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THE MOVEMENTS OF MIGRATORY BIRDS IN PERIODS OF SEVERE COLD WEATHER

by

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A report from the Nature Conservancy Council
to the Council of Europe
under contract 90/84

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SUMMARY

1. Published data on the cold weather movements of European migratory bird populations are reviewed together with information on the mortality rates and condition of birds during severe weather. Particular emphasis is placed on waterfowl and waders since they include the species most likely to need increased protection during cold weather.
2. Cold weather movements can be identified from ringing recoveries, count data, observations of marked birds and radar observations. The interpretation of data from each of these sources is discussed.
3. The importance of obtaining both quantitative data and comparative data from mild winters is emphasised.
4. During the present century severe winters occurred in 1916/17, 1939/40, 1946/47, 1955/56, 1962/63, 1978/79 and 1981/82. The weather conditions in the three most recent cold winters are described briefly.
5. Increased mortality of birds during cold weather is often observed directly and may also be inferred from ringing recoveries. *Tringa totanus*, *Haematopus ostralegus*, *Tadorna tadorna*, *Columba palumbus*, *Turdus iliacus* and *Sturnus vulgaris* are the species most severely affected.
6. Populations of passerine birds and of *Ardea cinerea* decline following severe winters. In contrast, there is little evidence that wader and wildfowl populations decline. This may be due partly to the difficulty of gathering appropriate data for these species.

7. Cold weather mortality usually occurs when birds exhaust their body reserves as a result of food deprivation. Exposure is rarely the underlying cause of mortality.
8. The limited data available for waders suggest that weight lost during cold weather can usually be regained rapidly when conditions improve.
9. During normal winter weather both waders and wildfowl spend a high proportion of daylight hours feeding. There is therefore limited scope for them to increase their food intake to compensate for the increased energy demands imposed by severe weather.
10. Most of the published information on movements of birds during cold weather is qualitative.
11. Movements of *Gaviidae*, *Podicipitidae* and seaducks have been recorded during severe winters, even though their feeding areas do not normally become frozen. A particularly large movement of such species into Britain occurred during the 1978/79 winter.
12. Both diving and dabbling ducks move south and west in response to cold weather. Most of the available data demonstrate movements into France and Spain of birds from Britain and the Low Countries.
13. Cold weather movements of *Anas crecca* have been studied in detail using ringing recoveries. This species moves out of affected areas in response even to brief periods of cold weather.
14. Many geese show patterns of cold weather movements similar to those of ducks. *Branta bernicla* and *Anser albifrons*, for example, move into Britain during cold weather on the continent.
15. Conspicuous southerly and southwesterly movements by inland-feeding wader species, particularly *Vanellus vanellus*, have been recorded. Such species are deprived rapidly of access to their food supplies by severe weather.

16. Cold weather movements by estuarine waders appear to be less marked although some examples have been recorded.

17. Many passerine species undertake cold weather movements. The groups most frequently recorded are *Alaudidae*, *Motacillidae*, *Fringillidae*, *Emberizidae*, *Turdus* species and *Sturnus vulgaris*.

18. Most of the published information on cold weather movements relates to northwest Europe. Most birds move out of the Low Countries and countries further north and east, into France and Iberia.

19. The situation in Britain and Northern Ireland is complex, with some species immigrating from the continent and others which normally winter in Britain, emigrating to France and Iberia. Within Britain, movements to the southwest and Ireland are common.

20. The pattern of cold weather in each cold winter is different, and this gives rise to differences in mortality and movements between such winters.

21. Birds generally remain in an area until the cold weather deprives them of access to food. Thus cold weather movements are most marked in those species whose feeding areas freeze over rapidly, and in populations in northerly and easterly areas which are most severely affected.

22. Knowledge of cold weather movements and mortality could be greatly increased by thorough analysis of existing count data and ringing recoveries.

23. Future field research should aim to improve international count coverage during periods of cold weather. Samples of birds which have moved into areas to the south and west of the cold should be marked so that their origins can be determined.

24. During severe weather hunting and other disturbance should be restricted in areas directly affected by the cold and in "refuge" areas to the south and west. The feasibility of a European system of cold weather hunting bans based on previously agreed meteorological criteria, should be investigated.

INTRODUCTION

Very severe winter weather causes increased mortality of many bird species (Jourdain and Witherby 1918, O'Connor and Cawthorne 1982, Elkins 1983). Some species such as *Vanellus vanellus*, *Turdus* species and *Alauda arvensis* undertake visible cold weather movements and it is apparent from count data that other species, particularly waterfowl, move out of areas affected by severe cold and snow. However, although these general effects are well known, very few quantitative studies of the effects of cold weather on avian mortality and migration patterns have been published.

During recent severe winters voluntary or statutory hunting bans have been introduced in some of the countries affected (Anon. 1963, Batten and Swift 1982, Saint-Gerand 1982). Under some circumstances birds which have emigrated from countries directly affected by the cold may have been subject to increased hunting mortality (Saint-Gerand 1982). The question has therefore arisen as to the extent to which hunting bans are needed in countries or regions to the south and west of those which are affected by severe weather. To answer this we need information on the species and numbers of birds which move out of areas affected by cold and on the regions, and where possible the sites, at which they congregate. It is also necessary to assess the effects of both cold weather and hunting on the mortality rates and population sizes of these species.

Thus the detailed objectives of this review are as follows:

(a) To identify those species and populations which undergo cold weather movements in Europe and to describe where possible their normal wintering areas and the areas to which they move during severe weather. Particular emphasis will be placed on quarry species, and on species whose habitats are likely to be affected by hunting disturbance.

(b) To identify the countries and regions, and where possible the sites, into which birds move during severe weather. Inevitably this section will be biased by the very variable amounts of information available from different areas.

(c) To set out priorities for further research into cold weather movements and mortality, both in terms of analyses of existing data and of future field work.

(d) On the basis of present knowledge to suggest what action could be taken to reduce the hunting mortality of birds fleeing from severe weather.

The review is concerned only with long distance movements of birds in response to cold weather. As a rough guide these are taken as movements of over 50 km. Movements of this type will have the most important implications for the control of hunting, as hunting bans can generally be imposed only on a regional or country-wide basis. Shorter movements generally involve the redistribution of birds between habitats (Davidson 1981), such as movement of waterfowl from frozen inland waters to the sea (MacMillan 1963).

First, I review critically the methods which have been used to study cold weather movements. Much of the available information has been collected incidentally as part of other studies or as casual observations, and such results must be treated with caution. I then consider severe weather patterns, mortality during cold weather, and the effects of severe weather on body condition. This is important information for the understanding of cold weather movements. Two sections summarise the available information on movements. In the first the information is summarised by species groups and in the second by areas into which birds move during cold weather. A short section then summarises the evidence for differences in movement patterns between cold winters. In the discussion I have synthesised the existing data on cold weather movement patterns, and identified current research needs. I conclude the review with some general suggestions on how the hunting of birds which have fled from cold weather might be regulated.

The lack of definitive information on this subject is readily apparent and many of the conclusions presented here will remain tentative until more rigorous data has been collected. There is an urgent need for more research in this area so that conservation proposals can be based on more sound data.

METHODS OF STUDYING COLD WEATHER MOVEMENTS

Verv large cold weather movements are easy to detect, either from direct observations of migrating birds or from counts of birds present in particular areas. However, such observations are rarely sufficiently complete for the origins and destinations of the birds involved to be determined. Ringing recoveries and studies of marked birds can provide information on these aspects, but they are also subiect to difficulties of interpretation. Many cold weather movements may involve a complex redistribution of the population rather than a simple movement of a population from one region to another.

Most of the information on cold weather movements is a by-product of other studies. It is important that the limitations of these data should be realised, and that the best use should be made of them by critical interpretion. Current evidence can be split into five categories: presence of unusual species, unquantified reports of movements and changes in numbers, count data, radar observations, and studies of marked birds. Each of these is considered below.

1 Presence of unusual species

The movement of *Podiceps grisegena* and other waterbirds into Britain during the 1978/79 winter (Chandler 1981) and that of *Cygnus olor* into Spain during the 1962/63 winter (Bernis 1964) are examples of this type of information. These data are the simplest to interpret, since observations of species which do not normally occur in an area clearly indicate that a movement has taken place. Occurrences of such species may also act as "indicators" that abnormal increases in the numbers of other species which are normally present in an area, result from a movement from elsewhere.

2 Unquantified reports of movements and changes in numbers

Much of the literature consists of observations of this kind. For example differences between the movements of *Vanellus vanellus*, *Turdus pilaris*, *Turdus iliacus* and *Alauda arvensis* in Britain during the 1962/63 winter have been documented by combining large numbers of casual records (Dobinson and Richards 1964). Such data must be interpreted with great caution. Observations of visible migration certainly indicate that movements are taking place, but it is usually impossible to know the origin or destination of the birds. Some indication may be obtained from the direction of movement, and this is usually recorded. Failure to observe migrating birds cannot be interpreted as a lack of movement, as many species migrate at night or at too high an altitude to be readily observed.

Loss of birds from an area is always very difficult to interpret. It can be due to mortality, or to a redistribution of birds into habitats nearby. Mortality can rarely be ruled out, although it is less likely if the numbers of birds in an area increase again after the cold weather. Thorough coverage can largely rule out local movements, but it is rarely clear if this has been achieved. Immigration of birds into an area implies some form of movement, but the birds may not have moved very far.

3 Count data

Systematic count data provide better opportunities for investigating the movements of bird populations in response to cold weather. During January 1979 large numbers of wildfowl moved into France, and 840 000 were counted compared with an average of 400 000 between 1967 and 1976 (Saint-Gerand 1982). During the cold winters of both 1978/79 and 1981/82 most of the Spitzbergen population of *Branta bernicla hrota*, which normally winter in Denmark, moved to Lindisfarne in northeast England, where only a small proportion of this population normally winters (Salmon 1982).

The problems of obtaining accurate counts are beyond the scope of this review. Although these problems may be considerable, most recent counts of waders and wildfowl are sufficiently accurate to detect major population shifts. Most of the difficulties of interpretation described above also apply to count data. For these reasons simultaneous counts over whole regions and countries are likely to provide the most useful information. Co-ordinated counts of waders and wildfowl over the whole of Europe are now organised each winter, but they are not frequent enough to provide detailed information on cold weather movements.

