twite ($P<0.0001$). Scottish female Twite were significantly heavier than both English and Irish female Twite ($P<0.0001$), which did not differ from one another. Mean fortnightly temperature showed a negative correlation with female body mass but only a very weak correlation with male body mass. These results largely concur with previous biometric analysis based on museum skins. Some of the difficulties of ageing and sexing Twite are also discussed.

INTRODUCTION

There are several reasons why researchers may temporarily take birds from the wild. The most common reason for trapping wild birds is to fit them with a marking device (usually a leg ring) to monitor their movement patterns (e.g. Chapter 3). As shown in Chapter 4, radio transmitters were attached to birds to analyse the habitat selection processes of individual birds in the breeding season. Through the standard process of ringing birds several biometric measurements, such as body weight and wing length, are generally taken (Redfern & Clark 2001). These data can be a good indication of the condition of the bird at the time of ringing (Gosler 2004). They can also be used to look

for variation between different geographical populations, which may indicate a degree of genetic isolation.

Clark & Sellers (2001) previously studied Twite biometrics. They analysed data obtained from Twite caught in Caithness, Scotland, along with data gathered from some other locations in the north of Scotland including, Fair Isle, Shetlands, and Orkney. To investigate geographical variations they also used museum skins of birds obtained in Ireland (mainly from counties Mayo and Kerry), England (including birds from the southern Pennines, Peak District and East Anglia), Scotland (Outer Hebrides, Shetland and Orkney, mainland Scotland) and Scandinavia (mainly birds from Norway but including a small number from Sweden and Germany). They concluded that there was roughly a southwest to northeast cline in body size of the European Twite. They also found a significant sexual dimorphism in wing length and body weight with the males being the larger sex.

Owing to the problematic nature of sexing and ageing Twite particularly in the winter season, (some adult females may exhibit male characteristics, e.g. red rump (pers. obs.)), and in the absence of DNA evidence, a strict sex verification process is required. Clark & Seller (2001) used the presence or absence of a red rump to determine the sex of the bird in their study and as a result, inconsistencies may have occurred in the sexing of some birds. In this paper we use a system of verification of sex, based on recaptures of the same bird in two of more subsequent years after the initial capture, and behaviour of colour ringed birds during the breeding season. Comparisons between the two sexes are drawn from each of the three countries as well as possible variations. This is the first comparison of live Twite biometrics from Ireland, England and Scotland.

In this paper we analyse and compare biometric data of Irish, English and Scottish Twite. Irish biometric data was obtained from ringing in counties Mayo and Donegal

between January 2006 and June 2008. Biometrics data from England was gathered in the South Pennines and the Cumbrian and Lancashire coasts, between September 2003 and May 2008. The Scottish data was gathered during the winter seasons 2001 to 2005 on Orkney.

METHODS

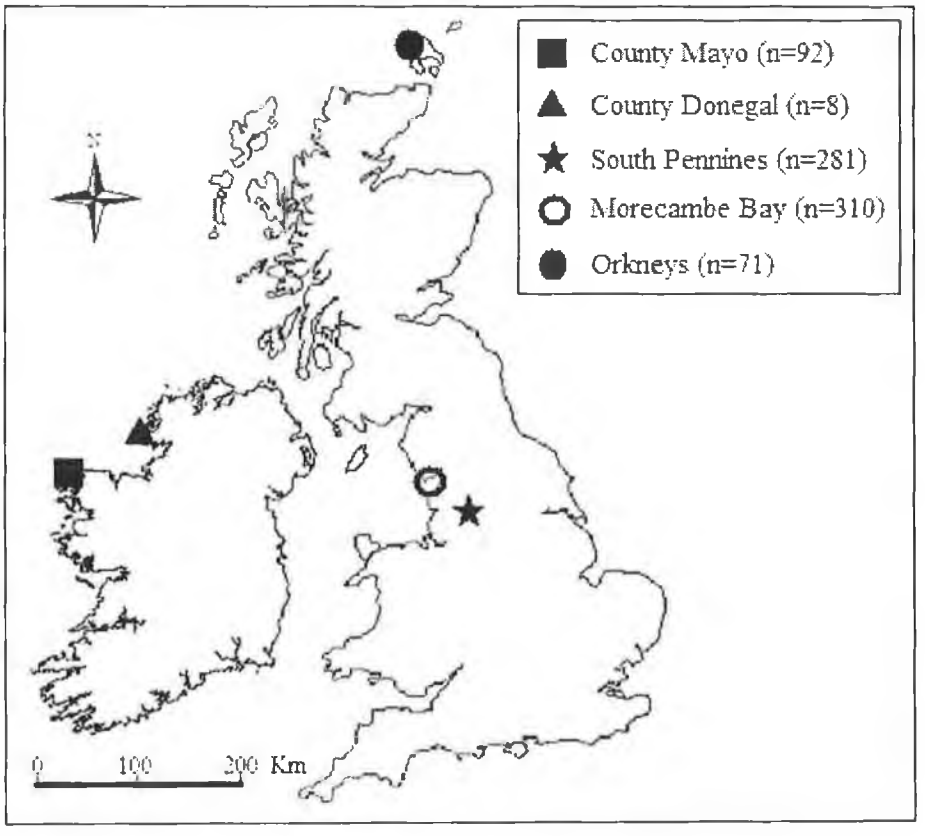
Study areas

In Ireland, ringing focused on populations at Termoncarragh (F6535) and Glenlara (F7039) in north county Mayo and Sheskinmore National Nature Reserve (G6896) in west county Donegal (Figure 1).

English birds were ringed in the South Pennines in counties Lancashire (SD8931) and West Yorkshire (SD9619), and at Heysham (SD3960) and the Ribble Estuary National Nature Reserve (SD3921) on Morecambe Bay in west Lancashire. Further catches were made on both sides of the Duddon Estuary (SD2077 and SD1880) in Cumbria (Figure 1).

The Scottish Twite were ringed at four sub-sites within a 10 km radius of Toab (HY5403), Orkney (Figure 1).

Figure 1. Location of ringing sites in Ireland, England and Scotland. n = the total number of birds trapped at those sites that were used in the analyses. The Morecambe Bay site includes the Duddon Estuary.



Catching techniques

In Ireland and England, birds were trapped at feeding stations baited with Niger *Guizotia abyssinica* seed using whoosh nets and drop-traps, as described by Redfern & Clark (2001). Whoosh nets were used in Scotland at sites baited with Rape *Brassica napus* seed, along with mist nets and tape lures.

Biometrics

The following data were collected:

(a) Age

(b) Sex

(c) Wing length (maximum flattened wing chord to the nearest 0.5mm)

(d) Weight (to the nearest 0.1g)

(e) Time of processing (GMT)

Ringers involved in this study developed a high degree of proficiency in ageing and sexing Twite. However, to ensure consistency of data between study sites we used a verification process to ensure that only birds of known sex were included in the biometric analysis. The following were included in the analysis:

(1) Birds that were retrapped a year or more after being initially ringed.

(2) All birds caught between May and September, unless EURING Code 3 or 3J (juvenile) that were not retrapped a year or more later.

(3) Birds with large amount of red on their rump in April (male).

(4) Re-trapped birds that were consistently sexed the same for all trap sessions (unless initially sexed as 3 or 3J and the aforementioned criteria had been met).

We cannot reliably relate all birds and individual ringers, so some variation between datasets may result from a possible variation in the measuring techniques of the different ringers involved.

Temperature data

On account of the influence of temperature on body condition (Gosler *et al.* 1998), we used mean temperature data for the corresponding two-week period prior to the date of capture of each bird. This temperature data was recorded in Belmullet (Ireland), Manchester Airport (England), and Aberdeen Airport (Scotland).

Statistical Methods

Due to known sexual dimorphism (Clark & Sellers 2001), between-country differences in wing length and mass were investigated separately for each sex. Inter-country differences in wing length were tested using Kruskal-Wallis and Games-Howell multiple comparisons as unequal variances could not be reconciled through transformation.

As captures in each country were distributed throughout different times of the year, we attempted to control for potential seasonal effects on mass (resulting effects of temperature) using statistical approaches. Where assumptions were met, we used ANCOVA and Bonferroni multiple comparisons and where assumptions were not met we used Kruskal-Wallis and Games-Howell multiple comparisons. All statistic analysis was done using SPSS statistical software.

Male versus female comparisons

Due to statistical interactions between factors, we examined sex-based differences in wing length and mass on a country by country basis. As data could not be transformed to meet t-test assumptions, we used a Mann-Whitney U test (Zar 1999).

RESULTS

Inter-country differences in wing length

English males have longer wing lengths than Irish males but shorter wings than Scottish male Twite (Kruskal-Wallis $X^2_{df=2}$ = 24.53, $p<0.0001$, Games-Howell post-hoc, Table 1, Figure 2).

Female wing lengths were consistent between countries (Kruskal-Wallis $X^2_{df=2}$ =5.164, $p>0.05$, Table 1, Figure 3).

Inter-country Differences in Body Mass

The linear relationship between male body mass and temperature was insufficient to support an ANCOVA and suggested that the timing of sampling would have little influence on inter-country differences in the body mass of male Twite. As unequal variances could not be reconciled through transformation, we tested inter-country differences in male mass using Kruskall-Wallis and Games-Howell multiple comparisons for unequal variances (Zar 1999).

Females mass was linearly correlated to the average temperature of the preceding fortnight, thus inter-country differences were tested using an ANCOVA with average temperatures of the preceding fortnight as a covariate to control for seasonal effects.

Male body mass differed by country (Kruskal-Wallis $X^2_{df=2}$=73.25 , $p<0.001$). For males, Scottish birds were heavier than Irish birds, which were heavier than English birds (Games-Howell, Table 1, Figure 4).

Data for female mass only met the assumptions of ANCOVA when an extreme value in the Irish data set was removed. We proceeded with analysis after removing the extreme value and explore the potential consequences of its removal in the discussion. With the extreme value removed, the body mass of Scottish females was heavier than both English and Irish females, which did not differ in mass (ANCOVA, Bonferonni multiple comparisons, Table 1; Figure 5).

Table 1. ANCOVA results for differences in female mass between countries, controlling for the effects of the preceding fortnight's average temperature.

Source	Sum of Squares	df	Mean Square	F	*P*
Corrected Model[a]	121	3	40.42	45.2	<0.0001
Intercept	6652	1	6652.28	7441.9	<0.0001
Country	31	2	15.63	17.4	<0.0001
Temperature[b]	17.9	1	17.95	20	<0.0001
Error	178	199	0.89		
Total	46573	203			
Corrected Total	299	202			

(a) Adjusted R^2= 0.396; (b) Covariate, average temperatures of preceding fortnight

Table 2. Summary of wing length and body weight for England, Scotland and Ireland

Variable	Country	Mean±SD	Range	N	Statistical Result
Male wing length (mm)	Ireland	76.3±1.8	72 – 81	67	Kruskal-Wallis
	England	77.0±1.8	71 – 82	428	$X^2_{df=2} = 24.53$
	Scotland	78.2±1.5	75 – 82	32	$p<0.0001$***
Female wing length (mm)	Ireland	74.8±1.7	72 – 78	29	Kruskal-Wallis
	England	74.9±1.6	71 – 79	151	$X^2_{df=2} =5.164$
	Scotland	75.6±1.3	71 – 78	34	$p>0.05$, NS
Male mass (g)	Ireland	15.5±0.8	14.0– 18.9	69	Kruskal-Wallis
	England	15.0±0.8	11.8– 17.6	411	$X^2_{df=2}=73.25$
	Scotland	16.9±1.3	14.9– 19.9	31	$p<0.0001$***
Female mass (g)	Ireland	14.9±1.1	13.5 – 19.6	30	ANCOVA
	England	14.7±0.9	12.2 – 18.4	142	$p<0.0001$***
	Scotland	16.7±1.1	14.9 – 19.9	34	(Table 1)

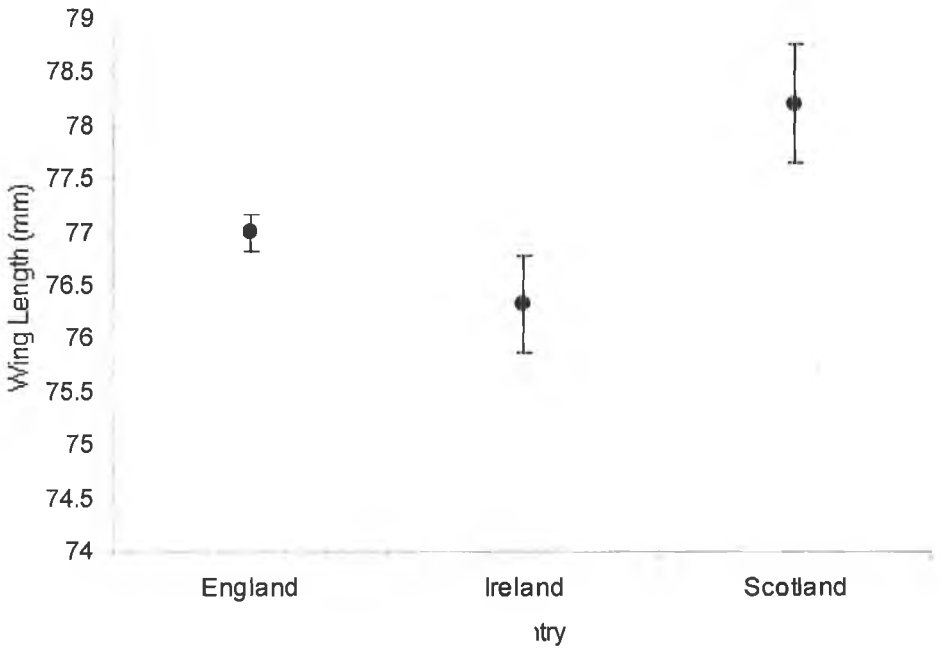


Figure 2. Male wing length of English, Irish and Scottish Twite (bars represent 95% CI). English Twite had longer wings than Irish Twite but shorter wings than Scottish Twite (Kruskall-Wallis Test, $X^2_{df=2}$ = 24.53, $p<0.0001$, Games-Howell multiple comparisons). See Appendix J for frequency charts for figures 2 and 3.

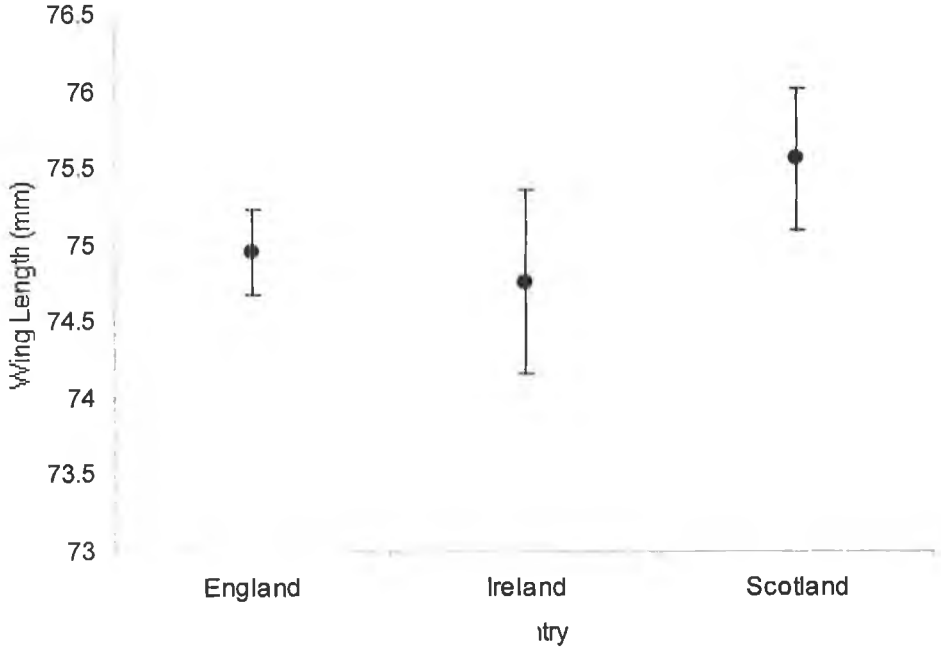


Figure 3. Female Twite wing length in England, Ireland and Scotland (bars represent 95% CI). Wing length was consistent between countries (Kruskal-Wallis $X^2_{df=2}$ =5.164, $p>0.05$).

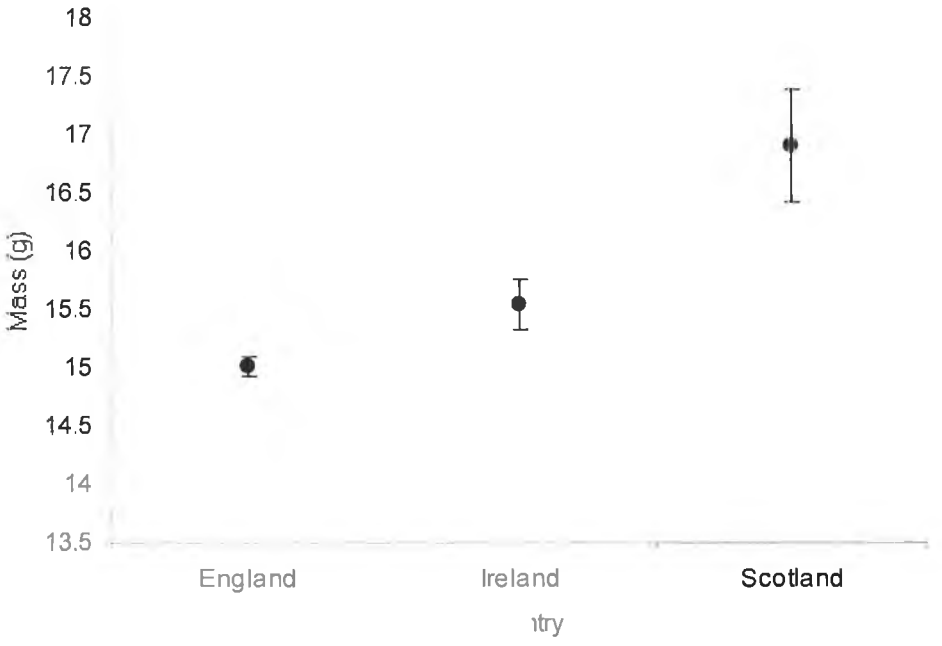


Figure 4. Male body mass of English, Irish and Scottish Twite (bars represent 95% CI). The mass of male birds varied by country as Scottish birds were heavier the Irish Twite, which were heavier than English Twite (Kruskal-Wallis Test, $X^2_{df=2} = 73.248$, $p<0.0001$, Games-Howell multiple comparisons).

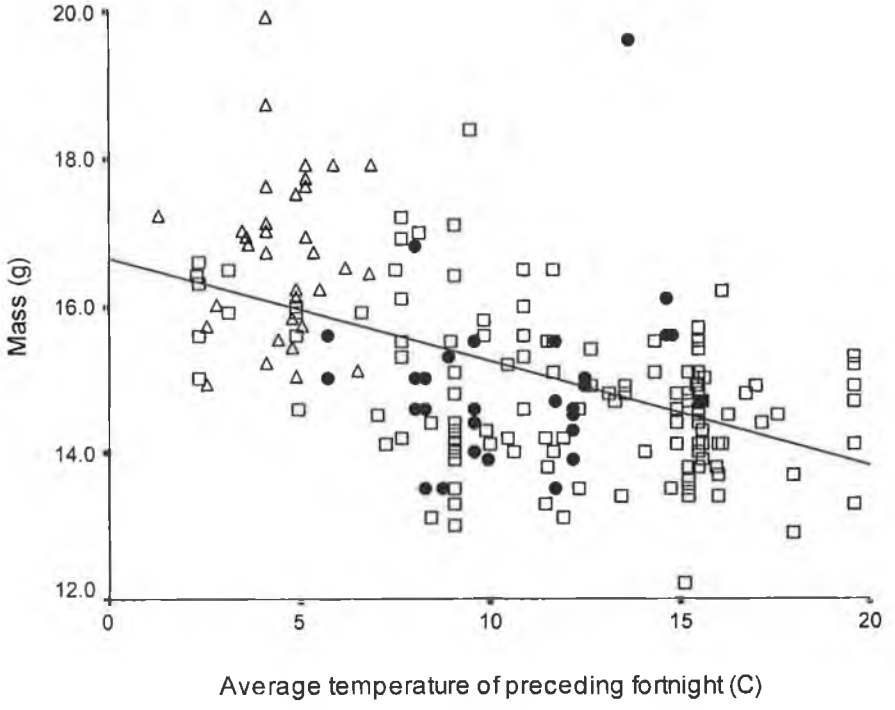


Figure 5. Relationship between body mass and temperature for female Twite in Ireland (•), England (□) and Scotland(Δ), $R^2 = 0.301$, $p<0.0001$ (with an Irish extreme value removed).

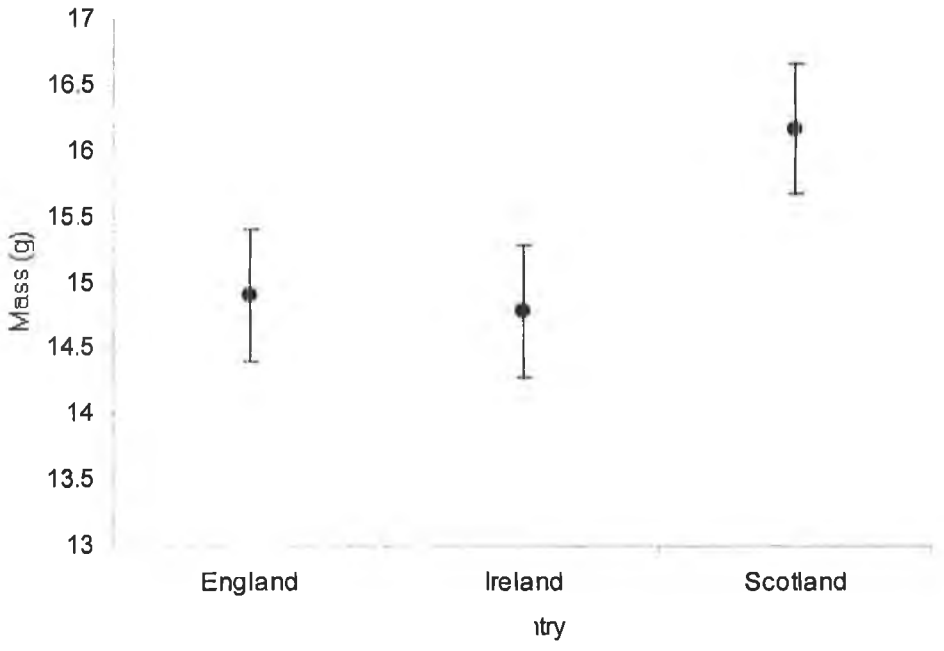


Figure 6. Estimated marginal means of Twite female body mass in England, Ireland and Scotland, accounting for effects of seasonality. The body mass of Scottish female Twite was heavier than both English and Irish female Twite, which did not differ in mass (Table 1).

