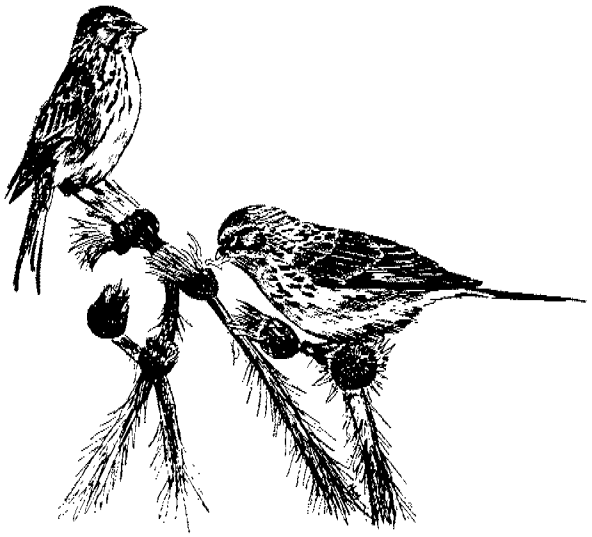
ENGLISH NATURE

Aspects of the breeding ecology of twite in the south Pennines



H A McGhie
A F Brown
S Reed
S M Bates

No. 118

Ornithology

English Nature Research Reports

ENGLISH NATURE RESEARCH REPORTS

NO. 118

ASPECTS OF THE BREEDING ECOLOGY OF TWITE IN THE SOUTH PENNINES

by

H.A. McGhie
Nurse's House, West Road, Muir of Ord, Ross-shire, IV6 7TD

*A.F. Brown
English Nature, Northminster House, Peterborough PE1 1UA

S Reed
Royal Society for the Protection of Birds, Westleigh Mews, Wakefield Road, Denby Dale, Huddersfield HD8 8QD

and

S M Bates
English Nature, Bullring House, Northgate, Wakefield, West Yorkshire WF1 3BJ.

*Contact for correspondence

Further copies of this publication can be obtained from:

Ornithology Unit
Uplands and Freshwater Team
English Nature
Northminster House
Peterborough
PE1 1UA

ISSN 0967 - 876X

CONTENTS

SUMMARY

This report provides the first quantitative study of the habitat associations of the internationally important population of twite *Acanthis flavirostris* found in the south Pennines of England. An intensive field study was carried out between May and August 1994 on three study areas in West Yorkshire; results from less intensive studies conducted in earlier years (1989-1993) are also included in this report. Thirty-seven nests and eight other pairs were located. Twite nested on the moorland edge at densities of 0.004-0.035 pairs per hectare and fed up to 2.6 km from the nest site. There was strong selection of bracken *Pteridium aquilinum* and heather *Calluna vulgaris* for nest sites in preference to various moorland grasses. There was no preferred aspect of nest slope and birds positioned their nests so as to face either downhill or towards an opening in the vegetation. 69% of clutches produced hatchlings, and 76% of broods produced fledglings, giving an overall breeding success of 53%. Birds fed almost exclusively on unripened dandelions *Taraxacum* seeds until this food source disappeared in mid-June, after which time they fed almost exclusively on sorrel *Rumex acetosa*. There was strong selection for fields with high densities of these plants, and the birds abandoned fields with high dandelion density for fields with high sorrel density after the dandelions lost their seeds. Densities of dandelion and sorrel were highest in unimproved meadows and lowest in pastures and reseeds. Twite abandoned fields after they were cut for hay or silage, as this destroyed their foodplants.

INTRODUCTION

The twite *Acanthis flavirostris* is a small Cardueline finch closely related to the linnet *A. cannabina* and more distantly to the redpolls *A. flammea* and *A. hornemanni* (Newton 1972). The twite is most notable for its disjunct world distribution: the main distribution is in the cold arid upland grasslands of central Asia, extending from Turkey in the west to western China in the east, and the Caucasus in the north to Afghanistan in the south. In Europe it is confined to the British Isles, Norway, the Kola peninsula, and some parts of Finland and Sweden (Vaurie 1959, Voous 1960, Harrison 1982, Davies 1988); a colony of Scandinavian birds established itself on Nolsoy in the Faeroes in the 1940s, but has been extinct since the late 1950s or 60s (Williamson and Petersen 1951).

The European populations have a long history of separation from both the Asian stock and from each other as the populations have become racially distinct: the British form, ssp. *pipilans* (Latham) (=*bensonorum* Meinertzhagen), is slightly darker than the nominate Scandinavian form, which is in turn darker than the central Asian subspecies *rufostrigata* and the Turkish and Caucasian subspecies *brevirostris* (Bannerman 1953, Newton 1972, Davies 1988).

Only three British upland bird species other than the twite show racial differentiation (Ratcliffe and Thompson 1988). In addition, other than the Scottish crossbill the twite is the only passerine to breed or winter in internationally important numbers in Britain; in view of this the twite is listed as a British Red Data Book species (Batten *et al.* 1990).

In spite of the importance of Britain's twite, the species has received remarkably little attention from researchers. The only field study of the breeding ecology of twite in Britain, carried out from 1966-70 (Orford 1973), was not quantitative, but information is available on habitat associations in the Forest of Rossendale (Haworth and Thompson 1988), and in the south Pennines as a whole (Brown *et al.* 1995, Stillman and Brown 1994). Brown *et al.* (1995) also analysed the Nest Record Cards held at the British Trust for Ornithology.

This lack of quantitative information, particularly on the habitat requirements of twite, makes it difficult to provide detailed advice on the management appropriate for maintaining or enhancing breeding populations of this species. The aim of the present work was to provide the information necessary to inform management decisions in order to safeguard the species in the south Pennines. The report provides the first published, quantitative information on feeding site and breeding site selection, diet, and breeding biology of twite. Reed (1995) provides quantitative information on locations of nests and feeding habitat preferences in the study area, and Brown *et al.* (*in press*) provide a quantitative analysis of nest record cards for Britain as a whole.

DISTRIBUTION AND NUMBERS OF TWITE IN BRITAIN

The twite is widely distributed as a breeding bird in Britain, but has disappeared from much of its former range.

1. Present distribution

In Scotland it is present in small numbers in Mid and Easter Ross, Inverness-Shire, and the Grampian Highlands (especially the southeast); it is scarce in the Lammermuirs and the Southern Uplands. The bulk of the Scottish population is found in Sutherland and Caithness, coastal Wester Ross, Morvern, the Hebrides, Kintyre, Colonsay, Jura, Arran, Orkney and Shetland. In England it is restricted to the Pennines from Durham in the north to north Staffordshire in the south. In Ireland it is practically confined to the north and west coasts, particularly Donegal. Very small numbers nest in north Wales (Gibbons *et al.* 1993).

2. Changes in distribution

Britain's most southerly breeding population, that of Devon, died out between 1929 and 1968 (Loyd 1929, Sharrock 1976). It disappeared from the Lancashire and Cheshire mosses by the mid-1950's (Oakes 1953) as these were destroyed for agriculture (Orford 1973), and has been lost from several Lancashire and Cumbrian localities since 1972 (Gibbons *et al.* 1993). Losses in Scotland have been widespread since the last century (Thom 1986), but since 1972 losses have been almost exclusively north of a line from Kintyre in the southwest to Fraserburgh in the northeast, so that the species has been practically lost from the Buchan hills, Torridon, and much of the Lochaber area (Gibbons *et al.* 1993). However, by far the most dramatic losses have occurred in Ireland, especially the southeast, where it has been in decline for at least the last 80 years (Hutchinson 1988), with very notable declines between 1972 and 1988 (Gibbons *et al.* 1993). Twite first bred in Wales in 1967 (Mullins in Parslow 1973), and there is an increasing population there (Gibbons *et al.* 1993). There has also been an increase in numbers in the Tayside hills (Gibbons *et al.* 1993). There is a clutch of five eggs in the Leicestershire County Museum (F J Turton collection) from Suffolk, which would represent the only known breeding record for that county. Although the distribution in the south Pennines has changed very little between 1972 and 1990 (Gibbons *et al.* 1993, Brown *et al.* 1995) there have been pronounced decreases in many areas in recent years (Curtis 1992), although Twite are known to have increased around Malham from 6-40 pairs between 1975 and 1978 (Clunas and Shorrock 1991).

3. Winter distribution

The Pennines population is migratory, birds leaving in early October and returning between the end of March and beginning of April (Reed in review, Clunas and Shorrock 1991). However, small flocks do occur in the Pennines throughout the winter. There are many ringing returns from the saltmarshes of the Wash and some from the Netherlands, France, and Belgium and some birds have been controlled on different sides of the North Sea in successive years. Davies (1988) considers that the use of the Low Countries as an alternative wintering ground may explain annual variations in numbers wintering on the Wash. The Scandinavian populations (*A. f. flavirostris*) winter in the Low Countries (thus overlapping with *A. f. pipilans*), Germany and sometimes further south and east (Bernhoft-Osa 1965). There is no evidence of Scandinavian birds wintering or breeding in Britain (Davies 1988). The Scottish and Irish populations probably only show local movements, and none have been recovered from the Wash in spite of reasonable numbers having been ringed in Caithness (H Clark, pers.

comm. to HM). Small numbers of Scottish birds have been controlled in Ireland (Davies 1988).