As many count programmes are continued over a series of years, and most are ongoing, it is possible to compare results from severe winters with those from other years, and to examine the variation in population distributions in different mild winters. Where sufficient counts have been carried out it is also possible to examine the situation before, during and after severe weather. Thus, systematic count data allow changes taking place in different regions to be related to each other, and to patterns during control periods of mild weather. Unfortunately detailed analyses of this type have yet to be carried out. Appropriate data exist, although coverage and frequency of counts is inevitably less than ideal. The published analyses are generally on a national basis, and lack systematic comparisons with other years.

Counts are also needed in order to assess the relative importance of the sites to which birds move during cold weather. The cataloguing of sites is beyond the scope of a review of this kind, but some lists of important wetland sites in Europe are already available (Scott 1980, Osieck and Morzer-Bruyns 1981). Where a site contains more than 1% of the wintering population a species in the country under consideration, it is considered as of "National importance" for that species. Where it contains 1% of the west European population it is considered to be of "International importance" (Prater 1981). The criteria given by Prater are based on counts made during mild winters. Major population shifts during severe winters could alter the relative importance of sites at those times. It is important to protect the habitats which a species needs for survival during both normal and severe winters.

4 Radar

Radar is very valuable for detecting movements of birds at night and for studying the volume and direction of movements over relatively large areas. However, it is usually impossible to identify species, or to estimate numbers precisely, using records from the types of radar used for most studies of bird migration.

Radar studies of migration across the southern North Sea and English Channel have detected cold weather movements, mainly involving thrushes (*Turdus* species) and *Vanellus vanellus*. They indicate that movements of *V.vanellus* in particular, are common during most winters, and occur in response to short periods of cold weather. The proximate factor initiating movements appears to be wind direction rather than temperature (Eastwood 1967, Lack and Eastwood 1962).

Little use has been made of radar to study cold weather movements, and there is undoubtedly much scope for further exploitation of this technique, particularly in conjunction with count data on the ground. Some attempt was made to integrate radar results with other observations from the 1962/63 winter (Dobinson and Richards 1964).

5 Studies of marked birds

Recoveries of ringed birds can provide much useful information on cold weather movements. Early studies concentrated on reporting unusual records (e.g. Spencer 1964), and often gave no indication of the proportion of the population which may have been involved. More recent studies have compared the distributions of recoveries from particular populations during severe and mild winters (Ogilvie 1981,1982,1983). Most ringing recoveries are reported by members of the public and, for wildfowl and other quarry species, most are from hunters. The number of recoveries from a particular area is dependent on the number of birds present, their mortality rate while they are there and the proportion of dead, ringed birds which are "found" and reported (the reporting rate). Because both mortality rates and reporting rates are affected by cold weather (e.g. by hunting bans), precise estimates of the regional distribution of particular populations cannot be made. However, by interpreting the recovery data in the light of known biases of this kind, it is possible to reach useful conclusions concerning the redistribution of populations during severe weather. Most analyses have considered the number of recoveries from each area as a percentage of the total number of recoveries. An alternative method is to consider the percentage of ringed birds potentially at risk which are recovered in each region during mild and severe weather. This has the advantage that the figures for the different regions are independent. An analysis of this type has been carried out for *Anas platyrhynchos* reared in captivity (Harrison and Wardell 1964), but not for wild populations.

Observations of individually colour marked birds can also contribute to the understanding of cold weather movements. For example, on the Tees estuary, certain individual *Pluvialis squatarola* are only present during cold winters (Townshend 1982). The movements of individual birds can rarely be followed by these methods. However, in early February 1978 18 marked *Cygnus bewickii* which had wintered at Slimbridge were recorded in North Germany. Severe weather followed and 14 of the individually marked swans were recorded back at Slimbridge, and another was seen on the Ouse Washes (Evans 1979).

In this section I have outlined the various types of evidence for cold weather movements and indicated their main limitations. Four important conclusions arise. First, quantitative studies are always preferable. Secondly, it is important to have "control" data from periods of mild weather. Thirdly studies should aim to cover the whole winter range of the species under consideration and not just individual countries. Unfortunately this has rarely been the case, although recent international co-operation in both counting (I.W.R.B.) and ringing (EURING) studies is a welcome development. Finally, conclusions will always be stronger if the are based on more than one type of evidence.

COLD WEATHER PATTERNS

In northwest Europe the winter weather is milder and windier than that in central Eurasia, due to the warming effects of the westerly and southwesterly winds from the Atlantic. Thus while central Eurasia experiences a continental climate with prolonged periods of freezing weather and snow during the winter, northwest Europe rarely experiences continued freezing and snow cover for more than a few days (Elkins 1983).

There have however, been a number of winters during the present century when winter conditions in northwest Europe have been markedly more severe than usual, particularly in 1916/17, 1939/40, 1946/47, 1955/56, 1962/63, 1978/79, and in 1981/82 (Jourdain and Witherby 1918, Ticehurst and Witherby 1940, Ticehurst and Hartley 1948, Geroudet 1956, Piechocki 1957, Dobinson and Richards 1964, Cawthorne and Marchant 1980, Chandler 1981, O'Connor *et al.* 1982). The winters of 1953/54 and 1961/62 were also colder than usual (Ogilvie 1981), but were generally not as severe as the seven winters listed above. Most of the data on the effects of such winters on bird populations have been gathered since 1960, and only weather conditions for severe winters since 1960 are discussed in detail below.

Although very severe winters are only one extreme of a continuum, conditions during the winters listed above were so much more severe than the others during this period that their effects on bird life were noticably abnormal, even to the casual observer. Most of the available data on cold weather movements comes from field observations carried out during these winters but similar effects do take place on a smaller scale in other winters. The mortality of first year *Ardea cinerea* in Britain is correlated with winter temperatures over the range of values experienced in both mild and severe winters (North and Morgan 1979) and small cold weather movements of *Anas crecca* often take place in response to relatively short periods of cold weather (Ogilvie 1983).

Severe winter conditions in northwest Europe generally result from a reversal of the prevailing winds from southwesterly to directions between northeast and southeast. Such airflows from over the cold continental landmass of Eurasia lower temperatures in northwest Europe. They usually result from a blocking high centred over Scandinavia and the Norwegian sea, which confines ameliorating depressions to the south and allows the effects of the prevailing anticyclonic conditions over central Eurasia to become dominant (Elkins 1983).

Two sets of conditions give rise to heavy snow falls. First, the inversion of moist, warm air from southwesterly depressions over cold air from a blocking high causes precipitation to fall as snow. The second situation applies mainly to Britain, and is the result of unstable northerly or northeasterly winds associated with a depression which has travelled east and stagnated over northern Europe. Cold winds following the depression pick up moisture over the North Sea and this falls in Britain as heavy snow. These situations are described in detail by Elkins (1983).

Weather conditions in each of the four cold winters since 1960 are now described briefly. Data on the state of the ground at 13 weather stations around the British coast have been used to measure the severity of winter weather in relation to hunting bans (Batten and Swift 1982), and these results are included below.

1 Winter 1961/62

Throughout the winter temperatures were below average, but the main feature was a cold spell of about three weeks in late December and early January (Dobinson and Richards 1964). More than half of the 13 British weather stations recorded the ground as frozen from 18 December to 5 January, except for a gap of two days on 22 and 23 December (Batten and Swift 1982). The cold weather did not, however, penetrate far into France (Ogilvie 1981).

2 Winter 1962/63

This was the coldest winter in central and southern England since 1740 (Booth 1968), and the snowiest for 150 years (Lamb 1963). Very severe cold weather and snow affected northwest Europe for a period of about 10 weeks from late December 1962 to early March 1963. The snow-bound area extended further west and south than usual to cover most of Britain (but not Ireland) and eastern and central France. To a lesser extent the snow limit also extended south through northern Italy, Yugoslavia, Greece and countries around the Black sea. In Britain December temperatures were as much as 4°C below average, while those in January and February were as much as 7°C below average (Dobinson and Richards 1964). Data from the 13 sample weather stations showed that over half of them recorded the ground as frozen for a continuous period of 74 days, from 21 December to 4 March.

3 Winter 1978/79

The cold weather of 1978/79 lasted almost as long as in 1962/63, but its effects were less severe because the freezing periods were interspersed with brief periods of slightly milder weather. From late December onwards freezing conditions and snow affected Denmark, West Germany, the Netherlands and Britain and extended south into most of

France by early January. In February the weather in France became milder, but in countries further north freezing conditions continued into March. Over half of the 13 British weather stations reported frozen ground on 49 of the 65 days between 17 December and 19 February. The longest continuous period of such conditions was 12 days between 23 January and 3 February (Batten and Swift 1982).

4 Winter 1981/82

Detailed descriptions of this winter have not yet appeared in the ornithological literature. In Britain there were two main periods of freezing weather from 6 to 26 December and from 5 to 16 January (Clark 1982). Over half of the 13 British weather stations recorded the ground as frozen for a continuous period of 21 days in December, and for a continuous period of 12 days in January. In contrast to the situation in 1978/79, strong winds were rare. For example at Hartlepool, Co. Durham, there were 15 days of freezing weather with wind speeds over 25 knots in 1978/79 but there were no such days in 1981/82 (Davidson 1982). During both periods exceptionally cold conditions were recorded with very hard frosts.

Frozen ground and snow cover are important factors influencing the ability of birds to feed. Freezing of large areas of freshwater and of estuarine mud flats has important effects on waders and wildfowl, while glazing of vegetation affects the survival of woodland passerines. These factors are not routinely recorded by meteorologists, but can to some extent be inferred from data on temperatures and state of ground. It has recently been shown that wind speeds can have an important influence on the effect of cold weather on waders (Dugan *et al.* 1981).

COLD WEATHER MORTALITY

Periods of severe cold weather undoubtedly result in increased mortality relative to equivalent periods in mild winters. Evidence for this increase in mortality comes mainly from counts of birds found dead in particular areas and from reports of ringed birds found dead by members of the public. Counts of live birds made during severe weather can also indicate the scale of the mortality but, except for very sedentary species, the interpretation of such data is complicated by cold weather movements.

