ABSTRACT

The ecology of bullfinches in Kent, particularly in and around a 2ha pear orchard near Brenchley, was studied between 1977 and 1980. The quantity and quality of their winter foods (both wild and cultivated) were assessed by field observation, feeding trials with captive birds, and laboratory analyses. In contrast to previous studies, fruit bud damage was not correlated with the size of the ash seed crop in autumn, probably partly because keys from some trees are, or become, unsuitable.

Changes in the size and chemical composition of buds and their flower initials were correlated with winter temperatures and this, coupled with the availability of bramble and dock seeds, influenced the timing of bud feeding. Annual variation in the nutritional quality of pear buds, and differences between varieties, probably determine preferences.

The bullfinch population in the study area was monitored by ringing and colour-marking, and various ringing and nesting data from the B.T.O. were analysed. Peak movement and mortality, especially of young birds, may occur in autumn, thus lessening the effects of shooting and trapping of bullfinches at this time. Of several deterrents examined in situ, none was both cheap and wholly effective. However, bud damage and its effect on the final crop may be reduced by various techniques, notably clearance of adjacent vegetation.

Sample branches within the study orchard indicated that the number of fruitlets set/bud, the proportion of fruitlets retained till harvest, fruit size, and bud numbers in the following year were greatest on damaged trees and, in one year, only loss of over 90% of buds reduced the final crop.

Hitherto, fruit growers have been given a simplistic view of bullfinch damage, and they tend to react prematurely to it, and in ineffective ways. However, more research is needed before detailed and reliable advice can be offered.
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A. INTRODUCTION
A.1. The bullfinch problem

The range of the bullfinch Pyrrhula pyrrhula extends from western Europe to eastern Asia. It was probably originally a woodland bird, but with woodland clearance and development of agriculture it has also become common in farmland, feeding on seeds in the summer and autumn, and flower buds in winter and spring. The seeds are often those of plants considered by man as weeds, or else from woodland and hedgerow trees, so seed-eating does not result in conflict with man. The buds, however, come from both wild trees and bushes, and varieties cultivated by man for ornamental purposes and fruit crops. In Britain, where the race P. pyrrhula nesa is endemic, records of bullfinch damage to buds stretch back at least to the reign of Queen Elizabeth I. Since then the bullfinch problem has always been present, though probably fluctuating in intensity from year to year and decade to decade. At the present time the bullfinch has a wide reputation as a serious pest, and views like those of the study orchard shown in Plate A are a common sight in some fruit-growing areas.

The reason for these attacks on buds is sometimes ascribed to mischief, since much of the demolished buds falls to the ground beneath the bird. In the early 18th century it was suggested that the birds were searching for insect larvae within the buds, a view still prevalent in the 1930's but shown to be false by the inquiry sponsored by the British Trust for Ornithology (B.T.O.) at that time. This inquiry showed that the central flower meristems (initials) are eaten and only the outer bud scales discarded (Fryer 1939).

It is the view of many that bullfinches are not, or should not be, a problem. Few people outside fruit growing areas are aware of the magnitude and regularity of bud damage to fruit trees and bushes in agricultural plantations. Most people who have experienced bullfinch damage have done so only in the garden environment where a few bullfinches and isolated trees and shrubs are involved. Indeed, house sparrows are often the main culprits in gardens (see Appendix 1 for Latin names of birds). It
Plate A. Views north (top) and south (bottom) in the study orchard at blossom time in 1979.

Note lack of blossom on trees at the southern edge nearest to the woodland.
is important to distinguish between this situation and the real problem areas where hectares of fruit trees flank woodland inhabited by many bullfinches. They differ not only in ecological characteristics but also in the attitudes of the people involved.

To the gardener, the bullfinch is a beautiful bird (which it undoubtedly is) that can usually be scared away when seen to eat buds. He does not worry unduly about a reduction in the quantity of fruit on a tree or two, or a lack of Forsythia blossom, and certainly would not consider killing the birds concerned. Numerous cures for the bullfinch problem have been suggested by gardeners, all of which are reputed to have been most effective when used in their gardens (though of course controlled experiments were almost impossible).

However, to the fruit grower, blossom and crops are his livelihood and trees damaged by bullfinches are therefore considerable cause for concern. It can be argued that some are prone to over-react, but when thousands of pounds may be involved this is surely understandable. Furthermore, any cure for the problem must be cost-effective both in terms of materials used and labour needed; time is money (a marked contrast to the domestic garden).

Different growers often have strong, yet different, views on why and when the damage occurs and on the efficacy of various damage prevention techniques. It might seem surprising that even those whose pockets are affected cannot agree on the factors influencing the damage or on the best course of action to prevent it. The reason is that the bullfinch problem is complex. The characteristics of bullfinch damage vary according to the number of birds involved, the variety of trees affected, the surrounding habitat, the degree of disturbance, the weather, and various other factors. No two farms are identical, and even on one farm successive years are different. It is therefore not surprising that no single cure fits every situation or will always work in one place. Fruit growers tend to have an understanding of the bullfinch problem only as it relates to their own farm.
At this stage it is interesting to reflect on why there is a bullfinch problem in Britain, for most bird species live in harmony with man and his activities, or at least pose him with no serious competition or difficulties. The explanation is that, above all other British birds, the bullfinch excels at eating flower buds - those parts of plants in which nutrients are concentrated in preparation for the production of flowers in spring and ultimately fruit or seed in summer or autumn. As we have seen, many of the buds come from wild plant species and indeed the vast majority of bullfinches have access to nothing else; the problem is that in some areas man provides a choice. It is man that plants fruit trees and bushes where bullfinches live, and man that cultivates special varieties with larger flower buds that are perhaps an even more attractive source of food than the wild alternatives. We should not therefore be surprised when 'man's' buds are eaten, perhaps especially at this time when the alternatives are being steadily removed from the countryside. In short, the bullfinch problem is a man-made and man-perpetuated problem.

Since 1954 the bullfinch has been the subject of a number of investigations. Wright and Summers (1960) studied the breeding biology and movements of bullfinches in Kent. Bud damage in orchards was found to be caused by locally bred birds, and they suggested that intensive trapping should reduce the local population and result in reduced bud damage.

In the early 1960's, Newton (1964a, 1967, 1968, 1970) studied the feeding ecology and population dynamics of bullfinches in Oxfordshire. He linked annual variations in the intensity of bud damage in orchards to variations in the supply of natural foods, and found that fluctuation in the crop of seeds produced by ash trees was the most important factor. The sedentary nature of bullfinches was confirmed and, based on the assumption that early shortage of seeds in winter resulted in an early start to bud-eating, he suggested that bullfinches are best trapped from autumn onwards, so that the seed supply will last longer for those birds that are not caught.
More recently, Summers (1981) studied the winter feeding ecology of bullfinches in West Sussex by identifying seeds and buds present in the guts of shot bullfinches. He found a significant negative correlation between the consumption of ash seed in January and incidence of bud damage in orchards. Bud damage has also been linked with bullfinch dispersal, most movement occurring in years of heavy damage, and with the quantity of pollen produced by ash trees, heavy damage occurring in winters following low pollen production (Summers 1979, Newton 1964a). Both Newton (1964a) and Summers (1982) attempted to feed captive bullfinches solely on pear fruit buds, and Greig-Smith et al. (in press) studied the chemical constituents of fruit buds. All concluded that buds were a poor diet compared to seeds, especially early in winter, and particularly those of the pear variety Doyenné du Comice.

The effects of bullfinch damage on the cropping of fruit trees have been described by Smith and Kendal (1975), Summers and Pollock (1978) and Summers (1982b), and useful comparisons can be made with deliberate blossom and fruitlet thinning (Knight 1980). For both pear and plum trees, only about 10% of flowers may be necessary to produce maximal fruit crops and reduction in the crop is rarely proportional to loss of buds. Some varieties can tolerate considerable bud loss without reduction in crop, while others show no tolerance.

In recent years fruit growers have had mixed success in preventing bud damage by bullfinches. They have complained that the currently available damage prevention techniques are often ineffective. Furthermore, some have suffered damage in winters when seeds of ash trees were present in apparently large quantities.

The aim of this study was, therefore, to re-examine the causes of, and potential solutions to bullfinch damage. The ecology of bullfinches in a small area in Kent was studied with particular attention being paid to bud-eating in a pear orchard central to the area. Food available and eaten during the winter was noted and chemical analyses of these foods were made. Captive
bullfinches were used in several feeding experiments designed to show why preferences for particular foods occurred in the wild population.

Bud loss in the study orchard was recorded in detail and the effects of this damage on the fruit crop were assessed. These data were supplemented by studies in two other pear orchards and by an annual assessment of the extent of damage in Kent.

The efficacy of damage prevention techniques was examined in several orchards; most currently used methods were involved. The numbers and movement of bullfinches in the study area were investigated by a programme of ringing and colour marking and the resulting data compared with an analysis of data collected by the B.T.O.
A.2. The study area

The study area (Fig. A.1) comprised about 150ha of farmland, woodland and gardens, though most records and observations were made within a central area of about 25ha. The town of Paddock Wood is about 2km to the north west and Brenchley about 0.5km to the south west. The area was chosen because it was known to contain many bullfinches and because the orchards within it had been regularly and severely damaged in previous years.

Although much of the farmland within the study area was arable, apple and pear orchards dominated the farmland within a 5km radius of the study area, comprising about 50% of the land surface. Woodland, broken into patches of about 20ha or less, comprised about 20% of the land; the remainder was about 20% open farmland (arable crops or grassland) and 10% gardens.

The orchard in which most damage and crop assessments were made (the study orchard: grid reference TQ 687 427) comprised 2.2ha of mature pear trees (about 510 Conference and 55 Doyenné du Comice). Since over 60% of pears grown in Britain are in Kent, and since Conference is the most commonly grown variety (M.A.F.F. 1973a), it was hoped that data from the study orchard would be applicable to many others. It was flanked by 3ha of woodland and scrub to the south, and 9ha to the west and north west. To the north was 3ha of gardens and to the east 8ha of open arable land.

The woodland within the study area was mainly broad-leaved, dominated by tall pedunculate oak standards (see Appendix 2 for Latin names of plants), but with a wide variety of other species; ash, hazel and hawthorn were the most common. The ground cover was mainly of bramble both in the more open areas and beneath the oak trees. In the open woodland areas and around fields, many annual and perennial species grew including bullfinch winter food plants such as dock and nettle. Hedges surrounding fields were mostly of hawthorn and were often left to grow tall. However, during the study, much of the woodland and some hedgerows were cleared, leaving only the oaks (see Section D.4).
Figure A.1. The study area
Fig. A.1 shows two other pear orchards within the study area. That to the north east of the study orchard contained only Conference trees, while that to the south (known as Brenchley 2) also contained some Comice trees. Both were regularly assessed for bullfinch damage, and some crop data were collected from the latter. The pear orchard near Castle Hill contained Conference, Comice and Williams' Bon Chrétien trees and was assessed for damage only at blossom time.
B. THE FOOD OF THE BULLFINCH

B.1. Introduction

Newton (1960, 1964a and 1967) described in detail the food of bullfinches in Derbyshire, Somerset and Oxfordshire, and compared this with data from other parts of Britain and other countries. Of greatest importance to the study of bud damage to orchards, is the winter diet, and Summers (1981) lists foods found in bullfinches shot in Sussex during six successive winters. As might be expected, considerable variation between years and locations was apparent, though some idea of food preferences and changes in diet through the winter may be inferred. The nutritional adequacy of buds has been investigated by means of feeding trials with captive birds (Newton 1964a, Summers 1982a), and Summers and Jones (1976) and Greig-Smith (in press) have analysed the chemical constituents of some bullfinch foods.

In this study, attempts were made to discover both the food available to bullfinches and the food eaten by them in the study area. In addition, various measurements and chemical analyses were made on samples of foods to determine their relative nutritional properties and to document changes that might occur during their development. These data are supplemented by results of several feeding trials. Efforts were concentrated on the winter diet, and particularly on ash keys, since these have been strongly implicated as being the major controlling factor of bullfinch damage (Newton 1964a, Summers 1979).
Plate B. Foods of the bullfinch.

Top left: The husk of a Conference bud following attack by a bullfinch. (x6)
Top right: Central meristematic tissue (flower initials) of a Conference bud, i.e. the part bullfinches normally eat (the husk was removed by hand). (x6)
Bottom (from left to right): Part of a seeding inflorescence of broad-leaved dock, a single dock seed extracted from this inflorescence, an ash key kernel, and a whole ash key. (x2)
B.2. **Methods**

**Food available**

The quantity of food available to bullfinches in the study area was assessed at regular intervals during each winter period. This usually involved classifying each food source on a scale of abundance, ranging from absent to abundant. The number of seeds remaining on sample ash trees close to the orchard was estimated. In the first year, three measures of ash availability were made on each sample tree. These were: an estimate of the total number of seeds (keys), the number of bunches of keys, and the number of bunches containing more than ten keys. Since the first of these measures (though subjective) proved sufficiently consistent in 1977/78, bunches were not counted in subsequent winters. The number of buds available to bullfinches was not estimated on a regular basis (except within the study orchard), but the supply of wild buds (e.g. hawthorn) was never seriously depleted.

**Food eaten**

All observations of bullfinches feeding in the study area were recorded. A single observation of one bullfinch feeding on one food plant was counted as one feeding record. Changes in choice of food plants could then be detected by totalling feeding records for each species at the end of each month. Efforts were concentrated in the winter months (when damage to orchards occurs) and few data were collected in the summer.

In each month, all types of habitats were visited. However, in the second and third winter periods, many bullfinches had been fitted with back tags and, in order to see and count these birds, it was often profitable for the observer to stay in a single position where bullfinches were known to congregate (e.g. near ash, pear and oak trees). Also, feeding records were most often obtained in areas where birds could be observed with minimum disturbance, though the best areas changed as the vegetation grew or as clearance of undergrowth progressed.
Thus, feeding records cannot be directly related to the proportions of the various food plants in the diet; some are exaggerated out of proportion. Nevertheless, they are valuable in showing changes in the diet, between months and years. The total number of pear buds eaten in the study orchard can be estimated, since these were counted when the damage was assessed.

Of the seeds eaten, the most detailed records were obtained for ash keys. In addition to sightings of bullfinches feeding on ash, data were obtained from keys collected from beneath fruiting ash trees. The fate of keys could be found by examining each one in turn. Some fall naturally and these may remain intact on the ground for some weeks. Some of these keys are eaten by small mammals, which chew through the outer seed coat and extract the kernel from within. In the study area, such keys could be identified by the appearance of the remaining seed coat which almost invariably had a hole at one edge where a length of seed coat had been removed.

Keys eaten by bullfinches were also easily identified by the presence of lengthwise splits in the empty seed coat. These splits are always found at the tip of the husk, forming a hole through which the bullfinch extracts the kernel. Thus counts of fallen keys were classified as uneaten, eaten by mammals or eaten by bullfinches. Insect larvae were often found inside uneaten keys, as were small round holes through which they emerge. The only other birds seen to feed from ash keys were blue tits in late summer, but these were probably searching for the insects, and were thought to be responsible for keys found with strips of husk torn from them at this time.

Food analysis

Samples of most major winter food items were collected for analysis. The size of sample depended on the size of the food items, ranging from about 50 or more large buds or ash keys to several hundred small buds or seeds. Pear bud samples typically comprised about ten branches, each with about five buds. Whenever
possible, samples were weighed on the day of collection, but some
were stored overnight in a cool place or in airtight, plastic-topped tubes. Also, attempts were made to separate those parts
normally eaten by bullfinches from the parts discarded—thus seed
kernels were analysed separately from their seed coats, and bud
flower initials separately from their outer husks—but this was
not always possible, especially with small seeds and buds.

In the first winter period, only wet (fresh) weights
were taken. In the second and third winters, samples were freeze-
dried and reweighed. Samples were usually small, and overnight
drying was found to be sufficient, though they were usually left
for 24 hours. They were then stored at room temperature until
further analyses could be carried out. Immediately prior to
further analysis, all samples were re-freeze-dried and then ground
to a fine powder in a ball mill.

Calorific value was determined with a ballistic bomb
calorimeter. Nitrogen content was determined by standard Kjeldahl
analysis and converted to percentage protein by assuming that
protein is 16% nitrogen (Kent-Jones and Amos 1967). The amino
acid content of some samples was determined using an amino acid
autoanalyser. Finally, the digestibility of a few samples was
determined by neutral detergent fibre analysis (Goering and Van
Soest 1970).

Feeding trials

All feeding trials were conducted at East Malling
Research Station (E.M.R.S.). Bullfinches were maintained in
dozen outdoor aviaries measuring approximately 2 x 3 x 2.5m, and
fed on a commercial cage bird seed mixture and canary seed. There
was some shelter from wind and rain. Feeding trials were
conducted either in these aviaries or in smaller portable cages,
usually indoors where there was also some protection from low
temperatures. The smallest cage measured 260 x 400 x 300mm.
The experiments were usually designed either to test whether bullfinches could maintain weight on a certain diet, or to find out which parts of buds or seeds were eaten. Sometimes these were combined with the chemical analyses described above, and some faeces were collected for analysis. Details of individual experiments are given elsewhere.
The food available and eaten in the study area

Introduction

Previous studies of the feeding ecology of bullfinches, in particular by Newton (1967), have shown that many plant species provide food for the bullfinch during the year. Depending on the species and the time of year, flowers, buds or seeds may be taken. Bullfinches occur almost throughout Britain, and the availability of food plants varies both locally and regionally; so the diet must vary similarly.

Perhaps the smallest variety of seeds is available in winter, since at this time no new supplies are produced, and those of many species fall to the ground where they are effectively lost to bullfinches. It is at this time that buds are taken. A comparison of the British bullfinch distribution with the distribution of its main winter food plants suggests that the latter may be an important factor limiting bullfinch populations in this country (see Figs. B.1 and B.2).

The study area was well supplied with bullfinch winter food plants (see also Plate B). Ash trees were present in woodland and hedgerows all around the study orchard, although those which produced seed crops were mainly to the west, north and north-east. Bramble was abundant in all woodland and hedgerows and often comprised the main ground vegetation. Dock also occurred throughout the study area, red-veined dock being most common in woodland areas and broad-leaved dock in more open places. They were rather patchily distributed. The study orchard itself had many dock plants growing in the grassed alleys, but these were usually cut down by the owner before they set seed.

Hawthorn was common in hedgerows and woodland edges, although blackthorn was relatively rare - particularly after the clearance in autumn 1979. Pear trees, other than those in the study orchard, were found only in other orchards as shown in Fig. A.1. In the north-east of the study area, adjacent to woodland, was a large orchard of Worcester apples which attracted bullfinches in spring, and several large crab-apple trees grew in
Figure B.1. The breeding distribution of the bullfinch in Britain and Ireland. From Sharrock (1976)
Figure B.2. The distribution of some major winter food plants of the bullfinch. From Perring and Walters (1962)
the woodland. A single, but very large damson tree grew about 100m from the study orchard. Oak was abundant throughout the area.

Bullfinches were seen to take food from over 50 plant species during this study, and, since little effort was made to discover summer food plants, when the greatest variety of seeds is available, the true list is probably much longer. Between December and early May, only nine species were important. These were the seeds of bramble, ash, and dock (two species), and the buds or flowers of hawthorn, pear, damson, apple, and oak. There was considerable overlap in the periods for which each was eaten, though in general seeds were eaten before buds, and oak flowers last. In May, fresh supplies of seeds became available, e.g. dandelion, chickweed, buttercup and greater stitchwort. Fig. B.3 shows the main seeds and buds eaten in the three winters.

1977/78

The first of the three main seeds to run out was dock, and no dock-feeding record was obtained after December. In fact, some seed could be found on a few plants in mid-January, but it was absent in early February. Both ash and bramble seeds remained important foods in January and February; in December about 100 fruiting ash trees were found within about 0.5km of the study orchard (see also Section B.5.5). However, by March, ash keys were restricted to very few trees, and bramble, though still present in some areas, was very thinly distributed; very few bullfinches were seen to feed on seeds at this time.

Pear buds were first eaten in mid-December, and many were taken from the study orchard until the end of February. By April, the pear buds were bursting and were no longer compact units; the rate of bud loss in the orchard was very low at this time, and individual flower heads were taken, rather than whole buds at one go. Similarly, hawthorn buds were taken from late February onwards, but in April, when the buds had burst, the flower heads were treated individually. By May, buds were
Figure B.3. Bullfinch feeding records in the study area

Data are from 560 observations of feeding bullfinches (few observations were made in May and December 1978). Only the main food plants are shown.
probably rarely taken and it is thought that oak and perhaps
sallow flowers became important.

1978/79

In late November 1978, 61 fruiting ash trees were found
in an area which, in early December 1977, had 81. The total
number of such trees within 0.5km of the orchard was thought to be
a little lower than in 1977. However, these differences could not
account for a 77% reduction in the number of ash-feeding records
obtained. Nor was this reduction due to lower observer effort – a
similar number of hours being spent in the area – or to a smaller
bullfinch population (see Section E.7). The decline in ash key
numbers on sample trees (Section B.5.5) was slower than in the
previous and subsequent winters, but very few trees had many keys
left in early March, when the last ash-feeding records were
obtained.

In contrast to the ash-feeding pattern, almost twice
as many bramble-feeding records were obtained in 1978/79 compared
with 1977/78. While in 1977/78 ash-feeding records outnumbered
bramble records by over 4:1, in 1978/79 bramble records
outnumbered ash records by nearly 2:1. One reason for the change
in diet may have been the presence of a large crop of bramble
seeds in autumn 1978 which remained plentiful to mid-March 1979.
There were also more dock seeds in 1978/79, and some plants in
the study orchard were not cut. Dock became noticeably scarce
in January, though bullfinches were found feeding on isolated
plants in early February. The relative abundance of bramble and
dock seed seemed common to other areas within a few kilometres
of the study orchard.

Pear buds were not taken until February – about six
weeks later than in 1977/78. The late start to bud-feeding seemed
generally true of both pear and plum orchards in Kent. As the
temperatures in both winter periods were very similar until the
end of February, when in 1979 the following month was colder than
in 1978, this late start is unlikely to have been due to
differences in bud development (Section B.4.2). It is more likely that the abundance of bramble and perhaps dock seeds reduced the need to eat buds in January 1979. In May, oak flowers were the most important food item.

The number of buds taken from the study orchard was less than half the number taken in 1977/78, and there may have been several reasons for this. The orchard was a little less secluded due to the trimming of the hedge on its northern edge, so bullfinches may have chosen to feed elsewhere. Since the damage started late, buds were larger, and fewer may have been needed by the birds. The general abundance of bramble seeds during the first month of damage may also have reduced the need for buds.

1979/80

At the end of November 1979, 85 fruiting ash trees were found in the area assessed in previous years, indicating, if anything, a slightly larger ash crop than in previous years. All but four of these were bulldozed when the ground cover was removed from the woodland to the west of the study orchard. Only mature oak trees were left, and the area became largely unsuitable for bullfinches. Observation of feeding birds was therefore concentrated on the woodland and gardens to the south, north and north-east of the orchard. However, there were at least a further 35 fruiting ash trees within 0.5km of the study orchard. Some of these trees had very few keys left in January, but others retained large numbers of keys even in mid-March (Section B.5.5).

Ash keys were the most important food between November and January, and they were eaten regularly until mid-February. Thereafter no birds were seen to feed on ash, even from trees which still retained large seed crops and from which bullfinches had previously fed.

Bramble seeds were far less numerous than in 1978/79, especially after the woodland clearance of November 1979. By
January, they had become thinly distributed and hard to find. Fewer feeding records were obtained than in both previous winters, and ash-feeding records outnumbered bramble records by 12:1 (though this was exaggerated by observations of tagged birds in ash trees that could be watched easily). With woodland clearance and cleaner orchard management, dock was uncommon even in November. Ash keys were almost the only seeds eaten in February.

As in 1977/78, bud-feeding started early; pear buds were taken from mid-December onwards. The preceding month had been unusually warm and buds may have been well advanced in their development. Alternatively, a lack of seeds – dock or bramble, but apparently not ash – may have been important.

Throughout the winter, temperatures were higher than in previous years, and this probably allowed rapid bud development and caused both an early start and an early finish to bud-feeding. Hawthorn buds were taken earlier than in previous years, and damage to pears finished early – at the end of March. Pear blossom was, at the end of April, about a fortnight earlier than in previous years. Clearance of woodland greatly facilitated observation of bullfinches feeding on oak flowers which occurred in April and May, previously only recorded in May. Outside the study area, blackthorn buds were taken in February and March, while in previous years most were taken in March and April.

Probably owing to woodland clearance, the actual number of buds taken from the study orchard was less than in previous years (Section C.3). However, many pear bud-feeding records were obtained from the small orchard to the north-east of the study area, and sightings of tagged bullfinches showed that these were the same birds that had previously fed in the study orchard.

Summary

In the three winter/spring periods, several factors affected the foods eaten by bullfinches. The effects of each factor are difficult to isolate, and no single factor emerged as
an overriding influence on bud-eating. Three important conclusions may be drawn:

1) In 1978/79, abundant supplies of bramble seeds, and to a lesser extent dock seeds, probably resulted in fewer ash keys being eaten and in a postponement of the start of pear bud-feeding.

2) In 1979/80, bud-feeding both started and finished early, and the most likely reason for this was the warm weather which encouraged early bud development. Lack of seeds may also have been involved.

3) Feeding on ash keys was not always correlated with their availability, and no evidence was apparent for a direct link between damage and ash crops.

Ash-feeding is discussed in greater detail in Section B.5.
Since no single food of the bullfinch is freely available all the year round, it is inevitable that a variety of foods should be taken. 'Availability' reflects not only the presence of plants bearing the seeds or buds, but also the quality of the seeds or buds present.

In general, bullfinches feed on seeds but not the flowers that produce them, so there must be a time during seed development when they become worth eating. Similarly, bullfinches feed on buds but not the shoots from which they grow, so there must also be a time during bud development when they become worth eating. As pear fruitlets are never eaten, it follows that the buds, or flowers, must at some stage become less attractive to feeding bullfinches. Less obvious, it may be possible for seeds to become less worthwhile: when they germinate, if they rot, or perhaps by becoming, in some way, over-mature.

In the context of bullfinch damage to orchards, some of these effects are not important. For example, all the seeds present before damage starts are mature (seed development is complete) and, in the study orchard, the end of pear bud damage was marked by a shift towards buds and flowers of other species rather than fresh supplies of seeds. Hence the early stages of seed development are unlikely to have affected bud-eating. On the other hand, it is possible that the seeds eaten before and during bud damage to orchards, became less attractive as food — in addition to becoming less numerous. In this study, an attempt was made to detect changes in ash seeds which might indicate that this was happening.

A knowledge of bud development is essential to a detailed understanding of bullfinch damage. That buds swell in spring is common knowledge, as is the fact that early springs follow mild winters. However, swelling buds as a food source are not easy to quantify, especially because they are, by definition, not static. Buds on fruit trees are first formed in summer and
are clearly visible at leaf fall in autumn. They remain dormant with little noticeable change for several months; only in January or February do they begin to swell visibly. Both fruit growers and researchers usually describe the stage of development of buds by their external appearance and may define as many as twenty stages in total (e.g. Hamer 1980). However, such descriptions give little indication of the value of the buds to bullfinches and are, in any case, mainly applicable in the last few weeks before and during flowering, i.e. when bullfinches turn their attention to other food sources.

Nevertheless, research on fruit bud development, usually aimed at predicting blossom dates or preventing frost damage to flowers, has revealed the climatic factors which have the greatest effect on blossom (and, by inference, bud development). Predictably, temperature has emerged as the principal controlling factor, and this is usually expressed in terms of accumulated day degrees, a measure of the total warmth above a chosen base temperature below which growth is negligible (Pearce and Preston 1954). At E.M.R.S., accumulated day degrees above 6°C, the base temperature found to be most appropriate for pear trees (see Pearce and Preston 1954, Anstey 1966), are calculated from daily maximum and minimum temperatures as in the Agricultural Crop Weather Scheme (Air Ministry 1928). These were used in this study. Whilst blossom dates may be predicted with greater accuracy if day degree data are combined with such factors as sunshine and earth temperatures (Harding et al. 1976), and whilst temperatures even during the preceding summer may have some effect on bud development (Pearce and Preston 1954, Jackson 1975), no attempt was made to assess such factors in this study.

In theory, day degrees can be totalled from any chosen starting date. In practice, certain dates result in a closer correlation between accumulated day degrees and blossom than others, and the best date varies with the location and variety (Anstey 1966, Hamer 1980). Since bullfinches sometimes feed on pear buds from December onwards, meteorological data from October onwards were considered in this study.
Janzen (1978) considered that, for an animal, 'a seed is likely to be a more balanced diet than any other plant part, except perhaps shoot tips.' Buds, especially the central tissues (Plate B), may be particularly nutritious, though the well-known preferences shown by bullfinches for the buds of particular varieties of fruit suggest that they vary in this respect. Annual variations may also occur in the nutritional quality of buds, perhaps depending on the size of previous seed or fruit crops (Lauckhart 1957), and this may influence both the feeding behaviour of birds and their breeding success (Sillvonen 1954).

Few data are available on the chemistry of buds. Newton (1964a) gives some data for whole oak buds from Dr. A. Carlisle of Merlewood Research Station, but he also rightly points out that bullfinches do not normally eat oak buds (though they will in aviaries), and that bullfinches discard the outer bud scales included in these analyses.

Summers and Jones (1976) analysed whole buds of three pear varieties for nitrogen content. Results were expressed as percentage of protein in the fresh weight sample. They recorded minor differences and considerable overlap in percentage protein between the varieties Williams' Bon Chrétien (mean 4.3%) and Conference (mean 4.1%). Both are regularly damaged by bullfinches, and both had higher protein levels than Doyenne du Comice (mean 3.4%) which is less commonly attacked. Combined data from three years indicated a rise in protein concentration in March. Summers and Jones also measured protein levels in seeds collected in autumn, and found 7.0, 14.8, and 18.6% protein in red-veined dock, great plantain and stinging nettle, respectively. They concluded that buds were low in protein compared to seeds, and therefore might have lower nutritional value, especially those of Comice.

During attempts to feed bullfinches solely on pear buds, Summers (1982a) calculated the calorific value of bud tissue eaten by the birds but did not find a significant difference between pear varieties. Nevertheless, in some tests, birds fed on Conference buds fared better than those fed on Comice buds,
perhaps because the edible portion of each Conference bud (22-30% of the weight of each bud) was larger than for Comice (14-16%).

The only other attempt to analyse the chemical constituents of pear buds is that of Greig-Smith et al. (in press). These authors assessed the levels of total soluble protein, free amino acids, starch, glyceride-glycerol, fructose, sucrose, glucose and phosphorus in whole buds of both Conference and Comice. Between February and early April, rises were detected in most of these, but significant differences between varieties were only apparent in the concentrations of fructose and free amino acids (both were most concentrated in Conference buds).

Both Summers and Jones (1976) and Greig-Smith et al. (in press) give data only for whole buds. Similarly, the calorific value of seeds is usually only measured for whole seeds (e.g. Kendeigh and West 1965). Although more laborious, analysis of the central meristematic tissues and kernels, which bullfinches eat, may give much more meaningful results, hence the investigations carried out in this study.

Whether nutrient levels in buds should be expressed as percentage dry weight or percentage wet weight is debatable. Summers and Jones (1976) used wet weights on the grounds that bullfinches feed to capacity in orchards, cramming as many buds as possible into their crops - volume of fresh buds being limiting. However, it may be that buds (or seeds) with a large water content are digested more rapidly than dry buds, in which case dry weight percentages would give a more meaningful picture of nutritional quality. Captive bullfinches certainly drink frequently when feeding solely on seeds (personal observation), as do red-billed queleas to aid digestion (Ward 1978). Budgerigars do not find this necessary (Wyndham 1980).

When Newton (1964a) fed bullfinches solely on buds, they spent much of the day feeding 'urgently'. In January, those fed on hawthorn rested for only half an hour at midday, and those fed on Comice or Conference rested for only one hour, also at midday.
Presumably feeding rate was not limited by the rate of digestion. They may well have crammed many bud initials into their crops, but digestion presumably kept pace with feeding. In February, the same birds rested for about two hours each day, and only in March was 'less urgent' feeding observed and half the day spent resting. Newton found marked differences in the ability of these birds to maintain weight while feeding on the different bud types. It seems likely that this was caused by differences in the rate at which bud tissue could be swallowed (i.e. dry weight of tissue) and that this was not limited by the volume of tissue already occupying space in the digestive tract - at least until March.

Various birds, especially those in the grouse family, select foods which are rich in nitrogen or other nutrients (e.g. Moss 1968, 1972, Mills and Mark 1977, Lance 1978, Green 1980). Their breeding success may be limited by their protein reserves (Jones and Ward 1976), and they may not always be able to increase their food consumption to compensate for lack of nitrogen - feeding to satisfy their energy, not nitrogen, requirements (Martin 1968). On the other hand, both seeds and buds may often be chosen depending on how easy they are to eat. For example, Willson (1971) found that several species of North American finches chose seeds that were easy to eat and not those with high energy content. Similarly, Willson and Harmeson (1973) found that in most cases preferences shown by cardinals and song sparrows were associated with the ease of eating rather than seed weight, protein, lipid or energy considerations. They also found that some seeds were digested more efficiently than others, and that this varied with temperature and between individual birds. High concentrations of tannin may reduce the digestibility of protein (Feeny 1970, Ford and Hewitt 1979), and protect some plant parts from herbivore predation (Dement and Mooney 1974).

In his review of toxins in seeds, Bell (1978) points out that there is an increasing volume of evidence suggesting that many toxins may play a critical role in governing specific relationships between animals and plants. Such toxins may be effective against only a single animal species or against many, and they occur in many different forms. Seed coats may contain
toxins effective against insects (Janzen 1978), though these may not affect the feeding behaviour of finches, which husk and discard the seed coat. Uncommon amino acids comprise one group of toxins, and hundreds of these have been isolated from plants (Bell 1976); some are poisonous to birds (see Bell 1978).

In winter, spruce grouse need to adapt to a diet of conifer needles which contain 75% indigestible matter (Pendergast and Boag 1971). Large quantities of these needles are eaten, but the degree of adaptation, through modifications of the gastrointestinal tract both anatomically and physiologically, is critical to their ability to utilise the diet. Pendergast and Boag suggested that periods of heavy snowfall, forcing birds to feed solely on pine needles, could place unconditioned birds under considerable stress. Similar weather conditions could force bullfinches to feed solely on buds if tree seeds were not available, and if adaptation to a bud-only diet is necessary then this could cause heavy mortality. Laboratory feeding experiments involving rapid changes of diet may also be rather harsh tests of the birds' ability to survive on the chosen foods (see Section B.6). Adaptation to particular diets may occur in many animal species. For example, Smith and Follmer (1972) found that squirrels took two days to adapt to some 'natural' diets.

It is possible that any of these varied aspects of feeding may influence the diet chosen by bullfinches. Most are beyond the scope of this study, but results of food analyses and feeding trials, and indeed the bullfinch problem as a whole, should be viewed in this wider context.

Finally, it is worth pointing out at this stage that, although feeding trials with captive birds can be a very useful method of examining food preferences and quality, the scope for such experiments with bullfinches is limited by logistic problems of feeding them on any of their natural foods in cages that are small enough to allow monitoring of bird weights, food eaten and collection of faeces, and yet large enough to allow realistic choice experiments or to hold sufficient food. Collecting fruit-buds for only a few birds is a major task since they are eaten
very rapidly, each bird being capable of eating the buds from two to three full-size pear trees/day.
B.4.2. Meteorological data, blossom and damage

Figs. B.4 and B.5 and Tables B.1 and B.2 summarise meteorological data collected at E.M.R.S., which can be related to bud development data collected in this study.

Each year had a cool spell in or towards the end of November, followed by a warmer period in December. In 1979, early December was particularly warm; of the years since 1958, only in 1974 was the December total of accumulated day degrees as great as in this month. In 1978 and 1979, both January and February were cold; in 1978 mean temperatures for these months were about average, but in 1979 they were well below average (January was the coldest recorded since 1963).

Unusually warm weather returned towards the end of February in 1978, although the April mean temperature was the coldest on record at E.M.R.S. In 1979, warmer weather returned at the beginning of March; mean temperatures for March and April were about average. The total of accumulated day degrees was greater throughout March and April 1978 than in March and April 1979, but by the end of April the difference was small.

The winter of 1979/80 was mild. The January mean temperature was below average, but the February mean temperature was two degrees above average. The total of accumulated day degrees rose quickly in February; and, with near-average March and April temperatures, remained well ahead of previous years' totals.

Using these data, the following predictions about bud swell can be made.
1) If buds are responsive to high temperatures in late November and early December, bud swell will have occurred at this time in 1979 - thus giving them a head start over previous years.
2) January should have been a month of relative dormancy in all three years.
3) Bud swell should have occurred from early February in 1980, late February in 1978, and early March in 1979.
Figure B.4. The number of day degrees over 6°C accumulated in 5-day periods during this study.

Data were recorded by meteorological staff at E.M.R.S.
cumulative day degrees from 30 November

D damage       B blossom

1977 / 78

1978 / 79

1979 / 80

D    J    F    M    A    M

Figure B.5. The number of day degrees over 6°C accumulated during the three winters of this study, and the periods of Conference pear bud damage and blossom.

Day degrees and blossom data were recorded by meteorological staff at E.M.R.S.; damage data are from the study orchard.
4) The latest year (slowest overall bud swell and latest blossom) should just have been 1978/79, and by far the earliest 1979/80.

Table B.3 gives blossom periods for Conference and Comice pears at E.M.R.S., and these fit the above predictions. Blossom in 1978 was a little earlier than in 1979, and blossom in 1980 was about a fortnight earlier than in 1978. In each year, Conference blossom started and finished when 180-210 and 275-280 day degrees respectively had accumulated after mid-December (Fig. B.5). The study orchard is about 46m higher than E.M.R.S., and temperatures were probably correspondingly lower. In each year, blossom in the study orchard was about a week later than at E.M.R.S.

The most detailed data on pear bud-eating periods resulted from the sample branches in the study orchard, and Fig. B.5 shows the main periods recorded. Apart from the developmental stage of the buds - controlled by temperature conditions - bullfinch damage is likely to be affected by the supplies of other foods and the number of buds available. Thus it has already been suggested that the start of damage was delayed in 1978/79 by abundant supplies of seed, and that the end of damage in 1977/78 was enforced prematurely when buds in the study orchard ran out. Data presented in this section do not suggest that temperature conditions controlled these events. However, buds were plentiful in 1978/79 and 1979/80, so the fact that in both years damage ceased when about 140 day degrees had accumulated, suggests that temperature was an important influence here. Damage commenced in December in both 1977 and 1980 despite the differences in temperature recorded; conditions earlier in the year may have been important.
Table B.1. Total accumulated day degrees over 6°C recorded at E.M.R.S. in 30-day periods

<table>
<thead>
<tr>
<th>period (dates)</th>
<th>1977/78</th>
<th>1978/79</th>
<th>1979/80</th>
</tr>
</thead>
<tbody>
<tr>
<td>01.10 - 30.10</td>
<td>181</td>
<td>180</td>
<td>188</td>
</tr>
<tr>
<td>31.10 - 29.11</td>
<td>87</td>
<td>118</td>
<td>63</td>
</tr>
<tr>
<td>30.11 - 29.12</td>
<td>45</td>
<td>49</td>
<td>72</td>
</tr>
<tr>
<td>30.12 - 28.01</td>
<td>9</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>29.01 - 27.02</td>
<td>19</td>
<td>3</td>
<td>41</td>
</tr>
<tr>
<td>28.02 - 29.03</td>
<td>62</td>
<td>34</td>
<td>35</td>
</tr>
<tr>
<td>30.03 - 28.04</td>
<td>46</td>
<td>92</td>
<td>109</td>
</tr>
</tbody>
</table>

1. 1980 was a leap year; the last two periods were 28.02 - 28.03 and 29.03 - 27.04.

Table B.2. Mean monthly temperatures recorded at E.M.R.S.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>October</td>
<td>12.1</td>
<td>11.8</td>
<td>11.7</td>
</tr>
<tr>
<td>November</td>
<td>7.5</td>
<td>8.9</td>
<td>6.6</td>
</tr>
<tr>
<td>December</td>
<td>6.5</td>
<td>5.2</td>
<td>6.5</td>
</tr>
<tr>
<td>January</td>
<td>3.5</td>
<td>0.4</td>
<td>2.8</td>
</tr>
<tr>
<td>February</td>
<td>3.3</td>
<td>1.9</td>
<td>6.3</td>
</tr>
<tr>
<td>March</td>
<td>7.1</td>
<td>5.4</td>
<td>5.7</td>
</tr>
<tr>
<td>April</td>
<td>6.7</td>
<td>8.6</td>
<td>9.1</td>
</tr>
</tbody>
</table>

Table B.3. Blossom periods recorded at E.M.R.S.

<table>
<thead>
<tr>
<th>Conference</th>
<th>1978</th>
<th>1979</th>
<th>1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>blossom period</td>
<td>28.04-16.05</td>
<td>29.04-18.05</td>
<td>14.04-01.05</td>
</tr>
<tr>
<td>date of full bloom</td>
<td>04.05</td>
<td>09.05</td>
<td>19.04</td>
</tr>
</tbody>
</table>

Comice

| blossom period | 02.05-23.05 | 06.05-21.05 | 17.04-10.05 |
| date of full bloom | 09.05   | 11.05  | 28.04  |
B.4.3. **Pear buds**

**Fresh weights**

The fresh weights of Conference and Comice buds and their central flower initial tissue in each of the three winter periods are shown in Figs. B.6 and B.7. Much of the early rise in whole bud fresh weights can be attributed to the swell of flower initials; in later weeks leaves grew from bud tissue, classified as husk, immediately surrounding the flower initials.

Whole bud data show that bud swell occurred earliest in 1979/80; buds of both varieties more than doubled in weight during February 1980, compared to only small increases in other years. Data for flower initials are useful because this is the part that bullfinches eat. These central tissues swelled throughout the periods of measurement, though only slowly in December and January. Rapid swell occurred earliest in 1980 and latest in 1979. Thus the weight of Conference flower initials probably increased by 300% in February 1980, 200% in February 1978, and only 50% in February 1979. The spacing of measurements makes it difficult to determine the 'start' of rapid bud swell precisely, but the general picture is in agreement with predictions made in Section B.4.2. Flower initials were comparatively heavy in December 1979 and early January 1980, suggesting that they had responded to the warm spell in late November and early December 1979.

Although whole buds of Conference and Comice were usually similar in weight, flower initials of Conference were consistently heavier than flower initials of Comice. Until January or February, Conference flower initials were about twice the weight of Comice, and even in the later stages of growth there was always a difference of at least 10mg.

**Dry weights**

Fresh buds easily dry out during dissection, so dry weights were measured in 1978/79 and 1979/80. Data from study
Figure B.6. Fresh weights of whole pear buds in the study orchard.

Note that in March 1978 samples were collected from Rocks Farm, and that in late March 1977 Conference buds on first-year wood were clearly larger than those on older wood.
Figure B.7. Fresh weights of pear flower initials in the study orchard.

See note on Fig. B.6.
orchard pear bud flower initials indicated clear differences between the two years and the two pear varieties (Fig. B.8). Rapid bud swell had certainly started by mid-February 1980, but may not have occurred until March in 1979, and Conference initials were always markedly heavier than those of Comice. There is also a suggestion that, even in January, initials were heavier in 1980 than in 1979. Whole bud (and husk) dry weights revealed a similar timing of swell, but the two varieties had buds of almost identical weights.

**Pear flower initials as a proportion of the bud**

During the development of pear buds, both their flower initials and outer husks (see Plate B) increase in weight, but data from the study orchard show that, at least until March, flower initials grow at a faster rate than the surrounding husks (Fig. B.9). Thus, as bud development progresses, flower initials comprise an increasing proportion of the bud. As with other bud swell parameters, a marked difference is apparent between the two winters. Swell occurred much earlier in 1980 than in 1979, and there is a clear indication that both varieties of pear buds had a 'head start' in 1980. Comice flower initials comprised a much smaller percentage of the bud than their Conference counterparts.

During the later stages of bud development, bullfinches eat only a small proportion of the tissues defined here as flower initials. This was confirmed when captive birds were supplied with well-advanced pear buds: on 24 April 1979, 15 and 16% of the dry weight of Conference and Comice buds respectively were eaten when the initials comprised about 50 and 40% of the buds, and on 15 March 1980, 12% of Conference buds was eaten when the initials comprised 42%.

**Water content**

Fig. B.10 shows the rise in percentage water content of pear bud flower initials and the surrounding husks, associated
Figure B.8. Dry weights of pear flower initials in the study orchard.

In late March 1979 Conference buds on first-year wood were clearly larger than those on older wood.

Figure B.9. Study orchard pear flower initials as a proportion of the bud.

i.e. \( \frac{\text{dry weight of flower initial}}{\text{dry weight of whole bud}} \) expressed as a percentage

Conference buds collected on first-year and on older wood in late March 1979 were identical in this respect.
Figure B.10. Water contents of pear bud tissues collected in the study orchard.
with bud development. Water contents recorded in January 1979 are probably too low; they were markedly lower than the lowest levels recorded in 1980. These were the first samples to be dissected for freeze-drying before fresh weights were measured. Predictably, the error appears to be greater for flower initials than for husks; the initials are smaller and more prone to drying. The Comice buds collected at this time were frozen for a few days before dissection and may have suffered less drying than Conference buds. These conclusions are supported by the fact that the fresh weight of Conference flower initials recorded in late January 1979 was lower than that recorded in early January (see Fig. B.7). Also, a further sample of whole Conference buds was collected in late January 1979 (but not subsequently dissected), and these had a normal water content of 58%. All data may be a little low since partial drying during dissection could not be totally prevented. On the other hand, some data may have been affected by rain prior to sampling; Hewitt et al. (1978) found that the water content of peach buds was higher than usual for 5 hours after a wetting treatment.

Allowing for these errors, bud swell, as measured by water content, shows marked agreement with data presented in previous sections. Early in both years, the water content of pear buds rose only slightly, but a rapid rise occurred in February 1980 and in March 1979, providing further evidence that bud swell was about a month earlier in 1980 than in 1979. The maximum water content recorded in this study was 80% for a sample of well-advanced Comice buds collected in late April 1980, though earlier in the year when buds were dissected, flower initials always contained about 10% more water than the surrounding husks.

Calorific value

The calorific value of pear bud tissues collected in 1979 are shown in Fig. B.11. Data are too few for a detailed comparison between the two pear varieties, although there is some indication that, in January and February, Comice buds were less energy-rich than Conference buds. Data for Conference buds show
Figure B.11. Calorific values of pear bud tissues collected in the study orchard in 1979.

Two independent samples of Conference husks were analysed in January.
that bullfinches select the least energy-rich part: the flower initials had consistently lower calorific values than the surrounding husks; whole buds were predictably intermediate. Data also indicate a downward trend in calorific value during bud swell. Similar differences and trends are possible in Comice buds.

