THE PROTECTION OF WOODLANDS

G. W. ST. CLAIR THOMPSON

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BY NATURAL AS OPPOSED TO ARTIFICIAL METHODS

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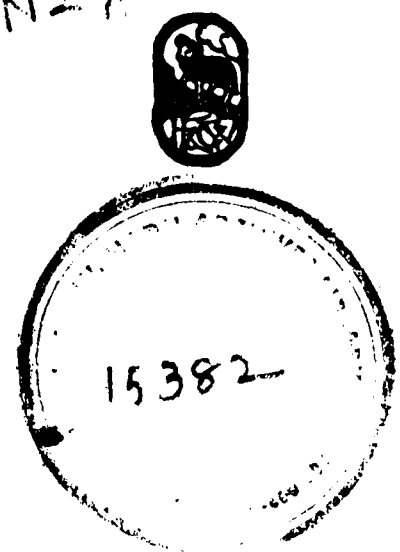
WITH TEXT FIGURES

H. F. & G. WITHERBY
326 HIGH HOLBORN, LONDON, W.C.
1928



Printed for Messrs. H. F. & G. Witherby by the Lowestoft Press; Lowestoft

PREFACE

The primary object of this work is not the discussion of pest destruction, but of pest prevention; for it is believed that the cause and not the effect of damage should receive first attention. In other words: prevention is better than cure. Rational forest protection takes that form which can both economically and permanently exclude or control the injurious fauna, and prevent it from ever attaining the proportions of a pest.

For these reasons, which are more fully elaborated in Chapter IV, natural is to be preferred to artificial protection; therefore the writer has endeavoured to show to what extent this condition can be fulfilled by the influence of good silviculture, which again can best be done by the consideration of the natural forest (Chapter I).

When silvicultural methods fail, it is necessary to introduce biological measures of control; and when both these natural forms of protection are unavailing, then, and only then, is it economic to take special artificial precautions.

To be practical, forest protection must be regarded from the standpoint of the tree, rather than of the insect, bird, or animal. It is unfortunate, therefore,

that so little is known about the economy of birds and animals, particularly the former, that it has been found necessary to go into such detail in Chapters II and III.

As far as the writer is aware, this aspect of Forestry, namely the study of animals and birds in relation to silviculture, has never yet been exhaustively investigated. It is true that the few extant works on protection discuss, in a more or less superficial manner, the main groups—beneficial, injurious, neutral—into which the vertebrates naturally fall. To show that such a classification is useless in practice is one of the objects of this thesis. Just as each species of tree and insect displays individual characteristics, so does the utility of birds and animals vary according to the type, age, and composition of the wood, and the different systems and objects of management.

With this in mind, the writer has not attempted to define the exact economic status of insects, birds and animals, but to show to what extent it may vary in different circumstances, and how and when the encouragement or suppression of various species should be carried out. To do this in a strictly practical manner has not been an easy undertaking, for only a very little is at present known about the food taken by the various species of forest birds, although we have a much more complete knowledge of the economy of insects and animals. The existing records of the insect food eaten by birds in this country are scattered, almost without exception,

throughout the pages of periodicals. Moreover, the subject is still further complicated from the fact that the analyses of stomach contents of birds (in the case of those birds and insects not entirely restricted to woodlands) may not reveal the true economic status of these birds at all. In fact, such generally proves to be the case (this will be more apparent with the rook, starling, chaffinch, etc.).

From this tangle of records, field-observations, stomach-analyses, etc., there emerges only one clear fact: that the study of the food and feeding habits of most forest birds *in the forest* has not yet been attempted in this country.

For this reason the certain amount of vagueness to be found in the following pages has been unavoidable; those insidious words "probably" and "possibly" are of only too frequent occurrence.

The main theme of this thesis is the suppression of injurious insects, birds and animals; nevertheless mention has been made of the effects of fungi and of physical causes wherever it has appeared desirable to do so.

Lastly, the logical conclusions which the writer has been led to make do not claim to be original. To some extent they confirm the views already held about the inter-relationship of the forest flora and fauna, and of the degree to which it is economic to carry into effect the theoretical advantages of forest protection; in other respects they will be seen to differ.

The writer wishes to make known his especial

indebtedness to the personal help of Dr. W. E. Collinge, of the York Museum, and for permission to make such extensive use of his recently published work on the food of birds. The results of the investigations by Von Vietinghoff in Germany have also been freely quoted.

For much helpful criticism and suggestions as to the arrangement of the subject matter the writer is indebted to Professor W. Dawson; for the correct nomenclature of the great majority of insects discussed to Dr. Scott of Cambridge University; for a personal account of the control of the large Larch sawfly outbreak in the Lake District to Professor Hickson of Manchester University; for much practical assistance from many others for their help and advice in compiling the data of Chapter II.

The occurrence, distribution, habits, and nomenclature of birds is taken direct or adapted from Mr. H. F. Witherby's "Practical Handbook of British Birds"; that of animals from Millais's and Barrett-Hamilton's monographs. A list of the most consulted works will be found in the Bibliography.

G. W. St. C.-T.

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CHAPTER I

FOREST CONDITIONS AND SILVICULTURAL PRINCIPLES

EVOLUTION

Every plant association occurring free in nature is the outcome of long ages of competition, not only between the same or different growth-forms, but between the vegetable and animal kingdoms. The successful struggle for existence has resulted in the 'survival of the fittest'.

It follows that much can be learnt from the study of different types of natural woodland; in fact, the proper understanding of the relationship between the tree and its environment is the basic principle of Silviculture.

Three variants, chemical, physical and biological, govern the distribution of a species in nature; these are often less accurately grouped together as climate, soil and environment. It was the struggle to utilize, or to protect against, the infinite combinations of each of these qualities that resulted in modification of structure, and a corresponding variety of species. Such modification gave the individual plant some advantage over its neighbour, so that it succeeded where the other failed; moreover, it lived to reproduce its characteristics in the next generation.

Briefly, then, competition has produced structural adaptation, which itself has resulted in limitation of range.

THE NATURAL WOODLAND ASSOCIATION

In an old-established natural forest the processes of suppression and decay are gradual, although both the type and composition of the flora are constantly and consistently changing. On newly colonized areas, on the other hand, which are in course of undergoing a transition from one type of vegetation to another, the ecological succession is comparatively rapid. In both cases the competition between trees, whether of the same or different species, results in the survival of that association which has utilized the locality factors—soil and climate—to the best advantage, which is synonymous with having offered the greatest resistance to the forces of destruction and decay.

This keen struggle for growing space, light, air and moisture, where the most vigorous trees gradually crowd out and suppress others which are less adaptable or badly handicapped, is sometimes very protracted. Usually, however, animals, insects or fungi play the largest part in hastening the death of the dominated trees—that is to say, those trees weakened by competition, for the power of resistance of a healthy tree to such attack is very great. There are few predators, and fewer parasites which, by themselves, are able successfully to attack a vigorous tree. On the other hand they have always followed

the line of least resistance, because many of these organisms not only profit by, but owe their existence to, the weakness of their host plants; hence, the great majority of forest pests have evolved from the purely physical struggle for survival between trees. In nature they help and not hinder the growth of vegetation.

In this way do we solve the secret of natural protection against the forces of destruction and decay: by a ruthless sacrifice of numbers nature succeeds in establishing at least one sound tree to take the place of its predecessor.

ECONOMIC ASPECT

The competitive influence is wasteful in the extreme. Not only does it sacrifice a large proportion of the total growing stock, but what is of far more importance it dissipates the vital energy of the final crop. The very fact that natural selection has evolved such an abundance of species shows that it has produced quality at the expense of quantity.

Therefore it appears that if the suppressed class in a wood is eliminated, the final crop should be correspondingly stimulated. Moreover, the majority of pests would also cease to exist.

So far we have regarded the welfare of the tree, and have assumed that the natural forest has been controlled and regulated by thinnings and cleanings, and that the resulting pure or mixed crop is composed of the dominant species. That is, unfortunately,

only an ideal. If it were always possible to consider the health of the crop to the exclusion of all else, we should quickly eliminate much of the risk of destruction, simply by anticipating it, and improving upon the natural order.

In practice this is impossible for financial reasons. A natural distribution of trees is usually uneconomic; some species are worthless, others may not represent the maximum productive capacity of the locality, either in volume or value. Especially is this true of a limited island flora such as that of the British Isles, where few hardwoods and only one indigenous conifer—the Scot's pine—are worth growing at the present time. Frequently it is economic to cut down the poor natural growth and replant with exotic species.

Furthermore, by introducing a new species without its accompanying parasites (or predators) it can succeed even better than in the country of its origin. These are a few of the reasons which militate against the idyllic management of natural woods.

THE ARTIFICIAL ASSOCIATION

It is assumed that the objects of management of any wood are to produce the maximum quantity of timber at the least risk, and to grow it as quickly as possible consistent with quality. That being the case it is evident that the natural order must be improved and replaced by an artificial state favourable to tree growth, but unfavourable to the

parasite. Accordingly, economic woodlands are found to vary between the following extremes:

(*a*) uneven-aged, mixed woods, including most natural stands converted and put on a financial footing, and mixed plantations managed either on the selection or group selection system. In either case the resulting type approximates very closely to the natural order, and the practice of silviculture (by encouraging only the most vigorous growth) tends to eliminate all those secondary pests more or less dependent on sickly and dead tissue, and does not encourage primary pests, except in so far as it may discourage insectivorous birds which are also dependent on dead wood for breeding purposes.

(*b*) even-aged pure plantations are certainly unnatural in type, and generally in composition. Only to a limited degree is it possible for the influence of good silviculture to suppress the secondary pests, while the primary pests are actually encouraged by the unbroken canopy and the continuity of the same species. Accordingly in order to form and maintain with success any even-aged pure crop the correct choice of species must be the first consideration of the forester, for silvicultural after-control is of only secondary importance.

Between these two extremes is found every type of artificial woodland. But since, in practice, the majority of woods grown in this country for timber production are artificial stands comparatively recently created, it is evident that choice of species is a very important matter.

CHOICE OF SPECIES

In the natural forest conditions are so delicately adjusted that it is only after a prolonged struggle and a great waste of energy and material that a few trees ultimately succeed in reaching maturity. It may be said that the contest between injurious and beneficial organisms is so evenly balanced that only the inherent vigour of the tree turns the scale in its favour. In other words the selection of the tree or mixture which can utilize the locality factors to the greatest advantage is the first and most important point in afforestation. Not only must the artificial woodland suit the type of ground, but it must also offer the greatest resistance to the natural forces of destruction—wind-fall, snow-break, frost and fire.

Although detailed discussion of those trees most suited to the varying conditions of soil, climate and environment in this country is outside the scope of this thesis, the financial considerations affecting choice of species must be mentioned. The distinction between the two extreme types of woodland has already been drawn, and it is evident that both are economically unsound, though for totally different reasons. The more natural type is either very restricted in number of species, or difficult to create; in both cases the extraction of timber and the regeneration of many gaps calls for skilled management and the result is often unprofitable.

In practice it is too conservative. At the opposite extreme is the pure, uniform stand formed and maintained contrary to all laws of nature, which nature is ceaselessly striving to convert to the old order by drastic measures. To maintain it in any degree of safety, expensive and specialized protection is required.

To sum up the situation: on one hand too slavish an observance of arboricultural principles results in under-production; on the other, the sacrifice of the welfare of the forest to the dictates of an arbitrary financial policy can only produce chaos, perhaps even the death of the whole crop. Somewhere between these two extremes of management lies the profitable middle course: it must be maximum production consistent with maximum natural protection, with artificial methods of control only in so far as they are justified by the results.

In actual practice, then, it is found that within certain limits it pays to grow the most valuable timber (for example, larch and Douglas fir rather than spruce or Silver fir, although they may not be *ideally* suited to the locality). Nevertheless, it is quite practicable to choose immune species of the same genera, as the following examples show:

(*a*) Japanese larch is almost immune to the canker *Dasycypha Wilkomii*. Other things being equal, it is preferable to plant with this species rather than with the European variety. If it is found undesirable to do so, it is possible to mix the two species, or, of course, the European larch with

another tree altogether, preferably a hardwood.

(*b*) Where oak is grown pure (as a top storey, although it may be underplanted) the sessile should always be preferred to the pedunculate variety, on account of the partial immunity of the former to attack by larvæ of *Tortrix viridana*. It is always possible, because the sessile is hardier, is content with a poorer soil, and thrives at higher altitudes; it is maintained that it is also preferable to do so.

PURE AND MIXED WOODS

The study of the natural forest shows very clearly that pure, or nearly pure, woods occur less frequently than mixed, and where present are often the result of a limited flora, or lack of opportunity (especially true in Britain), rather than of absolute suitability to environment. To digress for a moment, the status of the Scot's pine in this country is an excellent example. The many different areas, more suited to a conifer than a broad-leaved tree could only—in the past—be occupied by one species, which produced correspondingly uneven growth. Given the opportunity for adaptation, the Scot's pine evolved along two different lines, resulting in a northern and a southern variety with an obvious physiological difference in growth, but a less well-defined alteration in actual structure.

But besides lack of opportunity, there are good reasons why large areas covered by the same species

are so infrequent in nature. Briefly, then, the disadvantages of pure woods are:

(1) Since the whole ground space is normally utilized to its utmost capacity, it follows that the type of vegetation varies with the soil quality, in which, in both physical and chemical nature and in depth, is rarely constant, even within a comparatively small area. The result of forming pure woods is uneven growth, and the backward areas then become breeding places for the spread of an *unnatural number of pests*.

(2) Trees of the same species require the same degree of light, moisture, nutriment, etc., whereas different species are satisfied by different qualities, only competing with each other for growing space. Competition, and therefore *waste of energy* is at its highest in pure woods.

(3) Besides the fact that pure woods do not utilize the locality factors over a large area to the fullest advantage, they do not often represent the maximum productive capacity of the soil. This is best seen with those light demanding species which allow of underplanting.

(4) There are also less obvious physiological drawbacks to pure woods. In the case of light-demanders a more rapid and effective pruning of the branches results from mixture with shade-bearers. This also, of course, lessens the risk of disease.

(5) Isolation of individuals and groups from others of their own kind is the natural safeguard against infection from disease.

(6) The close association of different species usually reduces both the number and extent of pests. On the other hand it encourages the enemies of the injurious fauna, for predaceous animals and birds are not dependent on one type of insect or animal in the same way as insects are generally predaceous on one type of vegetation. On the contrary, the great majority attack whatever prey is most abundant. The inter-relations between animal, bird, insect and plant are so complex, however, that this matter is better understood by a closer study of the characteristics of each organism, particularly of birds (see Chapter II).

For these reasons it appears logical to suppose that pure woods should be formed only in special circumstances, for short rotations, or on small areas.

The main economic drawback to mixtures lies in the fact that they are difficult to manage, but weighing the advantages with the disadvantages one can only conclude that the little added trouble in establishing and maintaining a mixture more than repays for the risks taken with a pure crop. It has been said that anyone can manage a pure plantation by rule of thumb, but that it takes a skilled forester to regulate the yield of a mixed stand. Hence, the difficulty of management is not always a valid argument.

There is only one silvicultural objection to a mixture. Although isolation of species may and generally does prevent the spread of selective plant-feeders, the association of certain species of trees

is absolutely necessary for the propagation of some insects and fungi. The commonest example is that of an organism requiring two host plants for its complete life-cycle, as in the case of *Chermes abietis-laricis* on spruce and larch, or a *Melampsora* fungus on poplars and pines. Here the obvious remedy is to study the pest and choose the mixture accordingly. Other organisms are omnivorous feeders (such as the larvæ of *Orgyia antiqua*), and mixtures are non-effective.

THE ECONOMIC WOODLAND

The safest and most practical method of overcoming the various disadvantages of pure and mixed woods is generally recognized to be the establishment of small irregular groups or blocks, of different species. Each group is a pure crop at first (though later it may be underplanted), and the choice of species and size of the block is calculated to utilize the different types of ground, the aspect and other locality factors to the fullest advantage. It is a compromise between the two types, and in reality is an extension of the group selection system, where the groups may vary from a few trees or half an acre to fifteen or twenty acres.

The risk of loss, though not eliminated, is considerably reduced, while the productive capacity of the area is much greater than under a pure crop. Moreover, damage, when it does occur, is practically

limited to one group, and from the arrangement of the groups is prevented from spreading.

THE ORIGIN AND GENERAL CONTROL OF PESTS

Certain epiphytic plants, such as ivy, honeysuckle, convolvulus, etc., and lichens may weaken trees by retarding growth, but these and weeds are outside the scope of this thesis.

Fungi, which are to a great extent dependent on dead or sickly tissue for their *initial* development, are also suppressed by the practice of silviculture, and not by the agency of animals, birds, or insects. The spread of root fungi is often attributed, with good reason, to small mammals, particularly to moles and rodents, which carry the fungal spores from place to place. The suppression of these pests is an important preventive measure in itself, apart from other considerations. Except in the nursery no active measures are taken against fungi—in addition to good silviculture—though choice of species, especially in relation to soil conditions, and in replanting a felled area, is often influenced by the risk of fungal attack. In the case of those species, like the larch, that suffer greatly from facultative fungi, special precautions to keep the crop clean and in a vigorous condition are often introduced. Nevertheless, in general, the observance of ordinary silvicultural rules and the proper choice of mixtures

is sufficient protection in itself. On the other hand, generally only those insects attacking dead or sickly timber are quite amenable to silvicultural control; for many pests are sometimes encouraged, as has been shown, by the formation of pure and even-aged stands. These primary pests are of two-fold importance: not only do they themselves commit extensive damage, but, by reducing the vitality of the tree, or injuring the protective covering of bark, make it possible for a host of secondary pests, including fungi, to gain hold—after which, if not remedied, the death of the tree is only a question of time. There are many examples of this: punctures made by *Chermes abietis-laricis* are generally supposed to admit spores of the larch canker (Massee, 55. 1918); oak mildew follows defoliation by larvæ of *Tortrix viridana*; pine beetles sometimes follow attacks of pine weevils (Ivor Trägårdh, 55); etc.

From a silvicultural point of view insect pests, whether injurious as larvæ or imagines, may be divided according to the type of food plant of the larvæ, for if this is absent their increase is checked:

(1) Only old, or sickly stems, dying branches, recently felled timber, fresh stumps or roots.

Bark-beetles and weevils generally. Many of these *larvæ*, if attacking a sound tree in excessive numbers, may so weaken it that it is unable to throw off the attack. But this only happens after the adults have increased to such an extent that an

unusually large number of eggs are laid. In high forest many of these pests breed in suppressed branches, but damage is usually only severe after felling, when special control measures must be taken. For full details see Bulletin No. 8 (45), where, also, Escherich is quoted: "Bark beetles are suppressed by the practice of silviculture, in contrast to the weevils which are favoured by it." Accordingly Escherich (15) classifies bark-beetles as secondary pests only.

(2) Perfectly healthy as well as sickly timber, and bark. *Agrilus viridis*, *Aromia moschata*, *Saperda carcharias*, *S. populnea*, *Trypanus cossus*, *Zeuzera pyrina*, *Aegeria apiformis*, *Sirex gigas*, *S. noctilio*, *Coccidæ*, *Chermes laricis*, *C. corticalis*.

Risk of damage by this group is greatly diminished by good silviculture. Their spread is due to neglect on the part of the forester, by not isolating the attack in time, for it is often necessary to take special exterminatory measures, such as pruning or cutting out the affected trees.

(3) Living roots.

Melolonthinæ, *Elateridæ*; also seedlings at or below the ground level by larvæ of a moth, *Agrotis segetum*. Most injurious in nurseries, where special precautions must be taken.

(4) Leaves, needles, shoots or twigs.

Cryptorrhynchus lapathi, *Chrysomela populi*, *Phyllodecta vitellinæ*; *Lepidoptera* generally; *Tenthredinidæ*; *Cecidomyia saliciperda*; *Aphididæ* and

Chermesidæ. These defoliatory larvæ and "plant-lice" constitute the largest group of primary pests. Since they are encouraged by the artificial associations of trees, they are controlled by other than silvicultural measures.

A fuller discussion of each species of insect is not possible (see under (15), (19), (29), (33), etc.), but these four groups are more fully treated in Chapter IV. A list of the commoner insects of primary and secondary importance is given in Appendix II.

Summary: the most effective way of controlling insects has been shown to consist in depriving them of their breeding-places (i.e. the larvæ of their food). Where this happens to be healthy growth, it is obvious that other means have to be adopted.

Insectivorous forest birds, which are fully discussed in Chapter II, are generally discouraged by the formation of pure, uneven-aged stands, containing no dead or dying timber, while those species which feed partly on the foliage or seeds of the forest are actively encouraged. It is evident that the practice of silviculture is, in this respect, both directly and indirectly harmful to the welfare of the forest.

Animals (Chapter III) are apparently least affected by the substitution of artificial for natural woods. This might be expected from their adaptability. Some animals, such as mice and voles, are much less abundant in a fully stocked even-aged

stand than in the natural forest; others, such as squirrels, are undoubtedly encouraged.

Any further generalizations about forest animals, birds, and insects can only be vague and unsatisfactory. Each species must be treated separately in order to realize its individual importance.

CHAPTER II

FOREST BIRDS

Family: CORVIDÆ (Crows, Rook, Jackdaw, Magpie, Jay).

General: several species represented in every wooded district. Omnivorous feeders, characterized by preference for carrion and eggs. Single-brooded, building bulky nests in trees, or in a hole (the jackdaw). The numbers of most species are increased by winter immigration. Sociable, resident, sometimes flocking in winter.

(1) THE HOODED CROW.

Distribution: common in wild, mountainous or wooded districts in Scotland, Ireland, N. England.

Considerable numbers arrive on the east coast, and spread inland, staying from October to April.

Habitat: uncultivated districts bordering woods.

Nesting-habits: 4-6 eggs end of March, April.

Food: obtained on the ground. Small mammals, birds, nestlings, eggs; less commonly insects or insect larvæ (chiefly ground beetles).

Economic Status: does not occur in sufficient numbers, nor is it by preference a woodland bird, to be important. Wherever it occurs it should be

exterminated, by shooting, trapping, and destroying the eggs and young (but not the nests).

(2) THE CARRION-CROW.

Distribution: though its range frequently overlaps that of (1), and interbreeding is not uncommon, it generally occurs where the hooded crow is absent. Locally common wilder, generally wooded; localities England, Wales, and Scotland South of the Forth.

Habitat: more or less restricted by man to uncultivated and wooded districts.

Nesting-habits: 4-5 eggs, early in April.

Food: mostly obtained from the ground, and similar to above.

Status and Destruction: as (1).

(3) THE ROOK.

Occurrence: gregarious at all seasons; still spreading in Scotland, more or less in proportion to destruction of (1) and (2). Abundant, and well distributed in the British Isles, South of Sutherlandshire.

Habitat: cultivated, but also wilder districts, showing a preference for woods, but not dense forests, or mountainous country. A bird of grassland rather than heathland.

Breeding-habits: 4-5 eggs end of March, April; rookeries as common in Scot's pine as in broad-leaved trees.

Food: as with other *Corvidæ*, being an omnivorous feeder, diet varies greatly with locality (see under

38). Stomach analyses have been made, chiefly of birds obtained from agricultural districts.

Florence (17) gives insects: injurious 23.7%, beneficial 5.2%, occasionally eggs.

Collinge (10) gives wireworms and clickbeetles 6.5%; moth larvæ 4%; ground weevils 3.5%; other injurious insects 13.4%; beneficial insects 3.5%; eggs, mice and young birds 1.4%. Total: injurious 23.9%; beneficial 4.9%.

It has generally been supposed that the food of the rook consisted largely of beetles and various larvæ, but compared with some other birds the insect food is rather small (Collinge gives 59% vegetable food).

In pest areas Eckstein (40) examined 265 rooks, of which 215 contained cockchafers; Rorig (40) 31 birds out of 212. On the other hand, Florence (17) and Leigh (24) examined 285 and 209 birds respectively without finding a trace of *Melolonthinæ*; and Theobald (39), out of 268 birds, found only 3 to contain Melolonthid larvæ.

Abroad, rooks are of great importance in areas defoliated by moth larvæ (40), flocking to the infestations, and feeding their young on the larvæ. In pest areas of *Nematus Erichsonii* in the Lake District (49, 1908), rooks were observed to take the larvæ from the trees, and dig the pupæ from the ground. Where larvæ of *Tortrix viridana* have defoliated oak to a marked extent, rooks have repeatedly been observed to flock to the trees; larvæ of *Cheimatobia brumata* are also taken.

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Also taken, occasionally, larvæ of *Cynipidæ* from oak-galls (20) ; *Hylobius abietis*, *Syrphidæ*, *Aphididæ*, *Rhagium sp.*, *Chrysomelidæ*, adult *Ichneumonidæ*, also pupæ (not uncommonly). Besides Von Vietinghoff, Theobald (39) notes larvæ of *L. monacha*, and Hooper (22) of *Bombyx neustria*. But considering the large numbers of rooks examined, and their feeding habits in wooded country, these insects are so rarely taken, that in this respect the rook as a means of natural control can be ignored.

Economic Status : in this country the only claim of the rook to be rated as a beneficial forest bird is on account of its destruction of *Melolonthinæ* and *Elateridæ*. It is of no use in the normal natural control of defoliatory larvæ, for it has always been observed feeding on such pests *after* the main damage has been done. Nevertheless, in pest areas it should, of course, be encouraged. Whether the practical forester will admit that the 3 birds containing *Melolonthinæ* out of 762 examined represents a useful proportion is a matter of opinion ; but the writer, in opposition to those authorities, who have made deductions from isolated observations holds the view that the utility of the rook is very much overrated.

This is further borne out by a comparison of the proportion of *Elaterid* larvæ and imagines in the stomachs of rooks and starlings (adapted from Leigh, 24).

	Number of Stomachs	Number of times occurred	Percentage
Rook	209	19	9
Starling	486	130	26.7

and lepidopterous larvæ occurred in the rook in 14 cases, compared with 121 cases in the starling.