Increases in winter mortality do not necessarily lead to increases in mortality for the whole year, and certainly do not always cause declines in the size of breeding populations. It is generally agreed that most bird populations are limited by density dependent processes, so that increased mortality at one stage in the annual cycle may be compensated by decreased mortality later in the year, or by increased recruitment of young birds to the breeding population (e.g. Krebs 1970, Potts 1979, Hill 1984). Studies in the United States have shown that hunting of *Anas platrhynchos* does not increase their annual mortality rate over that expected in unhunted populations (Anderson and Burnham 1976), although this may not be true for species such as diving ducks which have lower mortality rates (Patterson 1979). Similarly studies of attempts to control *Columba palumbus* and *Corvus frugilegus* in Britain by culling have indicated that killing even relatively large numbers of birds is insufficient to reduce population levels (Murton 1966, Dunnet and Patterson 1968).

1 Direct mortality during cold weather

Three species from estuarine habitats, *Tringa totanus, Haematopus ostralegus and Tadorna tadorna* are particularly vulnerable to cold weather mortality. Counts of dead birds on the north shore of the Wash during the 1962/63 winter showed that the three species most commonly found dead were *T. totanus* (144), *Calidris canutus* (104) and *T. tadorna* (58) (Pilcher 1964). Most *H. ostralegus* left the Wash at the start of the cold weather, while the *C. canutus* found dead were a very small percentage of the large numbers present. On the Ythan estuary in 1978/79, 55 *T. totanus* and 38 *H. ostralegus* were found dead, these figures representing about 7% of the December count totals (Baillie 1980). High mortality of *H. ostralegus* has also been recorded on the Ythan in previous severe winters (Heppleston 1971). An even larger mortality of *T. totanus* and *H. ostralegus* was recorded from the Montrose basin during the 1981/82 winter, with 341 dead *T. totanus* and 104 dead *H. ostralegus* being found (Clark 1982). These figures are thought to be underestimates of the number of birds which died, as some corpses are likely to have been washed out to sea. The *T. totanus* figure represents between 17% and 23% of the population of 1500-2000 *T. totanus* which winter on the Montrose Basin in mild winters. Considerable though less marked mortality of these species occurred on other estuaries during the 1981/82 winter (Clark 1982). The 73 *T.tadorna* found dead on Sheppey during the 1962/63 winter represented about 5% of the local population (Hori 1964). Other studies also give evidence of high cold weather mortality of these species (O'Connor and Cawthorne 1982, Swennen and Duiven 1983, Boyd 1964, Dobinson and Richards 1964, Ticehurst and Witherby 1940).

The above percentages of populations of these species which were killed by the cold must be considered in the context of the normal mortality rates of these species. Annual mortality of adult *H. ostralegus* is about 10% (Goss-Custard *et al.* 1982, Safriel *et al.* 1984), while that of adult *T. tadorna* is about 11% (Patterson 1982). However interpretation of the data is further complicated because disproportionate numbers of the birds killed by cold weather are probably juveniles. This has been shown for *T. totanus* and *H. ostralegus* on the Ythan (Heppleston 1971, Baillie 1980). Annual mortality rates of young birds are usually higher than those of adults, but reliable estimates have not been made for these species.

Dobinson and Richards (1964) used a questionaire survey to assemble a list of 15 508 birds which were found dead in Britain during the 1962/63 winter. The wader species with the largest numbers of corpses found were *Vanellus vanellus* (883), *H. ostralegus* (780), *T.totanus* (621), *Scolopax rusticola* (609) and *Numenius arquata* (516). Such figures are difficult to interpret because of the lack of similar data from mild winters, and of count data on the relative sizes of the populations. Nevertheless, all these species are at least partly dependent on inland feeding during the winter. During freezing weather inland sites are unsuitable for feeding even in the absence of snow cover because birds cannot penetrate frozen soil with their bills. Most waders achieve high mid-winter weights as an energy reserve against food shortage (page 27), but *T.totanus* wintering in east England are unable to maintain high reserves at this time (Davidson 1982b).

Corresponding evidence of waterfowl mortality is scarcer, perhaps because casual searches for corpses usually take place along tide lines. The only waterfowl species for which Dobinson and Richards (1964) reported over 200 individuals found dead were *T. tadorna* (710), *Fulica atra* (604), *Gallinula chloropus* (297) and *Anas penelope* (207). Two other species with large numbers of casualties were *Podiceps cristatus* (196) and *Melanitta nigra* (165). The numbers of wildfowl found dead in Britain during the 1962/63 winter generally reflected the relative abundance of the species, rather than differential mortality (Boyd 1964). More ringed *Cygnus olor* than usual were recovered dead during the 1962/63 winter, when the survival rate of all age classes combined was estimated as 54%, against a six-year average of 62% (Ogilvie 1967).

Recoveries of ducks also provide evidence of increased mortality during cold weather, but in this case the immediate cause of most of the mortality is shooting. Ogilvie (1981) showed that the percentage of *Anas crecca* recoveries in western France increased in each of the four winters 1953/54, 1955/56, 1961/62, and 1962/63, due to increased hunting of birds escaping cold weather in Britain and the Netherlands. Mortality of British *A. platyrynchos* and *A. crecca* was estimated to increase by 10 to 15% during the 1978/79 winter (Ogilvie 1982). Casual observations support the view that hunting mortality in France is greatly increased when wildfowl migrate there in response to severe weather (Raffin and Lefeuvre 1982).

Mortality of passerines and other land birds is even more difficult to document directly, as the corpses of small birds usually disappear quickly after death. Three species stand out in Dobinson and Richards' (1964) list as having died in large numbers: *Columba palumbus* (3 749), *Turdus iliacus* (775) and *Sturnus vulgaris* (1 333). Better evidence of increased mortality of such species comes from ringing recoveries, because numbers of deaths can be related to patterns of mortality in other years and, potentially, to numbers of ringed birds at risk. During January and February 1979 increases of over 50% in the recovery totals compared with the previous mild winter were recorded for *Motacilla alba*, *Troglodytes troglodytes* and *Sturnus vulgaris* while increases of between 20% and 50% were recorded for *Prunella modularis*, *Erithacus rubecula*, *Turdus merula*, *Turdus philomelos* and *Emberiza schoeniclus* (Cawthorne and Marchant 1980). During the 1980/81 winter large increases in the recovery totals for *M. alba*, *E. schoeniclus*, *T. philomelos*, *T. troglodytes* and *E. rubecula* were recorded (O'Connor and Cawthorne 1982).

Thus conspicuous mortality of many species takes place in cold weather. There is scope for more rigorous recording in future, and particularly for the collection of control data from mild seasons. More detailed analyses of the existing ringing recovery data would produce new and useful information.

2 Changes in population size

Many of the ducks wintering in northwest Europe breed in Iceland, Scandinavia and northern Russia (Cramp and Simmons 1977) where there are insufficient observers to monitor the breeding populations. Numbers wintering in Europe are counted regularly, but indices of changes in winter numbers have not yet been published. These will give some indication of whether cold weather mortality severely depresses duck populations. It will be necessary to compare numbers in winters before and after cold ones, as movements of birds make numbers counted during cold winters very difficult to interpret. Such measures are complicated by the incorporation of breeding success in the summer following the cold winter. For some high arctic breeding species spring weather conditions in the arctic can cause very large fluctuations in breeding success, and hence in numbers returning the following autumn (e.g. *Branta bernicla*, Ogilvie and St.Joseph 1976). For *Anas platyrhynchos* the numbers are also complicated by the large number of birds which are artificially reared and released.

After the 1962/63 cold winter, observations suggested that British breeding duck populations were not greatly reduced (Allen and Rutter 1964, Boyd and King 1964) although numbers of *Tadorna tadorna* breeding on the Ythan estuary in northeast Scotland declined by 20% (Young 1964). Ogilvie (1967) recorded a decline of 25% in a winter index of *Cygnus olor* numbers between 1960-61 and 1964-65, which he attributed to the cold winters of 1961/62 and 1962/63. However the decline appears to have started before then, and might have been caused by other factors.

Population changes for a small number of water birds in Britain are calculated from the Waterways Bird Survey organised by the British Trust for Ornithology. This showed that *Gallinula chloropus* populations declined by 16% between 1978 and 1979 but *C.olor*, *A.platyrhynchos* and *Fulica atra* were unaffected (Marchant and Hyde 1980). Similarly, after the 1981/82 winter, significant declines of 21% for *C.olor* and 18% for *G.chloropus* were recorded, but neither *A.platyrhynchos* or *F.atra* populations changed significantly (Taylor and Marchant 1983).

Few census studies took place prior to the 1960s, but a sample census of *Ardea cinerea* nesting in England and Wales has been carried out since 1928. Results up to 1977 have been published (Stafford 1971, Reynolds 1974, Reynolds 1979). Declines of 22% after the winter of 1939/40, 34% after the winter of 1946/47 and 52% after the winters of 1961/62 and 1962/63 were recorded. Population recovery times following these declines were about four, three and seven years respectively. The slower recovery after the 1962/63 crash may have been due partly to the effects of toxic chemicals (Reynolds 1979).

Few long term censuses of breeding waders have been carried out, because, like wildfowl, many of them breed in relatively inaccessible arctic areas. Small numbers of breeding waders are included in British census plots for the Common Birds Census and the Waterways Bird Survey. These limited data showed a 56% decline in breeding *Vanellus vanellus* following the 1962/63 winter (Bailey 1967), but no decline following the 1978/79 or 1981/82 winters (Marchant and Hyde 1980, Marchant 1983). The recovery time following the 1962/63 decline was about seven years, but the data are difficult to interpret as the pre-1963 population level has not been regained subsequently. The Waterways Bird Survey provided population indices for *Haematopus ostralegus*, *Tringa totanus*, *Tringa hypoleucos*, *Gallinago gallinago* and *Numenius arquata* between 1978 and 1979, and for *H.ostralegus*, *V.vanellus*, *T.totanus* and *T.hypoleuchos* between 1981 and 1982 (Marchant and Hyde 1980, Taylor and Marchant 1983). The only significant change was an increase of 18% in *T.totanus* numbers between 1981 and 1982. Declines between 1978 and 1979 of 18% for *T.totanus* and 24% for *G.gallinago* were not significant. These data are currently the best available, but they are based on small numbers of pairs, and probably on sub-optimal habitats for these species.