4. Numbers

Several attempts have been made to estimate the size of the south Pennines population, both on the wintering grounds of the Wash (Davies 1988) and on the breeding grounds (Brown *et al.* 1995, Stillman and Brown 1994). Davies (1988) assumed that all twite on the Wash originate in the Pennines and estimated a breeding population of 8,400-25,300 pairs in the 75 ten-kilometre squares in which breeding twite were located in England between 1968 and 1972 (Sharrock 1976). Brown (*et al.*) 1995 calculated a population of 200-400 in their south Pennine study area. Gibbons *et al.* (1994) give a population estimate of 65,000 pairs for Britain and 3,500 pairs for Ireland.

STUDY AREAS AND STUDY PERIOD

Observations were made between 18 May and 5 August 1994 on three study areas in the south Pennines of West Yorkshire (vc 63) situated near Halifax: nests have been found on Rishworth Moor since 1989 by SR, and on Midgley Moor since 1993; SB located nests on Withens Clough in 1993 (Map 1). The main period of study, involving the work on habitat selection, was carried out largely by HM under contract to English Nature. AB, SR and SB assisted during this period.

The boundaries of the study areas were set in 1994, so as to include all fields in which twite originating from the breeding grounds were thought or known to feed in between May and August.

Midgley Moor is a spur of Warley Moor, between Middle Dean in the west and Luddenden Dean in the east, and facing south to the Calder Valley. The highest point of the 304.14 ha study area is 405m asl and the unenclosed land extends down to c325m asl. The moor is very well drained, and the primary water source available to birds is the pair of reservoirs at the northeast edge of the unenclosed land; there are some very small water sources in fields (Map 2).

The Withens Clough study area is much larger, at 1319.10 ha, and reaching 402m asl at Stoodley Pike. The unenclosed land is largely separated from the enclosed land to the east by Cragg Vale, a tributary of the Calder Valley. The moor is wet, except on the steeper slopes, and a large reservoir is present in Withens Clough (Map 3).

The Rishworth Moor study area covers 563.13 ha and reaches 435m asl at Dog Hill. The enclosed land is to the north, east and south of the moor, which is very wet (Map 4).

Midgley Moor, and to a lesser degree, Withens Clough, are both managed for grouse shooting. The unenclosed lands of all three areas are used as rough grazing for sheep. The enclosed lands are divisible into hay and silage meadows, improved reseeds and pastures; cows are more common in the better grazings and meadows, while sheep are commoner in the poorer and higher pastures.

Ecological history of the study areas

The geology of the south Pennines is dominated by a series of thick sandstones, the Millstone Grits, intercalated with thin shales and these underlie the moors on each of the study areas (Edwards and Trotter 1954).

The ice of the Devensian Maximum (30,000-15,000ybp) covered practically the whole of Ireland, all of Wales, Scotland, northern and eastern England. The south Pennines and Peak District would have been the only unglaciated uplands in Britain (Raistrick 1926a,b, 1927; Bowen 1973); the presence of wind-etched stones on the moors is evidence of a very harsh arctic desert climate (Raistrick 1926a,b, 1927; Edwards and Trotter 1954).

The unglaciated areas of the south Pennines, including Calderdale, either held many ice dammed lakes (eg Raistrick 1929, 1934) or inlets of a much larger Lake Humber (Gilligan 1918, Carruthers 1947, Gaunt 1974). When these drained, either through breaching moraines or by ice retreat, the valleys (including Calderdale) were deepened, leaving tributary valleys such as Luddenden Dean, Cragg Vale and Hardcastle Crags as hanging valleys. These tributary valleys then began to cut back their headwaters (Edwards and Trotter 1954, Tallis 1964a,b,c), a process still active today.

Summary information on the climatic and vegetational history of the study areas is given in Table 1.

There was a widespread appearance of humified fresh peat in the Sub Boreal (VIIb) - Atlantic (VIII) transition period associcated with an increasingly oceanic climate. This peat often contains tree stumps, and the development of blanket bogs and peat may have been facilitated by anthropogenic deforestation (Moore 1975); blanket peat is common on Withens Clough, absent from Rishworth, and restricted to the highest ground on Midgley Moor (Curtis *et al.* 1976, Soil Survey of England and Wales 1983).

There is a long history of occupation in the study area. There is evidence of Mesolithic and Neolithic occupation on Midgley Moor, Manshead Hill, and Blackstone Edge (Faull and Moorhouse 1981). More importantly, an unusual unexcavated Bronze Age ring-work is present on Midgley Moor (Radley 1967). In a pollen analytical study of the peats of Rishworth Moor, Bartley (1975) found a general decline in oak *Quercus* and increase in birch *Betula* after 2,060 BC, when there was also a steady increase in the pollen of weeds of pastures, continuing until 470 BC. Such largescale forest clearance was typical of the Iron Age, showing the establishment of crop farming. There was a rapid return of tree cover after 30 AD ± 80, and Bartley suggests that the abandonment of the site and the proximity to the Roman Road built in 120 AD may be no coincidence. There are remains of an Iron Age fort on Midgley Moor, and possibly also on Withens Clough (Welsh 1993).

Although it is probable that forest clearance continued everywhere, in West Yorkshire it appears to have accelerated in the Middle Ages where the Anglo Saxon placename components "royd" and "leah", indicating a clearing in woodland and latterly a clearing near woodland (Pearsall 1950, Gelling 1976), are common; these indicate a formerly even distribution of woodland below 305m asl (Pearsall 1950, Faull and Moorhouse 1981). Vikings started to settle Yorkshire in 867 AD (Welsh 1993), and continued to clear forests and till the land (Faull and Moorhouse 1981).

With such widespread forest clearance, large sheep ranches or *vaccaries* were established, often by Cistercian monks (eg Pearsall 1950); such a ranch was established in Withens Clough itself between 1309-1314, with Turley Holes Moor and Mankinholes Moor being used for grazing (Faull and Moorhouse 1981). A deer park was also established on Erringden Moor (Welsh 1993). Peat cutting was widespread on Withens Clough, where the names Turvin Clough and Turley Holes are derived from the element "turf" (Faull and Moorhouse 1981, Welsh 1993). The blanket peat is now much eroded here, possibly through human interference with drainage (eg Tallis 1964a,b,c; Pearsall 1950).

Land enclosure mainly occurred between 1750-1850, and enclosure acts were granted for the Cragg Vale area between c1650 and c1840 (Faull and Moorhouse 1981); Sunderland Pasture on Withens Clough was established in 1836 (Welsh 1993).

The proximity of the south Pennine moors to large urban centres meant that these moors were some of the most severely affected by the Industrial Revolution. Populations of many species of plant were either diminished or extinguished completely; among the more notable losses are those of Bog Myrtle *Myrica gale*, Bog Rosemary *Andromeda polifolia*, and Sundew *Drosera intermedia* (all may still be found, but only extremely rarely). However, by far the most important loss has been that of the bog mosses *Sphagnum* spp., which have declined from being among the dominant bog plants before the Industrial Revolution (Farey 1811-15) to a smattering of small colonies; their role as the principal peat forming plants has been shifted to the great *Eriophorum* bogs (Press *et al.* 1983) now so typical of the south Pennines as a whole.

Data on the climate in the vicinity of the study areas is available from Bellevue weather station in Halifax. Records extend from 1892-1982 and are deposited in Halifax Library. Annual rainfall is 912.8 mm; November is the wettest month, and June the driest (Table 2). January has the greatest number of days with measurable precipitation (20), and June the lowest (13); however, January has the lowest rainfall per day of rain, and November the highest (Table 3). January and February are the coldest months (3.1 ± 0.2°C) and July the warmest (15 ± 0.1°C) (Table 4).

METHODS

Nest finding and nest visits

Cold searching for nests was found to be an extremely inefficient search method. Most nests were found by following the lines of birds flying from the feeding grounds to the moors. When on the moors, the male bird was often seen to perch close (usually less than 15m) to the nest when the female was incubating, and the nest could be found by flushing the female, usually at a distance of 1-2m and only exceptionally more. Once the young hatched, the female was extremely reluctant to flush, and usually did so at less than 0.5m. Nests can only be found on days without rain and with little wind. Although nests were mainly found by following lines, all parts of the Midgley and Withens Clough study areas were checked at least once a week. On Rishworth, the entire moor was searched for twite in 1994, with more visits to suitable areas within the moor. In previous years, nest searches ceased at the end of June. Once a nest was found it was visited approximately once every three or four days, never less than two days apart or in inclement weather so as to minimise disturbance and the risk of desertion. Nests were coded, so that nest W1 was the first nest found on Withens Clough, likewise for nests M1 and R1 on Midgley and Rishworth respectively.