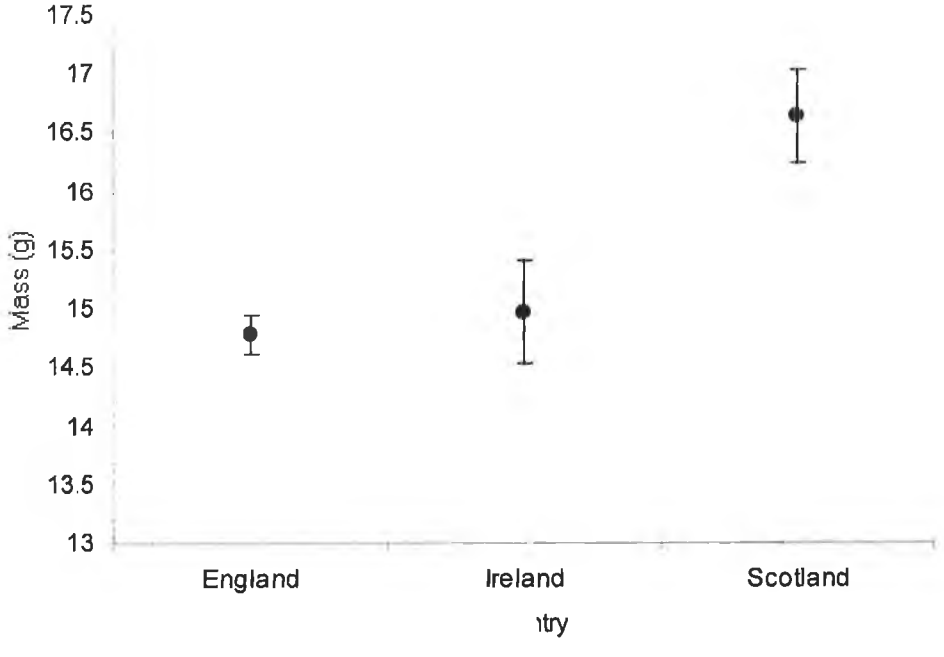


Figure 7. Twite female body mass in England, Ireland and Scotland. The body mass of Scottish female Twite was heavier than both English and Irish female Twite, which did not differ in mass (ANCOVA, $R^2_{adj} = 0.396$), Bonferonni multiple comparisons, (Table 1).

Male versus female comparisons

In Ireland and England males were both longer winged, and heavier, than females. In Scotland males had longer wings than females but both sexes weighed approximately the same (Table 3).

Table 3. Summary table of wing length and body mass for males versus females from the three countries.

		Wing Length				Mass			
		n	Average ± sd	Z*	p	n	Average ± sd	Z*	p
England	Male	409	77.00±1.80	-10.887	<0.001	409	15.01±0.86	-2.950	0.003
	Female	139	74.95±1.72			139	14.80±1.00		
Ireland	Male	67	76.34±1.87	-3.708	<0.001	69	15.58±0.87	-3.263	0.001
	Female	29	74.76±1.57			30	14.98±1.19		
Scotland	Male	32	78.29±1.51	-5.809	<0.001	31	16.91±1.32	-.0381	0.703
	Female	34	75.56±1.33			34	16.69±1.11		

*Mann-Whitney U test statistic

DISCUSSION

Comparisons between Irish, English and Scottish Twite

Wing length

Male wing length varied by country, with male wing length increasing from Irish to English to Scottish birds. This concurs with Clark & Sellers' (2001) analysis of museum skins where they concluded that a northeast – southwest European cline exists in Twite body size. In contrast however, female wing lengths were consistent between the three countries. This may be due to the small sample size for females, as there were fewer than males (Table 3).

Body mass

Temperature showed only very weak correlation with body mass for males, regardless of country of origin. It is therefore likely that the observed differences between Irish, Scottish and English male bird masses are real rather than an artefact of unequal sampling (Table 1; Figure 4). In contrast however, we observed a strong negative correlation between temperature and female body mass (Figure 5). We have no explanation for this difference between males and females, or whether it is a *bona fide* difference, or an effect of a small sample size.

English and Irish females had similar body masses but were both approximately a gram less than Scottish females, even after controlling for effects of seasonality.

The removal of the extreme value from the Irish female sample was justifiable as it allowed analysis of the rest of the data. Removing the outlier does however reduce the

average of the Irish data and could potentially create a difference where there may actually be none. However, a well-developed brood patch was apparent on this bird (BTO code BP3), which indicated that it was in the process of egg laying. In addition, being trapped in May, this was the only female biometrics data to be gathered during the breeding season in Ireland.

We have no clear explanation why there is a difference in male mass between Ireland and England but none in females. It is possible that this reflects varying dispersion patterns between sexes, as is the case with some other members of the finch family, such as the Chaffinch *Fringilla coelebs*, in which females tend to migrate considerably further than males (Newton 1972).

Differences and similarities between Twite biometrics in the three study areas may be strongly influenced by the movement dynamics of the respective populations. Atkinson (1999) and Raine *et al.* (2006) illustrate the movement patterns of the Twite that breed in the South Pennines. A large proportion of these birds move to the southeast coast of East Anglia for the winter season with the remainder over-wintering there. Raine *et al.* (2006) found that most of the wintering flocks that were targeted in counties Cumbria and west Lancashire originated in the western Isles of Scotland. Similarly we have evidence that some of the western Isles breeding population over-wintered in our study areas in counties Mayo and Donegal (Chapter 3). This overlap between some of the Irish and west coast of England wintering populations may explain biometric similarities between the two cohorts. The Scottish data was gathered on Orkney in the north of Scotland during the winter period. It is thought that wintering flocks on Orkney are composed of local breeders, along with breeders from Shetland and Fair Isle. These birds appear to only move relatively short distances between their breeding and wintering sites (Clark & Sellers 1998, Brown & Atkinson 2002). This apparent lack of

overlap with the Irish and English populations may explain the biometric differences between these two areas.

If sample sizes permitted, further study on the biometrics could attempt to compare the biometrics of resident and migrant birds in the study areas using ring recovery data. It seems that our current sample contained both migrant and sedentary birds (see Chapter 3), whose wing length and body weight may vary.

The results of this comparison between Irish, English and Scottish Twite would make an interesting forerunner for a genetic study investigating variation between the three countries, extending into the Scandinavian population.

Comparisons between males and females

Sexual dimorphism was evident in Ireland and England with males being both longer winged, and heavier, than females. In Scotland males had longer wings than females but both sexes weighed approximately the same (Table 3). This dimorphism in our sample concurs with Clark & Sellers (2001).

According to published data this sexual size dimorphism is typical amongst small passerines and many other taxa e.g. Bennett and Owens (2002). Gosler *et al.* (1998), found that wing length measurements were the most repeatable metrics to determine sexual size dimorphism in a group of 27 passerines. Jehl & Murray (1986) conclude that this dimorphism occurs as a result of sexual selection. It is possible that factors such as foraging differences between males and female may be important in the evolution of dimorphisms (Andersson 1994).

The ageing and sexing of Twite

As with other small brown passerines e.g. Lesser Redpoll *Carduelis flammea*, sexing and ageing individual Twite at particular times of the year can be problematic due to a wide variation in an individuals' plumage or it's degree of maturity. Initially, birds were aged using the ageing criteria of Svensson (2006), however, some discrepancies in our ageing and sexing were found in the three countries as the study progressed and as birds were retrapped over a year later. Although generally, the presence of a red rump indicated that the bird was a male, both the Irish and English studies found example of females with a considerable amount of red on their rump. In the field, birds of the year (EURING age code 3 and 5) without a red rump were by and large left unsexed as some males may not have developed the red rump until late into the spring. The presence of a moult limit, quality and colouration of feathers was also used to age and assist in sexing the bird. As we had no means by which to control for any possible discrepancies in ageing technique between individual ringers we pooled all age groups together.

The biometrics of *C. f. pipilans*

The Twite that occur in Ireland, England and Scotland, *C. f. pipilans*, are considered a subspecies of the nominate *C. f. flavirostris*, which is found in Norway (Cramp 1993). The reason for this classification of sub-species is due to a slightly different morphology to the nominate race. Although Clark & Sellers (2001) did find a significant difference in wing measurements between the museum skins of the Scandinavian and Irish and British population, there is no genetic evidence to support or refute this classification. Several hundreds of Twite have been ringed of the nominate race (Bernhof-Osa 1965, Bub 1976), however, as many of these measurements followed different measuring methods to those used in our study (e.g. measurement of the maximum flattened wing chord) we cannot meaningfully compare wing measurements. Table 4 presents some

wing and body mass measurements taken by Bub (1976) during the winter season of 1963/64 in Wilhelmshaven in northern Germany. Bub (1976) used the maximum flattened wing chord as the wing measure. Both wing length and body mass means concur with Clark & Sellers (2001) that *C.f. flavirostris* is larger than *C.f. pipilans*. The genetic (or other) verification of the subspecies *C.f. pipilans* would add urgency to conservation efforts for our endemic species to Ireland and Britain.

Table 4. Wing length (mm) for both sexes (a) and body mass (b) and for *C.f. pipilans* and *C.f. flavirostris*. These comparisons should be treated with caution due to possible discrepancies between methods and correct sexing of birds.

(a)

Male wing length (mm)	**Country**	**Mean**	**Range**	**N**
	Ireland	76.3	72 – 81	67
C.f. pipilans	England	77	71 – 82	428
	Scotland	78.2	75 – 82	32
C.f. flavirostris	Germany	79.5	78 - 82	77
Female wing length (mm)				
	Ireland	74.8	72 – 78	29
C.f. pipilans	England	74.9	71 – 79	151
	Scotland	75.6	71 – 78	34
C.f. flavirostris	Germany	77	74 - 79	75

(b)

Male body mass (g)	**Country**	**Mean**	**Range**	**N**
	Ireland	15.5	14 - 18.9	69
C.f. pipilans	England	15	11.8 - 17.6	411
	Scotland	16.9	14.9 - 19.9	31
C.f. flavirostris	Germany	17.4	13 - 21	486
Female body mass (g)				
	Ireland	14.9	13.5 - 19.6	30
C.f. pipilans	England	14.7	12.2 - 18.4	142
	Scotland	16.7	14.9 - 19.9	34
C.f. flavirostris	Germany	16.7	12 - 23	497

Biometrics data for Ireland is listed in Appendix H.

CONCLUSION

Male Twite in Scotland were found to have a longer wing length than Irish and English Twite, which did not differ from one another. There were no inter-country differences in the wing lengths of female Twite. Scottish male Twite were found to be heavier than Irish male Twite, which were heavier than English male Twite. Scottish female Twite were heavier than both English and Irish female Twite, which did not differ from one another. Mean fortnightly temperature showed a negative correlation with female body mass but only a very weak correlation with male body mass. These results largely concur with previous biometric analysis of Clark & Sellers (2001) based on museum skins. It is recommended that samples from the six subspecies, particularly the Irish and British, and Scandinavian populations, should be genetically assessed for their verification.

REFERENCES

Andersson, M.B. (1994) *Sexual Selection*, Princeton University Press, USA.

Atkinson, P.W. (1998) The wintering ecology of the Twite *Carduelis flavirostris* and consequences of habitat loss, PhD thesis, University of East Anglia.

Bennett, P.M & Owens, I.P.F. (2002) *Evolutionary Ecology of Birds: Life History, Mating System and Extinction*, Oxford University Press.

Bernhoft-Osa, A. (1965) Om Birgiriksens *Carduelis flavirostris* trekk, *Stavanger Museums Arbok* **35:** 109-118.

Brown, A.F. & Atkinson, P.A. (2002) Twite. In *The Migration Atlas: Movements of the Birds of Britain and Ireland* (eds Wernham, C.V., Toms, M.P. Marchant, J.H., Clark, J.A., Siriwardena, G.M. & Baillie, S.R.), pp 657-659. T. & A.D. Poyser, London.

Bub, H. (1976) Flügelmaße und Gewichte des Berghänflings (*Carduelis f. flavirostris*), *Ornithologosche Mitteilungen* **27:** 6-12.

Clark, H. & Sellers, R.M. (1998) Movements of Twites in Scotland, *Scottish Birds* **19:** 270-279.

Clark, H., & Sellers, R.M. (2001) Biometrics of the Twite Carduelis flavirostris, *Ringing & Migration* **20:** 328-337.

Cramp, S. (1993) *Handbook of the Birds of the Western Palaearctic*, Oxford University Press, Oxford.

Gosler, A.G. (2004) Radio-tagging In. Sutherland, W.J., Newton, I., Green, R.E., (eds.) *Bird Ecology and Conservation, A Handbook of Techniques,* Oxford University Press, UK.

Gosler, A.G., Greenwood, J.J.D., Baker J.K., Davidson N.C. (1998) The field determination of body size and condition in passerines: a report to the British Ringing Committee, *Bird Study* **45:** 92-103.

Jehl, J.P. & Murray, B.G. (1986) The evolution or normal and reverse sexual size dimorphism in shorebirds and other birds. In R.F. Johnston, ed. *Current Ornithology,* **3:** 1-86, Plenum, New York, USA.

Newton, I. (1972) *Finches*, Collins, London.

Raine, A.F., Sowter, D.J., Brown, A.F., Sutherland, W.J. (2006) Migration patterns of two populations of Twite *Carduelis flavirostris* in Britain. *Ringing and Migration* **23:** 45-52.

Redfern, C.P.F. & Clark, J.A. (2001) *Ringers' Manual*, BTO, Norfolk, UK.

Svensson, L. (2006) *Identification Guide to European Passerines*, 5th edn, Stockholm.

Zar, J.H. (1999) *Biostatisical Analysis 4th Ed.* Prentice Hall, Illinois, USA.

CHAPTER 6

The conservation of Twite *Carduelis flavirostris* in Ireland

Overview

This chapter draws on the information on the status, movement patterns and habitat requirements presented in the preceding chapters to summarise important, previously unknown, aspects of the ecology of Twite in Ireland. The primary aim of this summary is to outline the status of Twite in terms of their conservation in Ireland and use this information to offer practical conservation recommendations.

1. Introduction

Despite apparent population declines and range contraction in Ireland over the past 40 years (Sharrock 1976, Gibbons *et al.* 1993, Cabot 1999), no study had ever focused on Twite in Ireland. The reasons for this lack of research interest most likely relate to factors including: the remoteness of the Twite's breeding areas and distance from interested ornithological researchers and academic institutes; the potential difficulty of the research topic; and the Twite's lack of 'conservation profile' such as those of other species, e.g. Corncrake *Crex crex*. This thesis addresses many of the previously unknown aspects of the Twite's ecology in Ireland and thus, represents a large contribution to our knowledge of the Twite in Ireland. It also adds to, and compliments, work already done in Britain. Information from this study has already served as an important guide for species policy-makers in Ireland, e.g. 'The status of birds in Ireland: an analysis of conservation concern 2008-2013' (Lynas *et al.* 2007). Data gathered in the course of this study has been used to inform several publications on the status of Twite in Ireland e.g. Gordon (2005), Hillis (2006, 2007, 2008), O'Clery (2008), McLoughlin (2008), McLoughlin & Cotton (2008) and McLoughlin *et al.* (in press). In this summary chapter I highlight the most important findings of my research, discuss issues relating the Twites' ecology in Ireland, and offer suggestions for conservation efforts and further research.

2. Conclusions from this study

2.1 Population status

1) The breeding population of Twite in Ireland is estimated at between 54 and 110 breeding pairs.

2) These birds breed in colonies at only a few coastal locations, mainly in north county Mayo and west and northwest county Donegal. There is still evidence of breeding (less than 15 pairs) on Rathlin Island and in other areas along the county Antrim coast. Less than five pairs still breed on the Dingle Peninsula, west county Kerry.
3) Many areas in counties Donegal, Mayo, Galway and Kerry, where Twite were previously observed to breed no longer sustain breeding populations.
4) Heavy overgrazing and the plantation of commercial coniferous forestry in the uplands, and changes in farming practices appear to be the main reasons for the loss of many of these breeding populations.
5) Breeding Twite populations in Ireland can be categorised as being 'Endangered' using the IUCN criteria for the categorisation of Red List species and are therefore considered to be facing a 'very high risk of extinction in the wild' in Ireland.
6) The wintering population is estimated at a minimum of 650 to 1,100 birds.
7) This figure indicates that migrants augment Irish Twite populations between October and April.
8) The wintering population is found mainly along the northwest, north, and northeast coasts of Ireland from west county Mayo to county Louth.

2.2 Movement patterns

1) Prior to this study, only very small numbers of Twite had previously been ringed in Ireland (Table 1). The data in Table 1 reflects our relatively large contribution to ringing, and the general knowledge of Twite in Ireland. The large increase in the number of Twite ringed since 2005 in Ireland is a direct result of this study.

2) Of the total number ringed, a large proportion of the Irish Twite breeding population spent the winter season within 28 km of their breeding area. This indicates that Irish breeding Twite are largely sedentary.
3) Twite populations are vulnerable to changes in land management practice within this area. However, if adequate conservation measures were put in place within 28 km of breeding areas, this would benefit these populations of Twite during both the breeding season and throughout the winter.
4) The 28 km radius around breeding areas should form the core of targeted action plans for the conservation of Twite in Ireland.
5) The minimum distance travelled from nest to foraging area by radio tracked birds was 1.06 km with a maximum distance of 1.49 km.
6) A large proportion of individuals appeared to use an area of less than 150 ha, including their roost site, for much of the winter.
7) We have one confirmed and one probable record of Twite wintering in the study areas that appear to be of Scottish origin. This concurs with our hypothesis of a population augmentation in the winter season as discussed in Chapter 2.

Table 1. Yearly totals of Twite ringed on the island of Ireland since 1980.

Year	No. ringed	Year	No. ringed	Year	No. ringed
		1999	2	1989	0
2008	28	1998	0	1988	1
2007	189	1997	1	1987	1
2006	306	1996	0	1986	0
2005	16	1995	0	1985	0
2004	2	1994	0	1984	0
2003	0	1993	4	1983	1
2002	0	1992	0	1982	0
2001	1	1991	0	1981	0
2000	0	1990	0	1980	0

Total number of Twite ringed since 1980: 562

2.3 Breeding habitat requirements

1) Twite almost solely use long Heather *Calluna vulgaris* for nesting with very few birds using Bracken *Pteridium aquilinum*.
2) Nests were situated on steep rocky sea-cliff slopes facing between north and northeast in direction.
3) All nesting colonies were situated within 2 km of their preferred foraging habitat.
4) Throughout the breeding season, dry-humid acid grassland was the most selected habitat in county Mayo with lower saltmarsh being the most selected in Donegal.
5) Gravel tracks and roadside verges are important foraging habitats in the early breeding season.
6) Freshwater streams (upland rivers) are used for drinking, gathering grit and bathing. This habitat was the second most used habitat in the county Mayo analysis.
7) Dandelion, Common Sorrel, Chickweed, Sea Thrift, Sea Plantain, Thistle and Autumn Hawksbit were observed to be the most targeted food plants during the breeding season.

2.4 Twite biometrics

1) Male Twite in Scotland had a longer wing length than Irish and English Twite, which did not differ from one another.
2) There were no inter-country differences in the wing lengths of female Twite.
3) Scottish male Twite were heavier than Irish male Twite, which were heavier than English male Twite.

4) Scottish female Twite were heavier than both English and Irish female Twite, which did not differ from one another.
5) Mean fortnightly temperature showed a negative correlation with female body mass but only a very weak correlation with male body mass.

3. Conservation recommendations

With a declining population that is now between 54 and 110 breeding pairs, the Twite is vulnerable to extinction as a breeding species in Ireland. Conservation efforts for the Twite in Ireland must target all aspects of its ecology in both the breeding and winter seasons.

3.1 Breeding season - nesting areas

Of a total of 72 nests sites observed, 68 were in long Heather (>0.3 m) with four in Bracken. The nests located in Heather were generally associated with steep slopes, often with the Heather over-hanging rock. They invariably faced between north and northeast in direction. Raine (2006) noted that most of the 212 Twite nests found in the South Pennines during his study of Twite were in long Heather or Bracken. He notes that these nests were generally on east facing slopes and suggests that this provides some protection from the prevailing wind. This explanation may also be applicable to the direction Irish nest colonies face. However, it is difficult to test this hypothesis in Ireland as very few southwest facing slopes in our study areas have adequate Heather height. Raine (2006) also mentions several unusual examples of birds nesting on such places as a cliff wall and half way up the fronds of Bracken at the edge of a canal. On South Uist in the Western Isles of Scotland, Wilkinson & Wilson

(in press), found that Twite nested in young coniferous trees. These examples of nesting sites would, however, be unusual.

It is clear that long Heather is vital as a nesting habitat for Twite in Ireland. Overgrazing and burning, which result in grasses such as *Molinia caerulea* and *Nardus stricta* dominating, and undergrazing which results in shrub encroachment, are both detrimental to nesting habitat. Further threats to nesting habitat include afforestation and peat harvesting of blanket bogs.

As observed by Raine in his South Pennines study, we also noted Twite colonies within 50 metres of nesting Peregrine Falcon *Falco peregrinus* and Kestrel *Falco tinnunculus*. The presence of these raptors did not appear to interfere with the Twite breeding success, but may actually have been of benefit to the colony through protection from Ravens *Corvus corax* and Hooded Crows *Corvus corone* (Norrdhal *et al.* 1995, Raine 2006)

Between late April and September birds in the study areas roosted in long Heather, and occasionally Bracken. In an area where long Heather is lost, Twite lose both nesting and roosting areas. After the breeding season when flocks move away from their natal areas, in the absence of Heather, birds have been observed roosting in Bracken. As discussed by Raine (2006) this raises an interesting conservation conflict where Bracken is removed from such important habitats as machair, which is listed as a priority habitat under Annex I of the EU Habitats Directive. An example of this conflict in the study area is at Sheskinmore National Nature Reserve west county Donegal. Extensive beds of Bracken occur adjacent to a mixed crop cereal plot. Twite regularly feed on Quinoa *Chenopodium quinoa* seed in this cereal plot throughout the autumn. Flocks of up to 60 birds, including many of the breeding birds from our

Figure 1 a-b Twite breeding habitat on steep north facing rocky slopes with long Heather.

(a)

(b)

Maghera study area (7 km to the south, Chapter 3), roost in the adjacent Bracken beds. Linnet *Carduelis Cannabina* also used these beds as roost sites.

Conservation actions in nesting areas

In terms of conservation actions for Twite nesting areas, suitable habitat should be identified within the current known breeding range of Twite, i.e. areas with a sloped gradient on blanket bog with existing heather coverage. As the loss of areas of long Heather will result in the loss of Twite nesting habitat it is vital that such areas be maintained and enhanced through adequate management. This management should entail grazing stocking limits that will allow the growth of large Heather patches of a variety of age and height. Initially, this could be achieved through summer grazing by Sheep, as they target grassy areas rather than Heather during the summer (Thompson *et al.* 1998). Thompson *et al.* (1998), recommend a grazing density of less than two ewes per hectare for a good Heather condition. These large patches of Heather of varying age and height would also benefit other upland species such as Red Grouse *Lagopus lagopus*, which is also listed on the red list of Birds of Conservation Concern in Ireland (Lynas *et al.* 2007). In county Mayo, where long Heather accounted for just 2% of the study area, this Heather enhancement and maintenance would greatly increase the proportion of available nesting sites.

However, any such measures have to be cognisant of potential impacts on the Chough *Pyrrhocorax pyrrhocorax*, an Annex I species under the EU Birds Directive, and indeed other species of flora and fauna. Chough require a short sward of less than 5 cm for foraging (Kerbiriou *et al.* 2006), and are present as a breeding species in all of the known Twite breeding areas in Ireland (Gray *et al.* 2003). As a consequence of its Annex I status, areas with significant national breeding population of Chough qualify for Special Protection Area (SPA)

status. Although our study area in county Mayo is not listed as a SPA for Chough, the west county Donegal study area is. Due to its SPA status, the National Parks and Wildlife Service (NPWS) offer an incentive to farmers to manage their farms specifically for Chough under the NPWS Farm Plan Scheme (FPS). The prescriptions within the NPWS FPS Chough measure does not specify stocking rates, however, it requires that a sward height of 2-3 cm be maintained over 40% of the target habitat within the Chough SPA. In a scenario where Heather cover decreased as a result of heavy grazing for Chough, Twite nesting habitat may be negatively affected. In cases where the grazing element of the Chough measure conflicts with habitat protection within Special Areas of Conservation (SAC), this Farm Plan may not be applied. The Chough measure of the Farm Plan cannot be applied to commonages.