Censuses of wintering waders are more complete, but they suffer the same limitations as for wildfowl. Annual indices of January numbers of British waders are given for 1973 to 1982 by Marchant (1982), and I have also examined the index data for 1983 (M.Moser pers. comm.). The index data covers sixteen species, *Haematopus ostralegus*, *Charadrius hiaticula*, *Pluvialis apricaria*, *P. squatarola*, *Vanellus vanellus*, *Calidris canutus*, *C. alba*, *C. alpina*, *Philomachus pugnax*, *Limosa limosa*, *L. lapponica*, *Numenius arquata*, *Tringa erythrops*, *T. nebularia* and *Arenaria interpres*. Species showing a marked decrease between 1978 and 1980 were *P.apricaria* (64%), *V.vanellus* (16%), *P.pugnax* (43%) and *T.erythrops* (58%). The first two species are vulnerable to freezing of their inland feeding areas but as only a small part of their populations is found on estuaries, these data must be treated with caution. Changes in numbers counted could reflect changes in the proportion of the population using estuaries rather than changes in total population size. Both *P.pugnax* and *T.erythrops* increased by over 100% between 1981 and 1983, and these large fluctuations may simply be due to the small size of the populations involved. Between 1981 and 1983 there was again a decrease in

P.apricaria (-20%), but *V.vanellus* increased by 34%. Decreases were also recorded for *H.ostralegus* (-13%), *C.canutus* (-30%) and *T.totanus* (-14%). *H.ostralegus* and *T.totanus* are both conspicuously vulnerable to cold weather mortality (above). *C.canutus* are highly mobile and difficult to census, and the change may represent a change in distribution rather than a real decrease. January indices calculated from all European wader counts between 1973 and 1981, provide no evidence of decreases between 1978 and 1980, as a result of the 1978/79 winter (Prater 1981).

Census data for passerines are more complete than for other groups of birds, at least from Britain, where national population indices for many species have been produced since the early 1960's. Data on population decreases following three recent severe winters are given in Table 1. Information from farmland, woodland and waterways plots is tabulated separately. The Common Birds Census began in 1962 so less reliance should be placed on the 1962-1963 changes. The maximum decrease recorded was 64% for *Alcedo atthis* between 1981 and 1982, followed by a 47% decrease both for farmland *Certhia familiaris* and woodland *Troglodytes troglodytes* between 1978 and 1979. Smaller species appear to suffer bigger decreases than large ones, and this has been demonstrated statistically for changes between 1978 and 1979 (Cawthorne and Marchant 1980).

There are some notable differences between the population changes recorded following the 1978/79 and the 1981/82 winters. For example, *Regulus regulus*, *Aegithalos caudatus* and *C.familiaris* all decreased in 1979 but not in 1982. It appears that glazing of tree trunks during the 1978/79 winter made foraging difficult for arboreal insectivores, and the strong winds which were prevalent during that winter may also have contributed to the foraging difficulties and energy loss for these small birds. In 1981/82 the long period of frozen ground affected seed eaters and other ground feeding species most severely (Marchant 1983).

Population recovery times following such cold weather are best examined from the increases recorded following the 1962/63 cold winter. *T.troglodytes*, *Turdus philomelos* and *Turdus viscivorus* which had decreased by over 50% took about four years to recover, while many of the species which had experienced smaller decreases took only one year. Waterways data indicate that *Motacilla alba* and *A.atthis* only took one year to recover from their 1978/79 population decreases, but *Motacilla cinerea* had shown no signs of recovery before the population was further reduced by the 1981/82 winter three years later (Taylor and Marchant 1983). *A.atthis* and *M.cinerea* populations increased in 1983, but not enough to regain their pre-1982 population levels. For many species, decreases following cold winters represent one extreme of a continuous relationship between breeding population size and weather conditions during the preceding winter. Using census data gathered between 1962 and 1980 it has been shown that for 10 species there is a significant correlation between breeding population size and temperatures during the previous winter (O'Connor *et al.* 1982).

To summarise, there is evidence for population decreases in only a few species of wildfowl and waders following cold winters, but this may be partly due to difficulty in gathering appropriate data. There is good evidence that cold winters have caused population decreases in a wide range of passerine species, and that there are differences between winters and between species in the magnitude of these decreases. Passerine populations probably take between one and four years to recover from even very large population crashes. However populations of waders and wildfowl might take longer to recover if they underwent such decreases, as they generally have lower reproductive rates and higher adult survival.

CONDITION OF BIRDS DURING COLD WEATHER

Most birds dying during cold weather die of starvation rather than of exposure. Weights of birds found dead during cold weather are generally well below the average for the species and time of year (Ash 1964, Dobinson and Richards 1964). *Haematopus ostralegus* which died in the Waddensee during a cold spell in January 1976 weighed 38% less than those caught for ringing at the same time in other winters (Swennen and Duiven 1983). However, apart from these general observations there is very little information on the condition of birds which have died of starvation. *Anser albifrons* which had starved to death during the winter of 1962/63 weighed 42% less than expected. They had very little subcutaneous fat and their livers and pectoral muscles were reduced (Beer and Boyd 1963). Similarly, *Tringa totanus* and *H.ostralegus* which died in east Scotland during the winters of 1978/79 and 1981/82 had used up nearly all their fat and protein reserves. The *T.totanus* contained less than 1% fat compared with 10.75% for a sample of birds collected during mild weather (Davidson and Evans 1982). Similar results were obtained for *Vanellus vanellus* and *H.ostralegus* which died of starvation in Sweden during a cold spell in the spring of 1966. In both species, fat levels of dead birds were over 90% lower than those of controls collected during a mild spring (Marcstrom and Mascher 1979).

Many species of birds increase in weight during autumn, reaching a mid-winter peak in December or January, and then declining until the spring (Newton 1968, Evans 1969, O'Connor 1972, Owen and Cook 1977, Baillie 1978, Pienkowski *et al.* 1979). Thus at the onset of cold weather most birds have some energy reserves which will enable them to survive a few days when feeding is reduced to the extent that energy intake does not balance expenditure. It is thought that the weight cycle of such birds is regulated so that they carry most reserves when the probability of needing them is greatest. The decline in late winter takes place when the cost of carrying extra reserves outweighs the chance of needing them during a late cold spell. An alternative explanation of the weight cycle is that body reserves cannot be maintained in the face of food shortage in late winter.

These alternatives are discussed in detail by Pienkowski *et al.* 1979, who point out that they can be tested by examining weight patterns following late winter cold spells. The "regulation hypothesis" predicts that weight will be regained following a decline during cold weather, while the "food shortage" hypothesis predicts that it will not. Some evidence that *Calidris alpina* can regain weight following a cold spell is given by Pienkowski *et al.*, and more conclusive evidence for *Pluvialis squatarola* on the Tees estuary in northeast England has since been obtained by Dugan *et al.* (1981). A mean weight of 265 g in December 1978 fell to 137 g on 12 January 1979 during a period of cold weather, but mean weights had risen to 238 g by 28 January 1979. Observations of colour marked individuals showed that this was not due to mortality of light birds.

Further support for the view that waders regulate their body reserves over the winter period comes from observations on captive *C.alpina* which followed weight cycles similar to those observed in the wild (Clark 1983). These birds were kept in outdoor aviaries and fed *ad libitum*. A similar experiment with captive *Calidris canutus* did not produce a weight decline in late winter, but the birds were kept in an indoor aviary and this very artificial situation may have interfered with their normal weight regulation (Goss-Custard *et al.* 1981).

The *P.squatarola* mentioned above appear to have regained their normal winter weights from a value close to the minimum survival weight over a period of not more than 16 days. Few other data on the time needed to regain weight during cold weather are available. A starved *A.albifrons* taken into captivity during the 1962/63 winter took about 12 days to regain weight (Beer and Boyd 1963).

Evidence that some waders and wildfowl have only limited ability to cope with increased energy demands comes from studies of time bugets and feeding biology. On the Wash, eastern England, *C.alpina* and *C.canutus* spend over 95% of their time feeding during daylight hours in mid-winter (Goss-Custard *et al.* 1977). Larger species spend slightly less time, the figures being about 90% for *T.totanus*, 80% for *P.squatarola* and *Limosa lapponica* and 60% for *H.ostralegus* and *Numenius arquata*. The prey biomass available to most of these species also declines over the course of the winter, in many cases by over 50%. Thus, at least the smaller wader species probably have little ability to increase their prey intake in the event of cold weather, even if conditions remain suitable for feeding. One difficulty with interpreting data of this kind is that very little is known about night-time feeding by these species. Most of the limited data available suggest that it does take place, but that birds are usually less successful than during the day. However a recent study of *P.squatarola* on the Tees estuary has suggested that some birds may greatly increase their intake rates at night. These birds feed in localities away from their day-time feeding areas and exploit ragworms which are active on the surface of wet mud at night (Dugan 1981). More work is needed to evaluate the importance of night-time feeding for waders.

Wildfowl also spend most of their time feeding during the winter. On the Ouse Washes, Cambridgeshire, *Anas penelope* spend between 68% and 81% of daylight hours feeding (von Kanel 1981). Limited observations in March suggested that 48% of the night was spent feeding, compared with 81% of the day. In an independent study in the same area Owen and Thomas (1979) found that *A.penelope* spent 91% of daylight hours feeding. *Gallinula chloropus*, *Anas strepera* and *Fulica atra* wintering in the Ouse washes also spent over 90% of daylight hours feeding (Thomas 1982). *Anas clypeata*, *Anas crecca*, *Anas platyrynchos* and *Anas acuta* spent less time feeding but the exact percentage of the day spent feeding is not easily estimated from the graphs of percent of birds feeding against time of day, presented by Thomas (*loc cit.*). On the Ouse Washes most of these ducks are primarily diurnal feeders. In contrast, *Anas crecca* in the Carmargue do 70% of their feeding at night because of threats from aerial predators by day (Tamisier 1972).