It is obvious too, that the bird which specializes in the adult stage is of more use than that feeding mainly on larvæ.

Theobald (39) gives :

268 rooks, 10 imagines plus 196 larvæ.
696 starlings, 302 imagines plus 329 larvæ.

Thus, notwithstanding the fact that the capacity of the rook is many times greater than that of the starling, both specifically and quantitatively the smaller bird is of much greater utility.

This example is an excellent illustration of that little-understood problem : whether a species which is in itself useful should or should not be sacrificed for the sake of a species of even greater utility. The rook is particularly injurious to game and young birds in coniferous areas (38).

The following figures (Schleh 40) show the relative importance of (1), (2) and (3) in cockchafer pest areas.

No. of insects in 100 stomachs :

	Larvae	Adults	Total Insects
Hooded Crow	2	5	7
Carrion Crow	33	55	88
Rook	181	55	236

Control : there can be little doubt in the comparison of these two birds (for their distribution is also similar) that the rook should be discouraged from nesting, wherever the starling also occurs. It

has repeatedly been shown (10, etc.) that the rook in its present numbers is decidedly injurious to the agriculturalist, and this should be an additional reason for its discouragement. This is most easily done by shooting the adults when they are preparing to nest in early March, or if it is desirable to establish a rookery, by shooting the young birds either on May 4th or 11th, according to season.

Under the 'Rabbits and Rooks Act, 1925' (Short Title) a rookery which appears to be injurious to the welfare of agriculture or forestry can be controlled or destroyed on application to the County Council, with or without the owner's permission; this does not apply in Ireland.

(4) THE JACKDAW.

Occurrence: as (3).

Habitat: frequently consorts with rooks, but is rather more of a woodland species, for, though it nests in colonies, it also breeds in isolated pairs, especially in beech woods.

Nesting-habits: 4-6 eggs late in April, usually nesting in hollow timber.

Food: omnivorous, mostly obtained from the ground, and similar to that of (3), but more insectivorous. Collinge (10) gives 39.5% injurious, 2.5% beneficial insects, 2% egg remains, 2% young birds. Among the injurious insects are: *M. vulgaris*, *P. horticola*, *A. lineatus*; *Cheimatobia brumata* and *Hybernia defoliaria*. Also *N. Erichsonii* (larvæ) (49, 1908); and commonly *Geometridæ*.

Abroad it is of considerable use in control of *Melolonthinæ*.

Summary: though of much greater general utility than (3), like the rook it is undesirable as a breeding bird, i.e. in April, May and June. It has also been observed to interfere with the nesting of the barn owl (25), and the writer has noted the same thing with the little owl; so that in localities where hollow trees as nesting sites are scarce, it should be prevented from breeding.

In other months of the year it is very beneficial, though less so than the starling.

(5) THE MAGPIE.

Occurrence: sedentary resident, fairly common locally in all but game-preserving wooded districts, except N. Scotland and W. Ireland.

Habitat: woodlands, of all types except young plantations (as a breeding bird), but usually not at high altitudes.

Nesting-habits: 5-7 eggs, April, in typical domed nest, either in a tree or high thorn hedge.

Food: omnivorous, mostly obtained from the ground, and includes acorns, mast, eggs and nestlings, less frequently small mammals, including moles (30). Collinge (10) gives the following figures from 24 stomachs:

Wireworms, 43, clickbeetles 26, cockchafer larvæ 41, weevils (chiefly *Sitones spp.* and *Otiorhynchus sp.*) 99, various beetle-remains 180; besides this acorns

occurred 3 times, young birds once, egg shells 5 times, one field vole, and a young long-tailed field mouse. Field observations show that nestlings most frequently taken are those of woodpigeon, blackbird and song-thrush; but this damage varies with locality.

Eckstein (40) examined 26 birds from pest areas, and cockchafers occurred 9 times.

Newstead (31) found in one nestling 6 adult cockchafers, and in an adult a field vole. Newman (30) notes that they take larvæ of *Melolonthinæ* in nearly every month of the year.

Economic Status: mainly beneficial, in small numbers only (compare the jay), but unlike (6) its old (and sometimes new) nest is used by other species, notably long-eared and tawny owls, and the kestrel. It has, therefore, an added value, which is considerable.

Control: if the numbers of the magpie are so increased by protection that the eggs and young of warblers, the chaffinch, etc., or of gamebirds, suffer, they should be reduced by shooting or trapping the adults at the nest, *after* that has been built (usually by the first week in April) and before the arrival of the summer migrants (early May).

(6) THE JAY.

Occurrence: as (5); the Irish jay, only subspecifically distinct, is similar in habits, food, etc., but is restricted to Ireland, where, of course, the typical race does not occur.

Habitat: as (5), but quite restricted to woodlands, and commonest in those containing oak.

Nesting-habits: 4-7 eggs, April or May; nest built usually from 10-20 feet, in trees or undergrowth.

Food: a general predator, with a well-developed taste for flesh, particularly eggs, young birds, less frequently mice. Collinge (10) gives the following figures from 18 stomachs: cockchafer larvæ 22, beetle remains 38; egg-shells of blackbird 5 times, young birds twice, mice twice; acorns 9 times and mast 4 times.

Newstead (31) examined 23 stomachs:

6 cockchafers, very many clickbeetles; eggs twice, and of 11 birds shot in autumn and winter 9 contained acorns. One bird contained 120 larvæ of *Cheimatobia brumata*; and another 127 adult clickbeetles; various moth larvæ and ground beetles and weevils generally (i.e. useful against many injurious forest species).

Von Vietinghoff (40) has investigated the economic status of the jay very thoroughly. In nun-moth pest-areas it fed largely on all four stages, including the ova, not noticed with (1), (2), (3), (5) or the starling. Ova were nearly always present, in numbers varying from 30 to 500, averaging 150 (Loos found 2,000 ova in a bird in January), but larvæ occurred in almost negligible quantities.

Continental authorities are of the opinion that the jay is of limited use in control of cockchafers (but this is not the case in the British Isles, where, however, it is less useful than the magpie).

Rorig (40), 109 birds, only 1 cockchafer.

Eckstein (40), 97 birds, adults occurred in 11 stomachs.

Both Eckstein and Von Vietinghoff have records of *Hylobius abietis*.

Field observations include many instances of egg destruction, chiefly of gamebirds, blackbirds, thrushes, woodpigeons, but also of smaller birds, especially the chaffinch and goldcrest.

It was observed to be the most useful bird preying on cocoons of *N. Erichsonii* (49, 1908).

Economic Status: it is extremely difficult to arrive at the conclusion of the exact value of the jay, so much depending on other factors. Roughly it may be said to be undesirable when the various arboreal warblers, starlings, or an occasional pair of jackdaws or magpies are present, and in preserved woods. It is of some use where these birds are absent, or almost absent; but of great utility in oakwoods, or in areas where recurrent pests (*Melolonthinæ*, *Tortricidæ*) are to be expected. Except in April, May and June, therefore, it is useful in small numbers, and for all practical purposes may be treated as (5).

Control: as (5), though the nest is useless for other birds to breed in.

Other members of the family include the raven (*Corvus corax*), which is so uncommon, except in a few favoured localities in Scotland and N. England, that it is of little, if any, importance. Wherever it occurs its influence is slightly beneficial.

Family: STURNIDÆ (The Starling).

(1) THE STARLING.

Occurrence: gregarious and abundant, still on the increase in many parts, especially N. and W. Scotland; for full account of spread in Scotland, see under 56 (1895).

Habitat: though commonest near grassland and cultivation, also occurs in open woods, particularly of broad-leaved trees. It is not found in dense coniferous stands; nor in woods at high altitudes (14).

Nesting-habits: holes in buildings and trees, sometimes cliffs; frequently those bored by the Greater spotted and green woodpecker. Sometimes double-brooded, 5-7 eggs, end of April.

Food: see also under Corvidæ (3) the rook. A very complete record of food exists, but unfortunately the great majority of birds are from cultivated districts.

Collinge (10) gives as adult food: injurious insects 26.5%, beneficial insects 2.5%. Nestlings in U.S.A. (from 10): ground beetles 7.2%, *Melolonthinæ* 13.5%, various weevils 3.7%; lepidopterous larvæ 39.3%; and as the fledging period is about 20 days, and the young are visited from 250 to 350 times a day, the number of injurious insects consumed is very great.

Newstead (31) observed that a brood in one day (17 hours) consumed: 140 larvæ of *H. defoliaria*,

72 of other moths, and a large number of *Coleopterous* larvæ and imagines.

Whereas, spread over the year, the total insect food is only 32.5%, in April, May and June these figures are respectively 65%, 92%, 87% (10).

Florence (17) examined 65 adults, without finding any Melolonthid remains, but all other writers have found considerable numbers of adults, especially in May and June ; but only infrequent larvæ throughout the year.

Continental literature contains many references to the swarms of starlings which invariably appear on the outbreak of moth and cockchafer pests, and it is justly regarded as the most useful bird in their suppression. In this country the same thing has been observed with pests of *T. viridana*, *N. Erichsonii*, and *Lophyrus pini*.

Being a general insect predator, apparently all insects are eaten when the opportunity offers, the following having been noted : larvæ and imagines *Calosoma spp.* (40) ; *Coccinellidæ*, *Syrphidæ* and *Ichneumonidæ*, also *Aphididæ*, *Tenthredinidæ* (and pupæ in June), *Chrysomelidæ* in July, and lepidopterous pupæ in February (20). Various staphylinid beetles are frequently eaten. Eckstein considers it of some little use in pest areas of *Hylobius abietis* ; but in this country it has not been observed to flock in search of them.

Summary : the main insect food of the adult beetles is obtained from the ground, and in summer a certain amount of moth larvæ from all types of

vegetation, which are also fed to the young in large quantities. Other insects are taken, but are apparently not searched for.

Economic Status : there are few more useful birds at all months of the year, but especially in summer.

Protection : destruction of the sparrowhawk.

Encouragement : the results from the judicious use of nesting boxes on the Continent have been so extraordinarily successful, that in all well-managed wood, where natural sites are probably very limited, a very great deal can be accomplished by the same means in this country.

Special Status :

(1) The starling sometimes roosts in plantations in such numbers that they are disfigured, and growth checked, or a proportion of the trees may be killed outright. In practice it is necessary to post men with shot-guns, and boys with sticks, to scare off the flocks an hour before sunset, but this is only possible over small areas. Another successful method is to fly an ordinary sporting kite, such as is used to make partridges ' sit ', over the plantations : this is just as effective, and much less expensive than shooting, but it is, of course, dependent on a wind. Sitka spruce appears to suffer most from this damage.

(2) Starlings turn out the greater spotted and green woodpeckers from both old and new borings, and even turn out the eggs and young of the former

bird, when the nest is left unguarded (52). This is a serious injury, which can be remedied by shooting the offenders in time, and also by adequate provision of artificial sites. Such a state also indicates the abundance of food and the necessity of encouraging the starling.

Family: FRINGILLIDÆ (Finches).

General: mainly resident, flocking in winter; more or less insectivorous in summer, almost entirely seed-eaters at other times. Many species are common and well-distributed; building open nests in trees and hedges, except the house and tree sparrows.

(1) THE CHAFFINCH.

Occurrence: everywhere common; continental immigration from October to April.

Habitat: all types of woodland, in summer and winter; but only on the edges of dense coniferous stands. Though not nesting in coniferous areas before canopy has closed, winter flocks occur there.

Breeding-Habits: double-brooded, 4-5 eggs, May and June.

Food: usually obtained from the ground, but commonly searches the foliage in spring and summer, and takes insects on the wing.

Coleoptera: chiefly imagines of *Rhyneophora*, including *Myelophilus* (40); sometimes imagines of

Elateridæ, and of small *Carabidæ*, also *Chrysomelidæ* (24). In pest areas of primary importance in control of *Melonthinæ* (40), Newman also notes the adults in summer. Where both *Aphididæ* and *Coccinellidæ* occur, the former are taken and the latter left, though occasionally ladybirds are eaten (10 and 20).

Lepidoptera: one of few birds taking all stages, but specially ova and larvæ, of all families, including *Lymantriidæ* (40), but most commonly *Tortricidæ*, and *Geometridæ*. In certain pest-areas Von Vietringhoff found all birds examined had remains of *Lymantria monacha*, and other authorities remark on the frequency with which they hawk for the adults, nipping off the wings, which litter the ground below.

Hymenoptera: no record of *Ichneumonidæ*, but probably imagines very occasionally; in pest-areas very occasionally larvæ of *Lymantria monacha* containing *Tachinid* ova, were eaten. Larvæ of *Lophyrus pini* (40), and in pest-areas very frequently full-grown larvæ of *Nematus Erichsonii* (49, 1908); i.e. commonly *Tenthredinidæ* (also 21).

Diptera: occasionally imagines; including *Tachinidæ* (40).

Rhynhota: commonly *Aphididæ*, including *Larch Aphis* (17), and *Chionaspis salicis* (39); also *Coccidæ* (39); spiders.

Collinge found 15% of total food consists of injurious insects; but this proportion is higher in wooded districts, and in summer. The young are fed mainly on lepidopterous larvæ. In winter, acorns, mast, sweet chestnuts, sycamore, maple and conifer-

ous seed; and commonly newly germinated seeds (*cotyledons*), are added to the diet of weed seeds and hibernating insects.

Economic Status: as with other finches and seed-eaters, damage to seed beds, and to naturally regenerated areas (especially of beech) can be considerable. In the nursery ordinary precautions, such as coating the seeds in red lead, etc., which is necessary against mice and voles; and either netting the beds or employing scarecrows, are sufficient to prevent extensive damage. With natural regeneration, matters must be left to chance, and as there is no record of flocks of chaffinches ever doing appreciable damage, one is forced to the conclusion that the forester has adopted the farmer's prejudice against the bird, without in any way considering the facts. It will be seen from the above food-analysis that the chaffinch is a useful bird of primary importance, and should be strictly protected.

Protection and Encouragement: destruction of natural enemies, especially sparrowhawk, jay and squirrel.

(2) THE GREENFINCH.

Occurrence and Habitat: common, and more in evidence in winter flocks. It is not a forest species, and its importance (if any) is only due to depredations in the nursery, where ordinary measures (as against other graminivorous birds, mice, etc.) are sufficient.

Food: practically no insects are eaten by the adults, but mainly seeds, and buds of broad-leaved trees (10).

Economic Status: harmful, of only secondary importance.

Destruction: any special measures are unwarranted by the results. It is quite safe to neglect this species.

(3) THE CROSSBILL.

Occurrence: uncommon and local resident in England, Wales, and Ireland; less rare Scotland. A regular winter immigration, periodically becomes an 'invasion', as in 1888-9, 1909-10.

Habitat: restricted to coniferous woods, in summer mainly Scots pine, in winter commonly larch, occasionally spruce. Entirely arboreal.

Nesting-habits: double-brooded, 3-4 eggs February and April.

Food: very largely coniferous seed; but occasionally larch buds are destroyed, which may, however, contain insects. Florence found 382 and 503 coniferous seeds in two birds (17). It is not known whether 'woolly aphis' is eaten, but *Chermes abietis-laricis* is extracted from the 'false cones' of spruce (44, vol. 3). Larvæ of *Lophyrus pini*, and *Aphididæ* are also noted (56, 1910). The writer has carefully watched the young feed in March on regurgitated coniferous seed; but no insects were noted as being fed entire; these probably constituting less than 1% of total food.

Economic Status: occurs in such small numbers that damage, even in seed collecting districts, is quite unnoticed; (but see under (58), 1896). It is probable that squirrels, in their present numbers, do twenty times as much injury. Nevertheless, its influence is decidedly harmful, though the crossbill is rigorously protected by law in the breeding season.

(4) THE HOUSE-SPARROW.

Occurrence: sedentary resident; gregarious; abundant, except in very hilly districts.

Habitat: near buildings, but sometimes found breeding at a considerable distance from them, in more open types of broad-leaved woods, and on edges of Scots pine-stands.

Nesting-habits: about 3 broods, 4-5 eggs April onwards; breeding in practically any hole (except in the ground); failing this, an untidy nest is built in the branches, or in large nests of other species.

Food: chiefly obtained from the ground, but larvæ of defoliatory insects are searched for to feed the young. Being an omnivorous feeder, the diet varies much according to locality, and whatever its relation to agriculture it is by no means a harmful bird in the forest, though it will make havoc of an unprotected seed-bed.

Collinge's analysis of birds from fruit-growing districts gives 35% injurious insects, roughly the same as in the forest, but in agricultural districts this falls to 5% or 6%.

The food is rather similar to that of (1), but includes more ground forms, especially weevils, and few *Lepidoptera*, *Hymenoptera*, or *Diptera*, and of these rarely the egg or adult stages. It is of some importance in control of *Melolonthinæ* in pest-area (40). There is a case on record (21) where over 700 cockchafer remains were found beneath a nest after the young were fledged, but this is exceptional, though beetles do form the staple insect food. *Aphididæ* and *Coccidæ* are eaten (32), but of less value than (1), because it does not search for them to the same extent. It also appears from Collinge's examination of nestlings that *Coccinellidæ* are not infrequently taken.

(5) THE TREE-SPARROW.

Occurrence: locally common, except W. of England and Wales; less frequent E. and S. Scotland; local Ireland.

Habitat: mainly where (4) is absent. Occurs deeper in woods, but commoner in broad-leaved than coniferous types. For all practical purposes the two species may be treated as one genus, though from the nature of its environment the tree is more useful than the house sparrow, and for the same reason its diet is apparently more insectivorous.

Economic Status of Genus: beneficial, but of less importance than (1). In the forest, insectivorous birds are usually so scarce that no species can be spared; but in areas where other species (particu-

larly the tits) appear to be suffering as a result of the superabundance of sparrows, their nests should be systematically destroyed. Both species, but more particularly the tree-sparrow, turn out tits from nesting holes, and they may also limit the available sites for starlings and nuthatches. The writer has also found the tree-sparrow breeding at the expense of the lesser spotted woodpecker.

Summary: since the distribution of the chaffinch coincides with that of the sparrows, and the former is undoubtedly the more useful species, it is obvious that the one should be encouraged at the expense of the other. It is doubtful whether active repressive measures against the adults would ever be of any use, except in those isolated districts where numbers are not quickly replaced from other areas.

Probably it is best to tolerate the adults while destroying the nests (eggs and young), where these occupy sites suitable for other species. Artificial sites can be constructed for most tits, while excluding the sparrow (see Appendix).

Other members of the family include:

(*a*) The bullfinch (*Pyrrhula pyrrhula*), a seed-eater and bud-destroyer.

(*b*) The redpolls (*Carduelis linaria*), which feed on small seeds, including birch and hornbeam.

(*c*) The brambling (*Fringilla montifringilla*), a winter visitor feeding on mast and seeds.

(*d*) The common linnet (*Carduelis cannabina*), mostly feeding on weed seeds, but also partly insectivorous.

(*e*) The goldfinch (*Carduelis carduelis*), observed feeding on *Coleophora laricella* (49, 1922).

None of these birds, or for that matter the greenfinch, are of any economic importance in forestry.

Family: CERTHIIDÆ (The Treecreeper).

(1) THE TREECREEPER.

Occurrence: sedentary resident, nomadic in winter. Fairly common in small numbers in most wooded localities in the British Isles.

Habitat: entirely arboreal. Appears to prefer broad-leaved to coniferous trees, but commonly occurs on the latter, if the stand is not dense. Not found in young woods, where diameter is less than 6 inches.

Breeding-habits: usually double-brooded, 5-7 eggs from May onwards, nesting in cracks or behind loose bark of trees.

Food: obtained from bark, usually rough, of trunks and branches. An extremely selective feeder, and 100% insects and spiders.

COLEOPTERA: apparently all stages, especially ova, of bark-infesting species, including *Myelophilus* and *Pityogenes* (40); but chiefly *Curculionidæ*. Includes *Coccinellidæ* (31 and 40).

LEPIDOPTERA: particularly ova, but sometimes small larvæ (31), doubtless of most families, but hairy caterpillars are definitely refused (40).

HYMENOPTERA: pupæ (31), probably larvæ and imagines.

DIPTERA: larvæ (31), and imagines.

RHYNCHOTA: *Coccidæ* very commonly (17, 31). The writer found one young ash completely cleared of *Chionaspis salicis* by a pair of treecreepers. The young are fed on small lepidopterous larvæ and diptera (12).

Economic Status: except in pest-areas, when it may be useful, of rather limited value, if it is not slightly injurious. It is one of the very few birds feeding on *Coccinellidæ*, and even in pest-areas Baer found that only odd bark-beetles and weevils were taken. The treecreeper should not, at all events, be encouraged.

Family: SITTIDÆ (The Nuthatch).

(1) THE NUTHATCH.

Occurrence: sedentary resident, nomadic in winter. Fairly common in England, east of Shropshire and south of Cheshire, rather uncommon Wales and Yorkshire. Introduced Ireland, 1909, apparently with success (42).

Habitat: commoner in old woods than elsewhere, and never far away from oak, though it hunts for food on other trees also. Occurs sparingly, and usually in winter, in coniferous stands. Entirely arboreal.

Breeding-habits: sometimes double-brooded, 5-8 eggs May, nesting in old holes of trees, often reducing size of opening with mud.

Food: obtained from trunk, branches, twigs and leaves.

COLEOPTERA: all stages *Rhyncophora*; particularly *Pityogenes bidentatus* (40), but only occasionally imagines of *Melolonthinæ* (40), as might be expected.

LEPIDOPTERA: only ova and imagines (40), at any rate of *Lymantriidæ*; it doubtless includes small larvæ of other families. Observed searching larch shoots, probably for *Coleophora laricella* (12).

HYMENOPTERA: no record of imagines; ova of *Tenthredinidæ*, larvæ of *cynipidæ* (42).

DIPTERA: imagines.

RHYNCHOTA: commonly *Aphididæ* (12).

Spiders; in winter: nuts, yew berries, mast, acorns; but not leaves or needles, or coniferous seed.

Economic Status: in deciduous, and to a lesser degree in mixed woods, the nuthatch is of primary importance. In its habits it closely resembles the woodpeckers, and as bark-beetles and weevils are its staple food it exemplifies the importance of mixing broad-leaved trees with species such as Scots pine, which are liable to such primary pests.

Encouragement: as for tits.

Family : PARIDÆ (Tits, the Goldcrest).

General : local residents, well distributed in the British Isles, except N. Scotland (unless otherwise stated). Nest in holes in trees, rarely rocks or banks, except the long-tailed tit, which builds in trees, bushes and hedges, and the goldcrest in conifers. Excepting the last two species, the tits are rather general feeders, but largely insectivorous. Nomadic in winter, joining treecreepers and nuthatches in small bands.

(1) THE GREAT TIT.

Occurrence : fairly common, except W. Highlands (local).

Habitat : in all types and kinds of woodland, commonest where beech or oak predominate.

Breeding-habits : breeds in dense woods (though not typically) where nesting sites are available. Sometimes double-brooded, 6-8 eggs, early May.

Food : searches foliage, twigs and branches ; also the litter at base of trees in winter for hibernating larvæ and for pupæ ; and also stumps for beetles, etc., as well as mast, hornbeam seed, sweet chestnuts, etc.

COLEOPTERA : all stages of *Rhyncophora*, especially of *Scolytidæ*. Also various ground-beetles ; *Melolonthinæ* (30, 40), *Agriotes spp.*, some *carabidæ*, etc. No record of *Coccinellidæ*.

LEPIDOPTERA : all stages, even of *Lymantriidæ* (40) ; particularly ova, and larvæ of *Cheimatobia brumata* and *Hybernia spp.* (42).

HYMENOPTERA : *Syrphidæ* and *Chalcidæ* (17) ; *Ichneumonidæ*, both pupæ and imagines (31) ; commonly *Cynipidæ* ; and *Tenthredinidæ* (49 and 44, vol. iii.) ; also *Pimplinidæ* (40).

DIPTERA : pupæ of *Tachinidæ* (40).

RHYNCHOTA : *Aphididæ*, *Coccidæ* (10), but not as often as other tits. Spiders. Newstead calculated that a brood in 3 weeks require 8,000 insects, and Collinge that 62.5% of the adult's food consists of injurious insects.

Economic Status : the great tit is an omnivorous feeder ; so far as is known, with the possible exception of the *Coccinellidæ*, capturing everything that it sees. As a general predator, therefore, it is of great use ; feeding on whatever is most abundant.

(2) THE BLUE TIT.

Occurrence : fairly common in small woods.

Habitat : is considerably less fond of woods as breeding-places than other tits, but occurs in many types of broad-leaved forest, especially in winter, when in company with other birds.

Breeding-habits : single-brooded, 7-10 eggs, May.

Food : searches trees as above, but also examines rough-barked trunks. In winter adds bud-scales, very occasionally buds of deciduous trees ; mast and sweet chestnuts (31), birch seeds.

COLEOPTERA : *Rhyncophora* commonly ; in pest-areas of some importance against *Melolonthinæ* (40).

LEPIDOPTERA : all stages, particularly of *Tineidæ* (31), and other small moths, including larvæ of *Tortricidæ* and *Lymantriidæ* (40).

HYMENOPTERA : larvæ of *Syrphidæ* (17) ; occasionally *Ichneumonidæ*, both pupæ and imagines (31). Commonly the larvæ of *Cynipidæ* and *Tenthredinidæ* (49).

DIPTERA : commonly larvæ and pupæ (17), some imagines ; therefore largely neutral.

RHYNCHOTA : a considerable proportion of food consists of *Aphididæ* and *Coccidæ* (31), one of the few birds actively searching for the latter. *Chermes abietis-laricis* has occurred in some quantities (17). Spiders.

Collinge : 78% of food injurious insects. Young fed on lepidopterous larvæ and *Aphididæ*.

Economic Status : wherever it occurs (unfortunately almost restricted to broad-leaved trees), the blue tit is of primary importance, specializing in *Rhynchota*, particularly the 'woolly' *Chermes spp.*, the felted beech coccus (*Cryptococcus fagi*) ; and the ash and willow scale (*Chionaspis Salicis*) (31).