Recording habitat features

Maps of the main vegetation communities were made for each study area. The vegetation classes selected for unenclosed areas corresponded well with those of Newton and Warburton (1984). The main features of each class are described in Table 5.

Preliminary maps were prepared from 1:c.9800 aerial photographs held at English Nature (Wakefield) by tracing the major vegetation classes; these maps were corrected and detail added in the field. All patches of c10m^2 or greater were plotted. The vegetation maps were copied to 1:10,000 OS maps, and the areas of each vegetation class were calculated by photocopying these maps onto 1mm^2 graph paper (100mm^2: 1 ha); no effort has been made to allow for slopes, but as these are restricted in area on all three study sites the areas given will only be a slight underestimate of the actual land area.

Enclosed land currently in agricultural use was either improved, mainly by addition of animal dung, or unimproved. Each field was classed as being either long or short sward (Table 6). Many former pastures have reverted to *Molinia, Nardus, or Juncus*; these have been included in the unenclosed land when at the boundary of the moorlands, as management input is minimal or nil; where these pastures exist as "islands" in cultivated land they are included in the enclosed land. These lack wild flowers.

In addition to these classes, the density of dandelions *Taraxacum (vulgaria)* agg. and sorrel *Rumex acetosa* was estimated for each field, as these are widely cited as the most important foodplants for twite (Hewson 1967, Newton 1972, Orford 1973, Marler and Mundinger 1975, Reed 1994). Three dandelion density classes were identified: D1, D2 and D3 with <50, 50-100, and >100 flowerheads per m^2. Sorrel classes, S1, S2 and S3, had <10, 10-30, and >30 plants per m^2 respectively. Where dandelions or sorrel were absent, the fields were classed as D0 and S0 respectively.

The area of each field was calculated using the method described above, for unenclosed lands.

The total area of each study area was calculated from the 1:10,000 maps, and the remainder after the areas of enclosed land, unenclosed land, reservoir, woodland, and quarry bottom were totalled was put into an "other" class, consisting almost entirely of roads, paths, houses, and streams.

On finding a nest, certain habitat features were recorded (Table 7). Nest sites were plotted on the vegetation maps (Maps 5-7), and detailed information on each nest is included in Appendix I.

Visits to enclosed land

Enclosed lands were numbered (Maps 8-10) individually, field numbers 1-3 on each study are underlined on the maps to avoid confusion with *Calluna* age classes. Fields were regularly checked, with half of the Withens Clough area, all of Rishworth, and half of Midgley being visited per day. The maximum numbers of twite were recorded for each field, also giving a "twite day" (day when at least one twite was present).

The analysis of field usage was complicated by the changes in field content (sward type and dandelion/sorrel content) over the study period, whether by fields growing up after removal of grazing pressure or by cutting. Dandelions and sorrel were not available to birds throughout the study period, and the differing distribution of the two plants obviously affected field usage. The last observation of twite feeding on dandelions was on 13 June (after most dandelions had lost their seeds), and the first observation of birds eating sorrel was on 14 June; this was chosen as the cut off point. As the Rishworth study site was not searched methodically until June, analyses have only been done for the second (sorrel) period.

Analysis involved computation of cumulative hectarages. For example, a 5 ha field observed to contain long meadow (M1) on two days and found cut on a third would contribute 10 ha to the cumulative total hectarage of long meadow for this field and 5 ha to that for the cut class. For each period it was thus also possible to calculate a total available hectarage for each class in each study area.

RESULTS

Vegetation on the study areas

The Midgley, Withens Clough, and Rishworth study areas occupy total areas of 304.14 ha, 1319.10 ha, and 732.08 ha respectively (Tables 8-10, Maps 2-4). Each study area contains a combination of farmland and moorland. Farmland occupies an area of 142.75 ha on Midgley (46.94% of total land area), 293.75 ha on Withens Clough (22.27%), and 134.78 ha on Rishworth (18.41%).

The unenclosed lands differ markedly in composition between the three sites. The dominant vegetation type on Midgley Moor is *Calluna*, which occupies 50.64% of the area available to nesting twite (the total area minus that of woods, reservoirs, other, and fields). The heather is intensively managed, and of the total of 50.64%, less than half (21.20%) is mature. Bracken *Pteridium aquilinum* occupies 4.98% of the available area. *Nardus* is the most widespread grass occupying, at 24.26%, double the area that *Molinia* does (10.16%). The dry nature of the moor is reflected in the low proportional area of *Juncus*, and the absence of *Eriophorum*.

Withens Clough has a greater area of *Calluna* than Midgley, with 202.11 ha compared to 72.59 ha on Midgley, but 126.15 ha of this is highly eroded. However, *Calluna* occupies a much smaller proportional area on Withens Clough (21.46% of land available to nesting twite). The extensive plateau is dominated by *Eriophorum*, and this occupies 24.95% of the land available to nesting twite. *Molinia* dominates the Sunderland Pasture and the wetter parts of the slopes in Withens Clough itself and in Turvin Clough, and occupies 29.60% of the available land. *Nardus* only occupies 2.05% of the available land. *Juncus* is abundant around the edge of the reservoir, and occupies 2.49% of the land available. Bracken is very widespread on the steeper slopes (10.01% of land available).

The vegetation of Rishworth Moor is clearly indicative of extreme overgrazing: *Calluna* is absent, and the moor is dominated by grasses of poor nutritional value to sheep. *Eriophorum* is the most widespread class, occupying 41.11% of the land available to nesting twite; *Molinia* (23.15%) and *Nardus* (14.25%) are also abundant. Large bracken beds are found on the slopes and invading the *Molinia*, and these occupy 12.52% of the moor.

Diet and use of grit

Twite were most frequently observed to eat dandelions on each study site between 18 May and 13 June, by which time practically all dandelions had lost their seeds. The technique for getting at unripe dandelion seeds was to pull away one or two of the segments of the involucre and to pick out the seeds from their point of attachment to the receptacle. Where dandelions were too tall for the seeds to be reached from the ground, the bird would jump onto the stem just below the flower head, which would bend under the bird's weight, and the bird would pick out the seeds while holding the stem under one or both feet.

Twite were often found in one particular field in the Withens Clough study area, where they fed in short turf containing only *Poa annua* at a density of >200 seeding heads per m^2 (very high). This single field (no. 118) of 3.59 ha (not including a 0.57 ha patch of *Molinia*) contributed twenty twite in eight twite days (out of ten visits) to the total of thirty-three twite in twelve twite days for the short improved (Is) class for this area (see Tables 12 and 13); on 24 May and 6 June. Twite were seen picking at turf in field no. 44, but it was not ascertained whether they were feeding on more *Poa* or finding grit. The male of nest M4 (Midgley) flew twice to the nearby abandoned quarry on 10 June, and was presumed to be feeding in short *Poa annua*. Two birds were seen to pick at *Calluna* buds on 19 May in the Midgley area; and another two to pick at apple *Malus* buds in front of Catherine House at the Withens Clough study area.

Sorrel did not ripen on the study areas until 15 June. Twite fed predominantly on this plant until the end of the study period. Docks *Rumex obtusifolius* and *R. crispus* ripened around one week earlier, but twite were never seen to feed on these. Twite fed in tall (c50-80 cm) sorrel, removing the large seed from the epicalyx on the plant.

Twite were found in three days (out of nine after 15 June) in field nos. 118 and 119 in Withens Clough, with six and seven twite respectively, feeding on *Poa annua*. Twite were found in a field with very short turf (no. 111 in Midgley), and were thought to be feeding on abundant Tormentil *Potentilla erecta*. Between 8 and 12 twite (probably fledglings) were found eating *Calluna* buds on 28 July. SR found the family of R20 feeding on *Eriophorum vaginatum* near the nest site on 25 June 1994, after the birds fledged on 24 June. AB found the female of nest RD (Rishworth) feeding in melancholy thistle *Cirsium helenioides* near the presumed nest site (the nest of this pair was not located) on 27 July. HM found a large party of around twelve twite feeding in *C. helenioides* at Cockhill (Withens Clough study area) on 29 July, although creeping thistle *Cirsium arvense* was much more abundant.

Twite of both sexes were regularly seen to take grit, although where both members of a pair were present the female did so more frequently than the male, presumably to aid egg shell formation. Grit was obtained from roadsides, a pile of asphalt (adjacent to field no. 118 at Withens Clough), a heap of rock salt for gritting roads (at Cockhill in Withens), the crumbling concrete of a wall (by Washfold Bridge, Withens), and from rills and exposures between the nesting and feeding grounds.