Conversely, the consequence of increased Heather coverage in Chough nesting areas would be reduced numbers of Chough as noted on Ramsay Island by Bullock (1980).

Figure 1. Colour ringed adult female Twite (a-b) provisioning chicks in a brood of five in a nest in long Heather in county Donegal.

(a)

(b)

Figure 1. (c) Colour ringed adult female Twite provisioning chicks in a brood of five in a nest in long Heather in county Donegal, and (d) leaving the nest carrying faecal sac

(c)

(d)

3.2 Breeding season - foraging areas

Using the Fossitt (2000) classification, Twite mainly foraged in dry-humid acid grassland, lower saltmarsh, buildings and artificial surfaces, and disturbed ground and spoil. Following the habitat classification system of Chapter 4, these habitats equate to meadows, short grassland, and roads and tracks. Raine (2006) found a similar preference for meadows that were rich in seeding wildflowers and avoidance of reseeded pasture, freshly cut fields, and areas of shrub or woodland. An interesting difference, however relates to the preferred sward height of English and Irish birds. South Pennines birds selected a medium to long sward, whereas in Ireland Twite preferred a short sward height. It is possible that this is the result of many of the medium and long sward fields in the Irish study areas also being largely composed of improved grassland that tends to be preserved for silage harvesting. Enclosed short-sward fields with patches of Thistle, Sorrel or Dock *Rumex obtusifolius* (generally avoided by sheep) may have accounted for the use of some of these fields. Common Chickweed, Common Mouse-ear *Cerastium fontanum*, and Pearlwort tended to occur in damp patches of dry-humid acid grassland and occasionally damp drains where the ground had been heavily trampled during the previous winter.

Between April and September, Twite primarily targeted the seeds of Dandelion, Sorrel, Annual Meadow Grass, Common Chickweed, Sea Thrift, Sea Plantain, Thistle, Pineappleweed, Pearlwort, and Autumn Hawksbit. These plants tended to be targeted when they had reached peak seeding condition.

Figure 2. Typical Twite foraging habitat in August and September comprising large densities of *Leontodon autumalis* and *Plantago maritima* on dry-humid acid grassland habitat.

Our radio tracking studies show that for breeding birds the minimum distance travelled from nest to foraging area was 1.06 km with a maximum distance of 1.49 km. This reflected the availability of suitable foraging habitat. In the South Pennines, Raine (2006) determined the minimum distance travelled from nest to foraging area to be 1.31 km with a maximum of 3.54 km. He suggests the ideal foraging distance should not exceed 2.5 km.

The breeding home range size of the Irish radio tracked birds using the Minimum Convex Polygon (MCP), ranged from 25.4 to 70.5 ha. Using the concave polygon range size estimator, which removes unused areas from the MCP gives a range size of between 3.6 and 31.3 ha. This shows the confined area in which Twite nest and forage throughout the breeding season. Birds

tended to forage in the same small number of areas throughout the summer. Once juvenile birds became independent of their parents in July, August, and September, they too showed a strong selection for these feeding areas. The MCP of four juvenile birds tracked in August ranged from 3.8 – 31.7 ha. As juvenile Twite spend much of their time foraging, their strong selection for this area reflects the abundance of favoured seed plants. This is backed-up by our transect data in both counties Mayo and Donegal through which we observed adult and juvenile birds using the same four or five fields, or the same strip of saltmarsh from late June to September.

With this intensive use of a small number of feeding areas by Twite from April to September, maintaining this food supply should form an intrinsic part of a conservation plan for Twite in the breeding season. Changes in current grazing regimes should be discouraged in the favoured Twite feeding areas. Wildflowers on roadside verges, gravel tracks and parking areas should be maintained and should never be sprayed or cut between April and September. Although in this study, Twite were only occasionally observed feeding on Cottongrass *Eriophorum* spp., Raine (2006) notes the importance of patches of Cottongrass to juvenile birds who feed on wind-blown seeds at peat hags and gullies. He also observed birds in April feeding on Purple Moor-Grass *Molinia caerulea*.

Our analysis of Twite habitat selection also showed the importance of upland streams for bathing and drinking. In the habitat selection rankings (Chapter 4) this habitat, following Fossitt (2000), was referred to as 'upland river'. Within this habitat, Twite were generally observed at relatively shallow riffle and pool stretches of narrow streams. Birds also appeared to gather grit at these points.

In the study areas, as all of the primary feeding areas occurred in small villages (rural settlements with between approximately 8 and 40 dwelling houses), these need to be the focus of the Twite breeding season conservation plan.

Conservation actions in the foraging areas

The potential conservation conflict between Chough and Twite has already been discussed, however, the Chough is only one of many species of flora and fauna that may be affected by measures designed to conserve and enhance Twite populations in Ireland. It is essential that any measures introduced to benefit Twite populations are mindful of the greater biodiversity of the area in which they occur. As already discussed, the diet of Twite is composed solely of the seeds of weed species, which are closely related with traditional extensive agriculture practices. Several other rare or declining bird species dependant on similar farming practices to that required by foraging Twite include Corncrake *Crex crex*, and Yellowhammer *Emberiza citrinella*. The Corn Bunting *Miliaria calandra* was also associated with traditional extensive agriculture in Ireland but is now thought extinct as a breeding species here. Corncrake populations have severely suffered in the past 40 years due an increase in intensive silage cutting (Whilde 1993, Newton 2004), whilst only very few Yellowhammer still breed in the west of Ireland. Conservation measures for Twite including the maintenance of traditionally managed meadows, late cutting of meadows and the provision of cereal plots would benefit these other rare and declining bird species. In many ways, the Twite can be used as a key species for the wider conservation of many other vulnerable bird species. Twite conservation actions will also benefit species such as Sky Lark *Alauda arvensis*, Tree Sparrow *Passer montanus*, and Linnet, all of whose populations have declined in recent years (Newton 2004).

The maintenance of traditional meadows in a Twite conservation plan will also be beneficial for invertebrate diversity, including bumblebees for which there has been much concern over recent declines. These declines in bumblebees (e.g. *Bombus distinguendus*) also relate to agricultural improvement of traditional meadows (Fitzpatrick *et al.* 2007).

3.3 Winter season

Although no chapter in this thesis focuses on the winter aspect of the Twite's ecology in Ireland, we did gather some data through fieldwork activities including: ringing; monitoring locations and activity of winter (October – March) flocks; and radio tracking of birds in March.

The main wintering sites of Irish Twite were within 28 km of their breeding areas. Although Twite can move over 400 km between breeding and wintering sites (Brown & Atkinson 2002, Raine *et al.* 2006) it appears that Irish birds will remain within 28 km of their breeding areas if an adequate food supply is present. At the Termoncarragh (Co. Mayo) wintering site on the Mullet Peninsula, 8.5% of the birds ringed were retrapped during subsequent winters (Chapter 3). This shows relatively strong site fidelity for a short-lived bird.

Two birds radio tracked at Termoncarragh over a 12-day period had Minimum Convex Polygons (MCP) of 74.2 ha and 112.2 ha. Using the concave polygon range size estimator, which eliminates unused areas in their range, gives a range size of 29.8 and 81.4 ha respectively. This relatively small range size reflected the distribution of feeding sites in the area. Other observations of colour ringed Twite between October and March suggest the majority (100 – 150) of wintering birds on the Mullet display a strong selection for areas within the range of the radio tracked birds. The principal habitat type in this area is

machair, an Annex I priority habitat under the EU Habitats Directive. However, the target of foraging Twite are ring feeders, which are used for supplementary feed for cattle being over-wintered on the machair. Twite specifically focused on five feeding sites in which haylage (cut forage grass, stored in an airtight plastic wrap) was used as the supplementary feed. This haylage contains relatively high densities of wildflower seeds including Dandelion. Wintering Twite elsewhere on the Mullet Peninsula also show a strong association for cattle ring feeders.

Ring feeders are recognised as a source of damage to machair habitat through intense trampling from cattle, which causes degradation. Machair on the Mullet Peninsula, once noted as one of the finest examples of machair habitat in Ireland, has suffered heavily from intensive agricultural management and its conservation value has subsequently been radically reduced (Anon 2008). As the presence of ring feeders on the Mullet Peninsula benefits Twite during the winter, this raises an interesting conflict of conservation interests between the conservation of machair habitat and the provision of a winter food source for Twite. A comparable conservation conflict occurs with Petalwort *Petalophyllum ralfsii*, which also occurs on machair habitat. Petalwort requires a short sward through a relatively intense grazing regime (Anon 2007b). In the absence of Petalwort, this grazing regime may be seen as detrimental to the machair habitat as a whole and reduces biodiversity. However, as it is listed under Annex II of the EU Habitats Directive, conservation measures such as short cropping have been introduced through the NPWS Farm Plan Scheme. If a Twite farm plan measure was to be introduced, one solution to the current damage to machair caused by ring feeders could be to have carefully selected areas on the machair that farmers are permitted to place their ring-feeders where damage would be limited. This would not be in contravention of any existing REPS or FPS measure (Anon 2000, Anon 2005, Anon 2007), but may

contravene Good Farming Practice (GFP) if severe poaching of the ground resulting in a pollution risk, were to occur.

The inclusion of any Twite-specific measure into future agri-environment schemes may, however, be pose some issues as Twite are not listed as an Annex I species on the EU Birds Directive. The NPWS FPS only covers habitats and species listed in under the EU Habitats Directive and EU Birds Directive, and commonages under the Commonage Framework Plan (CFP). REPS, however, covers the whole farm and is not confined to designated areas, e.g. Special Areas of Conservation (SAC), Natural Heritage Areas (NHA) or Special Protection Areas (SPA).

Figure 3. Ring feeder on machair habitat on the Mullet Peninsula. Twite target seeds from the haylage cattle feed.

Wintering Twite in the Donegal study area showed a similar concentration in one feeding area provided adequate food resources remained. In Sheskinmore National Nature Reserve (NNR) (largely composed of dune and machair habitat), Twite focused on a one-hectare cereal plot containing a Linseed *Linum usitatissimum* / Quinoa *Chenopodium quinoa* mixture. Flocks of up to 80 birds were observed consistently from late October to February, at which point seed resources were exhausted.

During the winter Twite in Scotland are associated with stubbles from crops such as Rape *Brassica napus* and Turnip *Brassica rapa* and initiatives, e.g. 'Neaps for Linties' have been introduced there to encourage farmers in the north to grow Turnip specifically for over-wintering Twite (Anon 2007a, RSPB 2007). In Ireland the Land Invested in Nature, Natural Eco-Tillage (LINNET) scheme encourages a similar initiative to farmers as part of Rural Environment Protection Scheme (REPS) 3 & 4 (Anon 2005; 2007). To date however, in the Twite strongholds in Ireland the uptake of this option is very slow with the Sheskinmore Cereal Plot being the only scheme with suitable cereal / crops in either of the study areas. Also, in many cases the recommended seed types, with the exception of Quinoa, are too large for Twite and therefore not available to them. As Quinoa is native to Bolivia, some have questioned its widespread use, particularly on priority habitats under the EU Habitats Directive.

Wintering Twite are strongly associated with saltmarshes, particularly in England and the Low Countries, where they target *Salicornia* spp. (Atkinson 1999, Dierschke & Bairlein 2004). Modelling by Atkinson (1998) suggests that loss of saltmarsh in the southeast of England could go a long way to explaining the decline of Twite there. Raine (2006) suggests that recreation and

conservation of saltmarsh should be an integral part of a country-wide recovery plan.

The saltmarshes adjacent to Lough Foyle, Co. Derry sustain between 50-150 Twite each winter season (Chapter 2), and their importance for Twite (most likely Scottish migrants) should not be under-estimated. Areas of saltmarsh within 28 km of the known breeding colonies (and extended areas including neighbouring counties) need to be studied to identify sheltered areas that would potentially provide large densities of *Salicornia*.

Other winter flocks around the northeast, north and northwest coasts target disturbed ground, drift lines and small areas of saltmarsh, where they also feed on the seeds of plants including: Sea Arrowgrass *Triglochin maritima;* Orache *Atriplex* spp. and; Sea Mayweed *Tripleurospermum maritima*.

Conservation measures for wintering Twite in the study areas should include the provision of trial cereal plots in areas regularly used by birds. The provision of an artificial feeding station as described in Chapters 3 and 4 and as considered by Raine (2006) could also be part of winter season conservation measures. Any such measures must be situated near adequate roost sites e.g. Bracken litter, Rushes *Juncus* spp. etc.

4. Twite and the general public

Over 30 public Twite talks and guided walks have been given during the course of this study, including a 15 minute showing of the life history of Twite on the RTÉ television wildlife series 'Living the Wildlife'. Almost invariably, the general public have never heard of a Twite. However, once people are aware of its existence and hear a little on its life story it does capture the

imagination as a 'forgotten native bird of Ireland'. Although the Twite is a relatively inconspicuous and difficult bird to identify, and will never be as 'popular' a species as the Corncrake or Golden Eagle *Aquila chrysaetos*, public awareness of its existence is an important aspect to its conservation. This awareness needs to start in the areas where Twite occur, perhaps through an annual visit to schools near the Twite strongholds. Many of these areas are also Gaeltachts and in some ways, the fortunes of the Twite could be seen as a parallel to those of the Irish language. This establishment of an emotional attachment and an instilling of pride should be cultivated in people in having a species of bird that is almost unique to an area.

The farmers of the areas where Twite occur generally do not know of its existence. The extensive agricultural farming practices, particularly of north Co. Mayo and west Co. Donegal are, by and large, the reasons why the Twite occur there. These farmers and land-users should be informed and educated on the importance of their farming practices along with ideal "does and don'ts" for Twite. This could be done through REPS training courses, or, as these areas are relatively sparsely populated by means of a door-to-door system. It will ultimately be down to the future farming practices of farmers as to whether the habitat requirements of Twite will be met.

5. Recommended Twite conservation actions

Conservation efforts for Twite in Ireland need to focus initially on the 28 km radius around known breeding colonies in Ireland. Within this area the following should be identified and mapped: all known breeding colonies; outline of approximate breeding home range (following Raine's maximum range of 3.5 km); important foraging areas for the breeding season and winter, and; winter roost sites. In addition, sites with the potential to sustain breeding

Twite should be identified with a view to carrying out the recommendations of Table 2. These recommendations should be available to REPS planners and ultimately should be incorporated as a measure under REPS and the NPWS Farm Plan Scheme (FPS).

The implementation of successful conservation plans for bird species can often be complicated due to the large areas the species may cover between winter and summer. In the case of Twite however, due to the sedentary nature of our population, action plans focused in the areas they frequent have the potential to be highly successful. This conservation plan is now urgently needed to prevent further declines in the population and possibly extinction as a breeding species in Ireland.

Table 2. Recommended conservation measures for Twite in Ireland. The recommendations closely follow those of Raine (2006) and Atkinson (1998).

Variable	Recommendations
Breeding Requirements	1 Identify the core breeding areas, which should be steep slopes with suitable nesting vegetation
	2 Identify former breeding areas which do not currently hold birds and, where suitable, target for habitat restoration
	3 Maintain, or create, a heterogenous mix of moorland vegetation, particularly of long Heather
	4 Prevent the development of a monoculture of grasses, particularly Molinia caerulea or Nardus stricta
	5 Reduce overgrazing by lowering stocking density to a density suitable for maintaining a mixed moorland flora
	6 Prevent burning of large areas of blanket bog, particularly within 300 m of the coast
	7 Prevent succession of moorland to scrubland and woodland by controlled grazing, cutting or burning
	8 Maintain bracken stands but prevent it from increasing in dominance or encroaching on dwarf shrubs
	9 Prevent afforestation of potential breeding areas by careful consideration of the location of proposed plantations
	10 Local education on the Twite
Feeding Requirements	1 Ensure an unbroken chain of natural food sources, within a 2.5 km radius, throughout the breeding season
	2 Identify important foraging areas and maintain current management regime
	3 Avoid agricultural 'improvement' of enclosed fields within a 2.5 km radius.
	4 Restoration of improved, flower-poor fields to traditionally managed hay meadows
	5 Maintain meadows with seeding wildflowers throughout the breeding season
	6 Ensure adequate grazing in areas with high densities of Sea Plantain due to previous heavy grazing
	7 Undertake hay harvesting as late in the season as possible and reduce the incidence of multiple cuts
	8 Where fields are harvested, leave an uncut strip at the meadow edge
	9 Liaise with local authorities to stagger roadsides cuts every two years to maintain alternative feeding areas
	10 Avoid the chemical spraying of wildflowers.
	11 Liaise with REPS planners to ensure that recommended REPS measures do not conflict with Twite foraging requirements
	12 Avoid topping of thistles and sorrel in potential feeding areas
	13 Encourage and maintain patches of Eriophorum in moorland areas
	14 Create feeding stations, using Niger seed, where appropriate. Use before and after the breeding season (ie. not May to July)
	15 Local education on the Twite

Table 2 continued.

Wintering grounds	1 Identify and protect key wintering sites
	2 Identify and protect saltmarsh within 30 km of known breeding areas
	3 Recreate new areas of saltmarsh and ensure these have a high density of Salicornia seed
	4 Ensure new patches have a low rate of natural seed depletion by protecting against wind and wave action
	5 Maintain areas of fresh water adjacent to Salicornia patches
	6 Create suitable roosting areas, such as areas of Reeds, Rushes, or Bracken
	7 Create feeding stations, using Niger seed, where appropriate
	8 Create a series of cereal plots within 30 km of known breeding colonies
	9 Local education on the Twite

6. Suggested further study

As this is the first study to focus on Twite in Ireland, a large amount of time was consumed gathering baseline data on the national status and the location of breeding colonies. This information is a crucial element to any ecological study. Once I had identified the breeding strongholds in Ireland, I was able to then focus my attention on more detailed aspects of their ecology such the dynamics of breeding birds and their habitat and dietary requirements. Now that we have this knowledge of the Twites ecology in Ireland, we are at a point where conservation actions can be drawn up and implemented based largely on the information contained in this thesis. This thesis can also facilitate further research on the ecology of Twite in Ireland. The following areas (some of which should be pursued with some urgency) represent potential research avenues:

1) Further breeding surveys.
2) Breeding biology: Analysis of the breeding biology of the Twite. This would involve the access and monitoring of nests and the analysis of pulli biometrics. This data would be combined with habitat use and selection data to give an assessment of breeding success.
3) Testing of pilot conservation management plan for Twite through introducing experimental farm management actions, e.g. cereal plots, experimental wildflower meadows, etc.
4) Land management in areas with the potential to sustain a breeding population to restore habitat to meet the Twites breeding habitat requirements
5) Winter ecology: Analysis of habitat use and selection studies during the winter season.

6) Testing of pilot conservation management actions for Twite during the winter season, e.g. cereal plots.

7) Further to our analysis of biometrics from Ireland, England and Scotland, a genetic study of these three countries and ultimately extending this study to incorporate variation with Scandinavian and Asian Twite would clarify the taxonomic status races of the world.

It is important to acknowledge that this study was carried out over a period of only three full breeding seasons and that populations of short-lived birds such as the Twite can fluctuate considerably. Also, only continuous studies of the Twite's ecology here will be able to identify the influence of such factors as weather conditions during the breeding or winter season on survival.

7. The future of Twite in Ireland

The future of Twite as a breeding species in Ireland is uncertain and largely depends on the future direction of Irish, and European, agricultural policy. Efforts to conserve and enhance Twite populations should proceed with urgency. Conservation actions could be channelled through the NPWS FPS or REPS and initially target the Irish breeding and wintering strongholds. REPS already has facilities under which such a scheme could be run, e.g. REPS Supplementary Measure 1 (Anon 2007), and this would most likely work well and cost effectively for breeding season habitat. The FPS would focus more specifically on Twite during the winter than REPS, which may be too general. Relatively simple actions targeted at Twite in their strongholds could be highly successfully and would benefit the surrounding biodiversity. The loss of Twite as a breeding species in Ireland would indicate a far greater loss than

that of one species. It would most likely reflect a general loss of biodiversity, particularly of once common weed species that are important for the survival of many other species of fauna. Our current knowledge of Twite in Ireland now contrasts with the situation of the Corn Bunting on which no study was ever done prior to its extinction. We can intervene now in the form of species action plans to conserve Twite as a resident species of Ireland while we still have a viable population. We have a moral obligation to conserve Twite as a species in it's own right, and also to preserve for future generations to enjoy and appreciate.

REFERENCES

Anon, (2000) Rural Environment Protection Scheme: Farmer's Handbook for REPS 3, Dept. Agriculture & Food.

Anon, (2005) *Farm Plan Scheme for Designated Areas and Commonages,* National Parks and Wildlife Service, Dublin.

Anon, (2007) Rural Environment Protection Scheme: Farmer's Handbook for REPS 4, Dept. Agriculture & Food.

Anon, (2007a) Neaps for Linties. *Shetland Bird Club Newsletter* **148:** 7-8.

Anon, (2007b) Conservation Assessment of petalwort (*Petalophyllum ralfsii* (Wils.) Nees & Gottsche) in Ireland, National Parks and Wildlife Service, Dublin.

Anon (2008) *The Status of EU Protected Habitats and Species in Ireland*, National Parks and Wildlife Service, Dublin.

Atkinson, P.A. (1998) The wintering ecology of the Twite *Carduelis flavirostris* and consequences of habitat loss. PhD thesis, University of East Anglia.

Bullock, I.D., Drewett, D.R., Mickleburgh, S.P. 1983. The Chough in Ireland. *Irish Birds* **2:** 257-271.

Brown, A.F. & Atkinson, P.A. (2002) Twite. In *The Migration Atlas: Movements of the Birds of Britain and Ireland* (eds Wernham, C.V., Toms, M.P. Marchant, J.H., Clark, J.A., Siriwardena, G.M. & Baillie, S.R.), pp 657-659, T. & A.D. Poyser, London.

Cabot, D. (1999) *Ireland*, Collins, London.

Dierschke, J. & Bairlein, F. (2004) Habitat selection of wintering passerines in salt marshes of the German Wadden Sea. *Journal of Ornithology* **145:** 48-58.

Fitzpatrick, U, Murray, T.E., Paxton, R.J., Breen, J, Cotton, D., Santorum, V., Brown, M.J.F. (2007) Rarity and decline in bumblebees – A test of causes and correlates in the Irish fauna, *Biological Conservation* 132, **4:** 185-194.

Fossitt, J.A. (2000) *A Guide to Habitats in Ireland.* The Heritage Council, Kilkenny.

Gibbons, D.W., Reid, J.B. & Chapman, R.A. (1993) *The New Atlas of Breeding Birds in Britain and Ireland:* Poyser, London.

Gordon, T. (2005) *The Birds of Inishbofin*, Inishbofin Development Company, Inishbofin.

Gray, N., Thomas, G., Trewby, M & Newton, S. (2003) The 3rd International Chough Survey in Ireland 2002/03. *Irish Birds* **7:** 147-156.

Hillis, J.P. (2006) Rare Irish breeding birds, 2004: The Third Annual Report of the Irish Rare Breeding Bird Panel (IRBBP). *Irish Birds* **8:** 97-108.

Hillis, P. (2007) Rare Irish breeding birds, 2005-2006. (IRBBP). *Irish Birds* **8:** 249-262.

Hillis, P. (2008) Rare Irish breeding birds, 2007. The Seventh Annual Report of the Irish Rare Breeding Birds Panel (IRBBP). *Irish Birds* **8:** 365-372.

Kerbiriou, C., Gourmelon, F., Jiguet, F., Le Viol, I.E., Bioret, F. & Julliard, R. (2006) Linking territory quality and reproductive success in the Red-billed Chough *Pyrrhocorax pyrrochorax*: implications for conservation management of an endangered population. *Ibis* **148:** (2) 352–364.