(3) THE COAL-TIT.

Occurrence : in most woods, not only the commonest tit, but the commonest bird, particularly in Scotland (14).

Habitat : restricted to woodlands, occurring in all types, and showing a preference for Scots pine ; occurs up to limit of tree growth.

Breeding-habits : 7-10 eggs, May. Single-brooded. Nest more often built in a hole in a bank than with other species.

Food : obtained as (2), but more commonly seen searching the trunks of trees than other tits, and also comes to the ground to search for pupæ concealed in the grass (21). Adds beech, mast and seed from newly-opened cones in winter.

COLEOPTERA : *Rhyncophora* : of only secondary importance in control of *Melolonthinæ* in pest-areas (40), so practically useless.

LEPIDOPTERA : all stages, including larvæ of *Lymantriidæ* ; one stomach proved to contain over 90% of larvæ of *Lymantria monacha* (40) ; but particularly larvæ of *Coleophora laricella* (5), and of *Tortricidæ* (*Rhyacionia spp.*) ; of the latter 122 larvæ were found in one stomach (5).

HYMENOPTERA : cocoons of *Ichneumonidæ* and *Braconidæ* have occurred but rarely (31) ; also imagines of *Pimplinidæ* (40), commonly *Tenthredinidæ*, even larvæ eaten to a considerable extent (49).

DIPTERA : larvæ and pupæ (17), not often imagines of various species obtained, more often at rest than in the air.

RHYNCHOTA : very commonly *Aphididæ* and *Coccidæ*. Spiders commonly.

Economic Status : the coal-tit is a true forest

species, and because of its other characteristics is quite the most useful member of the genus.

(4) THE MARSH-TIT.

Occurrence: rather uncommon England and Wales; recently introduced, apparently successfully, to Ireland (44).

Habitat: shows only a slight preference for wet ground, occurring quite as often in ordinary woods, but is eminently a bird of the lower storey and of damper underwoods, compared with the habitat of (3).

Breeding-habits: sometimes double-brooded, 7-8 eggs, May.

Food: little is definitely known of the insects eaten; Newstead gives weevils (including *Orchestes spp.*), *Cynipidæ*, and small beetles (31), also *Coccidæ* (32). Jourdain adds beech mast; and coniferous seed is apparently eaten to a greater extent than with other species.

Economic Status: less useful than most species, but distinctly beneficial.

(5) THE WILLOW-TIT.

Occurrence: replaces (4) in Scotland, south of Spey Valley, rare in England, unknown Ireland. Very closely allied to above, and characteristics are nearly identical. Little, or nothing, is known about its food.

(6) THE CRESTED TIT.

Occurrence: confined to Spey Valley and W. Inverness-shire, where it is not uncommon, and believed to be spreading.

Habitat: coniferous woods.

Breeding-habits: single-brooded; 5-6 eggs, early May; usually nesting in rotten stumps.

Food: obtained as that of (3), chiefly searching the buds, needles and twigs, but also stumps.

COLEOPTERA: includes the most injurious forms, all stages, particularly ova and imagines.

LEPIDOPTERA: chiefly ova and imagines, probably of most forms, but very rarely larvæ of *Lymantriidæ*, even in pest-areas (40).

HYMENOPTERA: no record.

DIPTERA: larvæ (40).

RHYNCHOTA: no record, but undoubtedly *Aphididæ*. Spiders. Young fed on larvæ and *Aphididæ* (42).

Economic Status: wherever it occurs this species is of great importance, because of its preference for *Coleoptera*, and the small bud and needle infesting *Lepidoptera*.

(7) THE LONG-TAILED TIT.

Occurrence: fairly common.

Habitat: woods and plantations of deciduous species (also hedges, gorse, etc.), rarely spruce.

Breeding-habits: sometimes double-brooded, 8-12 eggs, April; nest constructed in branches, etc., never placed in holes.

Food: obtained from the smaller twigs, leaves or needles, rarely the trunk.

COLEOPTERA: *Rhyncophora*, especially *Curculionidæ* (42); probably all stages.

LEPIDOPTERA: all stages, particularly ova and small larvæ forms, of *Tortricidæ* (31), commonly *Tineidæ* (31), and *Noctuidæ* (22).

HYMENOPTERA: occasionally imagines (31), and pupæ (17).

DIPTERA: no record, probably imagines.

RHYNCHOTA: commonly *Aphididæ*; and *Coccidæ* (32). Spiders, birch seed. In winter mostly *Coleoptera* and *Rhynchota*.

Economic Status: of restricted utility, on account of habitat, but of primary importance, especially when it wanders in winter.

(8) THE GOLDCREST.

Occurrence: fairly common, except after very severe winters. The firecrest (*R. ignicapillus*) has the same characteristics, but is only a winter visitor in small numbers.

Habitat: all types of coniferous woods, particularly of spruce, silver fir and Douglas fir, but not young plantations.

Breeding habits: double-brooded, 7-9 eggs, May and June.

Food: 100% insects and spiders; entirely arboreal, obtained from twigs and needles.

COLEOPTERA: small *Rhyncophora*, certainly imagines; ova; probably larvæ and pupæ.

LEPIDOPTERA: mainly ova, but small larvæ were met with, and small moths, such as *Tineidæ* (40).

HYMENOPTERA: a small percentage of imagines only (31).

DIPTERA: imagines, mostly taken on the wing. 12-15 larvæ of *Cecidomyia sp.* occurred in one crop (40).

RHYNCHOTA: a large percentage of *Aphididæ*; also *Coccidæ* (32). Spiders frequently.

Economic Status: usefulness due to its constant search for *Rhynchota*, its staple food; this is of greater importance since it feeds on them throughout the winter. These birds must annually destroy enormous numbers of *Chermesidæ*.

Summary of the family: not excepting the woodpeckers, the *Paridæ* are quite the most useful birds of the forest, individually and collectively searching the trees at all seasons. In addition (7) and (8) always, and (3) sometimes, are independent of holes in trees for nidification. In any wood two or more species are always represented. Since the family as a whole seldom capture insects on the wing, the risk of destruction of useful *Hymenoptera* and

Diptera is lessened. In no stomach analysis or field observations to date, have *Coccinellidæ* been remarked. Their importance and, therefore, their protection and encouragement, can scarcely be over-estimated.

Protection: destruction of sparrowhawk, and to a certain extent of the house- and tree-sparrows, where these occupy suitable nesting holes.

Encouragement: in woods devoid of unsound timber, nesting boxes *must* be provided by the middle of March to induce most tits to nest. (See Appendix.)

Family: MUSCICAPIDÆ (Warblers, Flycatchers, etc.).

General: the species of forestry importance are summer visitors, less common in, if not absent from, Ireland and N. and N.-W. Scotland. Rather specialized feeders, but insects form over 90% of food of adults; young fed principally on lepidopterous larvæ.

(1) WILLOW-WARBLER.

Occurrence: end of March—end of September. Commonest arboreal warbler.

Habitat: frequently a rather open type of woodland, standards with coppice ideal; otherwise only on outskirts of denser stands (see 60, 1910), including plantations, particularly of deciduous trees.

Breeding-habits: ground cover necessary for concealment of nest; bracken, grass, heather, etc. Often double-brooded, (15%-20%, Brock, 60), 6-7 eggs, May, July.

Food: searches leaves and twigs of bushes, hedges and trees; captures insects on the wing.

COLEOPTERA: ova and imagines of *Rhyncophora Agriotes spp.*

LEPIDOPTERA: ova and small larvæ, chiefly *Noctuidæ* and *Geometridæ* (31), probably also *Tineidæ*; rarely *Lymantriidæ* (40); imagines of most, if not all, *genera*.

HYMENOPTERA: no record; probably imagines only.

DIPTERA: imagines very commonly.

RHYNCHOTA: commonly *Aphididæ*, including 'whoolly aphis' (22). Spiders, elderberries.

Economical Status: beneficial, of secondary importance, because bulk of food is of a neutral nature. Brock (60, 1910) gives 21 pairs breeding in a mixed Lothian wood of 26 acres, and estimates that young, while fledging, alone require 7,500 lepidopterous larvæ a day.

(2) CHIFFCHAFF.

Occurrence: as above. Rather less common than above, but is more confined to forest trees; only local from Yorkshire to Firth of Forth.

Habitat: as above, but more arboreal, consequently found deeper in the woods, and in denser

stands, but not in either pure or mixed wholly coniferous stands without undergrowth. In rather open pure pine forests, soil quality IV-V (40), as with the wood-wren (but not the willow-warbler).

Breeding-habits: as above, usually 6 eggs, but nesting in low bushes and small trees, 2-3 feet above the ground.

Food: as above, but from its habits more restricted in number of species. Not larvæ of *Lymantriidæ* (40), but undoubtedly of small *Lepidoptera*. Mainly ova and imagines of moths: aphids. Wholly insectivorous.

Economic Status: beneficial, of primary importance, for above reasons.

(3) WOOD-WARBLER.

Occurrence: mid-April-September. Locally not uncommon south of Ross and Sutherland; rarer in Ireland.

Habitat: as above, but even more exclusively a woodland bird, especially fond of oak and beech. Found in middle of dense mixed coniferous woods, without undergrowth (40).

Breeding-habits: as (1), 6-7 eggs, end of May, but single-brooded.

Food: as (1), but apparently more imagines are taken; the undersides of leaves are searched for ova, etc. (42).

Economic Status: as (2), but unfortunately it is the least common of the three. Appears almost inseparable (as a breeding bird) from beech.

(4) LESSER WHITE THROAT.

Occurrence: as (3). Fairly common south of Westmoreland, except W. Wales; unknown Ireland.

Habitat: as (1).

Breeding-habits: 4-6 eggs, similar to (2), except that it nests higher.

Food: as (1), especially larvæ of *Lepidoptera* (42), but not of *Lymantriidæ* (40). Probably only rarely *coleopterous* imagines, though an adult *Coccinellid* has been noted (40). Commonly *Aphididæ* (42).

Economic Status: least important, as not really a forest species.

(5) THE REDSTART.

Occurrence: end of April-mid-October. Well distributed, locally not uncommon, except N. Scotland and Ireland.

Habitat: open stands and clearings, often hilly country, but not particular. According to Von Vietinghoff fond of mixed coniferous rather than deciduous woods, but in this country occurs in all types, especially among old timber, though this is partly on account of breeding-habits. Where nesting sites are available it occurs among sound timber.

Breeding-habits: only occasionally double-brooded; 5-7 eggs, May. Nest built in an old woodpecker boring, or holes and fissures in trees; particularly in loose stone walls.

Food: feeding-habits intermediate between arboreal warblers and the robin. Rather specialized.

COLEOPTERA: small *Rhyncophora* (captured on the ground, in foliage, or on the wing). No record of *Coccinellidæ*, which are doubtless distasteful.

LEPIDOPTERA: larvæ; pupæ (40), imagines; probably ova too. Particularly larvæ of *Tortricidæ*, 39 being found in one crop (31); imagines of *Tineidæ*, and other small moths.

HYMENOPTERA: larvæ of *Tenthredinidæ* (42); but many imagines, which must include useful forms.

DIPTERA: form a considerable percentage of food; therefore, mostly of a neutral nature.

RHYNCHOTA: no record, but doubtless *Aphididæ*. Spiders, elderberries.

Economic Status: beneficial, of considerable importance, since the bird is readily encouraged to nest in artificial sites (unlike the ground-nesting warblers).

(6) THE STONECHAT, AND (7) THE WHINCHAT.

Occurrence, etc.: widely distributed, but rather local, of very similar habits, haunting commons and heaths covered with gorse, broom, heather, bracken or rough grass, and up to a considerable altitude, nesting on the ground, 4-5 eggs, end of May.

Food: obtained from the ground, or from bushes, consisting mainly of small ground beetles (*Rhyncophora* etc.) Newstead (31) notes sawfly and noctuid larvæ in the stonechat, and these are probably fed to the young in some quantities.

Economic Status: beneficial, of considerable importance. Both these birds are apt to be neglected, but in reality they occupy a unique position in forestry.

(8) The robin, like the redstart, is chiefly important from the fact that it inhabits nesting boxes, and can be easily encouraged. It is generally distributed, comparatively common in woods, where it feeds almost entirely on insects obtained from the ground and foliage. It is useful in the control of *Lymantriidæ* (40), and of *Tenthredinidæ* (Hickson). *Rhyncophora* obtained from the ground are also destroyed. To some extent the robin can replace the arboreal warblers.

Other closely-allied species, of less importance, but also found in woods are (*a*) the blackcap, (*b*) the grasshopper-warbler, (*c*) the garden-warbler, (*d*) the nightingale.

Summary of the family: though individually of little importance, collectively the arboreal warblers form a very valuable check on the numbers of small defoliatory larvæ, and to a less extent of *Rhyncophora*. Since they feed principally on the adult and egg stages their utility is increased; with the tits and the goldcrest (*Paridæ*), they form practically the only group of actively aphid-searching birds. In addition (1), (2) and (3) are common hosts of the cuckoo.

From the fact that they do not usually search foliage, except in pest-areas, the hedgesparrow, common wren, song-thrush, mistle-thrush, blackbird, etc., are of very limited value. Of these the thrushes are the most important, for sawfly larvæ have been found, on analysis, quite frequently (17). The flycatchers are certainly undesirable, feeding, as they do, mainly on *Diptera* and *Hymenoptera*, and accounting for many *Ichneumonidæ*, *Braconidæ*, *Chalcidæ*, *Tachinidæ*, etc., while the benefits they confer are of relatively little importance. Flycatchers should on no account be encouraged by the provision of nesting boxes.

Protection: destruction of sparrowhawk, jay and carrion-crow. Since (1)-(4) nest on or near the ground their eggs are often taken by mice, voles and the hedgehog, and the young by stoats, weasels and snakes.

Encouragement: an admixture (however slight) of broad-leaved with coniferous trees—especially of beech—is the easiest and surest encouragement, but this is useless if nesting sites are not available. If the woods are small, this does not matter, as they will nest on the edges, and their usefulness will extend for several hundred yards into the stand (10). Otherwise bracken, grass, brambles, etc., in rides and ditches, should not be cleared—other things being equal—till after the young are fledged, i.e. the beginning of July.

Family: HIRUNDINIDÆ (Swallows and Martins)

Family: CYPSELIDÆ (The Swift).

The swallow, house- and sand-martins, and swift, are all birds with very similar habits. Food is obtained in the air, and consists, therefore, of flying insects, commonly small *Coleoptera*, infrequently *Lepidoptera*, most often *Diptera*, *Hymenoptera*, and *Rhynchota* (*Aphididæ*).

In relation to the forest they are rather unimportant, as the buildings where they nest in colonies, or sandpits inhabited by sand-martins, do not often occur near extensive areas of woodland.

Formerly it has been supposed that their influence is very beneficial, and no doubt it is to man, but in the forest they must always be undesirable.

Lepidoptera and *Rhynchota* are not caught in sufficient numbers for the benefit to be important, but *Coccinellidæ* have occurred in the very few stomachs examined in such numbers (31) that it is evident that these birds are the *only important destroyers of ladybirds* (except parasites), and are not deterred by the unpleasant taste, which makes them so obnoxious to most other birds. They have occurred in house-martins (many), and swifts, and four nestlings of the latter all contained *Coccinellidæ* of three different species (31).

Hymenoptera would include at least three important genera parasitic on various stages of very injurious insects.

Diptera would include the *Tachinid* flies, also of considerable economic value.

It is quite evident, therefore, that any of these birds are very undesirable; and though the eggs, young and adults are protected by law they may easily be prevented from nesting.

Family: PICIDÆ (Woodpeckers, the Wryneck).

General: mainly resident, rather local, often wandering to new areas in winter, but entirely restricted to the neighbourhood of trees. Fairly well distributed in Great Britain but absent from Ireland. Single-brooded, nesting in holes, usually self-excavated, in unsound and dead timber.

Largely dependent on dead and dying timber for sufficient food supply (*Rhagium spp.*, etc.); therefore, woodpeckers owe their existence mainly to bad silviculture, preventing or controlling the inevitable insect ravages, though as the only natural means of suppressing certain primary pests, they are of the greatest value in practical forestry.

It is noticeable that woodpeckers do not breed in young plantations, or in any perfectly healthy woodland, though they may appear there in winter.

Probably there is no family, with the exception of the *Paridæ* (tits and goldcrest), which is so generally beneficial and necessary to the well-being of a wood.

(1) THE GREATER SPOTTED WOODPECKER.

Occurrence: fairly well distributed south of Tweed, rapidly re-establishing itself in Scotland (it was exterminated by 1850), and is now reported from Inverness-shire. The Northern race, only sub-specifically distinct, is a regular winter visitor to Scotland and N. England, sometimes appearing in considerable numbers.

Habitat: the commonest woodpecker in coniferous areas, but is equally fond of woods of broad-leaved trees.

Nesting-habits: 5-6 eggs, end of May, in an excavated hole in dead coniferous timber (never in living, for obvious reasons), and in other unsound or dead trees, especially birch and beech (56, 1912), of over 10 inches Q.G.

Food: not only searches stumps, the trunk and branches, but in certain pest-areas examines twigs and foliage. Its numbers, both as a breeding bird, but particularly after breeding, are influenced by food supply to a marked extent, and Vietinghoff notes that it was the only bird whose numbers were above normal in a mixed coniferous wood where the nun-moth pest was of long standing.

Typical stomach analysis of birds from such areas (40):

(1) 155 eggs, quantities of remains of adults; beetles and weevils.

(2) 11 larvæ, 1 large beetle (?), 2 spiders.

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(2) 11 larvæ, 1 large beetle (?), 2 spiders.

(3) 37 larvæ, various carabidæ (?), egg remains, a spider.

It was apparently of some importance in control of *Pityogenes bidentatus* and *Myelophilus piniperda* (40), though Altum doubted its utility with the latter. In this country many field naturalists have noticed it searching for larvæ of *M. piniperda*.

Homeyer also noted marked increase with bark-beetle pests (40). It is unnecessary to give a list of species taken, for it does not appear to refuse any sort or stage of insect found on trees (15). *Coccinellidæ* have only once been found (31) when four imagines occurred in one stomach. Collinge (11) noted *Pissodes sp.* which did not occur in analyses of other woodpeckers, but this, no doubt, was due to lack of opportunity. Besides certain *Ichneumonidæ*, this bird is the only effective natural agent in the control of *Siricidæ* and *Trypanidæ* in the larval stage. It is not known to feed on *Rhynchota*.

The amount of insect food eaten has not been determined, but of 4 American species of Dryobates, the average is 78.5% (from Beal and McAtee, under 10). When insect food is unattainable, this woodpecker can support life on coniferous seed, only occasionally also taking acorns, mast and large berries. Scots pine cones are most frequently attacked, and the characteristic appearance of these cones wedged in some fissure or hole in dead wood is the surest indication of the bird's presence. This trait is of great importance, since it enables it to tide over an

unfavourable period, or exist on insects in a fairly healthy wood eked out by seed (which can well be spared). Therefore it is found in woods freer from disease than with other woodpeckers, yet its utility is not in the least diminished on this account, but rather increased.

Physical Damage: this woodpecker, so far as available evidence shows, has never been known to bore or disfigure healthy timber.

Economical Status: beneficial, of greater importance than other members of family.

Protection: the sparrowhawk seems particularly attracted towards such a conspicuous, slow-flying, and noisy bird; and its remains have been found far too frequently, considering the comparative scarcity of this woodpecker (44, etc.). Second only in importance is the starling, which must be prevented from evicting the rightful owner and its eggs (see under Starling). The squirrel has also been known to destroy the nest (6).

Encouragement: the writer does not advocate the provision of nesting-boxes (see under 43), because they have never met with any success in this country; and boxes that are provided, should, of course, be quite cheap contrivances, put up to accommodate the starling.

It is of no use to encourage this bird to breed where the area is so well managed that timber insects (which generally means dead or dying trees) are absent. On the other hand coniferous woods are always liable to sudden attacks of bark-beetles, weevils,

or defoliatory larvæ, and it is of the utmost importance to have these woodpeckers breeding, in order to check the increase of the pests in time. As with other birds, it is far better to have a resident stock feeding to some extent on neutral matter (in this case seeds, harmless insects, ants and spiders), for it is impossible to produce birds at a moment's notice, and normally they will only appear after the pest has obtained a strangle-hold.

The only method advocated in such woods is to leave a few dead birch, alder or other hardwoods, which will neither provide a harbourage for harmful insects or fungi (except *Armillaria mellea*), nor interfere with the growth of the proper crop. Any such stumps or barkless coniferous stumps should also be left to breed *Rhagium*, and other dead-wood feeders, ants, etc.

In other words, too rigorous an observance of those rules, which demand that all woods should be entirely free from dead wood, is not only pedantic, and costly in execution, but indirectly harmful to the welfare of the whole crop.

(2) THE LESSER SPOTTED WOODPECKER.

Occurrence: uncommon, even locally; in general, rare; restricted to England south of Yorkshire.

Habitat: chiefly old woods of broad-leaved species as a breeding bird.

Breeding-habits: 4-6 eggs, May; only excavates nesting hole in soft timber.

Food: searches branches as often as the trunk. Structurally least well adapted of the woodpeckers to bore for larvæ, not usually excavating deeper than two inches, and only as much in softer timber, on which account the species comprising its food are correspondingly limited. Newstead (31) found both crops examined full of *Scolytid* larvæ.

Economic Status: where it occurs, of considerable utility, especially against such increasingly important insects as *Saperda populnea* and *Chrysomelidæ*. It seems to be inseparable from dead wood, however, and so of little value, especially since (1) can be encouraged to breed in all localities where this bird occurs.

(3) THE GREEN WOODPECKER.

Occurrence: the commonest woodpecker in most localities south of Cheshire, rapidly becoming rarer further north.

Habitat: though sometimes occurring in pine-woods in winter, practically restricted to broad-leaved trees, and of these elm, ash, poplar and willow seem favoured, though not occurring in dense formation. It is curious how few trees can supply a pair of these birds with all the food necessary for themselves and their young.

Nesting-habits: 5-7 eggs, May, in a hole preferably in dead or soft wood, or in the sapwood of a large tree. In spite of Collinge's investigations, it cannot be denied that borings are occasionally made in sound timber, but it is the writer's opinion that the

green woodpecker alone does such damage, which is very limited in extent.

Food: differs from that of (1), in consisting partly of ants; other neutral food includes spiders, occasionally acorns. Collinge (10) gives: injurious insects 75%; ants 20%; spiders etc., 5%. Actual numbers of insects are surprisingly large: 1,300 beetles in one crop, 1,100 in another, and 300-800 quite commonly; 57 *Rhagium* larvæ were found in one stomach. In 78 analyses only one *Coccinellid* was found. Newstead (31) noted larvæ of *Sesia spp.*

Economic Status: beneficial, of primary importance, though the writer considers it of less importance than (1), on account of habitat. The increasing popularity of poplars and willows, however, must not be forgotten.

Protection and Encouragement: as for (1).

(4) THE WRYNECK.

Occurrence, etc.: a summer visitor to S. and S.E. England, elsewhere rare, and not occurring in sufficient numbers to be of any importance, particularly as its favourite food is ants and their pupæ.

Summary of the family: the following insects are given by Collinge (10) as occurring in 91 analyses of three species of woodpeckers, chiefly of (3):

Tomicus spp., *Hylobius abietis*, *Myelophilus pini*, *perda*, *Hylesinus fraxini*, *Cryptorrhynchus lapathi* *Hylastes ater*, *Saperda populnea*, *Cyleborus dispar* also larvæ of *Rhyacionia buoliana*, *Sesia culiciformis*,

and *Zeuzera pyrina*. See also under the food of species; but, as before stated, it is doubtful if any species of beetle, moth or fly, or any stage, is refused when found, and the utility of the respective species should be interpreted in relation to their habitat, particularly during the breeding time, and to their method of obtaining food.

Family: CUCULIDÆ (The Cuckoo).

(1) THE CUCKOO.

Occurrence: April-August, birds of the year till September. Well distributed.

Habitat: open woodlands, and edges of denser coverts, not usually in pure Scots pine (40), or at high elevations. In afforested areas numbers vary with those birds on whom it is parasitic.

Nesting-habits: usually from 8-12 eggs, laid singly, from end of May onwards in nests of other species, chiefly warblers, wagtails, pipits, the hedgesparrow or robin.

Food: searches all types of vegetation for larval forms, less commonly for pupæ or imagines. A specialized, but voracious feeder.

COLEOPTERA: chiefly small ground *Rhyncophora*, but of limited use, though Homeyer (40) calculates that 100 cuckoos in 15 days *can* account for 2,880,000 *Scolytidæ* in a pest area. Cziki (40) of 37 cuckoos,

5 contained adult *M. vulgaris*. The largest numbers in one crop were 110 larvæ of *T. viridana*, and 10 adult *M. vulgaris* (15). Baer (41) found 12 in one stomach, and Ogilvie (34) found numbers in one Cuckoo in June. *Melolonthinæ* are obtained from the ground and from foliage. Newstead (31) gives larvæ of *Coccinellidæ*, probably all stages taken. Various ground *Carabidæ* are commonly eaten, and no doubt *Elateridæ*.

LEPIDOPTERA : commonly larvæ, but also other forms (doubtfully ova) of most if not all families. Typical stomach analysis from area-infested by *Lymantria monacha* (40) : 45 larvæ, and many beetle remains. Besides commoner *Lepidoptera*, includes *Zeuzera pyrina*, *Porthesia auriflua*, *Bombyx neustria*, *Lasiocampa quercifolia*, *Pygæra bucephala* (commonly, 10).

HYMENOPTERA : chiefly *Tenthredinidæ*, both larvæ and imagines. *Lophyrus pini* commonly (10, 31), *Nematus spp.* (10). Imagines of useful species have not been noticed, and it is doubtful if they could ever occur in any quantities, as the bird does not take insects on the wing.