Geese appear to spend an even higher proportion of the day feeding. This may be because they often attend roosts at night, and thus their feeding activities are largely restricted to daylight hours. At Slimbridge, Gloucestershire, *A.albifrons* spend over 90% of daylight hours feeding (Owen 1972), while in the Netherlands *Branta leucopsis* spend 77% to 86% of their time feeding (Ebbinge *et al.* 1975). The condition of geese declines between late autumn and late January or February due to a combination of declining food quality and short daylight hours (Owen 1980). Feeding conditions, and hence the condition of the birds, improve when grass growth starts in early spring. Thus the time when cold weather is most likely to occur coincides with the time when geese are most likely to have difficulty in meeting their energy requirements.

COLD WEATHER MOVEMENTS IN RELATION TO TAXONOMIC AND ECOLOGICAL GROUPS

1 Divers, grebes and sea-ducks

Most species of this group winter mainly in marine habitats. In northwest Europe cold weather movements result primarily from indirect effects such as turbulence or wave action preventing feeding, rather than from freezing of the feeding areas. Most of these species frequent areas where they are not readily hunted, and thus are less at risk from hunting and disturbance than inland species. For the same reasons they are difficult to census, and the best evidence for cold weather movements comes from the 1978/79 winter when a large movement into Britain resulted in many records from inland waters.

This movement involved *Gavia arctica*, *Gavia stellata*, *Podiceps grisegena*, *Podiceps auritus*, *Podiceps nigricollis*, *Melanitta fusca*, *Mergus serrator*, *Mergus merganser* and *Mergus albellus* (Chandler 1981). Several different influxes occurred, all probably involving birds from the eastern North Sea. The divers, grebes and scoters occur mainly on the sea, but *M.serrator* are primarily estuarine feeders and *M.merganser* and *M.albellus* usually frequent large areas of fresh water in winter. *M.albellus* are reluctant to leave their normal wintering sites until complete freezing of the water surface takes place, continuing to feed under the ice as long as holes remain to give access (Cramp and Simmons 1977).

Limited evidence suggests that influxes of these species into Britain have taken place in other severe winters. During the 1962/63 winter increased numbers of *G.stellata* were recorded in Dorset (Ash 1964), while increased numbers of *M.merganser* were recorded at several sites in Britain, including over 300 at Walton Reservoir, Surrey (Dobinson and Richards 1964, Ash 1964). British wildfowl count data indicate that an influx of *M.albellus* took place during the 1981/82 winter, but fewer birds were involved than in 1978/79 (Salmon 1982).

There is evidence for movements further south by three other species of sea-ducks: *Aythya marila*, *Bucephala clangula* and *Somateria mollissima*. Increased numbers of these species were recorded in France during the winter of 1978/79, with over twice as many *A.marila* and *S.mollissima* counted as during mild winters (Saint-Gerand 1982). It is probable that these birds originated from populations which normally winter along southeast North Sea coasts and in Denmark. Count data also suggest an influx of *A.marila* into southeast England during the 1962/63 and 1981/82 winters (Ash 1964, Harrison and Hudson 1964, Salmon 1982). Unusually large concentrations of *Bucephala clangula* were recorded on some British estuaries and reservoirs during the 1962/63 and 1981/82 winters (Ash 1964, Dobinson and Richards 1964, Salmon 1982), but most of these were probably birds which normally winter in Britain.

Without systematic count data it is impossible to separate redistribution of birds within the country from influxes from elsewhere. During the 1962/63 winter concentrations of *Podiceps cristatus* occured on the rivers Thames and Trent and on the south coast of England, but these were probably all birds which normally wintered in Britain (Dobinson and Richards 1964). Similarly, increased numbers of *Mergus serrator* on the river Leven in Scotland during the same winter were probably due to local movements (MacMillan 1963).

2 Ducks and other freshwater species

Freshwater species are vulnerable to the freezing over of waterbodies during cold weather, because they are then deprived both of food and of a safe refuge from predators. Most of these species frequent estuaries to some extent, and a first response to cold may therefore be to move to estuarine habitats which freeze over less quickly than inland waters. The feeding behaviour of individual species is also important in determining their response to cold weather. Diving ducks such as *Aythya fuligula* and *Aythya ferina* are completely deprived of food when inland waters freeze over, but grazing species may be able to find food on the surrounding land. Thus *Anas penelope* have been recorded feeding on plants such as kale which were not completely covered by snow (Harrison and Hudson 1964, von Kanel 1981). Many of these species undertake cold weather movements, frequently to areas in which they will be vulnerable to any hunting which may take place.

Continental *Anas platyrynchos* populations undertake large cold weather movements, but British wintering birds are generally sedentary. A large movement of *A. platyrhynchos* into France during the 1978/79 winter probably involved birds from Denmark, the Netherlands and Belgium. Ringing recovery data indicate that few British birds were involved (Ogilvie 1982). A more detailed analysis of recoveries of hand-reared *A.platyrynchos* ringed in Britain provided evidence of increased dispersal within Britain during the 1962/63 winter, but as in other years the proportion of birds which were recovered abroad remained small (Harrison and Wardell 1964). Thus concentrations of *A.platyhynchos* on unfrozen areas in Britain during the 1962/63 winter (Dobinson and Richards 1964, Harrison and Hudson 1964) almost certainly resulted from local movements of British birds rather than from immigration from the continent.

Anas crecca is perhaps the prime example of a cold weather migrant, and as such its movement patterns have been studied in some detail, mainly using ringing recoveries. British count data indicate extensive emigration during cold winters, and also concentration of the remaining birds on unfrozen rivers and estuaries (Dobinson and

Richards 1964, Harrison and Hudson 1964, Salmon 1982). French counts during the winter of 1978/79 showed a substantial increase over normal population levels (Saint-Gerand 1982), probably due to immigration of birds from Denmark, the Netherlands and Belgium as well as Britain (below).

Recoveries of *A.crecca* ringed in Britain, the Netherlands, Denmark and France have been analysed by Ogilvie (1981, 1982, 1983), especially in relation to weather conditions. *A.crecca* from Britain, the Netherlands and Denmark move south or southwest into southern France and Iberia in response to cold weather in their normal wintering areas. Movements into west Britain and Ireland also occur, and these mostly involve Dutch-ringed birds. More Dutch-ringed birds move to France during mild winters and therefore southerly movements by this population are less apparent from the recovery data. Some Danish birds moved south in years when other populations did not, apparently in response to factors other than cold weather. Movements to Iberia by the three northwest European populations took place mostly in response to very severe and prolonged cold spells. French *A.crecca* from the Rhone delta moved south into Iberia and west to the Atlantic coast of France during cold weather (Impekoven 1965). Some movements of these birds into north Italy were also detected.

Sex differences in the migratory response of *A.crecca* to cold weather have been demonstrated, with females usually moving south before males. However, the males generally "catch up" with the females if the cold weather is prolonged. The extent of cold weather movements by *A.crecca* varied according to the severity of the winter, but some movement took place even in response to relatively short cold spells.

Less detailed data are available for other species of dabbling ducks. Count data indicate extensive movements of *Anas strepera*, *Anas penelope*, *Anas acuta* and *Anas clypeata* into France during severe weather (Saint-Gerand 1982, Salmon 1982). Counts also suggest that many *A.clypeata* moved out of Britain during the 1962/63 winter (Harrison and Hudson 1964), while 1978/79 ringing recovery data for *A.strepera*, *A.acuta* and *A.penelope* suggest emigration from Britain (Ogilvie 1982). Concentrations of these three species in Britain during cold weather (Dobinson and Richards 1964, Harrison and Hudson 1964, Salmon 1982) probably result from local movements by British wintering birds. *A.penelope* also emigrate from major British coastal sites during cold weather (Harrison and Hudson 1964, von Kanel 1981).

The two common inland species of diving ducks, *Aythya fuligula* and *Aythya ferina* were also present in France in greatly increased numbers during the winter of 1978/79 (Saint-Gerand 1982). Again it is probable that many of these birds came from countries along the southeast side of the North Sea, but there is no published evidence for this. British counts during 1981/82 suggest emigration by both species (Salmon 1982), while ringing recoveries of *A.fuligula* from the winter of 1978/79 show a cold weather movement from Britain to France (Ogilvie 1982). Counts from Britain also indicate concentrations of both species in coastal and other areas of unfrozen water during cold weather (MacMillan 1963, Dobinson and Richards 1964, Harrison and Hudson 1964, Pilcher 1964, Salmon 1982).

The feral population of *Oxyura jamaicensis* which breeds in the English counties of Staffordshire and Avon also undertakes cold weather movements. Because of this very restricted distribution, movements are easily detected from observations outside the species' normal range. Extensive cold weather movements within Britain took place in the winter of 1978/79, mostly into south England and south Wales (Vinicombe and Chandler 1982). Similar movements also took place during the 1981/82 winter (Salmon 1982).

Two other freshwater species for which there is some evidence of cold weather movements are *Ardea cinerea* and *Botaurus stellaris*. The former species moves only relatively short distances, but there was probably a movement of English birds to the south coast of England during the 1962/63 winter (Dobinson and Richards 1964). There is no evidence of extensive movements to the continent, despite fairly widespread ringing of this species in Britain. *B.stellaris* appear to move into Britain during cold winters, with increased numbers recorded away from the small number of British breeding localities (Bibby 1981). Between the winters of 1960/61 and 1978/79 there was a significant correlation between the severity of the winter and the number of such records.

3 Geese and Swans

Most *Anser anser* emigrated from the Netherlands during the 1978/79 winter (van den Bergh *et al.* 1981), probably into France. There is no evidence that continental *A.anser* moved into Britain, but a small movement of British wintering *A.anser* into relatively snow-free Ayrshire was recorded during the 1981/82 winter (Salmon 1982). *Anser brachyrhynchus* show more marked evidence of cold-weather movements within Britain, birds from Scotland and possibly also the Wash, moving to Lancashire during cold weather (Salmon 1982). There is again little evidence that continental wintering populations move to Britain during severe weather, but a bird from the Svalbard population which had been ringed in the Netherlands in January 1981 was shot in northwest England in February 1982.