Lynas, P., Newton, S.F. Robinson, J.A. (2007) The status of birds in Ireland: an analysis of conservation concern 2008-2013. *Irish Birds* **8:** 149-166.

McLoughlin, D. (2008) Dingle Peninsula Twite Survey, 2006, *The Dingle Peninsula Bird Report 2005-2007*. 72-74. In O'Clery 2008.

McLoughlin, D. & Cotton, D. 2008. The Status of Twite *Carduelis flavirostris* in Ireland 2008. *Irish Birds* **8:** 323-330.

McLoughlin, D., Benson, C., Williams, B. & Cotton, D. (in press) The Movement Patterns of Two Populations of Twite *Carduelis flavirostris* in Ireland. *Ringing and Migration.*

Newton, I. (2004) The recent declines of farmland bird populations in Britain: an appraisal of causal factors and conservation actions. *Ibis* **146:** 579-600.

Norrdhal, K., Suhonen, J., Hemminki, O., & Korpimaki, E. (1995) Predator presence may benefit: kestrels protect curlew nests against nest predators. *Oecologia* **101:** 105-109.

O'Clery, M. (2008) *The Dingle Peninsula Bird Report 2005-2007.* Corca Dhuibhne Branch, BirdWatch Ireland.

Raine, A.F. (2006) The breeding ecology of Twite *Carduelis flavirostris* and the effects of upland agricultural intensification. PhD thesis, University of East Anglia.

Raine, A.F., Sowter, D.J., Brown, A.F. & Sutherland, W.J. (2006) Migration patterns of two populations of Twite *Carduelis flavirostris* in Britain. *Ringing and Migration* **23:** 45-52.

Royal Society for the Protection of Birds (2007) Over-wintered Stubble: Farming and Crofting for Wildlife, Advice Sheet of RSPB. Edinburgh, Scotland.

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

Thompson, D.B.A., MacDonald, A.J. & Hudson, P.J. (1998) Upland moors and heaths. In *Managing Habitats for Conservation,* ed. Sutherland, W.J. & Hill, D.A. pp. 292-325, Cambridge University Press, Cambridge.

Whilde, A. (1993) *Threatened Mammals, Birds, Amphibians and Fish in Ireland,* Irish Red Data Book 2, HMSO, Belfast.

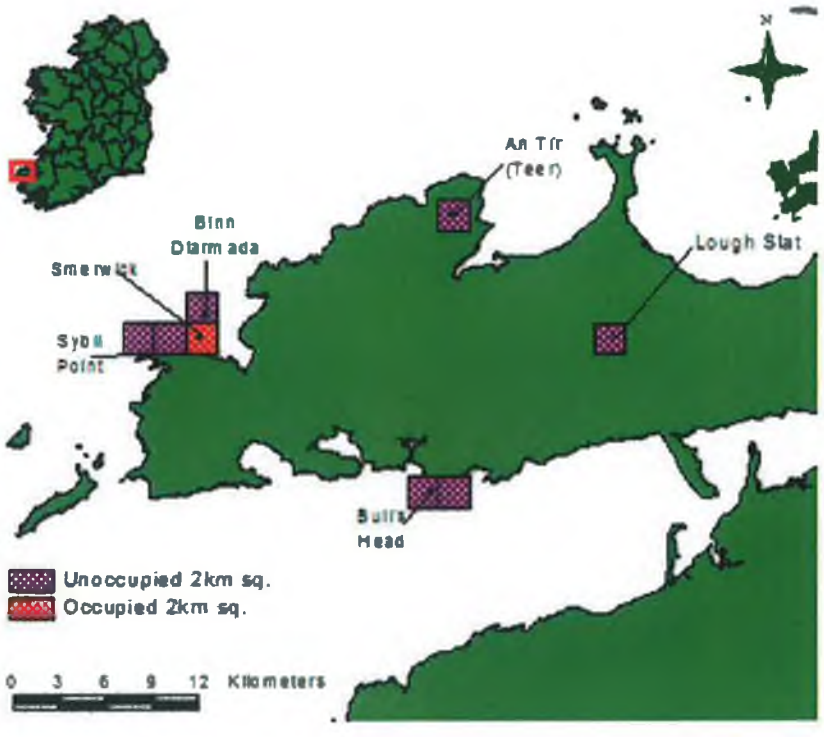
Wilkinson, N.I. & Wilson, J.D. (in press) Breeding ecology of Twite *Carduelis flavirostris* in a crofting landscape. *Bird Study.*

APPENDIX A

Twite survey of the Dingle Peninsula, County Kerry, 2006.

A survey of the four areas on the Dingle Peninsula previously found to sustain breeding Twite took place between 21st and 26th June, 2006. The areas visited are shown in Figure A1. Both Teer and Bull's Head were found to be almost completely devoid of heather mainly due to heavy sheep grazing. Although Lough Slat did have a small amount of good quality heather, a large proportion of this area has been planted with commercial coniferous forestry since the 1960's and 1970's.

Figure 1. The Dingle Peninsula showing occupied and unoccupied tetrads during June 2006.



Although no Twite were detected during this Twite survey, on 7th June, Dave Watson, a corncrake fieldworker, who is experienced in the identification of Twite, had the following observations of Twite near Smerwick;

A group of four Twite were observed on the approach to Smerwick beach at Q349065. He noted juveniles in this group. On the same day he had a Twite singing in a meadow at Q348073, and saw a bird with material in its mouth at Q350078.

The area around Binn Diarmada and Smerwick appear to provide good quality breeding habitat for Twite. Binn Diarmada has heather suitable for nesting and many of the extensively farmed fields in Smerwick village (c.1.5km southwest of Binn Diarmada) have a good abundance of suitable food plants. Linnet were found to be common in Smerwick village.

APPENDIX B

Dingle Peninsula Twite Survey, 2006

McLoughlin, D. (2008) Dingle Peninsula Twite Survey, 2006, *The Dingle Peninsula Bird Report 2005-2007*, pp 72-77. In O'Clery 2008.

Dingle Peninsula Twite Survey, 2006

Derek McLoughlin

Despite being a resident species here, remarkably little is known about the ecology, movements or even current population status of Twite *Carduelis flavirostris* in Ireland. Twite populations in Ireland have thought to be in decline since the beginning of the last century. However, serious declines have taken place over the past thirty years with the 1988-1992 *Breeding Atlas* showing a drop of 52% on the 1968-1972 *Atlas*. On foot of this decrease, Twite has been listed in the *Irish Red Data Book* and on the Red List of Birds Of Conservation Concern in Ireland. Changes in land use are thought to be among the primary causes for the decrease.

North Mayo and west Co. Donegal are thought by many to be the two main strongholds for the species in Ireland, sustaining a combined total of about 50 breeding pairs. Twite are also known to breed in small numbers in counties Sligo, Galway and Kerry, however, little or no breeding data are available in these counties for the past ten to fifteen years.

The Dingle Peninsula appears to have undergone a large decrease in Twite populations over the past 25 years with one of the last flocks of over 100 being recorded in November of 1982. Since then, records of wintering Twite are few and far between and breeding records are almost absent.

As part of a study on the Ecology of Twite in Ireland, Derek McLoughlin visited three areas on the Dingle Peninsula previously noted to sustain a breeding population of Twite namely Lough Slat, Sybil Point — Binn Diarmada and Bull's Head.

Twite (Photo: Micheál Casey).

Survey method

As twite can use feeding areas of up to 3 km from their breeding grounds, the duration between nest visits of over an hour is not uncommon. Consequently, standard transect survey techniques in an area with a low breeding density (such as the Dingle Peninsula) can overlook breeding birds.

In this survey, over 90 minutes was spent in each area considered suitable for nesting Twite. The reason for this being that any bird returning to a nest would be detected on call or sight, in which case probable breeding could be confirmed. This method is also useful for confirming the absence of breeding Twite in a particular area.

Timing of survey

The earliest fledglings observed in counties Mayo and Donegal was 11th June. As the Dingle Peninsula survey took place between 21st and 26th June, some Twite may already have fledged and moved towards feeding grounds where they may not have been detected.

Survey areas

Lough Slat Grid reference: Q61 07/
Date of visit: 21st June 2006.
Breeding twite were observed by Frank King in the 1960's when he noted up to nine pairs nesting in a semi-colony on a steep heathery slope overlooking Lough Slat. Planting of coniferous forestry hadn't commenced in the vicinity prior to this record.

In the 2006 visit, the areas surrounding the Lough were scanned to locate any suitable Twite nesting habitat in the vicinity. The only suitable nesting habitat occurred towards the south end of the lake, on the north facing slope. This area is by and large inaccessible to sheep. Good quality heather was found, which is the preferred nesting habitat for Twite in Ireland and Britain. However, no Twite were observed to be present.

Lough Slat was also revisited during the breeding season by Frank King in the mid-nineties but no Twite were noted.

Although some suitable feeding areas occur to the northeast, much of the area around Lough Slat is now either covered with coniferous forestry or heavily grazed by sheep.

Sybil Point (Grid ref. Q 31 06) to **Binn Diarmada** (Grid ref Q 35 08).
Date: 23rd and 24th June 2006.
Although several small tracts of heather occur along this stretch of coastline, the most significant area is on the north-west face of Binn Diarmada, Grid ref. Q 354 090.

Meadows in Smerwick village, Grid ref. Q 345 075, were observed to contain good numbers of Linnet *Carduelis Cannabina*, and appeared to be suitable for Twite.

Although no Twite were detected during this survey, on 7th June, Dave Watson, a Corncrake fieldworker, had the following observations of Twite near Smerwick;

A group of four Twite were observed on the approach to Smerwick beach at Q 349 065. He noted juveniles in this group. On the same day he saw a Twite singing in a meadow at Q 348 073, and saw a bird with material in it's mouth at Q 350 078.

Prior to 2006, the most recent breeding records for twite in this area were in 1999 and 2000.

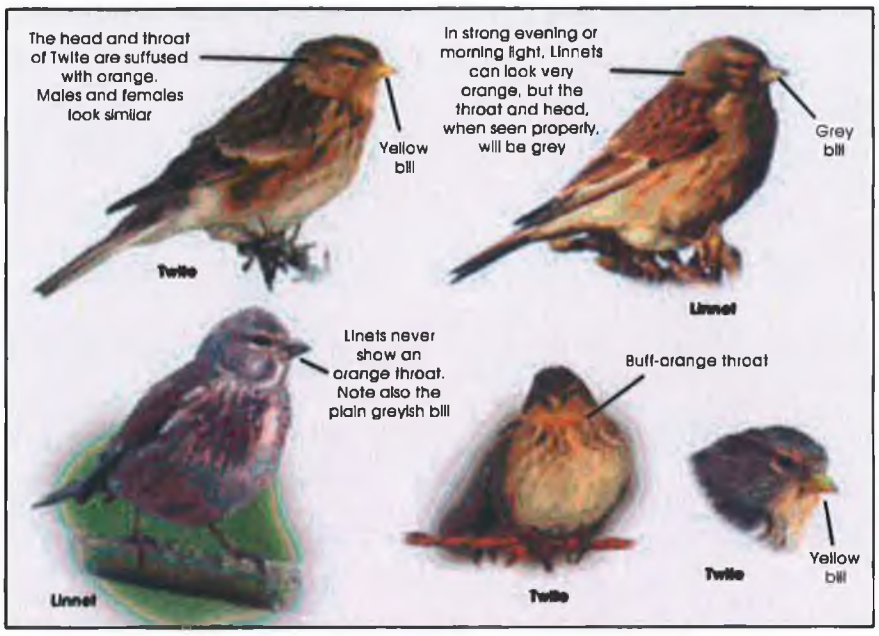
Bull's Head (Grid ref. V 49 98)
Date: 25th June 2006.
The stretch of coastline was walked from Trá Chathail (Grid ref. V 490 986) to south of An Dun Meánach (Grid ref. V 519 985). Only very few small patches of heather occurred on this headland, apparently due to sheep grazing. This, coupled with the distance from the nearest suitable feeding grounds, makes the Bull's Head an unlikely area to find breeding Twite.

Previous recent breeding records from the Dingle Peninsula
Teer (or Tír) (Grid. ref. Q50 14) and Bull's Head and Beal, near Lispole have records of Twite during the breeding season in 2000. No Twite have been recorded in these areas in the breeding season since.

Conclusion

In the breeding season of 2006 adult Twite with juveniles were observed near Smerwick village in the first week of June. Based on the location of suitable habitat in this area, these quite possibly nested on Binn Diarmada. This can be confirmed during May of 2007 through effort watches of the Smerwick area.

Lough Slat appears to have lost the breeding population it sustained during the 1960's. Teer and



Identification of **Twite** and **Linnet**
(Photos: Micheál Casey, except Linnet, lower left, by Anthony McGeehan).

Bull's Head both appear to be affected by heavy overgrazing and thus no longer have habitat suitable for breeding Twite.

Overall, partly due to their 'little brown job' jizz, and the relatively low observer effort along the west coast of Ireland, it is probable that breeding Twite are being overlooked. However, it is likely that the Twite breeding population on the Dingle Peninsula is in the low- to mid-single figures.

Many thanks to the following people who were very supportive with information and advice. Sincere apologies to anybody I have inadvertently left out. Don Cotton, Jill Crosher, Jaime Durrant, Brendan Kavanagh, Frank King, Gerry Murphy, Michael O'Clery, Tim O'Donoghue, Dave Watson.

Many thanks also to National Parks and Wildlife Service, and to Gerry and Bridie Murphy for the wonderful hospitality in Castlegregory.

If you see Twite anywhere on the Dingle Peninsula, please let us know! Contact moclery@tinet.ie

APPENDIX C

Numbers of possible, probable and confirmed breeding birds for 2005, 2006 and 2007.

Numbers of possible, probable and confirmed breeding birds for 2005, 2006 and 2007.

2005 Survey area	Evidence of breeding		
	Possible breeding	Probable breeding	Confirmed breeding
Benwee Head	0	6	7
Erris Head	0	1	5
West Donegal	0	4	3
Other 2005 records	2	1	0
Total	2	12	15

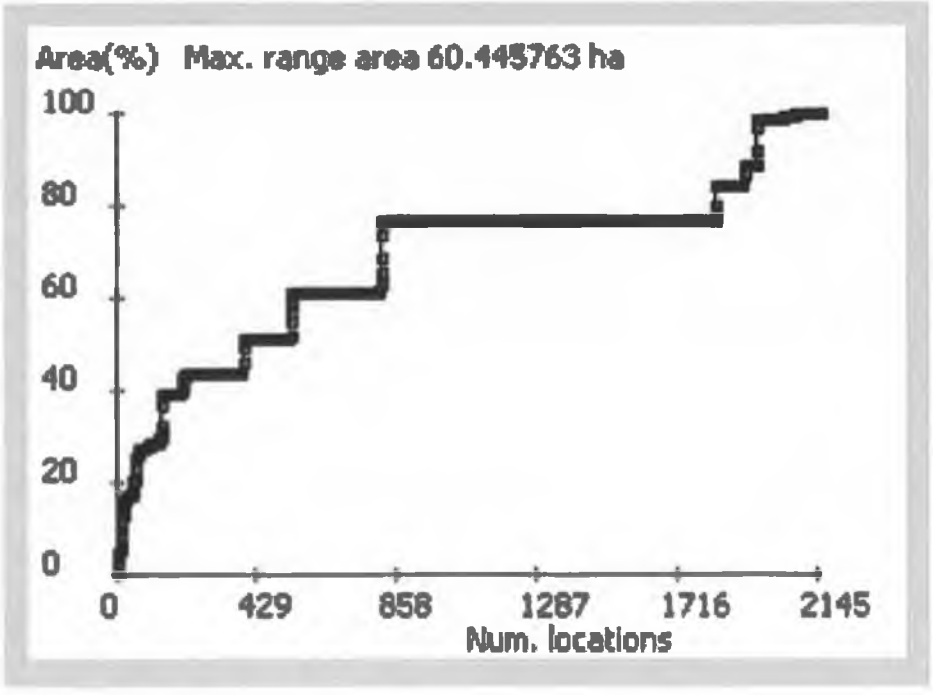
2006 Survey area	Evidence of breeding		
	Possible breeding	Probable breeding	Confirmed breeding
Benwee Head	0	2	6
Erris Head	0	2	5
West Donegal	0	3	6
Other 2006 Records	0	2	1
Total	0	9	18

2007 Survey area	Evidence of breeding		
	Possible breeding	Probable breeding	Confirmed breeding
Benwee Head	0	4	6
Erris Head	0	6	7
West Donegal	0	6	5
Other 2006 Records	0	0	0
Total	0	16	19

APPENDIX D

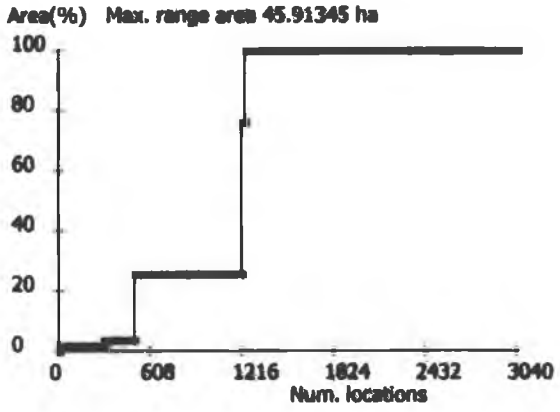
A sample Minimum Convex Polygon (MCP) analysis incremental plot and an example of the number of locations to required reach range stability

Plateaus indicate range stability, i.e. the widest plateau is indicative of when the study animal was most settled.

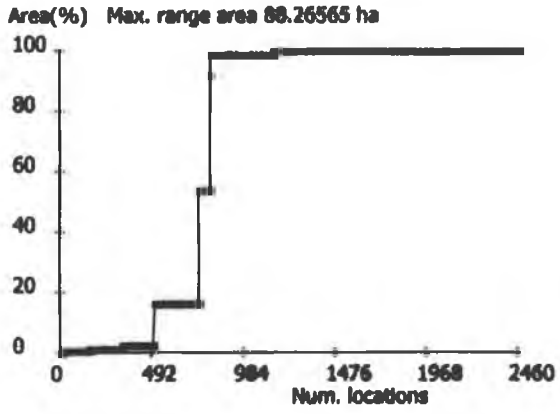


Number of locations to required reach range stability. R1 and R2 refer to the ranges of the birds radio tracked in March 2007 at Termoncarragh (Chapter 3).

R1 = c. 1200 locations



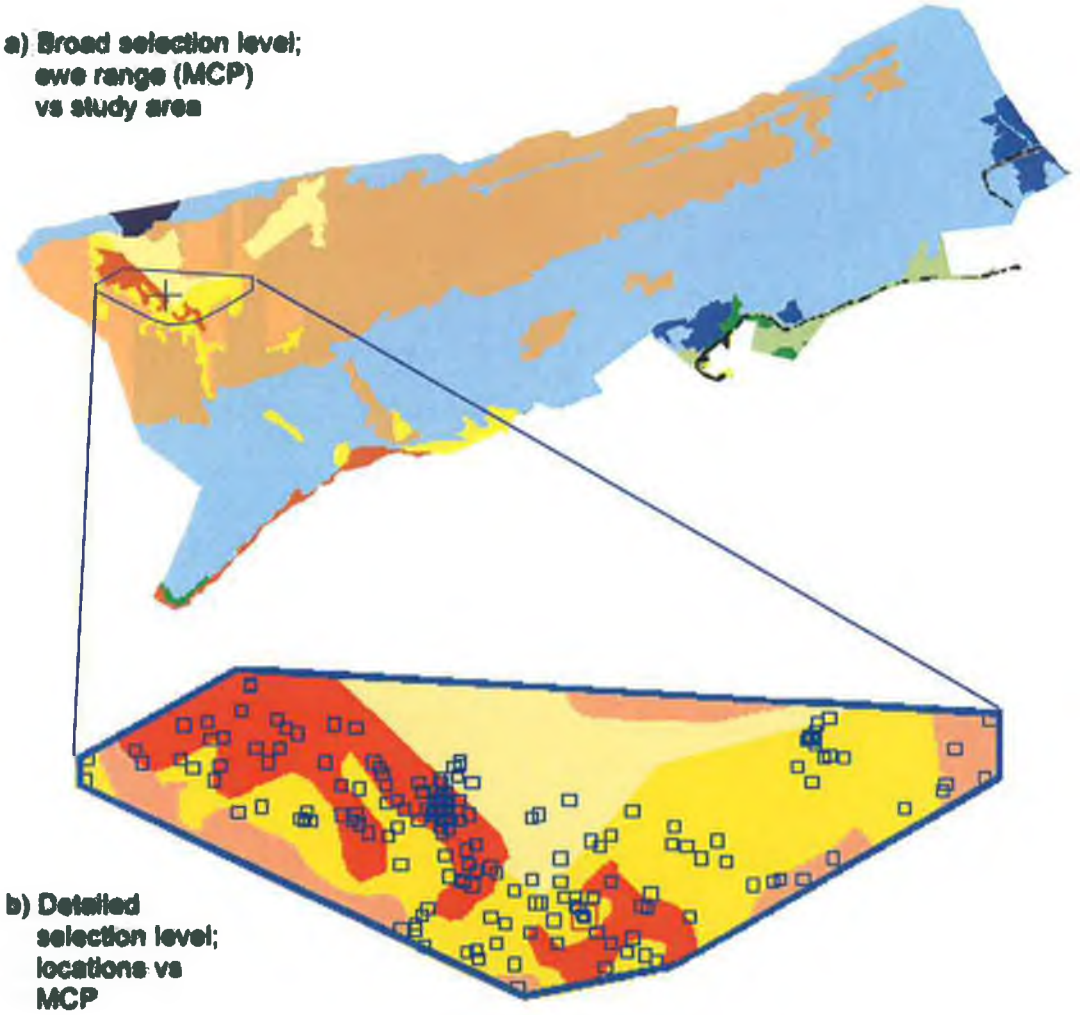
R2 = c. 800 locations



APPENDIX E

Two stage approach used in resource selection analysis

Two-stage approach used in resource selection analysis from Williams (2009)



Williams, B. (2009) ***Resource selection by Scottish Blackface sheep on a mosaic of upland and peatland habitats: implications for conservation management,*** **unpublished PhD thesis, NUI, Galway.**

APPENDIX F

Raw transect data from Chapter 4

Month	YYMODD	No.	Activity	Sw_height	Grazers	Feed_source	Fossitt_code
April	70424	2	Bathing				FW1
April	70424	2	Feeding			Dandelion	BL3
April	70424	2	Feeding			Sorrel	GS3 / PB3
April	70424	4	Feeding			Poa annua	BL3
April	70424	2	Feeding			Dandelion	BL3
April	70424	5	Feeding			Dandelion	BL3
April	70425	1	Feeding	s	s1	Poa annua	GS3
April	70425	3	Feeding			Sorrel	BL3
April	70425	2	Feeding			Molinia	PB3
May	70502	2	Feeding	m	0	Dandelion	BL3
May	70502	6	Feeding	s	s2	Dandelion	GS3
May	70502	4	Nesting		0		HH3 / PB3
May	70503	2	Feeding	s	s1	Dandelion	GS2
May	70503	3	Feeding			Poa annua	BL3
May	70503	4	Nesting				HH3 / PB3
May	70508	2	Bathing				FW1
May	70508	2	Feeding			Dandelion	BL3
May	70508	2	Feeding			Dandelion	GS3
May	70510	6	Nesting		0		HH3 / PB3
May	70510	4	Nesting		0		HH3 / PB3
May	70510	3	Feeding	s	s1	Molinia	PB3
May	70510	4	Nesting				HH3 / PB3
May	70510	1	Feeding	s	s1	Sorrel	PB3
May	70510	2	Feeding			Dandelion	BL3
May	70510	2	Feeding			Dandelion	BL3
May	70510	3	Feeding	l	0	Sorrel	GS3 / PB3