DIPTERA : a small proportion of neutral dipterous larvæ only.

RHYNCHOTA : occasionally *Aphididæ* (42).

Proportions : Collinge (10) gives 83% injurious, 17% neutral insects, as follows : 50% *Lepidopterous* larvæ, 8.5% moths, 14.5% various beetles, 4.5% sawflies and larvæ, 6% *Dipterous* larvæ, 6% neutral vegetable matter.

Economic Status : so beneficial is the food of adult cuckoos, chiefly due to lack of useful parasitic insects and *Coccinellidæ*, that broods of the less useful small birds can well be spared. At the same time larvæ, the least useful stage attacked by predators (compare tits eating ova, and nightjars imagines) decreases the actual utility of the bird ; nevertheless, it is of primary importance to forestry. Unlike other birds, cuckoos are not forced to remain in particular areas for nesting purposes, and, therefore, they are free to move about wherever food is most abundant. Small flocks of ten or a dozen birds are sometimes seen in this country, and it is safe to assume that they would congregate in larger numbers were a caterpillar pest to occur over a larger area than usual, for on the Continent flocks of over a hundred are known.

Protection and Encouragement : similar to that for *Muscicapidæ*. The greatest enemy of the adult cuckoo is undoubtedly the sparrowhawk, and of the unfledged young, which are extremely noisy, ground vermin such as stoats and weasels.

Family : CAPRIMULGIDÆ (The nightjar).

(1) THE NIGHTJAR.

Occurrence : early May-mid-September. Generally distributed.

Habitat : open spaces covered with bracken, gorse, heath, etc. ; open glades in woods.

Nesting-habits : often double-brooded, 2 eggs, May and July, laid on the ground among the rank vegetation.

Food : 100% adult insects, taken on the wing, during dusk, nighttime and early morning. Amount of food consumed is very large, for digestion is quite rapid, yet stomachs are generally found packed full (10). The same authority gives very full details of species taken, a very good example of what should obtain for every forest bird :

	Per cent.	
Unidentified moths	18.5	*Lepidoptera* 49.0%
Moths of no forest importance	29.0	
Cheimatobia brumata	1.5	
Melolontha vulgaris	10.5	*Coleoptera* 48.0%
Phyllopertha horticola	5.0	
Rhizotrogus solstitialis	4.5	
Geotrupes spp.	1.5	
Diptera (chiefly Tipula sp.)	13.0	*Diptera* 13.0%
Unidentified beetles	16.5	

This gives insects injurious to the forest roughly 50%. Cziki (40), 60% of stomachs examined contained *M. hippocastani*. Baer (40) found that uncommonly large numbers of nightjars accompanied the nun-moth pests.

Newstead (31) found *Noctuidæ* and *Geometridæ*, also *Elateridæ*. It has been noticed as useful in control of *Lophyrus pini* (45). With those species of which the females are almost wingless (i.e. *Cheimatobia brumata*, *Orgyia antiqua*) the nightjar is, of course, of no economic importance.

Economic Status : of the first importance, particularly on newly reclaimed areas, where cockchafer and bark-beetle pests are likely to be severe. The nightjar is probably the only bird which is so consistently useful in proportion to the very little damage done (for it is likely that flying ladybirds and parasitic flies are also taken when encountered). It specializes in the adult stage, the most useful period to prevent the spread of any pest.

Protection and Encouragement : the adult birds have few enemies, but the young are taken by ground vermin, and the eggs by hooded and carrion crows, mice, voles, and the hedgehog. Usually, however, it should be the aim of the forester to encourage these birds to nest, for which reason large areas of heather, etc., should not be burnt at the same time, and never in the breeding-season (mid-May to mid-August). Gamekeepers frequently shoot the nightjar in mistake for a hawk.

Family : STRIGIDÆ (Owls).

General : well distributed, sedentary residents, except some birds inhabiting mountainous, exposed localities. Single-brooded, generally nesting in holes. Nocturnal feeders (except the little owl), preying on very similar animals, obtained from the ground. So

marked is the particular locality preferred by each of the five species that their typical environment can be summarized as follows:

Long-eared owl—coniferous forest.
Short-eared owl—moors and fenland.
Tawny owl—broad-leaved woods.
Barn owl—parkland, grass and fenland.
Little owl—hedgerow timber and shelter belts in cultivated districts.

(1) THE LONG-EARED OWL.

Occurrence: not uncommon N. England and Scotland; local elsewhere, winter immigration on E. coast, as well as a limited south internal migration.

Habitat: dense woods, and therefore usually of coniferous trees, but also of varying degrees of mixture with broad-leaved species.

Nesting-habits: 3-5 eggs, March, laid in old nest of magpie, crow, sparrowhawk, etc., or in a squirrel's drey, sometimes on the ground, under cover of brambles, gorse, etc., but always in or about woods.

Food: seldom obtained during the day. Mainly rats, mice, voles, small rabbits; also ground nesting birds and nestlings in summer. Useful 80%, harmful about 6% (10). Newman (30) gives cockchafers in April and May, and squirrels in May.

Economic Status: beneficial, of primary importance, particularly near newly formed plantations.

Encouragement: it is not so necessary to free the nests of other species to provide nesting sites for this bird, for not only does it lay in March, but also sometimes on the ground. The squirrel has been known to suck the eggs, though itself destroyed by the adults (6).

(2) THE SHORT-EARED OWL.

Only inhabiting moors and fens, and not usually those near woods, this owl is of importance only in so far as it occurs on newly-planted areas, and because its great consumption of mice and voles (also rabbits) may prevent the migration of these rodents to woods in winter.

(3) THE TAWNY OWL.

Occurrence: common, but where its distribution overlaps that of (1), absent.

Habitat: replaces (1) in broad-leaved woods, or woods of smaller extent than those suited to the long-eared owl. Essentially a woodland species, and apparently fond of beech. Prefers to roost in conifers.

Nesting-habits: 3-4 eggs, April or May, in old nests, as (1); hollow trees commonly; rarely on the ground.

Food: Collinge: 167 pellets contained remains of: 162 long-tailed field mice; 83 shrews; 21 grass mice, 30 water voles, and 5 rabbits.

Archibald (4): frequently water voles, moles and young rabbits; more seldom leverets, squirrels and small birds.

It has been noticed to bear off adult squirrels (60, 1912).

Economic Status: to the forester the tawny owl is the most useful raptorial bird in the British Isles.

Encouragement: as with all other birds, but particularly with owls, shelter in winter is of primary importance, in maintaining resident stock. The writer has noted a very typical case in this connection. In a pure planted beech wood of about thirty acres there are less than a dozen scattered Scots pines. For four consecutive winters a pair of tawny owls have been observed roosting in one of these pines during the day, in spite of the fact that the wood is an isolated, narrow shelter-belt on the top of a ridge. It is quite certain that the leafless beeches would not have afforded sufficient shelter from rain, wind, snow, etc., for the trees are too well grown to have any dead wood or large hollows in them (besides affording no nesting places). The pines, on the other hand, contain at least 3 available magpies' nests, which, of course, are well preserved in such situations, and here the owls annually rear a brood.

This is just an isolated record, one of many which might be cited as illustrating how easy and natural it is to encourage useful birds, without any cost or inconvenience.

There are several records of these owls inhabiting ordinary wooden boxes or small barrels, which have been securely wedged in the fork or branches of some large tree.

(4) THE BARN-OWL.

Occurrence: fairly common in suitable situations, though more or less replaced and much less in evidence in afforestated areas than (3).

Habitat: broad-leaved woods, though the writer has two independent records of the bird wintering in comparatively young spruce plantations.

Nesting-habits: 4-6 eggs, May; always in a hole in a tree or building.

Food: similar, though generally less useful, than (3). Useful 83%, harmful 16%, approximately (10). Collinge: 410 pellets contained 149 long-tailed field mice, 62 field voles, 34 bank voles, 25 house mice, 64 shrews, 125 brown rats, 5 moles; 122 house sparrows, 11 blackbirds, 12 starlings, 5 thrushes, 17 other small birds; 81 cockchafers and 53 other beetles.

Whenever it occurs, like all other owls, this species is of primary importance, but its partiality for small birds (a nest of young have been fed almost entirely on young starlings, 44, 1911) make it undesirable compared with (1) or (3).

(5) THE LITTLE OWL.

Occurrence: recently introduced (c. 1870), and still spreading in Wales and N. England, otherwise common, though not in Ireland.

Habitat: at present almost confined to agricultural districts, orchards, etc.; it may become of increasing importance in forestry.

Nesting-habits: 3-5 eggs, April or May; laid in a hole in a tree, or less frequently in the roots, or a rabbit burrow.

Food: often seen hunting during the day, but most active at night, more omnivorous than other owls. The food of the young includes 10% wild birds, (10). With adults, a collective examination of stomach contents, pellets and 'hoards' gives the percentage of species of birds; house-sparrow 2.5%, starling 2.25%, woodpigeon 2.25%, chaffinch 0.55%, cuckoo 0.2%, other neutral birds 2.5%. (Total 10.25%) (10).

Besides mice and voles, the shrew and mole occurred occasionally. The insect food eaten is very varied, and, except for ground beetles, is undoubtedly taken only as opportunity offers, (i.e. is not searched for); they include:

COLEOPTERA: *Melolonthinæ*, *Elateridæ*, but not commonly *Carabidæ*; also *Hylobius abietis*, *Scolytus spp.* and *Hylesinus fraxini*.

LEPIDOPTERA: *Hybernia defoliaria*, *Cheimatobia brumata*, *Tortrix viridana*.

HYMENOPTERA: *Nematus spp.*

Of birds obtained in May, June and July, *only*, 10.0% *Elateridæ*, and 5.1% *Melolonthinæ* (10).

Economic Status: the food of such a general predator varies greatly with locality (the most abundant insect, animal or bird being taken most often), and this is, to some extent, an advantage. Nevertheless, even where it occurs in the forest, the writer considers it of much less importance than (1) or (3). Insect food amounts to 50.44%, and this can be taken to better advantage by the very species of birds on which it preys (especially the starling and chaffinch). In afforested areas it is an open question whether the comparatively high percentage of avian food would not include warblers, and nestlings of other very useful birds.

Treatment: until this owl spreads and colonizes the woodlands, it can be ignored; but where it is already established, it is the writer's opinion that it should be discouraged in favour of (1), (3) or the Kestrel.

Family: AQUILIDÆ (Buzzards, Hawks).

General: single-brooded; building their own nests; occur as isolated birds or pairs.

(1) THE COMMON BUZZARD.

Occurrence: sedentary resident for the most part, though young wander in autumn to unoccupied territories. Very local distribution, restricted to Wales, S.W. and N.W. England, the Pennines, and the Scottish Highlands. Exterminated as a breeding bird in Ireland. The rough-legged buzzard of similar food-habits occurs in winter in Eastern England and Scotland.

Habitat: now confined to wild, mountainous

country, preferring the vicinity of woods which border moorland, or sparsely wooded valleys.

Nesting-habits: 2-3 eggs, April or May, nesting on trees (oak and larch preferred), or on ledges of a cliff or steep hillside.

Food: obtained from the ground. Chiefly small mammals to the size of a hare, ground nesting birds and nestlings, and ground-beetles. Ogilvie (34): 8 crops contained 3 rabbits, 1 hare, 1 rat, 1 vole, 1 woodpigeon, 1 blackbird.

Collinge (10) examined 398 pellets, finding remains of: 176 long-tailed field mice, 76 grass mice (*Microtus agrestis*), 84 water voles, 22 rabbits, 18 small birds, 8 woodpigeons, 72 *Carabidæ* and 1,664 *Geotrupidæ*; also a mole and a red grouse.

A nest has been observed to contain 64 young rabbits (44, 1924), and the buzzard is one of the few birds which destroys moles in any numbers. In Scotland the leverets of the mountain hare are often taken, and in winter the adults also. Rabbits, moles and mice are its chief prey, however, with a few birds in summer.

It has once been recorded as taking a young nightjar.

Hänel (40) found 17 cockchafers in one bird, and no doubt *M. hippocastani* are also commonly taken.

Economic Status: distinctly beneficial (even on grouse moors, if not allowed to increase unduly). For general account see under 41.

Protection: the buzzard is protected by law during the breeding season, but that does not prevent game-

keepers from shooting the bird off the nest. It only requires to be left alone to increase.

(2) THE SPARROWHAWK.

Occurrence: common in all unpreserved wooded districts: sedentary resident.

Habitat: all types of woodland, even nesting in plantations over 15 feet high.

Nesting-habits: 4-6 eggs, early May, in a large shallow nest of twigs, often less than 20 feet from the ground. Prefers larch above all other trees, but also commonly builds in oak, spruce and Scots pine.

Food: chiefly birds up to the size of a woodpigeon, and newly-fledged nestlings; less commonly small mammals and beetles. Collinge (10) gives game-birds, poultry and insectivorous birds 42.5%, sparrows, blackbirds and woodpigeons 23.5%, injurious insects 15%, beneficial insects 4.5%, mice 6.5%. It appears that birds examined by this authority have been shot in the act of eating poultry and game-birds, and these figures are therefore not at all representative of the true economic status of the sparrowhawk. Accepting 20% insectivorous food, 7% mice and voles, and 8% game-birds, the remaining 65% consists normally of species other than game-birds. Though a certain amount of this will be of a beneficial or neutral nature (woodpigeons, sparrows, blackbirds, thrushes or other unimportant birds), most slow-flying birds occupying the same wood as the sparrowhawk will be killed off. Such species are greater and

lesser spotted woodpeckers (the former not uncommon, see 44, 1914), the wryneck (34), the cuckoo, jay, starling, and the smaller insectivorous birds, tits, nuthatch, treecreeper, arboreal warblers, etc. Probably the blackbird, jay and starling suffer most.

Newstead (31) examined 12 birds, and identified remains of song-thrush, bullfinch, skylark, 2 warblers, blackbird, blue tit, starling, "finch," "Small bird," "3 nestlings," and 7 pellets contained remains of 7 willow-warblers!

The following have been identified near a nest of this bird in Epping Forest (52, 1925): house-sparrow, woodpigeon, starling, great tit, chaffinch, redstart, tawny owl, jay, lesser spotted woodpecker, whitethroat . . . possibly green woodpecker and little owl. This is, of course, quite representative of the damage done.

Economic Status: the sparrowhawk is, without exception, the most universally destructive forest bird. It is a voracious feeder, frequently killing more than it requires at the same time; and the food required to support a pair of birds and rear a brood of 4-6 young is prodigious. No amount of destruction of the woodpigeon (a bird of some slight sporting and food value, and relatively of little forest importance), or of neutral species like blackbirds and thrushes, or of mice (which are eaten in far larger quantities by owls, the kestrel and even the weasel), can atone for such increasing destruction of the all too infrequent insectivorous woodland birds.

Control: the total destruction of the sparrowhawk in the British Isles would remove the greatest enemy of the small bird and the gamekeeper. No pains should be spared to exterminate it at all seasons from the forest, and fortunately this is not difficult in spring.

The birds can easily be shot off the nest (which is useful for owls and kestrels to breed in), but any trapping may result in more harm than good. The sparrowhawk is characterized by regular daily rounds in search of food, so that, if once seen, it may be expected near the same place at the same time next day. Covert shooting in winter usually puts a few sparrowhawks over the guns. See Appendix. Other species include: the golden eagle, locally resident in the Highlands, is useful by killing down blue hares. It should be strictly protected.

Family: FALCONIDÆ (Falcons).

(1) THE KESTREL.

Occurrence: common and well distributed, leaving the mountainous country, and Scotland generally, and rather less common elsewhere in the British Isles, in winter (partial migrant).

Habitat: any sort of country bordering woods, but not usually in the middle of large areas of forest.

Nesting-habits: 4-6 eggs, April or May; single-brooded; laying in old nests of other species (magpie, crow, sparrowhawk, etc.), in hollow trees, or on ledges of cliffs and quarries.

Food: chiefly obtained from the ground, and consisting of small mammals (rats, mice, shrews, voles, moles, and young rabbits), beetles (also taken on the wing), and small birds. Useful 81% ; harmful 6% (10).

Florence (17) : 3 stomachs contained remains of 3 shrews, 2 field voles, 10 *Noctuid* larvæ.

Newstead (31) : 16 stomachs contained remains of 11 field voles, 1 long-tailed field mouse, 1 grass mouse, 1 bank vole, 2 neutral small birds, 2 starlings, 4 nestlings. 57 pellets gave : 62 field voles, 1 bird, 5 ground beetles.

Collinge (10) examined 360 pellets : 223 long-tailed field mice, 153 field voles, 9 bank voles, 4 water voles, 11 brown rats, 20 grass mice, 10 house mice, 2 shrews, 2 moles, 1 young rook, 10 small birds, 6 cockchafers, 47 ground-beetles, 5 diptera.

Other authorities (field observations) confirm this, i.e. moles (not uncommonly), beetles and beetle larvæ (fond of catching flying cockchafers when swarming round oak trees), lepidopterous larvæ (from the ground and from foliage).

Continental authorities deem it of secondary importance in control of *Melolonthinæ*, for they occurred only in 5 out of 94 stomachs.

The writer has made a careful study of the economy of the kestrel, extending over four years, and is able to confirm these opinions, and the fact that 'small birds' usually prove to be sparrows, blackbirds, or species nesting on the ground in the open (pipits and larks). Destruction of woodland birds

is negligible, even in winter, for they are rarely taken on the wing, but usually off the ground, in which respect it differs from the sparrowhawk.

Economic Status: beneficial, of primary importance.

Encouragement: usually lack of nesting sites prevents the establishment of this species. By judicious adjustment (see under separate species) the nests of magpies, rooks, crows, sparrowhawks, etc., all much less useful birds, can be made available by the beginning of April.

Summary of the Order: the birds of prey here enumerated, with the exception of the sparrowhawk, together constitute the most powerful natural agent in the control of mice and voles, mustelidæ, in their present numbers not excepted. The varying degree of utility, or otherwise, is here given in an abbreviated form, for comparison (from Collinge). (See next page.)

Other *Falconidæ*, restricted to wild and mountainous country, and protected in the breeding season, include :

(1) The *Peregrine Falcon* mainly on large and small birds : restricted to mountainous country.

(2) The merlin, preys on small moorland birds, mice and voles.

(3) The hobby, a woodland bird, occurring locally in S. England, in summer, preys on small birds, flying and ground-beetles.

These birds (slightly harmful) are too uncommon to be of economic importance.

PERCENTAGE FIGURES

	Long-Eared Owl	Short-Eared Owl	Tawny Owl	Barn Owl	Little Owl	Buzzard (1)	Kestrel	Sparrowhawk
Mice and Voles	78.0	75.0	82.5	68.5	31.0	55.0	64.5	7.0 (1)
Shrews	4.0	2.5	3.0	9.0	?	?	?	?
Moles	?	?	?	?	?	1.0	?	—
Rabbits ...	?	3.0	?	?	—	15.0	?	?
Sparrows Starlings Blackbirds	10.0	9.5	2.5 (3)	9.5	4.5	9.0	8.5 (2)	45.0 (1) (4)
Other small birds ...	3.5	4.0	?	4.5			6.0	20.0
Gamebirds ...	?	?	?	?	0.5	?	?	8.0 (1)
Injurious Insects ...	2.0	3.0	5.5	7.5	30.6	20.0	16.5	15.0
Beneficial Insects ...	—	1.0	0.5	—	1.0		?	4.5
Neutral Insects	2.5	2.0	2.5	1.0	17.6		?	?

(1) Approximate figures.
(2) Not Starlings.
(3) Sparrows only.
(4) And Woodpigeons.

Family : COLUMBIFORMES (Doves).

General: the three species of any importance are :

(1) The ring dove, or woodpigeon, (2) the stock dove, and (3) the turtle dove.

(1) and (2) are resident, their numbers increased in winter by flocks from the Continent ; while (3) is an increasingly common summer visitor. For all practical purposes they may be treated under one heading.

The damage, which in the writer's opinion has been very greatly exaggerated, is of two kinds :

(1) Destruction of seed, and newly germinated seedlings (cotyledons).

(2) Destruction of buds, and leading shoots, of established trees.

(1) In the nursery this is, normally, prevented, but damage in naturally regenerated areas, particularly (if not entirely restricted to) those of oak and beech, may be more serious. Shooting is the most effective scare, as these birds are shy, and early morning is the best time to attack them. Sowing in spring, however, is the most effective prevention, as it reduces the risk to a negligible quantity, for, although the turtle dove will be just arriving, numbers of the other two most injurious species will have migrated.

(2) Has been much exaggerated, and unless enormous flocks descend to roost on young plantations, may be entirely neglected.

Summary: it must be remembered that pigeons tend to add to the sporting value of a wood, assisting the rental, and in any case will provide both pleasure and profit to the forester.

Any of the usual methods of attracting these birds to the gun may be employed, i.e. the decoy pigeon, or if water is scarce (pigeons are thirsty birds), their favourite drinking place may be watched at midday. Usually, however, pigeons have a favourite roosting tree, and waiting under this an hour before sunset will always yield a good bag.

Family: TETRAONIDÆ (Grouse).

General: sedentary residents, gregarious in winter, usually protected by destruction of enemies, and occurring in more or less wooded mountainous country. Single-brooded, polygamous, nesting on the ground. Local distribution.

(1) THE CAPERCAILLIE.

Occurrence, etc.: for accounts of extinction, reintroduction and spread, see under 35. Not uncommon in many coniferous forests in Scotland, even spreading to mixed woods (besides those containing birch).

Nesting-habits: 6-9 eggs, early May.

Food: adults entirely vegetable feeders. In no crops (58, 1879) were any traces of insects found, though various ground-beetles, etc., are *said* to be eaten in summer, and no doubt the food of young is at first largely insectivorous, though of a neutral nature.

Harvie-Brown ("The Capercaillie in Scotland," 1879) is of the opinion that healthy shoots are much preferred to those damaged by frost or insects, and in one crop counted 918 larch buds. In this country larch and Scots pine shoots, buds and needles seem preferred, though Fisher (16), apparently quoting from continental works, differs. Spruce is least liked. There is no data for Douglas fir. Buds and leaves of broad-leaved trees, birch, oak, etc., are also taken in large quantities.

Extent of Damage: greatest damage is done in newly planted or regenerated areas, adjacent to old timber. Capercaillie will stand on the ground, reach up and nip off the leading shoot, or terminal buds (much preferred to any other); but if the plants are more than 3 feet high the leader, at any rate, is immune. In deep snow, however, the birds are not only able to reach higher up the stem, but the amount of damage also becomes more acute.

Economic Importance: very injurious, except in woods where height growth has already been obtained. Of considerable sporting but negligible food value.

Control:

(1) Numbers should always be maintained at a minimum, consistent with game rights and laws.

(2) Young plantations should be made at some little distance from those mature woods which are known to be inhabited by capercaillie.

(3) Large transplants should be preferred.

(4) Spruce, other things being equal, should be planted nearest the coverts.

(5) When snow is on the ground, and the tops of the young trees are so conspicuous, it would probably pay to employ a boy to patrol the plantations, and examine the snow for tracks of hares, rabbits (and take stock of other animals), which would also scare away capercaillie and black game.

(2) BLACK GAME.

Occurrence, etc: woods in Scotland, N. England, Wales, N. Devon and Somerset, and some other counties (such as Shropshire) where, however, it is uncommon and very local. Occurs at greater elevations than (1).

Nesting-habits: the greyhen lays 6-10 eggs in mid-May, on the ground, usually amongst thick cover.

Food: rather more insectivorous than (1), but of very limited usefulness on this account. Vegetable food is similar to that of the capercaillie, but more varied, chiefly shoots and berries of moorland plants. It can, however, be exceedingly injurious to plantations, particularly of larch, from 8-20 years of age. In Merionethshire, a case came under the notice of the writer, where flocks of blackcocks and greyhens

so persistently visited a large plantation of larch in winter that the owner was threatened with severe loss. Shooting the birds was unsatisfactory, for comparatively few were killed, and the remainder renewed their depredations next day. The flocks came down from the rough woods of birch, etc., on the hillsides, and as the larch was the only plantation of its kind for some distance it apparently attracted the entire stock of birds. Eventually it was decided to post a number of guns on the edge of a wood at the mouth of the valley, and an organized drive was begun from over a mile away, one or two brace being bagged from each pack, as they fell into the cover behind the guns. Afterwards the cover was beaten out, and the stock of grouse materially reduced; in addition to which the remainder were so shy that a few shots in the larch plantation were sufficient to scare away the birds for some days.

In Scotland it has been noted as doing so much damage that particular plantations have been rendered worthless for timber production, and re-afforestation on such areas considered impracticable. Crop examination proves neutral beetles in large numbers, also 'spangle-galls' (*Neuroterus lenticularis*) (34).

Control: except in mature woods, where damage of this sort is of little importance, every effort should be made to thin the resident stock, even at the risk of reducing the sporting value of the neighbouring woods. Measures similar to those advocated for (1) apply to the same extent for black game. Fortunately once the stock has been reduced, it is com-

paratively easy to maintain it at that level, or to even further diminish it. Special precautions need to be taken during snowy weather, which covers up most of its food, or after severe frosts, which damage birch buds, for it has been often noticed (34) that damage to forest trees is then most severe; in fact, larch sometimes appears to have been grazed, so thoroughly have the buds been stripped from the twigs. Ogilvie also notes that Corsican pine is practically immune, and that Japanese is preferred to European larch, though both suffer immoderately.

Family: PHASIANIDÆ (The Pheasant).

General: since the pheasant now occurs wild in some unpreserved localities, and is, moreover, so important a factor in the management of many English woodlands, it has been included as a bird of some economic importance.

(1) THE PHEASANT.

Occurrence: variable, spreads into unpreserved woods from estates where it is reared. It is a hardy bird, but not usually found further north than the Lowlands, where it is replaced by black game.

Habitat: in and about woods of all types, fond of roosting in dense young plantations of conifers.

Nesting-habits: 10-15 eggs, April or May; polygamous, single-brooded, nesting on the ground.