Similar conclusions would be drawn if these data were converted to fresh weight calorific values. Pear flower initials have a high water content and, compared to husks, would be even less energy-rich. Water contents of the two pear varieties are similar and would not affect the differences described.

**Protein levels (dry weight)**

The nitrogen contents of dried pear bud tissues collected in 1978/79 and 1979/80 have been converted to protein levels and these are shown in Fig. B.12. Marked increases in protein levels were apparent in February 1980 and March 1979, especially in the flower initials. In 1979, the protein level recorded in Conference flower initials appeared to rise earlier (or faster) than that in Comice, but in 1980 the opposite may have been true.

It is interesting to note that Comice flower initials were less protein-rich than those of Conference early in 1979/80, even though the two varieties had been similar in this respect the previous winter. Also, initials, and to a lesser extent husks, of both varieties were less protein-rich in 1979/80 than in 1978/79; for Conference, the 'minimum' protein levels were lower by 84% in initials and 95% in husks; for Comice, protein levels were lower by 70% in initials and 86% in husks.

During the later stages of bud development, bullfinches seem not to select the most protein-rich portion. Thus, while Conference bud tissues discarded by captive birds on 15 March 1980 had lower dry weight protein contents than whole buds, Comice and
Figure B.12. Dry weight protein levels in pear bud tissues collected in the study orchard.

In late March 1979 higher protein levels were found in both initials and husks of Conference buds from first-year wood than those on older wood - whole buds were analysed only from old wood on the same day.
Conference tissues discarded on 24 April 1979 had protein contents similar to and higher than their respective whole buds.

**Protein levels (fresh weight)**

Summers and Jones (1976) assessed the fresh weight protein levels in whole pear buds; data from this study are shown in Fig. B.13. for comparison. Samples thought to have dried prior to weighing (see page 55) have been omitted and some data for whole buds are calculated from initial and husk data. Since both protein and water contents of pear bud tissues rise by similar amounts during bud swell, fresh weight protein levels remain fairly stable and thus cannot be used as an indicator of bud development.

The mean protein levels shown in Table B.4 clearly show that the flower initials have a greater percentage protein than the outer husks. In contrast to dry weight measurements discussed above, fresh weight protein levels in the husks did not vary much between the two years. However, the differences in fresh weight flower initial protein levels between years and varieties are similar to dry weight measurements.

<table>
<thead>
<tr>
<th>Table B.4. Fresh weight pear bud protein levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>bud tissue</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>flower initial</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>outer husk</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

1. March 1980 data excluded
Some values were calculated from initial and husk data.
Also see note on Fig. B.12.
Table B.5. Pear bud digestibility

<table>
<thead>
<tr>
<th>bud tissue</th>
<th>date</th>
<th>% undigested</th>
<th>Conference</th>
<th>Comice</th>
</tr>
</thead>
<tbody>
<tr>
<td>flower initial</td>
<td>19.02.80</td>
<td>10</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>outer husk</td>
<td>&quot;</td>
<td>35</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>flower initial</td>
<td>15.03.80</td>
<td>19</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Digestibility

Results of digestion analyses of five pear bud samples are shown in Table B.5. The outer husks of pear buds are tough and woody, so it is not surprising that these were less digestible than the central flower initials. The initials were apparently more digestible than ash keys, and so may be assumed to be an unwasteful food source for bullfinches. Obviously more data are needed, but those given above suggest that Conference flower initials may become less digestible during bud swell, and that Comice buds (initials and husks) may be slightly less digestible than Conference buds. Certainly the fall in digestibility recorded might have been predicted since cell walls (which are indigestible) are laid down and thickened during bud development.

Comparison of Conference and Comice buds

Data presented in the previous pages show that large changes occur within pear buds during the months when bullfinches normally feed on them. Conference and Comice buds were in many ways similar, and the timing of the changes recorded in both varieties appeared to be highly correlated with temperature conditions. Most notable was the difference between the rate of bud development in the winters of 1978/79 and 1979/80. The former winter was very cold and the latter very mild, and, probably as a result, bud development in 1978/79 was about one month later than in 1979/80. This, in turn, is probably why damage to Conference trees ended in mid-March 1980 but not until mid-April.
1979, even though there was no shortage of buds in either year. It is probably no coincidence that in both these winters damage ended when about 140 day degrees above 6°C had accumulated from 30 November (see Fig. B.5); either the buds were no longer nutritionally profitable, or alternative foods - also dependent on temperature conditions - had become more desirable.

No single bud parameter emerged as an overriding factor determining bud quality which would, in turn, determine the start and finish of bud-feeding, and varietal preferences. Fresh weight protein levels did not vary markedly during bud development so are unlikely to have affected the timing of bud-feeding, but other factors - fresh and dry weights (of whole buds and flower initials), water content, calorific value, dry weight protein level and digestibility - did vary during bud development and may all have influenced bud-feeding, perhaps indirectly via some unmeasured parameter(s). The fact that bullfinches eating well-advanced buds tend to select only a small fraction of the bud tissue previously termed 'flower initial', suggests that the buds do become less profitable, but more experiments are needed before the most important criteria can be identified.

Conference and Comice buds differ in their external appearance; those of Conference are rounded, blunt and hairless, while those of Comice are relatively pointed and hairy. However, bullfinches commonly feed on a wide variety of other buds - with much greater differences than these - so other factors probably account for the well-known and often marked preference shown by feeding birds for Conference buds, over Comice (Wright and Summers 1960, Newton 1964a). On the other hand, counts of buds in the study orchard clearly showed that, whilst Comice might be less preferred, they can hardly be described as disliked - about 175,000 Comice buds were eaten during the three winters monitored - and the deciding factors might not be obvious.

Both calculated and measured fresh weight protein levels of whole buds from the study orchard fell into the range reported by Summers and Jones (1976), with the exception of those outside the period monitored by them, and the single sample of buds on
first-year wood collected in March 1979 (Summers and Jones did not sample first-year wood buds). Furthermore, in both years, the mean fresh weight protein level of whole Comice buds was lower than that of whole Conference buds - as in their analyses.

However, closer inspection of data from this study indicates that Conference buds, and particularly their flower initials, may not always be more protein-rich than Comice buds. For example, in January and February 1979, buds of the two varieties had almost identical dry and fresh weight protein levels; only subsequently did Conference become the more protein-rich variety. With this in mind, it is interesting that, despite broadly similar damage levels in Conference study orchard trees in 1978/79 and 1979/80, damage to Comice trees was severe in 1978/79 but negligible in 1979/80; perhaps the Comice buds were of sufficiently high nutritional quality only in 1978/79. Year-to-year variation in protein levels within the flower initials was so great that the protein level (both fresh and dry weight) in Comice was markedly higher than that in Conference initials in 1979/80. Annual differences in varietal preferences shown by bullfinches, and the tendency for some birds to return repeatedly to certain individual trees (Newton 1960, Wright and Summers 1960), may also be caused, in part, by variation in bud quality.

Lauckhart (1957) suggested that the nutritional quality of buds is partly determined by the magnitude of previous seed crops. Thus, the lower protein levels recorded in the study orchard in 1979/80 compared to 1978/79, may have been caused by the relatively heavy crop of pears produced by both varieties in 1979 compared to 1978 (see Section C.3). Thus, annual variations in the severity of bullfinch damage may result partly from annual variations in fruit crops.

A further argument for the importance of protein level as an indicator of bud quality is the fact that flower initials, which are eaten by bullfinches, were always richer in protein than the surrounding husks, which are discarded. Only when feeding on well-advanced buds did bullfinches eat bud tissues with lower than average protein content. Clearly the two bud portions differ
in their chemical make-up, perhaps in ways which affect their quality as foods. Similarly, the dramatic rise in dry weight protein levels recorded in both varieties, presumably reflects chemical changes, some of which might influence bud-feeding. Compared with fresh seeds, fresh buds are low in protein, but dry weight protein levels are not so different. Indeed, once bud swell commences, flower initials of pear buds soon exceed seeds in this respect, so it is difficult to draw definite conclusions about whether seeds or buds should be preferred.

The fact that bullfinches select the least energy-rich portion of buds suggests that factors other than calorific value determine this aspect of their feeding behaviour. The digestibility of the various bud tissues is likely to be important since this would determine how much energy could be assimilated by the birds. Ideally, this should be assessed from feeding trials with live birds, since the applicability of digestion analyses carried out in this study is not known. Nevertheless, the high digestibility of flower initials, compared to husks, is promising, and suggests that further experiments might yield useful information.

Of all the parameters measured, the most marked and consistent difference between Conference and Comice buds was the size of their initials, measured in terms of fresh or dry weight or in terms of the proportion of the bud comprised by the initial. This difference was also noted by Summers (1982a). In the early stages of bud swell, Comice initials were only half the size of Conference initials. Thus Comice initials did not reach the size of January Conference initials until February or March, by which time the latter were, of course, even larger. Any or all of the other factors mentioned may play some part in both the timing of bud-feeding and varietal preferences, but it seems very likely that the most important factor determining which variety is the most profitable food source on any given date may simply be the size of the flower initial within each bud.
B.4.4. **Blackthorn and hawthorn buds**

Of the many non-cultivated buds available to bullfinches, those of blackthorn and hawthorn are probably eaten most frequently, and both occur throughout the bullfinch's British range (Figs. B.1 and B.2). In the study area, surprisingly few hawthorn feeding records were obtained, perhaps indicating the presence of more profitable foods; blackthorn was relatively uncommon, but many feeding records were obtained from other areas where it was abundant.

As shown for pear trees, bud swell and blossom in these species is probably influenced by temperature conditions, and since they flower at different times of year - blackthorn in late March or April, hawthorn in May or early June - differences in the intensity of their response to temperature might be expected. If their bud swell is temperature-controlled, we should expect to find that swell was earliest in the mildest winter of this study (1979/80) and latest in the coldest winter (1978/79). To confirm this, and to compare these buds with pear buds, several samples were collected from the study area and analysed. Results are given in Tables B.6 and B.7 and Figs. B.14-16. Unlike pear buds, these wild buds were too small for hand dissection; much useful information might be obtained if sufficient time or manpower were available.

**Table B.6. Calorific value of hawthorn buds**

<table>
<thead>
<tr>
<th>date</th>
<th>bud tissue</th>
<th>calorific value (kcal/g) (dry weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>early February 1979</td>
<td>whole buds</td>
<td>5.31</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot; husks discarded by bullfinches</td>
<td>5.43</td>
</tr>
</tbody>
</table>

**Table B.7. Digestibility of blackthorn and hawthorn buds**

<table>
<thead>
<tr>
<th>date</th>
<th>bud tissue</th>
<th>blackthorn</th>
<th>hawthorn</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.04.79</td>
<td>whole buds</td>
<td>12</td>
<td>28</td>
</tr>
<tr>
<td>&quot;</td>
<td>husks discarded by bullfinches</td>
<td>21</td>
<td>29</td>
</tr>
</tbody>
</table>
Figure B.14. Weights of whole hawthorn and blackthorn buds collected in the study area. Buds collected in December 1977 and January 1980 were larger than average.
Figure B.15. Water contents of whole hawthorn and blackthorn buds collected in the study area.
Figure B.16. Protein levels in whole hawthorn and blackthorn buds collected from the study area.
Fresh and dry weight measurements showed clear and consistent differences between the buds of blackthorn and hawthorn, and in the rate of bud swell in the three winters. Bud swell appeared to be about six to eight weeks earlier in 1979/80 than in 1978/79, and 1977/78 was intermediate - just as expected. Throughout the periods monitored, blackthorn buds were far lighter than those of hawthorn. The buds of the two species had very similar water contents, but these were a little lower than pear buds. As with pear bud samples collected early in 1979, the first blackthorn and hawthorn samples collected may have dried before being weighed, and bearing this in mind it seems likely that the water content of these wild buds rose earlier in 1979/80 than in 1978/79 - again as expected.

The two hawthorn bud samples analysed for calorific content gave results very similar to pear bud samples and were therefore much as might have been expected, but some less predictable results were obtained from protein analyses. Dry weight protein levels rose during bud swell, but differences between years in the timing of this rise were not very marked; indeed, blackthorn buds appeared to be more advanced in 1978/79 than in 1979/80 - contrary to expectation. Two factors may have contributed to this discrepancy. First, whole buds and not just flower initials were analysed; data from pear buds showed that changes in protein levels in whole buds were comparatively small and slow and thus were not very sensitive as indicators of bud swell. Secondly, differences in the timing of changes in protein level may have been masked by differences in the level of protein initially present in the buds each year (cf. pear buds). Fresh weight protein measurements clearly showed that at least blackthorn buds had a higher level of protein in 1978/79 than in 1979/80.

Neither of the hawthorn samples analysed for digestibility seemed notably digestible, although both were apparently more digestible than ash key kernels in the same month. Whole blackthorn buds were apparently as digestible as pear flower initials had been earlier in the year, suggesting that a larger proportion of each bud might be edible.
Several attempts were made to find out what proportion of hawthorn and blackthorn buds bullfinches eat by supplying captive birds with several hundred buds of one or other species, and comparing the mean dry weight of discarded husks with that of whole buds. Inconclusive results were obtained, because the birds selected the larger, more advanced buds available. It had also been hoped to confirm bullfinches' selection of the protein-rich part (i.e. the flower initials) of these buds by comparing the mean protein content of discarded husk with that of whole buds. Although, at least for blackthorn, discarded husks were less rich in protein than whole buds, the results were again of doubtful accuracy because of the non-random selection made by the birds.

It is not possible to determine from these data whether bullfinches should prefer blackthorn, hawthorn or pear buds, because it is not known which factor - or factors - is most important to the birds in any given month. Thus, although blackthorn buds were smaller than hawthorn buds, they are eaten more quickly (Section B.8) and may be more digestible. In 1978/79, blackthorn protein levels were higher than in hawthorn, but in 1979/80 there was little difference. Hawthorn protein levels seemed similar to those of Conference pear buds, though, with a lower water content, fresh weight levels were slightly higher in hawthorn; blackthorn protein levels were higher than those of pear buds, fresh weight levels exceeding even those of Conference flower initials. However, as with pear buds, the relationship between protein levels in whole buds and the nutritional quality of the parts eaten by bullfinches is not known.

Blackthorn and hawthorn buds also differ in structure: blackthorn buds produce only one or two flowers each, whereas hawthorn buds often produce about sixteen (pear buds produce about eight). Thus, when the buds burst, individual blackthorn flower heads are actually larger than those of hawthorn. Bullfinches may, therefore, prefer blackthorn buds at or near this stage of bud development.
B.4.5. **Oak, cherry, Forsythia and damson buds**

**Oak**

Although the flowers of oak trees were a major source of food for bullfinches in the study area, no buds were seen to be taken. When offered oak buds, captive bullfinches ate them in large quantities (e.g. 500 buds eaten by two birds in two days), so presumably the wild birds chose not to do so. Analysis of samples of oak buds collected in 1979 produced the following results.

Between January and March, no evidence of bud swell was found: the mean fresh weight of buds remained at 50-60mg, the water content at 30-40%, and protein levels varied only slightly (Fig. B.17). Whole oak buds had lower levels of protein than blackthorn and hawthorn buds. However, since they were much drier than pear buds, their fresh weight protein level exceeded that of pear buds - this was true of both flower initials and husks. In January the oak buds had a slightly higher calorific value (whole buds 5.54kcal/g, husks 5.30kcal/g) than other buds examined.

The most important reason why bullfinches rarely eat oak buds may be that their flower initials are not easy to separate from the outer husks. Hand dissection of buds was laborious and it was noticeable that bud tissues discarded by captive bullfinches (in March) contained a large amount of flower initial. Comparison of the mean dry weight of these discarded tissues with that of whole buds indicated that the birds had eaten about 14mg (almost 50%) of each bud, whereas the hand-dissected initials weighed only 6mg (nearer 20%) of each bud. Furthermore, the mean dry weight protein content of discarded tissues was actually higher than that of whole buds, suggesting either a non-random selection by the birds (cf. hawthorn and blackthorn) or that more husk than initial had been eaten. Tannins are known to be present in oak leaves, and these may also occur in the buds, though captive bullfinches were not deterred.
Figure B.17. Protein levels in oak buds collected from the study area in 1979.
Cherry

Bullfinches are not noted for taking buds from the wild cherry, though some were eaten in the study area. Whole cherry buds are intermediate in size between those of hawthorn and pear, and considerable bud swell was recorded in 1978 when the fresh weight of buds rose from about 30mg in February to 60mg by early April. The flower initials are easy to separate from the outer husk, but the initials are small; on 10 April 1979, initials weighed only 2.7mg (dry weight) and comprised only 12% of the total bud weight. On the same day, whole buds contained 5.2 and 15.3% protein (fresh and dry weight respectively) — levels not markedly different from those of other buds tested.

Cherry buds were readily eaten by captive birds in April and dry weight measurements suggested that 12% of the bud tissues were eaten (as above). However, this figure and protein content data acquired may not have been wholly representative since, as with other similar feeding trials, larger than average buds seemed to have been eaten.

Forsythia

Forsythia is probably the garden plant from which bullfinches most commonly eat buds, perhaps because it flowers early in the year and therefore has buds which swell at the time when bullfinches rely on buds for food. The observation of a bullfinch feeding on Forsythia buds within the study area on 25 January 1980 prompted the collection and analysis of a sample of these buds; the results were as follows.

Whole buds weighed 17mg fresh weight (8mg dry weight) and were thus intermediate in size between blackthorn and hawthorn buds. Flower initials were easily separated from the husks, and weights of husks discarded by the bullfinch indicated that about 35% of each bud (2.8mg dry weight) was eaten. Whole buds contained 4.0 and 8.5% protein (fresh and dry weight...
respectively), though contrary to expectation discarded husks had a higher dry weight protein content of 9.1%.

Faeces from the feeding bullfinch contained only 33.1mg N/g (equivalent to 11.6% uric acid), but the bird selected a variety of foods while under observation and the faeces probably resulted from both buds and seeds. Captive bullfinches fed on seeds (pages 77 and 88) produced faeces with higher nitrogen contents and the low figure recorded here may be a result of the presence of buds in the diet.

**Damson**

Buds of cultivated damson trees are small, resembling those of blackthorn, but are often taken by bullfinches. A single old damson tree was discovered in the study area in 1980, and most of its buds were subsequently eaten. Samples of these buds collected on 4 February and 4 March indicated that a considerable amount of bud swell had occurred during the intervening period; flowers were visible early in March, so few buds would have been available thereafter.

Whole buds weighed 3.2mg fresh weight (1.1mg dry weight) in February and 11.5mg fresh weight (3.7mg dry weight) in March. Associated increases in protein levels were from 16.6% dry weight (5.8% fresh weight) in February to 19.5% dry weight (6.2% fresh weight) in March. Thus the concentration of protein in whole damson buds was as great or greater than the level recorded in pear flower initials at this time (and presumably protein was even more concentrated in the damson flower initials). This suggests that, if protein or a related factor is indicative of buds suitable for eating, damson buds should be popular with bullfinches - as indeed they are.
B.4.6. Dock and bramble seeds

Seeds of very few plant species remain available to bullfinches in late winter and early spring. In the study area, the main alternatives to buds at this time were seeds of ash, dock and bramble (see Plate B). Seeds of dock and bramble were small, their kernels weighing about 0.8–0.9mg and 1.5mg (dry weight) respectively, and they are difficult to dissect by hand. As a result, no attempt was made to detect changes in the chemical constituents of the kernels over a period of time (cf. ash seeds). Data collected from whole (undissected) seeds collected in this study and by other workers should be used with caution because a large proportion of each seed (about 50% in the case of bramble) is discarded by feeding bullfinches. Furthermore, some dock and bramble plants growing within the study area appeared to have seeds with virtually no kernel. This was particularly noticeable of some dock plants in the study orchard, perhaps sterile hybrids, whose seeds remained in large numbers even when bullfinches had exhausted those on other plants.

The level of protein in dried seeds of dock was as follows: whole dock seeds 10.1 and 14.1% (red-veined and broad-leaved dock respectively), and dock seed kernels 16.4% (broad-leaved only). These protein levels are similar to those in pear bud tissues in the early stages of bud swell, but since the seeds were much drier than buds (up to only 23% water), their fresh weight protein levels were much greater. The calorific value of whole dock seeds was found to be 5.13 and 5.24kcal/g (red-veined and broad-leaved respectively).

Research testing the ability of bullfinches to maintain weight on particular diets has so far centred on buds as the food source (Newton 1964a, Summers 1982b); even control birds are usually fed on commercial cage bird seed mixtures rather than seeds of plants normally encountered by bullfinches in this country. In years when ash seeds are scarce, bullfinches may rely heavily on bramble and dock seeds, and four experiments were conducted during this study which tested the sufficiency of these
seeds as the major source of food for captive birds (normally fed on commercial seed).

In the first experiment, two bullfinches, housed in a large outdoor aviary in early January, were provided with ample wild food plants, including bramble, dock and ash seeds, and pear, hawthorn and blackthorn buds. Perhaps because the new diet was enforced suddenly, these birds became unusually restless, and although many bramble and dock seeds were eaten, neither bird survived more than three days.

The second experiment was started in mid-January and again involved two bullfinches — a male and a female. Wild food plants were provided in abundance as in the first experiment but, in addition, 120g of canary seed was supplied (perhaps 10 days' supply). Much of the canary seed was eaten early in the experiment, and after a few days, observations from a hide showed that bramble and dock seeds comprised the bulk of the diet chosen by the birds. The ash keys provided were of medium size and were mostly ignored (see page 109). All canary seed appeared to have been eaten by the 24th day when the female died. The male continued to feed on bramble and dock until day 31 when, for logistic reasons, he was given 36g of canary seed. Until this time, fresh supplies of all food plants had been supplied as necessary. From day 34, only bramble seeds were supplied and very little other food remained in the aviary after two or three days. The bullfinch fed and survived on bramble seeds until day 77 when his normal seed mixture was returned.

Thus, for over a month, mostly in March, the male bullfinch lived on bramble alone, and in mid-February he survived on bramble and dock seeds for at least a week without apparent harm. Presumably, therefore, bramble and dock seeds are nutritionally adequate at these times of year — survival in January or December when the days are shorter might not have been possible.

In the third experiment, conducted in November, a male and a female bullfinch were housed in small indoor cages where
they could be weighed regularly. Their normal seed mixture was replaced by dock seeds provided in trays of about 750 cm² area. The female lost 1.8 g weight (9% of her weight) in only 24 hours and the male, even though he had had access to dock seeds for four days previously, lost 2.4 g (11% of his weight). Their normal seed mixture was then returned and, two days later, when the birds had regained weight, a further dock-seed-only period resulted in similar rates of weight loss.

The final experiment was conducted in December, and involved three bullfinches, all housed indoors and all of which were allowed access to dock seeds for seven days prior to experimentation. Dock seeds were provided in abundance, either in trays as above or still attached to the plant, but when the normal seed mixture was removed, no bird maintained weight even for one day.

One bird lost 1.3 g (6% of its weight) in 24 hours, and then died the following night having lost a further 2.5 g. The second bird lost 1.5 g (7% of its weight) in two days, but then maintained weight for seven days when small ash keys were also made available. During this time it ate 1.0-2.0 g of ash seed kernel each day. When the ash was removed, leaving only dock seeds, the bird lost 3.3 g in 24 hours and died. The third bird (also used in the third experiment above) lost 1.4 g (7% of its weight) in two days. Small ash keys were then also made available and the bird recovered and then maintained weight for eight days, eating 1.0-1.2 g of ash seed kernel each day. When the ash was removed, it lost a total of 4.0 g weight in four and a half days, but recovered when the normal seed mixture was returned.

Some captive birds will feed even in total darkness (Kendeigh et al. 1969), and night-time feeding cannot be ruled out in these indoor experiments; the birds with seed trays could have sat within them and fed without danger at any time of day. Thus, the fact that all birds lost weight when provided with abundant dock seeds in conditions where food requirements should have been minimal and where feeding might not have been restricted
to daylight hours, suggests that wild birds in harsher conditions could not survive on dock seeds alone at this time of year.

The reason for the apparent inadequacy of the dock-only diet is not clear. When feeding on small seeds, bullfinches can pluck several from the plant at a time, and then husk them individually, so feeding rates are difficult to assess, but close observation of bullfinches from a hide enabled some estimates to be made. The male bird used in the second experiment above was timed at 45-66 seeds/min. and the female at 15-26 seeds/min. At these rates, even the female might be able to eat a sufficient quantity of seed each day to permit survival; 30 seeds/min. would amount to about 7.7g of kernel in only five hours.

Faeces were collected from the floor of the cage in which the bullfinch fed on dock seeds alone for four and a half days. Assuming all the nitrogen contained in these faeces was in the form of uric acid, they contained 25.3% uric acid. Dock seeds might therefore be more digestible than ash keys but less digestible than canary seeds (see page 88). A similar sample from a bird fed on both ash and dock seeds contained 21.2% uric acid — intermediate between birds fed solely on one or the other.
B.5. Ash Keys

B.5.1. Introduction

As outlined on page 16, research into the ecology of bullfinches has, so far, indicated that the seeds of ash trees (usually known as 'keys') are an important food in winter. Published data suggested that bud damage to orchards was greatest in years of poor ash seed crops, and slight in years of good ash seed crops. Ash keys, and the kernels within them, are the largest food items taken by bullfinches (see Plate B), and as a result they are often thought of as a food source which, when available, largely eliminates the need to eat other seeds or buds. Fruit growers have come to expect that buds should only be eaten when the supply of ash keys is exhausted or when the buds are well developed.

That there should be some overlap in ash and bud feeding, and that a mixed diet should be eaten by bullfinches is not surprising, but in recent years some fruit growers have incurred heavy damage within orchards when the local supply of ash keys was apparently large. Further indications that the ash/bud feeding relationship might be more complex than at first thought come from this study where bud damage occurred in each winter despite the presence of ash keys.

The large size of ash keys greatly facilitates the observation and timing of feeding birds, counts of keys on and beneath trees, feeding experiments and analyses of the seed kernels. Bullfinches feeding on ash keys usually do so for several minutes at a time, often sitting in one place - next to or on top of a bunch of keys - for most of the feeding spell. Each key is plucked from the bunch and husked individually, and the kernel is broken up before being swallowed. Only the beak is used in this procedure, although in this study bullfinches were twice observed flying with a key to a broad inner branch from which dropped keys and portions of kernel could be retrieved. Similar behaviour in both wild and captive bullfinches is also described by Nicolai (1956). Keys dropped from outer branches
sometimes have beak marks, suggesting unsuccessful attempts to split the husks.

That bullfinches select keys from some ash trees in preference to those of others is well known. For example, Newton (1964a, 1967) found that bullfinches fed from only five out of 105 seeding trees in Marley Wood. He thought that some trees might have consistently better palatability than others, while Janzen (1971) suggested that inter-tree variance in ash seed oil content could be important. Various data collected during this study are presented in this section in an attempt to evaluate ash keys as a food source for bullfinches.
B.5.2. The ash-feeding period

One important facet of any food is the time of year it is eaten. In a year of abundant ash keys, Newton (1964a) found that most were eaten between November and March. He estimated that ash keys formed about 20% of the bullfinches' diet in November, December and March, and over 40% in January and February. In addition, the October and April diets contained 1 and 2% ash respectively. The decline in ash feeding was not due to a lack of keys, since 30% of the seed crop still remained on the trees in April.

In the study area, ash-feeding started at the end of October or in November each year, and captive bullfinches readily ate hundreds of keys (over a period of days) at this time. In 1980, one wild bullfinch was seen feeding on ash keys as early as 7 August when the keys were still green and unripe, so presumably they are edible even at this early stage, and the relative lack of feeding records before November may indicate the presence of more desirable seeds in most years.

In the study area, wild bullfinches were not seen eating ash keys as late in spring as Newton recorded; even though some trees retained keys in March and April in 1979 and 1980, ash-feeding ended in February each year. Captive bullfinches ate keys provided even in late April and, in March 1979, keys collected during the winter of 1977/78 were eaten when left in the aviaries for four days. Such 'late' keys were never seen to be eaten easily, though the reasons for difficulties observed may have included factors other than the age of the keys.

The end of ash-feeding may be determined by the appearance of new food supplies (e.g. buds), by the exhaustion of the ash seed crop or by a reduction in the desirability of the seeds themselves, and the above observations suggest that the last of these possibilities may be important. It might otherwise seem strange that bullfinches should abandon such an apparently easily obtained food. For example, even if only small keys (say 20mg dry weight) were eaten, an average rate of 2.5 keys/min. amounts to 9g
in only three hours. On the other hand, similar calculations can be applied to pear buds, and these suggest that the first of the three possibilities might also be important; flower initials of 7mg dry weight eaten at a rate of 12 each minute amount to 9g in less than two hours. (For further details of feeding rates see Section B.5.4).
B.5.3. **Chemical constituents of ash keys**

Few data are available on the contents of ash keys or their kernels, so a number of analyses were carried out in this study. All the results described below refer to kernels only (the part bullfinches eat).

**Water content**

Fig. B.18 shows the water content of 14 ash key kernel samples, including eight taken from three trees in close proximity in the same year. The keys were very moist in August when they were still soft and green, but they dried out considerably thereafter. Drying apparently continued even into April in 1979, long after the keys had become hard and brown, but the samples collected in October 1980 suggest that the rate of drying varies between different years or different trees. Furthermore, the effect of rain prior to sampling is unknown.

**Calorific content**

Calorific contents of 5.52 to 6.36 kcal/g dry weight were recorded (Fig. B.19). The samples taken from trees 1 and 3 show a clear reduction in calorific content between January and April, a trend which was not affected by storage of keys at 29°C. In contrast, no clear trend was apparent in keys of tree 2.

The calorific contents of canary seed kernels recorded in this study (4.96-5.24 kcal/g) and whole dock seeds (page 75) were lower than those of ash kernels.

**Protein content**

Fresh and dry weight protein contents of ash seed kernels are shown in Fig. B.20. Dry weight levels rose in keys from trees 1 and 3 (both fresh and stored keys) but not in tree 2.
Figure B.18. Water contents of ash key kernels in 1979 and 1980; keys were produced in 1978 and 1980 respectively.

+ keys from three adjacent trees (the January sample from one tree was not analysed)
• isolated samples

Figure B.19. Calorific values of ash key kernels in 1979.

+ keys produced in 1978 on three adjacent trees (some from tree number 3 were also stored at 2°C)
• keys produced in 1978 on isolated trees
○ keys produced in 1977 and stored throughout 1978
Figure B.20. Protein levels in ash key kernels in 1979. Symbols are as for Fig. B.19.
It is interesting that the sample with the highest protein content also had a very low calorific value; data presented in Fig. B.21 seem to indicate that the calorific value of ash seed kernels is related to their protein content, data from trees 1, 2 and 3 being particularly striking. Rises in fresh weight protein levels are a result of both drying out and increases in dry weight levels discussed above. Stored keys from tree 3 dried out slowly, but the keys stored for one year were particularly dry, having only 3% water, so these samples had extreme fresh weight protein levels.

The dry weight protein levels of ash keys are greater than those found in dock seeds (page 75), but similar to that in canary seed kernels (20.7%). Until some bud swell had occurred, the dry weight protein levels of pear bud flower initials were usually lower than in ash keys.

**Fat and carbohydrate content**

In crude terms, the calorific value of plant and animal tissue is determined by the relative proportions of protein, carbohydrate and fat, since these have different energy contents (5.4, 4.1 and 9.3 kcal/g dry weight respectively). Given the percentage protein and the total calorific value of the material, it is therefore possible to calculate the percentages of carbohydrate and fat. Using data from trees 1 and 3 (see Fig. B.21), calculations indicate the following levels in ash seed kernels.

<table>
<thead>
<tr>
<th></th>
<th>calorific content (kcal/g)</th>
<th>% protein</th>
<th>% carbohydrate</th>
<th>% fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>6.47</td>
<td>17.0</td>
<td>41.7</td>
<td>41.3</td>
</tr>
<tr>
<td>April</td>
<td>5.93</td>
<td>20.8</td>
<td>49.2</td>
<td>30.0</td>
</tr>
</tbody>
</table>

The increase in protein levels recorded would in itself result in decreased calorific value (nearer to 5.4 kcal/g), but these calculations suggest that changes in the relative proportions of
Figure B.21. The relationship between ash-free calorific value and protein content of ash key kernels.

Symbols are as for Fig. B.19. Arrows show order of samples where applicable.
carbohydrate and fat are also necessary to result in the observed decrease in calorific value. Similar calculations indicate that kernels of canary seeds and the flower initials of pear buds have much lower levels of fat (about 10-15%).

**Digestibility**

Results of digestion analyses of ash key kernels given in Fig. B.22 indicate that they were much less digestible than canary seed (which was 94% digestible) and that they become less digestible between August and the following May. Indeed, by the end of this period the keys were almost as indigestible as the husks of pear buds (see Table B.5).

In experiments with captive bullfinches, a diet of ash keys was noticeably 'wasteful'; bullfinches produced much larger quantities of faeces than those fed on canary seed. A sample of faeces collected from the floor of a cage in which a bullfinch had eaten only ash keys for five days had a low nitrogen content. Assuming all nitrogen was in the form of uric acid, the faeces contained only 13.5% uric acid (dry weight), perhaps indicating that large quantities of indigestible carbohydrate, fat or protein had passed straight through the gut, thus diluting uric acid from the kidneys. A similar sample from a canary-seed-fed bullfinch contained 34.0% uric acid.

**Discussion**

Canary seed fed to captive bullfinches contained only 6% water and this did not appear to be disadvantageous. However, the drying of ash keys was accompanied by other changes that may have been related to water content. The seed coats became tougher and more brittle while the kernels became darker and more rubbery, no longer snapping in half easily like moist kernels. As a result, the keys probably became progressively more difficult to husk, and the kernels more difficult to break into pieces small enough to be swallowed.
Figure B.22. Digestibility of ash key kernels, expressed as the percentage dry weight of kernel remaining undigested.

+ Keys produced in 1978 on three adjacent trees and sampled in 1979 (four separate samples from tree number 3)
- Keys produced in 1980 (August sample) and 1979 (December and June samples). June samples had been collected in March and stored.
Grodzinski and Sawicka-Kapusta (1970) give a calorific value of 5.712 kcal/g dry weight for ash seed kernels, well within the range recorded in this study. They also suggest that the calorific values of tree seeds change slightly during their maturation and that differences also occur between different geographic regions, habitats, and years (especially when this includes years of heavy and light seed crops). Data from this study suggest both changes during maturation and differences between trees, though the importance of this variation is not known.

Grodzinski and Sawicka-Kapusta also combined their data with those of Nemec (1948) and found a significant correlation between calorific values of whole seeds of various trees and their fat contents. Whole ash keys contained about 26.5% fat and 5.48 kcal/g. This suggests that the calculations indicating 30-40% fat in the kernels may be correct, since kernels have higher calorific values, and therefore probably more fat, than whole keys.

Whilst the digestion analyses may not precisely duplicate the bullfinches' ability to digest ash keys, the data do suggest that, as winter progresses, more keys and more indigestible tissue would have to be eaten for a constant amount of food to be absorbed in the gut. Since bullfinches do not eat pear bud husks with 35% indigestible matter, it is possible that ash keys may also be rejected in spring when they approach this level of digestibility. The samples collected in January suggest that some variation occurs between trees and this might encourage bullfinches to select trees with particularly digestible keys. It is interesting that the least digestible sample collected in January was from tree 2, which also had a noticeably high protein content and low calorific value at this time. Keys on tree 2 may have matured more rapidly than those on trees 1 and 3; they were also considerably larger.

Summing up, it appears that the keys of some ash keys continue to mature at least until April. They become drier and less digestible, the protein level rises, the calorific value falls, and by inference the fat level falls and the carbohydrate
level rises. The keys of different trees are not always similar, and some seem to mature faster than others.

Since these changes are still occurring at the end of the usual ash feeding period, it is quite possible that one or more of the parameters measured determine, in part, when bullfinches stop eating ash keys in spring. Different rates of maturation may also explain, in part, the preferences for keys of particular trees shown by feeding bullfinches.
B.5.4. Feeding rates and ground counts in the study area

Introduction

Bullfinches were regularly seen eating ash in the study area, and their feeding rate was often recorded. Such feeding rates can be usefully combined with samples of fallen keys (ground counts) to give some idea of the ease with which keys are eaten and the popularity of the various trees involved. If, as has been suggested, the keys of some trees are more easily handled than those of others, and if they become more difficult to husk and eat as they mature, bullfinches might be expected to feed at different rates in different trees and at different times of year. Similarly, the number of keys, and the proportions husked and unhusked, in ground counts might be expected to vary.

Caution is necessary since bullfinches may vary in their ability to feed quickly, and feeding rates recorded may often not be maximal; one bird was observed feeding consistently at over 4 keys/min. when the mean for several other birds in the same trees was only 2.5 keys/min. Also, ground counts reflect both the success (and failure) of attempts by bullfinches to husk the keys and the natural rate at which the keys fall. Finally, it is not always easy to select only freshly fallen keys, so some ground counts may have included keys which fell weeks before the sample date.

1977/78

Feeding rates of several bullfinches eating a total of 135 ash keys were calculated. The mean feeding rates were 2.4 keys/min. in late November and 2.5 keys/min. in mid-December. Bullfinches were not timed later in the winter, but no feeding difficulty was observed in late February when several birds were eating the last remaining keys from a tree which seemed to have been preferred from early in the winter.

Keys collected during ground counts totalled over 1,000 and data from regularly sampled trees are presented in Table B.8.
Table B.8. Percentages of ash keys eaten by bullfinches in samples collected from beneath trees in the study area in the winter of 1977/78

<table>
<thead>
<tr>
<th>tree</th>
<th>date 05/12</th>
<th>12/12</th>
<th>03/01</th>
<th>19/01</th>
<th>20/01</th>
<th>08/02</th>
<th>14/03</th>
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<tr>
<td>A</td>
<td>41*</td>
<td>56*</td>
<td>33</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0*</td>
<td>25*</td>
<td>22*</td>
<td>100</td>
<td>82</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>53</td>
<td>51</td>
<td>27</td>
<td>0*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>50</td>
<td>75</td>
<td>77</td>
<td>75</td>
<td>58</td>
<td></td>
<td>(92)</td>
</tr>
<tr>
<td>E</td>
<td>19*</td>
<td>0*</td>
<td>51</td>
<td>0*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>48</td>
<td>43*</td>
<td>21*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>67</td>
<td>71*</td>
<td>(81)*</td>
<td>81</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* less than 30 keys in sample, i.e. very few had recently fallen from the tree.

( ) sample probably included keys which had fallen some weeks previously.

These data are in broad agreement with those of Newton (1964a), who found that 20–60% of keys from some ash trees were eaten during the winter of 1962/63. Some of the trees listed were large (e.g. tree D), and others were small, and some were more difficult to sample than others because of ground vegetation. However, an attempt was always made to collect at least 30 keys in each sample, so smaller samples were due to a lack of recently fallen keys.

Bullfinches fed from all seven sample trees and brief checks beneath a number of other ash trees within the study area indicated that very few trees were completely ignored by bullfinches. The data show that trees A and B were rarely fed from, at least until mid-January, but that tree D was particularly popular. Trees A, C, E and F lost the last of their seed crop in January, but trees B and D still retained some keys in late February when ash-feeding stopped.
Data from tree D are particularly interesting, since it was adjacent to an open field and therefore easy to sample. Almost all keys collected were thought to be fresh, and snow and frost on 19 and 20 January enabled keys-of-the-day to be selected. An estimated 7,600 keys fell from this tree on 19 January by 1230 hours, about 5,700 of which had been eaten by bullfinches. Most bullfinches in the study area may have been involved in this onslaught, and they succeeded in husking at least 75% of all keys attempted (the actual percentage depends on how many keys fell naturally). At least 50% of the unhusked keys had no obvious defects. A further 5,500 keys had fallen by 1500 hours on the following day.

Of keys which fell on 20 January, 58% were husked. No husked keys showed signs of poor quality, such as insect holes or very small kernels, but of 29 unhusked keys, 17 (59%) had been partly eaten by insects or had small kernels. Three of the remaining 12 good keys had beak marks, indicating an attempt at husking. Selection for good-kernelled keys had been recorded with captive bullfinches, and wild birds had also been seen dropping keys apparently deliberately, so the unhusked, poor quality keys found in this ground count were probably purposely rejected by the feeding birds. The increase in the overall percentage of poor quality keys from 13% or less on the 19th to 25% on the 20th may indicate that a large proportion of the good keys had already been eaten by the 20th. The birds may therefore have had to spend more time searching for the few that remained.

The deterioration of the quality of keys remaining on trees such as tree D may have caused the sudden interest in keys from tree B. Until 20 January, very few keys fell from this tree, either naturally or because of feeding bullfinches, and it was not exposed to wind or other disturbance. If its keys were difficult to husk, only a small percentage might be expected to be husked, but this was not apparent in the ground count of 20 January when 82% of those collected were husked. Of the 31 husked keys, only three (10%) showed signs of poor quality, whereas six out of seven unhusked keys (86%) had very small kernels or had been eaten by larvae. Thus, about 24% of the tree's keys may have
been of poor quality and, as with tree D, some were probably dropped on purpose. Like a tree recorded in the 1981/82 survey, this tree never became very popular even though the husking success rate was obviously high, and it still retained 200 keys in mid-March. It is possible that each key took a lot of time or effort to husk, or the kernels may have been distasteful or difficult to break up, but no data for this are available.

On three occasions in late January and early February, bullfinches were observed searching for unhusked keys on the ground beneath ash trees. This behaviour is relatively unusual, and may have been caused by the reduced quality of keys remaining on the trees. Keys from the ground would have been damp and probably easily husked (see page 107).

1978/79

Bullfinches in the study area ate ash relatively rarely in the winter of 1978/79, and none were timed feeding. As might be expected, ground counts indicated that only a small percentage of keys were husked by bullfinches. Searches below several trees in mid and late November confirmed that little ash-feeding occurred in this month. In early December, 18% of a small sample of keys from one tree had been eaten by bullfinches, and twice as many bore beak marks indicating some attempt to husk them. The kernels of this tree were large (46mg dry weight). Snow in January enabled freshly fallen keys to be collected beneath one tree adjacent to the study orchard. Of keys falling in the first four days of January 43% were husked, compared to 67% of those falling on 26 January. These keys had kernels of 35mg mean fresh weight in December and were therefore relatively small.

The lack of ash-feeding in this winter may have been partly due to a shortage of suitable keys, but, as suggested in Section B.3, the abundance of bramble seeds in this winter may have reduced the need to eat ash keys.
1979/80

Feeding rates of several bullfinches eating a total of 95 ash keys were recorded. The mean feeding rate was 1.7 keys/min. in December and 1.1 keys/min. in late January; the maximum feeding rate observed in both months was 2.0 keys/min. In January it often took each bird about 10 seconds to husk a key and then 50 seconds to break up the kernel.

These data suggest that these ash keys were more difficult (i.e. more time-consuming) to eat than those eaten in 1977/78. Since the faster feeding rates recorded in December 1979 were observed in preferred trees whose seed stocks were exhausted by January 1980, it is also possible that the remaining keys were less suitable and perhaps even more difficult to eat. This would have encouraged the early start to bud-feeding recorded in the study orchard in this winter.

Ground counts made on 22 November indicated that ash-feeding had started by this time, though only a small percentage of fallen keys had been husked by bullfinches (maximum of 27%). All the ash trees sampled regularly in previous years were then felled when the woodland was cleared, but subsequent ground counts beneath other trees indicated that up to a maximum of 52% of keys from individual trees were husked.

Early in the winter, observation of feeding birds clearly showed that some trees were preferred to others and it is quite likely that over 52% of their keys were eaten by bullfinches - they had been impossible to sample. Some trees may have had insect larvae in a large proportion of their keys, since bullfinches were seen to reject about 50% of keys during one observation period in mid-December. One tree adjacent to the orchard had noticeably large keys, and a ground count in January showed that none were eaten by bullfinches.
Summary

Observation of feeding birds and collections of keys from beneath ash trees provided some interesting data which help to explain the relationship between ash-feeding and bud-eating in bullfinches. Very few of the ash trees in the study area were totally ignored by bullfinches. Some were preferred to others, but when the stocks of preferred keys deteriorated, the 'less preferred' keys were also taken. This change did not seem to be reflected in the proportion of keys husked by feeding bullfinches; indeed, this seemed largely determined by the number of poor quality keys on each tree. However, differences in feeding rates were probably caused by differences in the ease with which keys were eaten, and it appeared that keys available in 1979/80 were probably more difficult to eat than those available in 1977/78.

If the true size of the ash crop suitable for bullfinches in any particular area is to be found, very extensive data are needed including chemical analyses and measurements of the keys, as well as ground counts and close observation of birds feeding within the sample trees. Fruit buds are most likely to be taken when ash keys are difficult to eat or of poor quality, and this may occur long before all keys have fallen, since some trees seem to have very few suitable, easily eaten keys.
B.5.5. The decline in ash seed stocks

Research has shown that bud damage to orchards is correlated with the size of the ash seed crop produced in the preceding summer (Newton 1964a, Summers 1979). The size of the seed crop has been assessed by counts of fruiting trees and of keys falling from them, and indirectly by the use of ash pollen data. In this study, fruiting trees were counted (see Section B.3) and the number of keys on sample trees was estimated during the winter. Fig. B.23 shows the mean percentage of keys remaining on sample trees in the study area and Fig. B.24 shows the extent of the variation on individual sample trees.

Differences in the rate of decline of the ash seed stock between and within years reflect differences in both the natural rate of ash key fall and the frequency with which bullfinches fed within the trees. Most sample trees were situated over dense ground vegetation, so frequent ground counts to assess the extent of bullfinch feeding were not possible, but both 'preferred' and 'less preferred' trees were present in each year's sample, and the most rapid declines recorded in each year probably relate to preferred trees. Caution is necessary, however, since the natural rate of fall from at least one tree from which bullfinches took few if any keys was considerably greater than the combined effects of natural fall and bullfinch feeding in a more popular tree, and in each year there were probably trees within the study area with more extreme rates of ash key fall than those on sample trees.

Marked differences between years are apparent. In 1977/78, the decline in ash seed stocks was rapid; by 20 January one tree had only 1% of its keys left, and by the end of March all sample trees had less than 50 keys remaining. In 1978/79, the decline was slow and steady; all sample trees retained at least 200 keys at the end of January, and even in March none were completely devoid of keys. Since bullfinches ate relatively few ash keys during this winter, the pattern of decline probably represents the natural drop of keys to a greater extent than in other years. Considerable variation between trees was apparent in 1979/80. One tree, from which bullfinches fed in December,
Figure B.23. Declines in ash seed stocks in the study area.

Ten trees were sampled in 1977/78, four in 1978/79 and eight in 1979/80. Numbers of keys left on these trees are expressed as percentages of the number present early in December.
Figure B.24. Declines in ash seed stocks in the study area.