Field usage

During the period when dandelions were available, the number of twite and the number of twite days in Withens Clough were both clearly related to the density of dandelions (Table 12). The area with dandelions is very much smaller than the area without. In Midgley only twite days were apparently

related to dandelion density (Table 11), with a disproportionately high number of twite in the low-density class (D1); this was because of the intensive usage of certain short meadows (around Acre), contributing 47 twite in 8 twite days to the totals of 49 in 9 days for that class. These large fields had short turf with scattered longer grasses (mainly *Holcus* and *Festuca*), and the twite may find it easier to forage in such a sward. When grouped, these relaltionships are clearly evident (Table 13).

Roadsides were an important habitat in both study areas, attracting more twite than enclosed land without dandelions (D0). Twite were also seen to bathe and drink in roadside drains, and, as mentioned above, roadsides are an important source of grit.

During the period when sorrel was available, the relationship between field usage and sorrel density was very strong (Tables 14-17), both in terms of twite numbers and twite days, in Withens and Rishworth, but not so on Midgley. This is perhaps surprising, given that sorrel is a very rich food source, with a large plant producing many hundreds of large seeds. It is important to note that once a field was cut, destroying the sorrel plants, twite were never seen to use it again.

Fields in which twite were only found after 14 June had a higher density of sorrel than either those only used before 14 June or those used throughout the study period. Those which were only used in the first period had a higher density of dandelions than those used throughout (Tables 18-20), so there is evidence that twite actively search for high densities of their main foodplants.

Breeding Biology

Breeding density on the moors was not related to the total hectarage of adjacent fields: there were 5/143, 4/294 and 6/135 pairs/ha of field on Midgley, Withens and Rishworth, respectively.

Thirty-four nests were found at the egg stage and three were found at the chick stage. In addition two recently fledged broods and six nest sites were also located. Comprehensive data were not available for all nests: sample sizes therefore differ between variables (Table 21).

The mean clutch size for nests found at the egg stage and revisited at least once (to avoid inclusion of incomplete clutches) was 5.27; there was little variation in clutch size between sites or years (Table 21).

The earliest first egg date was 6-11 May and the latest 7 July; most females begin to lay in mid-May and the latest first egg date for a first brood (possibly a replacement) was 9-10 June. First egg dates may have been slightly later in 1994, but sample sizes are small and should be treated with caution; there was no consistent variation in first egg dates between sites (Table 22). One brood (M4) were known to have hatched on 1 June and fledged on 12 June, giving a nestling period of 12 days (Table 23).

Of a total of 158 eggs in 30 clutches which were revisited, 47 eggs (29.7%) in 9 clutches (30.0%) were destroyed. The main cause of loss was predation, accounting for the loss of 27 eggs in 5 clutches. Ten eggs in 2 clutches were washed out. Further to this, 9 eggs (5.7%) in 8 clutches failed to hatch, leaving 102 young (64.6% of eggs) in 21 broods (70.0% of clutches). Of these, 9 young (5.7% of eggs) in 2 broods (6.7% of clutches) were washed out, and 12 young (7.6% of eggs) in 2 broods (6.7% of clutches) were predated. This means that 46.2-51.3% of eggs survive to fledging, and that 50-56.7% of clutches produce fedglings (Table 24). Detailed results for each study site in 1994 were as follows:

On Midgley, of 27 eggs in five clutches found at the egg stage, 1 c/5 (18%) was disturbed by sheep (deposited at Leeds Museum), 1 c/6 (22%) was predated, and 1 of a c/5 (4%) failed to hatch; of 15 hatchlings (55%), 4 (15% of eggs, 27% of young) were washed out, leaving 11 fledglings (41% of eggs, 73% of hatchlings). The remains of two fledglings were found, and may have been predated by a kestrel; another fledgling was found dead on the road, and may also have been predated. On Withens Clough, of 11 eggs in two clutches found at the egg stage, all fledged. Another nest found with 5 young (1-2 day old) hatchlings produced 5 fledglings. A couple of pairs may have been predated before they had a chance to breed by a nearby pair of merlins. On Rishworth, of 17 eggs in 3 clutches found at the egg stage, 1 c/5 (29% of eggs) was predated, and of 12 hatchlings (71%) 1 h/6 was predated (35% of eggs), and 1 h/6 fledged (36% of eggs). Another h/6 was found, and all 6 young fledged (Table 24).

Nest failure rates were not significantly different from those calculated by Brown *et al.* (1995) from Nest Record Cards, and show that losses of clutches of eggs are greater than losses of broods of young (Table 25).

Breeding density

It is difficult to assess the numbers of breeding pairs on each study area, because birds are double brooded, and some pairs probably produced relays. However, from the timing of breeding (Appendix I), we can calculate that, in 1994, nests MA, M4, M5, M6, and M7 were definitely produced by different pairs, as were nests nests WA, W8, W9, and W10, and nests RB, RC, RD, R17, R19, and R20. If we divide the figures of 5, 4, and 6 pairs into the area available to nesting twite on Midgley, Withens Clough, and Rishworth respectively, the densities are: 0.035, 0.004, and 0.011 pairs per hectare for Midgley, Withens Clough, and Rishworth respectively.

Breeding site selection

Of 10 nests found on Midgley, 8 (80%) were in long *Calluna*, which occupies 21.20% of the area available for nesting. All 13 nests found on Withens Clough were in bracken, which forms 10.01% of the available land. Of 25 nests found on Rishworth, 23 (92%) were in bracken, which constitutes 12.52% of the available land; 1 nest (4%) was in *Eriophorum* (41.11% of the moor), and 1 (4%) in *Molinia* (23.15% of the moor). These results indicate strong selection for bracken and long *Calluna*, but the preference between the two is not clear (Table 26).

The patches of bracken in which twite nested on Withens Clough and Rishworth were significantly larger than the mean patch sizes for those areas. There was no selection towards larger patches of *Calluna* in the Midgley study area (Table 27).

The vegetation in which the nest was placed was the densest within a 30m radius centred on the nest (if bracken and mature *Calluna* are considered to be the densest vegetation types) in all cases except for the two nests in burnt heather. The distance to the edge of a patch varied considerably, with two nests being placed on the actual edge; all but two nests in bracken were in the middle of the patch (Table 28).

Nests in long *Calluna* tended to be positioned slightly above the ground, while those in bracken tended to be on the ground. The structure of these two vegetation types is radically different, and nests in heather were usually placed in a fork in the main stem, usually under a "roof" formed by a tumbled bit of heather. Nests in bracken were almost invariably on the ground, placed in the tumbled remains of the previous year's growth; bracken which had invaded *Molinia* did not form these roofed structures, presumably as the wetter ground rots the stems (Table 29).

There was no consistent variation between the height of the vegetation in the $1m^2$ in which the nest was placed and the surrounding $4m^2$ (Table 30), and there was no selection for denser bracken.

Nest sites and topography

The gradient of nest slopes tended to reflect the gradients predominating around the edge of each study area; Midgley is generally very flat (practically all <30°), Withens Clough has suitable bracken covered slopes generally of the order <30° with very limited areas of 30-45°, while Rishworth has some very steep bracken covered slopes of 30-45° (some areas are possibly even steeper) (Table 31).

The mean altitude of nests was 307m asl. The altitudinal distribution reflected the altitudes of slopes in the study areas, and there was no obvious selection for a particular altitudinal range (Table 32).

The direction in which the nest faced showed a significant and positive correlation with the direction of the nest slope (Table 33). The south-easterly mean direction to which nests faced on Midgley was obviously a reflection of the topography of the moor itself. Bracken suitable for nesting (ie. with roofs) on Rishworth is abundant to the south of Oldham Road, and widespread on a variety of slopes between this and Dog Hill. Similarly, bracken is found on both north- and south east-facing slopes on Withens Clough. Here, the distribution of nests is not correlated with aspect of slope but is a reflection of the distribution of suitable vegetation. The two nests which were built on the edge of a patch were the only two which were built so as to be diametrically opposed to the direction of the nest slope. These provide evidence that birds build so that there is some view from the nest, whether it be downhill, or uphill if the adjacent vegetation is short.

Distribution of nest sites in relation to feeding site

Birds which nested near each other tended to use the same fields for feeding in. Many of the fields were only used once or twice, such as fields adjacent to the nest site, and flocking was more frequent than Table 34 might suggest. The distances between nests and feeding grounds ranged from 0.10 km-c2.60 km, but most nests were more than 0.5 km from the main feeding grounds.

While all the birds on Midgley and Rishworth usually fed together, using very few of the available fields, those from Withens Clough were divided into two groups: those which nested in Withens Clough itself were never seen to feed anywhere other than the fields at Cockhill, while those birds which nested in Turvin Clough always fed in fields south of Turkey Lodge. Observations of these groups were good, and it is very unlikely that the two groups were mixing unnoticed.