Food: obtained from the ground. Besides grain, leaves, various seeds, including coniferous seed, acorns, mast and berries, many insects of great importance to the forest.

Collinge (10) gives: injurious insects 23.4%, beneficial insects 1.0%; but these quantities are, of course, higher in districts other than agricultural. The pheasant takes dipterous larvæ (*Bibio spp.*) in greatest numbers, but many beetles and their larvæ, lepidopterous larvæ and the wingless females of *Hybernia defoliaria*, as well as *Aphididæ*, fairly commonly. Florence (17) records 3 *ichneumon* cocoons in one crop. Archibald (4) notes quantities of the 'spangle-galls' (*N. lenticularis*) on oak-leaves. The number of insects occurring in crops is unusually large: 1,200 wireworms in one bird (31), and about 96,000 larvæ of *Bibio spp.* in only 84 crops (10).

It is apparently of only secondary importance in control of *Melolonthinæ* abroad (40), but that is due rather to lack of opportunity, for the adult beetles are much sought after.

Economic Status: beneficial, and of primary importance in recently felled coniferous areas threatened with damage by bark-beetles and weevils.

Protection and Encouragement: there are so few ground-feeding insectivorous birds in woods (the starling is the only other of any value) that, apart from game interests, the pheasant should be encouraged to breed wild, and, of course, preserved in the ordinary way against ground vermin.

Unfortunately, it is not usually possible to keep

DIVISION INTO GROUPS

Apart from game interests, and regarded in a strictly practical manner, the relationship of birds to the forest is most conveniently discussed under three headings :

(*a*) Insectivorous species, therefore, generally useful.

(*b*) Carnivorous species, both useful and harmful.

(*c*) Mainly phytophagous species, distinctly harmful.

INSECTIVOROUS FOREST BIRDS

The foregoing notes on the food and feeding-habits of these birds, regrettably incomplete though they are, nevertheless serve to show the potential value of such predators.

It has been shown that some birds are rather selective feeders, but the great majority (as far as available evidence shows) may fairly be described as preying on most stages and species of whatever insects occur in their particular field of activity. The nature of the food eaten is restricted in number of species less from choice than from lack of opportunity.

In other words, the economic status of *insectivorous* birds is largely determined by their habitat and method of obtaining food, for, as might be expected,

the majority prey on whatever insect is most abundant, provided that it is not actually distasteful (as are *Coccinellidæ*, *Chrysomelidæ*, and hairy larvæ to some birds).

Most insectivorous birds inhabit one of four rather definite regions or ' strata ' in the forest, where they search for food—the ground, trunk, and branches, foliage, or the air. Definite examples of such species are (respectively): starling, treecreeper, coal-tit and nightjar. Some birds are more adaptable than others ; thus the chaffinch feeds on ground insects, as well as searching foliage, and capturing insects in the air ; while other birds, such as the nightjar, swallow, martin and swift, feed exclusively on flying insects.

Nevertheless, in general, it may be said that each genus is characterized by a particular *method* of obtaining food, in which respect injurious forest insects, passing through three or four definite stages to attain maturity, differ to a remarkable extent.

It is the exception rather than the rule for insects to complete their metamorphosis in one environment : the *Rhynchota*, a low form of insect life, providing the most obvious exceptions, and it is noticeable that this produces an equally specialized type of predator in the treecreeper, which feeds on bark-infesting *Chermesidæ* and *Coccidæ*, and the goldcrest on the needle and twig forms. (In fact, these two genera are quite the most specialized of all birds in the nature of their food.) The *Scolytidæ* and *Rhyncophora*, though passing through the first three stages

in their life history in much the same environment, have a free flying adult period, when they feed on other tissues, foliage, bark or roots.

Most moths, again, feed as larvæ on foliage, hibernate or pupate on the bark or in the ground, and emerge as free flying insects. Enough has been said to show that this characteristic is of great biological significance, in that such a type of metamorphosis should have evolved with so many different orders of insects, proving that by this means they are best able to escape their natural enemies.

From a practical standpoint this means that any particular species, genus or even family of birds is usually unable, by itself, to maintain the numbers of any insect at the normal level; conversely, predators must be present in each of the four forest 'strata' in order to maintain the balance of nature with success and permanence.

Although the writer believes that he is the first to advance this aspect of biological control in the forest, it is reasonable to suppose that the natural and systematic protection *of* the forest by birds will only be attained on this condition. It is with this in mind that the following list of insectivorous birds has been arranged, the most important species (see Appendix) being given in large type:

(*a*) *From the ground*: STARLING, ROOK, jackdaw, magpie, whinchat and stonechat (and foliage of small trees), pheasant; in part: ROBIN, chaffinch, cuckoo, jay and sparrows.

(*b*) *From the trunk and branches*: WOODPECKERS, NUTHATCH; treecreeper; in part: most TITS.

(*c*) *From foliage*: TITS, goldcrest, arboreal warblers; in part: REDSTART, ROBIN, chaffinch, cuckoo, sparrows.

(*d*) *From the air*: NIGHTJAR, REDSTART (in part); harmful: SWALLOW, MARTIN, SWIFT.

Protection, encouragement, and discouragement of each species is dealt with in Chapter IV, by silvicultural, biological and artificial means.

ACTUAL CONTROL OF INSECTS BY BIRDS

It is frequently implied, or brought forward as crushing evidence by the less intelligent observer, that the failure of birds, firstly to prevent, and secondly to suppress, the enormous continental pests proves, *ipso facto*, that insectivorous birds are of little, if any, practical use in modern forestry. Your 'practical' forester establishes his pure plantation, and unintentionally it is true, but nevertheless effectively, thereby succeeds in producing an ideal state for the development of the insect, at the same time preventing the great majority of forest birds from breeding, and, therefore, from controlling the injurious insects just when they are multiplying. And is it fair to compare the reproductive power of an abnormal number of insects with that of a subnormal number of birds?

Whatever the limitations of birds to combat *pests* in a hyper-artificial environment (a subject, as stated

in the Introduction, outside the scope of this thesis), there is no doubt that the numbers of injurious insects are normally kept under control more by birds than by any other parasite or predator (see under Biological Control, Chapter IV). It is sufficiently obvious, too, that prevention is better than cure.

Given the opportunity, therefore, it will be seen from the following quotations that some birds can be of extreme importance in the control of certain insects, even when handicapped by the unnatural environment.

"The Hainich Wood, South of Eisenach, which covers several square miles, was stripped entirely bare in the spring of 1905 by larvæ of *T. viridana*. The wood of Baron von Berlepsch, in which there had long been nesting-boxes, was untouched. It actually stood out among the remaining woods like a green oasis. At a distance of a little more than a quarter of a mile farther the first traces of the plague were apparent, and at the same distance farther on still it was in full force. . . . The abundant use of nesting-boxes in the Prussian woods has, during the last two years, brought about in some places a sensible decrease in cockchafers and *T. viridana* by means of starlings" (43).

There is a well-authenticated instance of tits and jays effectively protecting a stand from the pine moth (*P. flammea*) (40, 1925).

"The foresters of the See Estate in Prussian Oberlausitz consider that the distribution of 600

starling nesting-boxes in their woods once saved these from the nun moth (*L. monacha*), for neighbouring properties were damaged. . . . Some birds are the only means of control with *T. viridana*, *Argyresthia atmoriella*, *Zeuzera*, *Saperda*, etc." (55, 1914).

"In 1908, nun-moth pupæ in enormous numbers were attacked by swarms of starlings on the Schnaken Estate in E. Prussia, and in two or three days destroyed them so completely that sufficient could not be obtained for experiments" (55, 1914).

Several authorities are of opinion that birds normally occur in insufficient numbers to control an insect outbreak, but this is not surprising considering the disadvantages with which they have to compete.

It was noticeable after the severe frosts in the early part of 1917, in England, which produced a heavy mortality among tits, goldcrests, wrens, tree-creepers, lesser spotted woodpeckers, etc., that in the following summer a most unusual plague of omnivorous caterpillars broke out all over the country (44, 1917, *inter alia*).

Again: "During the damage in Bavaria by *L. monacha* from 1889-91, the starlings collected in one locality alone was credibly estimated at 10,000, all busy feeding on the larvæ, pupæ and moths, not to mention enormous flights of tits and finches similarly engaged" (33).

For the following account of the influence of birds in suppressing the famous large larch sawfly outbreak in the Lake District, the writer is indebted to the personal help of Professor S. J. Hickson, of Manchester

University (see also account issued for private circulation). As this is one of the few bad outbreaks of insects over a large area in this country, the account is given at some length.

From 1905 onwards the infestation of the larch woods near Thirlmere in Cumberland by *Nematus Erichsonii* caused great concern, and by 1908 much damage had been done. Experiments were carried out by the Department of Economic Zoology of the University of Manchester to control this by tar-banding, hand-picking, and the provision of nesting-boxes for insectivorous birds. The first two methods appeared to be unsatisfactory and expensive.

In 1908, 60 nesting-boxes were put up; of these only 19 were used that year. In 1909, out of 174 more boxes 81 were used, suggesting an increase in the number of breeding-birds, and a further 105 boxes were erected in 1910. The chief species occupying those were the starling, various tits, and robin.

Field observations showed that when the pupæ were hibernating in the ground under a thin covering of moss and pine needles, great numbers were destroyed by rooks and starlings; and in the summer small insectivorous birds fed to a great extent on the larvæ. Chaffinches were very useful.

Writing in 1911, Professor Hickson says: "It was found by the investigation of a large number of cocoons collected on the Thirlmere Estate in the spring of 1910, that no less than 65% had been destroyed by the *ichneuman* flies [showing that they had not been suppressed by the birds], a percentage

far in excess of that of previous years. In the summer of that year (1910) nearly all the plantations on the estate were free from any serious attacks. The number of healthy cocoons, however, was so great that there can be little doubt some serious damage would still have been done had it not been for the assistance rendered by birds when the caterpillars were hatched." (In fact, on one estate, where only 6% of cocoons were parasitized, and nesting-boxes were not put up, extensive damage resulted. On another 1,000 larch trees were killed.)

"In the spring of this year (1911) the cocoons were more difficult to collect, and of those examined by Dr. Hewitt only 18% were parasitized, and we waited with some anxiety to see if there would be some signs of the return of the pest. Our friends, the birds, however, have done their duty, and the woods this summer were as green and fresh as any forester could wish to see them." In 1911, 347 boxes were in position, and of these 229, or 66%, were occupied. It may seem to some naturalists that this proportion—only two-thirds—is not a very satisfactory result after three years' trial, but it must be remembered that many of the boxes were purposely placed in bleak and exposed positions where birds were scarcest.

It is difficult to arrive at the exact amount of insect-food consumed by birds. Various figures have been given for the starling, willow-warbler, great tit, blue tit, and the cuckoo; and Echerich (15) gives statistics obtained by experimenting with

confined birds, which are less valuable on that account. Thus, in one day 2 great tits destroyed 187 pupæ of *B. neustria* ; 2 blue and 3 coal-tits nearly 10,000 over of *B. pini* ; 3 Marsh (?), 1 coal, and 1 long-tailed tit, and 3 goldcrest accounted for 600 lepidopterous larvæ.

The rate of digestion in many small birds appears to be about 3 hours (10), and as their crops are generally full when examined some idea of the numbers of insects eaten is obtained.

Observations by other authorities, including foresters, always confirm the view that many birds are of great use in checking outbreaks of defoliatory insects in this country. How much more useful are they in *preventing* outbreaks, by consuming hibernating insects during the other 4-6 months of the year, when their utility passes unnoticed ?

This aspect of the matter is not yet properly appreciated. Birds such as tits, goldcrests, woodpeckers, treecreepers, etc., which subsist very largely on insect-food throughout the 'dead season,' do infinitely more good than those summer migrants which arrive only to feed on the result of the multiplication of insects (the new generation). (Here, again, there is a marked difference between the predator and the parasite.) It is difficult to estimate the potential value of hibernating insects, whether larvæ, pupæ, or imagines, or egg-clusters, but the benefits conferred by their destruction before they multiply is in direct proportion to their prolificness.

Enough has been said to prove that the importance of *resident* insectivorous birds in any wood cannot be over-estimated, and the more artificial the wood the more necessary does it become to adopt measures for their encouragement.

All available evidence goes to prove that the swallow, martins and swift are directly harmful species. They should always be discouraged from breeding.

Up to the present, there is no proof that birds distinguish between healthy and parasitized insects. By feeding on the latter they may do *actual* harm, but *relatively* this is negligible, for, like spraying, fumigation, and hand-picking, birds, by reducing both the host, parasite, and hyper-parasite in equal proportions, are only preserving the balance of nature.

LIMITATIONS OF INSECT CONTROL BY BIRDS

Nothing is gained by overstating the value of insectivorous birds. There is one group of insects which immediately occurs to the practical forester as being outside the control of any organism, at one stage of the life of a coniferous wood—namely, bark-beetles and weevils when regenerating a felled area.

Escherich considers the enemies of the bark-beetles to be of little economic importance, and Munro is of the opinion that biological methods of

control must be ruled out "because they must always be slower, less effective and very much more expensive than control by trapstems" (45, No. 8). From the very nature of the breeding-habits of these pests, artificial methods of control must be adopted, for what is more unnatural than a tree-stump?

Here woodpeckers and other birds are quite helpless to prevent the sudden increase of *Rhyncophora*, for obvious reasons.

From the rather limited distribution of some birds (apparent from the foregoing notes) it may be argued, with some reason, that many are not of primary importance in the control of injurious insects. Especially is this seen in Ireland, which is remarkably poor both in species and numbers of forest birds (no woodpeckers, etc.). At the same time it may be said with equal truth that there are few indigenous forest insects capable of becoming pests over large areas.

"It is noticeable that many pine insects, occurring in N. Britain, have not been found in this country." ("A List of the Beetles of Ireland"; Johnson and Halbert, *Proc. Roy. Irish Acad.*, 1902). Further than this it is not possible to go, though the subject promises to afford an exceedingly interesting study in faunal distribution.

Here it is necessary to mention the ecological succession of woodland birds, first suggested by Brock (8): "A young plantation shows a botanical succession, and an accompanying ornithological

succession, which alters both specifically and quantitatively with the growth of trees. . . . It is an unstable type of fauna; whereas a natural woodland has a relatively stable fauna." The succession of breeding birds is as follows. Soon after formation the whinchat or stonechat may appear; these are the only birds for over a year (except the nightjar or long-eared owl), when the hedge-sparrow and robin may come. In five or six years the willow-warbler, chaffinch, and goldcrest may be found breeding, and, given the opportunity (stone walls, etc.), the coal-tit. After this, the population increases rapidly: magpies, jays, etc., replacing the first three colonizers.

This is of practical importance because of the lack of birds when first the plantation is formed—the most critical period. If established near an older wood, however, birds nest in the latter and feed in the younger plantation; and if not near a wood there should be no reason why the destructive *Chermes*, *Tineidae*, or other pests of young plants should occur, if the transplants were previously washed or sprayed before planting out, in the usual manner.

Summary: with the sole exception of the *Rhyncophora*, which are only controlled in part, it may be said with perfect truth that certain birds, occurring together, are of primary importance in suppressing all other injurious insects, when given the opportunity.

CARNIVOROUS FOREST BIRDS

This group is readily divisible into two classes:

(*a*). Species feeding on small mammals; useful.

(*b*). Species preying on insectivorous birds; harmful.

(*a*). A glance at the Table given after the family *Falconidæ* shows the very large percentages of mice and voles in the normal diet of owls and most hawks. When one considers that nearly 100% of the wooded property in England is strictly preserved, and that gamekeepers wage a ceaseless warfare against stoats and weasels (but usually spare owls, and sometimes also the kestrel), one can only come to the conclusion that raptorial birds are alone capable of controlling the numbers of mice and voles.

In other respects the kestrel, buzzard, and owls are rather useless, for they cannot exterminate rabbits, hares, moles, squirrels, against which artificial exclusion or destruction must be practised. Nevertheless, in the case of moles and mountain hares, raptorial birds are partly instrumental in preventing their increase.

Destruction of useful mammals is practically confined to that of the shrew, an unimportant animal which is generally distasteful.

(*b*). Included in this class are the hooded and carrion-crows, and in part the jackdaw, magpie

and jay, all of which destroy the eggs and nestlings of insectivorous birds. The crows are certainly undesirable in any wood, and the last three birds are considered to be harmful in preserved woods. The good done by them probably compensates for the damage, and in small numbers only they may even be distinctly useful (but see under separate species).

The worst enemy of the forester and the gamekeeper is, without question, the sparrowhawk. Once more the opportunity is taken of wholeheartedly condemning this bird, and advocating its destruction upon every possible occasion. This alone is one of the most useful and far-reaching measures for the protection of useful birds that it is possible to practise.

PHYTOPHAGOUS FOREST BIRDS

Although a certain number of birds, chiefly finches, may be harmful to unprotected seed-beds and on naturally regenerated areas, damage by this group is confined to a period not exceeding a month after the sowing of the seed. Artificial precautions must, in practice, be taken against them; fortunately they are inexpensive.

The damage done in the winter months to seed in the forest must not be charged against those birds which are otherwise insectivorous, and are enabled thereby to tide over an unfavourable period. In any case the acorns, mast, and various seeds

would only help to increase the numbers of rodents.

The crossbill is sometimes extremely troublesome in seed-collecting districts, and may even make the natural regeneration of an area a risky undertaking. Allowing that each bird consumes on the average 1,000 coniferous seeds a day (less of course for silver fir, and more for spruce), the damage done by a flock of thirty or forty of these finches is realized to be considerable.

Once again, the inevitable problem of game preservation comes up in connection with the damage by *Capercaillie* and black game. From the standpoint of the forest they are both extremely undesirable, and will make terrible havoc of young trees (see under *Tetraonidæ*).

CHAPTER III

FOREST ANIMALS

Family: CERVIDÆ (Deer).

General: wherever red, fallow, or roe deer roam wild, damage to neighbouring forests, more especially to young growth, is excessive. According to Fisher (16), this is done by eating acorns and mast, browsing buds, leaves, shoots and twigs, barking poles, breaking off leaders, bending down stems, trampling seedlings, and exposing and gnawing roots; in fact, red deer do everything but eat the actual timber.

Red deer are most, and fallow deer least, destructive; both are polygamous, and the hinds usually produce only one fawn each summer. Roe are generally monogamous, and have two young a year.

Though some trees are preferred to others, particularly exotic species, deer are omnivorous feeders.

(1) THE RED DEER.

Distribution: occurs wild in the New Forest, Exmoor, Co. Kerry, and in the Highlands of Scotland, where it remains above 1,500 feet in summer, coming down below 2,000 feet in winter.

Damage: (*a*) *Browsing*: prefer poplars, ash, oak, maple, beech, silver fir and larch; birch, alder, Scots pine and spruce are least liked (16). Beech, oak and silver fir (16), also Sitka spruce, recover best.

(*b*) *Barking*: prefer oak from 15-20 years, and spruce from 20-40 years, the bark containing a large amount of tannin; also ash, silver fir, beech and maple; least of all pines, larch, alder and birch (16). Thin bark is preferred to thick, smooth stem to those covered with branches, and isolated trees or those on edges of woods and rides. Damage is a little more severe in winter than in summer.

(*c*) *Fraying*: 'Fraying-stocks,' in which stags rub the 'velvet' from their antlers, are usually isolated, smooth poles. Fortunately, individual deer confine their attention to the same tree.

(*d*) *Trampling*: not usually serious, although it produces an irregular crop, particularly on slopes.

Economic Status: always injurious, of the first importance to forestry; the extent of the damage depending on the type, age and composition of the stand, the number of beasts, the length and severity of the winter, and the accessibility of good pasturage.

Preventive Measures:

(*a*) By excluding deer at all seasons. This is usually undesirable both from the point of view of sport and revenue, and from old woods; and in any case quite impracticable over large areas, except in odd cases. On the other hand, ground set apart for natural regeneration, and plantations under fifteen years of age (at least), must be fenced in (see Appendix).

(*b*) By a proper choice of species. In most cases Scots pine is the safest, and otherwise most suitable

tree to plant. The following is taken from Fisher (16):

> "Bark-peeling by red deer is a new habit (Note: it is almost certain that summer peeling is necessary and an inherent trait); as long as mixed woods under the selection system and coppice with standards offered plenty of nourishment, deer left the bark alone, but the present density of growth, which excludes grass, and the substitution of conifers for broadleaved trees, have rendered fodder scarce in the forests. . . ."

(*c*) By management. The denser the crop the less likely that deer will force a way through. In any case deer will be excluded from polewoods until the branches are shed up to 10 feet high, and in this respect Douglas fir would appear to be excellent. Compact blocks are better than long strips of wood, as damage is greatest on the outside and along firelines, etc.

(*d*) By artificial feeding. (See below). This includes 'Salt-licks.'

(*e*) By reducing and maintaining the stock at a certain optimum consistent with sport and silviculture. Hartig (16) gives actual figures, but these are of little, if any, practical value. The amount of damage can readily be recognized, and steps taken accordingly.

Summary of Policy: for the following extracts the writer is indebted to "Afforestation in Scotland" (26).

Firstly, in England and Ireland, as well as Scotland, a deer forest yields a much higher profit than either a grouse moor or a sheep walk. Where deer stalking can be combined with forestry it should

materially add to the revenue. The following measures are recommended:

(1) Divide the wintering ground of each individual deer forest into three parts; each part to be planted separately and not more than one part to be enclosed at one time.

(2) Wait fifteen years, and then throw it open to deer, immediately starting to plant up the second part, and so on.

(3) As soon as the new area planted has deprived the deer of nearly one-third of total wintering, cultivate whins and cut bracken so as to maintain sufficient winter food. The value of whins has already been proved, especially in snow.

"It is believed that this treatment of deer forests would never lessen the value of the ground for sporting purposes by more than one-third. . . . The partial substitution of wood stalking for hill work, the blotting out of some of the best beats, the unsightly deer fences, and the disturbance caused by the forest staff, are all factors tending to lower the rents that sporting tenants would be prepared to pay."

Nevertheless, it is more than probable that better heads and larger beasts would result, for the reason that since the destruction of the primeval pine forests in the Highlands in the last few centuries, the size of red deer has decreased.

The only modifications of forest policy are:

(1) That choice of species or mixtures may be slightly affected.

(2) That underplanting in unprotected areas is impossible.

On the whole, the greater the area the less risk of damage, because in practice there are many open places where trees do not thrive, and where deer will find food.

There is a case in point where a 10,000 acre estate is divided in the ratio of 6,000 acres woodland (mostly open and over forty-five years of age), and 4,000 acres hill ground, which annually yields 50 stags (total value in 1910 about £1,300).

In the area under survey 18,000 acres might be obtained at a rental of £2,070 (2/3½ per acre), for land which many eminent authorities have declared to be the best planting ground in Europe.

In deciding on the forest policy respecting red deer, "the question for the management is whether this silvicultural loss will be balanced by the economic gain."

Actual figures for increased costs of establishment, principally due to fencing, in comparison with the increased revenue derived from the sporting rights, are wanting; but it appears that on planting ground already established as a deer forest, neglect of such a profitable sport will result in loss.

(2) FALLOW DEER.

Distribution: wild in many parts of Scotland; but only in a few places in England (the New Forest, etc.). Introduced Ireland, but does not thrive.

Damage: in their feeding habits fallow deer are more restless than (1), and often commit more damage by browsing and treading down young growth. In the wild state they never strip bark, and only isolated trees or posts are selected for 'fraying-stocks.'

Economic Status: less harmful than (1) or (3), and can therefore be admitted to the woods in greater numbers. Their sporting value is much less than that of red deer, though they are hunted, and the venison is superior to that of either roe or red deer. Measures to protect the forest, as outlined for (1), can be modified for this species.

(3) THE ROE DEER.

Distribution: wild in many public forests, such as the New and Epping Forests; and on large estates, from which it may stray; introduced Ireland, where it is local in the North-west; common in many Scottish districts. More restricted to woodlands than (1) or (2).

Damage: similar to that by (2). At Brandon, larch suffers severely. Alder is practically immune, pines and spruce suffer least of conifers. The writer well remembers the characteristic damage to silver fir underwood in the Black Forest; here also Douglas fir was very much sought after, and the shoots severely browsed. The cotyledons of various seedlings are a great attraction.

Economic Status and Control: as for (2), but they are an unmitigated pest, for roe have little, if any,

true sporting value, and the venison is very inferior (worth only 4d. a pound), added to which their æsthetic value is limited to the frequent signs of damage (the beasts themselves being rarely seen). Foxes and golden eagles, especially the former frequently kill the fawns.

Family: LEPORIDÆ (Hares and Rabbits).

General: ground game is nowhere absent from unprotected forests. Hares and rabbits are entirely vegetable feeders, the extent of damage variable, and sometimes discounted by their sporting and food value. Fortunately both pests do not usually occur at once, for hares cannot feed on ground fouled by rabbits. They are voracious feeders, in spite of which the hare, like the squirrel, often bites off and leaves uneaten many shoots, chiefly of conifers. Natural boundaries, such as water, do not seem to confine either animal, the hare being particularly well fitted by nature to jump obstacles and swim wide rivers.

Apart from the fact that the difference in the tracks of these two animals is easily recognized in snow, the type of damage is also distinctive. Hares feed on buds and shoots higher up the tree than do rabbits, and gnaw the bark above snow-level, whereas the latter prefer to feed in the shelter of the 'snow-caves,' close to the ground.

An excellent account of the varying degrees to which various forest trees were damaged by rabbits and hares can be found under (1).

HARES.

General: breed sometimes two, generally three times a year, the doe making a shallow 'form' on top of the ground, and producing 2-5 young at a birth. A newly-planted area is a favourite breeding place, especially if netted only against rabbits, for the ground cover and young trees afford concealment. In such circumstances does will jump rabbit wire, five feet is a common leap (25), (seven and a half feet over a stone wall is on record (6), forgetting that for at least six weeks the young cannot follow her example, and the resulting damage in a confined space is often severe.