Points indicate maximum and minimum percentages of keys remaining on individual sample trees used to calculate data shown in Fig. B.23. D indicates when bud damage started in the study orchard.
lost nearly all its keys by early January, while another, which attracted bullfinches in February, still retained nearly 30% of its keys in March.

Fig. B.24 also shows the dates in each winter when bullfinches first took buds from the study orchard. In all years ash keys were present in large numbers when damage started. In both 1977/78 and 1979/80, 70-80% of the ash crop was still available when damage started (some keys fell before December each year when crops were first assessed, so the actual figures may not have been quite so great). Furthermore, ash and bud-feeding occurred concurrently in both these winters for about two months.

However, there does appear to be a correlation between the start of bud feeding and the time when the most favoured ash trees lost 65-90% of their keys. Thus it seems possible that only the most easily eaten ash keys were a more profitable food source than the pear buds, and when the best keys were in short supply, both less favoured keys and buds were eaten. The number of easily eaten keys available to bullfinches may often be correlated with the total number of keys present in autumn. The time when the best keys run short, and hence the time when buds are taken, may therefore often correlate with the initial size of the ash seed crop, but data from 1978/79 show that this is not always the case. Fewer trees held seed crops in this year, yet damage to the orchard started very late; the abundance of other seeds probably both reduced ash-feeding and delayed bud feeding.
B.5.6. **The size of ash keys**

**Introduction**

In the study area, particularly during the winter of 1977/78, it was noticed that bullfinches seemed to prefer the keys from certain ash trees. On the whole, large trees not exposed to the wind or to other disturbance seemed preferred, but a further influencing factor may have been the ease with which the keys could be husked, broken up and eaten. The latter factor might have been related to the size of the keys, larger keys presumably being stronger and therefore more difficult to handle. Keys on any one tree were often remarkably similar in size and shape, but those on different trees varied considerably.

It was rarely possible or desirable to collect large quantities of keys from trees in the study area, so most measurements, chemical analyses and feeding trials were conducted using keys from easily accessible trees elsewhere. In consequence, and since the study area ash trees were felled in 1979, little information is available on the size of keys within the study area. Data summarised in this section come mainly from feeding trials and from a survey of ash keys in the Weald of Kent, conducted during the winter of 1981/82.

**Ash key choice experiments**

Two experiments were conducted which involved a choice of ash keys of different size. In the first, branches with keys were cut from six different trees and hung in bunches from the roof of a large outdoor aviary containing ten bullfinches. Bunches from different trees were widely spaced so that keys falling from them could be easily identified, and mixing minimised. After eight days, two measures of preference were recorded: the number of keys husked from each bunch, and the percentage of keys below each bunch that were husked. Throughout the experiment ample supplies of the birds' usual seed mixture were available, and some keys remained on each bunch at the end
of the experiment. Results are shown in Table B.9 (for dimensions see also Fig. B.25).

**Table B.9 Ash key choice experiment 1**

<table>
<thead>
<tr>
<th>tree</th>
<th>dimensions of ash key kernel</th>
<th>keys husked</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>width(mm)</td>
<td>length(mm)</td>
</tr>
<tr>
<td>1</td>
<td>2.5-3.0</td>
<td>10-14</td>
</tr>
<tr>
<td>2</td>
<td>3.0-3.5</td>
<td>10-15</td>
</tr>
<tr>
<td>3</td>
<td>3.5-5.0</td>
<td>13-16</td>
</tr>
<tr>
<td>4</td>
<td>3.5-5.0</td>
<td>13-19</td>
</tr>
<tr>
<td>5</td>
<td>3.5-4.0</td>
<td>9-13</td>
</tr>
<tr>
<td>6</td>
<td>3.0-4.0</td>
<td>10-14</td>
</tr>
</tbody>
</table>

This experiment was conducted in March, quite late in the normal ash feeding season. The fact that many keys were husked suggests that they held some attraction for the bullfinches, but data from chemical analyses of other ash keys, presented in previous sections, indicate that some or all of these keys may have become rather unsuitable as a food source by this time. Furthermore, observations from a hide on the first day of the experiment suggested that the keys were difficult to husk. Earlier in the year, feeding rates in the study area of 1-3 keys/minute were frequent: about 10 seconds to husk the key and a further period to break up and swallow the kernel. In the experiment, only one key was seen to be processed in less than 70 seconds; up to 55 seconds were taken to husk keys, and up to 220 seconds to break up the kernel. Many, perhaps most, of the keys were probably dropped unhusked from the bunches and only eaten after they had remained on the ground for some time.
Despite these complications, the results do show that some keys were more difficult to husk than others. In particular, trees 3 and 4 had very few of their keys husked, both in terms of number and percentage. These keys were the largest and heaviest available, so they may have required the greatest husking effort. The other four trees had keys of similarly light weight, but they did differ in shape. Tree 1 had the narrowest keys and, judging from the dimensions given in Table B.9, keys from trees 5 and 6 were probably the thinnest (the thickness of these keys, see Fig. B.25, was not measured). Either (or both) these factors may be important. Preferences did not seem to correlate with amino acid levels within the kernels (Section B.7).

In the second choice experiment, keys from only two trees were used, one with large keys and the other with comparatively small keys. Each of four large outdoor aviaries, containing 7-10 bullfinches, were given a large bunch of keys from each tree, these being hung from the aviary roofs in opposite corners. Keys from the two trees were sufficiently distinct in size and shape for all fallen keys and husks to be sorted accurately. Keys fallen or dropped below each bunch were collected after two, four and six hours, and then after a further three days. Throughout the experiment, all birds had ample supplies of their usual seed mixture. Results are given in Table B.10.

Observation from a hide showed that a bullfinch attempting to husk a key which is already on the ground often carries it some distance, so, since almost all keys collected during the first six hours were directly below the bunches, it can be assumed that few second attempts at husking were made. Also, since very few keys would have fallen naturally during this period, the counts made probably accurately represent the success rate of bullfinches attempting to husk keys while sitting on the bunches.

The results indicate that neither sized key was easily husked; even the maximum percentages of keys husked in any one aviary during the first six hours were only 34% for small keys.
and 19% for large keys (both in the same aviary). One reason for such low success rates may be that even the small keys were a little too large. Disturbance of feeding birds by others in the same aviary may also have contributed to the large number of dropped unhusked keys; only about 5% of these had clear signs of husking attempts (slight splits etc.). The experiment was conducted in early November so, unlike the first choice experiment, the keys should not have matured excessively.

Table B.10. Ash key choice experiment 2

<table>
<thead>
<tr>
<th>ash key</th>
<th>tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>width (mm)</td>
<td>1 5.5-6.5</td>
</tr>
<tr>
<td>length (mm)</td>
<td>1 31-37</td>
</tr>
<tr>
<td>appearance</td>
<td>flat, no notch</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ash key kernel</th>
</tr>
</thead>
<tbody>
<tr>
<td>width (mm)</td>
</tr>
<tr>
<td>length (mm)</td>
</tr>
<tr>
<td>mean dry weight (mg)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>keys husked (total from all aviaries)</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
</tr>
<tr>
<td>0-2 hours</td>
</tr>
<tr>
<td>2-4 &quot;</td>
</tr>
<tr>
<td>4-6 &quot;</td>
</tr>
<tr>
<td>0-6 &quot;</td>
</tr>
</tbody>
</table>

6 hours-3 days (see text) 717 51-59 975 89-96

While factors other than key size may have been involved, the bullfinches clearly preferred the smaller keys. Of the keys taken from the bunches, a greater percentage of small keys (16%) were successfully husked than large keys (7%). Also, many more small keys were taken from the bunches (total of 772) than large keys (417) - a pattern recorded in every aviary during every two-hour period - and as a result, over four times as many
small keys were husked as large keys (cf. 126 and 29 respectively).

After three days, the evidence for second attempts on fallen keys was considerable; many keys had been moved within the aviaries and most had been successfully husked. Small keys continued to be more frequently husked; 96% of moved small keys and 91% of moved large keys had been husked. Of keys directly below the bunches, 89% of small keys and 51% of large keys were husked. Of dropped, unhusked keys, 19 small and 73 large keys showed clear signs of (unsuccessful) husking attempts. Approximately equal numbers of each key size had been supplied (1,900 small keys and 2,100 large keys), but after three days only 36 small keys and as many as 600 large keys remained on the bunches. Calculations suggest that, during this period, the bullfinches continued to remove keys of both sizes at the rates recorded in the first six hours. Clearly the 'preference' for small keys did not change.

It should be remembered that in neither of these experiments was it possible to gather data on the ease with which the seed kernels were broken up and swallowed - as distinct from the ease with which the keys were husked - so two experiments were designed to test this. These involved providing bullfinches with manually husked ash key kernels of different sizes in plastic pots. Inconclusive results were obtained because the birds were reluctant to feed on ash provided in this way; some totally ignored it for several hours, even in the absence of other food.

However, large keys usually contain large kernels; they may be difficult both to husk and break up. Thus, if ash key size is important, bullfinches may prefer small keys because of both their husking and breaking-up qualities.

**Experiments with large ash keys**

A feeding trial involving large ash keys was conducted in February, towards the end of the period in which bullfinches in
the study area were seen eating ash keys. Two groups of eight bullfinches (four males and four females in each) were provided with a plentiful supply of keys (with mean dry weight of kernels 45.1mg) scattered over the floor of their outdoor aviaries. The normal seed supply was covered up, though some remained available on the ground, and all birds were weighed daily.

After two days, all but one bullfinch had lost weight, while birds in adjacent aviaries, fed on their normal seed mixture, maintained constant weight. After three days a total of five birds had died from one group, having lost 2.7-6.4g (12-27%) weight, even though 66% of the ash keys remained unhusked. The three survivors in this aviary had lost 3.1-4.4g (12-18% weight). In the other aviary, where more of the usual seed had remained available, the bullfinches had lost 0.0-3.7g (0-15%) weight; 16-55% of keys in this aviary had been husked (keys from damper areas of the aviary floor seemed preferred). The experiment was terminated before other birds died.

During this experiment, although the birds readily recognised the ash keys as food, they seemed to have great difficulty in extracting the kernel from the outer seed husk, often spending over a minute attempting to split the husk without success. Even having extracted a kernel, birds often seemed unable to break it up and swallow it. They had fluffed-up plumage, indicative of low body temperature, and were obviously hungry, spending much time searching for their usual seeds.

That bullfinches prefer moist keys was confirmed by a subsequent test. About 400 keys (from the same tree used above) were soaked in water for 16 hours, and then these and 400 dry keys were left - in addition to the normal seed supply - in an aviary containing ten bullfinches. After three days, 89% of soaked keys were husked, compared to only 48% of dry keys. Furthermore, of unhusked soaked keys, 75% contained tiny, underdeveloped kernels, and since about 10% of keys from this tree were known to have substandard kernels such as these, it can be assumed that virtually all the viable moist keys had been eaten.
However, a third experiment showed that, even when soaked, these keys were 'handled' too slowly for bullfinches to maintain weight. On this occasion, one group of eight birds was supplied only soaked ash keys, and a second group of five birds was provided with soaked ash keys and a supplement of about 500 Conference pear buds each day. These buds were from prunings collected at the end of February, just prior to the experiment; they contained flower initials of sufficient weight to provide each bird with only 0.5-1.0g dry weight of bud tissue each day. All birds were allowed a period of three days' acclimatisation, during which their normal seed supply was available in addition to their future diet.

The results of this experiment closely resembled those of the first experiment described above. The weights of the bullfinches, measured daily, showed that these new diets were only marginally better than that of dry keys, since after four days all birds had lost 0.6-3.4g (3-14%) weight. Fewer of the usual seeds remained available in the aviary containing the birds with the bud supplement, and, probably as a result, these suffered the greatest weight losses. As in the first experiment, the birds experienced great difficulty in husking and eating the ash keys, and all became obviously hungry, feeding rapidly on their usual seed supply when it was returned. Again, the experiment was terminated to avoid further harm to the birds.

In these experiments, birds would undoubtedly have lost weight more rapidly if it had been possible to remove all their usual seed. This fact was confirmed during indoor feeding experiments where the food available could be more easily controlled. In one such experiment, two bullfinches, provided with freshly-collected large ash keys in December, ate only 2-2.5g (dry weight) of ash seed kernel each, and lost 0.6 and 1.6g weight in only 24 hours. One of these birds subsequently died. At this time, other birds maintained weight by eating 4.7-6.0g of canary seed.

At the time of the outdoor experiments described above, it seemed inexplicable that these bullfinches should experience
so much difficulty eating seeds which their wild counterparts handled with ease. In retrospect - considering the results of chemical analyses and choice experiments (described on previous pages), and experiments with medium-sized and small keys (described below) - it seems possible that the keys used here were simply too large and tough for the birds to handle.

**Experiments with keys of medium size**

Even when provided with medium-sized ash keys - those with kernels of ca. 30-40mg dry weight - bullfinches were not able to maintain weight easily. Two feeding experiments (also discussed in Section B.4.6) conducted in large outdoor aviaries indicated that buds and other seeds were taken in preference to keys with kernels weighing about 34mg dry weight. In both experiments, the aim was to feed bullfinches on a natural diet, so they were provided with a wide variety of freshly-collected seeds and buds, including large quantities of ash keys. In the first experiment, both observation from a hide and collection of discarded ash key husks showed that very few keys were eaten. In 20 minutes, one bird attempted to husk and eat 19 ash keys, but it succeeded with only 10. In two days, this bird ate 16 keys and the other only one; both subsequently died. In the second experiment, one bird succeeded in surviving on natural foods for several weeks, but throughout this period it fed on bramble and dock seeds rather than ash keys. Both experiments were carried out in the normal ash-feeding period (January and February).

One indoor feeding trial is also best described here, since it involved medium-sized ash keys. Keys from three trees were used, since none of them had sufficient keys for the whole experiment, and conclusions are further complicated by the fact that it was conducted in April, just outside the main ash-feeding period. Initially, ample supplies of both canary seed and small ash keys (kernels of ca. 25mg dry weight) were given to three bullfinches - one on its own and two together. After 13 days, the birds had changed weight only slightly (+0.6, +0.1 and -0.2g respectively). All had eaten canary seed; the single bird had
also eaten a mean of 2.9g of ash key kernel/day and the other two 1.4g of ash/day each.

Then, for 24 hours, only large ash keys (kernels of ca. 43mg dry weight) were supplied, and all other seed was removed. During this time the three birds ate a total of only 205 keys between them (8.8g dry weight of kernel) and lost 1.5, 2.1 and 1.5g bodyweight respectively. Clearly, too few keys were being eaten to allow long-term survival, so the usual seeds were returned and the birds allowed to recover. One day later, only ash keys were again provided, this time of two sizes: large (kernels of ca. 43mg dry weight), and medium (kernels of ca. 33mg dry weight). In 24 hours, all three birds again lost weight - by 1.3, 2.0 and 0.9g respectively - only slightly smaller losses than previously.

As before, the usual seeds were returned, and four days later two of the birds weighed the same or more than they had at the beginning of the experiment, but the bird which had previously lost most weight had gained only 0.8g. This bird had originally been the heaviest but was now only a little heavier than the lightest. A third and final ash-only period was then enforced for 48 hours; large and medium keys were available. After 24 hours, weight losses of 1.2, 1.8 and 1.7g were recorded, and the second bird died overnight. However, during the second period of 24 hours, the first bird actually maintained weight and the third lost only 0.3g. During the 48 hours, these two birds had eaten a mean of at least 4.0-4.5g of ash key kernel/day each, more than twice the amount eaten voluntarily during recovery periods when their normal seeds had also been available.

Whilst the general conclusion from these experiments must be that the food provided was in some way inadequate, these last results suggest that the combination of large and medium keys was not wholly so. At least for a short period, two bullfinches ate sufficient keys to prevent major loss of weight. As with the experiments with only large ash keys, it seems possible that the suitability of the keys used here was, in part, determined by their size.
Again it was not possible to distinguish between the two stages involved in eating the keys: that of extracting the kernel and that of breaking it up prior to swallowing. However, one final observation suggests that the second stage was at least sometimes difficult. Whenever large or medium-sized keys were given to bullfinches, extracted but not swallowed kernels were found discarded beneath or inside the cages. These had not been rejected outright, since beak marks were often visible where the birds had attempted to break them up, and indeed one or both the ends of the kernels (where they are narrowest) were often missing, presumably swallowed. In these cases, although the keys had been successfully husked, only the most easily broken part of the kernel had been eaten.

Experiments with small keys

Small ash keys — with kernels of less than ca. 30mg dry weight — were supplied to bullfinches in outdoor aviaries only on isolated occasions, and not as part of especially designed experiments. They were never supplied in large quantities, and were only intended to supplement the normal seed diet. Nevertheless, the data collected are interesting. For example, on one occasion in December, 73% of about 150 keys containing kernels of about 26mg dry weight were eaten by five birds in only one day, leaving only keys with tiny, underdeveloped kernels. On another occasion, in October, 87% of keys collected from one tree and 94% of keys from a second tree, both of which had keys described at the time as 'rather on the thin side', were husked in less than two days. Whilst these results may have involved some birds making several attempts to husk each key, they do not indicate that any difficulty was experienced.

More conclusive results came from two indoor experiments, in which bullfinches were fed solely on small ash keys, just as had been attempted with large and medium-sized keys. In contrast to the normal pattern, the ash keys used in the first of these experiments were collected from a tree within the study area, in early December. Wild bullfinches subsequently fed within
this tree and two counts of keys dropped onto the snow beneath indicated that they achieved 43 and 67% success at husking and eating the keys (other such ground counts indicated that these were normal success rates). The kernels had a mean fresh weight of 35mg, and thus probably weighed less than 30mg dry weight. Thus the keys were both small and known to be eaten by wild bullfinches. During the experiment, two bullfinches were provided only these keys, but they ate a total of 207 keys in nearly 7 hours of daylight, and increased in weight by 1.3 and 0.9g. After 24 hours, they had eaten a total of 355 keys, probably over 5g dry weight of kernel each, and lost only 0.3 and 0.5g respectively. Considering these birds were not allowed to acclimatise themselves to the diet, they fared much better than those fed on larger keys, in terms of number and weight of keys eaten, and in terms of maintenance of body weight.

In the second indoor experiment, the smallest ash keys recorded during this study were used. The keys were 4mm wide, and the kernels were 2.5-3mm wide, 10-14mm long, and had a mean of only 17.6mg dry weight each. For six days, three bullfinches had access to canary seed and ash keys, but the seed was then removed and, for the first time in this study, captive bullfinches demonstrated that they could survive on ash keys alone without loss of weight for several days. One bird ate a mean of 360 keys (6.3g dry weight of kernel)/day over a period of five consecutive days and lost only 0.7g body weight. The other birds were caged together and given the ash-only diet for two days during which one gained 0.1g and the other lost 0.3g. One of these two birds was subsequently caged individually and supplied only with ash for six days. During this time, it ate a mean of 505 keys (8.9g dry weight of kernel)/day, and put on 2.4g body weight. On the sixth day it put on 2.3g between 0850 hours and 1640 hours and ended the experiment at a healthy 24.3g body weight. Controls, fed on canary seed, maintained fairly constant weight during the first experimental periods, but gained 0.9g in the final six-day period.

Compared to other estimates of ash-feeding rates for captive bullfinches, 500 keys in a day is a considerable
achievement, equivalent to an average of 1 key/minute if feeding occurred only during daylight. Relatively little husking or swallowing difficulty can have been experienced, and it seems highly likely that it was the small size of these keys (or some related factor) which permitted this.

1981/82 Ash key survey

Preferences shown by bullfinches for the keys of certain ash trees can, to some extent, be judged by following the rate of loss of keys from trees during the winter, and by examining fallen keys and husks to determine the percentage eaten (or, more strictly, husked) by bullfinches. Accordingly, 21 easily accessible fruiting ash trees within 11km of the study orchard were visited on three occasions during the winter of 1981/82: on 19 November, 4 January and 8 March. In November, a sample of keys for measuring and weighing was cut from most of these trees (a sample of intact but fallen keys had to suffice for two trees which had no low branches), and the surrounding bullfinch habitat was classified as A (good) or B (moderate). On each occasion, the number of keys remaining on each tree was estimated, and on the first two visits a random sample of fallen keys was collected for subsequent examination. Measurements were made on a sub-sample of 20 keys from each tree, as shown in Fig. B.25.

Thus it was hoped that the degree of preference for the keys of the various trees would be indicated by such measures as the number or percentage of keys eaten by January or March, or the number of keys remaining uneaten on these occasions. Parameters which might influence preferences included various of the key and kernel dimensions, the weight of the kernels and also such factors as the size of the tree and the surrounding habitat. However, despite marked differences in apparent preferences, and in the keys, no clear relationship emerged — a fact which does not support the conclusions reached as a result of feeding experiments, i.e. that bullfinches prefer small keys because they are more easily handled than large ones. Further data from both field and laboratory environments are needed for a definite
Figure B.25. Measurements made on ash keys during the 1981/82 ash key survey.

Dimensions of husk/wing:
- length (1)
- maximum thickness (2)
- width 5mm from tip (3)
- width at base of wing (4)
- distance from kernel to tip (5)
- (2) minus (8) gave the thickness of the husk

Dimensions of kernel:
- length (6)
- width (7)
- maximum thickness (8)
- the mean dry weight of kernels in each subsample was also measured
conclusion to be drawn. Details of feeding rates, key and kernel characteristics (both morphological and chemical) and apparent popularity of several trees of a similar size in a small and uniform area would be of particular interest. Nevertheless, several points arising from the survey are worth discussing, since they illustrate the complexity of the task undertaken and show the range of values recorded for each parameter measured. Similar ranges might be expected in any similar survey in other years or regions. Results are tabulated in greater detail in Appendix 3.

The number of keys on fruiting trees varied dramatically and not always in relation to the size of the tree. Thus, in November, one tree had an estimated 74,000 keys, and another only 700; the mean was about 13,700 with a total of about 287,000 being present on the 21 trees. A few keys had already fallen from some trees, and of these up to 71% had been husked by bullfinches. In January, trees had lost 3-100% of their keys (mean 61%), and, of fallen keys, 10-93% had been husked by bullfinches. In March, trees had lost 11-100% of their keys (mean 77%); excluding three trees with most remaining keys, 99.6% of keys had fallen. Mean kernel dimensions varied from 10-18mm length, 3.5-5.0mm width, 0.9-1.7mm thickness and 17.5-58.0mg dry weight.

It may be important to realise that the ash seed crop was, in the area surveyed, smaller than average. Comparative data for other years are available for the study area, where only three fruiting trees were found in an area in which 20-25 had been present in both 1978/79 and 1979/80. This may have influenced feeding bullfinches; for example, it could be argued that in the year of the survey they ate keys of all types because there was insufficient choice. It is interesting that keys husked by bullfinches were found beneath 15 of the 21 trees in November (though 10 trees had lost very few keys), and all trees in January. Many keys were taken from some trees; for example, the tree with 74,000 keys in November had only 1,750 in January and 200 in March. Thus, between November and January, keys fell from this tree at a rate of about 1,300/day, 81% of which were husked by bullfinches.
Three trees retained large seed crops in March; these retained 8,000-34,500 keys (75-89% of the number of keys present in November). Their seed kernels were above average weight, ranging from 38.0-43.8mg mean dry weight, but were lighter than some very popular keys. Two of these trees were adjacent to roads, and this may have deterred some bullfinches from feeding within them; only 25 and 45% of fallen keys had been husked, so they may have been difficult to husk or, alternatively, some may have fallen naturally. Keys from one of these trees had been used in feeding trials described on pages 106-9; they had large kernels. The third apparently unpopular tree was in good bullfinch habitat and is further discussed below.

Seven trees had had at least 70% of their fallen keys husked by bullfinches, and therefore presumably had keys that were easily husked. Since between 96 and 100% of their keys had fallen by March, they might also be described as popular trees. Contrary to possible expectation, the keys and kernels were not particularly small. Indeed, the tree with the largest seed kernels recorded (58mg dry weight) fell into this group; it was a large tree with 46,000 keys in November, all but 150 of which had fallen by March, and 70% of which had been husked by bullfinches.

Some sample trees were very close to each other and were therefore vulnerable to predation by the same bullfinches. Any effect of key size on feeding preferences should be apparent in a comparison of such trees. Thus it is useful to compare data from the largest tree in the survey (with 74,000 keys) and the tree that was adjacent to it in the same hedge. The largest tree had much smaller keys than its neighbour and, as described above, many of its keys had been eaten by January. In contrast, only 3,000 of the 15,000 keys present on its neighbour had been eaten by this time, perhaps suggesting that small keys were preferred. However, all of the remaining 12,000 keys had fallen by March, and earlier counts of fallen keys suggest that 49% of these might have been eaten by bullfinches, so they must surely have been quite adequate as a food source.
The other group of trees in the survey consisted of three trees in the same hedge in good bullfinch habitat. Initially they had 11,400, 4,000 and 9,000 keys each, the last being one of the seemingly least popular trees described above. In January, they retained 120, zero and 8,000 keys respectively, and in March, 35, zero and 8,000. Thus, the last tree was conspicuously ignored by bullfinches. Yet the keys of all these trees were very similar and in no way abnormal; their kernels ranged only from 35-42mg mean dry weight. Furthermore, of the few keys that fell from the unpopular tree, 68% were husked by bullfinches, suggesting that they were not difficult to husk. Bullfinches ate many pear buds from an orchard adjacent to these trees, presumably in preference to keys from the unpopular ash tree.

**Large ash keys and bud damage**

If large ash keys are unsuitable for bullfinches, it follows that bud damage to orchards may be severe even when large crops of ash keys are available - if these are large keys - and that only trees with large keys should retain seed crops adjacent to heavily damaged orchards.

Few data are available, but measurements of keys encountered at blossom time in 1980 and 1981 confirm these ideas. While no small keys were found, three trees retained large crops of large keys adjacent to severely damaged orchards. In 1980, the kernels of two trees adjacent to damaged pear orchards were ca. 49 and 56mg dry weight (i.e. very large), and in 1981, a tree adjacent to a damaged apple orchard retained keys 7mm wide with kernels 4.5-5mm wide and 10-13mm long (i.e. large - see Tables B.10 and B.11). In contrast to these observations, and as discussed in the previous section, heavy damage occurred to a pear orchard in 1982 adjacent to an ash tree still retaining a large number of only medium-sized keys (ca. 38mg dry weight). Furthermore, the reason for bullfinches' apparent dislike of these keys did not seem to be directly related to the size of the keys.
Discussion

Ash keys are by far the largest seeds eaten by bullfinches in this country, and they vary markedly in the weight of their kernels, so it would not be surprising if some were too large. The evidence that only small ash keys are suitable comes mainly from avairy feeding experiments. In choice experiments, bullfinches seemed to prefer smaller keys, and when bullfinches were allowed to eat only ash keys, they seemed able to maintain weight for more than a short period of time only when small keys were available. Observations of birds attempting to eat large keys clearly showed that this was not easy for them. On the other hand, the survey of ash trees conducted in 1981/82 indicated that, while wild bullfinches do seem to select between different ash trees, factors other than the size of the keys may influence the choice. It is even possible that the importance of each factor may vary between years.

Little is known about the relative proportions of small and large keys found in this country, or what factors control this. In this study, some ash trees seemed to produce keys of similar size and appearance each year, and trees in close proximity to each other sometimes had very similar keys. This suggests that much of the variation known to exist may be genetically controlled; even if the suitability of keys is determined by a factor unrelated to key size, it may still be genetically controlled. Alternatively, there may be a tendency for suitable keys to be produced in certain years, or in certain habitats; the relative absence of ash-feeding within the study area in 1978/79 may have been due to a lack of suitable keys. Harper et al. (1970) found that the heavier seeds of some dock plants were the last to fall (naturally) and germinate, so a similar (or opposite) pattern might occur with ash trees.

It is interesting that Newton (1964a) found that bullfinches fed from only five out of 105 fruiting ash trees in Marley Woods, suggesting that only a small percentage of ash trees in Oxfordshire have small, easily husked or otherwise suitable keys. In this study, in 1977/78 and 1979/80, bullfinches may have
eaten keys from over 50% of fruiting trees, and in 1981/82 some keys were taken from all trees examined, so Kent may have a much larger proportion of suitable keys. Whatever the factors involved, it is suggested that considerable caution is necessary when attempting to predict damage levels from the apparent size of the ash seed crop.
Selection of and adaptation to a diet of buds

During this study, two fundamental questions were raised which merited some experimentation in search of answers. These were, firstly, do bullfinches need to eat buds in order to breed successfully or maintain themselves in good condition? and secondly, do bullfinches need to adapt to suddenly-imposed diets, behaviourally, physiologically or morphologically?

Bullfinches eat buds in spring even when seeds are available, so it is possible there is some element of seasonal necessity in bud-eating. Furthermore, aviculturalists deliberately supply fresh green food during the breeding season, since experience suggests that this results in more successful breeding. The following pilot experiment was therefore designed to detect differences in the breeding condition of captive bullfinches fed either on seeds alone or on seeds and buds.

One group of three male bullfinches (previously maintained on a commercial cage-bird seed mixture) was given an estimated total of 15,000-45,000 buds from recently-pruned Conference pear trees between early February and early March 1979. The number of buds eaten by each bird during this time was equivalent to the number on about 15 mature pear trees, and the weight of bud initials eaten was approximately 6g/bird/day. A second group of three male bullfinches was supplied only with seeds.

All six birds were then taken to Queen Mary College, London, and examined by Dr. C.R. Storey. Each was hemicastrated and placed under increased photoperiods to induce gonadal growth. In summary, all six bullfinches had regressed testes on arrival at Queen Mary College and no subsequent differences in the rates of testis growth was noted between the two groups.

Despite these results, it remains possible that buds provide nutrients found only in small amounts in seeds, and it must be remembered that such nutrients may be more easily obtained from cage-bird seed mixtures than from seeds eaten by wild birds.
Further experimentation may yet suggest that bullfinches do benefit from buds in their diet.

In considering the second question above, it is interesting that Newton (1964a) observed that seed-fed bullfinches became noticeably restless when first introduced to a bud-only diet, and that similar reactions were recorded during this study when bullfinches were transferred from a commercial cage-bird seed diet to one consisting of a variety of seeds and buds, usually selected by wild birds. Some kind of adaptation seemed to be necessary. To see whether morphological changes in the gut occurred when buds were made available to bullfinches in addition to their seeds, the following experiment was carried out.

Twelve seed-fed bullfinches were separated into two groups of six. One group was given a supplement of about 11,500 Conference pear buds during a period of eight days (ca. 240 buds/bird/day), and the other group maintained on seeds alone. All twelve bullfinches were then asphyxiated with chloroform and their guts carefully dissected out and examined. No visible external differences between the two groups were apparent, and although the length of the guts (measured from crop to anus) of bud-fed birds varied from 467-591mm and those of the seed-fed birds from 507-572mm, both groups had a mean gut length of 531mm.

These results may indicate that the length of the gut remains constant during such experiments. However, ideally, many more buds might have been provided and more detailed examination of the guts carried out. Even if no adaptation is needed, results of feeding trials with captive birds must be applied very carefully to the field situation.
A total of 27 samples were analysed for their amino acid content. Three of these were analysed during the summer of 1979 (Conference flower initials collected 24/01/79, canary seed kernels sampled 29/01/79 and ash key kernels collected 30/01/79); the remainder were analysed the following summer, and are listed below.

Conference flower initials: 5 samples collected at about 3-week intervals between 13/12/79 and 15/03/80.

Comice flower initials: 4 samples collected at about 3-week intervals between 13/12/79 and 19/02/80.

Whole dock seeds: 1 sample collected 24/01/80.

Ash key kernels: 13 samples of the 1979 seed crop collected 27/08/79 and seven dates between 19/12/79 and 28/05/80 (6 samples on 17/03/80).

Canary seed kernels: 1 sample from 29/01/79 (a sub-sample of that mentioned above).

The concentrations of 13 amino acids in these samples could be calculated and compared (Table B.11). In addition, threonine was present in most samples but was often masked by the large 'amide' peak, and valine and methionine were masked by a buffer change.

In the developing flower initials there was no clear indication of any particular amino acid increasing or decreasing as a percentage of the total, suggesting that little or no change occurs in their relative proportions during the period monitored. Indeed, the amino acid make-up of the two bud varieties, and of the seeds, was quite similar; 'amide', glutamic acid, amino butyric acid and alanine predominated in most samples, while other amino acids were present only in small quantities. Fig. B.26 shows that the total amino acid concentration (n moles/100mg) in the bud initials rose more dramatically than might have been expected from protein (nitrogen) determinations (page 57). These
Figure B.26. Total amino acid concentrations in pear flower initials in the study orchard in 1979/80.

Only amino acids listed in Table B.34 are included.
data also indicate that initials of Conference buds had a much higher concentration of amino acids than initials of Comice buds, whereas nitrogen determinations had indicated only small differences.

Table B.11. Amino acid levels in bullfinch foods

To facilitate comparison between seeds and buds collected in a single winter, two samples (1 Conference and 1 ash) analysed in 1979 have been omitted.

<table>
<thead>
<tr>
<th>amino acid</th>
<th>Conference flower initials</th>
<th>Comice flower initials</th>
<th>whole dock seeds</th>
<th>ash key kernels</th>
<th>canary seed kernels</th>
</tr>
</thead>
<tbody>
<tr>
<td>aspartic acid</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>'amide'1</td>
<td>44</td>
<td>25</td>
<td>16</td>
<td>24</td>
<td>21</td>
</tr>
<tr>
<td>glutamic acid</td>
<td>9</td>
<td>20</td>
<td>13</td>
<td>14</td>
<td>24</td>
</tr>
<tr>
<td>proline</td>
<td>2</td>
<td>2</td>
<td>9</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>glycine</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>alanine</td>
<td>9</td>
<td>14</td>
<td>9</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>isoleucine</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>leucine</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>tyrosine )</td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>phenylalanine)</td>
<td>3</td>
<td>7</td>
<td>8</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>γ amino butyric acid</td>
<td>19</td>
<td>14</td>
<td>17</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>histidine</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>lysine</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

mean total concentration of listed amino acids

(n moles/100mg)

4368  1323  678  1915  622

1. 'amide' was probably asparagine, serine and/or glutamine.
There was considerable variation in the concentrations of amino acids in the various ash samples. Even the six samples collected on the same day (from six different trees) were diverse; for example, 'amide' comprised 14-40% of the total, glutamine 5-19%, and γ amino butyric acid 3-20%. The total amino acid concentration on this day ranged from 1277-3234 nmol/100mg (including only those amino acids listed in Table B.11). Keys from the same six trees were used in a choice experiment (page 102), in which some keys appeared to be preferred to others, but these preferences did not seem to correlate with variations in the amino acid levels. The single isolated sample collected in August, when the keys were still green, contained by far the smallest concentration of amino acids (472 nmol/100mg), but no clear trends were apparent between December and the following May.

Only one tree was sampled twice - in January and February. Results from these two samples were very similar, with the greatest changes being in the concentration of 'amide' (27-24% of the total), glutamine (13-17%) and phenylalanine (14-10%); the total amino acid concentration fell from 1779-1486 nmol/100mg. Though more data, including replicates, are needed, the consistency of these data suggest that the variations recorded between other trees are genuine and not caused by experimental error.

The two samples of canary seed kernels were sub-samples from a single tube of finely ground material, but they were analysed about a year apart. Despite this, the resulting data were very similar; apart from 'amide', which increased from 18-24% of the total, all amino acid levels remained within 2% of that recorded in the first sub-sample, and the total amino acid concentration rose only 3% from 614-631 nmol/100mg. Again this confirms the accuracy of the technique employed.

The differences in the total and individual amino acid levels recorded in the various seed and bud samples may affect bullfinch feeding preferences, but extensive data coupled with feeding trials are needed. As is the case with insects, some amino acids may encourage feeding, while others may have the
opposite effect; indeed, the balance of amino acids may be more important than the total nitrogen or protein level (McNeill and Southwood 1978). Some amino acids are likely to be essential in the bullfinch's diet, and this may affect feeding preferences.
B.8. Feeding rates and food intake

A number of factors determine both the rate at which a bullfinch can collect food and the amount of food required. The weight of each food item and the time taken to swallow each one are likely to be particularly important, and the quality of the food and the rate at which it can be digested may also be limiting factors. Bullfinches often have a wide choice of seeds or buds and they probably choose the diet which satisfies their requirements most rapidly. At present, insufficient data are available to construct a reliable hierarchy of food profitability, but some comparisons can be made.

One problem is that observed feeding rates need not always be maximal; rates measured over only a few minutes may be misleading, and apparently leisurely feeding may be indicative of maximal rates over longer periods. Small seeds, and perhaps buds, can be plucked from the plant several at a time and then husked individually, and, late in spring, bullfinches are unable to manage some buds whole— they need to take several beakfuls. In either case, one peck does not necessarily represent one seed or one bud. Furthermore, observation of wild and captive birds during this study indicated that some individuals are able to feed more quickly than others.

Feeding rates observed during this study are given in Table B.12. In general, these rates are inversely correlated with the size of the food items. Thus, feeding rates on pear buds became progressively slower as the buds developed; in late March, bullfinches needed up to 11 pecks and up to 30 seconds for each bud. However, the amount of food swallowed may not have declined if a greater weight of bud tissue was taken from each bud. Feeding rates of up to 20 pear buds/min. were recorded, but only for a few seconds at a time; the overall mean was 12.8 buds/min. in January.

Wright and Summers (1960) estimated that bullfinches fed on gooseberry buds at 30 buds/min., and Newton (1964a) observed feeding rates of up to 50 hawthorn buds/min. (mean 30)
and 15-45 pear buds/min (mean 25) - a faster rate than recorded in this study.

### Table B.12. Feeding rates observed in this study

<table>
<thead>
<tr>
<th>captive birds</th>
<th>food type</th>
<th>feeding rate (items/min.)</th>
<th>month observed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>dock seeds</td>
<td>15-66</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bramble seeds</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>canary seeds</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>hawthorn buds</td>
<td>13-40</td>
<td>January &amp; March</td>
</tr>
</tbody>
</table>

| wild birds    | nettle seeds   | 15                        |                      |
|               | ash seeds      | 1-4                       |                      |
|               | Conference buds| 11-15                     | January              |
|               |                | 2-4                       | late March           |
|               | damson buds    | 45-60                     | January              |
|               | Forsythia buds | 40-50                     | January              |
|               | blackthorn buds| 17-60                     | January-May          |

1. more than one seed may have been taken in each peck

Detailed studies of the energy requirements of some birds (Kendeigh 1949, 1970, Gibb 1957, Kontogiannis 1968) indicate that a bird of bullfinch size might require about 20-30 kcal/day depending on ambient temperature, exercise and other factors. Feeding on ash keys containing 6.1 kcal/g (see Fig. B.19) a bullfinch might therefore require 3.3-4.9g/day. In reality, more would be required since ash keys are not completely digestible, and, in winter, free-flying wild birds would use a large amount of energy to power their mobility and to keep warm. During this study, captive bullfinches needed about 7g ash keys/day.

Bullfinches do not have the stomach capacity to eat a full day's food requirements in one session; the food is digested only slowly and a bird may need to fill its crop and the upper parts of its digestive tract several times each day. During this
study it was noted that hungry bullfinches took about 15 minutes to 'fill up' with canary seed, eating an estimated 1.4g (fresh weight) of seed. The maximum number of ash keys seen to be eaten in quick succession was 60, and each may have weighed 25mg, so this bird may have eaten 1.5g of ash. These data suggest that only about 1.5g fresh weight of food can be eaten at once. The profitability of various foods of the bullfinch can therefore be crudely compared to that of ash keys by calculating the time it takes to fill up and the number of feeding sessions needed to collect 7g of food. These comparisons are made in Table B.13.

Table B.13. Calculated rates of food intake for bullfinches feeding on selected seeds and buds

<table>
<thead>
<tr>
<th>food</th>
<th>seeds</th>
<th>buds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ash</td>
<td>dock</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>month</td>
<td>January</td>
<td>-</td>
</tr>
</tbody>
</table>

| feeding rate | (items/min) | 2.5 | 50 | 12 | 12.8 | 50 | 50 |
| fresh weight of item (mg) | 25 | 1.0 | 7.9 | 15 | 0.5 | 1.0 |
| dry weight of item (mg) | 20 | 0.85 | 7.4 | 5 | 0.25 | 0.35 |
| filling up time (hrs:mins) | 0:24 | 0:30 | 0:16 | 0:08 | 1:00 | 0:30 |
| time to eat one day's supply (hrs:mins) | 2:20 | 2:45 | 1:19 | 1:49 | 9:20 | 6:40 |
| number of items eaten in one day | 350 | 8235 | 946 | 1400 | 28000 | 20000 |

1. defined as the time needed to eat 1.5g fresh weight of food.
2. one day's supply is taken to be 7.0g dry weight of food.
These data suggest that only a small proportion of the day need be spent feeding on ash, dock or canary seeds, or Conference pear buds, and of these, canary seeds and Conference buds require the least time. However, buds are very moist and a bullfinch may fill up with Conference buds in less than 10 minutes, having eaten only 5mg dry weight of food. Unless the buds are digested rapidly, the bird would need to return to feed many times during each day. Bullfinches feeding solely on blackthorn buds would need many thousands each day and, according to the calculations listed, they would have little spare time.

Clearly, the longer the filling up time, the less meaningful this concept becomes; feeding on blackthorn buds would in any case need to be almost continuous, and digestion might well keep pace with the slow rate of food intake. Furthermore, the various foods are not equally digestible and have different calorific values.

Observations of feeding bullfinches provide support for some of these data. Thus, bullfinches feeding on ash often seem to have a lot of spare time, feeding intensively at dawn and dusk, but only sporadically during the day. Captive bullfinches fed on canary seed also followed this pattern, even on the shortest winter days. Newton (1964a) also found that bullfinches fed on a commercial seed mixture fed only for about two hours each day. Each of these observations suggests that sufficient food for survival may be collected in only a small amount of time. Captive bullfinches fed rapidly on dock seeds for periods in excess of 30 minutes, supporting the calculations which indicate that this should be possible. Similarly, in places where blackthorn buds were an important food for bullfinches, birds were seen feeding continuously for over 30 minutes.

Other observations show that these data allow only a simplified comparison to be made. For example, although in January and early February bullfinches were seen to feed on pear buds for up to only five or six minutes at a time, in later months some were seen to feed continuously for over 30 minutes. Furthermore, Newton (1964a) estimated that during feeding trials
captive birds fed on Conference pear buds for 6-8 hours each day. These observations suggest that less than 5mg dry weight may have been taken from each bud, or that considerably more than 7g dry weight of bud tissue may be needed - passing through the digestive tract more rapidly than seeds. The latter possibility is perhaps supported by data from the study orchard where, in the winter of 1977/78, calculations suggest that each bullfinch in the area ate about 1,000 buds/day, and yet also ate a large number of ash keys.
C. **BUD DAMAGE AND FRUIT CROP ASSESSMENT**

C.1. **Introduction**

Damage to ripe fruit by birds is easy to quantify, since every fruit damaged is unmarketable and the crop decreases in value accordingly. However, damage to fruit buds is less easy to assess, since a period of about six months may elapse before the crop is picked, and during this time a number of factors may complicate the relationship between bud damage and the value of the fruit crop. For pears, this relationship has been shown to be non-linear; Wright and Summers (1960) found that loss of up to 70% of buds on Conference pear trees could be tolerated before the crop was significantly affected, and Smith and Kendall (1975) found that up to 60% loss of buds on Comice pear trees was similarly tolerated. However, Smith and Kendall also showed that the bud damage-fruit crop relationship was linear for Victoria plums, even though only 10% of the flower buds usually produce fruit.

Summers and Pollock (1978) and Summers (1982b) simulated bullfinch damage on Conference pear trees over a five-year period. Trees not previously damaged suffered significant loss of crop when 30-92% of buds were removed artificially. The precise loss of crop varied between years; in three years 7-15% loss of crop occurred with 30% bud removal, but in a fourth year the effect of up to 92% loss of buds on the crop was not significant. In years following bud removal, crops were enhanced, thus compensating for the initial losses, and after the third harvest there was no overall effect of bud removal on the total crop. When buds were removed annually on the same trees, the effects on crop decreased; in the fourth and fifth years, bud removal had no significant effect on the crop. Fruit size of disbudded trees tended to increase in the year of damage and decrease in the year after. Buds remaining on disbudded trees set significantly more fruitlets each and tended to bear more pears each at harvest than buds on controls.

Research is currently in progress designed to help growers produce regular crops of large, good-quality fruits, and
Plate C. Conference fruitlets and pears in the study orchard.

Bottom: Large pears — several to each truss — on a heavily-damaged branch just before harvest in 1979.
amongst the techniques being employed, thinning of blossom coupled with the inducement of a heavy set of fruitlets on remaining flowers, is providing promising results with pears (see Knight 1980, 1982). Blossom thinning may be achieved by hand or, more recently, with chemical sprays; set may increase naturally, but can be induced or enhanced with chemicals. Despite the differences in timing and cause, bullfinch damage and blossom thinning seem to have similar effects, and blossom thinning experiments described by Knight (1980) confirm and extend conclusions drawn by Summers and Pollock discussed above. That blossom thinning encourages the production of many fruit buds in the following year is a particularly important discovery; without thinning, fruit trees sometimes tend to bear crops biennially, producing very few fruit buds after a heavy crop of small fruits in one year, and many fruit buds after a light crop of large fruits in the next (Knight 1978, 1980, Knight and Jackson 1980).

From these studies it is clear that considerable loss of buds can sometimes be tolerated by pear trees with little or no loss of crop. Bullfinch damage is only one of several factors, e.g. pruning, that may affect the crop; even orchards that have never been attacked by bullfinches always vary in the quantity of blossom/tree, fruitlet set, fruitlet drop and fruit size. It was therefore decided to follow in detail the damage incurred by pear trees within the study orchard and to investigate the effects of this damage on the fruit crop, supplementing these data with further damage and crop assessments in other orchards.
C.2. Methods

The study orchard (see also Section A.2)

In December 1977, before damage had begun, 36 Conference trees on a square grid through the study orchard (Fig. C.1) were selected for regular damage and crop assessment. (In later months and subsequent years, additional trees were selected to extend the range of damage levels being monitored, and to include Doyenné du Comice trees in the damage and crop assessment.) On each tree, two sample branches were marked with coloured plastic tape, one on the north and one on the south side of the tree, each branch having about 100 flower buds. Most pear flower buds are large and conspicuous with a plump rounded appearance. Vegetative buds, distinguished by their relatively small size and narrow, pointed appearance, are rarely eaten by bullfinches, so these were not sampled. At approximately ten-day intervals, buds on each sample branch were counted, both those eaten by bullfinches and those left intact. Counts were made throughout the period of damage which usually ended at bud-burst. Some assessment of damage after bud-burst, and of earlier partially damaged buds (where only part of the bud had been eaten) was made.

At blossom time, flowering buds on sample branches were counted. Since each bud normally produces several flowers, further samples were taken to assess the number of flowers in undamaged and partially damaged buds, and the proportion of damaged buds that survived to produce some flowers. These samples were taken in both heavily and lightly damaged parts of the orchard.