Cold weather movements of *Anser albifrons* have been studied in more detail, particularly during the 1962/63 winter. Ringing recoveries indicated extensive movement out of the Netherlands into France, and to some extent into Britain (Doude van Troostwijk 1965). Most birds left Slimbridge during the cold spell, apparently dispersing to other parts of Britain (Beer and Boyd 1964). However numbers on the Thames were similar to those in mild winters (Harrison and Hudson 1964). Count data from more recent severe winters confirm the pattern of emigration from the Netherlands and limited immigration into Britain (van den Bergh *et al.* 1981, Salmon 1982). *Anser fabalis* probably undertake similar cold weather movements and during the 1962/63 winter some reached Iberia (Bernis 1964). Immigration into Britain in February 1982 resulted in the Yare flock, Norfolk, reaching 329 birds, compared with 164 in the previous winter (Salmon 1982,Seago 1982).

The only *Branta* species for which there is good evidence of extensive cold weather movements is *Branta bernicla*. Ten reports of increased numbers suggest immigration to Britain during the 1962/63 winter (Dobinson and Richards 1964), although numbers on the Thames remained normal (Harrison and Hudson 1964). Immigration of *Branta bernicla bernicla* into Britain may have taken place during the winter of 1981/82, but a firm conclusion is impossible due to incomplete count coverage of the Wash. The whole Svalbard population of *Branta bernicla hrota* emigrated from Denmark in both 1978/79 and 1981/82, most birds joining the small population which normally winters at Lindisfarne in northeast England. Count data suggest that some redistribution of *Branta canadensis* took place in Britain during the 1962/63 winter (Dobinson and Richards 1964). Four Yorkshire-ringed birds were recovered in Pas de Calais, France, in January and February 1963 (Spencer 1964), but such movements appear to be exceptional.

Cygnus olor from Sweden and the Baltic vary the extent of their southward movements according to the severity of the winter. Some individuals reach France and southeast England during particularly severe winters (Harrison and Ogilvie 1967). Extensive emigration into France took place during the 1978/79 winter (Saint-Gerand 1982), and a similar movement may have taken place in 1962/63 when an influx to the

Channel Islands was recorded (Dobinson and Richards 1964). In 1962/63 many birds reached Spain and over 100 were shot there (Bernis 1964). These birds may have come from the Baltic population or from countries such as the Netherlands further south. They are unlikely to have come from Britain, where the population is highly sedentary (Ogilvie 1967). Within Britain concentrations of birds near towns and on the coast were recorded during the 1962/63 winter (Dobinson and Richards 1964).

The situation regarding the other two swan species is less clear. *Cygnus cygnus* are reported to have been unusually frequent in England and Ireland during 1962/63, but in the absence of data from Scotland it is unclear whether movement of birds within Britain, or emigration from elsewhere, was involved (Dobinson and Richards 1964). Increased numbers were recorded in Greece during 1962/63 (Bernis 1964) and in France in 1978/79 (Saint-Gerand 1982). Counts indicate some immigration of *Cygnus bewickii* into Britain during the 1962/63 winter (Dobinson and Richards 1964). A southwesterly movement within Britain took place in 1981/82, but there was no large scale immigration from the continent (Salmon 1982). In 1978 a return movement of marked birds which had wintered in Britain was recorded following a period of severe weather in Germany (Evans 1979). Extensive immigration of *Cygnus bewickii* into Britain was recorded during the 1978/79 winter.

4 Waders

Waders occupy a wide range of habitats in winter. Some species such as *Pluvialis squatarola* and *Calidris canutus* restrict their feeding to estuarine mud flats, while others such as *Vanellus vanellus* and *Pluvialis apricaria* feed mostly on inland pastures. Species such as *Numenius arquata*, *Tringa totanus* and *Haematopus ostralegus* are intermediate, often feeding on mud-flats at low tide and on coastal pastures at high tide. Another group of species including *Gallinago*

gallinago and *Tringa ochropus* occupy mainly freshwater marshes in winter. Inland feeding species are generally most vulnerable to cold weather, as their habitats are the first to freeze over. However, as most species use coastal habitats to some extent, it is most convenient to consider them as a single group. *Tadorna tadorna*, in common with many waders, feed mainly on estuarine invertebrates. They are therefore included in this section.

Observations indicate that a large scale emigration of *V.vanellus* and *P.apricaria* from Britain took place during the 1962/63 winter, mainly to France, Iberia and Ireland (Ash 1964, Dobinson and Richards 1964, Pilcher 1964, Spencer 1964). Similar emigrations during the winters of 1978/79 and 1981/82 were documented quantitatively from wader counts made on British estuaries (Marchant 1982). Declines of between 55% and 71% were recorded. However, because nearly all the birds wintering inland will have emigrated, these figures give a very conservative estimate of the percentage of these species which left Britain. Cold weather movements extended very far south in 1962/63, when an influx into Morocco was recorded (Smith 1965). However, the origin of these birds was unknown. These species undertake cold weather movements in response to relatively short cold spells. *V.vanellus* and *P.apricaria* for example, emigrated from a study area in southern England during a two week cold spell in February 1976 (Fuller and Youngman 1977). However, these species did not emigrate in response to several periods of up to three days of freezing weather which occurred during the following winter, although they did disperse locally.

Count data suggest emigration of both *Gallinago gallinago* and *Lymnocryptes minimus* from many parts of Britain during the 1962/63 winter (MacMillan 1963, Ash 1964, Dobinson and Richards 1964). Increased numbers of *Gallinago gallinago* were recorded in southwest

England and Ireland, while ringing recoveries also show movements to France, Iberia and Morocco. In contrast to these species increased numbers of *Scolopax rusticola* were recorded in Britain in 1962/63 and in 1981/82 (Dobinson and Richards 1964, Marchant 1982). In 1962/63 some westerly movement within Britain appears to have taken place later in the winter. Although many birds were found dead, numbers of *S.rusticola* in many parts of Britain remained high throughout the winter.

H.ostralegus vary in their movements in response to cold weather. Movements out of estuaries during cold spells were recorded on the Wash in 1962/63 (Pilcher 1964), the Waddensee in 1976/77 (Van Eerden 1977) the Ythan in 1978/79 (Baillie 1980) and possibly on the east coast of Britain in 1981/82 (Clark 1980). However no changes in numbers present were recorded at Poole Harbour in 1962/63, on the Waddensee in January 1976 (Swennen and Duiven 1983) and in North Wales in 1981/82 (Clark 1982). On the Waddensee in January 1976 the birds suffered 3-4% mortality, but mainly individuals with slight deformities were affected. The cold was preceded by a long period of exceptionally high tides which restricted feeding time, and the birds may have lacked the reserves needed for a long distance movement.

T.totanus counts are particularly difficult to interpret, as this species is very vulnerable to cold weather mortality (above). Movement of birds into south and west England appears to have taken place in 1962/63, with concentrations of birds in Sussex, Hampshire, Somerset and Devon (Dobinson and Richards 1964). Emigration from the Waddensee took place in 1976/77, and about half the wintering *T.totanus* from the Tees moved out during the winter of 1978/79 (Davidson 1982). *T.totanus* emigrated from the Ythan in both 1978/79 and 1981/82 (Baillie 1980, Clark 1982). Three records of marked birds suggest a short southerly movement to the Firths of Forth and Clyde.

Counts of *N.arquata* during the 1962/63 winter suggest movement into west England and Ireland, while recoveries indicate that some birds reached the Channel Islands and France (Dobinson and Richards 1964). Emigration from Hampshire took place during the same winter (Ash 1964). No change in numbers took place on the Tees in 1981/82, but increased numbers in north Wales may indicate some westerly movement (Clark 1982). Totals from the national estuary counts for January 1982 were 12% lower than in the previous year, but a change of this size could have been due to mortality.

Numbers of *Tadorna tadorna* on the Thames remained normal during the 1962/63 winter (Harrison and Hudson 1964), but two reports of decreases on the east coast of Britain and six reports of increases on the west coast suggest that some westerly movement may have taken place (Dobinson and Richards 1964). Some influx of continental birds into Britain appears to have taken place during the 1981/82 winter, but the picture is complex (Salmon 1982). The large influx into France which was recorded during the 1978/79 winter (Saint-Gerand 1982) probably involved birds from the Waddensee rather than from Britain.

There is no clear evidence of cold weather movements by *Calidris alpina*. Local concentrations on ice-free shore in Ayr, Lincolnshire, Sussex, Hampshire, Dorset and Devon were recorded during the 1962/63 winter (Ash 1964, Dobinson and Richards 1974). *Calidris canutus* present a similar picture, with increased numbers in Hampshire in 1962/63 (Ash 1964), and large numbers remaining on the Wash throughout that winter (Pilcher 1964). In 1981/82 a large influx was recorded in February at Foulness, with 33 380 birds counted, compared with 6 440 in the previous month (Marchant 1982). However the January index from British estuary counts was 17% down, suggesting the possibility of emigration. *Charadrius hiaticula* also formed local concentrations in 1962/63 (Dobinson and Richards 1964). A series of movements of birds ringed in southern England suggest a southwesterly movement within the country as a result of the severe weather (Spencer 1964).

There is some evidence of immigration into Britain by *Limosa lapponica* and *Pluvialis squatarola* during cold winters, presumably by birds which normally winter on the Waddensee. During 1962/63 constant numbers of *L.lapponica* remained in Poole Harbour throughout the winter (Ash 1964), while most birds left the Wash in early January (Pilcher 1964). In 1978/79 and 1981/82 however, increases of 46% and 64% were recorded in the January estuaries count for Britain (Marchant 1982). Two to three-fold increases were recorded at the major Ribble and Foulness sites. There is less evidence of large scale influxes by *P.squatarola*. Numbers in Poole Harbour remained constant throughout the 1962/63 winter (Ash 1964), while the British estuaries count total for January 1982 was 13% down on the previous year (Marchant 1982). Detailed studies on the Tees estuary showed that ten colour marked individuals were present during the winters of 1978/79 and 1981/82, but not in other years (Townshend 1982). The normal wintering sites of these birds were unknown.