Hares dislike the 'drip' from trees, and ground-cover is essential to them, so that, except in severe weather, when attracted by the warmth, food and shelter afforded by trees, they do not occur in well-managed woodlands.

Damage is of two kinds: biting off shoots and buds, sometimes for food, but often from wantonness, and gnawing bark, the astringent property of which is said to be necessary in winter to counteract the bad effect of the poor, coarse, or sodden herbage at that season. But it must be remembered that whereas buds and shoots are only eaten in times of great want, bark-gnawing is an annually recurrent habit, only varying with individuals, and to satisfy

their cravings these animals will go long distances and overcome many obstacles. They are more nomadic and nocturnal in habits than rabbits, do not often feed in company, and move from place to place wherever the supply of food is greatest. Thus, damage by such a selective feeder is generally slight. Lowland hares always prefer farm crops to the buds, needles, etc., of trees; but although they will dig through snow to obtain the former, if anywhere near woods and plantations, they prefer to migrate to the easiest food supply, and then only the depth and duration of snow limits the extent of the damage. Buds, shoots and twigs are grazed up to three feet above the snow-level; beech, sycamore, maple, ash, poplar and oak, also larch, silver and probably Douglas firs, being preferred to pines and spruce.

Danger is greatest to young plantations with ground cover, nearest open fields or farm crops, and in severe weather.

Bark-gnawing in any weather is confined to oak, beech, ash, sycamore, maple and poplars, though where none of these trees occur smooth-barked stems of conifers, particularly of spruce, and least of all of pines, up to pole size, are also attacked. The value of hares as food varies with locality; those from grassland or crops are best, but those on moors, and blue hares generally, are not worth shooting.

For cost of netting an area against hares, see under (4).

(1) THE COMMON OR BROWN HARE.

Well distributed over Great Britain South of the Highlands, breeding up to 2,000 feet in Wales, and at a considerable altitude (more or less coincident with farm crops) in Scotland.

Damage to the forest by this species is less severe than by the mountain hare, as it much prefers grass, clover, roots, etc., and even furze, broom and various marshy plants, to trees.

In most agricultural areas where winters are severe, and hares numerous, protection to plantations (see Appendix) should be continued until they are at least eight feet high; but they need never be netted where the numbers of hares are kept within reasonable limits, or where the regeneration areas are surrounded by high forest.

Conclusion: if the unplanted and newly regenerated areas, and the neighbouring open country, is shot over in the ordinary way, damage by this species will be negligible.

(2) THE BLUE OR MOUNTAIN HARE.

Indigenous to the Highlands, but established by introduction in hills of the Lowlands, N. England, Cheshire, Yorkshire, Derby; and in a few localities in Wales, as N. Carnarvonshire.

Similar in habits to above, though will often hide in crannies and rocks when pursued. Damage is usually greater, for many hundreds of these hares are sometimes seen descending from the hill-tops

to the valley woods. It is generally considered impracticable on such areas to plant without netting against these vermin (see Appendix). Trapping is not recommended, but organized hare drives (though affording little sport) attain their object by slaughtering great numbers at a time. All hares when pursued make for rising ground, so that if the woods are beaten out, and the circle of beaters gradually closes round a certain hill, where the guns are posted, the latter, if hares are numerous, generally see more than they can kill. Six guns have been known to kill nearly 1,300 hares in one day.

On deer forests, grouse moors and sheep-walks these animals are an unmitigated nuisance, and it is no unusual thing for several farms and estates to organize such drives. After snow, a thorough inspection of outlying plantations must be made to ascertain the number of hares, and the probable extent of damage; and though thoroughly unsportsman-like this is from most points of view the best time to track down and shoot them.

Conclusion: this species is almost as injurious as the rabbit, and every opportunity should be taken to reduce the breeding stock to a minimum.

(3) THE IRISH HARE.

Indigenous to, and common in Ireland. In relation to the forest intermediate between (1) and (2), but, on the whole, harmful enough to make the netting of hill plantations essential.

(4) THE RABBIT.

Distribution and Habits: everywhere common, though only recently established in many Highland districts. In some seasons occurs up to 2,250 feet in Inverness-shire (14), but being very sedentary, the rabbit, unlike the hare, does not descend to the valleys in winter, and perishes in protracted hard weather. The limit of zonal distribution is, therefore, about 1,500 feet. In fairly dry ground it burrows, often very extensively (6), chalky and sandy soils being ideal, but on wet peaty moors it lives on top of the ground, then being known as a 'bush-rabbit.' The rabbit readily adapts itself to a woodland life, feeding impartially on the forest flora and on farm crops, grass, furze, broom, heather tops, bog plants, etc. It is very prolific, breeding at all seasons, but less commonly from September to January, and usually produces from 4-6 young three or four times a year. At this season the does will climb wire netting in order to breed undisturbed (54, 1925).

Since it can more readily be excluded from newly afforested areas, and from the fact that it establishes colonies, and that both skin and flesh find a ready market, the rabbit produces less absolute financial loss, and it sometimes happens that a considerable revenue is derived from them.

From September to March is the best time to kill down rabbits, as they are then in their burrows; it is also the best time to sell them.

Damage: very similar to that done by hares, but is much more local in extent. Whereas the hare is a rather dainty feeder, injuring scattered groups of trees, the rabbit grazes down all before it, the extent of damage being regulated only by the distance from the warren. Smooth bark is selected for gnawing, so that even polewoods of broad-leaved trees are sometimes damaged, but usually stumps up to four inches quarter girth suffer most.

The following are severely damaged by gnawing and grazing (1): Austrian and Scots pines, silver fir, larch and Norway spruce; also oaks, ash, maple, sycamore, sweet chestnut, poplars and willows. Young growth only attacked of: beech (sometimes barked); also Douglas fir, Nordmann's fir, to a less extent of *Abies grandis*, *A. nobilis*, *A. cencolor*, *Picea alba*, and Sitka spruce. Quite uninjured: Alder, birch and Corsican pine.

This list shows only the degree to which various trees suffer when all occur together. Probably any pure crop suffers from one if not both types of damage (though Corsican pine does seem to be rabbit-proof); at all events Sitka spruce is known to be badly grazed (54, 1922). In general, however, this list may be found of use as showing the relative susceptibility of each tree in woods where rabbits are not exterminated. Transplants are always preferred to seedlings.

It has been shown that rabbits are detrimental to game-coverts, by eating down the underwood.

Destruction:

(1) By shooting. Though this can never exterminate the stock, organized methods will, on all areas but those newly-planted with the more susceptible species, so thin the numbers that risk of damage is reduced to a minimum. The record bag of rabbits in one day is 7,000; other figures are 5,086, 3,684, and 3,333 (28); so that, where abundant, the first measures in their extermination should always be a properly organized shoot (see "The Rabbit," by J. E. Harting, 1898).

(2) By netting. After the whole area has been shot over, and a few days' grace given, all warrens should simultaneously be netted in the early morning, when most of the inhabitants are feeding. The rabbits are then disturbed as much as possible, so that most of them bolt back to their burrows at the same time. Though nets are rather expensive, this is the only outlay, and is one of the most successful methods of bagging a large number. When this has been repeated two or three times in a month, then is the time to enclose the area (500 acres is a good general size), which should be done as quickly as possible, the posts, of course, having been driven in beforehand, so that a man can erect about 120 yards a day.

(3) By trapping and snaring. If done in the right way this is such a successful method that whatever other means of extermination are adopted it should be tried. If the burrows are being ferreted it is

only possible to empty a part of them in one day, and the traps and snares should be set a good distance from where the dogs and ferrets are working. In any case the best time for setting them is the late afternoon, if care is taken to eliminate the human scent. See under (9) and (1).

(4) By ferreting. In the Breckland, and on any very loose soil, this is a favourite method, perfected by Norfolk warreners. For a short account see under (27). At first, in a big warren, a fair number are killed, sometimes as many as 250 a week, but it does not compare with either (1) or (2) in rapidity. Its real use is by systematically emptying and stopping up the burrows, to make sure that the last rabbit is exterminated. The labour of digging out every rabbit is very great, and to destroy the last few may take several weeks; in fact, it is said that the last may well cost ten shillings.

Periodical inspection, especially after snow, and during the breeding season (when does with young will climb the netting in order to breed undisturbed, see (54), 1925), must be carried out. Although it is stated (27) that in the Breckland it takes about three months for two warreners to clear a 500 acre block, this is an under-estimate, as the writer has ascertained by careful inquiry, for it appears that an average of 1,500 acres can be cleared in the six months from September to March.

This, however, applies only to a certain district, and where the burrows are less scattered the destruction of the last few rabbits is a much less arduous

job. With a combination of shooting, netting, trapping, snaring and ferreting, a large warren should be entirely emptied in a month, and if the surrounding area has already been enclosed, the few stray rabbits within it should be exterminated at the same time.

In this connection it is most important to enclose an area where rabbits are very abundant (such as an extensive warren), in order to keep them *in*, and destroy the stragglers outside; but this does not, of course, apply to the Breckland or other districts, where, on account of the scarcity of food, the burrows are scattered haphazard over the country.

Control: in plantations, particularly of broad-leaved trees, round which it may be desirable to remove the wire netting after a certain age, branches of thorn trees, ash, etc., which would otherwise be burnt, may be laid on the ground in winter for food. Rabbits much prefer to bark these than trunks, and this is a most valuable precaution, far better than painting the tree stems with obnoxious mixtures, as the following extract shows (28):

"I remember rabbits once attacked a small plantation of larch which had been carefully painted twice over with a so-called infallible mixture against hares and rabbits. They ate paint and bark . . . the mixture was almost as effectual in killing the larch as were the rabbits."

Though fresh yew foliage is sometimes eaten by rabbits without bad effects, it is known that dead boughs are extremely poisonous to most stock,

including deer. On certain areas, therefore, this method of control might be practised successfully, but it appears to be of very limited application.

By the Rabbits and Rooks Act 1925 (Short Title), the owner of land adjacent to rabbit warrens, who is suffering from the depredations of these animals on his crops (in the broad sense of the term), can, if the owner of the rabbits refuses to keep down their numbers, apply to the County Council to take active measures for their destruction.

It has been pointed out that rabbits (unlike hares) are more or less restricted to their burrows, though in summer many lie out all day under cover, and in some districts make no burrows at all. The danger of attack varies in accordance with the distance from the burrows, and therefore they should not be less than a hundred yards from the protected area. Frequently one sees a thriving colony so near the netting that it is only a question of time before they burrow underneath, and then not one, but many, forage nightly in the plantations. Such gross neglect of a simple precaution is unfortunately common.

Family: MURIDÆ (Mice and Voles).

General: It is unnecessary to discuss every rodent, for each produces a similar type of damage on the particular area where it occurs, and the extent of injury is regulated less by the species of tree or animal than by the relative abundance of the latter.

In their relation to the forest these animals fall naturally under three headings: (1) The water vole. (2) The field vole. (3) The field mouse.

These rodents are omnivorous feeders, capable of existing on most vegetable products, insects and birds' eggs, so that damage to trees is normally the result of the absence of other food, to an even greater degree than with hares or rabbits. In the nursery, seeds, seedlings and transplants are destroyed, and in young plantations and polewoods the roots, bark, and cambial layer are gnawed (even the wood in bad attacks), producing an ideal state for the entrance of fungal spores. There is no doubt that the spores themselves are often carried in the fur or on the feet of these animals, so that damage by them is far more extensive than would appear possible.

Primarily, however, damage in the nursery is due to the sudden disappearance of the ground vegetation and the substitution of edible seeds and seedlings, and on newly regenerated areas to the gradual suppression of the soil cover, particularly of grass, their staple food. Equally gradually in the latter case, most voles and mice are driven to more suitable areas, but the bank vole appears to thrive under these conditions, and the final disappearance of the ground cover frequently culminates in a disastrous attack on the young trees.

The thinner the previous vegetation, the less risk of damage, which, consequently, is small on dry sandy soils compared with moist or rather heavy grasslands.

Prevention should consist in depriving these animals of the ground cover which is so essential to them, in protecting their natural enemies (the stoat, weasel, kestrel, buzzard and owls), and in checking their winter immigration into woods from fields.

Prevention: (*A*) *The Nursery.*

(1) The selected site, if covered with vegetation, should be ploughed and allowed to lie fallow for at least six months, or a crop of potatoes may be grown.

(2) The nursery should be established on a slope with a northerly aspect, as far away from grassland as possible, and paths should be of gravel. All rubbish on or round a new area should be burnt on the ground. It should be surrounded by a trench 12″ wide and 15″ deep with smooth vertical walls which should be visited every morning (especially in autumn), and the captures killed.

(3) All seed should be covered in red lead, or large seeds should be steeped in a 2% solution of carbolic acid (16).

(4) Seed should be sown in spring, especially in temporary or newly-established nurseries.

(5) Where valuable sowings of broad-leaved species are endangered, it is sometimes thought advisable to sink old corrugated iron sheets (where available), to a depth of 9 inches round the seed-bed.

(6) Where the soil is seen to be riddled with holes and runs, poisoned seed may be poured down them, but not scattered on the surface, as this may attract

otherwise useful birds. Ordinary 'nipper' mouse-traps are used, but a better trap is given in (1).

(*B*) *Newly Regenerated Areas.*

(1) Burn all heather, grass, etc., thoroughly, before March. If it is thought that voles are abundant, a trench 12"-18" deep should be dug along the lee edge, and the excavated soil banked up on the opposite side to the fire. This also prevents a ground fire spreading, and is easily done on loose, peaty or sandy soil.

(2) Plant closely, and thin frequently, in order to decompose raw humus.

(3) Encourage foxes, weasels, owls and kestrels.

(4) In certain areas, next to grass fields, it may be necessary to dig trenches (see above). Fisher (16) states that 10,800 mice were thus caught in one autumn.

(1) THE WATER VOLE.

Distribution : common near streams all over Great Britain, up to 2,000 feet in Inverness-shire (14); absent from Ireland.

Damage : part of its normal diet, especially in winter, consists of the roots, bark and cambial layer of trees; from their situation poplars, willows and ash suffer most. Banks are undermined.

Additional Control : easily trapped (see under (1)), but it is doubtful, except with cricket bat willows, whether this is economic.

(2) THE SHORT-TAILED FIELD VOLE OR GRASS MOUSE.

Distribution, etc. : common in England, Wales and S. Scotland up to 2,000 feet; absent from Ireland. Numbers are subject to exceptional increase, and sporadic plagues have occurred on the Borders (1876, 1889-92, etc.), and is often locally very injurious, attacking any tree.

Damage : where mixed with conifers, broad-leaved trees are preferred, especially oaks and ash ((60), 1893). Does not normally occur in the forest, but is abundant on newly regenerated areas, to which it also migrates in large numbers in winter.

Also two closely allied species :

(*a*) The northern grass mouse or field vole (*Microtus agrestis, Linn.*) replaces the above in Scotland, up to the top of the highest mountains, descending in some numbers in winter to woods for shelter. Often causes great damage to coniferous plantations, apparently preferring them to broad-leaved trees ((60), 1893).

(*b*). The bank vole, absent from Ireland and N. Scotland, occurs up to 700 feet elsewhere. Found on the edges of woods, where it is the commonest vole in summer. It was this vole which caused such destruction in the Forest of Dean (1814, 1836), and the New Forest (1814).

Summary : it has been proved that the sporadic increase of these animals is due more to a scarcity

of their natural enemies, than to any other cause or causes combined.

Voles are sometimes the product of bad silviculture, as when a light demanding species is grown pure. This produces a grassy surface, which is ideal for the pupation of certain insects (Gillanders, (54), 1913), and also for the increase of voles, which have been known to destroy up to 25% of cocoons of the large larch sawfly (3). Thus they are a natural control due to: (1) bad silviculture, (2) rank grass induced by defoliation and the manurial quality of the larvæ. In such cases they are of limited use in controlling a plague, but none at all in *preventing*.

(3) THE LONG-TAILED FIELD MOUSE

is represented by many sub-species. Regarded specifically, these 'wood mice' are common all over the British Isles, up to limit of tree growth. It is essentially a woodland and arboreal species, subsisting entirely on the forest flora. It is very prolific, producing 3-5 young every 25 days, and breeding when 4 months old; but is common only in rather open broad-leaved forest, especially coppice with standards, where the underwood affords it shelter and food. It feeds on acorns, mast, sycamore seed, etc., and bites open cones; besides roots and tender bark, to reach which it frequently climbs small trees, it also eats out the heart of the buds. It is entirely absent from dense woods with no ground cover, so that, with good silviculture, damage by this species is negligible.

Also: (*a*) the dormouse, which is only locally common in woods in England S. of Staffordshire, and in Wales generally. It is the most arboreal rodent, an inveterate plunderer of small bird's nests (tits, finches, and ground-nesting warblers), but does a limited amount of good by eating insects.

Summary: mice, unlike most voles, generally breed in the woods, living on forest produce all through the year; they are the product of bad silviculture.

Family: SCIURIDÆ (Squirrels).

(1) THE RED SQUIRREL.

Distribution: Common in most large woods in England, occurs up to 1,000 feet in Wales, and up to limit of tree growth in Scotland (1,400 feet in Aberdeen, (6)). It is still spreading in Scotland after being practically exterminated (see under (35)), and was reintroduced into Ireland c. 1815, where it is now common.

Habitat: Restricted to woodlands, especially of beech and Scots pine, preferring an open sunny stand, with some ground cover.

Breeding-habits: in the south it breeds twice a year, but in the north only once, the first brood of 3 or 4 young appearing from mid-March to mid-May, according to locality. A nest or 'drey' is made of strips of bark, twigs, leaves, moss and grass, in a

hole in a tree, but quite often in the fork or branches of a conifer (rarely larch).

Natural Enemies: the most effective enemy of the squirrel is the marten, which hunts the adults in the trees, and destroys the young. It is now too uncommon to be of use. In Scotland, especially in well-grown woods, where the animal has no safe retreat for even a partial hibernation, great numbers die from cold and exposure in severe winters. At such a time they are seen on the ground quite dazed and helpless. The long-eared and tawny owls destroy the adults, but in limited numbers only; and stoats, which are extremely active climbers, have been seen to pursue them into the trees.

Damage: besides larvæ, pupæ and imagines of various insects, especially of beetles, and the eggs and young of many birds (and small birds themselves), its staple food consists of the seeds, buds, shoots, inflorescences, and even leaves of various trees, also the soft inner bark and cambial layer of most species, but particularly of beech, ash, sycamore, Scots pine and larch. Acorns, mast and sycamore seed are scratched up from seed-beds and eaten, and cotyledons and seedlings devoured. By eating the male inflorescences, biting off, but not eating unripe seed and cones, and by its great consumption of coniferous seed, to obtain which it strips the scales from the cones, it militates against natural regeneration, and in seed-collecting districts incurs great loss. It has been said that the squirrel destroys twenty times as much as it eats, and is usually eating.

But stripping the bark near the tops of trees, which results in the loss of the leader, is the most serious damage done by this animal (see under (2)). It is most severe in hot, dry summers in pinewoods, in woods with a sunny, southern exposure, and in the early morning after a heavy dew. Larch and ash suffer most (58, 1896).

The extent of damage is very great: thus, at Glen Tanar, Aberdeenshire, 1,000 trees worth £500 were ruined in one year (6), and it is estimated that the re-introduction of the squirrel into Scotland by benevolent naturalists has meant hundreds of thousands of pounds sacrificed in the depreciation of timber alone, for it appears to select the most vigorous young trees, between twenty and thirty years old, which have not yet attained their maximum height growth.

It was considered worth while to pay £213 for 14,123 squirrels shot and trapped on the Cawdor Estates in sixteen years.

Besides the many smaller birds which suffer as a result of the squirrels' carnivorous tastes, the eggs of the long-eared owl and great spotted woodpecker have been proved to be taken (6); fungi, especially the white agarics, truffles, and some mushrooms, are much sought after, and are a very effective bait for trapping (see Appendix). Its inquisitiveness, fondness for following anything straight, and the habit of eating cones, nuts, fungi, etc., on the top of a low stump whence it can keep a look-out, are traits which are very useful in trapping this animal.

Utility: the squirrel is partly insectivorous. It has been noticed to strip bark off Scots pines for larvæ of *M. piniperda*; cockchafers, larvæ of *Cynips kollari*, the spruce gall aphis (*Chermes abietis-laricis*) and certain fungi (58, 1896) are also eaten.

Destruction: with this, as with many other animals, co-operation between estates is absolutely essential. Squirrels have been found on open moors, and swimming lakes and rivers, supposedly migrating to new areas, but it is doubtful whether an isolated area could ever again become colonized, once it was depopulated. On the other hand, it is useless and expensive to destroy squirrels on one area if the adjoining one is fully stocked.

In this connection the Highland Squirrel Club has shown the way; between 3d. and 4d. a tail is given, and in fifteen years 60,450 have been paid for (35). If such destruction was simultaneously organized all over Scotland, there is little doubt that this rodent would be exterminated in ten years.

(1) In practice, shooting has been found the most satisfactory method, although the shot may injure the trees. Where numerous, one can wait for them near a favourite feeding place, or on the edge of a ride, or by exciting their curiosity in some way, i.e. by a revolving piece of looking-glass. In winter feeding several places with acorns, chestnuts, beech mast, fried bacon (fish is an excellent bait) should be very productive. But it is stated (2) that to train a dog well repays the trouble, for it 'points'

or barks at every tree containing a squirrel (which 'freeze' immediately they see a man).

(2) Though said to be less productive than shooting, there is little doubt that organized trapping would alone clear a wood of squirrels. See (1), (2), (9).

(3) Indiscriminate poisoning is illegal, but highly effective if properly conducted (1). A few grains of Strychnine should be introduced into a cut in an acorn, chestnut, or fungus and left near a feeding-place.

(4) There is no reason at all why squirrels should be allowed to breed. The 'dreys' are not difficult to find, and both adults and young can then be destroyed.

Summary: in Scotland and N. England generally the squirrel appears to be infinitely more destructive than further south. In the Breckland it is common, but damage by bark-peeling has not been observed, except in isolated cases. This is very remarkable, but is partly explained by the regular and abundant crop of cones, for here these rodents seem to prefer coniferous seed to anything else. They are rarely shot or trapped, yet do not appear to increase, no doubt on account of the dry climate and scarcity of surface water, for they are very thirsty creatures. In addition, the present scattered and open nature of the stands probably provides them with a certain amount of ground-food. At any rate, it has not been thought necessary to take any active repressive measures.

(2) THE GREY SQUIRREL.

Distribution: (see article in *The Field*, 1915, by H. Boyd Watt). Since 1915, it appears to have spread, and to be common in S.E. England, Buckinghamshire, Bedfordshire and Middlesex, parts of Yorkshire, and Dumbarton. It owes its introduction into this country mainly to the short-sighted policy of Zoological Gardens, and to the enterprise of the owners of certain large estates.

Damage: this species is much more destructive than the native squirrel (58, 1925). It has been observed to strip sycamore, sweet chestnut and beech of their opening buds, and to peel bark from twenty to thirty-year-old sycamores, so that scores of trees were ruined. It is an inveterate destroyer of eggs and young birds (6), and though it drives out the red squirrel is much the greater of two evils. Concerted Government action might still exterminate the pest, and the cost could be defrayed by those persons and societies responsible for its introduction.

Family: TALPIDÆ (Moles).

(1) THE MOLE.

Distribution, etc.: common all over Great Britain, up to high altitudes, but absent from Ireland. It breeds only once a year, producing 3-5 young in April or May in a nest from two to six inches below

the surface of the ground. This fortress is recognizable by being a much larger 'mole-hill' than most, and generally under cover of a hedge, bush, or in thick grass. It burrows, for preference, in moist sandy soils, within six inches of the surface; but is very abundant on any loose soil, where it can find worms. The mole is characterized by being an inordinately voracious and rather thirsty animal. Besides worms, its food is chiefly insectivorous, and it must destroy a large number of *Melolonthid* and *Elaterid* larvæ, and 'cutworms' or larvæ of *Agrotis segetum*, as well as of adult beetles and other insects. Occasionally eggs, small birds and mice are destroyed. In woods, plantations and on unplanted ground it is generally useful, but, on account of its extensive tunnelling, very harmful to seedlings and transplants. This damage is of three kinds:

(1) By 'lifting' and undermining seedlings, and plants up to four or five feet in height. Taproots are also bitten through, though not eaten; in any case the plant suffers a severe check, if it does not die of exposure or lack of moisture; usually the plant is blown over by the next wind.

(2) In dry sandy districts the rain-water quickly flows away down the natural drains made by the mole, and is lost to the plant.

(3) The mole tunnels afford shelter to mice and voles, which are thus enabled to breed and spread in safety.

It is therefore obvious that moles must be exterminated in the nursery, and systematically trapped on regeneration areas, both before and after planting them up.

Destruction: the weasel is the only effectual enemy of the mole, but it is probable that it is attacked more from necessity than choice. Owls, the buzzard and the kestrel, especially the last two birds, account for a certain number.

But the encouragement of its natural enemies is not sufficient; and it must be constantly trapped from October to March, when its skin is most valuable, and also during the breeding season, which is the most effectual time to control its increase, but is usually neglected.

In the Breckland, damage by moles is so extensive on recently planted areas that 'firming', or stamping in the disturbed plant, has to be done twice a year, and costs from 2/- to 5/- an acre (average 3/-) each time, in addition to the costs of trapping. 'Screefing' has been abandoned in favour of furrow-planting, as this minimizes the danger, but since it still costs on some areas from 12/- to 20/- an acre before crop is finally established, the mole is easily realized to be a pest of primary importance. The most effective preventive measure in planting is to furrow-plough and plant on top of the reversed furrow-slice, but it is argued that in dry districts it is better to plant in the bottom of the furrow. However that may be, it would certainly appear preferable to save the average 15/- an acre, and, by using slightly larger transplants, reduce the risk of loss in a dry summer to a minimum.

Family: SORICIDÆ (Shrews).