Fruitlet set was assessed by counting the number of fruitlets on each sample branch before the 'June drop', and the final crop by similar counts of pears just before picking in September (see Plate C). Fruit quality was assessed by weight and diameter measurements, samples being taken from heavily and lightly damaged parts of the orchard.

In the winters of 1978/79 and 1979/80, some additional trees were completely enclosed in netting and sample branches
Figure C.1. Diagram of the study orchard showing grid of standard sample trees and their coordinates.

- Conference (every fourth tree in each direction)
- Comice (alternating between two rows)
established when the netting was removed before blossom. This was designed to ensure that at least some trees were totally undamaged.

Records were also kept of buds damaged by tractors, breakage of branches due to heavy crops, and fruits damaged by tits. Information on yield from the orchard was given by the owners. As far as possible, sample branches were maintained between years, but pruning and low numbers of buds sometimes necessitated replacement or the addition of new sample branches to existing ones.

Rocks Farm and Brenchley 2

Damage and crop were assessed by similar, though less intensive, methods in two other pear orchards. The first of these orchards was on Rocks Farm, part of E.M.R.S., which had a variety of apple orchards, two pear orchards and some open land. The orchard selected contained 850 Conference trees, 32 Comice and 22 Beurré d'Amanlis, and occupied 2ha.

Data were obtained from sample branches on 22 Conference trees, one Comice, and three Beurré d'Amanlis. The Conference sample trees were spread evenly through the orchard on a roughly rectangular grid. The trees are pruned to a different system from those in the study orchard, and as a result, sample branches were usually smaller, bearing fewer buds. The orchard was flanked by apple trees on all but the west side, where it was separated from an open field by a rough track.

The second orchard, known as Brenchley 2, lay approximately 0.5km to the south of the study orchard (see Fig. A.1). It contained 588 Conference and 44 Comice trees. Damage and crop assessment was made on sample branches on 38 Conference trees on a square grid through the orchard during 1978/79 and 1979/80.
This orchard was flanked by open fields to the north and south, and a tall hedge and open field to the west. To the east was a road lined with hedges, and beyond this an open field. Tall coppiced woodland was close to the north-east corner.

Other orchards

Orchards damaged by bullfinches can be recognised at a distance at blossom time, when damaged trees contrast with those retaining all their flowers (see Plate A). The extent of damage in about 50 orchards was assessed visually each April or May, when the trees were in flower. The surrounding habitat was also assessed. Details are given in Section C.8.
C.3. Study orchard results

C.3.1. Conference 1977/78

Although house sparrows do eat buds of various bushes and trees including pears (Southern 1945, Fryer 1939, and personal observation), none were seen feeding on study orchard buds. Bullfinches ate buds within the orchard mainly between late December and early March (Fig. C.2), and counts of buds on sample branches indicated some variation in the rate at which buds were taken. Of an estimated 940,000 buds present in December 1977, when pruning had finished, only 75,000 remained in March. In all, 92% of buds in the orchard were eaten: a total of about 865,000. In January, most buds were taken from the trees nearest the surrounding woodland, but when buds on these trees became scarce, many were taken from the rest of the orchard (see page 246). Fig. C.3 shows the extent of damage on three dates and the distribution of the pear crop as shown by sample branches; the crop was clearly concentrated where the damage was least.

A range of damage levels from 53-100% loss of buds was provided by the standard sample trees, and sample branches were established on three further trees with damage down to 35% (no trees were free of damage).

Blossom (see Fig. C.4)

Buds not damaged by bullfinches produced a mean of 8.16 flowers each, though individual buds varied from 3 - 18 flowers. Samples taken in heavily and lightly damaged parts of the orchard were not significantly different.

Outer bud scales of damaged buds were removed from sample branches during bud counts, and as a result the number of damaged buds that eventually produced some flowers was reduced. Thus on sample branches about 1.4% of damaged buds flowered, while on other trees about 4.5% flowered. In the lightly damaged part of the orchard, blossom trusses from these 'half-buds' (not on sample branches) amounted to less than 5% of all blossom trusses;
Figure C.2. Rates at which bullfinches fed on Conference buds in the study orchard during the winter of 1977/78.

1. Feeding rate is defined here as the total number of buds damaged/day on the orchard's sample branches between bud counts (dates of bud counts are indicated by vertical lines).
Figure C.3. The spread of bullfinch damage through the study orchard (Conference trees only) during the winter of 1977/78, and the resulting crop, as indicated by sample branches.
Figure C.4. Study orchard Conference blossom in 1978

Numbers of flowers/truss expressed as percentages of the total.
Damaged buds bearing no flowers were not counted.

A 159 undamaged buds (all parts of the orchard)
B 23 damaged buds in lightly damaged parts of the orchard
C 100 damaged buds in heavily damaged parts of the orchard
they produced 1-5 flowers (mean 2.87). However, in the heavily damaged part of the orchard, where very few undamaged buds remained, blossom trusses from half-buds amounted to about 60% of all blossom trusses. They produced significantly fewer flowers \((P < 0.01)\) than in the lightly damaged area; the range was still 1-5 flowers, but the mean was 1.61.

**Fruitlet set**

Damaged sample branches had fewer flowers and set fewer fruitlets than undamaged branches \((P < 0.001)\), but undamaged buds remaining on heavily damaged trees set more fruitlets each than those on lightly damaged trees \((P < 0.01)\), so the reduction in the overall set (the number of fruitlets/original bud) was less than might have been expected (Fig. C.5). On many sample branches, set was increased by the presence of half-buds (in addition to those undamaged), although the increase in set/surviving bud with increasing damage was significant even in the near absence of these half-buds \((P < 0.001, \text{Fig. C.6})\). Excluding half-buds, set was increased from a mean of 0.83 to 1.72 fruitlets/bud \((\text{a factor of 2.07})\) when damage increased from 35-60% to 91-100%.

On the most heavily damaged trees (retaining only half-buds) the probability of flowers setting fruit was even further increased. Twelve sample branches (on 10 trees) had only half-buds remaining. Though apparently totally devastated, they set 17 fruitlets from 25 half-buds \((0.68 \text{ fruitlets/half-bud})\). Since the damage level on these trees was effectively 100%, they probably averaged about 1.61 flowers/half-bud (see Blossom). Thus they produced about 0.42 fruitlets/flower: equivalent to 3.45 fruitlets/undamaged bud.

**Fruitlet drop**

Many fruitlets set fell before picking in September. Trees that had suffered most damage tended to drop least fruit, though this effect was not significant. For example, the most
Figure C.5. Conference set in the study orchard in 1978.

Set was measured as the number of fruitlets set/original (top) and surviving (bottom) bud, on sample branches with different levels of bullfinch damage.
Figure C.6. Conference set in the study orchard in 1978.

Details are as for Fig. C.5 (bottom) except that branches were included only where half-buds comprised less than 10% of the surviving flower clusters (see text).
heavily damaged trees (96-100% loss of buds) retained a mean of 49% of fruitlets set, while the least damaged trees (35-60% loss of buds) retained a mean of only 27%. The effect of this, combined with variation in set discussed above, was that by picking time sample branches damaged by less than 75% all had about 13 pears/100 buds (see Final crop). These factors also resulted in heavily damaged trees having a larger number of pears in each truss (cf. means of 1.56 and 1.25 pears/truss on trees with 90-100 and 50-70% loss of buds respectively (Fig. C.7, P<0.01).

Wind damage

Storms in mid-September caused nearly 20% of pears to fall (normally very few fall at this late stage of growth). Trees damaged by less than 85% bore 48% of the total orchard crop of pears before the storms and 52% afterwards, but this change was not statistically significant.

Pear size

The size of pears on sample branches was assessed visually; each was classified as marketable or unmarketable according to its size. This crude assessment indicated that about 15% of fruit were too small. No major differences between heavily and lightly damaged parts of the orchard were noted.

Fig. C.8 shows the weights of a sample of picked pears; very few pears less than 80g were picked (data from subsequent years indicate this to be equivalent to a diameter of about 47mm). Pears left on trees, and those of a size classified as unmarketable on sample branches, were usually below 80g. The mean weight of picked pears was 150.6g (equivalent to 57.5mm diameter).
Figure C.7. Study orchard Conference pear trusses in 1978.

Numbers of pears per truss expressed as percentages of the total

A  138 trusses from lightly damaged parts of the orchard
B  84 trusses from heavily damaged parts of the orchard
Figure C.8. Study orchard Conference pear weights in 1978.

Numbers of pears picked in classes of 20g, expressed as percentages of the total sample of 100 pears.
Damage to ripe fruit by tits

Counts of fruit damaged by tits (on sample branches) showed that about 10% of all orchard fruit had been damaged by the time of picking (a total of about 4,000 pears). Over 40% of this damage had occurred in a period of 16 days just before harvest. Although more tit-damaged fruits were found in lightly bud-damaged areas (where pears were more numerous), a slightly greater percentage (12%) of pears were tit-damaged in areas of high (85-100%) bud damage (cf. 8% tit-damaged in areas of less than 85% loss of buds). This relationship was not found to be significant.

Final crop

Table C.1 and Fig. C.9 summarise the final pear crop data from sample branches. Both marketable and unmarketable fruit are included. Since there were no undamaged trees, those with 35-60% loss of buds have been used as a baseline.

Table C.1. The effect of bullfinch damage on the final crop in 1977/78

<table>
<thead>
<tr>
<th>% bud loss</th>
<th>35–60</th>
<th>61–80</th>
<th>81–85</th>
<th>86–90</th>
<th>91–95</th>
<th>96–100</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of trees in sample</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>7</td>
<td>19</td>
</tr>
<tr>
<td>mean pears/ original bud</td>
<td>0.126</td>
<td>0.136</td>
<td>0.089</td>
<td>0.072</td>
<td>0.045</td>
<td>0.014</td>
</tr>
<tr>
<td>mean pears/ surviving bud</td>
<td>0.22</td>
<td>0.42</td>
<td>0.52</td>
<td>0.55</td>
<td>0.64</td>
<td>1.07</td>
</tr>
<tr>
<td>% crop change</td>
<td>0</td>
<td>+8</td>
<td>-29</td>
<td>-43</td>
<td>-64</td>
<td>-89</td>
</tr>
</tbody>
</table>
Figure C.9. The Conference crop in the study orchard in 1978.
Crop measured as the number of pears remaining/original (top) and surviving (bottom) bud, on sample branches with different levels of bullfinch damage
Buds surviving on heavily damaged trees retained a significantly greater number of pears/bud than those on lightly damaged trees (P< 0.05). As a result, marked reductions in crop (i.e. the number of pears/original bud) were only apparent on trees with over 80% loss of buds. Slightly enhanced crops were apparently achieved by trees damaged by 61-80%, these having a mean of 8% more pears than trees with 35-60% loss of buds, but this effect was not significant. Overall there was a very significant reduction in crop with increasing damage (P<0.001).

If it is assumed that, in the absence of bullfinch damage, all trees would have produced a crop of similar size to the least damaged trees, i.e. 0.126 pears/bud, the orchard crop would have been about 2.9 times as large as that recorded. Thus bullfinch damage in this season may have reduced the orchard crop by 65%; if loss of crop had been directly proportional to loss of buds, a 92% crop reduction would have resulted.
C.3.2. **Comice 1977/78**

Trees of this supposedly non-preferred variety were situated at the western edge of the orchard, adjacent to woodland. They were first assessed for damage in late February, by which time over 70% of buds had been taken. All of the nearly 400 sample buds (on seven trees) were damaged by mid-April, though four of these buds did produce some flowers. Thus over 99% bud loss occurred, a damage level similar to that of neighbouring Conference trees. About 100,000 buds had been eaten.

A sample of blossom trusses (Fig. C.10) showed that undamaged Comice buds produced significantly fewer flowers than neighbouring Conference trees ($P < 0.01$). They produced 3-10 flowers (mean 6.78). This was significantly fewer than in subsequent years ($P < 0.001$), perhaps indicating some year-to-year variation (numbers of Comice flowers in 1979 and 1980 were not significantly different). Half-buds (damaged buds producing some flowers) had 1-4 flowers (mean 1.51). On the sample branches, only a single pear set, and this remained till picking; so the crop was regarded as a total failure.
Figure C.10. Study orchard Comice blossom in 1978.

Numbers of flowers/truss expressed as percentages of the total. Damaged buds bearing no flowers were not counted.

A 45 undamaged buds
B 47 damaged buds
C.3.3. Conference 1978/79

Damage

When the first bud count was made in December 1978, 29 of the 36 standard sample trees were unpruned. Sample branches on these bore a mean of 1.8 times as many buds as had been present on the same branches after pruning and before damage in 1977/78. Variation in the number of buds produced was not significantly correlated with damage, set or crop in 1977/78. Pruning in this season reduced the total number of buds in the orchard by over 50%.

Bullfinches ate buds within the orchard between February and mid-April 1979 (Fig. C.11), much later than in the previous winter. Counts of buds on sample branches indicated that peak numbers were eaten in March and that the rate of loss from the orchard was much less than in 1977/78. Of an estimated 840,000 buds present in the orchard after pruning, about 510,000 remained undamaged in late April. Some 39% of buds in the orchard were eaten - a total of about 330,000 - many fewer than in 1977/78. Most damage occurred in the south-west corner of the orchard. Fig. C.12 shows the extent of damage on three dates and the distribution of the pear crop as shown by sample branches; overall, the crop was not obviously affected by the damage.

Sample branches on four trees were completely free of damage. A further ten trees were covered in nylon netting during the damage period, and sample branches were established on these when the netting was removed at bud-burst. Also, a further eight trees in the most heavily damaged part of the orchard were selected for damage and crop assessment. Thus a range of damage levels from 0-100% loss of buds was sampled.

Blossom (see Fig. C.13)

Buds not damaged by bullfinches produced 4-15 flowers (mean 8.50). Samples taken in heavily damaged (60+% loss of buds)
Figure C.11. Rates at which bullfinches fed on Conference and Comice (shaded) buds in the study orchard during the winter of 1978/79.

Feeding rate was measured at in Fig. C.2.
Figure C.12. The spread of bullfinch damage through the study orchard (Conference trees only) during the winter of 1978/79, and the resulting crop, as indicated by sample branches.
Figure C.13. Study orchard Conference blossom in 1979.

Numbers of flowers/truss expressed as percentages of the total. Damaged buds bearing no flowers were not counted.

A 200 undamaged buds
B 100 damaged buds
and undamaged parts of the orchard were not significantly different.

Outer bud scales of damaged buds on sample branches were not removed during bud counts (cf. 1977/78). Most damaged buds did not flower, but those that did produced 1-6 flowers (mean 1.96). Since very few trees were heavily damaged, these 'half-buds' contributed only a tiny proportion of the orchard's blossom (cf. 1978).

**Fruitlet set**

Damaged sample branches had fewer flowers and set fewer fruitlets than undamaged branches (P < 0.001) but, as in the previous year, undamaged buds on heavily damaged trees set more fruitlets each than those on lightly damaged trees (P < 0.001, Fig. C.14). In this season, set was doubled (from a mean of 3.40 to 6.86 fruitlets/surviving bud) when damage increased from zero to 91-100%. A large proportion of flowers were pollinated (Plate C), especially on heavily damaged trees. Bees were placed in the orchard during the blossom period (unlike 1978 and 1980).

**Fruitlet drop**

Many fruitlets fell before September (mostly in June and July), but trees that had suffered most damage dropped least fruit (P < 0.001, Fig. C.15). Fruitlet drop was also closely correlated with total fruitlet set (i.e. set/original bud, P < 0.001), trees with the largest sets allowing most fruitlets to fall. (Some breakage of branches occurred, which further reduced crops on some trees. This, and a small amount of summer pruning, was included with the normal fruitlet drop.) Trees with 91-100% loss of buds retained a mean of 60% of fruitlets set, while undamaged trees retained a mean of only 11%. The effect of this, and the variation in set discussed above, was that by picking time sample branches damaged by less than 90% all had about 38 pears/100 buds (see Final crop). As in 1978, heavily damaged trees had a
Figure C.14. Conference set in the study orchard in 1978/79.

Details are as for Fig. C.5.
Figure C.15. Conference fruitlet drop in the study orchard in 1979.
Drop was the percentage of fruitlets initially set which fell before picking, on sample branches with different levels of damage.

Figure C.16. The relationship between Conference pear weight and diameter in a sample of 60 pears from the study orchard.
significantly larger number of pears in each truss (cf. means of 2.84 and 1.29 pears/truss on trees with 70-100 and zero % loss of buds respectively; Fig. C.17, P<0.001).

**Pear size**

Accurate data were obtained by measuring the diameter of a sample of pears in both damaged and undamaged parts of the orchard (Fig. C.18). The relationship between the diameter and weight of the pears is illustrated in Fig. C.16. To these data the model $\log_{10}(\text{weight}) = A + B \log_{10}(\text{diameter})$ was fitted by least squares, where A and B are constants. The values of A and B thus estimated were -2.669 and 2.742 respectively, and the model accounted for 96.3% of the variance.

Trees with heavy damage (60+% loss of buds) had most pears between 50-65mm diameter (100-210g) with a mean of 57.0mm (140g). Trees with light damage had most pears between 45-60mm diameter (70-170g) with a mean of 51.9mm (110g). These differences were statistically significant (P<0.001). The large fruit (see Plate C) were selected for immediate sale — without storage — to obtain a better market price than was possible for the smaller fruit. Owing to a general abundance of small pears in 1979, only those of 50mm or more were picked in the study orchard. Thus, undamaged trees bore about 23% unmarketable fruit and heavily damaged trees only 7%.

Pears were picked two days after measurements were made, so in commercial terms the final size of pears would have been a little larger (1-2mm diameter), and the unmarketable percentages a little smaller.

**Damage to ripe fruit by tits**

Counts of fruit damaged by tits (on sample branches) indicated that about 2% of orchard fruit had been damaged by the time of picking (a total of about 6,000 pears). These were evenly
Figure C.17. Study orchard Conference pear trusses in 1979.

Numbers of pears/truss expressed as percentages of the total

A 100 trusses from lightly damaged parts of the orchard
B 100 trusses from heavily damaged parts of the orchard
Figure C.18. Study orchard Conference pear size in 1979.

Numbers of pears in classes of 5mm, expressed as percentages of each sample.

A 100 pears from lightly damaged parts of the orchard
B 100 pears from heavily damaged parts of the orchard
distributed through the orchard and no correlation with bullfinch damage was detected.

Final crop

Table C.2 and Fig. C.19 summarise the final pear crop data. Both marketable and unmarketable fruit are included.

Table C.2. The effect of bullfinch damage on the final crop in 1978/79

<table>
<thead>
<tr>
<th>% loss of buds</th>
<th>0</th>
<th>1-30</th>
<th>31-60</th>
<th>61-90</th>
<th>91-100</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of trees in sample</td>
<td>14</td>
<td>16</td>
<td>8</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>mean pears/ original bud</td>
<td>0.378</td>
<td>0.375</td>
<td>0.404</td>
<td>0.386</td>
<td>0.185</td>
</tr>
<tr>
<td>mean pears/ surviving bud</td>
<td>0.378</td>
<td>0.423</td>
<td>0.793</td>
<td>1.91</td>
<td>4.11</td>
</tr>
<tr>
<td>% crop change</td>
<td>0</td>
<td>-1</td>
<td>+7</td>
<td>+2</td>
<td>-51</td>
</tr>
</tbody>
</table>

Trees with up to 90% loss of buds retained a mean of 38.4 pears/100 buds, and there was no significant trend for reduced crops up to this damage level. Trees with 31-90% loss of buds appeared to have slightly enhanced crops (but this was not significant). Above 90% loss of buds, marked reduction in crop occurred: four trees with 91-95% bud loss had a mean crop reduction of 27% and two trees that lost 96 and 97% of their buds had a mean crop reduction of 65%. As can be seen from Fig. C.19, variation between sample trees in the number of pears/original bud was considerable and there was no significant correlation with
Figure C.19. The Conference crop in the study orchard in 1979. Details are as for Fig. C.9.
damage level. In contrast, the number of pears retained on surviving buds clearly increased with damage ($P<0.001$).

The overall reduction in the number of pears within the orchard caused by the bullfinch damage can be estimated if it is assumed that, in the total absence of damage, all trees would have cropped similarly to those in the zero damage level category. Only four (11%) of the standard sample trees had over 90% bud loss, and therefore markedly reduced crops, so it will be apparent that the overall reduction in the orchard crop could not have been more than 11%. In fact, since even the most heavily damaged trees produced some pears, and since those with 31-90% bud loss produced enhanced crops, the overall loss of crop was estimated to be only 4%. It is also likely that a smaller percentage of large pears would have been picked in the absence of damage. If loss of crop had been directly proportional to loss of buds, a 39% crop reduction would have resulted.

Finally, since crop reduction was only recorded on trees with over 90% bud loss, it is clear that the overall crop was reduced only because the damage was unevenly distributed. If bud feeding had been more evenly spread within the orchard, no crop loss would have occurred.
C.3.4. **Comice 1978/79**

By late 1978, Comice sample branches had nearly twice as many buds as had been present before damage in 1977/78, but pruning reduced the total to just over 400 buds before damage started this season. Bullfinch damage to this variety occurred mainly in March (Fig. C.11). The sample branches established in February 1978 lost 17–96% of their buds (mean 74%), a total of about 75,000. The adjacent row of Conference trees lost 65% of its buds (see Fig. C.12). Two Comice trees were covered in nylon netting to prevent damage, and sample branches were established on these and a third additional tree before blossom.

These ten sample trees fell into two damage groups: 0–21 and 70–96% bud loss, and Table C.3 summarises the available data.

<table>
<thead>
<tr>
<th>% loss of buds</th>
<th>0–21</th>
<th>70–96</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of trees</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>mean set/original bud</td>
<td>0.62</td>
<td>0.20</td>
</tr>
<tr>
<td>mean set/surviving bud</td>
<td>0.68</td>
<td>1.14</td>
</tr>
<tr>
<td>mean pears/original bud</td>
<td>0.21</td>
<td>0.10</td>
</tr>
<tr>
<td>mean pears/surviving bud</td>
<td>0.23</td>
<td>0.56</td>
</tr>
<tr>
<td>% fruitlet drop by picking</td>
<td>66</td>
<td>51</td>
</tr>
</tbody>
</table>

Despite the small number of trees sampled, both set/original bud and pears/original bud were significantly correlated with % loss of buds ($P<0.01$ and $P<0.05$ respectively). Also, when the three most heavily damaged trees are excluded (these had very few buds remaining and consequently gave variable set and crop data), both set/surviving bud and pears/surviving bud were significantly correlated with % loss of buds ($P<0.05$). Fruitlet drop was not significantly correlated with % loss of buds.
These data indicate the presence of tolerance or compensation mechanisms similar to those found in Conference. Thus, while the fruitlet set and crop on each sample branch was reduced by the heavy bud loss, buds left on heavily damaged branches set more fruitlets each, and tended to retain a greater percentage of these till picking time, than did buds on lightly damaged branches.

Comice blossom data are presented in Fig. C.20. Undamaged buds produced 4-12 flowers (mean 8.81) and half-buds 1-4 flowers (mean 1.67).
Figure C.20. Study orchard Comice blossom in 1979.
Numbers of flowers/truss expressed as percentages of the total.
Damaged buds bearing no flowers were not counted.

A 100 undamaged buds
B 42 damaged buds
Bullfinches ate buds within the orchard between mid-December 1979 and March 1980 (Fig. C.21). The rate of damage as shown by sample branches varied more than in previous years (probably at least partly because of attempts by the owner to prevent damage, discussed on page 263). Despite a total lack of pruning, only an estimated 690,000 buds were present in the orchard before damage commenced (less than in both previous years — when pruning did occur). Of these, 32% were eaten by bullfinches, a total of about 220,000 buds, leaving 470,000 in April. The damage was more evenly distributed through the orchard than in previous years, though the west side of the orchard was most heavily damaged. Fig. C.22 shows the extent of damage on three dates and the distribution of the pear crop as shown by sample branches; the crop was not obviously affected by the damage.

Sample branches on five standard sample trees were free of damage, as was one of the three additional sample trees established in spring 1978. Three trees were covered in nylon netting to prevent damage, and sample branches were established on these before blossom (one suffered very slight damage). The eight additional sample trees established in spring 1979 were also maintained in 1980, giving a total of 50 sample trees. Thus a range of damage levels from 0-87% bud loss was sampled.

Several sample branches were inadvertently sprayed with a weed-killer, and this affected subsequent cropping patterns. Also, the three protected trees were later shown to be atypical in some respects (see page 188). Data from all these branches have been excluded from fruitlet set and crop calculations.
Figure C.21. Rates at which bullfinches fed on Conference buds in the study orchard during the winter of 1979/80.

Feeding rate was measured as in Fig. C.2.
Figure C.22. The spread of bullfinch damage through the study orchard (Conference trees only) during the winter of 1979/80, and the resulting crop, as indicated by sample branches.
**Blossom** (see Fig. C.23)

In contrast to previous years, a significant difference ($P < 0.001$) was recorded between the mean blossom truss sizes of undamaged buds in different parts of the orchard; buds produced 5-17 flowers (mean 8.20) where damage was low, and 3-13 flowers (mean 7.30) where damage was high (30-90% bud loss). This difference could be explained if some late, undetected damage occurred, resulting in some partially damaged buds being included in the second sample. About 5% of damaged buds flowered, producing 1-4 flowers each (mean 1.50). Outer bud scales of damaged buds on sample branches were not removed during bud counts (cf. 1977/78).

**Fruitlet set**

Heavily damaged sample branches had fewer flowers and set fewer fruitlets than undamaged branches ($P < 0.05$), but, as in previous years, undamaged buds on heavily damaged trees set more fruitlets each than those on lightly damaged trees ($P < 0.001$, Fig. C.24). Set was doubled (from a mean of 1.52 to 3.01 fruitlets/surviving bud) when damage increased from zero to 76-90%. The increased set on surviving buds appeared to fully compensate for up to 55% loss of buds, and although not statistically significant, sample branches with 21-55% damage set more fruitlets/original bud than those with 0-20% damage.

**Fruitlet drop**

As in previous years, many fruitlets fell before they were picked. In contrast to previous years, the general trend did not seem to be related to bullfinch damage. Both the most heavily damaged trees and the least damaged trees had identical fruitlet drops of 76%. Thus, no compensation for low fruitlet set (i.e. set/original bud) on heavily damaged branches occurred.

It is interesting that the greatest drop (82%) was recorded on branches that had set most pears/original bud (those
Figure C.23. Study orchard Conference blossom in 1980.

Numbers of flowers/truss expressed as percentages of the total.
Damaged buds bearing no flowers were not counted.

A 100 undamaged buds from undamaged parts of the orchard
B 100 undamaged buds from damaged parts of the orchard
C 44 damaged buds
Figure C.24. Conference set in the study orchard in 1980. Details are as for Fig. C.5.
with 21-55% bud loss), perhaps indicating that the set had greater influence on drop than did the damage (see also page 196).

Conflicting data were obtained for the number of pears in each truss. Samples of 100 trusses selected at random in damaged and undamaged parts of the orchard (Fig. C.25) indicated mean truss sizes of 1.31 and 1.58 respectively; these means are significantly different (P<0.05). These figures do not agree with data from sample branches presented in Fig. C.26. The latter data came from a much larger sample (c. 2,300 trusses), and in the light of their consistency and general agreement with data from previous years, and the high significance of the correlation (P < 0.001), it is suggested that they are more reliable. Examination of base data for the random samples suggests the presence of two atypical trees in the undamaged area with abnormal numbers of large trusses.

Data from sample branches indicate an increase in truss size with increasing bullfinch damage, from a mean of 1.14 pears/truss at 0-20% loss of buds to a mean of 1.54 pears/truss at 76-90% loss of buds. Since, in this season, fruitlet drop was not correlated with damage (cf. previous years), the increase in truss size is probably a residual effect of variation in set: buds remaining on heavily damaged branches set more fruitlets each than those on lightly damaged branches.

**Pear size**

Accurate data were obtained by measuring the diameter of a sample of pears in both damaged and undamaged parts of the orchard on two dates in September, these being ten days apart (Fig. C.27).

On both occasions, damaged trees bore marginally larger fruit, but the difference was not significant. On the second occasion, most pears were between 50-65mm diameter (overall mean 55.7mm on undamaged trees and 56.3mm on damaged trees).
Figure C.25. Study orchard Conference pear trusses in 1980.

Numbers of pears/truss expressed as percentages of the total.

A 100 trusses from undamaged parts of the orchard
B 100 trusses from damaged parts of the orchard
Figure C.26. Conference pear truss sizes in the study orchard in 1979/80.

Truss size is the mean number of pears/truss on sample branches with different levels of bullfinch damage.
Figure C.27. Study orchard Conference pear size in 1980.

Numbers of pears in classes of 5mm, expressed as percentages of each sample

A 200 pears on 9 September       B 100 pears on 19 September
Between the two dates on which measurements were made, pears in both damaged and undamaged parts of the orchard increased significantly in diameter ($P < 0.001$), by nearly 6mm. They were picked five days after the second sampling date, and therefore probably further increased in size by about 3mm diameter. All fruit over 45mm were picked; the second sample indicated that only 3% of pears in the orchard were smaller than this, so very few were wasted.

**Damage to ripe fruit by tits**

Sample branches indicated that 5.8% of fruit had been damaged by tits 15 days before picking, indicating that about 10,000 orchard fruit were damaged. A further increase in damage probably occurred before pears were picked. Tit-damaged fruit were evenly distributed through the orchard, and no correlation with bullfinch damage was apparent.

**Final crop**

Table C.4. and Fig. C.28 summarise the pear crop data from sample branches. Both marketable and unmarketable fruit are included.

Trees free of damage retained a mean of 36.3 pears/100 buds. Despite the significant increase in the number of pears retained on each surviving bud with increasing damage ($P < 0.001$), and in contrast to previous years, all levels of damage resulted in reduced crops on sample branches. This reduction was significant ($P < 0.01$), and calculations similar to those of previous years indicate that an overall orchard crop loss of about 21% occurred (but see below).
Details are as for Fig. C.9.

Figure C.28. The Conference crop in the study orchard in 1980.

\[ r = 0.60, P < 0.001 \]

\[ r = 0.52, P > 0.01 \]
Table C.4. The effect of bullfinch damage on the final crop in 1980

<table>
<thead>
<tr>
<th>% loss of buds</th>
<th>0</th>
<th>1-20</th>
<th>21-40</th>
<th>41-55</th>
<th>66-75</th>
<th>76-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of trees in sample</td>
<td>6</td>
<td>10</td>
<td>12</td>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>mean pears/ original bud</td>
<td>0.363</td>
<td>0.322</td>
<td>0.271</td>
<td>0.256</td>
<td>0.205</td>
<td>0.129</td>
</tr>
<tr>
<td>mean pears/ surviving bud</td>
<td>0.363</td>
<td>0.344</td>
<td>0.392</td>
<td>0.508</td>
<td>0.706</td>
<td>0.703</td>
</tr>
<tr>
<td>% crop change</td>
<td>0</td>
<td>-11</td>
<td>-25</td>
<td>-29</td>
<td>-44</td>
<td>-64</td>
</tr>
</tbody>
</table>

Bud numbers and the pear crop

In the winter of 1979/80, no trees were pruned, and as a result the number of buds counted on sample branches in December 1979 could be compared with the number that had been present on the same branches in February 1979 (after pruning and before damage). Overall, in December 1979 sample branches had about 76% of the number of buds present in February 1979. However, some sample branches showed large increases in bud numbers and these were found to be those that had been heavily damaged in the intervening period, and which, as a result of this, had carried few fruitlets in spring 1979. Thus the bud ratio was highly correlated with both the intervening damage and set (P < 0.001, Fig. C.29). The bud ratio was not significantly correlated with the intervening crop, i.e. the number of pears at harvest. In summary, trees 'rested' in 1979 (because of damage and/or subsequently low fruitlet set), produced many more buds than other trees.
Figure C.29. The effect of bud loss (top) and fruitlet set (bottom) on the number of buds subsequently produced by sample branches in the study orchard.

See text for definition of bud ratio.
Since the trees most heavily damaged in 1979/80 were also the trees most rested in 1979, it follows that each had more buds (before damage started) than trees that were to be free of damage. Thus, in reality, the bullfinch damage in 1979/80 had the effect of making the number of buds on each tree more uniform than it would have been in the absence of damage, and, in contrast to previous years, the damage gradient within the orchard in spring 1980 was not reflected in a blossom gradient.

This is important because a tree with very few pears remaining on each bud might have a large number of pears on the tree as a whole if it has a large number of buds. Thus, the heavily-damaged trees described in the previous section (Final crop), may have had large crops even though they had relatively few pears/ original bud.

If in February 1979 all trees had equal numbers of buds (this is likely once the trees were pruned 1'), then the ratios of 'new':'old' bud numbers on sample branches can be used to give an index of the number of buds on each sample tree in December 1979, from which an index of the final crop on each sample tree can be calculated (since the crop achieved on each bud is already known). Data are summarised in Table C.5, and these suggest that between zero and 66-75% damage, crops actually increased, though this trend was not significant (P<0.1).

If it is assumed that in the total absence of damage in the winters of both 1978/79 and 1979/80, all trees would have cropped similarly to those in the zero damage level category in Table C.5 (crop index of 0.229), the overall effect of the recorded variations in bud production can be quantified. Calculations indicate that without this damage the total orchard crop in 1980 would have been 10% smaller than was recorded. On the other hand, if damage had occurred in 1978/79 but not in 1979/80, the 1980 crop would have been even larger than it was.

1. Data presented for bud numbers in December 1979 suggest that, if anything, damaged trees would have most buds, which would accentuate the effect being described.
Table C.5. Indices of final crop on trees of different damage levels in 1980

<table>
<thead>
<tr>
<th>% loss of buds</th>
<th>0</th>
<th>1-20</th>
<th>21-40</th>
<th>41-55</th>
<th>66-75</th>
<th>76-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1979/80)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean bud ratio&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.63</td>
<td>0.65</td>
<td>0.99</td>
<td>1.05</td>
<td>1.72</td>
<td>2.11</td>
</tr>
<tr>
<td>mean pears/ original bud&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.363</td>
<td>0.322</td>
<td>0.271</td>
<td>0.256</td>
<td>0.205</td>
<td>0.129</td>
</tr>
<tr>
<td>mean index of crop/ tree (i.e. 1 x 2)</td>
<td>0.229</td>
<td>0.209</td>
<td>0.268</td>
<td>0.269</td>
<td>0.353</td>
<td>0.273</td>
</tr>
<tr>
<td>% change in index</td>
<td>0</td>
<td>-9</td>
<td>+17</td>
<td>+17</td>
<td>+54</td>
<td>+19</td>
</tr>
</tbody>
</table>

1. For definition see text. The bud ratio was significantly correlated with damage in 1979/80 (P<0.001).
2. Values taken from Table C.4.

Thus, in summary, bullfinch damage early in 1979 caused some trees to produce large numbers of buds late in 1979. These buds then more than offset further loss of buds in the winter of 1979/80, and the orchard pear crop picked in 1980 was larger than might have been expected if there had been no damage in either year.
C.3.6. Comice 1979/80

Comice trees produced many buds and lost very few to bullfinches. Sample branches had about 2.6 times as many buds as in 1978/79 (trees were not pruned), and only 0.6% were eaten: a total of perhaps 1,500 buds. Undamaged buds produced 5-12 flowers (mean 8.59, Fig. C.30) and set a mean of only 0.14 fruitlets/bud (fewer than in 1979). Sample branches indicated that 77% of fruitlets fell before they were picked, leaving a mean of only 0.033 pears/bud. Even though the sample branches together had over 1,000 buds, the final crop data seemed unrepresentative of most Comice trees, sample branches having a poorer than average crop. The maximum recorded crop on one sample branch was 0.12 pears/bud.
Figure C.30. Study orchard Comice blossom in 1980.

Numbers of flowers/truss expressed as percentages of the total sample of 100 undamaged buds.
C.3.7. Conference trees protected from damage

Ten trees were protected from bullfinch damage during the winter of 1978/79, and three different trees were protected in 1979/80. Both these groups can be compared with the other sample trees.

1978/79

Protected trees set a mean of 3.40 fruitlets/bud, of which 89% fell, leaving 0.380 pears/bud till picking. These data are almost identical to those from the four unprotected sample trees which escaped damage (equivalent figures of 3.43 fruitlets/bud, 89% fall, and 0.368 pears/bud). The protected trees were thought to have suffered a range of damage levels in 1977/78 (probably about 60-100% loss of buds), and the undamaged, unprotected trees were known to have lost 35-96% of their buds in that year.

1979/80

Since the three trees that were protected in 1979/80 suffered 0-1% bud loss - due to slight damage after the netting had been removed - they can be compared with the nine unprotected sample trees which also suffered 0-1% bud loss in that year. Protected trees bore a mean of 1.36 fruitlets/bud of which 83% fell, leaving 0.236 pears/bud till picking. The unprotected trees set 1.35 fruitlets/bud, of which 75% fell, leaving 0.340 pears/bud. None of these differences was significant, perhaps because samples were small. The protected trees were thought to have suffered about 55-95% loss of buds in 1978/79, whereas the unprotected trees were known to have suffered 0-32% loss. A sample of fruit from each of the above protected trees indicated that the tree that was probably most heavily damaged in 1978/79 bore significantly smaller fruit (P<0.001) than the others (Table C.6).
### Table C.6. The effect of damage history on pear size

<table>
<thead>
<tr>
<th>tree</th>
<th>AP</th>
<th>BP</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>probable % loss of buds 1978/79</td>
<td>95</td>
<td>78</td>
<td>56</td>
</tr>
</tbody>
</table>

**Pears in each size class (mm)**

<table>
<thead>
<tr>
<th>Size Class</th>
<th>AP</th>
<th>BP</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-29</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-34</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35-39</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>40-44</td>
<td>8</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>45-49</td>
<td>25</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>50-54</td>
<td>13</td>
<td>17</td>
<td>21</td>
</tr>
<tr>
<td>55-59</td>
<td>18</td>
<td></td>
<td>18</td>
</tr>
<tr>
<td>60-64</td>
<td>4</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>65-69</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Mean pear diameter (mm)**

<table>
<thead>
<tr>
<th></th>
<th>AP</th>
<th>BP</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>46.4</td>
<td>53.2</td>
<td>53.8</td>
<td></td>
</tr>
</tbody>
</table>


C.4. Discussion and compensation mechanisms

Orchard management

The primary aim of this study was to follow the progress of bullfinch damage and the actions of fruit growers 'in situ', not to carry out controlled experiments to provide evidence as to the nature and importance of every facet of the problem which emerged. As a result, the effect of bullfinch damage on the crop could not always be quantified, and the efficacy of deterrent measures applied to the orchard (discussed in Section D) was not easy to test. Nevertheless, because the actions of fruit growers were not manipulated, a very wide range of orchard management and protection techniques was experienced during the three years in which damage and crop records were made. These served to illustrate the complexity of both damage and crop assessment in orchards. The variety of techniques and attitudes was further increased in September 1979 when a change of orchard ownership occurred. Over the study period, it was possible to follow attempts to reduce bud damage ranging from the use of black 'cotton' to the clearance of many acres of woodland, and to compare the effects of heavy pruning in one year with the complete absence of pruning in another.

However, it is clear that, even without the intervention of fruit growers, the effects of pear bud feeding by bullfinches on the subsequent fruit crops are not simple. Damage and crop assessments in the study orchard showed considerable variation in such factors as bud numbers, flower truss sizes, fruitlet set, fruitlet drop and pear size, and it seems likely that data from other orchards and from the study orchard in subsequent years would show continuing variation in these and other factors.

Of considerable importance to the study of bullfinch damage is the conclusion that tolerance to, or compensation for, bud loss seems to be the rule, rather than the exception, at least for Conference pear trees. Five major compensation mechanisms became apparent: the ability of partially damaged buds to flower, an increase in fruitlet set on surviving buds, a decrease in
fruitlet drop, an increase in fruit size, and an increase in bud numbers in the following year. Each of these is discussed in detail below.

'Half-buds'

When bullfinch damage is simulated by hand (e.g. Summers and Pollock 1978), complete destruction of the bud is likely; none of the flower initials within the buds is likely to survive. Also, if, during counts of buds, scales remaining on damaged buds are removed (as was done in the study orchard in 1977/78 to assist identification of subsequently damaged buds), few damaged buds are likely to flower. However, this study has shown that bullfinches do not totally destroy all the buds they attack; a small percentage of buds produce some flowers, and these have been termed 'half-buds'.

The existence of 'half-buds' complicates damage and crop calculations. Strictly, the level of bullfinch damage might be calculated as the percentage of flowers lost. When large numbers of whole buds remain, this measure of damage differs only marginally from the percentage of buds damaged. However, at high levels of damage, it is possible for a large proportion of surviving flowers to result from 'half-buds', as in 1978 when in one part of the study orchard 60% of blossom trusses were from 'half-buds'. 'Half-buds' produce fewer flowers than do undamaged buds; means of 1.53-2.81 were recorded in this study. Nevertheless, the flowers that are produced seem to achieve a good set (see below) and subsequently retain a high proportion of fruitlets set. The resulting pears are also likely to be large. These conclusions are supported by blossom thinning experiments with both Conference and Comice, where removal of some flowers from within flower trusses may be more beneficial than removal of equivalent numbers of whole flower trusses (Modlibowska and Wickenden 1977, Knight 1980). The fruit grower may therefore take some comfort in the knowledge that even 100% buds damaged is rarely 100% crop destruction; the few surviving flowers have a high potential.
The percentage of damaged buds surviving to produce flowers was 4.5% in 1977/78 and 5% in 1979/80. In these years, most bud damage occurred very early in the winter (in January and February) when buds were small. However, observations of bullfinches feeding on buds in the later stages of bud swell showed that each flower head was then treated individually (rather than the whole bud). One result of this feeding behaviour is that a larger percentage of attacked buds is likely to retain some flowers and any detrimental effect of the damage on the final crop will be smaller. In 1978, samples of 'half-buds' from different parts of the orchard indicated some variation in the number of flowers remaining in each bud. Those in the lightly damaged part of the orchard, with a mean of 2.87 flowers/'half-bud', were probably attacked later in the year than those in the heavily damaged area, with 1.62 flowers/'half-bud'. The difference in the number of flowers might therefore be a result of different feeding techniques. Also, buds in the most heavily damaged area may have been attacked more than once, some of the flowers which survived the initial attack being subsequently eaten.

Fruitlet set

In general, for a flower to set marketable fruit, pollen, often of a different variety, must land on the stigma (pollination). The pollen tube must then grow down the style and fuse with the ovule (fertilisation). Conference flowers sometimes set parthenocarpic fruits (i.e. without pollination and fertilisation), but these are usually small and misshapen. It is common practice to place beehives in orchards at blossom time to increase pollination, and, in this respect, it is interesting to note that in the study orchard the greatest set was recorded in 1979, the only year in which beehives were present. Weather conditions are most important, affecting the behaviour of bees and other pollinating insects as well as the growth of the pollen tube. However, set seems to vary over and above these factors, often apparently depending on previous years' crops; the physiological and morphological characteristics of a good quality flower, i.e. one that is likely to set fruit, are not known.
Data from this study indicating variation between years in the set of fruitlets on buds remaining after damage are therefore not unusual. However, in all three years, the number of fruitlets set on each remaining bud was highest on trees most heavily damaged by bullfinches, a trend also noted by Summers and Pollock (1978). In undamaged flower trusses, the number of fruitlets set/surviving flower was doubled in all three years and, at least in 1978, set on flowers in 'half-buds' was quadrupled. Thus, a sparsity of buds resulting from bullfinch damage was at least partly made up for by good fruitlet set. For example, a tree with 80% bud loss, but with set increased by a factor of 2.5, would set a total of 50% of the total number of fruitlets set by an undamaged tree. In 1980, increased fruitlet set at damage levels of 21-55% may have more than compensated for bud loss, so these trees may have the potential to bear larger crops than undamaged trees.

The increased set/bud was manifest in two ways. First, more buds set at least one fruitlet, resulting in more fruitlet trusses, and secondly, more flowers in each blossom truss set fruitlets, resulting in more fruitlets in each truss.

Three reasons for increased set/bud might be considered:

1. Weather conditions (such as wind direction) and the microclimate of the orchard (including the effects of neighbouring trees, slope, etc.) might have affected the behaviour of pollinating insects or the ability of flowers to set fruit, resulting in a pattern which, by chance, correlated with bullfinch damage.

2. A general lack of pear flowers in damaged areas of the orchard might have enabled insects to visit a greater percentage of them than in areas where flowers were more plentiful.

3. Physiological changes within surviving flowers, as a result of bullfinch damage, might have affected their attractiveness to insects or their ability to set fruit.
The pattern of set on surviving buds within the orchard was fairly similar in all three years, with smallest sets being recorded on trees in the north and east of the orchard. Thus, orchard microclimate cannot be completely ruled out as a contributory factor. The southern edge of the orchard was highest, Comice trees (often used as pollinators for Conference) were only at the western edge, and the eastern edge was always the most exposed; all these factors could have affected pollination.

However, two observations indicate that the pattern of set on surviving buds was not correlated with damage merely by chance (or indirectly via orchard microclimate). Firstly, good sets were biased towards sample trees in the south of the orchard in spring 1979, more so than in 1978 and 1980 when trees in the south-west and west achieved the best sets. This was probably because in 1978/79 damage was similarly biased towards southern trees. Secondly, the pattern of set did not seem to be affected by changes in the orchard's surroundings (which might have affected the microclimate). For example, in early 1979 a tall hedge bordering the north of the orchard was removed, in the winter of 1979/80 woodland undergrowth to the south and west of the orchard was cleared, and the quantity of Comice blossom varied enormously, from virtually none in 1978 to a very large amount in 1980. In addition, trees in damaged parts of the orchard but protected with nylon netting did not fit in with the general pattern of set described above; these undamaged trees set relatively few fruitlets on each bud, despite being in 'favoured' parts of the orchard.

It would seem probable that fruitlet set on surviving buds was increased by bullfinch damage. Any effects of orchard micro-climate appeared to be secondary.

The second possibility (2 above) seems feasible in the light of data from 1978 and 1979. It could be argued that the greater the number of flowers on a tree, the smaller the probability of each flower being visited and thereby pollinated by an insect. Thus, in 1978 and 1979, when distinct 'blossom gradients' were visible within the study orchard, those areas with
least damage and therefore most blossom might be expected to have the poorest set/surviving bud, as in fact they did. Two objections appear to this theory. Firstly, bees most frequently visit those trees with most blossom, since this increases their feeding efficiency. As a result, set/bud might remain the same or even be increased (Smith 1972, Smith et al. 1974). Secondly, the gradient of damage recorded in 1980 was not reflected by a gradient of blossom density (see page 184), so the observed gradient of fruitlet set recorded in this year could not have been caused by a blossom density effect.