Appendix F

Habitat_category	Area	County	Field_no.	Enclosed ?
Stream	Tippe	Mayo		Unenclosed
Road / track	Tippe	Mayo		Unenclosed
Rough grazing	Tippe	Mayo	M5	Enclosed
Road / track	Glenlara	Mayo		Unenclosed
Road / track	Portacloy	Mayo		Unenclosed
Road / track	Porturlin	Mayo		Unenclosed
Meadow	Maghera	Donegal		Enclosed
Road / track	Loughros	Donegal		Enclosed
Bog: heather>30cm	Maghera	Donegal		Unenclosed
Road / track	Glenlara	Mayo		Unenclosed
Meadow	Glenlara	Mayo	G37	Enclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
Meadow	Portacloy	Mayo		Enclosed
Road / track	Porturlin	Mayo		Unenclosed
Bog: heather>30cm	Claddagharone	Mayo		Unenclosed
Stream	Maghera	Donegal		Unenclosed
Road / track	Loughros	Donegal		Unenclosed
Meadow	Maghera	Donegal		Enclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
Bog: heather>30cm	Tippe	Mayo		Unenclosed
bog: heather<30cm	Tippe	Mayo		Unenclosed
Bog: heather>30cm	Tippe	Mayo		Unenclosed
bog: heather<30cm	Glenlara	Mayo		Unenclosed
Road / track	Glenlara	Mayo		Unenclosed
Road / track	Glenlara	Mayo		Unenclosed
Rough grazing	Tippe	Mayo	M5	Enclosed

Month	YYMODD	No.	Activity	Sw_height	Grazers	Food_source	Fossitt_code
May	70511	1	Feeding	s	s1	Mouseear	GS3
May	70511	2	Feeding			Pearlwort	FW1
May	70511	2	Nesting				HH3 / PB3
May	70511	1	Feeding			Poa annua	BL3
May	70511	5	Nesting				HH3 / PB3
May	70511	2	Feeding	s	0	Molinia	PB3
May	70511	1	Bathing				FW1
May	70521	3	Feeding	s	0	Dandelion	BL3
May	70521	2	Feeding	m	0	Sorrel	GS3
May	70521	1	Feeding	s	s1	Poa annua	GS3
May	70521	2	Feeding	s	s2	Sorrel	GS3
May	70521	1	Feeding	s	c	Chickweed	GA1
May	70521	6	Nesting				HH3 / PB3
May	70521	2	Nesting				HH3 / PB3
May	70521	3	Nesting				HH3 / PB3
May	70522	4	Nesting				HH3 / PB3
May	70522	9	Nesting				HH3 / PB3
May	70522	3	Feeding	s	s1	Eriophorum	PB5
May	70522	1	Feeding	s	s1	Eriophorum	PB5
May	70522	2	Feeding	s	0	Dandelion	GS3
May	70522	1	Feeding	s	c1	Poa annua	GS2
May	70529	2	Nesting				HH3 / PB3
May	70529	4	Nesting				HH3 / PB3
May	70529	2	Feeding			Dandelion	GS3
May	70529	1	Feeding			Dandelion	BL3
May	70529	3	Feeding			Sorrel	GS3

Appendix F

Habitat_category	Area	County	Field_no.	Enclosed ?
Meadow	Portacloy	Mayo		Enclosed
Stream	Portacloy	Mayo		Enclosed
Bog: heather>30cm	Buddagh	Mayo		Unenclosed
Road / track	Portacloy	Mayo		Unenclosed
Bog: heather>30cm	Claddagharone	Mayo		Unenclosed
bog: heather<30cm	Claddagharone	Mayo		Unenclosed
Stream	Porturlin	Mayo		Enclosed
Road/track	Glenlara	Mayo	G23	Enclosed
Meadow	Glenlara	Mayo	G26	Enclosed
Meadow	Glenlara	Mayo	G27	Enclosed
Meadow	Glenlara	Mayo	G33	Enclosed
Improved	Glenlara	Mayo	G14	Enclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
Bog: heather>30cm	Tippe	Mayo		Unenclosed
Bog: heather>30cm	Buddagh	Mayo		Unenclosed
Bog: heather>30cm	Claddagharone	Mayo		Unenclosed
bog: heather<30cm	Claddagharone	Mayo		Unenclosed
bog: heather<30cm	Claddagharone	Mayo		Unenclosed
Meadow	Porturlin	Mayo		Enclosed
Meadow	Portacloy	Mayo		Enclosed
Bog: heather>30cm	Maghera	Donegal		Unenclosed
Bog: heather>30cm	Maghera	Donegal		Unenclosed
Meadow	Maghera	Donegal		Enclosed
Road / track	Loughros	Donegal		Unenclosed
Meadow	Maghera	Donegal		Enclosed

Month	YYMODD	No.	Activity	Sw_height	Grazers	Food_source	Fossitt_code
June	70606	7	Feeding			Sorrel / pearlwort	FW1
June	70606	1	Feeding			Chickweed	GS3
June	70606	2	Feeding	0	0	Thistle	GS3
June	70606	1	Feeding			Sorrel	FW1
June	70606	2	Feeding	l	c1	Sorrel	GS3 / PB3
June	70606	4	Feeding	l	0	Thistle	GS4
June	70606	3	Nesting				HH3 / PB3
June	70606	1	Nesting				HH3 / PB3
June	70606	2	Nesting				HH3 / PB3
June	70606	1	Nesting				HH3 / PB3
June	70606	2	Nesting				HH3 / PB3
June	70606	2	Feeding	l		Sorrel	HH3 / PB3
June	70606	3	Feeding	l	0	Sorrel	GS3 / PB3
June	70606	1	Feeding			Sorrel / Thistle	GS3
June	70606	3	Feeding	s	s3	Chickweed	GS3
June	70612	2	Nesting				HH3 / PB3
June	70612	6	Nesting				HH3 / PB3
June	70612	4	Nesting				HH3 / PB3
June	70612	1	Feeding	s	s1	Poa annua	FW1
June	70612	3	Feeding	l	0	Sorrel	GS3
June	70612	2	Bathing				FW1
June	70612	1	Feeding			Pearlwort	BL3
June	70612	1	Feeding	s	s2	Poa annua	FW1
June	70619	2	Nesting				HH3 / PB3
June	70619	1	Feeding			Heather	PB3
June	70619	2	Feeding			P. maritima	GS3

Appendix F

Habitat_category	Area	County	Field_no.	Enclosed ?
Stream	Glenlara	Mayo		Unenclosed
Meadow	Glenlara	Mayo	G2	Enclosed
Meadow	Glenlara	Mayo	G3b	Enclosed
Stream	Glenlara	Mayo		Unenclosed
Rough grazing	Glenlara	Mayo	G19	Enclosed
Meadow	Glenlara	Mayo	G34	Enclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
Rough grazing	Tippe	Mayo	M1	Enclosed
Rough grazing	Tippe	Mayo	M5	Enclosed
Meadow	Agha	Mayo	A2	Enclosed
Meadow	Agha	Mayo	A20	Enclosed
Bog: heather>30cm	Claddagharone	Mayo		Unenclosed
Bog: heather>30cm	Claddagharone	Mayo		Unenclosed
Bog: heather>30cm	Buddagh	Mayo		Unenclosed
Stream	Portacloy	Mayo		Unenclosed
Meadow	Portacloy	Mayo		Enclosed
Stream	Portacloy	Mayo		Unenclosed
Road / track	Portacloy	Mayo		Unenclosed
Stream	Portacloy	Mayo		Unenclosed
Bog: heather>30cm	Maghera	Donegal		Unenclosed
Bog: heather>30cm	Maghera	Donegal		Unenclosed
Rough grazing	Loughros	Donegal		Enclosed

Month	YYMODD	No.	Activity	Sw_height	Grazers	Food_source	Fossitt_code
June	70619	4	Feeding			Sorrel	GS3
June	70619	2	Feeding			Poa annua	GS3
June	70619	1	Feeding			Chickweed	GS3
June	70619	2	Nesting				HH3 / PB3
June	70620	2	Feeding	s	s2	Chickweed	GS3
June	70620	6	Feeding	m	0	Chickweed	GS3
June	70620	1	Feeding	s	s1	Juncus spp.	GS3
June	70620	3	Feeding	s	s2	Sorrel	GS3
June	70620	3	Feeding	s	s1	Sorrel	GS3 / PB3
June	70620	3	Feeding	l	0	Thistle	GS3
June	70620	8	Feeding	l	0	Sorrel	GS3 / PB3
June	70620	2	Feeding	l	0	Pearlwort	BL3
June	70620	1	Feeding	s	s2	Pearlwort	GS3
June	70620	3	Feeding			Sorrel	HH3 / PB3
June	70620	1	Feeding	l	0	Sorrel	GS3 / PB3
June	70620	3	Feeding			Calluna	PB3
June	70620	2	Feeding			Sorrel / Thistle	GS3
June	70620	4	Feeding	s	s3	Chickweed	GS3
June	70620	2	Bathing				FW1
June	70620	3	Feeding	s		Sea thrift	PB3
June	70620	2	Feeding			Eriophorum	PB5
June	70620	6	Nesting				HH3 / PB3
June	70620	4	Nesting				HH3 / PB3
June	70620	1	Nesting				HH3 / PB3
June	70620	4	Nesting				HH3 / PB3
June	70621	6	Nesting				HH3 / PB3

Appendix F

Habitat_category	Area	County	Field_no.	Enclosed ?
Rough grazing	Loughros	Donegal		Enclosed
Meadow	Maghera	Donegal		Enclosed
Grassland<0.03cm	Maghera	Donegal		Unenclosed
Bog: heather>30cm	Maghera	Donegal		Unenclosed
Meadow	Glenlara	Mayo	G2	Enclosed
Meadow	Glenlara	Mayo	G3	Enclosed
Meadow	Glenlara	Mayo	G4	Enclosed
Meadow	Glenlara	Mayo	G4a	Enclosed
Rough grazing	Glenlara	Mayo	G5	Enclosed
Meadow	Glenlara	Mayo	G8b	Enclosed
Rough grazing	Glenlara	Mayo	G19	Enclosed
Road / track	Glenlara	Mayo	G22	Enclosed
Meadow	Glenlara	Mayo	G33	Enclosed
Rough grazing	Tippe	Mayo	M1	Enclosed
Rough grazing	Tippe	Mayo	M5	Enclosed
bog: heather<30cm	Tippe	Mayo	M6	Enclosed
Meadow	Agha	Mayo	A2	Enclosed
Meadow	Agha	Mayo	A20	Enclosed
Stream	Agha	Mayo		Unenclosed
bog: heather<30cm	Agha	Mayo		Unenclosed
Rough grazing	Agha	Mayo	A7	Enclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
Bog: heather>30cm	Tippe	Mayo		Unenclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
Bog: heather>30cm	Claddagharone	Mayo		Unenclosed

Month	YYMODD	No.	Activity	Sw_height	Grazers	Food_source	Fossil_code
June	70621	2	Feeding	s	0	Mouseear	GS3
June	70621	4	Feeding	s	s2	Sorrel	GS3
June	70628	1	Feeding	s	s1		GS3
June	70628	1	Feeding	l	0	Sorrel	GS3
June	70628	1	Feeding	s	c2	Chickweed	GA1
June	70628	3	Feeding	s	0	P. maritima	GS3
June	70628	2	Nesting				HH3 / PB3
July	70703	2	Bathing				FW1
July	70703	2	Feeding				GS3
July	70703	2	Feeding	l	0	Sorrel	GS3 / PB3
July	70703	4	Nesting				HH3 / PB3
July	70703	5	Nesting				HH3 / PB3
July	70703	2	Feeding			Sorrel	PB3
July	70703	6	Feeding			Self-heal	PB3
July	70703	2	Feeding	l	0	Sorrel	GS3 / PB3
July	70703	10	Feeding	l	0	Poa / Sorrel	GS3
July	70703	5	Feeding			Sorrel	GS3 / PB3
July	70703	8	Feeding	s	s3	Chickweed	GS3
July	70703	10	Feeding	s	s1	P.maritima/thrift	GS3
July	70706	3	Feeding	s	s1	P.maritima/thrift	CM1
July	70706	2	Nesting				HH3 / PB3
July	70706	2	Feeding	m	0	Sorrel	GS3
July	70707	19	Feeding	s	0	P.maritima/thrift	CM1
July	70707	3	Feeding	s	0	P.maritima/thrift	CM1
July	70707	6	Feeding	s	0	P.maritima/thrift	CM1
July	70711	2	Bathing				FW1

Appendix F

Habitat_category	Area	County	Field_no.	Enclosed ?
Meadow	Porturlin	Mayo		Enclosed
Meadow	Porturlin	Mayo		Enclosed
Meadow	Maghera	Donegal		Enclosed
Meadow	Maghera	Donegal		Enclosed
Improved	Loughros	Donegal		Enclosed
Grassland<0.03cm	Maghera	Donegal		Unenclosed
Bog: heather>30cm	Maghera	Donegal		Unenclosed
Stream	Glenlara	Mayo		Unenclosed
Meadow	Glenlara	Mayo	G24	Enclosed
Rough grazing	Glenlara	Mayo	G19	Enclosed
Bog: heather>30cm	Tippe	Mayo		Unenclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
bog: heather<30cm	Glenlara	Mayo		Unenclosed
Rough grazing	Tippe	Mayo	M8	Enclosed
Rough grazing	Tippe	Mayo	M5	Enclosed
Meadow	Agha	Mayo	A8	Enclosed
Rough grazing	Agha	Mayo	A13	Enclosed
Meadow	Agha	Mayo	A20	Enclosed
Grassland<0.03cm	Agha	Mayo		Unenclosed
Grassland<0.03cm	Loughros	Donegal		Unenclosed
Bog: heather>30cm	Maghera	Donegal		Unenclosed
Meadow	Loughros	Donegal		Enclosed
Grassland<0.03cm	Maghera	Donegal		Unenclosed
Grassland<0.03cm	Maghera	Donegal		Unenclosed
Grassland<0.03cm	Maghera	Donegal		Unenclosed
Stream	Porturlin	Mayo		Unenclosed

Month	YYMODD	No.	Activity	Sw_height	Grazers	Food_source	Fossil_code
July	70711	1	Feeding	s	s1	Self-heal	GS3
July	70711	2	Feeding	s	s2	Thistle	GS3
July	70711	1	Feeding			Heather	PB3
July	70711	4	Nesting				HH3 / PB3
July	70717	1	Feeding	s	s2	Poa annua	GS3
July	70717	2	Feeding	s	s1	Chickweed	GS3
July	70717	2	Feeding	l	0	Thistle	GS4
July	70717	2	Feeding	s	s1	Chickweed	GS3
July	70717	1	Feeding			Poa annua	BL3
July	70717	1	Feeding	m	0	Sorrel	GS3
July	70717	4	Feeding	m	c1	sorrel / chickweed	GS3 / PB3
July	70717	3	Feeding	l	0	Chickweed	GS3
July	70717	2	Feeding	l	0	Sorrel	HH3 / PB3
July	70717	5	Feeding	l	0	Thistle	GS3 / PB3
July	70717	1	Feeding	s	s1	Chickweed	GS3
July	70717	2	Feeding	l	0	Thistle	GS3
July	70717	5	Feeding	s	s1	P.maritima/thrift	GS3
July	70719	6	Feeding	m	0	Thistle	GS3
July	70719	2	Feeding			Self-heal	BL3
July	70719	3	Feeding	l	0	Thistle	GS3
July	70719	4	Nesting				HH3 / PB3
July	70720	8	Feeding	s	0	P.maritima/thrift	CM1
July	70720	2	Feeding	s	0	P.maritima/thrift	CM1
July	70720	4	Feeding	m	s1	Chickweed	GS3
July	70720	2	Nesting				HH3 / PB3
July	70720	3	Nesting				HH3 / PB3

Appendix F

Habitat_category	Area	County	Field_no.	Enclosed ?
Rough grazing	Porturlin	Mayo		Enclosed
Meadow	Porturlin	Mayo		Enclosed
Bog: heather>30cm	Claddagharone	Mayo		Unenclosed
Bog: heather>30cm	Buddagh	Mayo		Unenclosed
Meadow	Glenlara	Mayo	G37	Enclosed
Meadow	Glenlara	Mayo	G33	Enclosed
Meadow	Glenlara	Mayo	G34	Enclosed
Meadow	Glenlara	Mayo	G28	Enclosed
Road / track	Glenlara	Mayo	G25	Enclosed
Meadow	Glenlara	Mayo	G22	Enclosed
Rough grazing	Glenlara	Mayo	G19	Enclosed
Meadow	Glenlara	Mayo	G1	Enclosed
Rough grazing	Tippe	Mayo	M1	Enclosed
Rough grazing	Tippe	Mayo	M5	Enclosed
Meadow	Tippe	Mayo	M7	Enclosed
Meadow	Agha	Mayo	A2	Enclosed
Grassland<0.03cm	Agha	Mayo		Unenclosed
Meadow	Loughros	Donegal		Enclosed
Road / track	Loughros	Donegal		Unenclosed
Meadow	Agha	Mayo		Enclosed
Bog: heather>30cm	Tippe	Mayo		Unenclosed
Grassland<0.03cm	Maghera	Donegal		Unenclosed
Grassland<0.03cm	Maghera	Donegal		Unenclosed
Meadow	Maghera	Donegal		Enclosed
Bog: heather>30cm	Maghera	Donegal		Unenclosed
Bog: heather>30cm	Maghera	Donegal		Unenclosed

Month	YYMODD	No.	Activity	Sw_height	Grazers	Food_source	Fossitt_code
July	70730	1	Feeding	s	s1	thistle	GS3
July	70730	5	Feeding	l	0	Sorrel	GS3
July	70730	2	Nesting				HH3 / PB3
July	70730	18	Feeding			P.maritima/thrift	CM1
August	70801	25	Feeding	m	s1	Chickweed	GS3
August	70801	10	Feeding	m	0	Pineappleweed	GS3
August	70801	8	Feeding	l	c1	sorrel / chickweed	GS3 / PB3
August	70801	6	Feeding	l		Pineappleweed	GS3
August	70801	5	Feeding	s	s2	Grass spp.	GS3
August	70801	4	Feeding	s	s3	Pineappleweed	GS3
August	70801	3	Nesting				HH3 / PB3
August	70801	8	Feeding	l	0	Thistle	GS3 / PB3
August	70801	3	Feeding	s	s1	Chickweed	GS3 / PB3
August	70801	2	Feeding	l	0	Thistle	GS3
August	70801	6	Feeding	m	0	Autumn Hawksbit	GS3
August	70801	1	Feeding	m	s1	Dock	GA1
August	70801		Nesting				HH3 / PB3
August	70801	20	Feeding	s	s	P. maritima	GS3
August	70813	8	Feeding	m	0	Autumn Hawksbit	GS3
August	70813	2	Feeding	m	s1	Autumn Hawksbit	GS3
August	70813	1	Feeding	l	0	Thistle	GS3 / PB3
August	70813	1	Feeding	l	0	Yorkshire fog	GS3
August	70813	4	Feeding	s	s1	Chickweed	GS3
August	70813	28	Feeding	s	s1	Autumn Hawksbit	GS3
August	70813	8	Feeding	l	0	Sorrel	HH3 / PB3
August	70813	5	Feeding	s	s1	Chickweed / Mouseear	GS3

Appendix F

Habitat_category	Area	County	Field_no.	Enclosed ?
Meadow	Maghera	Donegal		Enclosed
Meadow	Maghera	Donegal		Enclosed
Bog: heather>30cm	Maghera	Donegal		Unenclosed
Grassland<0.03cm	Maghera	Donegal		Unenclosed
Meadow	Glenlara	Mayo	G1	Enclosed
Meadow	Glenlara	Mayo	G3a	Enclosed
Rough grazing	Glenlara	Mayo	G19	Enclosed
Meadow	Glenlara	Mayo	G26a	Enclosed
Meadow	Glenlara	Mayo	G33	Enclosed
Meadow	Glenlara	Mayo	G37	Enclosed
Bog: heather>30cm	Glenlara	Mayo		Unenclosed
Rough grazing	Tippe	Mayo	M5	Enclosed
Rough grazing	Agha	Mayo	A13	Enclosed
Rough grazing	Agha	Mayo	A15	Enclosed
Meadow	Agha	Mayo	A17	Enclosed
Improved	Agha	Mayo	A18	Enclosed
Bog: heather>30cm	Tippe	Mayo		Unenclosed
Grassland<0.03cm	Agha	Mayo		Unenclosed
Meadow	Glenlara	Mayo	G1	Enclosed
Meadow	Glenlara	Mayo	G2	Enclosed
Rough grazing	Glenlara	Mayo	G5	Enclosed
Meadow	Glenlara	Mayo	G32	Enclosed
Meadow	Glenlara	Mayo	G33	Enclosed
Grassland<0.03cm	Glenlara	Mayo		Unenclosed
Rough grazing	Tippe	Mayo	M1	Enclosed
Meadow	Tippe	Mayo	M7	Enclosed

Month	YYMODD	No.	Activity	Sw_height	Grazers	Food_source	Fossil_code
August	70813	1	Bathing				FW1
August	70813	2	Nesting				HH3 / PB3
August	70813	6	Feeding	s	0	Autumn Hawksbit	GS3
August	70813	3	Feeding	m	0	Catsear	GS3 / PB3
August	70813	7	Feeding	m	0	Mouseear	GS3
August	70813	3	Feeding	m	c1	Sorrel	GA1
August	70813	1	Feeding	m	s1	Chickweed	GS3
August	70813	25	Feeding	s	s2	Chickweed	GS3
August	70813	15	Feeding	s	s	P. maritima	GS3
August	70817	19	Feeding	s	0	P. maritima	CM1
August	70817	25	Feeding	s	0	P. maritima	CM1
August	70828	12	Feeding			Sea thrift	GS3
August	70828	63	Feeding	m	s1	Autumn Hawksbit	GS3
August	70828	23	Feeding	m	s1	Thistle	GS3
August	70828	6	Feeding	s	s2	Pineappleweed	GS3
August	70828	2	Feeding	s	s1	Thistle	GS3 / PB3
August	70828	2	Feeding	s	c1	Chickweed	GS3
August	70828	14	Feeding	s	0	Self-heal	GS3
August	70828	2	Feeding	s	0	P. maritima	GS3
August	70828	8	Feeding	l	0	Thistle	GS4
August	70828	4	Feeding	s	0	Chickweed	GS3
August	70828	2	Feeding	s	0	Autumn Hawksbit	GA1
August	70828	1	Feeding	s	s1	P. maritima	GS3
August	70828	3	Feeding	l	0	Sorrel	HH3 / PB3
August	70828	14	Feeding	s	s1	Thistle	GS3
August	70828	25	Feeding	s	s1	Pineappleweed	GS3

Appendix F

Habitat_category	Area	County	Field_no.	Enclosed ?
Stream	Tippe	Mayo		Unenclosed
Bog: heather>30cm	Tippe	Mayo		Unenclosed
Rough grazing	Agha	Mayo	A9	Enclosed
Meadow	Agha	Mayo	A13	Enclosed
Meadow	Agha	Mayo	A17	Enclosed
Improved	Agha	Mayo	A18	Enclosed
Meadow	Agha	Mayo	A22	Enclosed
Meadow	Agha	Mayo	A23	Enclosed
Grassland<0.03cm	Agha	Mayo		Unenclosed
Grassland<0.03cm	Maghera	Donegal		Unenclosed
Grassland<0.03cm	Maghera	Donegal		Unenclosed
Grassland<0.03cm	Glenlara	Mayo		Unenclosed
Meadow	Glenlara	Mayo	G1	Enclosed
Meadow	Glenlara	Mayo	G2	Enclosed
Meadow	Glenlara	Mayo	G3a	Enclosed
Rough grazing	Glenlara	Mayo	G5	Enclosed
Meadow	Glenlara	Mayo	G27	Enclosed
Meadow	Glenlara	Mayo	G28	Enclosed
Meadow	Glenlara	Mayo	G33	Enclosed
Meadow	Glenlara	Mayo	G34	Enclosed
Meadow	Glenlara	Mayo	G35	Enclosed
Improved	Glenlara	Mayo	G36	Enclosed
Grassland<0.03cm	Agha	Mayo		Unenclosed
Rough grazing	Tippe	Mayo	M1	Enclosed
Meadow	Portacloy	Mayo		Enclosed
Meadow	Porturlin	Mayo		Enclosed

Month	YYMODD	No.	Activity	Sw_height	Grazers	Food_source	Fossitt_code	Habitat_category	Area	County	Field_no.	Enclosed ?
August	70831	25	Feeding	s	0	P. maritima	CM1	Grassland<0.03cm	Maghera	Donegal		Unenclosed
September	70909	30	Feeding	s	s1	P. maritima	GS3	Grassland<0.03cm	Glenlara	Mayo		Unenclosed
September	70909	26	Feeding	m	s1	Thistle	GS3 / PB3	Rough grazing	Glenlara	Mayo	G5	Enclosed
September	70909	45	Feeding	s	0	Chickweed	GS3 / PB3	Rough grazing	Glenlara	Mayo	G8	Enclosed
September	70909	20	Feeding	s	s1	Autumn Hawksbit	GS3	Meadow	Glenlara	Mayo	G9	Enclosed
September	70910	17	Feeding	s	0	Autumn Hawksbit	GS3	Meadow	Maghera	Donegal		Enclosed
September	70922	2	Feeding	m	s1	Chickweed / Autumn Hawksbit	GS3	Meadow	Glenlara	Mayo	G1	Enclosed
September	70922	45	Feeding	s	s1	P. maritima / Autumn Hawksbit	GS3	Grassland<0.03cm	Glenlara	Mayo		Unenclosed
September	70922	15	Feeding	s	s1	Dock	GA1	Improved	Glenlara	Mayo		Enclosed
September	70922	6	Feeding	s	0	Self-heal	CM1	Grassland<0.03cm	Maghera	Donegal		Unenclosed
September	70922	32	Feeding	s	0	P. maritima	CM1	Grassland<0.03cm	Maghera	Donegal		Unenclosed

Notes:

YYMODD = year, month, day. Example: 31st August, 2007 is written as '70831'.