Breeding behaviour

The song is similair to that of the linnet but with a more nasal quality, and often incorporating the nasal "dzee" flight call. Song was often delivered from a rock or the top of vegetation close to the incubating female; each male had a favourite post from which to sing, which became white with droppings. The male of nest M4 often sang from the top of a 2m hawthorn 20m from the nest. Males did not sing after the young hatched. Before singing, a male would often sidle up to a female, bobbing his head and flicking the spread tail up simultaneously (so exposing the pink rump), with a strong "dzee" call; the small crest would be raised when close to a female (females also raised their crest, when the observer was close to the nest).

The song-flight is of the slow "moth type" (Newton 1972). The male would fly to a height of c10m, and begin singing a scratchy, highly modulated song. While singing, the bird would stop flapping the wings and hold them stiffly in a downward and forward position (not unlike the normal flight of the

Common Sandpiper *Actites hypoleucos*) and spread the tail; the bird would twist and turn as it descended, displaying the white wing flashes and the pink rump. The whole display would last for approximately five seconds. Song flight was given in five situations:

1. Mate attraction: SR observed a male song-flighting on 27 April 1989; this is taken to indicate an advertisement function.

2. Intrasexual display: HM observed different males to song flight when intruding males approached their mates (or intended mates) on two occasions. On two of the six occasions the interloper did not retreat, and in one (where both males were on the ground) the male attacked the intruder with a head down posture, while in the other (where both males were on a fence) the female's mate flew at the intruder, both birds flying up and falling to the ground. The intruder was thought to have been seen off in both cases.

3. Pair bonding: where the pair were feeding on grit, the male would often rise and song-flight, especially in the presence of other males.

4. "Territorial" or breeding advertisement: when the female was incubating and the male was sallying to and from the feeding grounds, he would often burst into song-flight and then continue on the original line.

5. Distraction or displacement activity: when disturbed by one of us very close to a nest, and the male was in attendance, he would often give a full song-flight before flying off.

Ground display was observed by SR, while observing a feeding flock on 17 May 1989. A male lowered his wings and moved in a semi circle around a female, with his tail twisted so as to expose the pink rump to the female (see also Marler and Mundinger 1975); this display preceded copulation (Fig. 1).

Copulation was rarely observed. SR observed it on 14, 17 and 18 May 1989. In each case, the female crouched, fluttering her lowered wings with the tail spread and the head up. One copulation lasted 4 seconds, and was followed by a billing display, a prelude to courtship feeding (Newton 1972, Marler and Mundinger 1975) (Fig. 2).

Only females were seen to carry nest material, although they were always escorted by the male. The female of nest W8 or W10 was seen to collect wool from field 115 on 18 May 1994, although there were sheep on the moor around the nest site, and the female of nest M7 was seen to carry a few strands of long grass from field 28, which she too could have collected much closer to the nest. A female was seen with a beakful of sheep hair next to M4 on 10 June. The last time a bird was seen to carry nesting material was a female with a beakful of wool, 200m ESE of field 112 at Midgley.

Only females were ever flushed from nests. Males were generally either close by on the vegetation, or away feeding. The male came to feed the female every 15-30 minutes; the period between feeds was related to the distance between the nest and the feeding grounds, as males on Midgley visited the nests much more frequently than males on Withens Clough.

The male and female would leave the nest area to feed together once the young were approximately five days old, before which the female (and presumably the brood) was fed by the male, who visited approximately once every 15-20 minutes for periods of less than a minute. At some nests, such as W9, the female was never seen to brood the young after they were five days old, such were the length and frequency of her feeding trips.

The fledged young stayed close to the nest for up to a week, hiding in the long vegetation. These young were still being fed by the adults, as both members of the pair would fly in every half hour, remaining for up to a minute. SR observed that the young of nest R20 were fed on *Eriophorum* on the day after fledging (25 June). The most likely explanation for this behaviour was that the young were not yet strong enough to fly to the feeding grounds, which were often a considerable distance from the nest (Table 34). Once the young did move to the fields, they were easily identifiable by their greater curiosity and reluctance to fly off on approach. They also had a different call: while the contact call of the adult is strong and strident, that of the immature is much weaker and higher pitched.

Fig. 1. Precopulatory ground display (male on left)

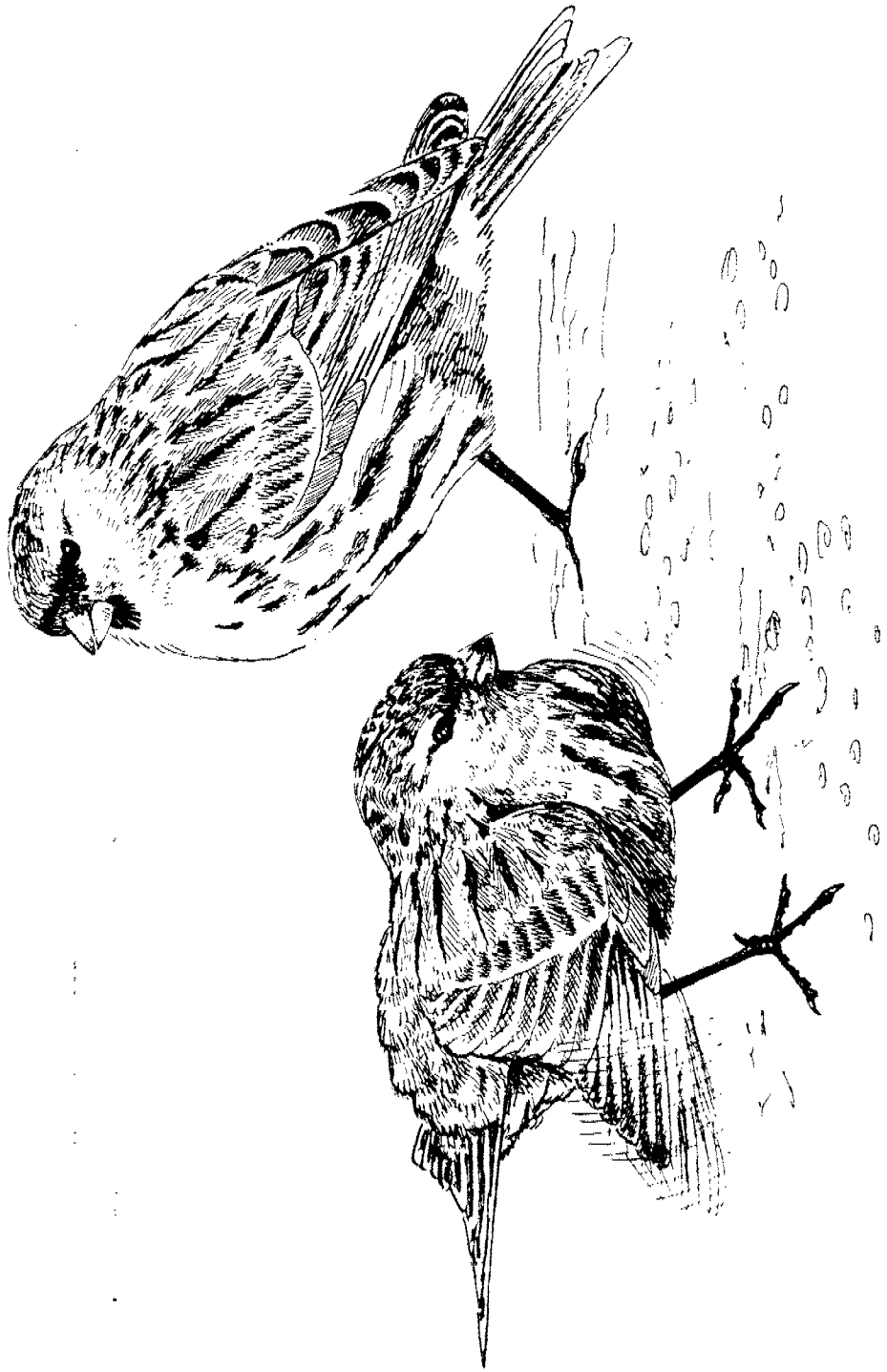


Fig. 2. Postcopulatory billing (male on right)

DISCUSSION

Diet and field usage

The diet of birds observed in this study agrees well with that of other studies. Saxby (1874) examined the stomach contents of many twite shot on Unst (Shetland) on the suspicion that they had been eating grain, but found that the stomachs only contained 'weed' seeds. Hewson (1967) found that at Tarbert (Sutherland) in August 1966 twite fed in agricultural land, and of fifteen instances where food was identified, fourteen cases involved sorrel and one rye grass and on many more occasions twite were seen on sorrel but could not be proven to be feeding. Only very rarely were twite seen to feed outside areas of present or past cultivation, on the moorland edge. Marler and Mundinger (1975) list dandelion, sorrel, dock and oat *Avena sativa* as "favoured forage" in their Norway, Scotland, and Ireland study areas. Sap exudes from the damaged involucre of dandelions, drying a dark sepia colour; it is possible that this is the source of the "black sticky substance, which had evidently adhered whilst feeding" which Taylor (1935) found coating the bills of two captured birds, and is responsible for the black colouration widely cited in guidebooks as typical of summer twite. Marler and Mundinger (1975) record that birds also fed on sorrel and docks along the sea-shore, and HM has also seen this on Noss in Shetland (1991), and on Skye (1993). Reed (in review) also recorded twite feeding upon chickweed *Stellaria media*, ragwort *Senecio vulgaris*, and creeping buttercup *Ranunculus repens* in the south Pennines. Newton (1972) lists a variety of other Composites, but these must be regarded as of minor importance to judge from the present, and other, studies. *Molinia* is an important foodsource when the birds return in the spring (Orford 1973, Reed in review). The method of dealing with tall dandelions, bending the stem and holding it with the foot, is found in all Carduceline finches (Newton 1972), and AB has found that twite also employ the technique on sea lavendar *Limonium* spp. in Norfolk in winter.