The fact that fruitlet set/surviving bud seemed to increase with increasing levels of damage wherever the trees were located in the orchard, and however much blossom they had, suggests that the third possibility (3 above) may be correct. Competition between the flowers for limited resources may be reduced when blossom density is reduced, thereby rendering remaining flowers 'stronger' or longer-lasting. Since the mechanism probably operates in response to annual pruning and blossom thinning as well as bullfinch damage, knowledge of its exact nature could be of considerable value to orchard management planning.

Fruitlet drop

Many fruitlets dropped in early summer from all trees. However, there was considerable variation between trees of different damage levels and between years. In 1978 and 1979, those trees with the greatest bud loss retained the largest percentage of fruitlets set; in 1979 this was particularly evident when 89% of fruitlets fell from undamaged trees while only 40% of fruitlets fell from trees with 91-100% bud loss. The result of this, coupled with increased fruitlet set described above, was that in 1978 and 1979, crops were significantly reduced only at very high levels of damage.

In theory, the observed variations in fruitlet drop could have been determined at the bud stage or at the fruitlet
stage, i.e., in response to bullfinch damage *per se* or in response to the number of fruitlets set.

Since damage and total fruitlet set are closely related, it is not easy to separate these hypotheses; in 1979, fruitlet drop was closely correlated with both total set and damage (P < 0.001). However, in 1980, despite a wide range of damage levels, fruitlet drop varied only slightly; the fruitlet drop recorded on undamaged trees was identical to that recorded on trees with 76-90% loss of buds. Fruitlet drop may therefore be controlled primarily by the number of fruitlets on the tree; a poor total set results in a low drop and vice versa. In 1980, large numbers of buds present on some trees before damage started, and increased set on surviving buds in response to damage, resulted in trees with heaviest damage bearing as many or even more fruitlets than undamaged trees. These heavily laden trees then allowed many fruitlets to drop despite previous bud loss.

It is interesting to note that the greatest fruitlet drop on undamaged trees was recorded in 1979 when beehives were placed in the orchard. At E.M.R.S., bees are used as an insurance against poor pollination (Way 1980), but it seems possible that in the study orchard bees increased the set (both at the bud and tree level) in excess of requirements, and that as a result an unnecessarily large 'wastage' of fruitlets occurred.

**Pear size**

In individual orchards and over a wide area there is often considerable annual variation in the mean size of pears picked, and in their size class distribution. For example, in some years there is an abundance of small fruit (as in 1979). Conference pears of less than 45mm diameter have little commercial value so are usually not worth picking, and in some years a fruit grower may pick only those pears of 50mm and over.

1. Since this study was terminated, demand for small fruit has declined further and only those over 55mm diameter may now be worth picking.
In general, the largest fruit fetch the best prices (exceptionally large fruit may sometimes be of less value). In years of heavy crop, fruit size (both apples and pears) tends to be small, so growers are sometimes advised to remove some fruitlets (by hand or with chemicals) if the set seems too great (Knight and Jackson 1980). With Conference pears, similar regulation of fruitlet numbers, and therefore fruit size, may be achieved by thinning blossom and then inducing a good set on remaining flowers (Knight 1980, 1982). Care has to be taken, however, since an unexpected poor set or large natural fruitlet drop can lead to a greater reduction in fruit numbers than was intended. The cost of manpower also has to be taken into account.

Since bullfinch damage often results in a reduced total set, even though the number of fruitlets set/surviving bud may be increased, it might be expected to have a beneficial effect on fruit size in some years. In both years when pears in the study orchard were measured accurately, damaged trees produced larger fruit than undamaged trees. The difference was statistically significant in 1979 when bud losses of about 60-90% increased the mean fruit diameter from 51.9 to 57.0mm, which in turn reduced the percentage of fruit which was unmarketable because of small size, from about 26% to 7%. M.A.F.F. advisory leaflet on the bullfinch (M.A.F.F. 1973b) states that bud damage does not materially improve the quality of fruit on undamaged branches. Whilst "quality" may refer primarily to appearance and shape, the statement would seem misleading with respect to fruit size.

The production of fruit by pear trees is, at least superficially, a wasteful process. Data from undamaged study orchard trees show that only a small proportion of flowers set fruit (about 40% in 1979 and only 10-20% in 1978 and 1980). Subsequently, 70-90% of these fruitlets may fall before they are picked. In theory, if 100% set was followed by 0% drop, each tree would produce perhaps 30 times its usual number of pears. Similar processes of over-production followed by natural thinning are found in many plants and animals, usually providing a form of insurance whereby the species can withstand and recover from
population reductions. In the case of pear trees, the ability to adjust fruitlet drop might allow compensation for poor set (or too good a set) or advantage to be taken of good growing conditions. Without such a mechanism, bullfinch attacks would result in a devastating loss of crop far more often than they do.

Trees with few pears as a result of bullfinch damage - i.e. where increased set on surviving buds and reduced fruitlet drop have not made up for the lack of buds - are presumably able to supply more energy and nutrients to each pear than those with many pears. This would explain why the most heavily damaged trees had considerably larger fruit. However, it is also suggested that the increase in fruit size due to bullfinch damage recorded in 1979 and 1980 was, in part, a result of reduced flower and fruitlet wastage. It seems likely that this wastage is large in most years, and under these circumstances 'bud thinning' by bullfinches can prevent excessive blossom and fruitlet drop, thereby enabling the tree to save its energy for those fruitlets which remain.

Bud numbers

One of the difficulties in attempting to assess the effects of bullfinch damage on fruit crops is that effects from a single year's damage may persist for several years. For example, Summers (1982b) found that, although a reduction in crop was recorded in the first year following bud loss, this was made up for by increased crops in the following two years. Unpruned trees in the study orchard in 1978/79 and 1979/80 provided useful opportunities to assess the effect of damage in one year on the number of buds subsequently produced.

Buds present on pear trees in winter are initiated in the preceding summer. Differentiation of Cox's Orange Pippin buds into leaf and flower buds seems to occur at least by early October since rapid development can be induced to show both bud types in prunings cut in this month (Skene 1980). This indicates that the number of flower buds to be produced (or perhaps the ratio of leaf
to flower buds) is determined by factors operative during or before the summer.

In December 1978, unpruned sample branches bore a mean of 1.8 times as many buds as were present on the same branches in December 1977. It seems likely that trees with small crops might produce more new shoots, or shoots of greater length than heavily laden trees, and since many of the 'extra' buds counted on sample branches in December 1978 were on such new shoots, one might expect to find some correlation between crop and subsequent bud data. However, in 1978 no correlation was detected between bud production and either damage, set or crop. It is possible that in this year when both the total set and crop were small, and were therefore producing large numbers of fruit buds, all trees were rested.

In 1979, variation in bud production was highly correlated with both bullfinch damage and set (page 182). Branches with a small total set (due to heavy damage) were presumably rested, and reacted by producing many buds for the following year's crop: up to about 1.6 times as many buds as were previously present on the same branches (see Fig. C.29). Branches with a large total set (particularly large this year when beehives were placed within the orchard) were perhaps 'overworked' in 1979 and reacted by producing very few buds for the following year's crop: down to about 0.6 times as many buds as were previously present.

This link between the number of fruitlets set and subsequent bud numbers appears to be widely accepted, and it seems likely that gibberellins released by the fruitlets (or their seeds) inhibit fruit bud initiation (see Knight 1980). It also explains the data collected from Conference trees protected from bullfinch damage in this study. Trees protected in 1978/79 had similar set, drop and crop data to those trees which had escaped damage naturally; the two groups of trees had incurred similar levels of damage in 1977/78, so their similarity in 1978/79 was to be expected.
Compared to naturally undamaged trees in 1979/80, trees protected in this year appeared to retain a smaller percentage of fruitlets and less pears/bud. The protected trees had suffered more damage in 1978/79 than the others; they would therefore have set less fruitlets and consequently produced more buds for the 1980 crop. They then set the same number of fruitlets/bud, i.e. more fruitlets/tree, and therefore allowed more to fall, leaving less pears/bud. The pear size data collected from trees protected in 1979/80 can also be explained in this way. The tree most heavily damaged in 1978/79 would have had the greatest number of buds, and therefore fruitlets, in 1980. Each fruitlet would have received only a small proportion of the tree's resources, hence their small size.

High bud production as a reaction to damage has two effects. Firstly, it gives damaged trees the potential to produce greater crops in the following year; enhanced crops following damage recorded by Summers (1982b) may have been due to this effect. Secondly, it provides a cushion against bullfinch damage in the following winter; in this study very few buds might have remained on outside rows of pear trees in spring 1980 if these trees had not had as many buds before damage started as they did. In the event, enhanced crops were recorded in 1980 despite considerable damage during the winter of 1979/80 (even greater crops might have been achieved in the absence of this damage).

The tendency for pear trees to crop biennially is probably, at least in part, due to variations in bud production. Such variations occur even in the absence of bullfinch damage and, at least in some years, persist after pruning. Thus the study of the control and effects of variation in bud production, facilitated in this study by bullfinch damage, may be of great importance to all orchards.
Damage and enhanced crops

In each of the three years for which records were made, the number of pears on trees with zero (or least) damage was exceeded by the number of pears on trees with moderate levels of damage. The differences were not statistically significant, but the recurrence of the trend each year suggests that the samples might have been too small. Table C.7 summarises the data.

Table C.7. Crop enhancement in the study orchard

<table>
<thead>
<tr>
<th>Year</th>
<th>1977/78</th>
<th>1978/9</th>
<th>1979/80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop at zero (or least)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of buds</td>
<td>0.126*</td>
<td>0.378*</td>
<td>0.229+</td>
</tr>
<tr>
<td>Maximum crop recorded</td>
<td>0.136*</td>
<td>0.404*</td>
<td>0.353+</td>
</tr>
<tr>
<td>% loss of buds at which maximum crop was recorded</td>
<td>61-80</td>
<td>31-60</td>
<td>66-75</td>
</tr>
<tr>
<td>% Crop increase</td>
<td>8</td>
<td>7</td>
<td>54</td>
</tr>
</tbody>
</table>

* Crop measured as pears/original bud. See Tables C.1 and C.2.
+ Crop measured as index of crop/tree. See Table C.5.

These data suggest that damage in moderation may not be detrimental, and thus fruit growers should reserve their concern over bullfinch damage until it reaches more extreme levels. The main difficulty with such an approach is that damage can reach very high levels quite quickly on vulnerable trees at the edge of orchards. It therefore follows that attempts to protect trees should be directed at these edge trees; even if the
total amount of bud loss is not reduced, it may be possible to spread the damage more evenly through the orchard. The orchard's crop may then benefit from 'bud-thinning' by bullfinches.

The total orchard crops and financial implications

It was estimated that sample branches comprised about 10% of sample trees in 1977/78, 10.4% in 1978/79 and 15% in 1979/80 (Conference only). All these values are approximate since they come from counts made on only a few trees, but they can be used in calculating the total number of buds in the orchard (see Damage in Sections C.3.1, 3.3 and 3.5), and the total number of pears in the orchard (Table C.8).

| Table C.8. Estimates of the number of Conference pears in the study orchard |
|---------------------------------------------|----------------|----------------|----------------|
| mean% of sample tree sampled               | 10.0           | 10.4           | 15.0           |
| mean sample branch length (buds)           | 184            | 171            | 203            |
| overall mean pears/original bud            | 0.044          | 0.363          | 0.278          |
| mean pears/tree                            | 80             | 600            | 350            |
| pears in orchard                           | 40,000         | 300,000        | 180,000        |

Data from the trees protected from damage in 1980 which were in some respects atypical (page 188) have been excluded from these calculations, and the overall mean pears/original bud is based on the mean pears/original bud for the various damage levels in Tables C.1, C.2 and C.4.

Data on the size of the crops picked from the study orchard were given by the owners, and the value of the crops can be estimated by assuming each bin of pears weighed 900 lb. and that pears were sold for 10p/lb. as in 1979. Estimates of the percentage of the crop that was lost because of bullfinch damage (or in 1980 the percentage increase in crop) have already been
made in previous sections, so it is possible to make a calculation of the sum of money lost (or gained) in each year (Table C.9).

Table C.9. Financial losses and gains in the study orchard due to bullfinch damage (Conference only)

<table>
<thead>
<tr>
<th>year</th>
<th>1978</th>
<th>1979</th>
<th>1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>bins of pears picked</td>
<td>17</td>
<td>75</td>
<td>68</td>
</tr>
<tr>
<td>approximate value</td>
<td>£1530</td>
<td>£6750</td>
<td>£6120</td>
</tr>
<tr>
<td>% of crop lost (or gained)</td>
<td>-65</td>
<td>-4</td>
<td>+10</td>
</tr>
<tr>
<td>estimated value of crop in absence of damage</td>
<td>£4371</td>
<td>£7031</td>
<td>£5564</td>
</tr>
<tr>
<td>cash lost (or gained)</td>
<td>-£2841</td>
<td>-£281</td>
<td>+£556</td>
</tr>
<tr>
<td>loss or gain/ha.</td>
<td>-£1291</td>
<td>-£128</td>
<td>+£253</td>
</tr>
</tbody>
</table>

The crops picked do not relate directly to the number of pears estimated to be in the orchard (calculated from sample branch data), since a variable percentage of pears was too small to be picked and those that were picked varied in size and thus market value. For example, in 1979 the pears were smaller than in 1980; a smaller percentage of them was picked and they weighed less. The estimated values of the crops, had there been no damage, do not take into account the reduction in pear size that would probably have occurred in each year, so the estimates of cash lost are over-estimates. It can be seen that only in 1978
was an appreciable loss incurred, and this was due to extremely heavy bullfinch damage. The loss of 1979 was apparently more than made up for in 1980. For comparison, it is interesting that the cost of tit damage to ripe fruit probably amounted to nearly £1,000 over the three years.

**Comice**

The timing and rates of damage to Comice pear trees, and the reasons why buds of this variety were eaten even though it is usually considered to be disliked by bullfinches, are discussed in Section B.

In the study orchard, the Comice pear crop was so small in 1978 that the trees could be assumed to be thoroughly rested, and therefore capable of producing a large crop in 1979. The number of buds on sample trees in the winter of 1978/79 - before damage - was much the same as in the previous year, but many buds were subsequently taken from some trees. In 1979, the set of fruitlets on surviving buds was much lower than on Conference buds, both on heavily and lightly damaged trees, although this was, in part, made up for by a smaller fruitlet drop on lightly damaged trees.

Comice trees were not pruned during the winter of 1979/80, and they suffered less than 1% bud loss. In 1980, the set of fruitlets and the subsequent crop on sample buds were even lower than in 1979, and were again much lower than on Conference trees of similar damage level. In this year, the fruitlet drop on undamaged Comice and undamaged Conference trees was very similar. Thus, on a bud-for-bud basis, Comice trees bore many fewer pears than Conference trees, but since Comice trees, although much the same size, carried more buds than Conference, the difference in crops at the tree level was not so great.

Perhaps the most important conclusion was that mechanisms compensating for bullfinch damage were apparent on Comice trees in 1979 when data permitted an analysis. Fruitlet
set on surviving buds was increased by nearly 70% when damage increased from 0-21% to 70-96% loss of buds, and fruitlet drop at these damage levels was reduced from 66 to 51%. More extensive data are needed before the magnitude of Comice's tolerance to bullfinch damage can be assessed, but in 1979 it appeared to be less than that of Conference trees. Comice sample branches with 70-96% bud loss (mean 79%) bore only half as many pears as branches with 0-21% bud loss, whereas Conference branches with 61-90% bud loss (mean 79%) bore at least as many pears as undamaged branches.

Conclusion

Bullfinch damage can cause a complete crop failure on pear trees. In 1977/78 trees most heavily damaged in the study orchard had no pears and the orchard crop was only one third of that which might have resulted in the absence of damage. However, it is clear that Conference pear trees (and probably to a lesser extent Comice) can sometimes tolerate considerable levels of bud loss without any loss of crop. Indeed, at some damage levels in some years the crop may be enhanced.

The main reason for this tolerance is that undamaged trees usually have excess flowers, and excess fruitlets, many of which fall to the ground. By increasing fruitlet set on surviving buds and reducing fruitlet drop (as reactions to bullfinch damage) some of the excess flowers and fruitlets are used in the production of the final crop. Since the trees' resources are distributed to fewer fruitlets, and since less energy and nutrients are lost, they are able to produce heavier crops (i.e. more and/or larger pears). Furthermore, the trees may also produce more fruit buds for the following year's crop, which in turn may cushion the effects of further damage or produce a large crop. These mechanisms are shown in Fig. C.31.
Fig. C.31. Compensation mechanisms

Previously damaged trees produce many buds

BULLFINCH DAMAGE

Some half-buds survive

BUD PRODUCTION

SOME BUDS UNEATEN

Damage increases set on remaining buds (though total set may still be reduced)

CROP

SET

Reduced set and waste allows greater growth

PEAR GROWTH

Reduced total set reduces fruitlet drop and hence waste

FRUITLET DROP
Bullfinch damage was assessed on 3 and 21 March 1978. Between these dates very little damage occurred, but some trees were pruned. On Conference trees, sample branches with 31-88 buds after pruning (mean 55) indicated damage levels of 0-90% loss of buds (mean 64%). The least affected trees were in the north and west of the orchard, where disturbance to feeding birds by vehicles and people was probably greatest.

Beurré d'Amanlis trees had lost a mean of 83% of their buds by the first assessment date (adjacent Conference trees were less heavily damaged with means of 61% bud loss on three trees to the north and 58% bud loss on three trees to the south but the difference was not significant). Subsequent heavy pruning as part of a long-term plan designed to restructure the orchard removed most of the 315 sample buds and no crop data were collected for this variety.

The Comice sample tree (63 sample buds pruned to 31) was not damaged, though it and other similarly undamaged trees of this variety were adjacent to Conference trees with up to 86% bud loss.

**Crop**

In the orchard as a whole set was good so that, despite the damage, the crop was similar to the previous year (Way 1979). Pears on sample branches were counted in September before they were picked. These branches bore 0.05-0.95 pears/original bud (mean 0.43) and 0.27-6.33 pears/surviving bud (mean 1.20).

Heavily damaged trees retained significantly more pears on each surviving bud than lightly damaged trees (P<0.05); thus trees with 51-80% bud loss retained 2.8 times as many pears/surviving bud as trees with 0-50% bud loss. This resulted in a
17% crop (i.e. pears/original bud) increase being recorded at this damage level. However, trees with 81-90% bud loss had a 43% crop reduction; the 3.0 times increase in the number of pears/surviving bud did not fully compensate for these high levels of damage. (Crop data are approximate; variable results were obtained and a significant correlation with damage was not established.)

Twenty-one pears remained on the Comice sample branch (0.68 pears/bud). Of about 550 pears examined, only three (all Conference) had been damaged by tits.

Compared with study orchard trees in 1977/78, Rocks Farm Conference trees retained about three or four times as many pears/bud (both original and surviving) at all levels of damage. A much smaller percentage of pears was damaged by tits.
No bullfinch damage was detected in the orchard.

Crop

The orchard crop of Conference pears was outstanding for volume but not for fruit size (Way 1980). Pears on sample branches were counted in mid-September, by which time the crops of four Conference sample trees had been picked. The remaining Conference sample branches bore 39-374 buds (mean 166) and retained 0.13-1.38 pears/bud (mean 0.57). Random samples within the orchard indicated a mean of 1.54 pears/truss (Fig. C.32) and a mean pear diameter of 45.9mm (Fig. C.33). Many pears were too small to be marketed; 38% were less than 45mm and 66% less than 50mm.

Beurré d’Amanlis trees with a total of 268 buds sampled, retained 0.51-1.15 pears/bud (mean 0.91). The Comice tree retained 0.34 pears/bud (12 pears from 35 buds). Of nearly 2,000 pears examined, only one (a Conference) had been damaged by tits.

Compared with undamaged study orchard trees in 1978/79, Rocks Farm Conference trees retained about 1.5 times as many pears/bud, and had a larger mean pear truss size. However, the pears were significantly smaller (P<0.001). The Comice tree retained about half as many pears/bud as did study orchard Comice trees with little damage. As in 1978, a much smaller percentage of pears was damaged by tits.
Figure C.32. Rock Farm Conference pear trusses in 1979.

Numbers of pears/truss expressed as percentages of the total sample of 161 trusses
Figure C.33. Rocks Farm Conference pear size in 1979.

Numbers of pears in classes of 5mm, expressed as percentages of the total sample of 100 pears.
C.5.3. 1979/80

Damage

No bullfinch damage was detected in the orchard.

Blossom and crop

A random sample of 100 Conference blossom trusses contained 2-9 flowers each (mean 6.01, Fig. C.34).

As a result of the previous year's over-cropping, the orchard produced a much smaller crop this year (Way 1981). Pears on sample branches were counted in September. Conference trees retained a mean of 0.93 pears/bud (a total of 1,298 buds were sampled). However, the crop was not uniformly distributed through the orchard; eight sample trees in the north had significantly more pears than the other sample trees (cf. means of 1.23 and 0.71 pears/bud, P < 0.01). This gradation was also apparent in the number of pears in each truss (Fig. C.35) and may have been caused by the presence of beehives near to the northern edge of the orchard. Overall, there was a mean of 1.74 pears/truss, but significantly different extremes (P<0.001) of 2.52 in the north and 1.24 in the south were recorded. Fig. C.36 shows the size distribution of pears within the whole orchard. Pears were slightly larger than in 1979 (mean 48.6mm diameter) but again many were too small to be marketed; 31% were less than 45mm diameter, and 49% were less than 50mm diameter.

Beurré d'Amanlis trees normally crop heavily in alternate years, and 1980 was an 'off' year. Only two pears were retained from 335 sample buds. The Comice tree retained only 0.08 pears/bud (5 pears from 61 buds). Of about 1,200 pears examined, only 6 (all Conference) were damaged by tits.
Figure C.34. Rocks Farm Conference blossom in 1980.

Numbers of flowers/truss expressed as percentages of the total sample of 100 undamaged buds.
Figure C.35. Rocks Farm Conference pear trusses in 1980.

Numbers of pears/truss expressed as percentages of each sample of 50 trusses. Samples were from the A north, B centre and C south of the orchard.
Figure C.36. Rocks Farm Conference pear size in 1980.

Numbers of pears in classes of 5mm, expressed as percentages of the total sample of 100 pears.
Compared with undamaged study orchard Conference trees, Rocks Farm trees produced significantly fewer flowers in each blossom truss ($P < 0.001$), but retained about 2.5 times as many pears/bud. The overall mean truss size was larger at Rocks Farm and, as in previous years, pears were smaller, though not significantly. The Comice tree retained more than twice as many pears/bud as did study orchard Comice trees.
C.6. Brenchley 2 results
C.6.1. 1978/79

Damage

Sample branches on 38 trees with 141-267 buds (mean 192) indicated that bullfinches had damaged 5% overall of the buds in this orchard with individual trees losing up to 30% and many others being free of damage. Damage was not concentrated in a particular part of the orchard; of the order of 50,000 buds were probably taken.

Crop

Nine sample trees with an initial total of 1,781 buds and a mean of 11% bud loss, were assessed for fruitlet set in June and crop in September. These set a mean of 4.54 fruitlets/surviving bud (4.04 fruitlets/original bud) but 90% of fruitlets dropped before picking, leaving 0.45 pears/surviving bud (0.40 pears/original bud). The mean number of pears/truss on sample branches was 1.42. The mean diameter of a random sample of pears in mid-September was 49.1mm (Fig. C.37); 21% were less than 45mm diameter and 52% less than 50mm. Tit damage to ripe fruit was negligible (two pears out of over 700 examined).

Compared with similarly lightly damaged study orchard trees in 1978/79, Brenchley 2 trees set more fruitlets/bud, but allowed a very similar percentage of fruitlets to fall. As a result, more pears remained on each bud till picking. Pears were about 3.0mm smaller - a significant difference (P<0.01) - and a greater percentage of them were too small to be marketed.
Figure C.37. Brenchley 2 Conference pear size in 1979.

Numbers of pears in classes of 5mm, expressed as percentages of the total sample of 100 pears.
C.6.2. 1979/80

Damage

Bullfinches took buds from this orchard from mid-December 1979 to March 1980, a similar period to that recorded in the study orchard in this season. Pruning in Brenchley 2 continued throughout much of this damage period, and such bud removal (amounting to about 45% of buds from each tree) complicated bullfinch damage assessment. An estimated maximum of 180,000 buds were taken by bullfinches, resulting in a final overall loss of buds of 28%, though some trees lost up to 75% of their buds. Estimates of the percentage loss of buds in the orchard on four dates are given in Table C.10.

<table>
<thead>
<tr>
<th>date</th>
<th>8/1</th>
<th>30/1</th>
<th>4/3</th>
<th>22/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>% loss of buds</td>
<td>4.3</td>
<td>15.8</td>
<td>24.6</td>
<td>28.0</td>
</tr>
</tbody>
</table>

Table C.10. The extent of bullfinch damage in Brenchley 2 in 1980

Blossom and crop

Undamaged blossom trusses had 3-12 flowers (mean 7.12, Fig. C.38).

After pruning, sample branches averaged only 50 buds on each sample tree, and late pruning in March and April meant that the final damage level of about half the sample trees was unknown. The final damage level, fruitlet set, fruitlet drop and crop were all known on 16 sample trees (initially 842 buds, mean damage 29%).

Heavily damaged trees set significantly more fruitlets/surviving bud (P<0.05) than lightly damaged trees, and tended to retain a greater proportion of fruitlets till picking. Consequently, there was a significant trend (P<0.01) for increased
Figure C.38. Brenchley 2 Conference blossom in 1980.

Numbers of flowers/truss, expressed as percentages of the total sample of 100 undamaged buds.
numbers of pears/surviving bud at harvest on trees with heavy damage. Indeed, the number of pears/original bud also increased with damage, but this was not significant; compared with six trees with 0-20% bud loss, seven with 21-40% bud loss had a 28% crop increase and three with 41-75% bud loss had a 62% crop increase. Overall, a mean of 0.63 pears/original bud were retained.

A random sample of 100 pear trusses, indicated a mean of 1.93 pears/truss (Fig. C.39), though data from sample branches with nearly 700 trusses indicated a slightly lower figure of 1.71 pears/truss. The size distribution of pears in the orchard on two dates in September is shown in Fig. C.40. In the nine days between the two dates, the mean pear diameter increased by 6.8mm to 56.2mm, leaving 10% less than 45mm diameter and 15% less than 50mm. By 10 September, 4% of ripe fruits had been damaged by tits (the final figure was probably greater).

Compared with study orchard trees in 1979/80, Brenchley 2 trees produced significantly fewer flowers in each blossom truss \((P < 0.001)\), but set almost twice as many fruitlets/bud (both original and surviving) at most damage levels. Overall, a smaller percentage of Brenchley 2 fruitlets fell than in the study orchard, though the reverse was true at bud losses of 0-20%. At the highest levels of damage, Brenchley 2 trees bore about three times as many pears/bud (both original and surviving), but the difference was less marked on lightly damaged trees. The mean number of pears per truss was greater in Brenchley 2 than in the study orchard, but the diameter and growth rate of pears were similar.
Figure C.39. Brenchley 2 Conference pear trusses in 1980.

Numbers of pears/truss, expressed as percentages of the total sample of 100 trusses
Figure C.40. Brenchley 2 Conference pear size in 1980.

Numbers of pears in classes of 5mm, expressed as percentages of each sample of 100 pears

A 10 September       B 19 September
C.7. **Rocks Farm and Brenchley 2 – discussion**

Data from Rocks Farm and Brenchley 2 illustrate some of the complexities involved in assessing the extent and importance of bullfinch damage, and show that considerable differences in cropping patterns and response to bud loss occur between different orchards.

Compared with trees in the study orchard, trees on Rocks Farm were older, more closely spaced, and pruned to a different system. They had received traditional spur pruning and were undergoing a three-year conversion to a lighter pruning system, whereas study orchard trees were pruned to a regulated system. These differences, and the fact that beehives were placed near to the orchard on Rocks Farm in all three years, may have been partly responsible for differences in cropping patterns. For example, in all three years, Rocks Farm trees retained more pears/bud than study orchard trees (the difference was considerable in 1978 and 1980). However, Rocks Farm trees had fewer buds than study orchard trees, so the orchard crop was not increased accordingly. A further factor, of unknown consequence, was that whilst the mean number of flowers in an undamaged blossom truss in the study orchard did not vary significantly between years, there was, at least in 1980, a significant difference between the means in each orchard ($P<0.001$).

In both 1979 and 1980, pears on Rocks Farm were smaller than study orchard pears, the difference being significant in 1979 when they averaged 7mm smaller than the smallest study orchard pears (i.e. those on lightly damaged trees). Many more Rocks Farm pears were therefore too small to be marketed. One possible reason for this is that Rocks Farm trees may have set more pears than study orchard trees, and may therefore have had their energy and nutrient resources rather more stretched.

Data from Rocks Farm also illustrate differences between pear varieties. When damage occurred in 1977/78, Beurré d'Amanlis trees were most heavily damaged, and Conference slightly less, while Comice were completely free of damage. Beurré d'Amanlis
trees crop in alternate years (and could presumably tolerate complete loss of buds every other year), while the Comice tree retained markedly less pears/bud than Conference in two of the three years. It is interesting to note that both Rocks Farm and study orchard Comice trees retained very few pears/bud in 1980.

Data from Brenchley 2 in 1978/79 show similarities with those from undamaged study orchard trees in that year. Fruitlet set was slightly higher, fruitlet drop very similar, and consequently the crop (measured as pears/bud) was slightly greater; pears were smaller.

Data from Brenchley 2 in 1979/80 are less similar to those from the study orchard in that year. Fruitlet set/bud was about twice as great, and fewer dropped so that considerably more pears/bud were retained till picking. These differences may have been due largely to heavy pruning and the presence of bees in Brenchley 2; the study orchard was not pruned and was not supplied with bees. It may be that in some respects pruning and bullfinch damage have similar effects on the cropping pattern, for example by increasing the number of fruitlets set on remaining buds and by reducing drop.

Despite the differences between these orchards and the study orchard, similar tolerance of bullfinch damage was apparent. In both the years when a range of damage levels could be studied - 1977/78 (Rocks Farm) and 1979/80 (Brenchley 2) - the overall crop was reduced by a considerably smaller percentage than the percentage of buds lost. In 1977/78 trees with 51-80% loss of buds had as large a crop as those with 0-50% loss of buds, and in 1979/80 the crop seemed, if anything, to be enhanced by bud losses of up to 41-75%. At least in 1979/80, this was due to both increased fruitlet set/surviving bud and decreased fruitlet drop on damaged trees (exactly the same response to bullfinch damage as that displayed by study orchard trees).

Bullfinch damage demonstrably affects the cropping patterns of pear trees in a wide variety of circumstances, and the degree and nature of the trees' response to bud loss differs
from orchard to orchard and year to year. However, data from Rocks Farm and Brenchley 2 confirm the conclusion drawn from the study orchard: that for Conference trees, tolerance to, or compensation for, bud loss seems to be the rule rather than the exception.
C.8. **Other orchards - annual damage in Kent**

**Methods**

Bud damage in an individual orchard, such as the study orchard, does not necessarily reflect the intensity or extent of damage over a wide area. For this reason, about 50 orchards in Kent were assessed for damage each year. Each was visited at blossom time, when the lack of blossom makes damage most conspicuous, and both damage and adjacent habitat were graded visually on the simple arbitrary scales shown below.

Damage in each orchard was graded as follows:

0 = no detectable damage
1 = very little damage (just detectable e.g. at orchard edge)
2 = some damage (easily detectable)
3 = heavy damage (usually some trees severely damaged)
4 = blossom of entire orchard virtually destroyed (reserved for extreme cases, e.g. the study orchard in 1978)

Often it was necessary to give one figure for the orchard as a whole and another for edge trees.

Adjacent habitat was graded as to its suitability for bullfinches - taking into account the amount of woodland, size of hedges etc. - as follows:

A = good bullfinch habitat (woodland, tall hedges etc.)
B = moderate bullfinch habitat (short hedges, gardens etc.)
C = poor bullfinch habitat (open land)

The orchards were chosen at random within four different areas: the Weald of Kent (orchards surrounding the study orchard), North Kent (near Sittingbourne), East Kent (near Canterbury) and some orchards near to East Malling and Maidstone. Most were pear orchards, and where possible the varieties were identified, but also included were one dessert plum and two damson orchards. Where possible, the same orchards were visited each year, though some were grubbed and access to others became restricted.
Results

In general, damage occurred where adjacent bullfinch habitat was assessed as good or moderate. Only occasionally were house sparrows thought to be partially responsible. Most orchards in North and East Kent suffered little or no damage in all years, and here the habitat was usually grade C or occasionally B. Damage was most frequent in the Weald of Kent, where habitat was often grade A or B.

In 1978, 16 out of 27 orchards visited in the Weald/East Malling/Maidstone areas had damage of grade 2 or more, compared to only 3 out of 21 in the Sittingbourne and Canterbury areas.

In 1979, 17 out of 27 orchards visited in the Weald/East Malling/Maidstone areas had damage of grade 2 or more, compared to only 5 out of 21 in the other areas. Although damage was more widespread, it was less severe (see below).

In 1980, 23 out of 29 orchards in the Weald/East Malling/Maidstone areas had damage of grade 2 or more, compared to 9 out of 17 in the other areas.

Table C.11 summarises changes in damage grade recorded in 52 orchards visited in both 1978 and 1979. Overall, a slight decrease occurred.

The increase in damage between 1979 and 1980 can be seen in Table C.12, which summarises changes in damage grade recorded in 49 orchards visited in both years.

Of 45 orchards visited in both 1978 and 1980, 6 showed a decrease in damage, 16 an increase, 11 no change and 12 had little or no damage in both years.
### Table C.11. Bullfinch damage in Kent in 1978 and 1979

<table>
<thead>
<tr>
<th>Area</th>
<th>Increase</th>
<th>Decrease</th>
<th>No Change</th>
<th>In Both Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weald</td>
<td>3</td>
<td>6</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>E.Malling/Maidstone</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Sittingbourne</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Canterbury</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5</strong></td>
<td><strong>8</strong></td>
<td><strong>12</strong></td>
<td><strong>23</strong></td>
</tr>
</tbody>
</table>

### Table C.12. Bullfinch damage in Kent in 1979 and 1980

<table>
<thead>
<tr>
<th>Area</th>
<th>Increase</th>
<th>Decrease</th>
<th>No Change</th>
<th>In Both Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weald</td>
<td>11</td>
<td>1</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>E.Malling/Maidstone</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Sittingbourne</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Canterbury</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14</strong></td>
<td><strong>1</strong></td>
<td><strong>16</strong></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>
Conclusion

Data from these orchards show that least damage occurred in the winter of 1978/79 and most in 1979/80. This was usually evident from both the number of orchards damaged and the grade of damage in those orchards. Some orchards showed opposite trends, though this could sometimes be linked with changes in adjacent bullfinch habitat. For example, in 1980 the only orchard to show a decrease in damage compared with 1979 was the study orchard, where extensive woodland clearance had occurred.
D. DAMAGE PREVENTION

D.1. Introduction

Bullfinches have caused damage to man's crops for hundreds of years, and a number of techniques have been developed to reduce damage. The merits of each technique have to be assessed individually (though they may be used in combination), and perhaps none should be expected to work in all situations. However, it is an interesting reflection on both the bullfinch and man that a truly cost-effective method of preventing damage has yet to be devised. Not one of the scaring devices or population-reducing techniques has yet to prove as effective as the forethought displayed by a sensibly positioned orchard well away from bullfinches. In this section, the various damage prevention techniques currently in use are described, together with results of attempts to reduce damage followed in this study.
Plate D. Two methods of reducing bullfinch damage.

Top: View north along the western edge of the study orchard after clearance of woodland and hedgerow.
Bottom: A chardonneret trap with a decoy.
D.2. Population reduction

Shooting

Techniques such as shooting and trapping have the advantage that they provide apparently sure evidence of success in the form of dead birds. Shooting, with its associated sporting enjoyment for some, has been a favourite weapon against bullfinches at least since the 16th century, when in 1566 an Act was passed offering one penny "... for the Head of everie Bulfynche or other Byrde that devoureth the blowth of Fruite..." (see Roach 1962). However, it no longer costs only one penny to shoot a bullfinch; the increased cost of shot and particularly man-hours makes this technique a predominantly spare-time pursuit. There are few fruit farms that can afford to employ someone to this end on more than a part-time basis, though many bullfinches are still shot each year.

During this study, only farms with extensive damage were found to shoot bullfinches regularly. On one, two men were employed full-time (12 hours/day) in spring to shoot bullfinches during the period of damage to a number of apple varieties. In addition, a bounty of £1 was paid for each bird shot at weekends. This onslaught proved to be an effective way of killing bullfinches at a time when trapping had become difficult, and in 1978, 100 birds were shot in about a month. As a damage preventative it was hard to assess, since some damage did occur and a number of other techniques were also in use on the same farm. Both the noise of guns and the human presence probably acted as additional deterrents to bullfinches.

Trapping

Bullfinches have been trapped for about 100 years. Initially they were sold alive as cage birds, or dead to taxidermists; more recently, although trapping is still legal (in some counties), the sale of birds has been prohibited. Summers and Wright (1959) modified an old French bird-catcher's trap (the
chardonneret) and gave guidance for baiting and positioning it to obtain maximum catches of bullfinches. The trap is a simple wire cage with a door which swings shut when a bird alights on a perch inside. Bait such as dock seed, or a live bullfinch decoy in a separate enclosed compartment, ensures that most of the birds caught are bullfinches. Some traps can catch four birds before they need emptying (Plate D), although they are generally checked twice each day to reduce discomfort to any birds caught.

Trapping is still popular since it is an efficient method of catching bullfinches with minimal effort, at least at some times of year. Traps have to be maintained and decoys cared for, but this needs less time than does shooting. However, the capture and caging of birds inevitably causes some adverse public reaction, and many of the growers spoken to during this study had had decoys released and traps destroyed. One farm with a particularly severe bullfinch problem collected all their traps (up to 25) each evening and put them out each morning, to reduce vandalism.

Rates of catching vary considerably, both from farm to farm and from month to month. Late summer and autumn seem relatively productive seasons while mid-winter is generally considered to be poor.

In this study, records were made of the age and sex of bullfinches trapped by six growers in Kent and East Sussex. The size of their farms and the usual extent of bullfinch damage were reflected in the number of traps they used, which varied from one to eight. The maximum catching rate for a single trap was about one bird/day, but over periods of a month or more, one to three/week was more usual. Those growers who used more traps, and who trapped throughout the year, generally caught more birds than did others, but these measures involved more time than most growers considered worthwhile. There was a tendency for the rate of catching per trap to be less on farms with several traps than on farms with one or two, perhaps indicating that the former group were partially saturated with traps. Also, all-year-round
trappers invariably experienced times of year when apparent returns for effort were low.

It is not really known why trapping works. In the case of traps baited with seed, the birds are obviously searching for food, and Newton (1964a) found that catches were greatest at times of food shortage. However, most growers now prefer to use a decoy (or call bird) as this is a more specific method of catching bullfinches. Most growers did not think that the sex of the call bird affected the numbers or sex of birds caught, though some felt that call birds still in juvenile plumage were less effective than adults.

In the study area a male and a female call bird were often placed close to mist nets, though some distance apart, in an attempt to increase catches of bullfinches. Between May and December 1979, when detailed records were made, 33 bullfinches were caught very close to a call bird, and data are summarised in Table D.1.

<table>
<thead>
<tr>
<th>sex of call bird</th>
<th>male</th>
<th>female</th>
</tr>
</thead>
<tbody>
<tr>
<td>adult male</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>adult female</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>juvenile (unsexed)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>juvenile male</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>juvenile female</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>total</td>
<td>16</td>
<td>17</td>
</tr>
</tbody>
</table>

While both male and female call birds attracted a similar number of other bullfinches, adults seemed to be attracted
more strongly by a call bird of the opposite sex (P=0.01). All but three of these adults were caught during the breeding season (in May, June and July), so some may have been unpaired birds searching for a mate. In contrast, juveniles were apparently attracted by call birds of either sex, and this may be the reason why growers had not noticed any sex bias (growers catch mostly juveniles). For both adults and young birds the attraction to a call bird is unlikely to be territorial, since there is little evidence for territoriality in bullfinches. A tendency to form flocks is more likely to be important. Bullfinches are often found in flocks where food is present, and solitary birds (including call birds) call loudly to make contact with others. Young birds in particular, since they are not experienced at finding food, will benefit from associating with others that have already found food.

This theory is supported by data from trapped birds recorded in this study. Fig. D.1 shows the ratio of young (first-year) to old (adult) bullfinches in a total of 434 birds trapped by the six growers in Kent and Sussex. As might be expected, the number of young birds caught (as a percentage of the total) increases from mid-summer onwards when they fledge, and reaches a peak late in the year when breeding finishes. Thereafter, a decline occurs at least until the summer of the following year. These trapping data can be compared with data from ringed birds (caught in mist nets) from the B.T.O. analysed in this study (see Fig. E.1). Mist net data can be assumed to show the normal changes in age ratio which occur each year in the British population of bullfinches as a result of births and deaths, and therefore the age ratio of birds available to be trapped by fruit growers.

Trapping and mist net data show basic similarities. However, whereas mist net data indicate a peak of about 75-85% young birds in the population in September or October, trapping data indicate a peak of 95-98% young birds caught, this peak extending into March during the winter of 1978/79. Newton (1968) recorded a very similar age ratio (97% first-years) in birds trapped between October and December 1964. Mist net data show
Figure D.1. Age ratios of trapped bullfinches.

Numbers of first-year birds, expressed as percentages of total catch taken by growers and sent to E.M.R.S. Bimonthly running means have been used, though no birds were trapped in March and May 1979, so points for these months come from birds trapped in February and April, and April and June respectively.

Small dots and dashed lines indicate combined samples of only 12-20 birds.
a reduction to about 50-70% young birds in the population by the end of December, while trapping data show perhaps 80-95% young birds caught at this time. By early summer the differences are less marked, though trapped birds still appear to have a greater proportion of young birds than are present in the population. Thus, young birds seem particularly prone to being trapped throughout their first winter, and perhaps into the following summer.

The sex ratios of bullfinches trapped and mist-netted can also be compared (Table D.2). Analysis of variance showed that the mean % male in each of the four categories tabulated was significantly different from all of the others. Mist net data indicate that males and females are present in the population in roughly equal numbers between September and April, and trapping data indicate that the two sexes are probably equally liable to be caught by fruit growers at this time of year (a possible slight bias towards females). The population liable to be mist-netted during the breeding season consists of about 60% males, whereas, of bullfinches trapped in the same months, 82% were males. Growers who had trapped bullfinches for several years confirmed that many males were usually caught in these months. If the ringing data represent a random sample with males predominating in summer because their mates are incubating eggs, then trapping seems to result in a further bias towards males.

It may be that unpaired males move further in search of a mate than do unpaired females, and are thus more likely to encounter and be caught by traps. It is also possible that the excess of trapped males is comprised of paired birds whose nesting duties are not time-consuming and therefore leave them with 'spare' time during which they are trapped (data presented on page 326 support the latter hypothesis). Females, when they do leave the nest, feed quickly and return as soon as possible.
Table D.2. A comparison of the sex ratios (% male) of bullfinches caught in mist nets and in traps.

Mist net data were extracted from Form BRC 19 (S.E. England only) during this study and include all bullfinches caught and sexed (both new and retraps, see also Section E.4). Trapping data come from bullfinches caught by fruit growers and sent to East Malling Research Station. Juveniles were excluded from the breeding season samples.

<table>
<thead>
<tr>
<th>time of year</th>
<th>number of seasons of bullfinches</th>
<th>total number</th>
<th>% male</th>
<th>range of percentages in different seasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>mist nets</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-breeding season (Sept-Apr)</td>
<td>5</td>
<td>6700</td>
<td>51</td>
<td>48-55</td>
</tr>
<tr>
<td>breeding season (May-Aug)</td>
<td>4</td>
<td>4047</td>
<td>60</td>
<td>58-61</td>
</tr>
<tr>
<td>traps</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-breeding season (Sept-Apr)</td>
<td>4</td>
<td>253</td>
<td>47</td>
<td>39-49</td>
</tr>
<tr>
<td>breeding season (May-Aug)</td>
<td>3</td>
<td>130</td>
<td>82</td>
<td>78-82</td>
</tr>
</tbody>
</table>

The efficacy of shooting and trapping

When the B.T.O. conducted a national survey of breeding birds, bullfinches were recorded in 83% of the 10km squares in Britain (Sharrock 1976); areas from which they were absent were mainly in the north and west. They estimated a total breeding population of some 600,000 pairs. With currently available
techniques it is most unlikely that fruit growers— in the south of England—could materially reduce such a large and widespread population, even for a few years. Nevertheless, they may be able to reduce the number of bullfinches around their farms, and this, in turn, might reduce bullfinch damage.

Some bird pests can easily be caught in large numbers. For example, oystercatchers feeding on cockles and mussels can be caught while roosting by using cannon nets (Davidson 1968). However, even though bullfinches form flocks in winter, their movements are very unpredictable and to catch more than a few individuals, whether for the purposes of ringing by using mist nets (as employed in the study area) or with the intention of killing them by shooting or trapping, requires a lot of time and equipment. Nevertheless, both shooting and trapping are effective methods of killing bullfinches. English (1953) considered that cotton, various sprays, stuffed cats and raptors were ineffective, and concluded that shooting was the only effective method of reducing damage (at this time trapping was not practicable). Newton (1968, 1970) recommended trapping. He argued that bullfinches are sedentary so that killing birds in a small area is likely to reduce the local population, and hence reduce damage. He also argued that bullfinch populations were limited by the seed supply in winter (probably seeds of ash) and that damage to fruit trees was heaviest in years when seeds were scarce. He therefore suggested that growers should trap in autumn so that the available seeds would be exhausted less quickly and hence delay the time when the bullfinches turn to fruit buds.

Although some growers seem to benefit psychologically from killing bullfinches, the ultimate test of the efficacy of shooting and trapping is a comparison of their cost with the resulting degree of damage reduction. In practice this is very difficult to do; even to demonstrate their effect on the local bullfinch population is not easy, since other factors combine to lessen any immediate effects observed.

First, although bullfinches are sedentary compared to many other species, some movement does occur. One bullfinch
may regularly range over several square kilometres in search of food (see Section E.8) and thus bullfinches from a large area may be killed in a single orchard; the 'local population' may be larger than is at first thought. Observations in the study area suggested that the population was to some extent mobile, with damage being done by many different birds as each passed through the area. In these circumstances, it is easy to see how, when birds are removed from the population, rapid infilling by birds from surrounding areas could occur. The more suitable the habitat (as, for example, where a pear orchard adjoins woodland) and the more food available in the area (perhaps as a result of population reduction), the greater will be the speed and extent of infilling. Bullfinch damage, and therefore trapping and shooting, occurs most often in areas of high bullfinch populations, so infilling may be particularly rapid. Movement, and therefore infilling, is probably least during the summer when breeding pairs remain close to their nest, but may reach a peak in autumn when young birds disperse, just when most trapping occurs, and indeed just when growers are currently advised to shoot bullfinches (M.A.F.F. 1973b).