Sw_height = sward height; short, medium or long.

Grazers = 0 is no domestic grazers; 's' is sheep; 'c' is cattle. 1 is less than 10; 2 is 10 – 20; 3 is 21+.

Enclosed? = is the field enclosed or not?

APPENDIX G

Sample radio tracking data from Chapter 4

E	N	ID	YYMODD	HHMI
-9	-9	908	80812	1400
-9	-9	908	80812	1402
-9	-9	908	80812	1404
-9	-9	908	80812	1406
-9	-9	908	80812	1408
-9	-9	908	80812	1410
-9	-9	908	80812	1412
-9	-9	908	80812	1414
70629	339571	908	80812	1416
-9	-9	908	80812	1418
70584	339707	908	80812	1420
-9	-9	908	80812	1422
-9	-9	908	80812	1424
-9	-9	908	80812	1426
-9	-9	908	80812	1428
70410	339623	908	80812	1430
70410	339623	908	80812	1432
70410	339623	908	80812	1434
70410	339623	908	80812	1436
-9	-9	908	80812	1438
-9	-9	908	80812	1440
-9	-9	908	80812	1442
-9	-9	908	80812	1444
-9	-9	908	80812	1446
-9	-9	908	80812	1448
70393	339727	908	80812	1450
-9	-9	908	80812	1452
-9	-9	908	80812	1454
-9	-9	908	80812	1456
-9	-9	908	80812	1458
70584	339707	908	80812	1500
-9	-9	908	80812	1502
-9	-9	908	80812	1504
-9	-9	908	80812	1506
-9	-9	908	80812	1508
-9	-9	908	80812	1510
-9	-9	908	80812	1512
-9	-9	908	80812	1514
-9	-9	908	80812	1516
-9	-9	908	80812	1518
-9	-9	908	80812	1520
-9	-9	908	80812	1522
-9	-9	908	80812	1524
-9	-9	908	80812	1526
-9	-9	908	80812	1528
-9	-9	908	80812	1530
-9	-9	908	80812	1532
-9	-9	908	80812	1534
-9	-9	908	80812	1536
-9	-9	908	80812	1538
-9	-9	908	80812	1540
-9	-9	908	80812	1542
-9	-9	908	80812	1544
-9	-9	908	80812	1546
-9	-9	908	80812	1548
-9	-9	908	80812	1550
-9	-9	908	80812	1552
-9	-9	908	80812	1554
-9	-9	908	80812	1556
-9	-9	908	80812	1558
-9	-9	908	80812	1600
-9	-9	908	80812	1602
-9	-9	908	80812	1604
-9	-9	908	80812	1606
-9	-9	908	80812	1608
-9	-9	908	80812	1610
-9	-9	908	80812	1612

-9	-9	908	80812	1614
-9	-9	908	80812	1616
-9	-9	908	80812	1618
-9	-9	908	80812	1620
-9	-9	908	80812	1622
-9	-9	908	80812	1624
-9	-9	908	80812	1626
-9	-9	908	80812	1628
-9	-9	908	80812	1630
-9	-9	908	80812	1632
-9	-9	908	80812	1634
-9	-9	908	80812	1636
-9	-9	908	80812	1638
-9	-9	908	80812	1640
-9	-9	908	80812	1642
-9	-9	908	80812	1644
70517	339724	908	80812	1646
-9	-9	908	80812	1648
-9	-9	908	80812	1650
-9	-9	908	80812	1652
-9	-9	908	80812	1654
-9	-9	908	80812	1656
-9	-9	908	80812	1658
-9	-9	908	80812	1700
-9	-9	908	80812	1702
-9	-9	908	80812	1704
70587	339751	908	80812	1706
-9	-9	908	80812	1708
70587	339801	908	80812	1710
-9	-9	908	80812	1712
-9	-9	908	80812	1714
-9	-9	908	80812	1716
-9	-9	908	80812	1718
-9	-9	908	80812	1720
-9	-9	908	80812	1722
-9	-9	908	80812	1724
-9	-9	908	80812	1726
-9	-9	908	80812	1728
-9	-9	908	80812	1730
-9	-9	908	80812	1732
-9	-9	908	80812	1734
-9	-9	908	80812	1736
-9	-9	908	80812	1738
-9	-9	908	80812	1740
-9	-9	908	80812	1742
-9	-9	908	80812	1744
-9	-9	908	80812	1746
-9	-9	908	80812	1748
-9	-9	908	80812	1750
-9	-9	908	80812	1752
-9	-9	908	80812	1754
-9	-9	908	80812	1756
-9	-9	908	80812	1758
-9	-9	908	80812	1800
70629	339571	908	80813	1256
70538	339584	908	80813	1258
70538	339584	908	80813	1300
-9	-9	908	80813	1302
-9	-9	908	80813	1304
-9	-9	908	80813	1306
-9	-9	908	80813	1308
-9	-9	908	80813	1310
-9	-9	908	80813	1312
-9	-9	908	80813	1314
70601	339632	908	80813	1316
70601	339632	908	80813	1318
70601	339632	908	80813	1320
-9	-9	908	80813	1322

-9	-9	908	80813	1324
-9	-9	908	80813	1326
-9	-9	908	80813	1328
70543	339634	908	80813	1330
70543	339634	908	80813	1332
70543	339634	908	80813	1334
70317	339747	908	80813	1336
70317	339747	908	80813	1338
70317	339747	908	80813	1340
70294	339757	908	80813	1342
70294	339757	908	80813	1344
70294	339757	908	80813	1346
70294	339757	908	80813	1348
-9	-9	908	80813	1350
-9	-9	908	80813	1352
70477	339922	908	80813	1354
70477	339922	908	80813	1356
70477	339922	908	80813	1358
70478	339897	908	80813	1400
70478	339897	908	80813	1402
70478	339897	908	80813	1404
70478	339897	908	80813	1406
70478	339897	908	80813	1408
-9	-9	908	80813	1410
-9	-9	908	80813	1412
-9	-9	908	80813	1414
-9	-9	908	80813	1416
-9	-9	908	80813	1418
-9	-9	908	80813	1420
-9	-9	908	80813	1422
-9	-9	908	80813	1424
-9	-9	908	80813	1426
-9	-9	908	80813	1428
-9	-9	908	80813	1430
-9	-9	908	80813	1432
-9	-9	908	80813	1434
-9	-9	908	80813	1436
-9	-9	908	80813	1438
-9	-9	908	80813	1440
-9	-9	908	80813	1442
-9	-9	908	80813	1444
-9	-9	908	80813	1446
-9	-9	908	80813	1448
-9	-9	908	80813	1450
-9	-9	908	80813	1452
-9	-9	908	80813	1454
-9	-9	908	80813	1456
-9	-9	908	80813	1458
70564	339691	908	80813	1500
70564	339691	908	80813	1502
70564	339691	908	80813	1504
70366	339610	908	80813	1506
70366	339610	908	80813	1508
70366	339610	908	80813	1510
70366	339610	908	80813	1512
70366	339610	908	80813	1514
70366	339610	908	80813	1516
70366	339610	908	80813	1518
70366	339610	908	80813	1520
70366	339610	908	80813	1522
-9	-9	908	80813	1524
-9	-9	908	80813	1526
-9	-9	908	80813	1528
-9	-9	908	80813	1530
-9	-9	908	80813	1532
70564	339691	908	80813	1534
70564	339691	908	80813	1536
70564	339691	908	80813	1538

-9	-9	908	80813	1540
-9	-9	908	80813	1542
-9	-9	908	80813	1544
-9	-9	908	80813	1546
-9	-9	908	80813	1548
-9	-9	908	80813	1550
-9	-9	908	80813	1552
-9	-9	908	80813	1554
-9	-9	908	80813	1556
-9	-9	908	80813	1558
70555	339620	908	80813	1600
70555	339620	908	80813	1602
70555	339620	908	80813	1604
-9	-9	908	80813	1606
-9	-9	908	80813	1608
-9	-9	908	80813	1610
-9	-9	908	80813	1612
-9	-9	908	80813	1614
-9	-9	908	80813	1616
-9	-9	908	80813	1618
-9	-9	908	80813	1620
-9	-9	908	80813	1622
-9	-9	908	80813	1624
-9	-9	908	80813	1626
-9	-9	908	80813	1628
-9	-9	908	80813	1630
-9	-9	908	80813	1632
-9	-9	908	80813	1634
-9	-9	908	80813	1636
-9	-9	908	80813	1638
-9	-9	908	80813	1640
-9	-9	908	80813	1642
-9	-9	908	80813	1644
-9	-9	908	80813	1646
-9	-9	908	80813	1648
-9	-9	908	80813	1650
-9	-9	908	80813	1652
-9	-9	908	80813	1654
-9	-9	908	80813	1656
-9	-9	908	80813	1658
70543	339634	908	80813	1700
70543	339634	908	80813	1702
70543	339634	908	80813	1704
70543	339634	908	80813	1706
70543	339634	908	80813	1708
70584	339707	908	80813	1710
70584	339707	908	80813	1712
70584	339707	908	80813	1714
-9	-9	908	80813	1716
70517	339724	908	80813	1718
70517	339724	908	80813	1720
70517	339724	908	80813	1722
70517	339724	908	80813	1724
70517	339724	908	80813	1726
70524	339837	908	80813	1728
70524	339837	908	80813	1730
70524	339837	908	80813	1732
-9	-9	908	80813	1734
-9	-9	908	80813	1736
-9	-9	908	80813	1738
-9	-9	908	80813	1740
-9	-9	908	80813	1742
-9	-9	908	80813	1744
-9	-9	908	80813	1746
-9	-9	908	80813	1748
-9	-9	908	80813	1750
-9	-9	908	80813	1752
-9	-9	908	80813	1754

-9	-9	908	80813	1756
-9	-9	908	80813	1758
-9	-9	908	80813	1800
-9	-9	908	80814	1140
-9	-9	908	80814	1142
-9	-9	908	80814	1144
-9	-9	908	80814	1146
-9	-9	908	80814	1148
-9	-9	908	80814	1150
-9	-9	908	80814	1152
-9	-9	908	80814	1154
-9	-9	908	80814	1156
-9	-9	908	80814	1158
-9	-9	908	80814	1200
-9	-9	908	80814	1202
-9	-9	908	80814	1204
-9	-9	908	80814	1206
-9	-9	908	80814	1208
-9	-9	908	80814	1210
-9	-9	908	80814	1212
-9	-9	908	80814	1214
-9	-9	908	80814	1216
-9	-9	908	80814	1218
-9	-9	908	80814	1220
-9	-9	908	80814	1222
-9	-9	908	80814	1224
-9	-9	908	80814	1226
-9	-9	908	80814	1228
-9	-9	908	80814	1230
-9	-9	908	80814	1232
-9	-9	908	80814	1234
-9	-9	908	80814	1236
-9	-9	908	80814	1238
-9	-9	908	80814	1240
-9	-9	908	80814	1242
-9	-9	908	80814	1244
-9	-9	908	80814	1246
-9	-9	908	80814	1248
-9	-9	908	80814	1250
-9	-9	908	80814	1252
-9	-9	908	80814	1254
-9	-9	908	80814	1256
-9	-9	908	80814	1258
-9	-9	908	80814	1300
-9	-9	908	80814	1302
-9	-9	908	80814	1304
-9	-9	908	80814	1306
-9	-9	908	80814	1308
-9	-9	908	80814	1310
-9	-9	908	80814	1312
-9	-9	908	80814	1314
-9	-9	908	80814	1316
-9	-9	908	80814	1318
-9	-9	908	80814	1320
-9	-9	908	80814	1322
-9	-9	908	80814	1324
-9	-9	908	80814	1326
-9	-9	908	80814	1328
-9	-9	908	80814	1330
-9	-9	908	80814	1332
-9	-9	908	80814	1334
-9	-9	908	80814	1336
-9	-9	908	80814	1338
-9	-9	908	80814	1340
-9	-9	908	80814	1342
-9	-9	908	80814	1344
-9	-9	908	80814	1346
-9	-9	908	80814	1348

-9	-9	908	80814	1350
-9	-9	908	80814	1352
-9	-9	908	80814	1354
-9	-9	908	80814	1356
-9	-9	908	80814	1358
-9	-9	908	80814	1400
70433	339989	908	80814	1402
70433	339989	908	80814	1404
70433	339989	908	80814	1406
70433	339989	908	80814	1408
-9	-9	908	80814	1410
-9	-9	908	80814	1412
-9	-9	908	80814	1414
-9	-9	908	80814	1416
-9	-9	908	80814	1418
-9	-9	908	80814	1420
-9	-9	908	80814	1422
-9	-9	908	80814	1424
-9	-9	908	80814	1426
-9	-9	908	80814	1428
-9	-9	908	80814	1430
-9	-9	908	80814	1432
-9	-9	908	80814	1434
-9	-9	908	80814	1436
-9	-9	908	80814	1438
-9	-9	908	80814	1440
-9	-9	908	80814	1442
-9	-9	908	80814	1444
-9	-9	908	80814	1446
-9	-9	908	80814	1448
-9	-9	908	80814	1450
-9	-9	908	80814	1452
-9	-9	908	80814	1454
-9	-9	908	80814	1456
-9	-9	908	80814	1458
-9	-9	908	80814	1500
-9	-9	908	80814	1502
-9	-9	908	80814	1504
-9	-9	908	80814	1506
-9	-9	908	80814	1508
-9	-9	908	80814	1510
-9	-9	908	80814	1512
-9	-9	908	80814	1514
-9	-9	908	80814	1516
-9	-9	908	80814	1518
-9	-9	908	80814	1520
-9	-9	908	80814	1522
-9	-9	908	80814	1524
-9	-9	908	80814	1526
-9	-9	908	80814	1528
-9	-9	908	80814	1530
-9	-9	908	80814	1532
-9	-9	908	80814	1534
-9	-9	908	80814	1536
-9	-9	908	80814	1538
-9	-9	908	80814	1540
-9	-9	908	80814	1542
-9	-9	908	80814	1544
-9	-9	908	80814	1546
-9	-9	908	80814	1548
-9	-9	908	80814	1550
-9	-9	908	80814	1552
-9	-9	908	80814	1554
-9	-9	908	80814	1556
-9	-9	908	80814	1558
-9	-9	908	80814	1600
-9	-9	908	80814	1602
-9	-9	908	80814	1604

-9	-9	908	80814	1606
-9	-9	908	80814	1608
-9	-9	908	80814	1610
-9	-9	908	80814	1612
-9	-9	908	80814	1614
-9	-9	908	80814	1616
70256	339536	908	80814	1618
70256	339536	908	80814	1620
70256	339536	908	80814	1622
70256	339536	908	80814	1624
70518	339577	908	80814	1626
70518	339577	908	80814	1628
70518	339577	908	80814	1630
-9	-9	908	80814	1632
-9	-9	908	80814	1634
-9	-9	908	80814	1636
70518	339577	908	80814	1638
70518	339577	908	80814	1640
70518	339577	908	80814	1642
-9	-9	908	80814	1644
-9	-9	908	80814	1646
-9	-9	908	80814	1648
-9	-9	908	80814	1650
-9	-9	908	80814	1652
-9	-9	908	80814	1654
-9	-9	908	80814	1656
70195	339657	908	80814	1658
70393	339727	908	80815	900
70393	339727	908	80815	902
70393	339727	908	80815	904
70393	339727	908	80815	906
-9	-9	908	80815	908
-9	-9	908	80815	910
-9	-9	908	80815	912
-9	-9	908	80815	914
70564	339691	908	80815	916
70564	339691	908	80815	918
-9	-9	908	80815	920
-9	-9	908	80815	922
-9	-9	908	80815	924
-9	-9	908	80815	926
-9	-9	908	80815	928
70333	339657	908	80815	930
70333	339657	908	80815	932
70333	339657	908	80815	934
70333	339657	908	80815	936
70333	339657	908	80815	938
-9	-9	908	80815	940
-9	-9	908	80815	942
-9	-9	908	80815	944
-9	-9	908	80815	946
-9	-9	908	80815	948
-9	-9	908	80815	950
-9	-9	908	80815	952
-9	-9	908	80815	954
-9	-9	908	80815	956
-9	-9	908	80815	958
-9	-9	908	80815	1000
-9	-9	908	80815	1002
-9	-9	908	80815	1004
-9	-9	908	80815	1006
-9	-9	908	80815	1008
-9	-9	908	80815	1010
-9	-9	908	80815	1012
-9	-9	908	80815	1014
70802	339426	908	80815	1016
70802	339426	908	80815	1018
70802	339426	908	80815	1020

70802	339426	908	80815	1022
70802	339426	908	80815	1024
70802	339426	908	80815	1026
70802	339426	908	80815	1028
70802	339426	908	80815	1030
-9	-9	908	80815	1032
-9	-9	908	80815	1034
-9	-9	908	80815	1036
-9	-9	908	80815	1038
70195	339657	908	80815	1040
70195	339657	908	80815	1042
70195	339657	908	80815	1044
70195	339657	908	80815	1046
70195	339657	908	80815	1048
70195	339657	908	80815	1050
-9	-9	908	80815	1052
70412	339945	908	80815	1054
70412	339945	908	80815	1056
70412	339945	908	80815	1058
70412	339945	908	80815	1100
70412	339945	908	80815	1102
70412	339945	908	80815	1104
70358	339349	908	80815	1106
70358	339349	908	80815	1108
70358	339349	908	80815	1110
70358	339349	908	80815	1112
70358	339349	908	80815	1114
70358	339349	908	80815	1116
70358	339349	908	80815	1118
70358	339349	908	80815	1120
-9	-9	908	80815	1122
70369	339944	908	80815	1124
70369	339944	908	80815	1126
70369	339944	908	80815	1128
70369	339944	908	80815	1130
70369	339944	908	80815	1132
70369	339944	908	80815	1134
70369	339944	908	80815	1136
70369	339944	908	80815	1138
70369	339944	908	80815	1140
70369	339944	908	80815	1142
70458	339940	908	80815	1144
70458	339940	908	80815	1146
70458	339940	908	80815	1148
70458	339940	908	80815	1150
70458	339940	908	80815	1152
70458	339940	908	80815	1154
70458	339940	908	80815	1156
70458	339940	908	80815	1158
70458	339940	908	80815	1200
70458	339940	908	80815	1202
70458	339940	908	80815	1204
70458	339940	908	80815	1206
70458	339940	908	80815	1208
70458	339940	908	80815	1210
70458	339940	908	80815	1212
70458	339940	908	80815	1214
70458	339940	908	80815	1216
-9	-9	908	80815	1218
-9	-9	908	80815	1220
-9	-9	908	80815	1222
-9	-9	908	80815	1224
-9	-9	908	80815	1226
-9	-9	908	80815	1228
-9	-9	908	80815	1230
-9	-9	908	80815	1232
-9	-9	908	80815	1234
-9	-9	908	80815	1236

-9	-9	908	80815	1238
70587	339751	908	80815	1240
70587	339751	908	80815	1242
70587	339751	908	80815	1244
70587	339751	908	80815	1246
70587	339751	908	80815	1248
70587	339751	908	80815	1250
70587	339751	908	80815	1252
70587	339751	908	80815	1254
70587	339751	908	80815	1256
70587	339751	908	80815	1258
70587	339751	908	80815	1300
-9	-9	908	80815	1302
-9	-9	908	80815	1304
-9	-9	908	80815	1306
-9	-9	908	80815	1308
-9	-9	908	80815	1310
-9	-9	908	80815	1312
-9	-9	908	80815	1314
-9	-9	908	80815	1316
-9	-9	908	80815	1318
-9	-9	908	80815	1320
-9	-9	908	80815	1322
-9	-9	908	80815	1324
-9	-9	908	80815	1326
-9	-9	908	80815	1328
-9	-9	908	80815	1330
-9	-9	908	80815	1332
-9	-9	908	80815	1334
-9	-9	908	80815	1336
-9	-9	908	80815	1338
70505	339274	908	80815	1340
70505	339274	908	80815	1342
70505	339274	908	80815	1344
70505	339274	908	80815	1346
70505	339274	908	80815	1348
-9	-9	908	80815	1350
70584	339707	908	80815	1352
70584	339707	908	80815	1354
70584	339707	908	80815	1356
70517	339724	908	80815	1358
70517	339724	908	80815	1400
-9	-9	908	80815	1402
-9	-9	908	80815	1404
-9	-9	908	80815	1406
-9	-9	908	80815	1408
-9	-9	908	80815	1410
70393	339727	908	80815	1412
70393	339727	908	80815	1414
70393	339727	908	80815	1416
-9	-9	908	80815	1418
-9	-9	908	80815	1420
-9	-9	908	80815	1422
70366	339610	908	80815	1424
70366	339610	908	80815	1426
-9	-9	908	80815	1428
70256	339536	908	80815	1430
70256	339536	908	80815	1432
-9	-9	908	80815	1434
-9	-9	908	80815	1436
-9	-9	908	80815	1438
70802	339426	908	80815	1440
70802	339426	908	80815	1442
70802	339426	908	80815	1444
-9	-9	908	80815	1446
70193	339342	908	80815	1448
70193	339342	908	80815	1450
70193	339342	908	80815	1452