Twite select fields with high densities of the two main foodplants, dandelion and sorrel, and abandon fields once they are cut. In addition twite move from fields with a high dandelion density to fields with a high sorrel density after the dandelions lose their seeds.

In its Asiatic range, the twite is found "in high agricultural areas and around the settlements of nomads in western China" (Schafer in Voous 1960).

Nest site selection

It is clear that there is very strong selection of long heather and bracken for nesting. The anomaly is as to why bracken (forming 4.98% of available land) is not used on Midgley, and why long heather (forming 3.39% of available land) is not used on Withens Clough. Given that birds are long-ranging, the distribution of these vegetation types in relation to the feeding grounds is probably of little consequence. The preference may be due to different microclimates in the two vegetation classes between Midgley and Withens Clough. Most authorities refer to long heather as the main nesting habitat, but Orford (1973) is incorrect in saying that "burnt patches are useless as breeding sites until the heather has regenerated". SR has found nests on Midgley Moor which were placed under the burnt stems, which can be quite tall if the heather was very "leggy" when burnt. It is, however, much more usual to find nests in tall heather. The use of bracken as a nest site is evidently more widespread in the south Pennines than in Scotland, although bracken is common there also. Bracken has increased considerably in the south Pennines in the last 200 years (Pearsall 1950, Orford 1973), and is found in areas which were formerly afforested; cows were formerly grazed on the moorlands much more commonly, and destroyed much more bracken than sheep do, trampling as much as they ate (Pearsall 1950).

The huge expanses of *Eriophorum* mosses in the south Pennines are practically devoid of twite, but there are some exceptions to this: in the Rossendale hills twite apparently breed in *Eriophorum* in preference to heather or bilberry at 300-345m (Nuttall 1972); a "few pairs" breed in bilberry or *Eriophorum* above 490m on the Buxton/Leek road in the Peak District, and *Eriophorum* is used along with heather and bilberry on the Cheshire/Derbyshire border (Orford 1973). An unusual situation is found in Rossendale, where the most common nest site is a tussock of *Molinia, Nardus, Eriophorum,* or *Juncus* at 210-395m, in "a recess in moorland grass similair to the situation usually chosen by a meadow pipit"; 18 of 28 nests were in such sites, and 9 of the remaining 10 in heather or bracken (Nuttall 1972). In the Outer Hebrides "It [the Twite] is exceedingly fond of nesting among the loose roots of the bent [marram?] where the wind has shaken away the sand and left long fringes hanging over the edges of the sandhills fronting the Atlantic" (Harvie-Brown and Buckley 1888). A clutch of eggs in the O A J Lee collection (Royal Museums of Scotland, Edinburgh) has the following associated information "built in a little hollow among the bent roots on a bank on the sea-shore (24.5.1899, Quanterness, Orkney).

Records of twite breeding in bushes are practically restricted to the Outer Hebrides, Orkney and Shetland, although a datacard in the Nicholls egg collection (National Museums of Scotland) states "typical in a very dense gorse bush about 2'-6", "so that this may also be an important habitat in Caithness. Saxby (1874) lists as nest bushes elder *Sambucus* spp. to 1.2m, roses *Rosa, Fuchsia magellanica,* honeysuckle *Lonicera periclymenum,* fruit bushes and Juniper *Juniperus communis* in Shetland. This is perhaps surprising considering the absence of native bushes, but it may be that the windswept nature of the land is the cause of the switch to bush nest sites. Datacards with two clutches of Tibetan twite eggs in the Rev. W. Serle collection at the National Museums of Scotland give the nest sites as "low down in a prickly bush" and "in a low thorny bush", and both make reference to the similarity to typical linnet sites. Nests in trees are not unknown. Venables and Venables (1955) list nests at 1.5m in pine *Pinus* spp., 3.6m and 4.2m in larch *Larix* spp., 4.5m in sycamore *Acer pseudoplatanus,* and 1.2m in Sitka spruce *Picea sitchensis.* Orford (1973) states that young conifers were used at two sites in Lancashire, nests at 0.5-1.5m in 1.5-3.0m trees against the trunks. The preference for young conifers as opposed to mature trees or broadleaves shows similarity to the two Tibetan nest sites and the Caithness and juniper sites (see above).

Nests are also known from rocks, cliffs and quarries. Data cards accompanying F Taylor's (Oldham Museum and Royal Museums of Scotland) and J H McNeile's (National Museums of Scotland) eggs show that High Moor Quarry at Saddleworth was a very good locality for twite, nests being found in tufts of heather or grass on the quarry face (4 of 7 nests), under stones or overhangs (2 of 7 nests), and in heather on the quarry floor (1 nest). These are similair to sites recorded by Orford (1973) for the colony in boulder scree at Longendale (Cheshire). Harvie-Brown and MacPherson (1904) record tufts of heather on ledges as being the commonest nest site in the North-West Highlands. Other nest sites are recorded, and include such bizarre sites as the shell of a rotten turnip.

The common factor in the majority of nest sites appears to be that the vegetation is tall and structured so as to provide shelter.

Brown *et al.* (1995), analysing results of a survey of the south Pennines found that the presence of twite was positively correlated with the percentage of cover of tall vegetation and negatively correlated to the percentage of wet flush cover (ie. *Juncus*). Haworth and Thompson (1990) found that in addition to a strong relationship with heather and bracken (especially heather), twite showed avoidance of *Molinia, Eriophorum,* and woodland. Brown *et al.* (1995), analysing Nest Record Cards at the BTO found that of 525 south Pennines nests, 184 (35%) were in heather, 110 (21%) were in *Juncus*, 74 (14%) were in *Eriophorum*, 74 (14%) were in *Molinia* and *Nardus*, 52 (10%) were in bracken, 16 (3%) were in gorse *Ulex* spp. or other ericaccous shrubs, and 15 (3%) were in various other sites.

At any one site the same vegetation type tends to be chosen by all pairs, and this is particularly true of both Midgley and Withens Clough, where two suitable vegetation types (bracken and heather) are used transposably (ie. used at one site but not the other, although both are present on both sites). A datacard for a clutch of 5 eggs from Suffolk reads "Mouth of River Orwell, Suffolk. Nest of coarse grass lined with wool and hair under shelter of sea lavender on dyke side. 22.6.1918". This information is in accord with the nest sites of the birds which colonized Welsh saltmarsh in 1967, and comes from an area used by twite in winter (Lack 1986), and the record should be regarded as notable, if not certain.

Twite select moorland edges for breeding (Haworth and Thompson 1990, Brown *et al.* 1995, Stillman and Brown 1994), and are associated with steep slopes; Haworth and Thompson's correlation between twite distribution and mixtures of *Eriophorum/Empetrum* may reflect the distribution of this vegetation type along the boundary between slopes and plateaux. Brown *et al.* (1995) found that the mean altitude of twite nests in the southern Pennines was 341m asl, which approximates closely to the mean altitude (307m asl) found in this study.

The wide-ranging behaviour shown by twite in this study is typical of Carduelines (Newton 1972). The greatest feeding range published for twite is that of 3 miles given by Gribble (in O'Connor and Shrubb 1986). Although food site selection revolves around the densities of the main foodplants, the distribution of nests in relation to these is puzzling: birds would often fly over patches of vegetation *en route* between the nest and feeding grounds which seemed identical to the vegetation of the nest site, and would likewise fly over apparently suitable fields.

Breeding biology

The displays of the European *Acanthis* finches are very similair (Andrews 1961, Newton 1972) and the differences are reflected in the different plumages of the males: while the linnet and redpolls have the red on the forehead and the breast, the twite has it confined to the rump, and consequently the ground displays give this feature greater emphasis: the redpolls tilt the head back to expose the black chin, the linnet raises the crown feathers, while the male twite exposes the rump (Newton 1972).