Secondly, the extent to which natural mortality adds to, or compensates for, bullfinches killed by man must be considered. The key point here is probably the timing of periods of food shortage (or any other natural population-reducing factor), since the removal of some birds from a population may result in increased survival of the remainder. Two situations may be envisaged. First, food shortage could occur in spring after the bud-eating period. In this case trapping and shooting in summer and autumn before bud-eating commences should not influence the survival of remaining birds; the population will be reduced and fewer buds should subsequently be eaten. However, the other possibility is that food shortage could occur early in the winter before bud-eating commences. In this case, trapping and shooting in autumn could result in less competition for food and more birds surviving the period of food shortage, and hence more birds subsequently eating fruit buds. The pattern of recoveries of ringed bullfinches of all ages indicates peak mortality during or after bud-feeding months (Flegg 1980), but data from Newton
(1964b), the B.T.O. (Section E.4. Age ratios) and from the study area indicate that peak mortality is usually before this time, although some mortality occurs throughout the year.

The third point of interest is that, as we have seen, traps catch a biased proportion of the population towards young birds, and males in summer. It is probably true of most bird species that young, inexperienced individuals are more likely to die through natural causes than adults, and in the bullfinch the decline in the first-year to adult ratio during the winter indicates that they also follow this pattern. If, as is suggested in Section E.5.1, as many as 86% of bullfinches die in their first year, then most of the birds trapped by growers were destined to die anyway. As Murton (1968) argues for woodpigeon shooting, which also kills a biased proportion of the population, the money and efforts spent may be largely wasted and little long-term effect on the population should be expected.

The effect of catching mostly males in summer depends largely on whether or not these are breeding birds. If, as Newton found in Wytham, bullfinch populations contain an excess of males, then it may be that many of those caught in the summer are non-breeders. On the other hand, if they are breeding birds, then they will be prevented from further breeding attempts and the autumn population will be reduced accordingly.

It should be said that sometimes, even a temporary reduction in the local bullfinch population may reduce damage by a worthwhile amount. For example, even if it takes an average of only two days for infilling and mortality factors to replace each bullfinch killed, then two bird-damage-days are saved each time a bird is killed during the damage period. A winter's total of 50 birds would represent 100 bird-damage-days saved, equivalent to perhaps 100,000 buds (see page 131). Furthermore, many growers claim to have had a long-term effect on the bullfinch populations in their areas. In some cases, where intensive and consistent trapping and shooting have occurred over a period of years, these claims are probably justified; the key to long-term population reduction is perseverance, as even a single year
without this enforced mortality may permit the population to recover completely.

Data from a farm near Hawkhurst in Sussex and from the study area permit some theoretical calculations. The first farm adjoined other farmland quite suitable for bullfinches and 4km² of Forestry Commission land. If the surrounding area contained only 80 pairs of bullfinches (at 20 pairs/km² the Commission land alone might support this population - see Section E.2), there could be about 800 birds after each breeding season. For the population to remain stable, 640 birds would have to die each year, leaving 80 pairs to breed. In the winter of 1977/78, 200 bullfinches were killed on the farm. It could be argued that natural mortality and infilling would compensate for these deaths, but in this case only 50 birds were caught in the following winter, despite continued trapping effort. Whilst this reduction in catch might have been due to reduced tendency for bullfinches to enter the farm (perhaps because food was more plentiful elsewhere), it may also have been due to a genuine population reduction. The latter possibility is made more plausible by the fact that 100 of the birds killed in 1977/78 were shot in March and April, probably after the main period of natural mortality when compensation might otherwise have taken place.

At this stage it is worth mentioning that growers wishing to protect apples may have an advantage over those wishing to protect pears. Since damage to apples is generally later than for pears, apple growers can perhaps afford to wait until natural winter mortality has taken its toll and then kill the survivors when they enter orchards to feed, thus reducing the breeding population. Pear growers have to catch birds early in the winter and their effect on the breeding population may be minimal.

In the study area, about 50 bullfinches were trapped between July and December 1978, and an additional 70 birds were caught about 750m away. Data presented in Section E.7 indicate that the population only doubled to about 100 birds in October. By January 1979, 60 birds remained. The following year no birds were trapped in the study area, but about 50 were caught 750m
away between September and November. The population rose from about 50 breeding birds to perhaps 150 birds in September. Subsequent mortality was considerable, and only 55 remained in January 1980. Thus, even with relatively little trapping, the population had fallen to a level similar to that recorded in 1979. Although an authoritative conclusion cannot be made, the data do suggest that trapping in 1978 was subsequently largely compensated for by reduced natural mortality and/or infilling. By the time damage started, the residual effect of trapping was minimal.

Although some guidelines can be given to ensure maximum catches or kills of bullfinches, there is still a lot to be learnt about the mechanisms by which trapping and shooting work and the effects they have on bullfinch populations and subsequent bud damage. It is likely that these attempts at reducing populations are of little or no use in some circumstances and of considerable benefit in others.
D.3. **Scarers**

**Introduction**

In order to prevent bud damage to orchards, one alternative to killing bullfinches is to make the orchard and its buds less desirable to the birds. In theory, this can be done by making the orchard or the route to it seem more dangerous, or by making the buds appear or taste unpleasant. There are several techniques, basically designed to scare bullfinches, that fall into this category.

First, it is useful to examine the normal feeding behaviour of bullfinches, to see whether they show the ability to respond to scaring devices in the way the grower desires. If they do seek out the least disturbed and most profitable foods and feeding sites, then, given the right technique, growers should be able to alter the normal feeding pattern by reducing the safety and profitability of their orchard (or parts of it) to a lower level than other potential feeding sites.

Bullfinches are essentially birds of woodland and scrub. It is in these habitats that their natural food plants are most common and, by the time buds form a substantial part of the diet, most of their food comes from trees and bushes. Dense vegetation also affords some shelter from bad weather and predators. Whether bullfinches eat buds from orchards because their natural foods are exhausted or as preferred alternatives, it follows that damage to orchards is most likely to occur in areas rich in woodland and scrub where the birds are most numerous. Also, orchards close or adjacent to this habitat are more likely to suffer damage than those surrounded by open spaces. If the aim of the birds is to enter the orchard by the safest route, feed, and then leave by the same route either to better shelter or to other feeding areas, then the orchard trees nearest to the woodland are likely to suffer most bud loss. Bullfinch damage does, in general, follow this pattern, although each situation may be influenced by several other factors, such as the tree varieties present, the number of buds there are, alternative
food sources, prevailing weather conditions, and perhaps even the time of day.

There is no fundamental reason why a bullfinch should eat all the buds from the nearest orchard tree before moving to the next since, when a proportion of the buds have been removed, the remainder will be less densely distributed; the move to the next tree may occur quite quickly. Most modern, well-kept orchards provide far less cover than unmanaged woodland. However, to a feeding bullfinch an unpruned orchard may compare favourably with more open woodland; plum and damson orchards, for example, can be particularly dense. In these cases, unless the bird has to leave to feed elsewhere, one part of the orchard may be as safe as another and no benefit is gained by staying close to the woodland.

Allowing for such variation in circumstances, bullfinch damage patterns do indicate considerable economy of effort by feeding birds. Concentration of damage on a few trees at the orchard edge often results in loss of crop and even a distorted tree shape, since the trees' resources are diverted from fruit production to growth. Some growers claim that their trees lean away from woodland because bud loss (including some vegetative buds) has been most severe on the woodland side, although such trees are more likely to be displaying a directional response to light.

Observations within the study orchard provided further evidence that bullfinches tend to economise their feeding effort by changing their feeding area in response to changes in bud density. For example, in 1977/78 buds were initially taken from the south and west of the orchard (Fig. C.3), but when buds became scarce in these parts, the birds ate more from trees in the north and east (Fig. D.2 and D.3).

The behaviour of bullfinches feeding within pear trees did not always indicate maximum feeding efficiency. Very rarely was every bud on a section of branch eaten during a single feeding session. Even when, say, four buds were equally available in a tight group, only one or two would be taken. It might be weeks
Figure D.2. Bullfinch damage to Conference trees in the study orchard between 15 February and 7 March 1978, as indicated by sample branches.
Figure D.3. Changes in the percentage of the study orchard's bullfinch damage on trees in the south and west in 1977/78.

Data are from sample trees, comparing rows A, B, 1 and 2 with the remainder. Relatively few buds were damaged in the final period (124 buds) compared to previous periods (572-1592), indicating the end of the damage period, hence the dashed lines.
before another of the group was damaged, the fourth perhaps remaining untouched. Bullfinches were even watched working up a branch and then turning to work back down again, taking some of the buds that they missed earlier. This behaviour may indicate that the buds were so numerous that little could be gained by eating every bud; only when they became scarce might it be more efficient to eat every bud found.

Wright and Summers (1960) and Newton (1964a) described the feeding behaviour of bullfinches in young orchard trees as being remarkably stereotyped: landing below but not at the tip of a branch — because terminal buds are difficult to reach — and then working down the branch taking every bud in turn until they reach the older wood where the lower density of buds prompts a fresh start near the tip of another branch. However, bullfinches are very agile; for example, they feed in blackthorn bushes which have very fine twigs, and in the study orchard terminal buds of pear trees, which have relatively stout branches, were frequently taken. Also, as described above, they rarely took every bud. Nevertheless, the distribution of blossom within the trees clearly showed that terminal buds were less preferred, probably because they were more difficult to handle than lower ones, although it is possible that bud size or content may also have been involved.

It seems likely that bullfinches regularly sample the various food choices available and react in predictable ways. It should therefore be possible for growers to manipulate these reactions — given the right deterrent technique.

The techniques currently in use can be divided into four broad categories designed to act on four of the bullfinch’s senses: hearing, touch, sight and taste. Some birds have an acute sense of smell, but these are not pests (Wright 1980); there is no evidence that strong odours affect bullfinch behaviour, despite claims that onions cut in half and hung from branches will prevent further damage.
Hearing

The available evidence suggests that most birds can perceive sounds up to 10 kHz (Schwartzkopff 1973). This is a somewhat lower frequency than man, although the difference in pitch is less than an octave. This precludes the use of ultrasonic deterrents and also means that fruit growers and general public alike must hear and perhaps be disturbed by audio deterrents. Disturbance to man is probably the main objection to this technique, but the regularity with which it is used indicates the confidence that some have in its success. Broadly speaking, there are two types: loud, explosive noises, usually generated by gas-fired bangers, and alarm calls broadcast by loudspeaker from tape recordings. Although bangers are used in a variety of circumstances, alarm calls are currently primarily used on airfields.

In the fruit farming industry, gas-fired bangers are used extensively. They are cheap to run, require only occasional attention and, being easily portable, they can be set up in an orchard at short notice and moved to another area when required. They are usually set to go off at 10 to 30 minute intervals; areas of about 2ha or more sometimes have more than one machine. The most common uses are against woodpigeons and rooks on cereals; starlings and thrushes on cherries; tits and starlings on ripe apples and pears; woodpigeons and thrushes on blackcurrants; and bullfinches on fruit buds.

Birds are alert to man and his gun, cats, dogs, foxes, moving cars, birds of prey etc. because they are all potentially harmful, but, like many other scaring devices, bangers suffer from the disadvantage of doing no real harm to the birds they aim to scare — in theory no deterrent is likely to have lasting success if it has no 'bite'. New objects in an area with which they are familiar may be regarded with suspicion, but only until the birds become habituated to them (Inglis 1980) and in the same way we should expect bangers to become less effective as time passes.
Few growers would claim to have stopped bird damage completely with a banger, and most agree that many birds, including bullfinches, continue to feed in orchards with this deterrent. The initial period of suspicion may last several days or perhaps as little as a few minutes.

A banger was used in the study orchard in 1978 and 1979, both in spring against bullfinches and in autumn against tits. It was usually positioned in the south west corner (where bullfinch damage was greatest) and set to go off at 10-15 minute intervals. Ideally, the efficacy of bangers as a deterrent against bullfinches could be assessed by comparing the progress of damage in two identical orchards, one with and one without a banger. However, in the absence of such a controlled experiment it is necessary to draw conclusions by examining the rate of damage near to the banger before and following its introduction, and from observations of bird feeding within the orchard when it went off.

In 1978, records of the rate of bud loss in the study orchard as a whole (Fig. C.2), gave the impression that the banger reduced the damage (it was introduced on 3 March). Bud counts on sample branches showed that the rate of damage between 24 February and 7 March was about average for the preceding weeks and that damage between 7 and 15 March was very much smaller. However, almost all the buds had already been taken from the orchard by this time; a few trees in the north east corner had about 50% of their buds left. If the rate of bud loss had continued at the previous rate, not one bud would have remained in the whole orchard in less than a week, and buds would have been very hard to find after only a day or two. With or without the banger, food had to be sought elsewhere. The banger was in fact positioned about 100 metres away from the area where most buds remained and where most damage was being done (see Fig. D.2), and is therefore unlikely to have caused such a rapid reduction in the overall damage rate, though it may have helped.

Data from 1979 do not indicate that the introduction of the banger on 8 March had much effect on bud damage. Fig. D.4
Figure D.4. Changes in the percentage of the study orchard's bullfinch damage on trees adjacent to a banger in 1979.

Data are from sample trees; trees A1-3, B1-3 and C1-3 were closest to the banger, which was introduced on 8 March. 219-553 buds were damaged during the five periods.
shows the damage to trees near to the banger as a percentage of damage in the whole orchard. Damage on these trees did decrease but probably primarily because of decreasing bud density.

House sparrows, chaffinches and blue tits were observed feeding within the orchard when the banger was present. In March 1978, six days after the banger was introduced, sparrows and chaffinches flew from the ground to neighbouring woodland trees when the banger went off, but returned after only two minutes. When the banger had been operative for only one day in August 1978 it had no apparent effect on tits, and in August 1979 many tits were caught within the orchard in mist nets despite the presence of the banger. The distribution of tit damage within the orchard was not noticeably affected.

The problems of habituation to bird scarers have been reviewed by Slater (1980). He suggested three ways of reducing habituation. These were to present the scarer periodically rather than continuously, to vary the site of the scarer frequently, and to reinforce the scarer occasionally with some real danger. The second and third of these are particularly relevant to bangers. They can be moved easily from one part of an orchard to another and this may help to increase their effectiveness. If bullfinches can be conditioned to flee from bangers, then considerable benefit may be gained. Operating on this principle, some growers back up their bangers with a shotgun on a daily basis and claim improved success as a result.

Many birds have alarm calls that warn others of the species and perhaps even unrelated species of danger (Marler 1955). The recognition of and appropriate reaction to alarm calls is probably learnt at an early age and they have considerable potential in the development of audible deterrents. It is even possible that super-normal alarm calls could be produced (Brémond 1980). Certainly success has been achieved with some species, such as starlings on airfields, by broadcasting their alarm or distress calls (Brough 1968), but this field of research is still in its infancy.
Bullfinches, however, are rarely noisy, and then only when using contact calls rather than warning notes. It is doubtful whether they have a loud alarm call that could be used as a deterrent. In this study, the distress calls of nestlings and adults emitted under the stresses of handling for ringing were recorded on tape. Such calls were never heard from free-flying birds. When the recordings were played back to feeding aviary birds under observation from a hide, they caused only a slight, temporary disturbance; their effect was no greater than that of other loud noises. More experiments are needed to confirm this. It is very difficult to relate such experiments to the orchard situation and debatable how often the use of expensive broadcasting equipment could be justified. Until further experiments have been carried out, bangers are likely to remain the most popular audio deterrent on fruit farms.

Touch

Three types of deterrents used against bullfinches can be included in this category: sticky sprays, black 'cotton', and 'scaraweb'.

Sticky substances, usually known as bird-lime, have been applied to branches to reduce bullfinch damage for hundreds of years; it was one of the original deterrents. Either the birds do not land or, if they do, they become stuck. While bird-lime may have been effective, it was undoubtedly a cruel and unselective way of killing birds, trapping a wide variety of species, and its use has been illegal for many years. When aviary perches were coated with a slightly tacky substance (not adhesive to the feathers) during tests at East Malling Research Station, the deterrent effect lasted only a few days (Muir, unpublished data). Furthermore, since such tacky substances may easily become too sticky, and may present considerable application problems, there seems little chance, legally or practically, that they will become acceptable.
'Cotton', as a bullfinch deterrent, was certainly in use by the middle of the 19th century, and it is still quite popular today. The modern nylon or polyester fibre equivalent is applied to trees by a long pole from which about six large bobbins unwind simultaneously. Often a row of trees is treated as a single unit with one or more passes down each side, so that each tree ends up with 12 or more strands. It lasts well and only needs to be applied once each year at the start of the damage season. The aim is not to make it impossible for the birds to land in the trees, but to ensure that, while moving within the orchard, they collide with the 'cotton' (it is usually coloured black and is very difficult to see). Most such collisions result in no harm; they merely surprise and inconvenience the birds. Some reduction or redistribution of damage might then be possible if birds associate the collisions with the orchard or the part of it with 'cotton'.

However, 'cotton' does have certain disadvantages. In the first place it is not easy to apply, especially if it is windy; strands are often blown across alleyways that should be kept clear for access. It can only be applied when pruning is complete, though fortunately it is degraded by U.V. light and mostly rots away before the next autumn when it would otherwise be irritating or hazardous to pickers. The biggest disadvantage, and the one that gives it a bad public image, is that, although the strands are sparsely distributed, some birds do become hopelessly entangled and die. Most victims are not bullfinches—thrushes are probably the most common—and many growers do not consider it an acceptable technique for this reason.

In this study, several farms were found to use 'cotton', usually only on trees likely to be severely damaged. In the study orchard, the western six rows of Conference pear trees, which included two rows containing sample branches, were 'cottoned' in January 1978. Counts on sample branches showed that by this time they had lost about 30% of their buds to bullfinches. By 24 February all but one of the 14 treated sample trees had lost over 90% of their buds, and by mid-April seven had no buds left at all (see Fig. C.3). Clearly any deterrent effect was not sufficient
to prevent damage on these trees. Fig. D.5 shows the damage on 'cottoned' trees as a percentage of the total orchard damage. There was no obvious avoidance of 'cottoned' trees in preference for 'uncottoned' trees - until February when the change was probably due to a lack of buds remaining on these trees. No bullfinches were found entangled in the study orchard, though in July 1979 one ringed in this orchard became entangled in another.

'Scaraweb', made by Chase Organics (GB) Ltd., is a fairly recently invented bird deterrent, and one that is not commonly used, except perhaps in gardens on individual trees. It consists of fine white fibrous strands that are teased apart and spread as a very loose blanket over each tree in turn. The resulting tangle of fibres is supposed to make it more difficult for birds to feed within the trees. It can only be applied in calm weather and requires two people and some practice before adequate cover is easily or successfully achieved. The fibres are broken down by U.V. light, but will last throughout the winter and early spring, when bullfinch damage occurs.

In this study, only one fruit farm used scaraweb on a large scale where, early in 1979, about 1ha of pears was treated at an estimated cost of £135 (including two man-days' pay). It appeared that some, though not complete, protection occurred, but this was difficult to confirm since 1978/79 was a year of relatively light damage.

In the study orchard, one tree was scarawebbed in early January 1980. Bud loss did continue but seemed to be reduced by the scaraweb. Following treatment the tree lost a further 15% of its buds, while four surrounding sample trees (including two that should have been less heavily damaged as they were further from the wooded orchard edge) lost a mean of 46% of their buds (17, 50, 58 and 61% each).

As a damage preventative, scaraweb merits further investigation. Where damage is likely to be severe, enhanced crops as a result of protection could easily outweigh the cost of application, and if only peripheral trees were treated, in an
Figure D.5. Changes in the percentage of the study orchard's bullfinch damage on trees with 'cotton' in 1977/78.

Data are from sample trees; rows 1 and 2 were 'cottoned' by 6 and 16 January respectively. Sample sizes are as for Fig. D.3.
attempt to spread bud loss through an orchard, the cost would obviously be much reduced.

Sight

Inglis (1980) discussed visual bird scarers and listed various techniques under two broad headings: those which act by a surprise/novelty effect, and those designed to resemble natural predators. As Inglis argues, those in the latter group are more likely to have lasting effect since they may be reinforced by sightings of real predators; in this respect sight deterrents suffer from the same habituation problems described for sound deterrents. Visual scarers can operate over large distances in open terrain and are designed to prevent birds landing on a vulnerable crop or sometimes to frighten them away shortly after arrival.

However, unlike many crops, orchards are not open and those with most bullfinch damage are adjacent to thick hedges or woodland. In order to be visible, the scaring devices must therefore either be above the trees or, if within the trees, be numerous or extensive. It is often suggested that a model bird of prey suspended above an orchard from a pole or gas-filled balloon might be an effective deterrent, but, in the majority of cases where such models have been used, habituation has been very rapid (see Inglis 1980). Perhaps this outcome could be predicted since birds recognise predators by a variety of visual cues including both shape and movement. Models may have the right shape, but they are inevitably very restricted in movement and can never accurately resemble a hunting raptor; at best a 'kestrel' could be made to 'hover' above an orchard. Furthermore, in this study, observations of bullfinch-kestrel interactions indicated a 'freeze until safe' rather than 'flee' response from the bullfinch. A model that induces this sort of response is of little use as a deterrent; the bullfinch might stop feeding for a few minutes but will soon realise the lack of danger and probably make up for lost time by feeding faster or for a longer time.
Thus perhaps it is not surprising that use of these predator-type deterrents is rare.

If visual deterrents based on predators are not very successful, then it is unlikely that those in the surprise/novelty category will be any better. However, they are commonly used in orchards against bird pests, perhaps because they are cheap and relatively easily made up. They usually take the form of plastic strips hung from trees or suspended above the orchard from wires between poles, or just coloured ribbon (most often yellow) draped across a number of trees (careful positioning is necessary if they are not to obstruct pruning or vehicular access). They are supposed to surprise birds by their unnatural appearance, and by the noise of the plastic flapping in the wind, in a situation where they are not expected. Although an initial period of success might result, it can only be a matter of time before the birds become habituated and make no aversive reaction to them.

In this study, the most ambitious example of this type of visual scarer was seen in early 1979. Strips of plastic fertiliser bags had been hung from several hundred metres of wire suspended on poles around the edges of two apple orchards. Both orchards suffered some damage and little evidence of a deterrent effect could be seen. No visual scarers were used in the study orchard.

Although there seems to be no evidence for it, the white rump of the bullfinch may act as a warning signal to other bullfinches, and there is therefore a chance that an effective scarer could be developed which incorporated a simulated bullfinch rump; devices mimicking woodpigeon wing bars may have some deterrent effect against that species (Inglis 1980).

**Taste**

Both birds and mammals perceive taste with sensory receptors known as taste buds. Compared to man's 9,000 taste
buds, birds have very few, and the bullfinch has less than 100 (Duncan 1960), situated at the back of the tongue. Furthermore, it is not known to what extent they are normally used in choosing food, and therefore to what extent the feeding behaviour might be modified through taste.

In the case of the bullfinch, clear preferences are shown for certain seeds and buds. For example, seeds of ash may be taken from only a few of the available fruiting trees, and Newton (1967) suggested that some might be less palatable than others. Distinct preferences are often shown for the buds of certain varieties of apple and pear trees. However, in all such examples there may be characters other than taste which determine the choice made. Aviary tests have shown that bullfinches will select between buds and seeds treated with various chemicals (Flegg, Muir and Hunter 1977) and more recent tests have shown a similar ability to choose between treated and untreated drinking water (Muir 1979). Some commercially available repellents such as Aaprotect (marketed by Bayer) and Morkit (marketed by Midox) were found to be partially effective, as were some fungicides, pesticides, and several materials suspected of causing irritation. However, concentrations needed to elicit a response were often high, so application may be costly and problems of phytotoxicity may arise. As with other deterrents that do not harm the birds, there is always the problem of habituation, and lasting success might be achieved only if several different chemicals could be used in rotation.

The idea of a chemical taste repellent is potentially attractive to fruit growers because it could be sprayed onto trees using standard equipment: orchards are routinely sprayed several times each year to control insect pests. Even with modern sprayers, only a very small fraction of the spray would be deposited on the fruit buds for which protection is desired, but this could be tolerated were the repellent to be cheap. However, the spray would need to remain effective for about two weeks, resisting mid-winter weather conditions, and as most sprays are water soluble this is a particular problem, especially as those with increased 'sticking' quality, for example by encapsulation,
often have reduced repellency. Regular application of sprays in winter also presents practical difficulties since the heavy machinery can cause excessive soil-structure damage.

Potentially effective taste repellents have been tested mostly in aviary or laboratory experiments, and there is always the danger that these conditions will produce results dissimilar to those obtained in the field. It could be argued that the repellent needs to be sufficiently effective to repel hungry bullfinches from the orchard, presumably to feed elsewhere on foods of lower nutritional value. If such alternatives were too distant or in some way inadequate, then there would be a greater tendency to stay within the orchard and feed. However, with crops such as pears where trees exhibit considerable tolerance to bud loss and effective protection could be achieved by merely spreading damage within the orchard, the repellent may not need to be so effective. It needs only to cause a shift in bud-eating from one part of an orchard to another.

One of the major problems of developing a chemical bird repellent is that it has to comply with strict guidelines with regard to toxicity to man and wildlife. Such guidelines may differ between countries; for example, methiocarb has been cleared for use as a bird repellent on some crops in the United States, but lacks this clearance in Britain. This particular compound seems to produce a conditioned taste aversion so that affected birds avoid further contact with the chemical, and this is thought to be the reason for its apparent effectiveness against birds such as red-winged blackbirds and common grackles in the States (Rogers 1980, Rogers and Lineman 1977).

In this study, four 'anti-bullfinch' chemical sprays were encountered. These were endrin and mesurol (despite the lack of clearance for their use from the Pesticide Safety Precautions Scheme), aaprotect and morkit. So far as could be ascertained, endrin was applied at 0.5kg/ha, mesurol at 2 to 4kg/ha, and aaprotect and morkit at manufacturer's recommended rates.
Endrin is included here because some growers claim that it acts as a repellent rather than as a poison. However, Feare, Summers and Longstaff (1978) showed that it was very toxic to bullfinches; captive birds died after eating 250 buds treated with 0.0375% endrin or only 60 buds treated with 0.15% endrin. Furthermore, they considered that observed reduction in bud-eating at the higher concentration was caused by the early onset of symptoms of endrin poisoning rather than rejection of buds on the basis of taste. In the light of this evidence, they argued that it seemed very unlikely that endrin acted as a repellent and that reductions of damage to orchards following endrin spraying were probably due to bullfinch mortality. Lack of bullfinch corpses within treated orchards may be due to their habit of feeding for only short periods before retreating to woodland. As endrin, like other sprays, falls on vegetation around and beneath the target trees, ground-feeding birds are often affected; thrushes, partridges and pigeons were reported in this study.

However, endrin was applied to several edge rows of the study orchard on 14 January 1980, and despite monitoring of the bullfinch population no evidence for mortality was found. Four colour-tagged bullfinches (see Section E.7) had been seen or caught three or more times in December 1979 and the first half of January 1980. One of these was observed eating buds from sprayed trees the day following application and the others are thought to have remained in the area and probably also ate sprayed buds. In later months all four were seen to have survived. Two other tagged bullfinches were seen eating sprayed buds on the day of application and one of these was seen later in the year when it had a nest only a few yards from the orchard. A further nine bullfinches were seen or caught once or twice shortly before the spray was applied. These were perhaps individuals visiting the study orchard infrequently, but three were subsequently seen again and four of those not seen were first-year birds, and therefore subject to a greater probability of dying from other causes in the period. The bullfinches observed feeding on endrin-treated buds and other species feeding within and below sprayed trees showed no unusual behaviour. Effects of endrin on damage within the study
orchard are discussed later in this section, since it was the last spray to be applied during this study.

Chemical deterrents were applied by the grower to the study orchard in 1976 (Flegg and Muir unpublished), and in all three years of this study. In 1976 aaprotect and morkit were applied to separate parts of the orchard during February when damage had started. Subsequent bud counts revealed a pattern of damage within the orchard that was very similar to that recorded in 1978 and no deterrent effect could be detected. The rows sprayed with aaprotect were close to the woodland and were most heavily attacked, losing 65% of the buds which were intact at the time of spraying.

Morkit was applied to the whole orchard on 20 January 1978. The rate of bud loss within the orchard as shown by counts on sample branches (Fig. C.2) was marginally less between 16 and 24 January than previous or subsequent rates, but this may have been due to normal fluctuations and sampling error. Certainly no major or lasting effect was apparent. Aaprotect was applied to the whole orchard on 1 March 1978 but this, like the introduction of the banger near this time, is not thought to have caused the reduction in the rate of bud loss recorded from 7 March onwards. There were very few buds left in the orchard at this time and the reduction in bud loss was inevitable. Also, the high rate of damage between 24 February and 7 March does not indicate any major initial effect.

Aaprotect was applied to southern and western orchard trees on 12 March 1979. The rate of damage to the whole orchard in the following ten days was identical to that recorded between 1 and 12 March (Fig. C.12). Fig. D.6 shows the bud loss on sprayed trees as a percentage of the bud loss in the whole orchard; there is no indication of a shift in bud-eating away from sprayed trees.

Data from 1980 are complicated by the extensive clearance of adjacent woodland and hedge that occurred in addition to the application of two sprays: mesurol and endrin on 14 and
Figure D.6. Changes in the percentage of the study orchard's bullfinch damage on trees sprayed with Aaprotect in 1979.

Data are from sample trees; rows A and 1 were sprayed on 12 March. Sample sizes are as for Fig. D.4.
24 January respectively. Also, the timing of bud counts on sample branches was not ideally matched to spraying dates. Fig. C.21 shows the rate of bud loss within the whole orchard in 1979/80 and Figs. D.7 and D.8 show the bud loss on sprayed trees as a percentage of the total orchard damage. When the first spray was applied, the overall rate of bud loss was not clear; a slow start was followed by heavy bud loss in mid-January, but the exact rate during this second period was not measured until four days after spraying. Nevertheless, data from both previous years suggest that, once started, damage usually continues at a steady rate, so it is reasonable to assume that, in the absence of sprays and further clearance, damage this year would have continued at a rate equal to or exceeding the mid-January level recorded. Fig. C.21 shows that shortly after the application of mesurol the rate of bud loss from the orchard was roughly halved, suggesting some deterrent effect of this spray. A further slight reduction in damage occurred following endrin spraying on 24 January, suggesting that this spray may also have had some deterrent effect, though a residual effect of mesurol cannot be ruled out. Since the rate of bud loss subsequently rose (in early February), clearance is unlikely to have been wholly responsible for these results.

Data presented in Figs. D.7 and D.8 can be examined for indications of shifts in damage away from sprayed trees. Mesurol was applied by the new owner to six rows of trees at the southern edge of the orchard including two rows containing a total of ten sample trees. Prior to spraying, these two rows received 50-60% of the total damage recorded, while between 18 January and 19 February (after spraying) the same two rows received less than 20% of the total damage recorded (see also Fig. D.10). This shift of damage strongly suggests that mesurol repelled bullfinches from sprayed trees, reducing the rate of bud loss on these trees to about one third of its previous level. Since damage on sprayed trees returned to 50-60% of the total in late February and March, by which time, under the influence of rain and weather, the mesurol would have lost much or all of its repellency, it seems unlikely that lack of buds and clearance were responsible for much of the initial shift of damage.
Figure D.7. Changes in the percentage of the study orchard's bullfinch damage on trees sprayed with Mesurol in 1979/80.

Data are from sample trees; rows A and B were sprayed on 14 January. Relatively few buds were damaged in mid-February (86 buds) compared to other periods (199-516 buds), hence dashed line.
Figure D.8. Changes in the percentage of the study orchard's bullfinch damage on trees sprayed with Endrin in 1979/80.

Data are from sample trees; rows A and 1 were sprayed on 24 January. Sample sizes are as for Fig. D.7.
Endrin was applied to trees on both the southern and western edge of the orchard including a total of ten sample trees. Prior to spraying, these trees received 70-80% of the total damage recorded (see also Fig. D.10). After spraying (between 23 and 30 January) there was, if anything, a slight increase in damage on these trees. Damage between 18 and 30 January was highly concentrated on sprayed trees but was mostly on western (rather than southern) trees. This was probably caused by bullfinches avoiding mesurol in the south but staying close to the hedge adjacent to the western edge. This hedge was grubbed at the end of January and, probably as a result, subsequent damage to the western orchard trees was markedly reduced.

Thus there is little evidence for any deterrent effect of the endrin spray. However, data suggest that mesurol caused both a reduction of bud-feeding in the orchard (even though it was applied to less than a third of the orchard) and a shift in damage away from sprayed trees. Both effects may have been caused by an unfavourable taste. Mesurol, as a bullfinch feeding deterrent, should be further investigated.
D.4. Vegetation clearance

It has been argued that bullfinch damage is most likely to occur where good bullfinch habitat adjoins orchards (Section D.3. Introduction). It follows that the removal of such habitat—tall hedges, scrub, woodland etc.—should reduce the incidence and intensity of damage.

Modification of the habitat as a means of altering bird numbers or behaviour is not a new idea, and was discussed in relation to bird roosting and feeding on airfields by Wright (1968). The modified habitat may prove more attractive than the original to certain species. Such a situation arose at Vancouver airport: short grass was allowed to grow long to deter roosting gulls etc. which were a hazard to aircraft, and hundreds of short-eared owls appeared, feeding on the increased population of small rodents (Lewis 1967). Nevertheless, the overall effect of similar grass management techniques at other airports has been very effective, reducing numbers of lapwings, gulls, corvids and woodpigeons frequenting the grassy areas (Brough and Bridgman 1980).

These deterrent measures show the advantage of having, at least potentially, lasting success. In the case of bullfinches the modified habitat (open, rather than wooded areas) should be unattractive to the birds for the same reasons that other already open areas are unattractive. Not only do open areas provide less food for the bullfinch; they are also more dangerous. There should be no habituation since these disadvantages to the birds are real, unlike those of bangers, yellow ribbons, etc.

Since bullfinches do not always avoid open spaces, clearance of woodland surrounding orchards is unlikely to prevent all bullfinch damage. For example, in the summer, bullfinches in the study area regularly fed on buttercups in a large open field, and pairs feeding young flew hundreds of metres across other fields to reach feeding sites. However, even these tended to follow hedges and woodland edges where this was possible. Perhaps the greatest indication that woodland and hedge clearance
is likely to reduce damage is simply the observation that orchards distant from such habitat rarely suffer bullfinch damage (see Section C.8. Results).

There is understandable reluctance to implement this form of bullfinch 'deterrent'. Both fruit growers and the general public are conservation-conscious and woodland clearance is regarded by many as removal of valuable environment rather than modification of the habitat. Financial investment in equipment and manpower may be large and continuing management may also be needed, so that several years may pass before expenditure is repaid by increased fruit crops. Growers would be well advised to assess the cost of damage, at the crop stage, before considering a programme of clearance. Additionally, many growers do not own the 'problem' woodland, and therefore may not be able to remove it, though they may consider, as an alternative, grubbing some orchard trees; edge trees may cost money to keep as well as providing the unwanted link between woodland and orchard.

During this study, although several growers were found to have cut back hedges, only two major clearance programmes were encountered. At one farm, in 1976 and 1977, all hedges were cut short (these had grown unchecked for several years) and about 4ha of scrub and woodland was cleared at a cost of about £3,500. Subsequent damage to apples and pears was much reduced.

Clearance within the study area, most of which occurred following a change of ownership, is shown in Figs. D.9 and D.10, and in Plate D. Much of the clearance was initially intended to improve corn fields and, in some places, to create areas for grazing sheep. Extensive land drainage programmes were also initiated.

The effects of this clearance on the extent and distribution of bullfinch damage within the study orchard can be seen in Figs. D.10 and D.12. Three separate effects are apparent.
Figure D.9. The study area after clearance of woodland and scrub in late 1979 and 1980.
Figure D.10. Effects of vegetation clearance and sprays on the distribution of bullfinch damage to the study orchard during three consecutive periods in 1979/80, as indicated by sample branches.

Woodland understorey had already been cleared from around the larger pond (p) and from beyond the hedge (h). Mesurol (M) was sprayed onto two sample tree rows on 14 January.
Figure D.11. The spread of bullfinch damage through the study orchard during the three winters of this study.

See Figs. C.3, C.12 and C.22 for details.
1. The distribution of damage in 1978/79 was different from the pattern recorded in 1977/78. This was probably due to the cutting back of a 5m high hedge at the north edge of the orchard to only 1m late in the summer of 1978. Orchard trees near this edge were then comparatively exposed and received a reduced proportion of the total bud damage in 1978/79.

2. The total damage recorded and the rate at which it occurred in 1979/80 was smaller than that recorded in 1978/79. In the fifty orchards sampled for damage annually (see Section C.8), no other decreases in damage were recorded. It therefore seems likely that the reduction in study orchard damage was due, perhaps primarily, to clearance of woodland and scrub to the west and south of the orchard. The application of the chemical deterrent mesurol in 1980 may also have reduced the overall damage rate temporarily. The low rate of bud loss, particularly in late February and March 1980, indicates that very few birds were feeding in this orchard, even though severe damage was known to be still occurring in other orchards. By this time, woodland to the south of the orchard had been cleared to a distance of about 25m.

3. Fig. D.10 shows the damage recorded during three consecutive periods in 1979/80. The distribution of damage within the orchard was clearly different in each of these periods. There are two main factors, other than clearance, that may have contributed to these changes. Firstly, mesurol was applied to trees in the south of the orchard late in the first period, and was probably partly responsible for the lack of damage on these trees in the second period; it is very unlikely that the spray was still effective in the third period. Secondly, as buds were eaten from edge trees, so the remaining buds became less densely distributed and a shift in damage to other trees might be expected (see Section D.3. Introduction). However, as explained on page 184, trees at the orchard edge started the season with more buds and subsequently lost too few for their bud numbers (or density) to be reduced to less than on other trees. Thus the effect of reduced bud density should have been minimal.
Effects of clearance are best seen by comparing the pattern of damage in the first and third periods in Fig. D.10. The western edge clearly received far less damage in the third period than it did in the first. This is thought to be largely due to the removal of the overgrown hedge adjacent to the west of the orchard at the end of January (Plate D), this edge then became very exposed (open to the road and the already cleared woodland beyond). During the third period, trees in the south of the orchard received about the same amount of damage as those in the north, whereas in the first period most damage occurred in the south. This change was probably caused by clearance of undergrowth in the woodland to the south between the two periods.

The damage recorded in the third period was spread almost throughout the orchard, with only a slight concentration on the least exposed edges. This particular effect of woodland clearance is important because the risk of losing crops on edge trees (as a result of unevenly distributed damage) is reduced. Even a gap of as little as 10-20m between woodland and orchard trees is likely to result in spreading of damage. When such a gap is made, fruit trees at the orchard edge are no longer the safest trees in the orchard; they are, if anything, more exposed than trees in the centre of the orchard. Thus, although bullfinches must enter the orchard at the edge, they are then quite likely to move further in to feed.

Evidence of the lasting effect of clearance in the study area on bullfinch damage was apparent in subsequent years. Damage during the winter of 1980/81 was far less than in any of the previous five years (probably amounting to only 1 or 2% bud loss), while the damage in other orchards in Kent was about average for the previous three years.

In 1981/82, orchards in Kent suffered more damage than in any of the previous four years, yet the study orchard lost only an estimated 23% of its Conference buds and 6% of the Comice buds. Furthermore, bud counts on sample trees showed that this damage was distributed almost throughout the orchard (Fig. D.12) and not concentrated on edge trees.
Figure D.12. Bullfinch damage to Conference trees in the study orchard on 8 March 1982.

On each sample tree, 103-245 randomly chosen buds (mean 140) were examined.
D.5. Netting

Netting is one sure way of preventing bullfinches eating buds from fruit trees and bushes. If the mesh is less than about 30mm, even the most determined bullfinch will not be able to squeeze through, and coarser mesh is also likely to be effective as the birds will be reluctant to enter the enclosure. Trees or bushes can be treated individually, or several enclosed together with the netting supported by poles and firmly anchored to the ground. It is essential to ensure that there is no gap, or birds may get trapped inside; this applies particularly to thrushes which may enter the enclosure at ground level and be unable to find a way out.

As a bullfinch deterrent, netting is potentially 100% effective, but its cost is often prohibitive. In this study, twelve full-size pear trees (up to about 4m high) were netted individually in 1979 and a further three in 1980. The netting (Netlon) was made of black nylon and had a square mesh of 30mm. It was draped over each tree and tied around the trunk, any gaps being closed with string. It was necessary to cut the netting during removal to prevent damage to the trees, so it could only be used once. By this method it took two people an hour to enclose two or three trees, and the netting cost about £4/tree. The cost of protecting a tree obviously should not exceed the amount likely to be earned from the resulting increased crop, and since each tree might yield only £10 to £20 fruit, netting is usually considered too expensive. However, with careful planning it is possible to reduce the cost of both netting and labour, and, if carefully supported, the netting could be used several years in succession.

Apart from the cost, one other problem may arise when netting is used in winter. Snow may accumulate on the netting and cause damage to both netting and trees. This problem will vary with mesh size and weather conditions. When snow fell during this study, no such problems were experienced.
With recent reductions in the price of netting, it may be worth considering this form of bullfinch damage prevention. Netting is effective against bird damage to ripe fruit and may be particularly suitable for use on high cash crops such as cherries, especially now that semi-dwarfing rootstocks like Malling Colt are becoming more common.
The effects of pruning and bullfinch damage on fruit crops are complex. In some ways they are similar, for example, both result in a thinning of fruit buds and therefore fewer fruitlets on each tree. Pear trees need to be pruned in most years if the quality and quantity of pears is to be maintained. This is usually done in autumn or winter, but there seems to be no reason a priori why it cannot be done late in spring, even at blossom time.

However, pruning and bud damage do not affect the crop independently. In particular, pruning may affect the number and percentage of buds taken from each tree by bullfinches and hence affect the crop. If, as seems likely from data presented in Section C, both the number and the percentage of buds left on each tree is important, then it is apparent that the time at which trees are pruned, relative to the time of bullfinch damage, may also be important. For example, if a tree has 2,000 fruit buds of which 1,000 are eaten by bullfinches, then pruning (which may reduce the number of buds by about 50%) would further reduce this total to 500 (25% of the initial number). If, on the other hand, pruning occurred before bud damage, then the tree might only have 1,000 buds when damage started; bullfinches might still eat the same number of buds as in the first example and no buds would remain. When pruning late, there is also the option of cutting out only the most heavily damaged branches. For these reasons, growers are probably well advised to delay pruning of their most vulnerable trees until most bud damage has finished, perhaps till late March when buds are bursting. As Newton (1964a) pointed out, this might interfere with normal pruning policy, but in some years it could considerably increase the yield of fruit. In theory, this form of damage preventative costs nothing, and thus it is surprising that it is not more widely practised.

In reality, most situations are more complex than the above examples. In particular, bullfinches very rarely remove every bud from a tree, and the fewer buds there are to start with, the fewer they are likely to take. Thus they may tend to
concentrate on unpruned trees and ignore pruned trees. Much depends on the alternative foods available. If bullfinches are eating little other than orchard buds, they may eat a certain number regardless of pruning, in which case pruning late will ensure that the maximum number of buds remain.

A closely related damage prevention technique is to leave some trees permanently unpruned. Such trees produce many buds each year, especially if they are heavily damaged, and may therefore alleviate the pressure on other trees. During this study, one grower left two edge rows of apples unpruned since these and other rows were heavily damaged each year, but annual variation in damage was too great for him to be sure whether or not the pruned trees were less heavily damaged as a result. Leaving peripheral trees unpruned in areas where severe damage is an annual event is a technique that merits further investigation; it could be argued that the presence of overgrown trees with an unusually plentiful supply of buds could actually encourage bullfinches to enter the orchard (see also Section D.7).
Bullfinches probably eat buds partly because there are no alternatives, and there is evidence to suggest that seeds, when available, are preferred to buds. It follows that if these seeds were provided, damage in orchards might be reduced. Bullfinches are rarely seen at bird tables, so the seeds would be best provided by growing the food plants. Nettle and dock are common orchard 'weeds' and could easily be encouraged, although the compatibility of this suggestion with current weed control practices (Atkinson and White 1981) would need close examination, and a few ash trees could be planted nearby. The presence of these food plants could reduce bud-eating until most seeds had been eaten, thus perhaps preventing damage from reaching critical levels.

There are two main objections to this as-yet untested strategy. First, bullfinches from surrounding areas might be attracted to the food, while it lasted, and then, rather than returning to their 'home ranges', remain to feed on nearby fruit-buds. Secondly, the abundance of food could allow more birds to survive the winter, thereby increasing the potential for damage in subsequent years. For these reasons Newton (1964a) considered that the provision of alternative foods was dangerous. However, the objections are difficult to test, the latter largely depending on when and why bullfinches normally die.

It seems likely that most winter mortality is caused by shortage of seeds, before buds are sufficiently large, but even in the absence of seeds, most birds surviving to January could probably last the whole winter, since from then on buds become larger and days longer. If this is so, the safest food provision policy might be to encourage plants, such as dock and nettle, that could be covered with netting until natural mortality has reduced the population. When orchard damage starts they could be uncovered as a new food source, reducing the need to eat fruit-buds.
Bullfinch damage in orchards is often characterised by greater bud loss on some varieties than others (Newton 1964a). Some varieties are rarely damaged, and, when planting orchards, these varieties should be planted in the most vulnerable places so that the 'preferred' varieties can be planted further from woodland and large hedges. As with woodland clearance, the 'gap' created between the source of bullfinches and the bud supply will have two effects. First, fewer bullfinches will cross the 'gap' and find the preferred variety, and second, damage will be spread throughout the trees rather than concentrated on a few edge trees.
D.9. Conclusion

On many farms, bullfinch damage is only very rarely severe, and in these cases, at least where the varieties concerned can tolerate some bud loss, the damage is best ignored, as any remedy would be considerably more costly than the fruit loss. However, on other farms, severe damage to some trees is regular; these trees must still be pruned, and sprayed with insecticides and fungicides, and therefore actually cost money to keep. In these cases the best course of action will depend on numerous interrelated factors.

In new plantings, vulnerable varieties should be planted well away from good bullfinch habitat, perhaps with less vulnerable varieties filling the gap. In established plantings, similar gaps may be produced, though perhaps at considerable expense, by clearing woodland; hedges should be kept well trimmed. In some cases where damage is always severe, the edge orchard trees may be removed in order to cut losses and create a gap.

Pruning should be left until after damage has finished, and it may be worth considering netting some trees when a large percentage of buds has been taken. Those growers willing to try feeding bullfinches on seeds should only do so when damage has started. Shooting and trapping are most likely to reduce the bullfinch population if pressure can be sustained for a long time, which may be costly.