General: there are two woodland species, the common shrew (*Sorex araneus, Linn.*), and the lesser shrew (*S. minutus, Linn.*). The former is by far the most numerous mammal in Great Britain (absent from Ireland), where it is generally distributed, up to a considerable elevation (6). Both are almost entirely insectivorous, and, therefore, distinctly useful. They have few enemies, as they are supposed to be very distasteful to animals and birds, though the barn owl would appear to hunt for them (see under owls). The large numbers of dead shrews seen in autumn is the result of old age, for after breeding three times they die in their thirteenth or fourteenth month (6).

Family: ERINACEIDÆ (Hedgehogs).

General: the hedgehog (*Erinaceus europæus, Linn.*), like the badger, is more insectivorous than carnivorous, and may do a certain amount of good by destroying beetles and beetle larvæ, and various insects, young mice and voles (occasionally), but can be very destructive to the eggs and young of ground-nesting birds. On the whole, it is a harmless creature,

which can be ignored. It is well distributed in the British Isles South of the Highlands, where it is rare.

Family: CANIDÆ (The Fox).

THE FOX

apart from considerations of sport, should be encouraged wherever hares are too plentiful, for especially by its destruction of the blue hare in hill-districts does it render a great service to the forester. Rabbits, moles, voles, mice and roe fawns are also destroyed, and the young broods of capercaillie and black game; but in the case of the last three its services are sometimes unwelcome. On grouse moors, and in game-preserving districts it can be very destructive, so that, in all but hunting shires, landowners are forced to keep its numbers down, either by shooting or trapping. It is common all over the British Isles.

Family: MUSTELIDÆ (The Badger, Stoat, Weasel, Polecat and Marten).

(1) THE BADGER.

Locally common in the British Isles, is of little if any importance in the forest. It is useful in destroying beetles and beetle larvæ, various insects,

mice, voles, young rabbits and hares, but is equally destructive to the eggs and young of ground-nesting birds. It may also excavate under wire-netting and admit rabbits to an area, but on the whole it is a harmless creature, and worthy of protection, if only for æsthetic reasons.

(2) THE POLECAT. (*Putorius putorius*)

Still lingers in very small numbers in Ross, Sutherland, Argyll and Inverness; practically extinct Hampshire, Devon, W. Midlands and the Lake District; but is commonest in Wales. Absent from Ireland. It is of limited value in a forest, where it does not often climb trees, or hunt squirrels, but preys on small mammals and ground-nesting birds and their eggs. It is exceedingly destructive, and only worthy of protection as a vanishing species.

(3) THE MARTEN. (*Mustela martes*)

The most arboreal of the *Mustelidæ*, though not entirely restricted to woodlands, is the inveterate enemy of the squirrel. Unfortunately it is very rare, though less so than the polecat, occurring in small numbers in the wild and wooded parts of E. Anglia, N. Devon, Hampshire, N. Wales, the Lake District, N. Yorkshire and Durham, and of local occurrence in the Highlands. It appears to be represented in many Irish counties. It may be

said to prey chiefly on birds, particularly black game and capercaillie, which are easily caught on their nests or when roosting. In other respects its food is similar to that of the polecat. Where squirrels are common every effort should be made to encourage the marten, but this is its only recommendation, for it is extremely destructive. It breeds twice a year, generally in a large bird's nest, a squirrel's drey, or among rocks, having usually two or three young. The marten is protected by law.

(4) THE STOAT.

Generally distributed in Great Britain up to the summit of mountains, and represented by a closely allied subspecies in Ireland. Single-brooded, 3-5 young April or May, which are brought forth in a hole in a bank, or among rocks or the roots of a tree. Like the weasel it hunts more by scent than sight, and has been known to track squirrels on the ground, and follow them up the trees, for it is a very good climber. It lives chiefly on small mammals, hares, rabbits, moles, voles (and often the water vole, for it is a good swimmer), and mice ; also eggs and birds whenever opportunity offers. It is useful in checking the increase of small mammals, especially hares and rabbits in hill-districts, but on the other hand is without doubt the greatest enemy of the game-preserver.

(5) THE WEASEL

Occurs all over Great Britain, but is absent from Ireland. It differs from the stoat in having two broods of 3-5 young a year, and being satisfied to a much greater extent with voles, moles and mice, though other mammals, birds and their eggs are also taken. The male commonly hunts moles along their tunnels, but the female is so small that she will even follow field mice underground. Both have been caught in mole traps, and frequently in rabbit traps. In spite of the fact that eggs, young and full-grown birds are taken, except when these occur in abundance (as in heavily-stocked coverts), the good done by the weasel far outweighs the evil.

Family : FELIDÆ (Cats).

THE WILD CAT

is so rare even in the Highlands that it is of little interest to the forester. It is protected by Law (as a vanishing species), but is harmful except in quite wild or mountainous country.

General : the utility or otherwise of the polecat, marten, and stoat vary greatly with the objects of management. They are undoubtedly injurious to game interests, and the marten to almost any bird, whether nesting on the ground, or in trees. It is equally certain that the weasel is a valuable asset to any forest, and should be rigorously protected.

THE ECONOMIC IMPORTANCE OF FOREST ANIMALS

To an even greater extent than with birds is it necessary to treat each species of animal separately. Generalizations are not only vague and unsatisfactory, but occasionally misleading.

It may be said, however, that certain animals are useful either as food, for their skins, for sport, or by their destruction of rodents.

Unfortunately, deer, hares, and rabbits, useful for food or on account of their skins, but of much greater sporting value, are among the worst enemies of the forester. In the Highlands deer and hares together preclude all possibility of unprotected regeneration; and matters are little better further south, where rabbits are an ever-present pest. The degree of damage by the latter, however, is very variable, and in many places it is quite possible and practicable to regenerate either naturally or artificially without 'wiring out' these rodents.

As pointed out when discussing the rabbit, damage depends greatly on the distance from the burrows, but even more on the availability of more suitable food—good grass, or farm crops. A good illustration of this came under the notice of the writer a short time ago. A small mixed wood of beech, ash, sycamore and pine, standing on very broken ground, was clear felled during the war—in

1917 to be exact. The time of felling evidently followed a good ash seed year, for there is now an excellent natural crop of young ash, with a few sycamore. The place is honeycombed with rabbits, yet very little damage has been done, in spite of the fact that ash is generally regarded as being one of the most susceptible trees. The only reasonable explanation is the fact that this area is completely surrounded by arable land, the favourite crop on this chalk-formation being lucerne or sainfoin, on which the rabbits feed.

Therefore, it is seen to be impossible to formulate any hard and fast rules about the necessity of exterminating rabbits and hares.

The only sporting animal which is not harmful to the forester is the fox, which, on account of its destruction of voles, mice, hares and rabbits, should by all means be encouraged. Here again, however, the interests of fox-hunting clash with those of game-preserving. The question of the good or harm done by animals (and some birds) must inevitably be left for the management to decide.

CHAPTER IV

PRACTICAL FOREST PROTECTION

GENERAL

Forest Protection may be divided into the following groups:

(1) *Natural Protection* (Indirect).

(*a*) Silvicultural prevention of damage, by stimulating the crop to its most vigorous growth, at the same time producing as far as possible an unfavourable state for the development of the parasite and predator. This can only be achieved by correct choice of species, mixture, method of regeneration and after-treatment; it is most successful against physical damage by frost, snow, windfall, fire, etc.; only partially effective against fungi and insects of least, if any, use in practice against injurious birds or animals.

(*b*) Biological control, by means of the active encouragement of beneficial organisms, and the suppression of their enemies. It is generally considered that the encouragement of useful insects is more difficult and altogether less satisfactory than that of predaceous birds.

(2) *Artificial Protection* (Direct).

(*a*) Prevention of damage by exclusion; normally

practicable, only with a limited number of animals (but in pest-areas of some insects).

(*b*) Active destruction of injurious insects, birds and animals, and isolation of fungi, by mechanical or chemical means.

In the Introduction mention was made of the fact that the subject of extermination after the predator had become a pest was outside the scope of this thesis. It is very necessary, therefore, to distinguish clearly between prevention and cure.

There is no comparison between biological and artificial *suppression* of pests, that by mechanical means invariably being more costly, generally less effectual, and sometimes coming into operation only after a certain amount of damage has been done. Nevertheless, artificial *prevention* is absolutely essential in some cases (2a), such as prevention of damage by fire, the isolation of fungi, trapping some insects, shooting destructive birds, or excluding animals.

SILVICULTURAL CONTROL

The importance of the correct choice of species, and the relative advantages of mixtures over pure woods, have already been stressed (Chapter I). It remains only to discuss the correlation between various kinds of management and pest-control, although from the study of the natural forest it was seen that the type of regeneration and formation nearest to the natural order must be the most effective. Conversely large areas clear-felled and replanted are at all stages of growth most exposed to danger.

Methods of management vary so much with species and mixtures that it is unnecessary to give here a more detailed description than the following broad silvicultural principles:

(1) Natural is to be preferred to artificial regeneration, wherever feasible. The most important point in the regeneration of any area is to establish the young crop quickly, uniformly and in a vigorous state, for if it 'hangs fire' the risk of damage from natural causes is out of all proportion to the time wasted—the effect is cumulative. Frequently, owing to continued dry weather when first put out, a certain number of the transplants die, and the remainder do not recover from their first set-back for some years. This is a very valid argument against planting, for natural regeneration establishes a vigorous crop of seedlings from the start, and the only expense is that of 'beating-up' the bare patches with seedlings obtained from the overcrowded areas, and of anticipating nature by thinning the young growth before it becomes too 'drawn up.' It is well known that the seedling is much more resistant to frost, drought, desiccating winds, fungal and insect attack than a transplant of the same age. Apparently, for the same reason, there is some change in the physiological processes of the tree which takes place after being moved, which undoubtedly makes it more acceptable to small rodents—mice, voles and rabbits—for they have been noticed to attack transplants (used to 'beat up' an area), but leave the seedlings.

In extenuation of the system of planting it is argued that the transplant has a much better and more fibrous root system than the seedling, but whatever theoretical reasons are advanced, *practical* results prove that it is better in a silvicultural (not necessarily an economic) sense to regenerate naturally wherever possible.

"It has repeatedly been observed during the survey that well-rooted plants not only resist but overcome the attacks of *Hylobius*, *Hylastes* and *Pityogenes bidentalus* . . . not only is this true of recently formed plantations, but it is equally true of older plantations and polewoods" (29).

If the area is regenerated artificially, one should avoid planting too close to over-mature or badly managed woods. Due regard should be given to the method of planting: thus 'screefing' is best on areas likely to suffer from *Melolonthinæ* (but see also the mole).

(2) Ground to be regenerated should, in theory, be clear of grass and weeds (except birch, hazel, etc., which diminishes frost danger); for surface vegetation encourages bark-beetles and weevils to hibernate. In practice, risk of damage from this cause rarely justifies the cost of ploughing; but burning is often practicable, and should always be done in March (to kill the resident stock of insects and animals *before* breeding). Burning the soil cover stimulates the after-regeneration to a marked extent: "Larch on burned areas do infinitely better than those on grass, and never show signs of *Chermes*" (19).

A more serious danger is the fact that voles increase rapidly under a dense soil cover, until about the third year after the establishment of a plantation, finding themselves suddenly deprived of their usual food, they are forced to attack the young crop.

Choice of ground should also—other things being equal—be governed by aspect (see the well-known example of the cause and effect of *Coleophora laricella* on larch; Hartig, Diseases of Trees, 1894).

(3) Selection of the site for a nursery, particularly a permanent nursery, is of some importance. For choice it should not be too near old woods from which insects spread (19); in particular, the proximity of oak trees encourage *Melolonthinæ* to lay eggs in the bare nursery soil. Nurseries near woods are more liable to attack from fungi (especially *Coleosporium senecionis*, *Peredermium pini*), seed-eating birds, bank voles, and those near grass fields from field voles (see under voles). Shelter belts should be of some species not reared in the nursery; preferably of beech. The soil should have been dug or ploughed at least twice, to expose the larvæ of *Melolonthinæ* and *Elateridæ* to the attacks of rooks, starlings, etc. Spring sowing is far preferable to autumn sowing, for it is scarcity of food in winter which increases the depredations of mice, voles, certain birds, etc. The soil should be kept clear of weeds, which rob the seedlings of light, air, growing space, moisture, etc. Groundsel, one of the commonest weeds, is also a host of the destructive fungus *Coleosporium senecionis*.

(4) It is a platitude to say that transplants must be as healthy and vigorous as possible, but it is not generally realized to what extent the age of transplants induces insect attack. Thus, ash seedlings are best transplanted as one-year plants, to lessen attacks of *Prays curtisellus*; but beech are best moved after two years, when they better resist *Phyllaphis fagi* (19).

(5) Thinning of polewoods should be governed by the rule 'little and often.' It should be so frequently carried out that stands are never allowed to become 'suppressed', but only 'dominated'. Besides the very material advantages, such as inducing greater windfastness and hastening the decomposition of raw humus, it is not too much to say that fully 75% of the evils caused by fungi and insects is primarily due to neglected thinnings.

(6) Unbroken canopy and a fully stocked stand must be maintained. If the soil is allowed to deteriorate, and weeds to cover the ground, the hibernation and pupation of insects is greatly encouraged (3, and 54m 1913). Moreover, dense canopy discourages most fungi, which prefer light and air, and probably also low forms of insect life, such as the *Chermesidæ*. The importance of underplanting, especially of larch (54, 1913) cannot be under-estimated, and though this often necessitates a rather drastic thinning of the final crop about the thirtieth year, the additional increment put on by the remainder is said to more than compensate for the loss of the thinnings. Other advantages from underplanting are the improvement

of the soil, the fuller utilization of the locality-factors (which, as we have seen, must always result from an uneven-aged crop), and the fact that after the light-demanders are cut out the lower storey becomes a nurse crop for the next generation.

From a biological standpoint the formation of an underwood is of great utility (see particularly under birds—*Sylviidæ*), by affording birds shelter and breeding-places.

From every point of view a two-storied growth is infinitely preferable to an even-aged stand, provided always a suitable choice of mixtures is attained (54, 1916).

(7) Cleaning the crop, in addition to improving the commercial value of the timber, greatly reduces the risk of facultative fungi. Usually, it is not begun sufficiently early for its full advantages to be felt; and since larch, the worst sufferer from such fungi, is most easily cleaned, it is surprising how little attention this point receives.

(8) Management of the felling varies with the type of subsequent regeneration, and particularly in coniferous woods may jeopardize the safety of the young crop. The selection, group selection, shelterwood or wedge systems of regeneration approximate most closely to the natural order, but are usually worked only over large areas. If adequate precautions are taken, it is more economic in practice to clear, fell small areas and replant, though danger from natural causes is always greatest.

Fisher (16) advocates natural regeneration under

shelterwood as offering the best protection against oviposition by *Melolonthinæ*; but Freiburger (55, 1924), who has experimented with the different methods, concludes that clear-felling is slightly preferable to either the group or uniform systems.

The truth of the matter is, that except in pest-areas common sense dictates the treatment, which varies with the composition of the wood, the objects of management, and risk of damage. In general, danger from frost, wind or drought is greater than that from insects, fungi or birds. The good result of a little forethought is well seen in felling mixtures containing Scots pine (29). Here, if the pines are extracted four years before regeneration begins, and a few trap stems and ground traps employed, there is little or no danger from bark-beetles or weevils to the subsequent crop. Lastly, "Time of felling, and period between that and removal of slash is, in Scots pine-woods, the most important factor governing the prevalence of forest insect pests" (29).

BIOLOGICAL CONTROL

(1) There are two factors only which govern the decrease of any organism:

(*a*) Lack of food (with insects usually of 'breeding-places').

(*b*) Presence of enemies.

It has already been shown to what extent the influence of silviculture is responsible for the first condition, and it was argued that, although the encouragement of the second condition was very desirable (by the same means), it was economic to do so only in extreme cases. In consequence, rather than sacrifice a proportion of the more valuable growing stock by substituting an innocuous but less profitable species (to act as a foil), it is generally considered politic to grow the most valuable crop, employing biological and purely artificial means to *prevent* damage; only, however, in so far as the expense is justified by the greater value of the growing-stock, and the added degree of safety. It is on this point that opinions differ, but with the present preference for purely artificial woodlands such precautions are not only justified; but regarded in the nature of an insurance, they are the best and cheapest way of assuring the welfare of the crop.

(2) For reasons outlined in Chapters II and III it is practical to consider only the biological control of two injurious influences—the insect and the animal:

(*a*) Insects by means of parasitic fungi and insects.

(*b*) Insects by means of predaceous insects and birds.

(*c*) Animals by means of predaceous birds and animals.

Here it will not be out of place to discuss briefly the relative importance of parasites and predators. The former are characterized by their almost complete

inter-dependence on one stage or one species or genus of insect; they can control their numbers but not annihilate—they are the police rather than the military force in nature. Moreover, from their mode of life it is readily understood that parasites cannot, by themselves, check any sudden increase of injurious insects (brought about by favourable weather, opportunity, or lack of predaceous enemies), for their generation is always one stage, usually one year, behind that of their hosts.

The degree of parasitation appears to be rather low, probably averaging less than 10% with any one species, though the subject has been so little studied that it is not safe even to generalize, much less express, a definite opinion. At all events in practice it is found that parasites are perfectly useless in checking the increase of their hosts, which multiply for three or four years before the degree of parasitation reaches 50%, when the attack is supposed to be entirely controlled by parasites, though usually other causes, such as unfavourable weather, *entomophilous* fungi, bacterial or protozoan diseases, appear to terminate it.

However important it may be in other fields of research, the artificial breeding of parasites to control injurious forest insects in this country, as it is at present understood, is entirely uneconomic, unsatisfactory and unsafe. It is useful only as a good example of something which is excellent in theory, but bad in practice; as successful in the laboratory, as it is unsuccessful in the forest.

The parasitic insect must be regarded as an ever-present and necessary form of natural control, which it is only possible to encourage by the discouragement of its enemies. In the forest these are flycatchers, swallows, martins and swifts, and no doubt a certain amount of good results from measures which prevent these birds (all summer migrants, be it noted) from nesting (see under separate species).

At all events it is reasonable to suppose that the degree of parasitation of injurious insects will be correspondingly raised at first, though subsequently hyper-parasitation of some useful insects must follow. The net result of such control measures it is difficult to estimate.

(3) The status of the predator is on an altogether different foundation. Considering the economy of predaceous insects first, it is realized that the cheapest form of encouragement is to prevent the nesting of those birds which destroy them. According to the very incomplete data available from volumetric crop analyses the most active enemies of the *Coccinellidæ*, arranged in order of importance are: SWIFT, MARTINS, SWALLOW, SPARROWS; treecreeper, chaffinch, starling. To other birds they appear to be singularly distasteful. Since the above four chief enemies of ladybirds are otherwise undesirable in the forest, discouragement of these birds will be sufficient protection in itself.

Other predaceous insects include *Calosoma sycophanta*, *Cecindela campestris*, *Clerus formicarius*, and

Rhizophagus spp., and these are apparently always eaten by birds whenever found; the first-named species has been found in the crop of a starling (40). But this group (that is, excluding the *Coccinellidæ*), and judged solely by the actual amount of good they do, are seen to be of relatively little importance compared with insectivorous birds.

(4) The economic value of insectivorous birds has already been summarized in Chapter II. Here it is necessary to decide to what extent birds are of use to the practical forester, and when and how the useful species should be encouraged, or the harmful birds destroyed. Much depends, as has been seen, on the situation of the woods, their age and composition, the probable risk of damage, the estimated cost of protection, and the objects of management. The results of biological prevention of damage are even less apparent than ordinary artificial protection, and it is this circumstance which prejudices the forester against the whole scheme. Being a practical man he asks, quite reasonably, "What results am I going to show for the outlay? Why should I meet trouble half-way? Why waste money to protect against something that may never happen for all I know to the contrary?"

True, it is only human nature to wait for the insect attack to develop into a pest before taking active steps for its suppression, but if the risk is there, is not prevention better than cure? Moreover, the fact that the woods are suffering, however slightly, from insect attack, can only mean that there is a

proportional loss of increment and vigour, though it may not be apparent to the forester. If, in addition, the amount of insect injury does not appear to be decreasing with the growth of the woods, but rather the reverse, then the danger of the attack suddenly assuming epidemic proportions is very great.

In practice, the subject narrows down to three points: what is the risk of damage; to what extent is it economic to reduce this; and what is the most effective way of doing it.

(5) Assuming that the crop is more or less suited to the area, the risk of damage may be said to increase according to the following conditions:

(*a*) With artificial regeneration (the more it diverges from the natural condition).

(*b*) With the intensity of management, being greater in pure, even-aged stands.

(*c*) With conifers, especially Scots pine (the only indigenous species), the risk diminishing with Norway spruce, sitka spruce, silver fir, European larch, Japanese larch (because they are deciduous); and being least with Corsican pine (as far as can be ascertained). Broad-leaved trees appear to offer greatest risk in the following order: oak, willows, poplars; ash, beech, sycamore; and, least of all, sweet chestnut.

(*d*) In young plantations near older (particularly over-mature) woods, and on newly-planted areas where timber has recently been cut, or where branch wood is left.

(*e*) In woods of light-demanding trees, that have not been underplanted, resulting in soil deterioration and the growth of weeds.

(*f*) In woods at high altitudes, and with a southern exposure.

(*g*) After physical injury to the trees by frost, snow, hail, wind-break, drying winds, or fire.

(*h*) After a hard winter following a dry summer; exceptional risk after two consecutive severe winters.

(*i*) Where the number of insects observed during the previous summer was above normal.

(*j*) Where the degree of parasitation of cocoons is below normal.

(*k*) Where annually recurrent pests are to be expected (*T. viridana*, *C. laricella*, etc., etc.).

(*l*) In localities where insectivorous birds are restricted, either in number or species (exposed places, high elevations, etc.).

(*m*) In unpreserved woods.

(*n*) With bad management, such as neglected thinnings, cleanings, etc.

Further than this it is not possible to carry the discussion.

(6) Assuming that the risk of damage is sufficiently serious to warrant the protection and encouragement of useful birds, and the destruction of harmful species, the new problem to solve is: to what extent is the cost justified. An abundant insect-eating fauna in *any* wood must always result in the more vigorous growth of the trees, and for

this reason alone (where birds are uncommon) encouragement is surely justified. The correlation between the vigour of the crop and the production of an increased increment is not precisely known, although, of course, it quite definitely exists. Because a stand is growing successfully and well, *does not mean that it cannot do better under even more favourable circumstances.*

This is an argument of more than ordinary application in the growing of hardwood species, for in addition to inducing a greater volume of wood (or, conversely, shortening the rotation), the technical value of the timber is greatly increased. To take a concrete example, one cannot but deplore the policy —or lack of policy—of the owners of those oak woods who are perfectly satisfied to allow the annual defoliation of the trees by *T. viridana*, and who ignore the fact that the 'Lammas-leaves' are only produced at the expense of the quantity and quality of the timber. On the contrary, they are the first to complain of the unprofitableness of planting oak because the growth is so little, and the rotation so long.

It is true that this is an extreme case, but nevertheless the principle is of very wide application.

It is a platitude to state that the costs of protection are justified only by the results. It is equally true that the practical man will only recognize results which are capable of being expressed in terms of hard cash. It is unfortunate, therefore, that those benefits resulting from the prevention of damage, which means stimulation of the crop

to better health and growth, must always remain unknown quantities.

Another aspect of the matter should also be discussed. However well the woods are being managed, one cannot prevent sudden damage by physical causes, such as that by frost and drought. But it is quite practicable to guard against the inevitable *consequences* of such calamities. The actual direct damage to the crop by physical causes is often considerable, but it is indirect damage by those insects which take advantage of its diminished vitality which is most to be feared.

It is of the greatest importance to check the increase of these insects in its initial state. Now the normal number of resident birds will not be sufficient to deal with this great increase, and it is unsatisfactory and unsafe to rely upon those scattered flocks of rooks, starlings and finches which appear only when the pest is already out of control, and after the damage has been done. One cannot rely upon luck under such circumstances.

It is a well-established fact that it is impossible to induce a correspondingly abnormal number of birds to breed either by the provision of nesting-boxes, or otherwise—that is to say, immediately they are wanted, and without any previous encouragement (for a practical example see under section 4, Chapter II). It is on this point that the efficacy of insect-control by birds is subjected to so much criticism. But in the very nature of things, is it reasonable to expect an abnormal number of birds to become

established on a new area, and to breed *before* the insects on which they prey have themselves bred and multiplied?—even supposing the requisite number of birds to be present in the neighbourhood? Of course it is not.

At this stage of the discussion the practical forester may observe, with complete justification, that it is as easy to criticize as it is hard to suggest a remedy. Then here it is. Maintain a sufficient *resident* stock of insectivorous birds in proportion to the risks of injury and loss—whatever they may happen to be. This is the ONLY ECONOMIC method of both normally controlling insect pests (except, of course, bark-beetles and weevils) and of anticipating and effectively checking their undue spread at all times when they are induced to increase abnormally.

In practice the only really economic method of wide application—that is to say cheaply, effectively, and permanently—is to put up nesting-boxes in the woods, these serving not only to attract birds to breed, and to breed in the right place, and in safety, but also they are utilized as safe roosting-places at night and as refuges in hard weather. In this manner only is it possible to breed birds, and also induce them to remain throughout the winter, at which time, as has been seen, it is as important, if not more important, to maintain them. There is only one other measure recommended for their encouragement, and that is the self-evident, and very necessary destruction of their enemies; in most localities this is synonymous with the extermination of the sparrowhawk.

(7) Although it is quite impossible to estimate beforehand the number of nesting-boxes which it is worth while putting up, in actual practice the problem solves itself, for insectivorous birds, which are primarily induced to breed by the provision of nesting-sites, will only continue to do so if the food supply is there. The following may be taken as a general example of what should be done to get the best results from this kind of protection.