Twite are socially monogamous (Newton 1972), and Marler and Mundinger (1975) found that the members of each pair stayed together for the production of second broods, and the two nests of each pair were within 30m in two cases but >400m in another (where the first nest had been destroyed). Williamson (1965) records that on Fair Isle he caught the two members of a pair together on 7 June, 16 July, 1 October, and 11 October, proving that, in this case at least, the pair bond extended until after the breeding season; there was no evidence that the pair bond was reformed in the following year. Marler and Mundinger (1975) found that the flight calls of the two members of a pair were more similar to each other than to those of other birds in the population, and on the basis of the difference in the calls given by a brood of young which were reared apart concluded that the twite, along with the American goldfinch *Carduelis tristis*, pine siskin *C. pinus*, and siskin *C. spinus*, alter their own calls to match those of their mate.

The centre of the male twite's territory is his mate (Marler and Mundinger 1975), and while the birds seemed tolerant of other pairs closely approaching the nest, the male would defend his mate from the advances of other males. As with other Carduelines, there seemed to be a certain degree of coloniality, as evidenced by the cluster of nests to the south of Oxygrains Clough (Rishworth), and the short distances between some pairs on Midgley. Twite were also considered to be semi-colonial with linnets. However, as with other Carduelines, some pairs also nested in isolation.

Both sexes played a part in rearing the young in all observed nests in this study and in that of Marler and Mundinger (1975). This is typical of Carduelines (Newton 1972). However, Williamson (1965) records how, at one nest, the female alone fed the young, visiting every half hour for up to a minute; this female left the nest at 3.15 and 3.30 am on two days, and settled down for the night at 8.45 pm: a 17.5-hour day.

The young are fed on a diet of seeds (eg. Taylor 1935, Newton 1972, Marler and Mundinger 1975), and these can be seen through the very thin skin of the nestling's crop. From the timing of the first and second broods the young of the first brood must subsist on dandelion seeds, while those of the second live on sorrel seeds.

The female removes the faecal sacs until the young are ten days old (Williamson 1965), by which time the young are capable of propelling their faeces to the rear rim of the nest (ie. that edge furthest from the entrance), a habit shared with linnets. Williamson (1965) found that of all faecal sacs removed by the female, a quarter are eaten by her, and we found no faecal sacs around the nest site so it is possible that the adults carry them to the feeding grounds.

The Mayfield probabilities show that breeding success was representative of the south Pennines twite population as a whole. A daily failure rate of 0.0307 for clutches and 0.0177 for broods means that 69% of clutches hatch (assuming a 12 day period), and 76% of broods produce fledglings (assuming a 15 day period), meaning that 51% of clutches produce at least some fledglings. Brown *et al.* (1995) found that there was no difference in terms of survival between first and second broods, and that nest failure rates were lower on heather moor than on grass heath or mixed heath; sample sizes were not large enough to test for these effects in the present study. It is not clear why the density on Midgley should be so much higher than on the other two study areas, but the proportion of meadows to pastures is higher there. The shorter distance between the nesting and feeding grounds may favour settlement on Midgley. Alternatively, as Brown *et al.* (1995) have shown that breeding success is greatest in heather, there may be greater recruitment of young on Midgley if young return to the same moor where they themselves were raised, or the long distance which adults and fledglings have to make to feed on Withens Clough and Rishworth may decrease survival. Information on natal philopatry and site fidelity is clearly of importance in this respect.

Twite commonly nest in association with linnets in the south Pennines, and feed in similar habitats. Mixed colonies may be common in the south Pennines, but are rare elsewhere. In eastern Scotland, where the range of the two species overlaps, twite are more definitely birds of the higher ground and linnets of the lowlands. Mixed colonies are recorded for Texa in the Inner Hebrides (Wild and McWilliam 1926) and the Morrich More, Easter Ross (R. Dennis, pers. comm. to HM). On Texa "the two species inhabit exactly the same area, nesting side by side in similair situations" (Wild and McWilliam 1926), whereas on the Morrich More the two species nest in a mosaic of heather, juniper, and gorse, with twite nesting in the heather and linnets nesting in the gorse.

In 1994 11 linnet nests and nest sites were located in the study areas and 6 others within 1 km of the boundaries of these. Of 6 pairs in the Midgley study area, 4 were in mature heather, one in a gorse bush at the edge of the enclosed land, and one in bilberry above Midgley chapel. Another 5 pairs were found in the Withens Clough area: 3 on the bracken slope to the south of Withens Clough itself, and 2 in bracken in Turvin Clough. Six other pairs were found outside the Withens Clough area: 3 in a clump of gorse above Crib Farm, 2 in bilberry bushes above Wine Tavern Farm, and 1 in long heather on the common land of Aaron Hill. One nest on Midgley Moor was within 10m of nest M6, and another was within 20m of M7; those in Turvin Clough were up to 1 km from the nearest twite nest, but those in Withens Clough itself were close to nest W9. Linnet nests are placed higher up in the branches of the heather than are twite nests, and suffer high mortality rate (Orford 1973).

Given that each species defends a very small territory around the nest site (Newton 1972, Marler and Mundinger 1975), territoriality (sensu Patterson 1980) does not limit the population size of either species, and there is unlikely to be nest site competition between the two species given the different nest sites chosen.

No aggressive interactions were observed between twite and linnets. On 3 June the male of nest W9 was sitting silently on his "song stone" when a male linnet joined him and started singing; there was no animosity between the two birds, which were less than 0.3m apart. When linnets were feeding in a field and a party of twite came along, the linnets were more likely to leave than to stay, and would often sit on a fence wire or a telegraph wire until the twite left. On 23 May, all four members of pairs W8 and W10 came to field 118 (Withens Clough), which had a male and female linnet (also from Turvin Clough) on the wall; when the male linnet started to sing one of the male twite flew up and did a large circular songflight over the singing bird, which then flew off.

Whereas twite favour longer meadows with dandelions or sorrel, linnets were generally found to feed in fields of short turf and would feed in fields which had been cut for hay or silage. Linnets do feed on dandelions, but to a lesser extent than twite, and do not often feed on sorrel, but tend to feed much more on the ground. The linnets which nested in Withens Clough itself flew to Cockhill in parties with twite, but on arrival there they would separate, with the twite feeding in the long meadows and the linnets feeding in cut fields.

Management for twite

The results of this preliminary study suggest that key requirements of breeding twite include the availability of tall vegetation (particularly mature heather or bracken) on unenclosed land, dandelion and sorrel-rich meadows within 1-2 km and a ready supply of both grit and water.

Destruction of nesting habitat by overburning, overgrazing, afforestation or agricultural intensifications or destruction of feeding habitat through "improvement" and reseeding of fields for hay or silage, application of agrochemicals, large scale increase in livestock numbers, or development for housing are all likely to be inimical to twite interests. The change from hay to silage may be of little consequence, as both crops are mown at the same time at present. However, cutting-dates of both are becoming earlier and this is a threat.

We suggest a number of prescriptions which might be applied, with caution, to the management of upland areas in the south Pennines, especially those which support or have recently supported a twite population or are adjacent to such areas.

1. Retain bracken on steep slopes especially if these are within c2km of suitable feeding sites.

2. Cut or spray bracken supporting breeding twite very late in the season (after 1 August).

3. Allow heather to grow longer on steep slopes by burning less frequently (if at all) and reducing grazing by fencing or reducing stocking densities.

4. Retain springs, pools and rills in fields and in roadsides for twite to drink and bathe in.

5. Do not re-seed, plough or apply inorganic fertiliser to enclosed fields within the feeding range of nesting twite.

6. Retain or introduce fields supporting high densities of dandelions and sorrel into the rotation on upland farms adjacent to the unenclosed land. Fields should preferably be within 1 km of the unenclosed bracken or heather covered slopes, but not more than 3 km distant.

7. Do not graze fields too closely and stock with horses or cattle in preference to sheep where possible. They tend to break up the ground more, encouraging weed colonisation.

8. Dandelion and sorrel fields should be left uncut or a border within them should be left uncut, until as late as possible in the season.

9. Avoid topping thistles and sorrel wherever this is possible.

10. Do not apply agrochemicals to fields or to wide road verges in areas used by feeding twite.

11. Retain existing *Molinia* patches and burn these in early spring to attract feeding twite.

12. Retain and encourage weedy field margins, lane verges and farmyards.

Land managers might be encouraged to apply some or all of these prescriptions by appropriately targetted positive management agreements as part of set-aside, ESA, Countryside Stewardship or wildlife enhancement schemes. These prescriptions are also likely to benefit other upland breeding birds.

Further research is needed to confirm and refine these recommendations. In particular, more data is required on nest-site selection and on diet during the breeding season. A study of natal philopatry and site fidelity would be invaluable, and could usefully be combined with a programme to monitor the effects of the introduction of favourable management prescriptions.

Finally, twite are not yet part of any long-term monitoring programme in this country. It is essential that such a programme is introduced, as there is much evidence that the internationally important population is declining.