When the damaged varieties tolerate some bud loss, any attempts at scaring bullfinches should be carried out only where damage is likely to result in a loss of crop; the primary aim should be to spread the bud loss over as many trees as possible. Varieties such as Conference, which may frequently tolerate up to 70% bud loss, should not be protected until the damage threshold is likely to be exceeded. Then it may be worth trying any of the legal and less costly alternatives such as bangers, 'cotton', sprays and scaraweb, even though the effects may be hard to see. Even if damage is likely to be severe, these measures should not
be introduced before bud-feeding starts, since their subsequent effectiveness may be reduced.
E. BULLFINCH POPULATIONS
E.1. Introduction

Whilst it is possible to isolate and discuss the effects of bud loss on fruit crops, any attempt to reduce bullfinch damage should take into account the number of birds eating buds. Bud-eating may start earlier in years when populations are large and the seed stocks are quickly exhausted, and, clearly, many bullfinches can do more damage than just a few. Furthermore, a knowledge of bullfinch movements and mortality patterns would be of great value to the grower who plans to reduce damage by trapping or shooting. In short, an understanding of bullfinch populations - breeding, movement and mortality - is essential to a clear understanding of bullfinch damage to fruit.

Data discussed in this section fall into three main categories: previous intensive studies (published in various journals), the British Trust for Ornithology (mostly analysed as part of this study) and the study area at Brenchley. B.T.O. data are collected by many amateur ornithologists and qualified ringers, and are recorded on special forms and ultimately on computer files. They are treated here under four different headings, as follows:

a) Breeding data extracted from forms known as Nest Record Cards, each of which contains details of one bullfinch nest found by the recorder.

b) Data from form BRC 19. On these forms ringers enter details of all bullfinches ringed and, if possible, subsequent recaptures. Details such as age and sex ratios in the live bullfinch population being sampled by the ringers have been investigated with these data.

c) Data from ringed birds found dead, or caught by other ringers, and reported to the B.T.O. (recoveries). These have provided details of mortality and movement.

d) The annual bullfinch population index determined by the B.T.O.'s Common Birds Census (C.B.C.). This has been extracted from papers in the journal 'Bird Study', since it gives indications of long-term population fluctuations.
Plate E. Bullfinch with a colour-coded back tag of the earlier design.
In this section, these various data are used to describe the characteristics of bullfinch populations which might affect the nature and extent of the damage they do to fruit, and which may help growers to reduce damage on their farms.
E.2. Previous intensive studies

At one time it was suggested that damage to orchards was caused by migratory continental bullfinches. However, careful measurements of bullfinches caught in orchards (Harrison 1958), and in Britain as a whole by bird ringers, show that only very rarely are individuals of this slightly larger European race present in this country.

Wright and Summers (1960) confirmed that damage to Kent orchards was caused by locally-bred bullfinches of the British race *Pyrrhula pyrrhula nesa*. Working in prime bullfinch habitat in the Weald of Kent, they estimated that the breeding population of a 350 acre (142ha) farm was about 20-25 pairs (equivalent to 14-18 pairs/km²). The earliest eggs were laid towards the end of April and the last young fledged in mid-September. A similar breeding season was recorded by Nicolai (1956). Only 46 young fledged from 34 nests found by Wright and Summers, largely because over 50% of nests were destroyed by predators. They estimated that the farm had a post-breeding bullfinch population of about 150 birds. Based on age ratios of mist-netted birds, they suggested that bullfinches have a low post-fledging mortality. To reduce bullfinch populations they recommended the use of chardonneret traps rather than shooting.

Newton (1964a, 1964b, 1967 and 1972) worked in Marley Wood, Oxfordshire, and found densities of over 50 pairs/km². He reported similar laying and fledging periods to Wright and Summers, but found that they were dependent on food supplies. Again, over 50% of nests were predated. He concluded that, when a breeding season was short, each pair of bullfinches might raise one or two broods (maximum of three), while in a long season they might raise one to three broods (maximum of four). Nicolai (1956) thought that two broods were usual, though three to five clutches might be laid. In contrast to Wright and Summers, Newton suggested that predation of recently-fledged young was likely to be high, and found that a period of up to eight weeks elapsed before fledged birds were fully represented in the mist-netted population. Of bullfinches caught in autumn, 77-83% were
juveniles, indicating the survival of 3.4-5 young/adult (depending on the length of the breeding season). The ratio of juveniles to adults peaked in October and declined throughout the winter; little change occurred in the subsequent summer months. The number of bullfinches estimated to be present in Marley Wood over two successive winters is shown in Table E.1. Considerable mortality occurred before the end of December in both winters. In most months, an excess of males was recorded (Table E.2), the difference being greatest in the summer.

Table E.1. Estimated total number of bullfinches in Marley Wood

<table>
<thead>
<tr>
<th>month</th>
<th>1962/3</th>
<th>1963/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>September</td>
<td>261</td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>146</td>
<td>227</td>
</tr>
<tr>
<td>November</td>
<td>126</td>
<td>230</td>
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<td>December</td>
<td>112</td>
<td>114</td>
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<tr>
<td>January</td>
<td>108</td>
<td>89</td>
</tr>
<tr>
<td>February</td>
<td>103</td>
<td>77</td>
</tr>
<tr>
<td>March</td>
<td>98</td>
<td>74</td>
</tr>
</tbody>
</table>

From Newton (1964a and 1964b)

Table E.2. Sex-ratios of mist-netted bullfinches in Marley Wood

<table>
<thead>
<tr>
<th>months</th>
<th>sample size</th>
<th>%males</th>
</tr>
</thead>
<tbody>
<tr>
<td>1962</td>
<td></td>
<td></td>
</tr>
<tr>
<td>September-December</td>
<td>269</td>
<td>54</td>
</tr>
<tr>
<td>1963</td>
<td></td>
<td></td>
</tr>
<tr>
<td>January-March</td>
<td>140</td>
<td>56</td>
</tr>
<tr>
<td>May-August</td>
<td>188</td>
<td>70</td>
</tr>
<tr>
<td>September-December</td>
<td>193</td>
<td>49</td>
</tr>
<tr>
<td>1964</td>
<td></td>
<td></td>
</tr>
<tr>
<td>January-March</td>
<td>79</td>
<td>57</td>
</tr>
<tr>
<td>May-July</td>
<td>72</td>
<td>74</td>
</tr>
</tbody>
</table>

From Newton (1964b)
E.3. Nest Record Cards

As part of this study, over 3,000 bullfinch Nest Record Cards were sorted by hand and analysed. The amount of information on each card varied considerably. In exceptional cases, all the following were entered: details of nest-site and habitat, date of egg-laying, clutch size, incubation period, hatching success, brood size and fledging success, and date. However, many of the parameters described are only of academic interest in the present context. Bullfinch nests are usually too difficult to find to make nest-destruction a feasible population control measure and many nests are destroyed by natural predators anyway.

The number of successful breeding attempts made by each pair of bullfinches in a year, and the number of young likely to be reared, would be of considerable use to growers. Unfortunately, precise data on these questions cannot be obtained from Nest Record Cards. This is because the success (or failure) of a single pair of bullfinches is rarely followed throughout the breeding season. Also, it is difficult to demonstrate peaks of egg-laying (for first, second, etc. clutches), because heavy predation, particularly early in the breeding season, effectively smooths out these patterns. Finally, the number of Nest Record Cards completed from June onwards is undoubtedly reduced by the difficulty of finding nests in thickening vegetation and a consequent lessening of interest in nest recording, so that the relative frequency of early and late nests is not known. Despite pleas for nest-recorders to cover the whole breeding season (Morgan 1974), such falling-off in nest recording may occur in many species.

Nevertheless, it is possible to define the approximate length of the breeding season, the duration of a breeding attempt and the average number of young reared in each successful attempt. From these, the potential number of broods and young reared/pair can be calculated. The start of the breeding season is probably well-documented by Nest Record Cards, because at this time the nests are relatively easy to find. In most years, some nests are found in April; sometimes the first eggs are laid in the first
However, usually egg-laying starts in earnest in the last ten days of April or the beginning of May, a finding which agrees with those of Wright and Summers, and Newton (Section E.2). Nest Record Cards indicate that nests with eggs laid in August are very rare, but this may not represent the true pattern; by extensive nest-searching, Newton found nests with eggs laid even in early September, though in another year egg-laying ended in mid-July.

Nest Record Cards indicate that a nesting attempt consists of about five days' egg-laying (eggs are laid daily), 13 days' incubation, and 15 days to fledging. In addition, the nest has first to be built, and fledged young need a period of parental care before they become independent; these may last as long as 5 and 20 days respectively (Nicolai 1956). However, post-fledging care and further nest-building probably overlap, so a total turn-round period of 45 days might be possible. At this rate, as Newton suggested, a maximum of three broods could be raised in a short season with laying in late April, early June and mid-July. In a long season, a fourth clutch could be laid in early September. Predation of nests is likely to reduce the number of successful breeding attempts to only two or three. If, as is indicated by Nest Record Card data, an average of four nestlings fledge from each successful nest, eight to twelve young might be raised by each pair. Allowing for some post-fledging mortality, these estimates are not inconsistent with the age ratio of mist-netted birds in autumn, which usually peaks at about four juveniles to every adult (see page 298).
E.4. Form BRC 19: the ringed bullfinch population

Introduction

In recent years, up to 10,000 bullfinches have been ringed annually, about 98% of these being full-grown birds, i.e. only 200 nestlings each year. The vast majority are now caught in mist nets.

Since 1976, details of all bullfinches ringed, and some of those retrapped, have been entered on form BRC 19. Each form contains details of bullfinches caught and ringed by one ringer in one region of the country; there are ten regions in total. Forms pertaining to S.E. England (Region 2) are the most numerous, comprising about one third of the total. As part of this study, all forms from both S.E. and S.W. England (Region 1) returned to the B.T.O. during 1976-1979 (a total of ca. 850) were sorted and analysed by hand. For some analyses it was necessary to know that all birds (including retraps) had been entered on the forms, so in these cases forms were only used if this was specified. (Although the majority of ringers probably enter all birds, only about two thirds state that they have done so.) For each bullfinch caught, details of place, date, ring number, age and sex are usually entered, and there is additional space for wing-length, weight, time of day and moult.

In isolation, changes in the numbers of bullfinches caught or ringed each month do not necessarily indicate similar changes in population levels. Relatively few bullfinches are caught during the winter, and this is at least partly due to reduced catching effort. The behaviour of the birds may also influence the number caught; for example, the winter lull could also be due to a tendency to feed at greater heights (i.e. above mist net height) at this time. Bullfinches are difficult to catch in windy weather, so particularly windy months will have depressed totals. Furthermore, in any one month, ringers may catch a biased proportion of the bullfinch population, and this is discussed more

1. Except where specifically attributed to other workers, all data and analyses discussed in Section E.4, including all those in tables and figures, result from my examination of these forms.
fully where appropriate. Despite these problems, data on the forms represent a very useful and in many ways representative sample of the wild bullfinch population.

Of greatest interest to fruit growers are data relating to the age and sex of bullfinches caught. Until their second autumn, when they reach full adult plumage, most bullfinches can be aged accurately (Svensson 1970); during this study only once was it known that a bullfinch could not be aged by Svensson's techniques (Flegg and Matthews 1980). B.T.O. ringers commonly use one of six age-codes for each bullfinch caught, and these are given in Table E.3.

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Season most often used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pullus (nestling)</td>
<td>summer</td>
</tr>
<tr>
<td>2</td>
<td>full-grown, year of hatching unknown (current year not necessarily excluded)</td>
<td>autumn</td>
</tr>
<tr>
<td>3</td>
<td>definitely hatched during current calendar year</td>
<td>summer/autumn</td>
</tr>
<tr>
<td>4</td>
<td>hatched before current calendar year, exact year unknown</td>
<td>spring onward</td>
</tr>
<tr>
<td>5</td>
<td>definitely hatched during last calendar year</td>
<td>winter/spring</td>
</tr>
<tr>
<td>6</td>
<td>hatched before last calendar year, exact year unknown</td>
<td>winter/spring</td>
</tr>
</tbody>
</table>

Additional codes (7 and above) are occasionally used for birds known to have hatched at least two calendar years previously.
Data presented in Tables E.4 and E.5 show the percentage of birds caught and ringed, falling into the four most common and most useful (for our purposes) age codes during the year. The differences between the two tables are, at least in part, caused by differences in the frequency with which birds in the different age groups are retrapped: the older a bird is, the more likely it is to have been caught previously, so those caught and given codes 4, 5 and 6 are more frequently retraps than those given code 3. Over half of bullfinches ringed are in their first calendar year.

Until some breast feathers have moulted (during their first autumn moult), juvenile bullfinches cannot be sexed easily by their plumage. However, most are sexable by October, and over 99% are sexed by ringers thereafter (Table E.6).

**Table E.4. Ages of bullfinches ringed**

Data are from form BRC 19, January 1976 to April 1978, S.E. England only. Only forms including all retraps were used. Birds given age codes 1 or 2, or code 4 in January to April, have been omitted; these were either nestlings or of unknown age. Birds given age code 7 or over were classed as age code 6.

<table>
<thead>
<tr>
<th>months</th>
<th>age code</th>
<th>mean % of year's total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-Apr</td>
<td>5</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>3.6</td>
</tr>
<tr>
<td>May-Dec</td>
<td>3</td>
<td>52.8</td>
</tr>
<tr>
<td></td>
<td>4, 5 or 6</td>
<td>37.0</td>
</tr>
</tbody>
</table>

100.1

Sample size 1,563
Table E.5. Ages of bullfinches caught

Data as for Table E.4, but all months 1976-1979 used, and retraps were included.

<table>
<thead>
<tr>
<th>months</th>
<th>age code</th>
<th>mean % of year's total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-Apr</td>
<td>5</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>6.4</td>
</tr>
<tr>
<td>May-Dec</td>
<td>3</td>
<td>42.4</td>
</tr>
<tr>
<td></td>
<td>4,5 or 6</td>
<td>41.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100.0</td>
</tr>
</tbody>
</table>

sample size 12,878

Table E.6. Juvenile bullfinches caught and sexed during the year

Data are from form BRC 19, S.E. England only, where all retraps were entered.

<table>
<thead>
<tr>
<th>% of catch sexed (and sample size)</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
</tr>
<tr>
<td>July</td>
</tr>
<tr>
<td>August</td>
</tr>
<tr>
<td>September</td>
</tr>
<tr>
<td>October</td>
</tr>
<tr>
<td>November</td>
</tr>
</tbody>
</table>
**Age ratios**

Young birds of many species suffer greater mortality than older, more experienced birds. In consequence, the ratio of first-year to adult birds in a population generally rises during the summer as first-year birds fledge, and then falls when differential mortality sets in. This pattern is obvious in the analysis of BRC 19 bullfinch data presented in Fig. E.1.

Between June and the end of the year, ringers almost always age bullfinches, distinguishing between birds fledged in that year and older birds. However, the forms indicate that from January onwards, particularly in 1976 and 1977, there is an increasing tendency to fail to make this distinction (in practice an increasing proportion of birds caught are given age code 4 instead of 5 or 6). In addition, catches of bullfinches in the winter, particularly in February and March, are smaller than in the summer and autumn. These two factors combine to produce decreasing reliability and increasing variation in the age ratios recorded after the autumn. The month of May usually shows a much increased catch of bullfinches, but by this time in 1976 and 1977 ringers in S.E. England did not accurately age 25 and 15% of the catch respectively. Ageing difficulties are largely a result of feather wear after the autumn moult; the colour of the diagnostic secondary and carpel covert tips becomes progressively more difficult to see. When these feathers are worn, it is more often possible to be sure about the age of a first-year bird (code 5), since a contrast in colour is often still visible between its juvenile coverts and any that it moulted in its first autumn, than of an adult bird (code 6), where there is no contrast. Thus, first-year birds are probably less often classed as 'don't know's' (i.e. code 4) than adults, and the first-year to adult ratio may therefore be over-estimated in months such as May 1976 and 1977 when the number of 'don't know's' was great.

Probably as a result of increasing ageing proficiency, only 7 and 4% of bullfinches were not aged in May 1978 and 1979 respectively (though the percentage still increases in later
1st year:adult ratios (expressed as percentage 1st years) in birds caught by ringers in SE England. Data come from form BRC 19 where all retraps have been entered. Small dots and dashed lines indicate samples in which the number of birds of unknown age exceeded 10% of that month's total, resulting in a possible error of c. 5% or more. All samples contained over 50 birds.
months). The age ratios for these months are therefore probably relatively accurate.

A very similar pattern is apparent from S.W. England in the same years (1976-79), though data are fewer.

Newton (1964b) found a time lag of up to eight weeks between birds fledging and appearing in the mist-netted population, presumably because their behaviour differed from that of adults at this time. This is probably the reason why the peak age ratio appears to occur in September at the earliest (even though fledging probably ended in August in some years). When the breeding season is particularly long, fledged birds could still be entering the mist-netted population in November. After this initial period, although young birds may move around and flock more than adults (Newton 1967), the different age classes of bullfinches are probably equally likely to be caught by most ringers. Thus, from the autumn peak onwards the data in Fig. E.1 should be representative of the whole bullfinch population (though still subject to the bias caused by ageing difficulties described above).

The data suggest that the age ratio normally peaks at about 80% young birds in September or October, falling to about 60% in January and perhaps 55% during the following summer. Similar figures were arrived at by Newton (1964b) (see page 288) and Bibby (1974).

Adult mortality between the end of September and mid-January may be very low. Ringing recoveries indicate that about 5.5% of adults may die during this period (Section E.5), and this figure can be used with the age ratios discussed above to calculate the juvenile mortality, and hence the total population reduction during this period.

This calculation indicates that a September/October starting population of 8.0 young birds and 2.0 adults (80% young birds, total population 10.0) would normally be reduced to 2.835 young birds and 1.890 adults by mid-January (adult mortality 5.5%,
60% young birds, total population 4.725). Thus, mortality of young birds is 65% and the total population is reduced by 53%. Any increase in adult mortality, for example if recovery data underestimated adult mortality in these months, would also imply increased mortality of young birds.

These data strongly suggest that the three or four months between the autumn peak and mid-January are months of high mortality, a view supported by Newton's data (Table E.1).

Recoveries of ringed birds show that many young bullfinches die shortly after fledging, before the autumn age ratio peak (Section E.5). This implies that more than 65% of bullfinches may die before mid-January, and that the average pair of bullfinches might fledge more than eight young for the peak ratio still to reach 80% young birds.

This combination of a high reproductive rate, followed by a high mortality of young birds which is probably density-dependent (Newton 1967), suggests that artificial reduction of bullfinch populations at this time might be difficult. Fruit growers trap and shoot bullfinches mostly in autumn, when they can most easily be killed in large numbers, but this may have little impact on the January population level.

Sex ratios

Monthly BRC 19 data from S.E. and S.W. England have been summarised in Tables E.7 and E.8 and show changes in the sex ratio of mist-netted bullfinches. These changes are similar to those recorded by Newton (Table E.2). Most notable is that in both regions, in all four years, males predominated in summer; the excess was significant in S.E. England in all four years (P<0.001) and in S.W. England in 1976, 1977 and 1979 (P<0.01). Combined data from all four years indicate an overall mean summer percentage of males of 60.4% (equivalent to 1.53 males : 1 female) in S.E. England, and 57.5% (1.35 males : 1 female) in S.W.
Table E.7. Sex ratios of bullfinches

Data are from form BRC 19, S.E. England; all forms and all sexed birds included.

<table>
<thead>
<tr>
<th>months</th>
<th>1976</th>
<th>1977</th>
<th>1978</th>
<th>1979</th>
<th>all years</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) adults¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan-Apr</td>
<td>55 (539)</td>
<td>49 (583)</td>
<td>52 (477)</td>
<td>52 (653)</td>
<td>51.8 (2252)</td>
</tr>
<tr>
<td>May-Aug</td>
<td>60 (1276)</td>
<td>58 (974)</td>
<td>63 (874)</td>
<td>61 (923)</td>
<td>60.4 (4047)</td>
</tr>
<tr>
<td>Sep-Dec</td>
<td>58 (453)</td>
<td>51 (417)</td>
<td>58 (286)</td>
<td>56 (308)</td>
<td>55.6 (1464)</td>
</tr>
<tr>
<td>all months</td>
<td>58.6 (2268)</td>
<td>54.0 (1974)</td>
<td>58.7 (1637)</td>
<td>56.7 (1884)</td>
<td>56.9 (7763)</td>
</tr>
</tbody>
</table>

b) juveniles²

| Oct-Dec³ | 44 (494) | 42 (770) | 49 (615) | 55 (467) | 46.9 (2346) |

1. Birds hatched in the previous year or earlier.
2. Birds hatched in that year.
3. Juveniles caught before October were frequently not sexed.
Table E.8. Sex ratios of bullfinches

Data are as Table E.7, but for S.W. England.

<table>
<thead>
<tr>
<th>months</th>
<th>1976</th>
<th>1977</th>
<th>1978</th>
<th>1979</th>
<th>all years</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) adults&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan-Apr</td>
<td>48 (141)</td>
<td>55 (154)</td>
<td>47 (106)</td>
<td>47 (79)</td>
<td>49.8 (480)</td>
</tr>
<tr>
<td>May-Aug</td>
<td>56 (454)</td>
<td>58 (302)</td>
<td>57 (184)</td>
<td>60 (182)</td>
<td>57.5 (1122)</td>
</tr>
<tr>
<td>Sep-Dec</td>
<td>51 (81)</td>
<td>52 (58)</td>
<td>56 (72)</td>
<td>51 (37)</td>
<td>52.4 (248)</td>
</tr>
<tr>
<td>all months</td>
<td>54.1 (676)</td>
<td>56.4 (514)</td>
<td>53.9 (362)</td>
<td>55.4 (298)</td>
<td>54.9 (1850)</td>
</tr>
</tbody>
</table>

b) juveniles<sup>2</sup>

| Oct-Dec<sup>3</sup> | 49 (142) | 46 (109) | 45 (133) | 36 (74) | 45.0 (458) |

1. Birds hatched in the previous year or earlier.
2. Birds hatched in that year.
3. Juveniles caught before October were frequently not sexed.
England; in both regions the excess of males was highly significant (P<0.001).

In the months following breeding, there was always a slightly smaller excess of adult males; the overall mean percentage of males was 55.6% (1.25 males : 1 female) in S.E. England and 52.4% (1.10 males : 1 female) in S.W. England. Significant excesses of males were found only in S.E. England: in 1976 (P<0.001), 1978 (P<0.01), 1979 (P<0.05) and in combined data for all four years (P<0.001). However, amongst young birds caught in October to December, when almost all can be sexed, there was nearly always a slight excess of females. This was significant in S.E. England in 1976 (P<0.05), 1977 (P<0.01), 1979 (P<0.05) and in combined data for all four years (P<0.01); it was significant in S.W. England in 1979 (P<0.05) and in combined data (P<0.05). As a result, if data from both age classes are combined (October to December only) the overall percentage of males is only 49.9% in S.E. England and 47.2% in S.W. England (1.00 males : 1 female, and 0.89 males : 1 female, respectively) - not a significant difference in either case.

During January to April, 51.8% of bullfinches caught in S.E. England were male (1.07 males : 1 female) compared to 49.8% (0.99 males : 1 female) in S.W. England; only in S.E. England in 1976 was there a significant excess of males (P<0.05).

Combined sex ratio data for adults were also examined for significant differences between seasons. In S.E. England the mean percentage males caught in each season was significantly different from each of those in the other seasons (P<0.01 and P< 0.001). In S.W. England the mean percentage males caught in summer differed significantly from those in spring and autumn (P<0.05), but spring and autumn data were not significantly different.

It is not known whether equal numbers of male and female bullfinches hatch; although it may be possible to sex nestlings by the colour of their tertials (Newton 1964b), no data have been published. However, data presented above indicate that, at least
in some years, more females than males survive to the end of their first calendar year. Comparative data for other species are few, but in the great tit more males than females fledge and males may have the higher winter survival rate (Dhondt 1970, Perrins 1979). These authors suggest that both these facts are caused by the natural dominance of males over females - males are generally larger than females. This is interesting since, although male and female bullfinches are of similar size (Newton 1966), females are usually dominant (Newton 1960, 1972, and personal observation during this study). Competition for food is thus likely to favour females and result in the observed excess of this sex.

A further drop in the percentage males might have been expected between autumn and spring, as competition for food continued. However, many of the bullfinches which die at this time are young birds - of both sexes - so the very slight residual excess of males in spring is not surprising.

The large excess of males in summer is also to be expected, since females spend a lot of time on the nest and so are less likely to be caught in mist nets by ringers. Perhaps of greater interest is the apparent excess of males in autumn - a greater excess than in spring. This suggests that, in summer, females suffer greater mortality than males. As Perrins (1979) suggested for tits, female bullfinches may regularly be caught at the nest by predators; only very rarely are people likely to witness such events, so predictably there are few, if any, ringing recoveries of this nature.

These data can be usefully compared with recoveries of ringed bullfinches and with birds trapped by fruit growers (Sections E.5, and D.2. Trapping).
Data from ringing recoveries

The effect of age and sex on mortality

Introduction

About 2% of ringed bullfinches are subsequently recovered (Mead 1974, Summers 1979), either dead, or caught by other ringers (usually termed controls). These amount to about 100 birds each year. Details of each recovery may include the age and sex of the bird, time and place of ringing, time and place of recovery, cause of death, and the time elapsed and distance moved between ringing and finding. As part of this study, 1229 bullfinch recoveries from the years 1967-78 were analysed. Some initial sorting and tabulation was possible using the B.T.O. computer, but recoveries were also sorted by hand.1

A smaller sample, from the years 1966-70, was analysed by Glue et al. (1971) to compare bullfinch with greenfinch mortality (Fig. E.2). They suggested that most bullfinches died between January and August, with peaks of mortality in mid-winter (January and February) and mid-summer (June and July). The lull in March and April was attributed to the use of buds as a food source at this time. Greenfinches, which do not eat buds, show a similar pattern of mortality, but with a single peak in spring (April).

In this study, the larger sample of recoveries enabled a more detailed analysis to be done. For example, the mortality of bullfinches of different ages has been examined separately. For this, bullfinches aged by the ringer as code 1, 3, or 5 (see Table E.3) are particularly useful, since their hatching year and hence their age are known. The overall pattern of recoveries analysed in this study (Fig. E.3) is predictably similar to that described by Glue et al., though there seem to be fewer winter recoveries - a difference worth investigating further.

1. As with the previous section, except where they are specifically attributed to other workers, all data and analyses discussed in Section E.5 result from my examination of these recoveries.
Figure E.2. The seasonal distribution of recoveries of greenfinches and bullfinches, expressed as the percentage of all recoveries.

From Glue, Flegg and Dymond (1971) as figured in Mead (1974)

Figure E.3. The seasonal distribution of recoveries of bullfinches, expressed as the percentage of the total sample of 1229 recoveries analysed in this study.
Before the pattern of recoveries is examined in detail, it is important to be aware of potential biases. These fall into two main categories:

a) Inevitably, recoveries tend to be made near areas of human populations, and the causes of death biased towards those that involve people—directly or indirectly. For example, a bird caught by a hawk in woodland is much less likely to be found than a bird killed by traffic in the centre of a town. The pattern of recoveries is dependent on man's ability to find the dead birds, and this varies with vegetation cover, weather, and the colour of the bird's plumage. For example, a dull-coloured female or juvenile bullfinch in thick grass on a wet and windy day is less likely to be found than a brightly-coloured male bullfinch on short grass on a warm summer day. In other words, many ringed bullfinches may die quite undetected, and the timing and cause of these deaths may differ from most recoveries.

For birds such as gulls, which are conspicuous and often associated with man, it may be safe to assume that the bias is only small (Flegg and Cox 1975), but for bullfinches, which are shy and inconspicuous, the bias may be large. The fact that retrap data sometimes indicate different mortality patterns from recovery data (Perrins 1971, Flegg 1973, Batten 1978, Newton 1979, and Tyler 1979) confirms the existence of such biases.

b) Even if ringing recoveries show the mortality pattern of the ringed population, this may differ from that of the whole population. In months when birds are being ringed, the probability of recovering dead ringed birds increases simply because there are more ringed birds in the population. At the other extreme, very few nestling bullfinches are ringed, so that no matter how heavy post-fledging mortality is, the probability of recovering many one-month-old bullfinches is small. Thus recoveries could indicate low summer mortality, even though juvenile mortality at this time was high. Careful examination of recoveries is therefore necessary.
Adult mortality

The seasonal mortality pattern of adult bullfinches is not given by recoveries of birds ringed as adults (code 6) because the proportion of the adult population which is ringed increases during the year as more and more are caught, and a greater and greater percentage of the total mortality would be represented by the ringing recoveries. Adult mortality is better shown by recoveries of birds ringed as juveniles (code 3) and recovered in or after their third calendar year (Fig. E.4). Birds given age code 1 or 5 could be treated similarly, or in addition, but those given code 3 are most numerous.

These data indicate that most adults die in January, February, May, June and July. Fewer die in March, April and August, and almost none in the last four months of the year: these have a total of only 2% of the year's recoveries.

Mortality of birds dying in their second calendar year

The seasonal mortality pattern of bullfinches dying in their second calendar year is not given by recoveries of birds ringed at this age (code 5), partly because of reasons given in the previous section with regard to adult mortality, and partly because birds dying at several years of age would also be included. As with adults, the pattern is better shown by recoveries of birds ringed as juveniles (code 3), but this time dying in their second calendar year (Fig. E.5).

Compared to adult mortality, there is little evidence of a spring lull in second-year mortality. September to December again have little mortality, with a total of only 6% of the year's recoveries.
Figure E.4. The seasonal distribution of recoveries of bullfinches ringed as code 3 and recovered in or after their third calendar year, expressed as the percentage of the total sample of 138 birds. Recoveries were sorted by hand during this study.

Figure E.5. The seasonal distribution of recoveries of bullfinches ringed as code 3 and recovered during their second calendar year, expressed as the percentage of the total sample of 258 birds. Recoveries were sorted by hand during this study.
Mortality of birds dying in their first calendar year

The seasonal mortality pattern of bullfinches dying in their first calendar year is not given by all recoveries of birds ringed as juveniles (code 3) at this time, since very few are caught until autumn and earlier mortality would be under-represented, and because birds dying several years later would be included. There are very few recoveries of bullfinches ringed as nestlings, so I have included some juvenile data as follows:

<table>
<thead>
<tr>
<th>Month</th>
<th>Recoveries included and sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>Bullfinches ringed as nestlings or juveniles in May or June; 8 died in July and a further 11 by the following June.</td>
</tr>
<tr>
<td>August</td>
<td>Bullfinches ringed as nestlings or juveniles up until July; 8 died in August and a further 52 by the following July.</td>
</tr>
<tr>
<td>September</td>
<td>Bullfinches ringed as nestlings or juveniles up until &amp; October August; 8 died in both months and a further 121 by the following August.</td>
</tr>
<tr>
<td>November</td>
<td>Bullfinches ringed as nestlings or juveniles up until &amp;December October; 18 died in November, 30 in December and a further 194 by the following October.</td>
</tr>
</tbody>
</table>

Compensation for different sample sizes has been made, and the resulting seasonal pattern is shown in Fig. E.6.

Data for the earliest months (July, August and September) are biased towards early-fledging birds which seem to suffer very high post-fledging mortality. Of seven recoveries of July- and August-ringed nestlings, only one was found dead before December, perhaps indicating a higher survival rate.

The data probably suffer from one further bias. Comparison of sex ratios of bullfinches ringed and recovered (see page 315) suggests that females are found less often than males. If this effect is caused by plumage differences (females being less conspicuous), then a similar effect might be expected with
Figure E.6. The seasonal distribution of recoveries of bullfinches in their first calendar year.

See text for method and sample size. Recoveries were sorted by hand during this study.
bullfinches in juvenile plumage, and the mortality up to about September may have been underestimated.

In conclusion, it seems that at least early-fledging bullfinches are at greatest risk immediately after fledging. September and October are relatively easy months, but recoveries increase from then until the end of the year.

Bullfinch mortality in the first, second and subsequent years

Data from the three previous sections have been combined to produce a model of bullfinch mortality in the first, second and subsequent calendar years of life (Fig. E.7).

Mortality is conspicuously high in July, when 30% of fledged bullfinches may die. Survivors, and perhaps later-fledging birds, may then have a relatively easy period of about two months. The following December to July have high mortality, but very few bullfinches seem to die in the months of September to December in the second or subsequent years. Adult bullfinches are recovered most often in January and February, or May, June and July, with a distinct intervening lull.

Annual mortality rates

Using the method described by Lack (1948), the percentage annual mortality rates of juvenile and adult bullfinches have been calculated. Recoveries of 522 birds ringed before the end of their first calendar year (age code 3) followed the pattern given below. Each year is taken to start on 1 August and end on 31 July.

<table>
<thead>
<tr>
<th>Year of recovery</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of recoveries</td>
<td>352</td>
<td>98</td>
<td>36</td>
<td>16</td>
<td>12</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>
Figure E.7. The seasonal distribution of recoveries of bullfinches in their first, second and subsequent calendar years, from Figs. E.4, E.5 and E.6.
Thus 67% died in the first year, slightly less than the 72% calculated by Newton (1964b) by the same method from a smaller sample. Of 30 recoveries of bullfinches ringed as nestlings, 23 (77%) died before 31 July of the next year, and data presented in Fig. E.7 indicate that 80% of nestling and newly-fledged bullfinches die in this period. However, each of these estimates is subject to the biases discussed in the section of first-year mortality.

Adult mortality is given by the following formula:

\[
\frac{D_2 + D_3 + D_4 + D_5 \text{ etc.}}{D_2 + 2D_3 + 3D_4 + 4D_5 \text{ etc.}}
\]

where \( D_2, D_3 \text{ etc.} \) is the number recovered in their 2nd, 3rd year etc.

Using this formula and data given above, adult mortality is 55% each year, less than the 68% calculated by Newton (1964b) but more than the c. 50% estimated by Bibby (1974). Recoveries indicate adult mortalities of similar magnitude in other passerines, such as mistle thrush (Snow 1969), blackbird (Batten 1978), great tit (Perrins 1979) and dipper (Galbraith and Tyler 1982). Whilst 55% mortality may not be representative of all adult bullfinches (i.e. if recoveries contain a large proportion of less-fit birds than the population as a whole), it can be combined with data from form BRC 19 (Section E.4) to produce a further estimate of juvenile mortality. The peak ratio of juvenile to adult bullfinches caught was 8 juveniles to 2 adults in September or October. In a stable population with 55% adult mortality, 0.9 adults and 1.1 juveniles - now one year old - would remain the following autumn, equivalent to 55% 'juveniles', which is consistent with the available ringing and catching data. This suggests that 86% of juvenile bullfinches alive in September or October die before the same time the following year. Once again, if mortality immediately following fledging is high, even 86% may be an underestimate of mortality between fledging and 31 July of the following year.
Male and female mortality

As male and female bullfinches have different behaviour patterns, at least during the breeding season, they may have different seasonal mortality patterns. Table E.9 shows that, throughout the year, many more male bullfinches are recovered than females; of sexed recoveries, 64.0% are males.

Table E.9. Sex of bullfinch recoveries (excluding controls)
Recoveries were sorted by hand during this study.

<table>
<thead>
<tr>
<th>months</th>
<th>male</th>
<th>female</th>
<th>unknown</th>
<th>sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-Apr</td>
<td>53.5(59.8)</td>
<td>36.0(40.2)</td>
<td>10.5</td>
<td>428</td>
</tr>
<tr>
<td>May-Aug</td>
<td>58.2(68.5)</td>
<td>26.8(31.5)</td>
<td>15.1</td>
<td>564</td>
</tr>
<tr>
<td>Sep-Dec</td>
<td>48.2(60.2)</td>
<td>31.8(39.8)</td>
<td>19.9</td>
<td>166</td>
</tr>
<tr>
<td>all months</td>
<td>55.0(64.0)</td>
<td>30.9(36.0)</td>
<td>14.1</td>
<td>1158</td>
</tr>
</tbody>
</table>

This preponderance of males is only partly due to more males than females being ringed. Examination of BRC 19 forms for 1976 indicated that, in this year, 54.2% of bullfinches ringed and sexed were males. (Although ringing data for other years were not examined, Table E.7 shows that birds caught in 1976 – including retraps – contained a similar proportion of males to the average for 1976-79). Thus, recoveries contain about 10% more males than expected. It is most unlikely that the discrepancy would be resolved if the sex of the 'unknown' birds were known, since all these would have to be male for recoveries to match the ringing data. Furthermore, most of the 'unknowns' were ringed – and some also found – when still in juvenile plumage, so they probably include both males and females.

There are two possible explanations for the discrepancy. First, males may be more prone to dying close to or because of people and their activities, and secondly, males may be seen and
examined closely by people because of their bright plumage. During the first and last four months of the year there are no major behavioural differences between the sexes, so they should be vulnerable to the same causes of death, yet 59.8 and 60.2% of sexed recoveries during these months are males. This suggests that males are found more often because of their bright colours. Between May and August, 68.5% of sexed recoveries are males, and this increased preponderance of males could be due to a greater tendency to die close to or because of people, or to a genuinely high summer mortality (or both). On page 303 it was suggested that males might have a slightly lower summer mortality than females, resulting in a post-breeding excess of males, and this would indicate that males that die in summer often succumb to causes involving people. Various reported causes of death are listed in Table E.10, but neither sex seems noticeably more vulnerable than the other to any single cause.
E.5.2. \textbf{Mortality causes}

\textbf{Introduction}

It has already been stressed that ringing recoveries may not give an accurate picture of bullfinch mortality, and this becomes even more obvious when the causes of death are examined (Table E.10). As with most species, the most frequent category is 'found dead', i.e. the cause of death is not known, but, when the cause is known, it is almost always a direct or indirect result of people. Of 1,229 bullfinch recoveries, only 16 (1.3\%) were attributed to predation by wild birds or animals, or bad weather - the only natural causes reported. It should be remembered that whilst over 50\% of recovered birds die as a result of cats, traffic, shooting, trapping or collisions with windows, 98\% of ringed bullfinches die undetected.

Nevertheless, detailed examination of bullfinch recoveries provides a valuable insight into the months and ways in which they are particularly vulnerable, even if the reported cause of death is the 'final straw' rather than the primary cause of death. For some causes of death, it is particularly useful to compare the seasonal mortality pattern of different age groups or sexes, bearing in mind the various biases discussed in the previous sections, in particular that post-fledging mortality is very much under-represented by the recoveries as a whole. I have not attempted to investigate regional differences or changes from year to year, though this might provide useful information.

Considerable uniformity is apparent in the relative frequencies of finding circumstances of male, female and unsexed bullfinches. The recoveries of unsexed birds include all those which died before acquiring adult plumage, and therefore probably include a greater percentage of young birds than the male and female samples. The most conspicuous difference between the two groups is that very few unsexed bullfinches were controlled, compared to males and females, but this may simply be due to sexing by both the finding and ringing ringer.
Figs. E.8 and E.9 show, for each cause of death, the number and percentage of recoveries reported in each month. Each of the causes of death are discussed in the following sections.

Table E.10. Finding circumstances of ringed bullfinches

Based on computer analysis of recoveries carried out during this study

<table>
<thead>
<tr>
<th>cause of death</th>
<th>male</th>
<th>female</th>
<th>unknown</th>
<th>all birds</th>
</tr>
</thead>
<tbody>
<tr>
<td>unknown (found dead)</td>
<td>36.0</td>
<td>37.9</td>
<td>39.8</td>
<td>36.9</td>
</tr>
<tr>
<td>cat</td>
<td>16.6</td>
<td>17.3</td>
<td>19.9</td>
<td>17.2</td>
</tr>
<tr>
<td>window</td>
<td>12.3</td>
<td>11.3</td>
<td>12.7</td>
<td>11.9</td>
</tr>
<tr>
<td>traffic</td>
<td>12.4</td>
<td>11.1</td>
<td>8.4</td>
<td>11.5</td>
</tr>
<tr>
<td>controlled(^1)</td>
<td>5.6</td>
<td>7.7</td>
<td>1.8</td>
<td>5.8</td>
</tr>
<tr>
<td>shot</td>
<td>5.6</td>
<td>5.7</td>
<td>5.4</td>
<td>5.6</td>
</tr>
<tr>
<td>trapped by fruit grower</td>
<td>5.5</td>
<td>4.9</td>
<td>6.0</td>
<td>5.4</td>
</tr>
<tr>
<td>entangled in netting</td>
<td>2.5</td>
<td>1.8</td>
<td>3.0</td>
<td>2.4</td>
</tr>
<tr>
<td>trapped in building</td>
<td>1.6</td>
<td>1.5</td>
<td>0.6</td>
<td>1.5</td>
</tr>
<tr>
<td>wild bird or animal</td>
<td>0.9</td>
<td>0.5</td>
<td>1.2</td>
<td>0.8</td>
</tr>
<tr>
<td>bad weather</td>
<td>0.7</td>
<td>0.3</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>other(^2)</td>
<td>0.7</td>
<td>0.5</td>
<td>0.6</td>
<td>0.7</td>
</tr>
</tbody>
</table>

1. These birds did not die; controlled birds are caught and released by ringers.
2. Includes bullfinches drowned (6), attracted to a domestic animal (1), and 'ring caused recovery' (1).

Found dead

The cause of death was unknown for 36.9% of bullfinch recoveries, but the monthly pattern resembles the cumulative pattern of the other finding circumstances, and this suggests that many of these birds died as a result of other known mortality factors. Birds that died of starvation may also be included in
Figure E.8. The seasonal distribution of recoveries of bullfinches caused by various factors, expressed as the number of birds recovered each month.

Recoveries were sorted by hand during this study.

'Other' includes wild bird or animal, bad weather, drowned, attracted to domestic animal and 'ring caused recovery'.
Figure E.9. The seasonal distribution of recoveries of bullfinches caused by various factors, expressed as the percentage of each month's recoveries. Recoveries were sorted by hand during this study. 'Other' includes wild bird or animal, bad weather, drowned, attracted to domestic animal and 'ring caused recovery'.
this category, since such birds might have no obvious symptoms. The proportion of recoveries that were 'found dead' was greatest between January and April, and this may indicate that food shortage and associated causes like an inability to maintain body temperature overnight are most common at this time of year.

**Cats**

Recoveries attributed to cats (or other domestic animals) comprised 17.2% of the total. The mortality pattern resembles that of all recoveries, and particularly that of adult birds (Fig. E.4). There are two peaks, one in summer and one in winter, and predation by cats as a percentage of all recoveries is greatest during these peaks - up to 28% in August.

The monthly pattern should reflect the tendency both for cats to hunt for birds, and for birds to be easily caught. Cold, wet and windy winter months with short days are probably not conducive to hunting, so one might expect a gradual reduction in recoveries towards winter. In this respect, the observed winter peak and the marked August to September drop in predation are of note.

Bullfinches are most likely to be caught by cats when they are most numerous (e.g. after the breeding season), when they feed close to the ground, when young, inexperienced birds are available, and when unwary birds (perhaps in poor condition) are numerous. Few of the numerous young bullfinches about in autumn are ringed, and this may account for the relative lack of recoveries in September; even despite this, 59% of recoveries between September and December are young birds. The mass of summer recoveries, which stops abruptly after August, is almost entirely made up of adult bullfinches, and this suggests that breeding birds are vulnerable to cat predation - in many years breeding may end in August. The start of the summer peak is in April or May - when breeding starts. Breeding bullfinches may be vulnerable for two reasons. First, breeding may at times be a strain on the birds, these becoming less wary than at other times.
Second, and perhaps of greater importance, breeding birds visit the nest site many times, especially when feeding young, and cats may capitalise on this by positioning themselves close to the nest to catch the parents. In September and October, recoveries due to cats are still frequent compared to other finding circumstances, but much reduced in number. This suggests that cats are still actively hunting, but that the bullfinches may be more difficult to catch. Moult in the bullfinch reaches a peak in these months, and they may become more secretive at this time.

The most likely explanation of the slight winter peak in predation by cats is that at this time, when food and day-length are short, bullfinches have to spend much of their time feeding and less time watching for cats. They also visit gardens in search of buds, and may therefore be more vulnerable. Bullfinches probably feed close to the ground most often in summer, and this too may result in higher predation by cats.

The pattern of male and female recoveries (Table E.11) follows the pattern described for all recoveries in Section E.5, with a preponderance of males caught in summer. Nearly 20% of recoveries of unsexed bullfinches were caught by cats, compared to about 17% of males and females (Table E.10), and this suggests that young, inexperienced birds are particularly vulnerable to cat predation.

Table E.11. The sex of ringed bullfinches caught by cats
Recoveries were sorted by hand during this study

<table>
<thead>
<tr>
<th>months</th>
<th>% of total (and % of sexed birds)</th>
<th>sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>male (and)</td>
<td>female (and)</td>
</tr>
<tr>
<td>Jan-Apr</td>
<td>41(50)</td>
<td>41(50)</td>
</tr>
<tr>
<td>May-Aug</td>
<td>63(72)</td>
<td>25(28)</td>
</tr>
<tr>
<td>Sep-Dec</td>
<td>34(45)</td>
<td>41(55)</td>
</tr>
<tr>
<td>all months</td>
<td>53(63)</td>
<td>31(37)</td>
</tr>
</tbody>
</table>
Deaths reported to be due to collisions with glass (or occasionally wires) comprised 11.9% of recoveries. The monthly pattern resembles that of all recoveries except that window deaths are fairly common in November and December, whereas deaths due to most other mortality factors are rare in these months.

Collisions with glass can be complete accidents, where a bird hits a window during normal flight, or, at least in some species, they may be due to territorial behaviour, where a bird attacks its own reflection. A third possibility is that, having entered a building, perhaps in search of a nest-site, a bird might fly into a window while attempting to escape, but this idea is not strongly supported by the distribution of recoveries resulting from birds trapped inside buildings; this appears to be a spring and summer activity and rarely occurs in winter (page 327).

In most species, territoriality is restricted to a few months of the year, and is usually displayed by one sex more than the other. Bullfinches are not territorial, so reflection-attacking is unlikely to be common, and, in addition, a detailed examination of recoveries did not indicate a bias towards either sex. Of 146 recoveries, 56% were male (65% of sexed recoveries) and between May and August 59% were male (70% of sexed recoveries). In each case, these percentages are almost identical to those of all recoveries given in Table E.9. The slight summer increase in males may be due simply to the fact that, since they do not incubate, they spend more time flying, and thus increase the risk of hitting obstacles.

It therefore seems likely that, for bullfinches, window casualties are usually complete accidents. The two peaks of mortality may be due to unwary and hurried birds during times of food shortage or during the breeding season. The lack of September and October recoveries suggests that at this time, perhaps while moulting, bullfinches tend to stay away from houses and gardens; a detailed examination of the age of the birds recovered shows that adults are very rarely found in August, when
the moult usually starts. Both adults and young birds are involved from November onwards, perhaps as they are attracted back to gardens to feed on buds of cultivated trees and bushes.

**Traffic**

Recoveries involving collision with moving vehicles comprised 11.5% of the total, though some were merely found dead beside a road and therefore presumed to be traffic casualties. Of these recoveries, 74.5% were found in the months of May to August, with a peak in June when traffic accounted for 21% of all recoveries. Although the amount of traffic varies during the year, and may be heaviest in summer, this alone could not result in the observed pattern of recoveries.