The small populations of *Tringa erythrops*, *Tringa nebularia* and *Philomachus pugnax* wintering in Britain are all at the northern edge of their winter range. All three species show declines in numbers during cold winters, perhaps as a result of cold weather movements (Ash 1964, Marchant 1982).

The response to cold weather of waders which normally winter on British estuaries probably varies with the severity of the cold. For *Pluvialis apricaria*, *Pluvialis squatarola*, *Vanellus vanellus* and *Numenius arquata* there is a significant negative correlation between the number of days of frozen ground and numbers counted on British estuaries. (O'Connor *et al.* 1981). In addition, negative correlations ($P<0.10$) were found for *Haematopus ostralegus*, *Calidris alba*, *Philomachus pugnax*, *Limosa limosa*, *Limosa lapponica* and *Tringa nebularia*. These relationships suggest that many wader species move out of Britain in response to cold weather but mortality may also be involved. Better interpretation must await detailed analyses of European wader counts and ringing recoveries.

5 Other species

Data on cold weather movements by species other than water birds and waders are even more sparse than those given above. Because of this and because most such species are not affected by hunting, I shall not attempt to review this very limited information in detail. Widespread winter count data are generally lacking, although in Britain three years of data on relative abundance will soon be available as a result of the BTO Winter Atlas Project. Similar winter atlas projects have also been carried out in Holland and France. The large sets of ringing recoveries available for many passerine species would undoubtedly repay further investigation.

Extensive information on passerine movements relating to Britain is given by Dobinson and Richards (1964). Visible movements by *Alauda arvensis*, *Turdus pilaris* and *T. iliacus* were recorded most frequently, but movements of many other species were also recorded. These include *Columba palumbus*, *Lullula arborea*, *Turdus philomelos*, *T. merula*, *Anthus pratensis*, *Sturnus vulgaris*, *Carduelis chloris*, *Acanthis cannabina*, *A. flammea*, *Fringilla coelebs*, *F. montifringilla*, *Emberiza calandra*, *E. citrinella* *E. schoeniclus* and *Plectrophenax nivalis*. Ringing recoveries from the 1962/63 winter provide evidence for movements of *Turdus viscivorus*, *T. philomelos*, *T. pilaris*, *T. iliacus* and *Anthus pratensis* out of Britain, mostly to France (Spencer 1964). British *T.philomelos* recoveries also provide evidence of emigration from Britain during the 1978/79 winter (Cawthorne and Marchant 1980).

SUMMARY OF MOVEMENTS BY COUNTRIES

Evidence for cold weather movements has been described in detail in the previous section. Here I shall summarise briefly the situation for individual European countries with respect to cold weather movements. Unfortunately there are no data from many areas, and future research should aim to remedy this. However, the conservation implications of cold weather movements will be greater in some countries than in others.

Birds generally move out of continental countries to the north and east of Belgium as a result of cold weather. Few data are available from Scandinavia, *Cygnus olor* (Ogilvie and Harrison 1967) and *Anas crecca* (Ogilvie 1983) being two of the few documented examples. Movements of geese and *A.crecca* out of the Netherlands have been demonstrated (Doude van Troostwijk 1965, van den Bergh *et al.* 1981, Ogilvie 1983), as have those of *Tringa totanus* and *Haematopus ostralegus* under some circumstances (van Eerden 1977). Circumstantial evidence of arrivals of birds elsewhere implies that many other species undertake similar movements.

The situation in Britain and Ireland is complex, with some birds such as grebes (Podicipitidae), *Branta bernicla hrota* and *Limosa lapponica* (Chandler 1981, Salmon 1982, Marchant 1982) moving in as a result of severe weather elsewhere, while other species such as *Anas crecca* and *Vanellus vanellus* (Ogilvie 1983, Dobinson and Richards 1964) move out. Many species also undertake cold weather movements within Britain, usually towards south and west England and Ireland. The apparent complexity of these movement patterns results in part from the more complete data available for Britain. A similar situation probably applies to northern France and other areas which are often at the edge of the area most severely affected by frost and snow. However mild areas of south and west Britain and Ireland provide refuges from the most severe effects of the cold weather in all but some exceptional winters.

France receives large numbers of additional wildfowl during severe weather (Saint-Gerand 1982). During the 1978/79 cold spell over twice as many wildfowl as usual were counted in France. *V.vanellus* and other inland wader species must also move to France in large numbers, but no quantitative data are available. Some birds undoubtedly pass through France on their way further south, and the extent of such southward movements must partly be determined by the weather in France itself. Some birds such as the *A.crecca*, which normally winter in the Rhone delta in the south of France, move south into Spain and north Italy in response to very cold weather (Impekoven 1965).

A number of species regularly move as far south as Spain and Portugal in response to severe weather. They include *V.vanellus* from Britain, and *A.crecca* from Denmark, the Netherlands, Britain and France (Dobinson and Richards 1964, Ogilvie 1983). During 1962/63 a substantial influx of *Cygnus olor* of unknown origin was recorded in Spain (Bernis 1964).

Movements of *A.crecca* into north Italy (Impekoven 1965) and *Cygnus cygnus* into Greece (Bernis 1964) have been recorded, but apart from these isolated examples little is known of cold weather movements into these countries.

DIFFERENCES BETWEEN WINTERS

The published data on cold weather movements are insufficient to review this topic in detail. Nevertheless, it is apparent that there are important differences in weather conditions during different cold winters, and in the consequent effects on bird populations. The few examples given below are intended merely to draw attention to the major differences which exist between cold winters.

Most differences are attributable to differences in weather conditions. In northeast England, for example, the winter of 1978/79 was much windier than that of 1981/82. *Pluvialis squatarola* on the Tees estuary had difficulty feeding and hence lost condition during 1978/79, but this did not occur during 1981/82 (Davidson 1982). The passerine species most severely affected also differed between these two winters. Breeding numbers of *Regulus regulus*, *Aegithalos caudatus* and *Certhia familiaris* all declined in 1979, but not in 1982 (Marchant 1983), perhaps due to increased glazing of tree trunks or higher wind speeds during the former winter (page 25).

The movement of grebes (*Podicipitidae*) and other water birds into Britain, which occurred during the 1978/79 winter (Chandler 1981), has not been repeated on the same scale in other winters. Far fewer *A.crecca* moved out of the Carmargue in response to the cold weather of February 1956 than in December 1962 and January 1963, perhaps due to differences in the timing of cold weather relative to the condition and physiological state of the birds (Impekoven 1965). Directions of movement also differed between the two years, with extensive movement to the Atlantic coast of France only in 1962/63.

Finally, it should be noted that many of the responses to severe weather are continuous ones which can be observed to some extent in winters not normally regarded as severe. Examples include the correlation between *Botaurus stellaris* immigration into Britain and the frequency of freezing weather (Bibby 1981), and those between freezing weather and wader numbers on British estuaries (O'Connor *et al.* 1981). Both *A.crecca* and *V.vanellus* show a variable amount of emigration from Britain according to the severity of the winter (Ogilvie 1983, Eastwood 1967).

DISCUSSION

1. Synthesis of movement patterns

In attempting to synthesise the information on cold weather movements, the lack of adequate data on many aspects must constantly be remembered. Nevertheless some generalisations can be made.

The timing of emigration is critical to survival. As most wildfowl and waders carry some fat reserves during the winter, they are usually able to survive several days of reduced feeding. It would be disadvantageous to emigrate in response to very short cold spells, as the risks of migration and of failure to find new feeding grounds must greatly outweigh the small loss of body reserves which can be made good when conditions improve. However, it is also important to emigrate while sufficient body reserves are available to fuel the movement south and the search for new feeding grounds. Faced with a prolonged cold spell, failure to emigrate will almost certainly result in death for individuals of many species. Almost nothing is known of the criteria by which birds "decide" at what stage to emigrate from an area affected by cold weather. *Vanellus vanellus* and *Pluvialis apricaria* undergo local dispersal at the onset of cold weather, and only move out completely after several days of severe weather. The presence of some individuals of *Pluvialis squatarola* on the Tees only during cold winters, raises the possibility that individual birds return to the same feeding sites in subsequent cold winters. There are obvious adaptive advantages in moving to a site which is known to contain a reliable food supply, rather than searching randomly for such an area. If birds from particular areas use specific sites as refuges during cold weather, this would have important implications for the protection of those populations. Although there is little good evidence for this at present, it is clearly a possibility for some species.

Most cold weather mortality results from starvation rather than exposure, and where sufficient food supplies are accessible, most species seem capable of surviving even relatively long periods of severe weather in their normal wintering areas. However, for other species freezing weather can very rapidly remove access to normal food supplies, and individuals must usually emigrate in order to survive. Waterfowl which rely on inland waters are likely to be forced to move before those which occupy estuarine and marine habitats. Most dabbling and diving ducks regularly undertake movements during cold weather, while seaducks are often able to remain on their normal wintering areas. In some areas ducks are able to move to the coast to exploit unfrozen estuarine habitats, but others probably move south immediately. Snow is the major factor which deprives geese of their feeding areas, and cold weather movements by several species have been reported.

Those wader species which feed in fields and other inland sites are most vulnerable to cold weather. Thus cold weather movements appear to be undertaken frequently by *Vanellus vanellus*, *Pluvialis apricaria*, *Gallinago gallinago* and *Scolopax rusticola*. Species such as *Numenius arquata*, *Tringa totanus* and *Haematopus ostralegus* which supplement their winter food intake by field feeding over the high tide period, are slightly less vulnerable. The extent of movements by these species is unclear. Both *T.totanus* and *H.ostralegus* suffer conspicuously high mortality during cold weather, and there are documented examples of these species emigrating from particular sites during cold weather. For other estuarine waders there is even less evidence of cold weather movements. Only under the most severe conditions do mudflats become sufficiently frozen to deprive these species completely of food, but reduced invertebrate activity at low temperatures will make foraging difficult during cold weather. Thus it appears that estuarine waders do not undertake cold weather movements to the extent observed in wildfowl and inland waders, but detailed analyses of ringing recoveries comparable to those now available for several species of wildfowl are lacking.