ACKNOWLEDGEMENTS

The production of this report would not have been possible without the help of many people, and we wish to thank them for their help. Yorkshire Water Plc and many private landowners granted us access to their land. Jack Fearn deserves special mention for his help liaising with landowners. The RAF (Tain) granted HM access to the Morrich More bombing range to study twite.

We received the help of several museums: Jan Dawson (Leicestershire Museums, Leicester), Clem Fisher (Merseyside Museums, Liverpool), Bob McGowan (National Museums of Scotland, Edinburgh), Stephen Moran (Inverness Museum), and Adrian Norris (Leeds Museum) all helped with information on their holdings of eggs and skins, and Adrian Norris also allowed HM to work on John Armitage's notebooks, which contained material on twite. Halifax Library gave HM access to the records of Bellevue weather station. Local naturalists were always willing to talk openly of their experiences of the twite and the natural history of the study areas and we wish to thank, in particular, Nick Carter, Roy Dennis, Hugh Clarke and David McAllister for useful discussions concerning twite. HM is indebted to Norman and Pauline Hitchen (Crib Farm) for their hospitality, and to English Nature for the opportunity to work with the birds. This study was funded in 1994 by English Nature under contract B02 to HM.

REFERENCES

Andrews, R.J. (1961). The displays given by Passerines in courtship and reproductive fighting: a review. *Ibis* 103 (3): 315-348 and 549-579.

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

Bartley, D.D. (1975). Pollen analytical evidence for prehistoric forest clearance in the upland area of west Rishworth, West Yorkshire. *New Phytologist* 74: 375-381.

Batten, L.A., Bibby, C.J., Clement, P., Elliot, G.D. and Porter, R.F. (1990). *Red Data Birds in Britain.* London, Poyser.

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

Bowen, D.Q. (1973). The Pleistocene history of Wales and the Borderland. *Geological Journal* 8: 207-224.

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

Carruthers, R.G. (1947). The secret of the glacial drifts; II: application to Yorkshire. *Proceedings of the Yorkshire Geological Society* 27: 129-172.

Clunas, A.J. and Shorrock, B. (1991). The birds around Malham Tarn. *Naturalist* 116: 73-91.

Curtis, L.F., Courtney, F.M. and Trudgill, S. (1976). *Soils in the British Isles.* London, Longman.

Curtis, W.F. (1992). Bird Report for 1991. Yorkshire Naturalists' Union.

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

Dennis, R.L.H. (1977). *The British Butterflies: their origin and establishment.* Oxon, Classey.

Edwards, W. and Trotter, F.M. (1954). *The Pennines and adjacent areas.* London, HMSO.

Farey, J. (1811-15). *A general view of the agriculture and minerals of Derbyshire.* London, Board of Agriculture.

Gibbons, D.W., Reid, J.D. and Chapman, R.A. (1993). *The new atlas of breeding birds in Britain and Ireland: 1988-1991.* London, Poyser.

Faull, M.L. and Moorhouse, S.A. (eds.) (1981). *West Yorkshire: An Archaeological Survey to AD1500.* West Yorkshire Metropolitan County Council.

Gaunt, G.D. (1974). A radio-carbon date relating to Lake Humber. *Proceedings of the Yorkshire Geological Society* 40: 195-197.

Gelling, M. (1976). The place-names of Berkshire III. *English Place-Name Society* 51: 1973-1974.

Gilligan, A. (1918). Alluvial deposits at Woodlesford and Rothwell Haigh. *Proceedings of the Yorkshire Geological Society* 19: 255-271.

Harrison, C. (1982). *An atlas of the birds of the Western Palaearctic.* London, Collins.

Harvie-Brown, J.A. and Buckley, T.E. (1888). *A Vertebrate Fauna of the Outer Hebrides.* Edinburgh, Douglas.

Harvie-Brown, J.A. and Macpherson H.B. (1904). *A Vertebrate Fauna of the North West Highlands and Skye.* Edinburgh, Douglas.

Haworth, P.F. and Fielding, A. (1988). Conservation and management implications of habitat selection in the Merlin *Falco columbarius* L. in the south Pennines, UK. *Biological Conservation* 46: 247-260.

Haworth, P.F. and 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.

Hewson, R. (1967). The status of the Twite. *Scottish Birds* 1967: 508-509

Hutchinson, C.D. (1988). *Birds in Ireland.* Calton, Poyser.

Johnston, D.H. (1979). Estimating nest success: the Mayfield method and an alternative. *Auk* 96: 651-661.

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

Loyd, L.R.W. (1929). *The Birds of Southeast Devon.* London.

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

Mayfield, H. (1961). Nesting success calculated from exposure. *Wilson Bulletin* 73: 255-261.

Mayfield, H. (1975). Suggestions for calculating nest success. *Wilson Bulletin* 87: 456-466.

Moore, P.D. (1975). Origin of blanket mires. *Nature* 256: 267-269.

Newton, E.M. and Warburton, L. (1984). *The vegetation communities of the uplands of West Yorkshire.* Biological Data Bank, West Yorkshire Region.

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

Nuttall, J. (1972). The status and distribution of the Twite (*Carduelis flavirostris*) in east Lancashire, with some notes on breeding biology. *Naturalist* 23: 140-141.

Oakes, C. (1953). *The Birds of Lancashire.* Edinburgh and London.

O'Connor, R.J. and Shrubb, M. (1986). *Farming and birds.* Cambridge, Cambridge University Press.

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

Parslow, J. (1973). *Breeding Birds in Britain.* Berkhamsted, Poyser.

Patterson, I.J. (1980). Territorial behaviour and the limitation of population density. *Ardea* 68: 53-62.

Pearsall, W.H. (1950). *Mountains and Moorlands.* London, Collins.

Press, M., Ferguson, P. and Lee, J. (1983). 200 years of acid rain. *Naturalist* 108: 125-129.

Radley, J. (1967). A Bronze-Age ring-work on Totley Moor and other Bronze-Age ring-works in the Pennines. *Archaeological Journal* 123: 1-26.

Raistrick, A. (1926a). The glaciation of Wensleydale, Swaledale, and adjoining parts of the Pennines. *Proceedings of the yorkshire Geological Society* 20 (3).

- (1926b). The Postglacial deposits of Airedale, Yorkshire. *Geological Magazine* 63.

- (1927). Periodicity in the glacial retreat in West Yorkshire. *Proceedings of the Yorkshire Geological Society* 21.

- (1929). Some Yorkshire glacial lakes. *Naturalist* 209-212.

- (1934). The correlation of glacial retreat stages across the Pennines. *Proceedings of the Yorkshire Geological Society* 22: 199-214.

Ratcliffe, D.A. and Thompson, D.B.A. (1988). The British uplands: their ecological character and international significance. *In* Usher, M.B. and Thompson, D.B.A. (eds.) *Ecological Change in the Uplands.* 9-36. Oxford, Blackwell Scientific Publications.

Reed, S. (in review). Factors limiting the distribution and population size of Twite (*Carduelis flavirostris)* in the Pennines. In review, The Naturalist.

Saxby, H.L. (1874). *The Birds of Shetland, With Observations on Their Habits Migration and Occasional Appearance.* Edinburgh, S.H.Saxby.

Sharrock, J.T.R. (ed.) (1976). *Atlas of breeding birds in Britain and Ireland.* Tring, British Trust for Ornithology.

Soil Survey of England and Wales (1983). 1: 250,000 Map and key, sheet 1. London, HMSO.

Stillman, R.A. and Brown, A.F. (1994). Population sizes and habitat associations of upland breeding birds in the south Pennines, England. *Biological Conservation* 69: 307-314.

Tallis, J.H. (1964a). Studies on southern Pennine peats, 1. The general pollen record. *Journal of Ecology* 52: 323-331.

- (1964b). Studies on southern Pennine peats, 2. The pattern of erosion. *Journal of Ecology* 52: 333-344.

- (1964c). Studies on southern Pennine peats, 3. The behaviour of *Sphagnum*. *Journal of Ecology* 52: 345-353.

Taylor, F. (1935). Colour of the bill and other notes on the Twite. *British Birds* 29 (4): 102-104.

Thom, V.M. (1986). *Birds in Scotland.* Calton, Poyser.

Vauric, C. (1959). *The birds of the Palaearctic fauna, Volume 1, Passeriformes.* London, Witherby.

Venables, L.S.V. and Venables, U.M. (1955). *Birds and mammals of Shetland.* Edinburgh, Oliver and Boyd.

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

Welsh, S. (1993). *Cragg Vale: A Pennine Valley.* Mytholmroyd, Pennine Desktop Publishing.

Wild, O.H. and McWilliam, J.M. (1926). Field notes on the Twite and the Linnet. *Annals of Scottish Natural History* 1926: 159-160.

Williamson, K. (1965). *Fair Isle and Its Birds.* Edinburgh, Oliver and Boyd.

Williamson, K. and Petersen a Botni, N. (1948). Notes on the ornithology of the Faeroe Islands 1945-47. *D.O.F.T.* 42: 212-215.