70193	339342	908	80815	1454
70193	339342	908	80815	1456
70193	339342	908	80815	1458
70193	339342	908	80815	1500
-9	-9	908	80815	1502
-9	-9	908	80815	1504
-9	-9	908	80815	1506
70193	339342	908	80815	1508
70193	339342	908	80815	1510
70193	339342	908	80815	1512
70193	339342	908	80815	1514
70193	339342	908	80815	1516
70193	339342	908	80815	1518
70193	339342	908	80815	1520
70193	339342	908	80815	1522
70193	339342	908	80815	1524
70193	339342	908	80815	1526
70193	339342	908	80815	1528
70193	339342	908	80815	1530
-9	-9	908	80815	1532
-9	-9	908	80815	1534
-9	-9	908	80815	1536
-9	-9	908	80815	1538
-9	-9	908	80815	1540
-9	-9	908	80815	1542
-9	-9	908	80815	1544
-9	-9	908	80815	1546
-9	-9	908	80815	1548
-9	-9	908	80815	1550
-9	-9	908	80815	1552
-9	-9	908	80815	1554
-9	-9	908	80815	1556
-9	-9	908	80815	1558
-9	-9	908	80815	1600
-9	-9	908	80819	800
-9	-9	908	80819	802
-9	-9	908	80819	804
-9	-9	908	80819	806
-9	-9	908	80819	808
-9	-9	908	80819	810
70193	339342	908	80819	812
70193	339342	908	80819	814
70193	339342	908	80819	816
70193	339342	908	80819	818
70193	339342	908	80819	820
70193	339342	908	80819	822
70193	339342	908	80819	824
70193	339342	908	80819	826
70193	339342	908	80819	828
70193	339342	908	80819	830
70193	339342	908	80819	832
70193	339342	908	80819	834
-9	-9	908	80819	836
-9	-9	908	80819	838
-9	-9	908	80819	840
70584	339707	908	80819	842
70584	339707	908	80819	844
70584	339707	908	80819	846
70584	339707	908	80819	848
70584	339707	908	80819	850
70584	339707	908	80819	852
70584	339707	908	80819	854
70584	339707	908	80819	856
-9	-9	908	80819	858
70316	339347	908	80819	900
-9	-9	908	80819	902
-9	-9	908	80819	904
-9	-9	908	80819	906

-9	-9	908	80819	908
-9	-9	908	80819	910
-9	-9	908	80819	912
-9	-9	908	80819	914
-9	-9	908	80819	916
-9	-9	908	80819	918
-9	-9	908	80819	920
-9	-9	908	80819	922
-9	-9	908	80819	924
-9	-9	908	80819	926
-9	-9	908	80819	928
-9	-9	908	80819	930
-9	-9	908	80819	932
-9	-9	908	80819	934
-9	-9	908	80819	936
-9	-9	908	80819	938
-9	-9	908	80819	940
70230	339261	908	80819	942
70230	339261	908	80819	944
70230	339261	908	80819	946
70230	339261	908	80819	948
70230	339261	908	80819	950
70230	339261	908	80819	952
70230	339261	908	80819	954
70230	339261	908	80819	956
70230	339261	908	80819	958
-9	-9	908	80819	1000
-9	-9	908	80819	1002
-9	-9	908	80819	1004
-9	-9	908	80819	1006
-9	-9	908	80819	1008
70517	339724	908	80819	1010
70517	339724	908	80819	1012
70524	339837	908	80819	1014
-9	-9	908	80819	1016
70517	339724	908	80819	1018
70517	339724	908	80819	1020
70517	339724	908	80819	1022
70517	339724	908	80819	1024
70517	339724	908	80819	1026
70517	339724	908	80819	1028
70517	339724	908	80819	1030
70393	339727	908	80819	1032
70393	339727	908	80819	1034
70393	339727	908	80819	1036
70393	339727	908	80819	1038
-9	-9	908	80819	1040
70366	339610	908	80819	1042
70366	339610	908	80819	1044
70366	339610	908	80819	1046
70366	339610	908	80819	1048
70517	339724	908	80819	1050
70517	339724	908	80819	1052
-9	-9	908	80819	1054
-9	-9	908	80819	1056
-9	-9	908	80819	1058
70564	339691	908	80819	1100
-9	-9	908	80819	1102
-9	-9	908	80819	1104
-9	-9	908	80819	1106
-9	-9	908	80819	1108
70393	339727	908	80819	1110
70393	339727	908	80819	1112
70393	339727	908	80819	1114
70393	339727	908	80819	1116
70393	339727	908	80819	1118
70393	339727	908	80819	1120
70393	339727	908	80819	1122

70393	339727	908	80819	1124
70393	339727	908	80819	1126
70393	339727	908	80819	1128
70393	339727	908	80819	1130
70393	339727	908	80819	1132
-9	-9	908	80819	1134
70325	339729	908	80819	1136
70325	339729	908	80819	1138
70325	339729	908	80819	1140
70325	339729	908	80819	1142
70325	339729	908	80819	1144
70325	339729	908	80819	1146
70325	339729	908	80819	1148
-9	-9	908	80819	1150
70584	339707	908	80819	1152
70584	339707	908	80819	1154
70584	339707	908	80819	1156
70584	339707	908	80819	1158
70584	339707	908	80819	1200
70584	339707	908	80819	1202
70584	339707	908	80819	1204
70584	339707	908	80819	1206
70584	339707	908	80819	1208
70584	339707	908	80819	1210
70584	339707	908	80819	1212
70584	339707	908	80819	1214
70584	339707	908	80819	1216
70584	339707	908	80819	1218
70584	339707	908	80819	1220
70584	339707	908	80819	1222
70584	339707	908	80819	1224
70584	339707	908	80819	1226
70584	339707	908	80819	1228
70584	339707	908	80819	1230
70584	339707	908	80819	1232
70584	339707	908	80819	1234
70584	339707	908	80819	1236
70584	339707	908	80819	1238
70584	339707	908	80819	1240
70584	339707	908	80819	1242
70584	339707	908	80819	1244
70584	339707	908	80819	1246
70584	339707	908	80819	1248
70584	339707	908	80819	1250
70584	339707	908	80819	1252
70584	339707	908	80819	1254
70584	339707	908	80819	1256
70584	339707	908	80819	1258
70584	339707	908	80819	1300
70584	339707	908	80819	1302
70584	339707	908	80819	1304
70584	339707	908	80819	1306
70584	339707	908	80819	1308
70584	339707	908	80819	1310
70584	339707	908	80819	1312
-9	-9	908	80819	1314
-9	-9	908	80819	1316
-9	-9	908	80819	1318
-9	-9	908	80819	1320
-9	-9	908	80819	1322
-9	-9	908	80819	1324
70584	339707	908	80819	1326
70584	339707	908	80819	1328
70584	339707	908	80819	1330
-9	-9	908	80819	1332
-9	-9	908	80819	1334
-9	-9	908	80819	1336
-9	-9	908	80819	1338

-9	-9	908	80819	1340
-9	-9	908	80819	1342
-9	-9	908	80819	1344
-9	-9	908	80819	1346
-9	-9	908	80819	1348
-9	-9	908	80819	1350
-9	-9	908	80819	1352
-9	-9	908	80819	1354
-9	-9	908	80819	1356
-9	-9	908	80819	1358
-9	-9	908	80819	1400

Notes:

E = Easting as per ArcView GIS

N = Northing as per ArcVew GIS

ID = Identification of individual bird; in this sample '9' represents the 9th bird radio tracked and '08' represents the year.

YYMODD = year, month, day. Example: 31st August, 2007 is written as '70831'.

HHMI = Hour and minute.

APPENDIX H

Biometric raw data used in Chapter 5

Ring no.	Recovery Type	Date	Location	Sex	Mass (g)	Wing (mm)	Age*	County	Bill (mm)
T934507	New Bird	29-Jan-06	Termoncarragh	M	16.2	77.5	6	Mayo	-
T934507	Retrap	29-Nov-07	Termoncarragh	M	14		4	Mayo	-
T934508	New Bird	29-Jan-06	Termoncarragh	M	16.7	75.5	5	Mayo	-
T934508	Retrap	18-Nov-06	Termoncarragh	M	15.8	78.5	4	Mayo	8.2
T934513	New Bird	19-Feb-06	Termoncarragh	M			5	Mayo	-
T934513	Control	16-Oct-06	Glenlara	M	15.4	78	4	Mayo	-
T934514	New Bird	29-Jan-06	Termoncarragh	M	16.2	77.5	6	Mayo	-
T934514	Retrap	7-Apr-07	Termoncarragh	M	15.2	78.5	6	Mayo	-
T934516	New Bird	5-Feb-06	Termoncarragh	F	15	72.5	5	Mayo	-
T934516	Control	9-Oct-06	Glenlara	F	15.1	73	4	Mayo	-
T934516	Retrap	18-Nov-06	Termoncarragh	F	14	74	4	Mayo	-
T934519	New Bird	19-Feb-06	Termoncarragh	M	14.7	74.5	5	Mayo	-
T934533	New Bird	5-Feb-06	Termoncarragh	M	15	74	5	Mayo	-
T934533	Retrap	7-Apr-07	Termoncarragh	M	14.9	74.5	6	Mayo	-
T934535	New Bird	5-Feb-06	Termoncarragh	M	16.4	74.5	5	Mayo	-
T934535	Retrap	7-Apr-07	Termoncarragh	M	15.4	77	5	Mayo	-
T934536	New Bird	5-Feb-06	Termoncarragh	F	15.6	77.5	5	Mayo	-
T934536	Retrap	18-Nov-06	Termoncarragh	F	14.3	79	4	Mayo	9.2
T934536	Retrap	20-Jan-07	Termoncarragh	F	14.5	77	6	Mayo	9
T934570	New Bird	19-Mar-06	Termoncarragh	M	15.2	75	5	Mayo	-
T934570	Control	13-May-07	Glenlara	M	14.5	74.5	4	Mayo	-
T934572	New Bird	8-Apr-06	Termoncarragh	F	14.6	73	4	Mayo	-
T934573	New Bird	8-Apr-06	Termoncarragh	M	16.1	77.5	6	Mayo	-
T934574	New Bird	8-Apr-06	Termoncarragh	M	14.8	72	4	Mayo	-
T934575	New Bird	8-Apr-06	Termoncarragh	M	16.5	76	4	Mayo	-
T934577	New Bird	8-Apr-06	Termoncarragh	M	15.9	77	5	Mayo	-
T934578	New Bird	8-Apr-06	Termoncarragh	M	18.9	76	4	Mayo	-
T934584	New Bird	8-Apr-06	Termoncarragh	F	15	74.5	5	Mayo	-
T934585	New Bird	8-Apr-06	Termoncarragh	M	16.7	75	4	Mayo	-
T934586	New Bird	8-Apr-06	Termoncarragh	M	15.5	77.5	5	Mayo	-
T934588	New Bird	8-Apr-06	Termoncarragh	M	16.4	73	5	Mayo	-
T934590	New Bird	8-Apr-06	Termoncarragh	M	16.5	76.5	4	Mayo	-
T934591	New Bird	8-Apr-06	Termoncarragh	F	16.8	74.5	6	Mayo	-
T934600	New Bird	15-Aug-06	Glenlara	F		75	3J	Mayo	-
T934600	Retrap	28-Sep-07	Glenlara	F	14.9		4	Mayo	-
T934600	Retrap	29-Nov-07	Termoncarragh	F	14.8		4	Mayo	-
T934603	New Bird	17-Aug-06	Glenlara	M		75.5	3J	Mayo	8.5
T934603	Retrap	9-Oct-06	Glenlara	M	14.6	75.5	3	Mayo	-
T934603	Control	24-Mar-07	Termoncarragh	M	14.9		5	Mayo	-
T934603	Control	7-Apr-07	Termoncarragh	M	14.5	74.5	5	Donegal	-

Ring no.	Recovery Type	Date	Location	Sex	Mass (g)	Wing (mm)	Age*	County	Bill (mm)
T934606	New Bird	17-Aug-06	Glenlara	F		73.5	3J	Mayo	-
T934606	Control	20-Jan-07	Termoncarragh	F	13.5	73	5	Mayo	-
T934606	Retrap	1-Sep-07	Glenlara	F	13.1		4	Mayo	-
T934610	New Bird	23-Aug-06	Maghera	M	16.9	76	3J	Donegal	-
T934610	Control	1-Feb-07	Sheskinmore	M	15.9	75	5	Mayo	-
T934614	New Bird	25-Aug-06	Glenlara	M	15.5	77	3J	Mayo	-
T934614	Control	30-Dec-06	Termoncarragh	M	14		3	Mayo	-
T934614	Control	7-Apr-07	Termoncarragh	M	13.6	76.5	5	Mayo	-
T934627	New Bird	29-Aug-06	Glenlara	M	15.6	79	4	Mayo	-
T934631	New Bird	29-Aug-06	Glenlara	F	15.6	75.5	3	Mayo	-
T934631	Control	20-Jan-07	Termoncarragh	F	14.5	74	5	Mayo	-
T934631	Control	7-Apr-07	Termoncarragh	F	14.8	75	5	Mayo	-
T934632	New Bird	29-Aug-06	Glenlara	M	15.6	74.5	3	Mayo	8
T934632	Retrap	29-Sep-06	Glenlara	M	14.6	76	3	Mayo	-
T934632	Retrap	9-Oct-06	Glenlara	M	14.5		3	Mayo	-
T934632	Control	18-Nov-06	Termoncarragh	M	14.4	75.5	3	Mayo	-
T934632	Control	20-Jan-07	Termoncarragh	M	14	75.5	5	Mayo	-
T934632	Control	24-Mar-07	Termoncarragh	M	15.4		5	Mayo	-
T934632	Control	7-Apr-07	Termoncarragh	M	14	75	5	Mayo	-
T934632	Retrap	13-May-07	Glenlara	M	13.9	75	4	Mayo	-
T934632	Retrap	28-Sep-07	Glenlara	M	14.5	76.5	4	Mayo	-
T934633	New Bird	29-Aug-06	Glenlara	M	15	75	3	Mayo	8
T934633	Retrap	29-Sep-06	Glenlara	M	14.5	75.5	3	Mayo	-
T934633	Retrap	2-Jun-07	Glenlara	M	15.1		4	Mayo	-
T934635	New Bird	29-Aug-06	Glenlara	F	16.1	77	3	Mayo	-
T934638	New Bird	29-Aug-06	Glenlara	M	16.5	76.5	4	Mayo	-
T934643	New Bird	29-Aug-06	Glenlara	M	16.1	76	4	Mayo	-
T934647	New Bird	29-Aug-06	Glenlara	M	16.2	79	3	Mayo	8.1
T934647	Retrap	29-Sep-06	Glenlara	M	15.6	79	3	Mayo	-
T934647	Control	18-Nov-06	Termoncarragh	M	15.8	79	3	Mayo	-
T934647	Control	7-Apr-07	Termoncarragh	M	14.5	78	4	Mayo	-
T934648	New Bird	29-Aug-06	Glenlara	M	15.1	75	3J	Mayo	-
T934648	Control	24-Mar-07	Termoncarragh	M	15.1		5	Mayo	-
T934648	Control	7-Apr-07	Termoncarragh	M	13.9	73	5	Mayo	-
T934648	Retrap	2-Jun-07	Glenlara	M	14.1		4	Mayo	-
T934648	Retrap	28-Sep-07	Glenlara	M	14.1		4	Mayo	-
T934650	New Bird	29-Aug-06	Glenlara	M	16.6	78	3	Mayo	-
T934650	Control	20-Jan-07	Termoncarragh	M	14.8	77.5	5	Mayo	-
T934658	New Bird	6-Sep-06	Glenlara	M	15	76	3	Mayo	-
T934658	Control	24-Mar-07	Termoncarragh	M	14.6		5	Mayo	-
T934658	Control	7-Apr-07	Termoncarragh	M	15.1	75	5	Mayo	-

Ring no.	Recovery Type	Date	Location	Sex	Mass (g)	Wing (mm)	Age*	County	Bill (mm)
T934658	Control	29-Nov-07	Termoncarragh	M	14.5	76.5	4	Mayo	-
T934661	New Bird	6-Sep-06	Glenlara	M	16.8	76	4	Mayo	-
T934662	New Bird	29-Sep-06	Glenlara	F	15.6	73.5	3	Mayo	-
T934662	Control	18-Nov-06	Termoncarragh	F	14.5	75	3	Mayo	-
T934662	Control	24-Mar-07	Termoncarragh	F	15.1		5	Mayo	-
T934662	Control	7-Apr-07	Termoncarragh	F	15.3	74.5	5	Mayo	-
T934662	Retrap	1-Sep-07	Glenlara	F	14.7		4	Mayo	-
T934667	New Bird	29-Sep-06	Glenlara	M	16.3	76.5	3	Mayo	-
T934667	Retrap	16-Oct-06	Glenlara	M	15.4		3	Mayo	-
T934667	Control	18-Nov-06	Termoncarragh	M	14.5	77	2	Mayo	-
T934667	Control	7-Apr-07	Termoncarragh	M	14.6	74.5	5	Mayo	8.9
T934669	New Bird	29-Sep-06	Glenlara	M	16.7	79	3	Mayo	-
T934669	Retrap	29-Sep-06	Glenlara	M	16.4		3	Mayo	-
T934669	Control	18-Nov-06	Termoncarragh	M	16	78.5	3	Mayo	-
T934669	Control	18-Mar-07	Termoncarragh	M	17.6		5	Mayo	-
T934669	Control	7-Apr-07	Termoncarragh	M	15.3	77	5	Mayo	8
T934675	New Bird	29-Sep-06	Glenlara	M	15.8	74.5	3	Mayo	-
T934675	Retrap	9-Oct-06	Glenlara	M	14.9	76	3	Mayo	-
T934675	Control	24-Mar-07	Termoncarragh	M	15.5		5	Mayo	-
T934675	Control	7-Apr-07	Termoncarragh	M	15	75.5	5	Mayo	-
T934683	New Bird	29-Sep-06	Glenlara	M	15.9	79	3	Mayo	-
T934683	Control	20-Jan-07	Termoncarragh	M	15	78.5	5	Mayo	9
T934688	New Bird	9-Oct-06	Glenlara	M	15.6	79	3	Mayo	-
T934688	Control	18-Nov-06	Termoncarragh	M	15	79	3	Mayo	8.9
T934689	New Bird	9-Oct-06	Glenlara	M	14.6	74	4	Mayo	-
T934689	Control	18-Nov-06	Termoncarragh	M	14	74	4	Mayo	8.4
T934695	New Bird	9-Oct-06	Glenlara	M	15	76.5	3	Mayo	-
T934695	Control	7-Apr-07	Termoncarragh	M	13.9	75	4	Mayo	-
T934695	Retrap	2-Jun-07	Glenlara	M	15.3		4	Mayo	9.7
T934696	New Bird	9-Oct-06	Glenlara	M	15.3	76.5	3	Mayo	-
T934696	Control	30-Dec-06	Termoncarragh	M	14.6		3	Mayo	-
T934696	Control	24-Mar-07	Termoncarragh	M	16		5	Mayo	-
T934696	Control	7-Apr-07	Termoncarragh	M	14.6	75.5	5	Mayo	-
T934714	New Bird	18-Nov-06	Termoncarragh	M	14.2	75	3	Mayo	8.7
T934715	New Bird	18-Nov-06	Termoncarragh	F	14	74.5	4	Mayo	8.4
T934717	New Bird	18-Nov-06	Termoncarragh	M	14.9	77.5	3	Mayo	-
T934717	Retrap	24-Mar-07	Termoncarragh	M	16.6		5	Mayo	8.7
T934721	New Bird	18-Nov-06	Termoncarragh	M	16.1	81	4	Mayo	-
T934721	Retrap	24-Mar-07	Termoncarragh	M	17.4		4	Mayo	-
T934725	New Bird	18-Nov-06	Termoncarragh	M	15.4	79	3	Mayo	-

Ring no.	Recovery Type	Date	Location	Sex	Mass (g)	Wing (mm)	Age*	County	Bill (mm)
T934725	Control	13-May-07	Glenlara	M	15.2	76	4	Mayo	8.2
T934727	New Bird	18-Nov-06	Termoncarragh	F	14.6	75	3	Mayo	-
T934727	Retrap	20-Jan-07	Termoncarragh	F	13.8	75.5	5	Mayo	-
T934727	Retrap	29-Nov-07	Termoncarragh	F	14.1		4	Mayo	8.7
T934728	New Bird	18-Nov-06	Termoncarragh	M	16.1	81.5	4	Mayo	-
T934732	New Bird	18-Nov-06	Termoncarragh	M	15	77	3	Mayo	-
T934732	Retrap	27-Oct-07	Termoncarragh	M	15		4	Mayo	8.2
T934736	New Bird	18-Nov-06	Termoncarragh	F	14.4	74.5	4	Mayo	8.2
T934737	New Bird	18-Nov-06	Termoncarragh	M	14.1	77.5	4	Mayo	8.7
T934739	New Bird	18-Nov-06	Termoncarragh	M	15.1	75	3	Mayo	-
T934739	Retrap	20-Jan-07	Termoncarragh	M	14.7	74.5	5	Mayo	-
T934739	Retrap	7-Apr-07	Termoncarragh	M	14.6	74.5	4	Mayo	9.5
T934741	New Bird	18-Nov-06	Termoncarragh	M	14.9	76.5	3	Mayo	-
T934741	Retrap	24-Mar-07	Termoncarragh	M	14.8		5	Mayo	8.3
T934742	New Bird	18-Nov-06	Termoncarragh	M	15.1	76.5	3	Mayo	-
T934742	Retrap	20-Jan-07	Termoncarragh	M	14.6	77	4	Mayo	-
T934742	Retrap	24-Mar-07	Termoncarragh	M	14.9		5	Mayo	-
T934742	Retrap	13-Apr-07	Termoncarragh	M	14.6	76.5	5	Mayo	-
T934743	New Bird	18-Nov-06	Termoncarragh	F	15.5	74.5	4	Mayo	-
T934743	Retrap	18-Mar-07	Termoncarragh	F	18.3		4	Mayo	-
T934743	Retrap	24-Mar-07	Termoncarragh	F	16.1		4	Mayo	8.4
T934743	Retrap	29-Nov-07	Termoncarragh	F	15.4	74	4	Mayo	8.8
T934745	New Bird	18-Nov-06	Termoncarragh	F	15.5	77.5	4	Mayo	9
T934746	New Bird	18-Nov-06	Termoncarragh	M	14.3	76	3	Mayo	-
T934746	Retrap	30-Dec-06	Termoncarragh	M	13.9		3	Mayo	-
T934746	Retrap	24-Mar-07	Termoncarragh	M	14.5		5	Mayo	8.5
T934747	New Bird	18-Nov-06	Termoncarragh	M	16.6	77	3	Mayo	-
T934754	New Bird	18-Nov-06	Termoncarragh	M	15.6	77.5	3	Mayo	-
T934754	Retrap	7-Apr-07	Termoncarragh	M	15.4	76.5	4	Mayo	-
T934754	Retrap	29-Nov-07	Termoncarragh	M	15.6		4	Mayo	8.8
T934762	New Bird	18-Nov-06	Termoncarragh	M	16.4	80	4	Mayo	-
T934762	Retrap	24-Mar-07	Termoncarragh	M	16.5		6	Mayo	8.7
T934763	New Bird	18-Nov-06	Termoncarragh	M	15.4	80	4	Mayo	8
T934774	New Bird	18-Dec-06	Sheskinmore	M	15.4	76.5	3	Donegal	-
T934774	Retrap	12-Mar-07	Sheskinmore	M	16	75.5	5	Donegal	8.4
T934787	New Bird	30-Dec-06	Termoncarragh	M	16.9	77	3	Mayo	-
T934787	Retrap	20-Jan-07	Termoncarragh	M	17.1	77.5	4	Mayo	8.8
T934802	New Bird	16-Jan-07	Sheskinmore	F	15.3	74	5	Donegal	-
T934802	Retrap	12-Mar-07	Sheskinmore	F	14.7	74	4	Donegal	-
T934805	New Bird	16-Jan-07	Sheskinmore	M	14.8	78	5	Donegal	-
T934805	Retrap	12-Mar-07	Sheskinmore	M	15	76	4	Donegal	8