The severity of the winter conditions affecting specific areas also has important effects on the extent of cold weather movements. This is illustrated by the contrasting behaviour of birds from Britain and from adjacent continental countries, which normally experience more severe winter conditions. *Anas platyrhynchos* from the Netherlands apparently move into France in large numbers during severe weather, while most British birds do not emigrate. Many geese emigrate from the Netherlands during severe weather, but most British geese only undertake movements within Britain. Indeed, some geese move into Britain from the continent during severe weather.

To summarise, birds must move out of an area if they are totally deprived of their food supplies, but otherwise they will generally attempt to stay. Frequency of deprivation of food supplies due to cold weather depends on feeding habitat and geographical location. Birds must move out of freshwater and inland habitats before estuarine and coastal ones at equivalent latitudes. Countries further to the north and east generally experience more severe winter conditions, and birds from these areas must thus undertake cold weather movements more frequently.

2. Future research priorities

It is apparent from the information which has been reviewed above, that cold weather movements of most European wildfowl and waders are poorly understood. The published data are inadequate for the formulation of soundly based conservation policies. The research priorities outlined below address the need for this type of information, rather than the many interesting questions of more theoretical interest which are raised. The proposals for future research are divided into two main sections; analyses of existing data and the collection of new field data.

(a) Analyses of existing data

(i) Count data for waders and wildfowl.

No attempt has yet been made to analyse systematically national and international wildfowl and wader counts in order to examine the effects of cold weather movements. Several counting programmes have now been running for over 10 years, and the data thus include the severe winters of 1978/79 and 1981/82. Analyses of count data should examine the regional distribution of birds before, during and after severe weather, and should compare seasonal fluctuations in numbers with those which occur during mild winters. Correlations of bird numbers with weather conditions in the counting region, and in areas from which birds being counted are likely to have come, should also be attempted. Detailed analyses of existing count data should also enable sites which are of particular importance to birds during cold weather to be identified. Some lists of ornithological sites within Europe have been prepared (e.g. Scott 1980, Osieck and Morzer-Bruyns 1981). It is important to establish which of these sites hold large numbers of birds during periods of cold weather.

(ii) Movement patterns as shown by ringing recoveries.

Descriptions of normal movement patterns, based on ringing recoveries have been attempted on an international basis for only a few species. It is impossible to understand cold weather movements without a thorough knowledge of movement patterns during mild winters.

(iii) Analyses of cold weather movement patterns from European ringing recovery data.

Such analyses should compare recovery distributions during mild and severe winters. Where possible analyses should take into account the numbers of ringed birds available to be recovered, and not just be based on the percentage of recoveries in each region. Due account will need to be taken of hunting bans and other factors which alter recovery rates during severe winters. Biases resulting from the method of recovery should also be considered.

(iv) Analyses of changes in survival rates and population size resulting from cold weather.

Count data from years following cold winters can be used to determine whether cold weather mortality has caused declines in the size of wintering populations. Mortality rates during mild and severe winters can be estimated for some species using ringing recoveries. Measurements of these parameters would facilitate objective assessment of the impact of cold weather mortality on the overall population dynamics of various species of wildfowl and waders. The analysis could be extended to populations subjected to different levels of hunting, so as to determine its likely effect on population size.

Many aspects of the analyses suggested above are interrelated, and they therefore need to be carried out in a closely co-ordinated way. The sequence of analyses should roughly follow that on the list, as it is necessary to understand basic cold weather movement patterns before investigation their effect on population dynamics. However such a sequence of analyses could initially be carried out for one or two selected species.

(b) Collection of new data

In addition to current counting and ringing programmes the following should be considered:

(i) Additional counts during periods of severe weather.

Most counting programmes are carried out on fixed dates each year, and often these do not coincide with periods of cold weather. Arrangements need to be made so that additional counts can be carried out at short notice during periods of severe weather. Counts should be made as frequently as possible while the cold weather lasts. Coverage of areas where large scale immigration is likely to take place is particularly important.

(ii) Marking programmes.

Observations of birds marked as part of other studies will continue to provide valuable information on cold weather movements. However, where information on the movements of particular species or populations is required, marking of birds in their normal wintering areas, and then waiting for a cold winter, will not be cost effective. Effort should instead be concentrated on marking the birds which have moved into particular areas as a result of severe weather, and following their subsequent movements. This would involve identifying areas likely to receive immigrants during cold weather (above) and then organising teams of suitably qualified people to carry out marking there. Care must be taken to avoid undue disturbance to the birds, and small catches which can be expeditiously processed will be appropriate.

The Wader Study Group are currently organising a project on the effects of severe weather on waders (Davidson and Clark 1982). This involves counts of birds found dead, population counts and limited catching to investigate weight changes. Any additional work on waders should be caried out in co-operation with this project.

3. Hunting regulations

The results presented above indicate that extensive movements of wildfowl and of some species of waders take place in Europe during periods of severe cold weather. There are also a number of reports which suggest that excessive hunting of some of these birds may take place, especially in France (Raffin and Lefeuvre 1982). However no measurements of hunting mortality during cold spells, or during mild winters have been made. Thus, at present, the level of threshold mortality for these populations is unknown (Anderson and Burnham 1976, Scott 1982) and there are no quantitative data which can be used to determine whether hunting during cold spells affects population levels. However Scott (1982) has argued that most wildfowl populations are limited in mid or late winter. If this is correct hunting mortality during cold spells could be additive, and could thus affect spring population levels. Restricting hunting of these populations during periods of severe weather would guard against this possibility. Restrictions would need to be implemented in the refuge countries on the basis of conditions further north. Because of the need to make decisions quickly and on firmly laid down criteria, meteorological data should be used to decide when to introduce such a ban.

In Britain hunting bans during severe weather are implemented on the basis of the state of ground at 13 coastal weather stations (Batten and Swift 1982). When the ground has been frozen for a period of seven days a call for voluntary restraint is made, and after 14 days of such conditions a statutory ban is introduced. Such bans apply to the whole of Britain. A similar but more flexible system could to be devised for the rest of Europe. The extent of hunting bans in countries to the south of cold weather would depend on how far south the freezing conditions extend. Duration of the ban would need a similar flexibility. It is particularly important that birds which have just arrived in refuge areas should be protected, as they may be in poor condition.

Although factors such as temperature and wind strength are clearly important to birds, the state of ground is a good indicator of feeding conditions and it is easy to use. A survey of data from European weather stations should be carried out so that the possibility of defining detailed criteria for the implementation of cold weather hunting bans can be investigated.

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Table 1 Population changes of some resident British breeding birds following recent cold winters

(a) Farmland census data

	1962-63	1978-1979	1981-82
Anas platyrhynchos	-30%	-7%	-8%
Perdix perdix	-19%	-26% *	-23% *
Gallinula chloropus	-60%	-7%	-20% *
Vanellus vanellus	-56%	-4%	1%
Alauda arvensis	-18%	-14% *	-35% *
Montacilla alba	-	-10%	-25% *
Troglodytes troglodytes	-78%	-43% *	-44% *
Prunella modularis	-5%	-8% *	-26% *
Erithacus rubecula	-12%	-12% *	-29% *
Turdus merula	-17%	-11% *	-14% *
Turdus philomelos	-57%	-15% *	-19% *
Turdus viscivorus	-75%	-10%	-26% *
Aegithalos caudatus	-	-47% *	-44% *
Parus caeruleus	-2%	-7% *	-14% *
Parus major	-3%	-8% *	-14% *
Certhia familiaris	-	-47% *	23%
Pica pica	-	-3%	14% *
Corvus monedula	-	20%	18%
Corvus corone	-	17% *	4%
Sturnus vulgaris	-	-7%	-17% *
Passer montanus	-	-26% *	-24% *
Fringilla coelebs	-	-1%	-7% *
Carduelis chloris	-	5%	3%
Carduelis carduelis	-	3%	-15%
Acanthis cannabina	-	-5%	-19% *
Pyrrhula pyrrhula	-	-17% *	-36% *
Embezira citrinella	-	-6%	-12% *
Emberiza schoeniculus	-	-24% *	-45% *
Emberiza calandra	-	-25% *	-32% *

(b) Woodland census data

	1978-1979	1981-82
Picus viridis	6%	-13%
Dendrocopos major	1%	6%
Troglodytes troglodytes	-47% *	-34% *
Prunella modularis	-9% *	-18% *
Erithacus rubecula	-7% *	-25% *
Turdus merula	-8% *	-13% *
Turdus philomelos	-11% *	-11% *
Turdus viscivorus	0%	-7%
Regulus regulus	-43% *	-1%
Aegithalos caudatus	-42% *	-6%
Parus palustris	-17% *	-21% *
Parus ater	-16% *	-7%
Parus caeruleus	-7% *	-10% *
Parus major	-10% *	-9% *
Sitta europaea	-4%	-10%
Certhia familiaris	-18% *	22% *
Garrulus glandarius	7%	1%
Pica pica	12% *	3%
Corvus corone	5%	8% *
Sturnus vulgaris	2%	4%
Fringilla coelebs	6% *	-4%
Carduelis chloris	-11%	-7%
Carduelis carduelis	4%	-8%
Pyrrhula pyrrhula	1%	-26% *
Embezira citrinella	4%	-6%

(C) Waterways census data

	1978–1979	1981–82
Cygnus olor	−2%	−21% *
Anas platyrhynchos	−1%	−3%
Gallinula chloropus	−16% *	−18% *
Fulica atra	−1%	−1%
Alcedo atthis	−24%	−64% *
Montacilla cinerea	−33% *	−42% *
Montacilla alba	−18% *	−25% *
Cinculus cinculus	−8%	−6%
Emberiza schoeniculus	−10%	−20% *

* Change statistically significant

Data fron British Trust for Ornithology Common Birds Census and Waterways Bird Survey. O'Connor *et al.* 1982, Marchant and Hyde 1980a & b, Marchant 1983, Taylor and Marchant 1983.

1962 was the first year of the Common Birds Census, and so the 1962-63 population changes are based on relatively small samples, and can only be assessed for a minority of the species listed for the two more recent winters.