As with other mortality factors, juvenile bullfinches are probably under-represented, and some effect of feeding height might be expected. However, like the pattern of cat-caught recoveries, the mass of traffic recoveries during the breeding season suggests that breeding behaviour causes accidents. Such breeding behaviour might include the use of roadside hedges as nest-sites, and repeated flights to and from feeding areas; roadside hedges are often dense and prickly, and are thus ideal for bullfinch nests, and feeding sites are often some distance away. In addition, bullfinches often feed on verges and banks close to roads in summer, and many are probably killed by cars as a result.

There is a very slight peak of traffic casualties in January and February, which may be caused by birds in poor condition as a result of bad weather and food shortage. Such birds may be less able to avoid fast-moving vehicles.

Several authors have described methodical surveys of corpses of all bird species found on roads through the year. A summer peak in mortality seems to be common to nearly all species; Hodson and Snow (1965) listed only house sparrow, wren and robin as standing out from this general pattern. Subsidiary winter
peaks are not common, though Finnis (1960) noted that song thrushes appeared more vulnerable than blackbirds during periods of snow. Hodson (1960) thought that the most important factor governing bird casualty figures was the speed and density of traffic, but also listed breeding activity and post-breeding flock movements to grain fields (primarily of house sparrows) as other major factors, and other authors have also expressed these views. Hodson (1962) also examined the types of road borders most often associated with casualties, and found that openings, for example in hedgerows, were particularly dangerous.

Perhaps the most interesting reports are those of Dunthorn and Errington (1964), and Hodson and Snow (1965), since these attempted to assess the biological importance of the traffic hazard. The former authors ringed many nestlings in hedges and farm buildings adjacent to roads, and noted that at least 11% of song thrushes, 12% of blackbirds, 3% of linnets and 4% of house sparrows were subsequently hit by traffic. These conclusions refer primarily to nestlings and to roadside populations, so cannot be applied to whole populations of these or other species. However, some of the conclusions reached by Hodson and Snow can be applied in this way. The survey they described covered a total of 349 miles of road and can be used (though with obvious caution) to provide estimates of bird casualty figures over Great Britain as a whole. Only for the house sparrow did calculations suggest that road deaths represented an appreciable percentage (estimated at 12.5%) of the total annual mortality of the species. Only 15 bullfinches were found in the survey (compared to 2,365 house sparrows), suggesting that 7,000 might die on roads in Great Britain each year. If, as Sharrock (1976) suggested, the total population of bullfinches is about 600,000 pairs, over 3 million probably die each year (including young birds). Thus, road deaths may account for less than 0.2% of bullfinch mortality.
Controls

Controls totalled 5.8% of recoveries, with small numbers in all months. Few ringed bullfinches are found dead in autumn, so controlled birds comprised a large percentage of recoveries at this time - up to 23% in October. Bullfinches ringed and retrapped by the same ringer at the same site (i.e. retraps) are not reported as controls - only those caught by a second ringer or those moving some distance are reported. Since different ringers rarely operate close together, a large percentage of controls had moved some distance: 43.7% had moved 10+km, a much larger percentage than in other recovery circumstances (Table E.13, Section E.8). The monthly pattern of controls may therefore be influenced by the times of year at which bullfinches most often move. There is a similarity between this pattern and the pattern of retraps (data from form BRC 19), and this may simply reflect the number of bullfinches caught and the percentage of these that are ringed. It is standard practice for ringers to identify the sex of all birds caught when this is possible. Probably as a result, controlled bullfinches of unknown sex are relatively rare compared to other recovery circumstances (Table E.10).

Controlled bullfinches are discussed further in Section E.8.

Shooting

Of all bullfinch recoveries, 5.6% were shot, and 69% of these were killed between January and April. Young bullfinches may be more easily shot than older birds, so the numbers shot in autumn, when few young birds are ringed, may be under-represented. Nevertheless, the winter and early spring peak is almost certainly caused by the actions of fruit growers protecting orchards at this time. Unlike trapping, which is easily continued throughout the year, shooting is best carried out when there are few leaves on the trees, and when the birds are feeding within the orchards, and this is probably why there are so few recoveries of shot birds.
between May and October. The shotgun is the largest single known mortality factor in March, when shot bullfinches comprise 16% of all recoveries.

Of shot bullfinches, 15.9% had moved 10km or more from the ringing site (Table E.13), twice as many as trapped birds. This may indicate that these birds had flown some distance in search of food (presumably fruit-buds) at this time.

Trapping

Bullfinches trapped intentionally by man (mostly fruit growers) comprised 5.4% of the total. The monthly pattern shows similarities to the pattern of controlled bullfinches, with only slight peaks in summer and perhaps winter (January), and can be compared with trapping data presented in Section D.2. Clearly the recovery pattern does not reflect the number of bullfinches trapped by fruit growers each month; most growers only trap in autumn and early winter, when bullfinches are easy to catch. This apparent discrepancy is probably caused by the fact that most bullfinches caught at this time are young birds, and therefore only a small percentage of them is ringed.

Trapped bullfinches comprised 15% of October recoveries, this peak being largely due to the lack of recoveries attributed to other causes at this time. Nevertheless, since the number of bullfinches trapped in autumn is very much underestimated by these data, the autumn peak is probably similarly underestimated. As experienced in this study, most bullfinches trapped in summer are males (Table E.12).

Table E.13 shows that only 7.6% of trapped birds had moved 10km or more. Furthermore, none of the 16 males trapped in summer had moved this far, a fact which suggests that these were locally-nesting individuals rather than unpaired birds wandering in search of mates (see also Section D.2. Trapping).
Table E.12. The sex of trapped bullfinches

Recoveries were sorted by hand during this study

<table>
<thead>
<tr>
<th>months</th>
<th>male</th>
<th>female</th>
<th>unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-Apr</td>
<td>9</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>May-Aug</td>
<td>16</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Sep-Dec</td>
<td>12</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>all months</td>
<td>37</td>
<td>19</td>
<td>10</td>
</tr>
</tbody>
</table>

Netting

Netting in which the birds became entangled caused 2.4% of bullfinch recoveries. Although entangled bullfinches were found in all months except November, most were reported in June and July, when many gardeners and soft fruit growers cover fruit bushes with fine netting. An almost identical pattern was reported for blackbirds (Batten 1978). Bullfinches do occasionally become entangled in 'cotton' intended to deter them from eating fruit buds, but deaths as a result of this would occur mainly in winter and spring.

Buildings

Of all bullfinch recoveries, 1.5% came from birds trapped inside buildings and other man-made structures. Deaths in this category are most frequent in April and May - at the beginning of the breeding season - and this suggests that these birds may possibly have been searching for nest-sites. In support of this, Nest Record Cards show that bullfinches do occasionally nest in ivy and other climbing plants on the walls of buildings. Both males and females were involved.
Wild birds and animals

The 10 recoveries in this category were classified as follows: long-eared owl (3), tawny owl (1), owl (1), kestrel (1), sparrowhawk (1), predatory bird (2), and wild animal (1). Since all the recoveries due to owls and both those due to predatory birds were described as either 'dead in owl pellet' or 'long dead', it is unlikely that the monthly pattern accurately reflects the times of year when these birds died. Six were males, two females and two unsexed.

Predation of bullfinches by wild birds and animals is probably far greater than these data suggest. Since most birds caught in this way are immediately eaten, the chances of finding the ring (in a pellet, droppings or on the remaining carcass) are slim. The predominance of owl-pellet recoveries is not surprising since many people dissect pellets out of curiosity or scientific interest.

On the other hand, predation is unlikely to limit bullfinch populations. Bullfinches may be caught by all five of the widespread British owls, but only in small numbers (Glue 1972). Kestrels take some bullfinches (Newton 1964a), and birds occasionally form their principal prey. However, open-country birds such as skylarks and meadow pipits are likely to be kestrels' most numerous victims (Davis 1975, Village 1982). Sparrowhawks feed almost entirely on birds, often in wooded districts. In recent years they have become much more widespread (Sharrock 1976), but in none of the studies summarised by Cramp and Simmons (1980) did bullfinches form more than 5% of the diet.

Bad weather

Six recoveries (0.5% of the total) were due to cold or stormy weather between December and March. Bad weather is one of the few reported mortality factors not connected with man and his activities or pets. Away from heavily-populated areas, many bullfinches may die because of bad weather and yet remain unfound.
On the other hand, the winter peaks of mortality due to cats and traffic may be a result of bullfinches being in poor condition during spells of snow etc.
E.5.3. Discussion

Killing bullfinches, either by shooting or trapping, is one of the primary methods employed by fruit growers to combat the bullfinch problem. The aim is to reduce the number of bullfinches eating buds on their farms either temporarily or permanently. It has long been thought that food shortage controls the upper limit of most bird populations (Lack 1954), including the bullfinch (Newton 1967), and ringing recoveries give some indication of the ways in which this control may be effected. It is therefore useful to consider shooting and trapping in the light of recovery data.

Perhaps the major point of interest is that juvenile mortality is much higher than that of adults. Recoveries of nestlings and newly-fledged bullfinches suggest that about 80% of these die by the end of July in their second calendar year, but this estimate assumes that the percentage of dead ringed birds that are reported to the B.T.O. does not vary with the age of the birds concerned, and that reported birds are representative of all bullfinches. The highest estimate of juvenile bullfinch mortality came from a comparison of age ratios of mist-netted birds and adult mortality as indicated by recoveries. This suggested that 86% of juvenile bullfinches alive in September and October die by July of the following year. If juveniles are more easily netted than adults in autumn, then this estimate will be too high. An adult mortality of 55% is suggested by ringing recoveries and age ratios of bullfinches caught in mid-summer. In a stable population, 1.1 juveniles from each pair would replace the adult losses. This implies juvenile mortality by mid-summer ranging from 73% if each pair fledged four nestlings, to 89% if each pair fledged ten nestlings.

Clearly, many (especially young) bullfinches die each year, and it could be argued that the effect of shooting and trapping is merely to allow other birds to survive (since there is more food to go round), or at most to bring forward the death of the birds concerned by only a short period of time. Whilst food may be the limiting factor, it is not clear exactly when
bullfinches die most often. Retrap data from form BRC 19 suggest that many young birds die between the autumn age-ratio peak and January. Recoveries indicate heaviest mortality of young birds immediately after fledging and subsequently from about December onwards. If mortality of adults and juveniles were to follow the pattern shown by recoveries, the age ratio of bullfinch populations would change only slowly for most of the year; only in July would a much greater proportion of juveniles die than adults. Clearly, at least one of the sets of data gives a false impression of bullfinch mortality.

Considering the many biases affecting recoveries, retrap data probably show most accurately the timing and extent of bullfinch mortality. Both Newton's (1964a and 1964b) local population study summarised in Section E.2 and this study (Section E.7) confirm that autumn and early winter have high juvenile mortality. If, as seems likely, this mortality is density-dependent, additional man-imposed mortality as a result of shooting and trapping (which kills primarily young birds) may have little impact on the population. Over the whole country, a total of 11% of recoveries were shot or trapped, and, whilst these factors may be more important locally, their obvious association with people probably increases their chance of being found and reported to the B.T.O. above all other known mortality factors. A very large increase in man-imposed mortality would be needed if the British population were to be markedly reduced.

Recoveries may accurately identify the timing of peak adult mortality - though probably not the magnitude of these peaks. The two peaks indicated are in winter and summer, and they probably coincide with times of food shortage and breeding, respectively. At these times bullfinches spend most of the daylight hours foraging for themselves or their young, sometimes in unfamiliar or exposed surroundings. As a result, some may be hungry and less vigilant and, in many cases, ringing recoveries probably result from such weakened birds; they are found and reported to the B.T.O. because they happened to succumb close to human habitation. Winter and/or breeding season peaks of mortality have been identified in a wide variety of recently-
studied birds, (e.g. gulls: Flegg and Morgan 1976, kingfisher: Morgan and G...
E.6. **Common Birds Census results**

Since 1962, the B.T.O. has organised a survey known as the Common Birds Census (C.B.C.). Observers adopt sites in farmland or woodland and visit them several times during the breeding season, recording territorial behaviour of all species encountered. The number of breeding pairs on the site is then estimated. For many species, the results give an excellent measure of fluctuations in the size of breeding populations, for example showing the effects of hard winters (Bailey 1967, Cawthorne and Marchant 1980). Bullfinch C.B.C. data are shown in Fig. E.10.

The bullfinch C.B.C. indices for woodland and farmland show broadly similar trends. A general rise is apparent between 1968 and 1974, after which the farmland index declined. In recent years, the most noticeable change was between 1977 and 1978, when woodland and farmland indices fell by 27 and 23% respectively. The fluctuations do not seem to correlate with winter temperatures, ash seed availability or bud damage severity. The coldest winters during the period were 1962/63 and 1978/79 (Cawthorne and Marchant 1980), yet a decrease was observed only for the 1978/79 farmland index. This observation is not surprising since neither of the local population studies operative in these winters (Newton 1964a, and this study) recorded marked mortality compared to subsequent milder winters. Ash pollen, and therefore perhaps ash seed, was relatively scarce in 1963, 65, 73, 74, 75 and 76 (see Section F), but the indices rose or were stable in at least four of these years. Bud damage was severe following 1963, 64 and 67 (see Section F), perhaps indicating a shortage of seeds in these winters, yet only in 1967/68 was there a fall in the indices.

Although large populations of bullfinches may result from large supplies of wild seeds (and thus a reduced need to eat buds), many bullfinches obviously have a greater bud-eating potential than just a few, so severe damage might be expected to follow years when the C.B.C. indices were high. Once again, this
Figure E.10. Bullfinch population indices in farmland and woodland from the Common Birds Census.


Thick lines indicate significant changes (P<0.05).
hypothesis is not supported by the data; damage data shown in Fig. F.1. seem quite unrelated to the height of the C.B.C. indices.

For some bird pests, national breeding population estimates may be of considerable help in assessing damage levels (Weatherhead et al. 1982), but comparisons made here suggest that this may not be true of the bullfinch. There are at least two main reasons for this. Firstly, as Snow (1965) described, C.B.C. techniques give only a 'very poor' estimation of the absolute size of breeding bullfinch populations, probably because observations of territorial behaviour in bullfinches are rare. The indices may still show general trends in the size of the population, but errors caused by variation in observers' ability to detect breeding bullfinches may be considerable (Bell et al. 1973). Secondly, the number of bullfinches alive in winter and early spring when bud-eating occurs may not always vary in line with the previous or subsequent breeding populations, since variations in breeding success and mortality will also be important. A third potential disadvantage with C.B.C. indices is that often they may not reflect local population fluctuations, for example in fruit growing areas. In this respect, it is interesting that Newton (1964a) recorded a decrease in the number of bullfinches in Marley Wood, Oxfordshire, between 1963 and 1964, and that Bibby (1974) recorded a marked decrease in bullfinches at Wicken Fen, Cambridgeshire, between 1969 and 1970, followed by a doubling of the population by 1972. In neither instance do their data support C.B.C. data.
The bullfinch population in the study area

Introduction

In this study, three methods of assessing the size and mobility of the bullfinch population in the study area were used. These were: observation and counts of bullfinches seen in the area, a small programme of ringing, and the fitting of coded tags to many of the birds caught.

Bullfinches do not hold territories (Nicolai (1956) found that they were not aggressive towards decoys even when placed near the nest), nor do they sing loudly or perch regularly in prominent places. They are therefore not easily counted. Standard line transect census and B.T.O. Common Birds Census techniques rely largely on this type of behaviour, so they are of limited use with bullfinches. However, frequent visits were made to the study area and observation of bullfinches enabled a general impression of the population size to be gained. Wright and Summers (1960) found this sort of technique to be fairly reliable for bullfinches. During each visit, as much of the area as possible was covered on foot, sometimes by two observers. By comparing place and time of sightings, the number of bullfinches present on any one day could be estimated.

Observation of bullfinches does not show how many different individuals may be visiting an area over a period of days. Therefore, between mid-1978 and early 1980, 127 bullfinches were caught in mist nets within the study area and ringed. Many were subsequently retrapped (up to six times). Mist nets were erected at various sites, depending on weather conditions (e.g. wind direction), the places where bullfinches were expected to be present, the extent of woodland clearance, and access (permission to net some areas was not requested until partway through the ringing programme). About 170m of nets could be used, and, in order to increase catches, two individually-caged bullfinches were usually placed close to one or two of the nets. All birds were aged, sexed, measured and weighed at a base and released within a few minutes of capture. In addition, some nestling bullfinches were ringed.
Following approval from the B.T.O., most bullfinches caught were fitted with individually colour-coded back tags (Plate E). These were constructed of a leather harness and a strip of plastic or nylon-coated vinyl (Saflag), bound together with cotton (Fig. E.11). Saflag (marketed by The Safety Flag Co. of America) proved most suitable; it is soft, durable, and can be ordered in 'fluorescent day-glo' colours. By gluing strips of Saflag together, or by marking the tag with black permanent ink, a simple two (maximum three) colour code was made. Tags were assembled before netting days, so that only a few minutes were needed to fit them to the birds. A tagged bird could then be identified individually without the need for recapture, though a good view was necessary so binoculars were essential, and often a telescope and tripod were helpful. Many tagged birds were sighted by waiting at known feeding areas; such sightings were particularly useful in late 1979 and 1980.

Each tag weighed only 0.6-0.9g and after an initial period of preening they had no visible effect on the birds' behaviour. Despite the fact that many of the birds tagged were juveniles and therefore prone to moving elsewhere or dying of natural causes, nearly 60% were subsequently retrapped or sighted. The first birds were tagged in the summer of 1978 and at least one of these was known to be alive two years later when observation was terminated.

Results

Analysis of ringing and retrap data by the methods of Fisher and Ford (1947) and Jolly (1965) was carried out by Dr. Hounsome on the Manchester University computer. Fig. E.12 shows the estimated population size between September 1978 and March 1980. Monthly estimates are variable due to small samples, so quarterly estimates are also given.

The population was largest in autumn: about 95-120 birds in 1978 and 116-148 in 1979, but a considerable reduction occurred by January in both the following years. About 55 birds were
Figure E.11. Colour-coded back tags fitted to bullfinches in the study area.

1. Addition of rapid-drying waterproof glue prevented thread untying.
2. A leather bootlace cut in half lengthwise.
**Figure E.12.** The number of bullfinches in the study area as indicated by a programme of ringing.

Methods used were those described by Fisher and Ford (1947): January to March 1980 only, and Jolly (1965): all other months including quarterly estimates.
frequenting the study area in the first quarter of both 1979 and 1980, although in May 1979 there seemed to be an influx of unringed birds, perhaps indicating some movement of bullfinches at this time. Probably as a result of using captive call birds near to the mist nets, the sample of bullfinches caught contained a larger proportion of young birds than might have been expected. For example, 85% of bullfinches caught between September and December were first-year birds, as were 67% of the January to March catch (cf. Fig. E.1). Nevertheless, this bias does not prevent the drawing of conclusions about the population.

All estimates of the number of bullfinches present in the study area on any one day (from field observations) were lower than the population estimates from ringing data. This, however, is not surprising, since bullfinches were often seen flying into and out of the study area. On any one day during the periods of damage to the orchard, no more than 20 bullfinches were thought to be present. The ringing data indicate that over a period of time other birds visited the orchard - the 'resident' population was constantly changing.

During April and May 1980, bullfinches were observed feeding in oak trees adjacent to the orchard. Tagged and untagged birds were involved, and several pairs were identified in which at least one of the birds was tagged. Data indicate that about 40 individuals were visiting these trees; not an unreasonable number if the total study area population was 50-60, as indicated by the ringing data.

In the summer of 1980, bullfinches were observed feeding in a field at the edge of the study area. Identification of tags showed that at least nine pairs were involved, some flying 600m to and from their nests. Clearance of woodland had by this time reduced the available nesting habitat considerably, and a residual population of nine pairs within reach of this field is not inconsistent with ringing data.

The nests of some pairs were located and the flight paths of several pairs were recorded. This was facilitated by
the tags, especially when long distances were involved. A concerted effort to find all breeding pairs and nests was not made, since many of the nests were thought to be just outside the study area, in private or inaccessible areas.

**Trapping**

In 1978, in an attempt to reduce the number of bullfinches feeding on buds within the study orchard, the owner set up two chardonneret traps in the adjacent woodland. He caught about 50 bullfinches between July and December 1978. In addition, about 70 bullfinches were caught about 0.75 km to the south of the study orchard. Bullfinches ringed in or near the study orchard were present in both these samples (five in the first and two in the second). Between September and November 1979, about 50 bullfinches, including two ringed in the study area, were trapped 0.75 km from the study orchard. Most trapped birds were juveniles (see page 236) and were caught when only a small proportion of the juveniles were ringed - hence the apparently low recovery rate of ringed birds, even close to the study orchard.

It seems likely that the lower autumn population peak in 1978 compared with 1979 was, in part, caused by trapping within the study area in 1978. However, there is no evidence to suggest that trapping in autumn affected the population during the months of January to March when bud-eating occurred. In both years, the population at this time contained about 55 birds. Seed supplies were probably more plentiful in the first of these winters since damage started late. Shortage of seeds may have caused the large mortality indicated by ringing data in 1979/80. It is not known how large the population would have been in the absence of trapping, and further data are needed before definite conclusions can be drawn.
E.8. Movement

It is commonly said that bullfinches are sedentary, and this forms the basis for arguments for trapping and shooting as potential damage preventatives. It is important to understand what 'sedentary' means if the efficacy of shooting and trapping is to be predicted.

Newton (1964b) found that little movement occurred around Marley Wood, Oxfordshire, in the early 1960's. Of some 400 bullfinches ringed in Marley, 146 were retrapped within the wood, four were retrapped in a wood less than a mile away, two were recovered half a mile away, eight were found dead in gardens a mile away, and one was caught alive three miles away. All these emigrants were first-year birds. In addition, of 500 bullfinches ringed within a mile of Marley, only 12 were caught in Marley and four recovered over a mile from where they were ringed. He concluded that movements were few and of short range. Nevertheless, some movement had occurred; the preponderance of retraps within Marley and the surrounding land is to be expected, since a lot of time was spent netting these areas. Newton found that movement was most frequent in spring and was predominantly of first-year males. He suggested that these birds 'circulated' at this time, moving in no particular direction, perhaps in search of a mate.

Summers (1979) listed recoveries of bullfinches ringed in Kent in the late 1950's. Of 94 recoveries, 92 had been shot or trapped by fruit growers, and only three had moved over 2km (none more than 5km). He concluded that neither dispersal nor the winter foraging range normally exceeded 2km from the ringing site. However, Summers also presented data from B.T.O. ringing recoveries covering the periods of 1910 to 60 and 1961 to 74, and suggested that an increase in movement had occurred. The percentage of birds moving 5–25km rose from 6.5 to 17.0%, and those moving over 25km rose from 0.5 to 5.2%, most movements being associated with particular years, perhaps when ash crops were small and damage to orchards was high. He also suggested that
more adults than first-year and more female than male bullfinches were involved.

Of 559 British ringed bullfinches recovered between 1972 and 1976, 9.1% had moved 10-100km and 0.5% over 100km (Spencer and Hudson 1978).

In a population with no immigration or emigration, a rise in retrap percentage should occur when more birds are ringed. The extent of this rise depends on the number of extra birds ringed and the size of the population. If a decrease in retrap percentage is recorded (or a smaller rise than is expected), this could indicate movement of unringed birds into the population.

In bullfinch populations, immigration obviously occurs each summer when newly-fledged unringed birds depress the overall retrap percentage, but this form of immigration can be excluded from calculations if birds fledged in one year are treated separately from birds fledged in all other years. It was the variation in retrap percentages that led Newton to conclude that male bullfinches moved in spring (see above).

At first sight, BRC 19 forms might appear to contain a mass of retrap data which could be analysed in this way. In practice, such analyses have two disadvantages. First, small-scale movements may affect retrap percentages and yet be of little importance to growers. For example, breeding birds, or perhaps newly-fledged birds, may tend to be retrapped very frequently because they often visit particular places (e.g. nest site or nearby feeding areas). At other times of year, more varied movement over only slightly larger distances will reduce the retrap percentage - even though no real immigration has occurred.

Second, and perhaps more important, is the effect of ringer behaviour. If ringers always caught birds at the same sites all year round, then even small changes in retrap percentages might indicate movement. However, many ringers operate at some sites only at one time of year. The overall
retrap percentage tends to decrease when intensively worked sites are abandoned, and when new sites are adopted.

Table E.13. Movement of bullfinch recoveries
Data were analysed by hand during this study

<table>
<thead>
<tr>
<th>recovery circumstance</th>
<th>0-9km</th>
<th>10-24km</th>
<th>25-99km</th>
<th>100+km</th>
<th>sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>controlled</td>
<td>56.3</td>
<td>33.8</td>
<td>8.4</td>
<td>1.4</td>
<td>71</td>
</tr>
<tr>
<td>shot</td>
<td>84.1</td>
<td>7.2</td>
<td>5.8</td>
<td>2.9</td>
<td>69</td>
</tr>
<tr>
<td>window</td>
<td>91.1</td>
<td>6.2</td>
<td>2.1</td>
<td>0.7</td>
<td>146</td>
</tr>
<tr>
<td>traffic</td>
<td>91.5</td>
<td>4.3</td>
<td>2.8</td>
<td>1.4</td>
<td>141</td>
</tr>
<tr>
<td>trapped</td>
<td>92.4</td>
<td>4.5</td>
<td>3.0</td>
<td>0.0</td>
<td>66</td>
</tr>
<tr>
<td>cat</td>
<td>92.4</td>
<td>5.2</td>
<td>1.9</td>
<td>0.5</td>
<td>211</td>
</tr>
</tbody>
</table>

Recoveries analysed in Section E.5. caused by the six major known circumstances were also examined for distances travelled (Table E.13). Clearly bullfinches recovered as controls move, on average, much further than those recovered as a result of other circumstances (the variation among the six circumstances was significant (P<0.01). Different ringers normally operate some miles apart, so the high proportion of long-distance controls is not surprising. Shot birds seemed to have moved further than all but controlled birds, though the variation among the five last circumstances was not statistically significant. The overall movement indicated by these data (12.4% moving 10+km, and 4.3% moving 25+km) agrees well with the recent analyses mentioned above.

Controls comprise a greater proportion of female bullfinch recoveries than of males (Fig. E.10), and this might indicate greater movement of females between ringing sites. However, this hypothesis is not supported by a more detailed examination of these recoveries; 56% of controls were male—compared to about 54% of bullfinches ringed (see page 314). Thus there is no appreciable bias towards either sex being controlled;
the apparent bias in Table E.10 is probably caused by a bias towards males in other recovery circumstances. All controls (of either sex) are likely to be reported to the B.T.O. ringing office, in contrast to birds found dead.

Table E.14. Movement of sexed bullfinch controls
Recoveries were sorted by hand during this study

<table>
<thead>
<tr>
<th>months</th>
<th>sex</th>
<th>0-9km</th>
<th>10+km</th>
<th>sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-Apr</td>
<td>male</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>May-Aug</td>
<td>male</td>
<td>12</td>
<td>9</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>5</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Sep-Dec</td>
<td>male</td>
<td>5</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>6</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>all months</td>
<td>male</td>
<td>22</td>
<td>16</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>16</td>
<td>14</td>
<td>30</td>
</tr>
</tbody>
</table>

Table E.14 shows the distances moved by male and female controls during the year. 42% of males and 47% of females had moved 10+km (not a significant difference). Considering bullfinches in all recovery categories, Summers (1979) suggested that more females than males moved long distances, and studies on other species have indicated a similar bias (see Greenwood et al. 1979, Burgess 1982). However, the latter authors argue that movement of females results primarily from a breeding system in which the male is dominant and defends the territory. Since male bullfinches are subordinate to females, and do not hold territories, movement might be expected to be, if anything, biased towards males.

The data indicate that more movement of females was recorded between September and December than in the other two seasons, and this was found to be significant (P<0.05). The month
of movement could be narrowed down to five or less months of the year for six female recoveries. Of these, only one could not have moved in autumn (ringed in March, recovered in June); the others all moved between July and December (all could have moved in October).

Males may have moved in all months as Table E.14 indicates. The month of movement could be narrowed down to five or less months of the year for four birds and, as with females, movement may be most frequent in autumn and early winter, since three of these birds were known to have moved between August and January, compared to one that moved between May and August.

In this study, 13 bullfinches were recovered within 1km of the orchard, though nine of these were trapped by the grower. One first-year male was trapped 2-3km away in May (having been present in the study area in January), and another first-year male was trapped 9km south east of the study area in January (having been present in the study area in September). Breeding bullfinches were observed foraging at least 600m from their nest, so it would be surprising if they did not move further than this at other times of the year when they are not constrained to return to one place many times each day. In winter, when seed supplies become patchily distributed, it would seem beneficial to have a wide foraging range.

Observation of bullfinches in the study area in winter, before pairing had taken place, suggested that the population was to some degree mobile, because the birds present on one day were not usually the same as were present the following day, each bird presumably wandering over a wider area.

To sum up, bullfinches may indeed be sedentary compared to many species, but it seems that many may move short distances, perhaps particularly in autumn when the population is largest (and when trapping is easiest). Summers' (1979) analysis of recent ringing recoveries suggests that 22.2% of bullfinches move over 5km; presumably many more move, say, 2km, and perhaps the majority move 1-2km regularly. As a result, any grower planning to reduce
the population of bullfinches on his farm will probably have to contend with birds within a radius of about 2 km and perhaps further if the farm habitat is good and bullfinches are attracted to it. At a density of only five pairs/km² this could amount to over 600 birds in autumn; at 50 pairs/km², as Newton (1972) found in Oxfordshire, over 6,000 bullfinches could be within reach at this time.
In the past 20 years, the 'ash theory' has been developed to explain bullfinch damage to orchards (Newton 1964a, Summers 1979). This theory suggests that bullfinches eat fruit buds only when seed stocks run out and that the seeds of ash trees, because they vary in numbers each year, are largely responsible for annual fluctuations in bud damage. Sights like those in Plate F - large bunches of ash keys and undamaged pear trees - might therefore be expected to go together. Furthermore, the size of ash pollen counts has been used as a measure of the size of the seed crop and hence as a damage indicator.

Fig. F.1 summarises ash pollen count, bullfinch damage and ash consumption data from several sources. Close correlation between pollen counts and the subsequent crop may exist for many wind-pollinated species (Cour and Bousquet 1981), and Hyde (1963) established a correlation between ash pollen counts and the ensuing ash seed crops between 1942 and 1961 - pollen counts were made at the Asthma Research Unit in Cardiff and seed crops assessed in England and Wales by the Forestry Commission. This period was characterised by years of bumper pollen fall interspersed between years of poor pollen fall. In the seven years in which pollen fall was below 30% of average the seed crops were rated as poor to very bad or failure, and in at least two of the four bumper pollen fall years the seed crops were good to very good. Enormous fluctuations in pollen fall were recorded between 1959 and 1962. As might be expected if the theory is correct, bullfinch damage was severe in several years between 1942 and 1963, and, at least between 1959 and 1963, severe damage and poor pollen fall alternated with slight damage and good pollen fall (Brough 1962, Newton 1967).

As Fig. F.1 indicates, pollen fall can be measured with a gravity slide (Hyde 1963) or with a volumetric spore trap (Hirst 1952). The spore trap is the more efficient technique, though both receive pollen mainly from nearby trees and plants. At Cardiff, where both techniques were run together between 1955 and 1971, annual counts since 1964 have not varied as much as in
Plate F. Over 1,000 ash keys in autumn (top), and undamaged pear trees covered in blossom in spring (bottom).

Published research suggests that damage is slight when the ash seed crop is good.
ASH POLLEN COUNTS

Cardiff¹
3000
2000
1000

Derby³
Cardiff²

20000
2000
1000

severe —
moderate —
slight —

high —
low —

data reproduced from Summers (1979)

BUD DAMAGE TO ORCHARDS

data reproduced from Summers (1981)

data from this study (Section C.8)

data summarised from Newton (1964a, 1967)

ASH KEY CONSUMPTION

data reproduced from Summers (1981)

data from the study area at Brenchley

Figure F.1. Ash crops and bullfinch diets.

1. Data from gravity slide (total pollen grains/5cm²), from Hyde (1963) and Summers (1979).
2 & 3. Data from spore traps (total pollen grains/m³), supplied by Dr. J. Mullins (Cardiff) and F. Jackson (Derby). The Cardiff trap was resited in 1962, but a correction factor has been applied.
4. Damage and ash consumption in the following winter, e.g. 1959 = the winter of 1959/60.
previous years. Thus between 1964 and 1971 data from the gravity slide show fluctuations only from 56 to 155% of the average. Data from the Cardiff spore trap show 1965 and 1976 to be particularly poor years (19 and 18% of average respectively) and 1970 to be a good year (232% of average), but in all other years between 1967 and 1979 this trap recorded fluctuations only from 40 to 123% of average.

If similar small fluctuations in ash pollen fall occurred in fruit growing areas in England since 1964 (even though Cardiff is, for example, 170 miles from Kent), ash seed crops in these areas may have been mostly average, and one could infer that severe damage should have been rare - perhaps restricted to the winters of 1965/66 and 1976/77. Summers (1979) found some support for this line of reasoning but, as Fig. F.1 shows, he recorded severe damage in 1964/65 and 1967/68, even though the preceding pollen counts had not been markedly below average.

During periods of near average ash pollen fall, other factors are likely to have their greatest effect on the seed crop and on bullfinch damage. Average pollen falls may sometimes not result in average seed crops; Summers suggested that the seed crop produced in 1967 was reduced by a wet spring and late frosts in May, which caused poor pollination and set. Ultimately, pollen fall is probably controlled largely by the climate, and different parts of the country may have different patterns of weather and therefore different patterns of pollen fall. Although Hyde (1963) found that ash pollen counts made at Cardiff were correlated with ash seed crops throughout England and Wales (and, to a lesser extent, as far as Denmark), pollen counts made at the Derby Chest Clinic in later years (Fig. F.1) show only minor similarities to those from Cardiff and marked differences in some years.

It is data from intensive studies on individual fruit farms which most clearly show that the 'ash theory' is, at best, a simplistic model. Damage to orchards recorded by Summers (1981) between 1969 and 1974 (Fig. F.1) is not strongly correlated with Cardiff pollen counts; it seems more closely correlated with Derby pollen counts. Also, there seems to be little correlation between
the ash eaten by bullfinches and the pollen counts during this period. Summers did find a significant negative correlation between the consumption of ash seed in January and damage, but also found that the timing of bud swell was an important factor—with more damage in years when buds swelled late.

Pollen counts from both Derby and Cardiff indicated that, during this study, less ash should have been available in 1978/79 than in the preceding or following winters, and some reflection of this was found in the number of fruiting trees (Section B.3). However, neither the amount of ash seed eaten, nor the pattern of damage seemed related to the number of fruiting trees; of apparently greater importance in the winter of 1978/79, was an abundance of bramble seeds, which probably delayed bud-feeding by about six weeks. In some years bullfinches may eat few herbaceous seeds because ash seeds are abundant, but in 1978/79 the reverse may have been true. The abundance of seeds such as bramble may be affected by weather conditions and by the effect of other predators (e.g. greenfinches and man). Birch seeds are an important food source for bullfinches in some parts of Britain (Newton 1967) and this seed crop also varies in size—rarely in step with ash seed crops (Hyde 1963). Suffice to say, whenever alternative seeds to ash are available in large quantities, they can cushion the effects of a bad ash crop.

In theory, if ash keys are preferred to buds, then bud-eating should not occur in years when sufficient keys are available. When an ash tree has a crop of seeds, it often has several thousands of them and thus represents a very concentrated food source; feeding bullfinches need spend very little time searching for keys, and only when the crop is virtually exhausted will their feeding efficiency be markedly reduced. Calculations based on seed consumption of captive bullfinches suggest that one large ash tree could support one bullfinch for a whole winter. Therefore, in any one area, depending on the number of bullfinches to be fed, damage to orchards should be inversely correlated with the ash crop only when the number of fruiting trees is below the threshold level.
However, data from this study (Section B.5) indicate that more ash trees may be needed than might have been expected, since the keys of many trees may not be suitable. In some areas, only a small percentage of trees may bear suitable keys, and damage could therefore be severe even when pollen counts are high and the ash seed crop is large. Allowance must also be made for keys falling naturally, since many of these are then unavailable to bullfinches.

Apart from questioning the all-importance of ash keys, this study has also added considerably to our knowledge of buds as a food source. Weather conditions were shown to influence the development of both cultivated fruit buds (Sections B.4.2 and B.4.3) and the wild alternatives (Section B.4.4). Warm weather caused rapid bud swell and cool weather slowed it down. Both the size (or weight) and the chemical constituents of the buds were affected so that in the cold winter of 1978/79 development was a full month later than in the warmer winter of 1979/80. Furthermore, these changes within the buds, and particularly within the central flower initials eaten by bullfinches, were found to be considerable: for example, the weight of Conference initials rose by ca. 300% in February 1980 and their dry weight protein concentration rose by ca. 20% in the same month. Bullfinches eat buds only when these are within certain developmental stages, and although the most important criteria have yet to be defined, it is clear that by influencing bud development, weather conditions also influence the times of year at which buds are best eaten. Thus, in the study orchard, warm weather late in the year seemed to advance bud development sufficiently for them to be eaten early in the winter, whilst cold weather in the later stages of bud development seemed to prevent buds bursting and thereby prolong the damage period.

Data collected during this study also showed that the buds of both wild and cultivated species vary annually in their chemical composition and, by inference, their nutritional value to bullfinches. As discussed on page 63, it seems likely that a heavy crop of pears tends to result in buds of low nutritional value in the following year, and hence less damage. Since wild
and cultivated buds differ in the degree and timing of their response to temperature, and since years of good and bad seed or fruit crops are unlikely to be synchronised, the choice of buds (or of seeds) made by bullfinches at any one time and location will depend on the availability and quality of each food type.

In Britain as a whole, it is probably fair to say that ash keys are a very important source of food for bullfinches in autumn and winter. Therefore, at a national level, the severity of bullfinch damage may be inversely correlated with the size of the ash seed crop or pollen fall, even when fluctuations in the latter are small. Locally, however, as summarised above, other factors play an important part in determining the severity of bullfinch damage to orchards. Only when ash pollen falls and seed crops approach the very high levels recorded in 1960 and 1962 can growers feel justifiably confident of a relatively damage-free winter, and only when the ash seed crop fails, as in 1961, can they be fairly sure of incurring heavy damage.

Having emphasised the complexity of bullfinch damage, it is now necessary to consider what practical advice could be offered to growers. Without exception, the first step should be to assess the need to do anything at all, in other words to assess whether or not the loss of buds is likely to result in a loss of crop. Fortunately, the most widely damaged top fruit variety - Conference pear - is remarkably tolerant, and in the study orchard in the three years followed, crops were not affected by up to 70, 80 and 90% loss of buds respectively. Whilst such tolerance might not occur in all years or in all fruit varieties, growers would be wise to record the progress of damage within an orchard carefully and, when the opportunity arises, to calculate the precise effect of the damage on the final crop for future reference.

Ideally, such assessment involves counting buds damaged and undamaged on several sample branches at regular intervals during the winter. When the buds begin to burst, bullfinches usually turn to alternative foods, so, if the development of the buds is also recorded by a series of measurements and
observations, the final level of damage can be predicted. If the damage is likely to be less than that which causes a loss of crop, no further action should be taken, especially since fruit size, bud numbers in the following year and even numbers of fruits may all be increased by moderate levels of bud loss (Section C.4). This study showed that on Conference trees the rate of damage usually drops considerably in March and loss of 70% of buds may regularly be tolerated without loss of crop. Data for other varieties are fewer, but growers are in any case well advised to keep records of their own trees, since no two situations will be identical.

If, on the other hand, damage is likely to increase to a level which would result in a loss of crop, a variety of steps should be considered. The initial reaction of many growers is to attempt to kill the offending birds, but this task is rarely easy (Section D.2). Many more birds may be involved than is at first thought, and others may move into the area shortly after some are killed. Furthermore, the remaining birds are likely to encounter less competition for food and may therefore survive in greater numbers than they would have done. The main point here is that only intensive and persistent shooting or trapping is likely to be fully effective. If it can be fitted into the orchard management routine, a month's concentrated effort immediately prior to the expected start of damage (or, in the case of tolerant varieties, before damage reaches critical levels) may be more effective than less intensive action over several previous months. Better results might be achieved if birds are shot and trapped concurrently.

With regard to the wide variety of deterrent techniques designed to make bullfinches feed elsewhere, it is important to realise that bullfinches almost always have a choice of foods available to them. Bullfinches can be found throughout Britain and Ireland (Fig. B.1), and only in parts of Southern England do they have access to fruit buds; even here wild buds and seeds are usually available. Therefore, all that is necessary is to render the vulnerable orchard trees less attractive than the alternatives, and any legitimate deterrent techniques that give
this result should be considered. Apart from netting, which hardly qualifies as a deterrent, none of the techniques monitored in this study gave full protection, and there is a need for further cooperation between manufacturers, research workers and fruit growers in this field, particularly in the production and testing of chemical repellents. As described in Section D.3, deterrents tend to lose their effect after a while, so use of several different deterrents over a period of weeks is advisable.

It cannot be over-emphasised that varieties with some degree of tolerance should not be protected until damage approaches critical levels. Delaying the use of deterrents in this way may save time and money, and will ensure maximum effect when it is needed. Furthermore, only vulnerable trees should be protected; if damage can be spread evenly over many trees its effect on the crop may be eliminated.

In the study area, the severity and effects of bullfinch damage were permanently reduced by clearance of hedges, scrub and woodland adjacent to the orchard. However, many growers have a great interest in, and respect for, the wildlife of their farms, and therefore might not consider some of these measures. Nevertheless, their knowledge of natural history should help them to manipulate the orchard and its environment with a view to minimising the effects of bullfinch damage. Only by making careful observations is it possible to identify the key factors influencing which trees suffer loss of crop, and hence to plan the best course of action.

Lastly, it is appropriate to return to fruit trees, and in particular to the many varieties which exist and which are continually being bred. As this study has shown, bullfinches select their diet from a range of alternative foods, often displaying preferences which may be hard to explain. Selection between outwardly similar varieties provides one of the greatest puzzles and demands the attention of fruit growers and research workers alike. A detailed survey of such preferences, coupled with chemical analyses and observation of feeding birds, would contribute much to our understanding of bullfinch damage, and
might open the way for the production of varieties which are immune from attack. In introducing Section D, it was observed that a sensibly positioned orchard well away from bullfinches is the most effective method of preventing damage. Careful choice and positioning of varieties could be a cost-free and equally viable alternative to this solution. Avoidance of the bullfinch problem in such ways should be greatly preferable to attempting to combat it.
ACKNOWLEDGEMENTS

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Finally, I must record here my heartfelt thanks to Liz, my wife, for constant encouragement and for typing this thesis.
Appendix 1. **Latin names of birds mentioned in text**

<table>
<thead>
<tr>
<th>English Name</th>
<th>Scientific Name</th>
</tr>
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<tbody>
<tr>
<td>Blackbird</td>
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</tr>
<tr>
<td>Blue Tit</td>
<td><em>Parus caeruleus</em></td>
</tr>
<tr>
<td>Bullfinch</td>
<td><em>Pyrrhula pyrrhula</em></td>
</tr>
<tr>
<td>Chaffinch</td>
<td><em>Fringilla coelebs</em></td>
</tr>
<tr>
<td>Common Grackle</td>
<td><em>Quiscalus quiscula</em></td>
</tr>
<tr>
<td>Dipper</td>
<td><em>Cinclus cinclus</em></td>
</tr>
<tr>
<td>Great Tit</td>
<td><em>Parus major</em></td>
</tr>
<tr>
<td>Greenfinch</td>
<td><em>Carduelis chloris</em></td>
</tr>
<tr>
<td>Grey Wagtail</td>
<td><em>Motacilla cinerea</em></td>
</tr>
<tr>
<td>House Sparrow</td>
<td><em>Passer domesticus</em></td>
</tr>
<tr>
<td>Kestrel</td>
<td><em>Falco tinnunculus</em></td>
</tr>
<tr>
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<td><em>Alcedo atthis</em></td>
</tr>
<tr>
<td>Lapwing</td>
<td><em>Vanellus vanellus</em></td>
</tr>
<tr>
<td>Linnet</td>
<td><em>Acanthis cannabina</em></td>
</tr>
<tr>
<td>Meadow Pipit</td>
<td><em>Anthus pratensis</em></td>
</tr>
<tr>
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<td><em>Turdus viscivorus</em></td>
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<tr>
<td>Oystercatcher</td>
<td><em>Haematopus ostralegus</em></td>
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<td>Red-winged Blackbird</td>
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<tr>
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<tr>
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</tr>
<tr>
<td>Sparrowhawk</td>
<td><em>Asio flammeus</em></td>
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<tr>
<td>Starling</td>
<td><em>Alauda arvensis</em></td>
</tr>
<tr>
<td>Woodpigeon</td>
<td><em>Columba palumbus</em></td>
</tr>
<tr>
<td>Wren</td>
<td><em>Troglydtes troglodytes</em></td>
</tr>
<tr>
<td>Plant</td>
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</tr>
<tr>
<td>-------------------------------</td>
<td>----------------------------</td>
</tr>
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</tr>
<tr>
<td>Bramble (Blackberry)</td>
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</tr>
<tr>
<td>Broad-leaved Dock</td>
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</tr>
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</tr>
<tr>
<td>Chickweed</td>
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<td>Greater Stitchwort</td>
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<td>Hazel</td>
<td><em>Corylus avellana</em></td>
</tr>
<tr>
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</tr>
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<tr>
<td>Red-veined Dock</td>
<td><em>Rumex sanguineus</em></td>
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<td>Wild Service Tree</td>
<td><em>Sorbus torminalis</em></td>
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Appendix 3. Results of the 1981/82 ash key survey

Some mean measurements recorded (see also Fig. B.25).
Parentheses indicate samples smaller than 20 keys.

<table>
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<th>tree</th>
<th>key width at 5mm (mm)</th>
<th>kernel-to-tip distance (mm)</th>
<th>husk thickness (mm)</th>
<th>kernel width (mm)</th>
<th>kernel thickness (mm)</th>
<th>kernel weight (mg)</th>
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contd.
Appendix 3 (contd.)

Habitats, keys remaining on the trees (KR), and the percentage of fallen keys which had been husked by bullfinches (%H).

Parentheses indicate samples smaller than 50 keys.

<table>
<thead>
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<th>bullfinch</th>
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<th>January</th>
<th>March</th>
</tr>
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<tr>
<td></td>
<td>KR</td>
<td>%H</td>
<td>KR</td>
<td>%H</td>
</tr>
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<td>440</td>
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<td>(0)</td>
<td>920</td>
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<td>B</td>
<td>13,600</td>
<td>71</td>
<td>1,000</td>
</tr>
<tr>
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<td>A</td>
<td>1,000</td>
<td>(38)</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>B</td>
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<td>4,000</td>
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<td>0</td>
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<td>140</td>
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<td>650</td>
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