Ring no.	Recovery Type	Date	Location	Sex	Mass (g)	Wing (mm)	Age*	County	Bill (mm)
T934807	New Bird	20-Jan-07	Termoncarragh	F	14.6	74	5	Mayo	-
T934807	Control	28-Sep-07	Glenlara	F	15.2		4	Mayo	8.1
T934809	New Bird	20-Jan-07	Termoncarragh	F	15	78	6	Mayo	8
T934814	New Bird	1-Feb-07	Sheskinmore	M	16	76.5	5	Donegal	-
T934814	Retrap	12-Mar-07	Sheskinmore	M	15.9	77	4	Donegal	8.3
T934817	New Bird	1-Feb-07	Sheskinmore	M	15.4	75.5	5	Donegal	-
T934817	Retrap	12-Mar-07	Sheskinmore	M	15.1	74	4	Donegal	-
T934817	Retrap	12-Mar-07	Sheskinmore	M	15.9		4	Donegal	8.8
T934818	New Bird	1-Feb-07	Sheskinmore	M	15.8	77	5	Donegal	-
T934818	Retrap	12-Mar-07	Sheskinmore	M	15.5	76.5	4	Donegal	8.2
T934829	New Bird	12-Mar-07	Sheskinmore	M	14.7	74	4	Donegal	-
T934829	Retrap	12-Mar-07	Sheskinmore	M	15		4	Donegal	9.1
T934864	New Bird	24-Mar-07	Termoncarragh	M	15.5	76	4	Mayo	-
T934866	New Bird	24-Mar-07	Termoncarragh	M	15.6	74.5	5	Mayo	-
T934867	New Bird	7-Apr-07	Termoncarragh	F	13.5	74.5	5	Mayo	-
T934868	New Bird	7-Apr-07	Termoncarragh	M	14.6	75.5	5	Mayo	-
T934873	New Bird	13-Apr-07	Termoncarragh	F	13.9	75.5	5	Mayo	-
T934882	New Bird	2-Aug-07	Glenlara	F	14.7	72	4	Mayo	-
T934882	Control	29-Nov-07	Termoncarragh	F	14.4		2	Mayo	-
T934914	New Bird	28-Sep-07	Glenlara	F	15	75	3	Mayo	8
T934920	New Bird	27-Oct-07	Termoncarragh	F	14.3	76	3	Mayo	-
T934920	Retrap	29-Nov-07	Termoncarragh	F	14.9		3	Mayo	8.9
T934922	New Bird	27-Oct-07	Termoncarragh	M	14.5	77	4	Mayo	8.8
T934924	New Bird	27-Oct-07	Termoncarragh	F	14.5	74	3	Mayo	8.9
T934925	New Bird	27-Oct-07	Termoncarragh	M	14	77	3	Mayo	8.4
T934926	New Bird	27-Oct-07	Termoncarragh	F	13.9	75	4	Mayo	8.7
T934929	New Bird	27-Oct-07	Termoncarragh	F	14.6	77.5	3	Mayo	8.6
T934934	New Bird	27-Oct-07	Termoncarragh	M	14.4	77	3	Mayo	8.9
T934942	New Bird	29-Nov-07	Termoncarragh	F	14.7	74	4	Mayo	8.8
T934949	New Bird	29-Nov-07	Termoncarragh	F	13.5	75	4	Mayo	8.5
T934969	New Bird	29-Nov-07	Termoncarragh	F	15.5	76	4	Mayo	8.8
T934972	New Bird	29-Nov-07	Termoncarragh	M	14.9	79	4	Mayo	8.9
T934975	New Bird	29-Nov-07	Termoncarragh	M	15.4	74.5	4	Mayo	8.3
T934992	New Bird	13-May-08	Glenlara	M	15.8	76	4	Mayo	-
T934993	New Bird	13-May-08	Glenlara	F	19.6	77	4	Mayo	-
T934994	New Bird	13-May-08	Glenlara	M	14.3	76.5	6	Mayo	-

* Age follows EURING codes.

APPENDIX I

Northern Ireland Species Action Plan: Twite *Carduelis flavirostris*

Environment & Heritage Service

Northern Ireland Species Action Plan

Twite

Carduelis flavirostris

March 2006

An Agency within the Department of the Environment

Environment & Heritage Service
www.ehsni.gov.uk

Northern Ireland Species Action Plan
Twite
Carduelis flavirostris
March 2006

1. Current Status

1.1 The twite *Carduelis flavirostris* is a small brown passerine bird in the finch family (Fringillidae) measuring around 14cm. Its heavily streaked plumage is much lighter on its underside, and darker above. Faint light coloured wing bars are visible, as is a pink rump that develops in males during the breeding season. Although similar to the linnet *Carduelis cannabina*, twite appear rounder with a longer tail. Like the linnet, it feeds entirely on seeds all year round and has a short stumpy beak.

1.2 In the breeding season, twite usually occur in treeless habitats particularly in the uplands, marginal uplands, sea coasts and cliffs. Upland habitats with heather, bracken and gorse are all popular breeding locations. Moorland edge habitat is often particularly attractive to them especially when in close proximity to farmland. Farming crofts on the Scottish islands attract large numbers of foraging twite. In Northern Ireland, breeding birds are thought to be limited to the North Coast where they occur around the cliff areas on coastal grassland and heath.

1.3 Across the UK, nests are generally located in heather, mounds of bracken litter, small trees, gorse, marram grass or stone ledges and walls. Northern Ireland twite most likely nest in tall vegetation. The finely built nest cup can be found low to the ground and may support between one and three broods of four to six eggs between mid-May and mid-July. Twite nest singly or in loose colonies. Birds may fly up to several kilometres away from the nest to forage for their young. They feed on a wide variety of seeds, exploiting each source as it becomes available. Dandelions, sorrel, thistle heads are common in the diet when they are available.

1.4 Large numbers of twite winter in Britain on saltmarsh, beaches, strand lines, dunes, machair, waste ground, winter stubbles and other farmland habitats. Here they feed often in large flocks on glasswort *Salicornia* spp., sea aster *Aster* spp., sea blite *Suaeda maritima*, sea lavender *Limonium* spp. seeds and other species of weed seeds. In Northern Ireland wintering flocks are concentrated around Belfast Lough and its surrounding industrial wasteland and Lough Foyle with smaller numbers along the rest of the Northern Ireland coastline. Occasionally birds are also recorded inland.

1.5 The twite has a disjunct breeding population in Europe. The central Asian population extends to parts of Turkey and Russia and accounts for around 40-200,000 pairs. There are no birds across mainland Europe except at the northwest fringes of Britain, Ireland, Norway and some of the other Scandinavian countries. A large stable population of between 100-500,000 pairs makes up the bulk of the European population in Norway. The overall estimate of European twite is over 170,000 pairs, representing just under half of the world population (Burfield & van Bommel, 2004).

1.6 The UK population of twite was surveyed in 1999. Previously the population was thought to be large at 65,000 (Gibbons *et al.*, 1993) but as a result of the 1999 survey it was re-evaluated a much lower level. The true population is still unknown but numbers were estimated to be between 7,600 and 16,700 (Langston *et al.*, in prep). Most of this British population is concentrated in Scotland, mainly on Shetland, Orkney, and Hebrides as well as in the Scottish Highlands. The South Pennines uplands hold the majority of England's small population. A small number of breeding pairs are in a single remaining colony in the Snowdonia region of Wales and there is thought to be a population of between 250 and 1,000 pairs in Ireland. In Northern Ireland, the population is likely to be limited to around ten pairs along the North Antrim Coast, also surveyed last in 1999.

1.7 The twite has witnessed large declines in its breeding range across the UK during the last century (Holloway, 1996). Although the trends are not accurately known, it is thought that the species has also undergone a serious depletion in numbers (RSPB, 1997).

1.8 The twite is specially protected in Northern Ireland under the *Wildlife (Northern Ireland) Order 1985.* It is listed in Appendix III of the Berne Convention. It is not listed as a Species of Conservation Concern in Europe as the population is considered stable.

1.9 The twite is red listed in UK Birds of Conservation Concern (Gregory *et al.*, 2002) due to its historical decline and is also red listed in the Birds of Conservation Concern in Ireland (Newton *et al.*, 1999) due to its historically declining population and declining breeding status. It is listed as a Northern Ireland Priority Species under the Northern Ireland Biodiversity Strategy.

2. Current Factors Affecting the Population

2.1 Little is known about the Northern Ireland population of twite. Breeding habitat on the North Antrim Coastline is considerably different from that used by twite in other areas of the UK. Limiting factors on the population may, therefore, be significantly different to populations elsewhere. The following factors are those which are thought to be most likely limiting the Northern Ireland population.

2.2 Switch from hay to silage – Northern Ireland has seen a dramatic switch from hay to silage production in the last 30 years. Instead of the traditional single annual cut of grass for hay, now, usually, at least two cuts are taken throughout the breeding season for silage. The gap between successive cuts is often too short to allow full development of the grasses and they go to seed for only a short period of time, if at all.

2.3 Loss of quality and extent of species-rich meadow – the dairy and beef industry are dependent on fast growing grass species for silage and grazing purposes. As a result, much of the Northern Ireland grassland is now dominated by rye grass at the expense of mixed species swards. Mixed species swards contain a various array of species that go to seed at different times, providing food for the twite throughout the season.

2.4 Increased grazing pressure reduces seed supply – modern management methods and improved grass yields allow increased stocking rates on farms. Stock removes grasses and weeds that would have previously gone to seed, providing food for the twite.

2.5 Overgrazing and loss of nest sites - cattle or sheep in particular can cause disturbance to the breeding habitat or the destruction of nesting locations in tall ground vegetation through trampling and feeding. Vegetation suitable for nesting can be lowered in height or removed completely.

2.6 Loss of summer farmland food supply - twite depend on access to an abundance of weed seeds in fields in relative proximity to a nesting site, to feed their chicks. Modern farms have a reduced number of weed species through the use of herbicides and modern cultivation methods.

2.7 Reduction in arable area – twite feed on weed seeds often associated with arable fields. Weedy fallow fields hold an abundance of weed species but are rare on the North Antrim Coast. Also, a reduction in the area of arable crops grown in Northern Ireland, through conversion to silage production or grazing means that there is even less of this habitat available to twite.

2.8 Road verge management – a potentially rich source of food is removed by road contractors before grass and weeds have a chance to set seed. This is unlikely to affect the Northern Ireland twite population due to their coastal location though could apply to some roads within a 3 kilometre range of the nest.

2.9 Moorland edge habitat of heather or bracken has been lost – conversion to grassland or poor heathland management practices have resulted in the fragmentation or complete loss of this excellent habitat for breeding twite.

2.10 Bracken removal and timing of bracken removal – where bracken is used as a nesting habitat by twite, extensive removal to stop encroachment could lead to a significant amount of breeding habitat being lost. If bracken removal is carried out in the summer months, there is a risk that a brood of young may still be in the nest. Burning bracken also removes the bracken litter which is often where twite build their nests. Suitable litter for nesting may take up to three years to return.

3. Current Action

3.1 The Management of Sensitive Sites Scheme (MOSS), launched in 2002 by Environment and Heritage Service (EHS), is a voluntary scheme designed to ensure the positive management of ASSI features to maintain their extent and favourable condition. Under the scheme, landowners can receive payment for carrying out conservation work within the framework of a written agreement. MOSS covers issues such as dumping, grazing and control of invasive species.

3.2 In 2000, the Northern Ireland Biodiversity Group (NIBG) produced its recommendations to Government (NIBG, 2000). These recommendations were accepted by the Northern Ireland Executive in 2002, with the publication of the *Northern Ireland Biodiversity Strategy* (DOE, 2002). As part of this process, a revised list of Northern Ireland priority species was published in March 2004. This list includes twite.

3.3 Department of Agriculture and Rural Development (DARD), through its Countryside Management Branch (CMB), has developed a series of agri-environment schemes including the New Environmentally Sensitive Area (NESA) scheme (revised in 2003) and the Countryside Management Scheme (CMS). Their objective is to create habitats and protect and enhance semi-natural habitats and species by encouraging more sensitive management practices. Both these schemes have similar management provisions, are voluntary and apply to the whole farm. These schemes provide a mechanism for delivering some of the targets listed in action plans for many species and habitats, targeting areas of as little as 0.1 ha of semi-natural habitat e.g. species-rich meadows, in order to maintain or improve their present conservation value. Both contain a range of prescriptions which have potential to be of benefit to twite. Around 230,000 ha of farmland is currently in agri-environment schemes in Northern Ireland, approaching a quarter of the total agricultural land in the Province. A sample of habitats is under long-term monitoring by QUB's Agri-environment Monitoring Unit (QUB, 2004b).

3.4 Under agri-environment schemes species-rich grassland, hay meadows, heather moorland, rough moorland grazing and scrub must all be managed according to a series of prescriptions which should have direct benefits for twite as well as the habitats themselves. In addition there are a number of arable options available to farmers notably: retention of winter stubble, conservation cereal, undersown cereal, rough grass margins and wild bird cover which provide summer and winter feeding opportunities. Rough grass margins will also provide tall grassy vegetation suitable for nesting.

3.5 DARD and the Royal Society for the Protection of Birds (RSPB) jointly employ an Agri-Environment Officer, whose main role is to contribute to the effective delivery of agri-environment prescriptions for biodiversity priorities, including twite.

3.6 RSPB currently employ a Priority Bird Species Officer, whose main role is to contribute to the effective delivery of the conservation of priority species which includes twite. This is carried out through close working with council employed biodiversity officers and the implementation of conservation actions, carried out at a local scale through a Local Biodiversity Action Plan (LBAP).

3.7 Site protection policies are included in Development Plans. These include the identification of Sites of Local Nature Conservation Importance (SLNCIs). Planning Service is currently considering which SLNCIs will be formally identified in Development Plans. Where such sites are confirmed in adopted plans, specific planning policies will be applied to development proposals on those sites.

3.8 Council employed biodiversity officers across Northern Ireland are writing and implementing an LBAP within their council boundaries. Those areas in which the twite is

a prominent bird, may select it as their flagship species and carry out some additional awareness raising, publicity or practical conservation work for it.

3.9 Other relevant information is gathered through specialist biological recording groups, Non-Governmental Organisations (NGOs), universities and other government bodies. Biological records are currently stored in the Museum and Galleries of Northern Ireland (MAGNI) at the Centre for Environmental Data and Recording (CEDaR). CEDaR was established in 1995 in partnership with EHS, MAGNI and the biological recording community. There are currently over 1.4 million records held by CEDaR and there are plans underway to make these records more accessible through the Internet. This will be achieved through the National Biodiversity Network, a union of organisations throughout the UK working together to create an information network of accessible biological data for biodiversity information.

4. Action Plan Targets

4.1 Maintain the twite as a breeding species in Northern Ireland.

4.2 By 2010, increase the Northern Ireland breeding twite population to 15 pairs.

4.3 By 2015, increase the Northern Ireland breeding twite population to 20 pairs.

4.4 By 2010, maintain the breeding range of the twite in Northern Ireland.

4.5 By 2015, increase the breeding range of the twite beyond the North Antrim Coastline of Northern Ireland.

4.6 Maintain the wintering number and range of twite in Northern Ireland at 23 x 10km squares (Lack, 1986).

5. Proposed Actions with Lead Agencies

5.1 Policy and Legislation

5.1.1 By 2008, target positive management through MOSS, agri-environment schemes, the LBAP process and grant aid for biodiversity to secure favourable management on suitable twite sites.
(ACTION: EHS, DARD, District councils)

5.1.2 By 2006, ensure that important twite habitats and their conservation management requirements are recognised and site protection policies are included in statutory and non-statutory plans e.g. Development Plans, Local Biodiversity Action Plans (LBAP's) and appropriate management strategies.
(ACTION: Planning Service, EHS, DARD, District Councils)

5.1.3 Ensure implementation of Good Agricultural and Environmental Condition (GAEC) to preserve the suitability and good condition of certain sites (particularly semi-natural habitats) for twite.
(ACTION: DARD)

5.1.4 If there is to be a review of agri-environment schemes under the Rural Development programme (2007-13) consider a review of CMS/ESA to include additional measures to benefit twite, e.g. an option to revert unimproved grassland to species-rich grassland.
(ACTION: DARD)

5.1.5 By 2010 increase the area of arable land in Northern Ireland through agri-environment schemes and a cereal national envelope to benefit twite and other farmland birds.
(ACTION: DARD)

5.2 Site safeguard and management

5.2.1. By 2006, produce ornithological selection criteria for ASSIs.
(ACTION: EHS)

5.2.2 By 2006, produce conservation objectives for all statutory sites including cSACs, ASSIs and NNRs ensuring that the objectives do not conflict with, and where possible enhance, the requirements of twite.
(ACTION: EHS)

5.2.3 By 2007, establish agreements with landowners for the positive management of areas important for breeding twite within ASSIs through the MOSS scheme.
(ACTION: EHS)

5.2.4 By 2007, ensure that the agri-environment scheme measures relevant to twite are carefully targeted at breeding sites along the North County Antrim Coast.
(ACTION: DARD)

5.2.5 By 2006, where appropriate, enhance management of relevant Nature Reserves/National Nature Reserves for breeding twite, ensuring that visitor access and dog walking is restricted, so as to reduce disturbance from the general public.
(ACTION: EHS, District Councils)

5.3 Species management and protection

5.3.1 By 2006, encourage landowners and site managers to avoid carrying out farming operations e.g. bracken control, during the breeding season, in the vicinity of identified twite territories.
(ACTION: EHS, DARD)

5.3.2 Continue to increase the level of uptake of agri-environment schemes in areas where twite are likely to be present (most of the North Antrim coast area is currently managed under ESA).
(ACTION: DARD)

5.3.3 By 2007, identify those road side verges which, if let to set seed, could significantly benefit twite.
(ACTION: EHS, Roads Service)

5.4 Advisory

5.4.1 By 2008, ensure that those responsible for implementing and supporting agri-environment schemes and MOSS agreements continue to receive effective training and up-to-date advice on appropriate land management practices which benefit twite and other upland farmland bird species.
(ACTION: EHS, DARD)

5.4.2 By 2008, ensure that farmers and landowners are aware of the presence of twite on their land and mechanisms available to instigate appropriate management.
(ACTION: EHS, DARD)

5.4.3 By 2008, ensure that information on twite in Northern Ireland is available to all those who could play a role in their conservation and recovery.
(ACTION: EHS, DARD)

5.5 International

5.5.1 Further develop links with the Republic of Ireland and other European and international organisations and programmes such as the European Environment Agency and the European Centre for Nature Conservation, to promote the exchange of information and experience in research, management techniques, education and conservation strategies.
(ACTION: EHS)

5.6 Future research and monitoring

5.6.1 By 2008, carry out a survey to accurately establish the population of twite in Northern Ireland and investigate the habitat used by the birds for nesting and foraging during the breeding season.
(ACTION: EHS)

5.6.2 Continue to carry out a monitoring programme of twite at regular intervals as part of the UK Statutory Conservation Agency/RSPB Annual Breeding Bird Scheme (SCARABBS) survey to assess changes in response to management.
(ACTION: EHS)

5.6.3 By 2007, monitor and review the effectiveness of agri-environment schemes, in maintaining and enhancing the twite population and its associated habitat in Northern Ireland.
(ACTION: DARD, EHS)

5.6.4 By 2008, design and commence a research project into the breeding and diet ecology of the twite to establish the limiting factor(s) of the Northern Ireland population.
(ACTION: EHS)

5.6.5 By 2008, design and commence a research project into the wintering ecology of the twite to establish, if any, limiting factor(s) of the Northern Ireland population.
(ACTION: EHS)

5.7 Communications and publicity

5.7.1 By 2010, following the results of the research, raise awareness of twite ecology and the limiting factor(s) of the Northern Ireland population.
(ACTION: EHS, DARD)

5.7.2 By 2006, ensure the provision of high quality advisory materials to landowners and seek opportunities to promote and publicise mechanisms for delivering positive management.
(ACTION: EHS, DARD)

5.8 Links with other action plans

5.8.1 It is likely that the implementation of this plan will also benefit the Northern Ireland populations of the following UK and Northern Ireland priority species:-

- Short-eared owl *Asio flammeus* (UK)
- Linnet *Carduelis cannabina* (UK & NI)
- Reed bunting *Emberiza schoeniclus* (UK & NI)
- Chough *Pyrrhocorax pyrrhocorax* (NI)

5.8.2 This plan should be considered in conjunction with the following UK and Northern Ireland Habitat Action Plans:-

- Maritime cliffs and slopes
- Coastal and floodplain grazing marsh
- Coastal saltmarsh
- Lowland meadows
- Upland heathland
- Lowland heathland

6 References

Burfield, I & van Bommel, F (2004). *Birds in Europe, Population estimates, trends and conservation status*. BirdLife International.

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

Gregory RD, Wilkinson NI, Noble DG, Robinson JA, Brown AF, Hughes J, Procter DA, Gibbons DW and Galbraith CA (2002). The population status of birds in the United Kingdom, Channel Islands and Isle of Man: an analysis of conservation concern 2002–2007. *British Birds* 95: 410–450.

Langston, R.H.W., Smith, T., Brown, A.F., and Gregory, R.D. (In prep). The status of Twite *Carduelis flavirostris* in the UK in 1999.

Holloway 1996 The historical atlas of breeding birds in Britain and Ireland 1875 – 1900. T & AD Poyser, London.

Newton. S., Donaghy, A., Allen, D. & Gibbons, D. (1999). *Birds of Conservation Concern in Ireland*. Irish Birds 6:3 333-344.

QUB, 2004b. Baseline monitoring of the countryside management scheme in Northern Ireland. Report to DARD.

RSPB 1997 *"Species Action Plan 1662. Twite"*, RSPB, Sandy, Bedfordshire

List of Useful Acronyms

ASSI	Area of Special Scientific Interest
BAP	Biodiversity Action Plan
CEDaR	Centre for Environmental Data and Recording
CMB	Countryside Management Branch
CMS	Countryside Management Scheme
DARD	Department of Agricultural and Rural Development
DCAL	Department of Culture, Arts and Leisure
DETI	Department of Enterprise, Trade and Investment
DOE	Department of the Environment
DRD	Department for Rural Development
EHS	Environment and Heritage Service
ESA	Environmentally Sensitive Area
ESCRs	Earth Science Conservation Review Site
HAP	Habitat Action Plan
JNCC	Joint Nature Conservation Committee
MAGNI	The National Museums and Galleries of Northern Ireland
NESA	New Environmentally Sensitive Area
NIBG	Northern Ireland Biodiversity Action Group
NICS	Northern Ireland Countryside Survey
NNR	National Nature Reserves
PPS	Planning Policy Statement
RA	Rivers Agency
RSPB	Royal Society for the Protection of Birds
SAC	Special Area of Conservation
SLNCI	Sites of Local Nature Conservation Importance
SoCC	Species of Conservation Concern
SPA	Special Protection Area
WFD	Water Framework Directive
WWT	Wildfowl and Wetlands Trust

APPENDIX J

Frequency diagrams for wing length of males and females for Scotland, Ireland and England

Frequency diagrams for male (top) and female (bottom) wing lengths for Scotland, Ireland and England from Chapter 5 figures 2 & 3.