Take the case of a rather isolated pure larch wood—a most unfavourable type—thirty years old and ten acres in extent, which is suffering from a recurrent insect attack. According to the nature of the pest it is first necessary to decide which bird or birds can most effectively control it, *in all its stages*. If it is a defoliatory pest, put up boxes for tits rather than for starlings, but if the larvæ pupate or hibernate in the ground then it may be more important to encourage starlings than tits. The more or less precise rôle played by each species has already been defined in Chapter II.

For the size of the wood, and if the pest had not yet become epidemic, a useful general number with which to begin would be twenty boxes for starlings and ten for various tits, and possibly two or three more for redstarts and robins. If the boxes had been placed in position in sheltered places near the edges of the wood, as near as possible to the centres of infestation, and early in the winter, then it is likely that the great majority would be occupied, for wandering parties of tits appear in all types of

woodland, and given the shelter of the boxes and an abundance of food would almost certainly winter and breed there.

If fifteen pairs of starlings and six pairs of tits nested the first year, it would be a satisfactory result for such a type of wood. Supposing this to be the case, the need for more boxes the next winter would have been clearly demonstrated, because, in normal circumstances, the pest would not yet be completely under the control of these birds. The number should therefore be increased to thirty boxes for starlings and fifteen for tits; of these probably 80% and 70% respectively are occupied. If by the end of that summer the numbers of insects have not decreased, it shows that the severity of the attack was under-estimated when the control measures were begun, and that a larger number should have been put up in the first place. If, however, the attack was not very severe, a sensible decrease in the numbers of the pest should have resulted, so that in the third summer probably only 50% of the boxes were occupied by tits, although the number taken by starlings may remain constant, or even increase, for these birds are not dependent on forest insects, feeding on them only when abundant. The great majority of these nesting-boxes may safely be removed to another area, leaving only 5-10 to preserve a breeding stock of starlings. If only 50% of the boxes are occupied by tits for two successive years then 40% of the unoccupied sites may be removed to another area, leaving a 10% surplus, as a safe margin in the event

of a sudden recurrence of that pest, or of another pest, due to physical causes.

This detail is of great importance, and although it may appear wasteful to have 10% unoccupied, it is a very wise precaution—and in any case in practice the number of boxes taken by any species varies slightly from year to year, so that it is not until the breeding season has begun that it is realized how many boxes are unoccupied, when it is, of course, too late to use them on another area.

The number of boxes on any area should be increased immediately an insect attack is anticipated, for reasons outlined in Section 5.

The following general observations are given as being of some practical bearing on the subject:

(*a*) The fewer breeding birds before the boxes are put up, and the larger the area of well-managed woods, the smaller the percentages of boxes occupied the first summer.

(*b*) It is neither usually practicable nor necessary to put up boxes before the wood has reached the pole stage, but the best time is immediately after the first thinning.

(*c*) Wherever young growth occurs near older woods it is essential to place the boxes along the edge of the latter, soon after the area is regenerated.

(*d*) The most favourable places for boxes are on the edges of woods, along fire-lines, or wherever natural clearings or gaps occur. It is useless to put them in the dense shade of polewoods. They

should face east, but not for preference, immediately towards the open ground. The higher they are placed, within reason, the better for most tits; on the other hand robins and redstarts will only nest within a dozen feet of the ground. The boxes for most birds should be as evenly distributed as possible, but starlings apparently prefer to nest in colonies.

(*e*) Boxes can be removed from woods which are to be felled within five years, and used on a new area.

(*f*) It should be worth while placing boxes near the nursery, particularly those for starlings and robins.

(*g*) The artificial feeding of birds, as advocated in (43), is not to be recommended, except in special circumstances. It is economic to do so only during very hard winters, and during prolonged snow, when insect food is practically unobtainable, and it is likely that a large number of birds will die in consequence.

(*h*) Planting berry-bearing shrubs for the same purpose is always impracticable (apart from game interests). Hiesemann (43) carries this to such extremes that it degenerates into the scientific 'farming' of birds, and this attitude does much more harm than good in prejudicing the forester against the whole scheme of rational and practical biological control.

(8) Regarded from a purely financial standpoint the cost of prevention and protection against insects is amply justified. Too much stress is laid on the

wholesale destruction of woods by this means, for one is apt to forget that the injurious insect fauna, wherever it is doing the least appreciable damage, is slowly but surely eating into the profits of forest management. In other words, the enormous continental outbreaks are exceptional, and because pests do not occur on the same scale in this country does not mean that they are actually unimportant, but that they appear to be unimportant by comparison.

The problem of biological control has only been cursorily discussed in these pages. Nevertheless, it is to be hoped that the following facts will have emerged as being as sound in practice as in theory: firstly, biological control is very effective UP TO A POINT; secondly it is the cheapest form of protection, because it is the most natural; thirdly, it is quite the most permanent, for once begun it continues to be automatic in its action.

Artificial protection and the influence of good clean silviculture (including proper choice of species) are only the basis on which it is possible to grow trees at all; biological prevention of damage is in the nature of an insurance, which can turn a risky undertaking into a sound business proposition. Other concerns are insured: why should not the business of forestry?

(9) The problem of effective, cheap and permanent control to counteract the bad effect of intensive silviculture is seen to have been solved by the proper encouragement of certain insectivorous birds. It is entirely a matter of opinion—or of

prejudice—as to whether or not this policy is adopted by the management. The small initial outlay for nesting-boxes has always shown itself to be a very good investment indeed.

There is no doubting the fact that there is at present, and will continue to be in the future, an increasing need for rational forest protection. In this country the chances of woods escaping serious damage have been all in their favour—in the past. In the future, if continental examples are to be believed, and the evidence is distressingly obvious, the chances will be against their success. The present is the turning-point in the history of British Forestry.

Properly to appreciate the growing importance of systematic, as opposed to chance methods of forest protection, one must needs turn to those essential differences which, until 1922, so clearly distinguished British from continental forestry practice.

Now German, and to a great extent, French forests have always been managed strictly for timber production and profit, both when State and privately owned. But in 1922 quite 97½% of British woodlands were in private hands, and of these a large proportion were maintained primarily for sport; the remainder were mostly picturesque survivals of natural forests.

In the former case game-preservation usually means an open canopy and understocked woods, also the suppression of 'vermin'; in both cases many dead and over-mature trees are left and ground

cover is abundant, so that, taking everything into consideration, a nearer approach to the ideal state for all insectivorous birds it would be hard to find. Serious forest pests, with but few exceptions (and these occurring in properly managed stands), have been conspicuous by their absence.

The distinction between the peaceful existence of our own woodlands and the chaotic state of continental forests is so marked that it needs no further elaboration.

Now the question arises: are we in Great Britain taking full advantage of continental experience in regenerating new areas, so that the future safety of our woodlands is assured? On the contrary, we are taking no more precautions than the German foresters did seventy or eighty years ago. Secure in the knowledge that we have never yet suffered from extensive insect outbreaks we are labouring under the delusion that therefore we never shall, although the majority of those insects which commit the greatest havoc abroad—such as the nun moth—actually occur in this country. Such insects are only awaiting the favourable opportunities of breeding afforded by large artificial woods to become as epidemic in this country as they have already proved themselves to be abroad. History will repeat itself.

Although some insects, notably the sawflies, have already become extremely troublesome locally, there is a very good reason for the fact that outbreaks of this nature in well managed woods have not been more frequent. Up to the present plantations that

have escaped damage have usually been small, and near more natural woods. Consequently the insectivorous birds which nest in the latter hunt for food in the adjacent plantation; in addition to which, considerable numbers of tits, finches, etc., wander about in winter, and feed on the hibernating insects.

It is logical to suppose that it is only a question of time before the newly afforested areas (the potential breeding-place of insects), becoming more and more removed from the old type of woodland (the breeding-place of birds), should at last reach a point when the natural control of insects by our resident stock of birds will be insufficient.

(10) The biological control of animals by predaceous birds and animals is of very limited practical application. It is thoroughly economic, however, to take steps to encourage the natural enemies of voles and mice, for, like insects, it is impossible to exclude the animals from the forest, and they are so small and subject to such prodigious increase that artificial control is out of the question.

Inducing owls, the buzzard and kestrel to nest (see particularly under Tawny Owl) and the protection of the weasel (but not the stoat), are methods to be thoroughly recommended at all times. If the woods have no sporting value the stoat should also be encouraged.

(11) Reviewing the objects and attainments of biological control, it must not be thought from the above strong arguments in its favour—too strong,

some may say—that the case for natural prevention of damage has been overstated. There is need for moderation in everything.

By stating the plain facts of the case, the writer has simply endeavoured to show that the increasing *necessity* for some form of cheap, automatic and lasting forest protection, no less than the material advantages to be gained in any wood by the increase of the insect-eating fauna, must at some time in the near future induce practical men to adopt the rational encouragement of birds as the *basis* of all their precautionary measures against injurious insects.

The fact that an intensive forestry campaign has already been begun in this country does not make this aspect of forest protection by any means premature.

ARTIFICIAL CONTROL

(1) Direct prevention of damage by the forest staff is attained either by mechanical or chemical means. It is justified only under the following conditions:—

(*a*) When silvicultural and biological methods, together fail.

(*b*) When the cost is less than that of other methods, taking into account its own efficacy and permanency.

Most of the following methods have already been elaborated under the separate headings of the animals concerned. They are usually more applicable in a nursery than the forest.

(2) Prevention of damage by mechanical means usually consists of a special measure directed against one particular pest, whether fungus, insect, bird or animal; as follows:

(*a*) Total exclusion, which is an expensive but highly necessary method of prevention, such as wiring out deer, hares and rabbits; and sometimes surrounding the nursery with trenches to prevent the spread of mice and voles, or covering over the seed-beds.

(*b*) Isolating the attack, by digging trenches to prevent the spread of fungi underground, or by wiring in rabbits, or grease-banding stems to prevent the ascent of insects (very rarely).

(*c*) By preventing the increase of the organism. This includes shooting *capercaillie* and black game, squirrels, deer, hares, and sometimes rabbits (usually means total exclusion); trapping squirrels and moles, sometimes also rabbits; voles and mice (in the nursery).

(*d*) By providing the organism with breeding-places and then destroying the young broods; applicable only to the destruction of bark beetles and weevils, by trap-stems or billets; or *Melolontha vulgaris* near the nursery by spreading dung in trenches, or trapping adults under sods of turf.

(3) Prevention of damage by chemical means, as follows:

(*a*) Covering nursery seeds with red-lead, or steeping in 2% carbolic acid solution, to make them poisonous to ground larvæ, voles, mice and seed-eating birds.

(*b*) Spraying or dipping transplants before planting out on a new area; this is probably more often neglected than any other preventive measure. It will be noticed that these measures prevent damage, not destroy pests, a subject which is outside the scope of this thesis.

(4) The cost of artificial is many times that of silvicultural and biological control. Continental literature is full of the accounts of costly failures. In Bavaria in the years 1889 and 1890, the expense of artificial protection alone—leaving out of account the loss of timber involved—was credibly estimated at £100,000. The almost complete failure of these methods was never better illustrated than by the fact that only two years later a further £75,000 was spent in ringing the stems with patent preparations, a control measure effective against only one small class of insects! Again in Saxony, between 1905-12, similar preventive measures averaged £5,800 a year. In the Meaux district of France the total expenses of collecting cockchafers in six flight years (1889 to 1904 inclusive) was £4,800, with the cheapest of labour—women and children. But such examples can be quoted ad nauseam.

FORESTRY AND GAME PRESERVATION

(1) In most cases woods, worked solely for timber production, do not represent the maximum value of the land. This is very true of the British Isles in general, and in particular of England, where the

scattered nature of the woods, their comparatively small acreage, and their proximity to agricultural land, are all characters which lend themselves to a more profitable exploitation over and above the mere growing of timber.

Pratt (54, 1925) sums up the points at issue when he says: "Although the fastest growing timbers may not be saleable for 25 years after planting [other than thinnings?] woods may produce by-products after three or four [with pheasant rearing the whole time], and if the forester works not only to produce timber, but to produce the maximum amount of something saleable, as if he were the manager of a factory, then the possibilities and combinations are endless, and forestry, instead of being the last resource of derelict land, can become a most interesting and a profitable profession."

The writer cannot here discuss all the possibilities of intensive silviculture, but no treatise on the economic protection of woodlands in this country would be complete without mentioning the influence upon it of sport and game preservation, which includes, besides deer stalking, hunting or shooting and fox-hunting (already briefly discussed), pheasant rearing, and the preservation of *capercaillie*, black game, woodcock, woodpigeons, hares and rabbits.

(2) It is necessary to distinguish clearly between the direct and the indirect value of sporting woods. The former, whether enjoyed by the proprietor himself (the 'pleasure-value'), or whether he obtains a certain price for it from a syndicate of sportsmen

or from the neighbouring estates, nevertheless represents a direct source of revenue. Except in the largest and densest coniferous stands it is always possible in this country to let whatever rough shooting there may be, and generally practicable to lease it entire to someone who keepers it, rears game, etc.

But it is the indirect advantages or disadvantages, resulting from the protection of game and the destruction of their enemies, which is of such importance *in the actual growing of trees*.

(3) The disadvantages of game preservation consist of the damage by capercaillie, black game, hares and rabbits (but not woodpigeons in ordinary numbers, the damage being done by the vast flocks of continental immigrants in winter); the cost of fencing regeneration areas against hares and rabbits; and possibly some slight modification of management in the case of pheasant-rearing.

In the majority of woods the harm done by hares and rabbits far outweighs their slight sporting value. However rigorously they are 'kept down' regeneration is bound to suffer; and having netted an area against these rodents is it worth while to throw it open when the risk of damage is reduced? This can only mean again exterminating them when the woods are regenerated.

For the same reason capercaillie and black game are even more undesirable, for they spread uninterruptedly from the old woods to the new plantations. They are not, however, of any great economic importance.

The fact of the matter is, that in small numbers these birds and animals are not particularly harmful; but then they are of little, if any, sporting value. On the other hand, where they are abundant they do far more harm than good. In either case they are uneconomic propositions.

(4) The value of woodcock shooting is variable, depending on the locality and the composition of the woods. It is highest in broad-leaved woods, particularly those containing an admixture of oak.

Without a doubt the popularity of covert shooting is an unmitigated blessing to the forester in this country. Besides the fact that the most important enemies of the pheasant are also those of the tree (indirectly) the bird itself is an asset to any wood, from the amount of injurious insects it consumes in the wild state.

This is well illustrated by a practical example which was communicated to me by Professor Hickson. The larch woods near Thirlmere (Cumberland) were preserved and keepered. In the autumn following an outbreak of the large larch sawfly (*N. Erichsonii*), the gamekeeper on one estate experienced considerable difficulty in 'showing' his pheasants. It was surmised that the attraction which kept them up in the woods on the hills was the abundance of sawfly cocoons which were found hibernating under the scanty covering of the forest floor. Accordingly a cock pheasant was sent to Professor Hickson for examination, and the keeper's diagnosis proved to be correct, for not only was the bird most inordinately

fat, but no less than 110 cocoons were taken from its crop!

It is reasonable to suppose, also, that large numbers of wireworms, click-beetles, cockchafers and their larvæ and hibernating bark-beetles and weevils, and even defoliatory larvæ, are eaten in some quantities. The small consumption of seed can be neglected.

If the woods are efficiently keepered the sparrow-hawk will be exterminated, and the numbers of stoats and weasels greatly reduced. It has already been shown that mice and voles can be controlled by the owls, kestrel and buzzard, and it is generally realized by the more enlightened gamekeepers that these birds rarely do any appreciable damage. At all events the forest management should stipulate that these birds should be protected. Squirrels are great egg-thieves, and keepers spare no pains to shoot and trap them. The crows, jackdaw, jay and magpie are also destroyed in preserved woods, and although the three latter species are of some utility they are generally unnecessary where rooks and starlings also occur.

Taking everything into consideration, then, it is apparent that by preserving the woods for pheasants the gamekeeper encourages natural protection of the trees, both directly (by destroying squirrels, rabbits—which are harmful to game—and by breeding an extremely useful bird) and indirectly (by exterminating the enemies of small insectivorous birds). Moreover, where the shooting rights are let, his

employer actually pays the forest management to allow him to do so! It may safely be said that pheasant-rearing is largely responsible for the scarcity of insect pests in those preserved woods, which constitute so large a proportion of the total woodlands in England.

By coming to some agreement with the keepers, too, it is possible to still further increase their sphere of usefulness, for instance by paying them 3d. or 4d. for every squirrel destroyed.

On estates where the management employs the keeper, he can do a great deal in his spare time —chiefly from December to March—by making nesting-boxes, repairing wire-netting, reporting damage, helping to exterminate rabbits, trapping moles and other forest vermin, etc., etc.

It is apparent that game preservation, if not carried to extremes, is both directly and indirectly a source of revenue which no forester can afford to ignore.

FORESTRY AND AGRICULTURE

Woods are so often near farms in this country that the following suggestions can usually be carried into practice:

(*a*) Cattle can do a certain amount of good on a new area, by grazing down the rank growth of grass and weeds, and disturbing the soil. According to Gillanders (19) they should be herded on a felled area, before regeneration is begun, because "the soil

is so much trodden away from the stumps that the bark falls off." Combined with trapping, this is a valuable protection against bark-beetles. On areas to be regenerated naturally, a great deal of good is done by the beasts in treading in the seeds, and disturbing the soil, in addition to destroying any growth of grass, etc.

(*b*) The keeping of poultry from time to time on certain areas is an exceedingly practical measure which is much neglected. Not only do the poultry obtain free food, but the destruction of injurious insects is often better and more completely done than by wild birds. When the site for the nursery is ploughed or dug over, if a hen-house is moved over the area, the birds will entirely free the ground of wireworms and chafer larvæ, and larvæ of 'cutworms' and other injurious insects. This is done with great success by farmers. Where insects are known to be hibernating in the forest soil the hen-house can be moved from place to place along the firelines, etc. On felled areas particularly, the beetles and weevils which hibernate in the soil cover, or are attracted to the stumps to breed, will be practically exterminated; although of course a certain amount of trapping must also be employed. Nothing but good can result from such simple measures, for they greatly reduce the costs of protection on many areas.

(*c*) The herding of pigs, for cockchafer larvæ, is a thoroughly unsound measure (see Appendix II, Notes).

APPENDICES

APPENDIX I

TREES

The silviculture and protection of the following trees have been discussed, and, with the exception of the Weymouth pine, they include only those species which it is economic to grow in this country:

BROAD-LEAVED TREES

C. Oaks (*Quercus pedunculata*, and *Q. sessiliflora*).
C. Ash (*Fraxinus excelsior*).
Beech (*Fagus sylvatica*).
Sycamore (*Acer pseudoplatanus*).
C. Sweet Chestnut (*Castanea vesca*).
Poplars (particularly *Populus serotina*).
Willows (particularly *Salix cœxrulea*).

[C=commonly coppiced.]

CONIFERS

Scots Pine (*Pinus sylvestris*).
Corsican Pine (*P. laricio*).
Weymouth Pine (*P. strobus*).
Douglas Fir (*Pseudotsuga Douglasii*).
Silver Fir (*Abies pectinata*).
Norway Spruce (*Picea excelsa*).
Sitka Spruce (*P. sitchensis*).
European Larch (*Larix europœa*).
Japanese Larch (*L. japonica*).

APPENDIX II

INSECTS

The following insects are generally regarded as being of some importance in British Forestry (see under 29), and have been mentioned from time to time throughout the text (the more important economically are in larger type):

INJURIOUS INSECTS

COLEOPTERA

SCARABÆIDÆ (Sub-family: MELOLONTHINÆ,	*MELOLONTHA VULGARIS*, [*M. melolontha*].
	M. HIPPOCASTANI (see 55, 1924).
	RHIZOTROGUS SOLSTITIALIS).
ELATERIDÆ	*AGRIOTES LINEATUS*, and other species (see 55, 1924).
BUPRESTIDÆ	*Agrilus viridis*.
CERAMBYCIDÆ	*SAPERDA CARCHARIAS* (see 57, 1920).
	S. populnea.
	Aromia moschata.

CHRYSOMELIDÆ	*Chrysomela* [*Melasoma*] *populi*.
	Phyllodecta vitellinæ.
	Scolytus intricatus.
	HYLASTES ATER.
IPIDÆ [*Scolytidæ*] (see under 49, Bulletin No. 8)	*Hylesinus fraxini*.
	MYELOPHILUS PINIPERDA.
	Pityogenes bidentatus.
	PISSODES NOTATUS.
	P. pini.
CURCULIONIDÆ (see under 49, Bulletin No. 8)	*HYLOBIUS ABIETIS*.
	Cryptorrhynchus lapathi.
	Orchestes fagi.

LEPIDOPTERA

TRYPANIDÆ	*TRYPANUS COSSUS* [*Cossus ligniperda*.]
ZEUZERIDÆ	*Zeuzera pyrina* [*æsculi, L.*]
SESIIDÆ	*ÆGERIA* [*Trochilium, Sesia*] *APIFORMIS*.
LYMANTRIIDÆ	*Lymantria* [*Liparis*] *monacha*, *Orgyia antiqua*.
NOCTUIDÆ	*PANOLIS PINIPERDA*.
	Agrotis segetum.
GEOMETRIDÆ	*BUPALUS* [*Fidonia*] *PINIARIUS*.
	HYBERNIA DEFOLIARIA.

TORTRICIDÆ	*TORTRIX VIRIDANA.* *RHYACIONIA* [*Evetria, Retinia*] *BUOLIANA.* *R. RESINELLA.*
TINEIDÆ	*COLEOPHORA LARICELLA.* *ARGYRESTHIA ATMORIELLA.* *Prays curtisellus.*

HYMENOPTERA

TENTHREDINIDÆ	*LOPHYRUS PINI.* *L. SERTIFER, Geoffr.* [*rufus.*] *NEMATUS* [*Holcocneme*] *ERICHSONII* (see 3, and 49, 1908).
SIRICIDÆ	*Sirex gigas.* *S. noctilio.*

DIPTERA

CECIDOMYIIDÆ	*Rhabdophaga* (*Cecidomyia*) *saliciperda.*

RHYNCHOTA (*Hemiptera*)

APHIDIDÆ	*Chermes viridis.* *C. corticalis.* *C. pini.* *C. cooleyi.* *Lachnus pini.* *Phyllaphis fagi.*

COCCIDÆ	*CRYPTOCOCCUS FAGI.* *Chionaspis salicis.*

USEFUL PREDACEOUS INSECTS

COLEOPTERA

CARABIDÆ	*Calosoma sycophanta.*
CECINDELIDÆ	*Cecindela campestris.*
CLERIDÆ	*Thanasimus* (*Clerus*) *formicarius.*
NITIDALIDÆ	*Rhizophagus depressus.*
COCCINELLIDÆ	*COCCINELLA SPP.*

DIPTERA

SYRPHIDÆ	*Syrphus pinastri.*

USEFUL PARASITIC INSECTS

HYMENOPTERA

ICHNEUMONIDÆ *CHALCIDIDÆ* *BRACONIDÆ*	generally.

DIPTERA

TACHINIDÆ	generally.

Unfortunately, it is impossible to discuss more fully the economy of insects. However, the following notes are of more than ordinary significance in relation to biological control, particularly since the writer can find no mention of the majority in text-books :

MELOLONTHINÆ: *M. vulgaris* is the primary host of the pig tapeworm (*Echinorhynchus gigas*), so that herding pigs in forests is far from desirable, both from a human and porcine point of view.

ELATERIDÆ: larvæ of various species attack pupæ of important parasites of *Lepidoptera* (of *L. monacha*, *Wichmann*, 55, 1924). Wireworms, therefore, commit two-fold damage.

CARABIDÆ: not all carabid beetles are useful, and *Harpalus* is one injurious genus (Prell, 55, 1925).

CLERIDÆ: *Thanasimus* (*Clerus*) *formicarius* attacks *Rhagium spp.* as well as bark-beetles. It is of greater value on this account, and this is an added reason (see woodpeckers) why stumps should be barked and left, rather than extracted at great cost (45, Bulletin No. 8).

COCCINELLIDÆ: experiments show that lady-birds can completely control plant-lice, though not exterminate them (Yearbook of Bd. of Agr. (U.S.A.), 1911). They are migratory to an extraordinary extent (37).

APPENDIX III

BIRDS

CLASSIFICATION OF BIRDS ACCORDING TO THEIR ECONOMIC IMPORTANCE

Wherever they occur, the following birds are considered to be of some economic importance apart from game interests.

B = more or less restricted to broad-leaved forest.
C = more or less restricted to coniferous forest.
M = rather indifferent to the type of woodland.
= injurious in preserved woods.

(1) Of primary importance, and which it is economic to encourage to breed :

M Starling (*Sturnus vulgaris*).
M Redstart (*P. phœnicurus*).
M Robin (*Erithacus rubecula melophilus*).
M Great Tit (*Parus major*).
B Blue Tit (*P. cæruleus*).
C Coal-Tit (*P. ater*).
B Marsh-Tit (*P. palustris*).
M Willow-Tit (*P. atricapillus*).
C Crested Tit (*P. cristatus*).
B Nuthatch (*Sitta europœa*).
M Greater Spotted Woodpecker (*Dryobates major*).
— Nightjar (*Caprimulgus europœus*).
C Long-Eared Owl (*Asio otus*).
M Tawny Owl (*Strix aluco*).

(2) Distinctly useful, but which it is not usually possible to encourage to breed, for economic reasons (but deserving rigorous protection at all seasons):

M Rook (*Corvus frugilegus*) [but see under that species].
M Chaffinch (*Fringilla cœlebs*).
B Willow-Warbler (*Phylloscopus trochilus*).
B Chiffchaff (*P. collybita*).
B Wood-Warbler (*P. sibilatrix*).
B Lesser Whitethroat (*Sylvia curruca*).
— Whinchat (*Saxicola rubetra*).
— Stonechat (*S. torquata*).
B Long-tailed Tit (*Aegithalus caudatus*).
C Goldcrest (*R. regulus*).
M Lesser Spotted Woodpecker (*Dryobates minor*).
B Green Woodpecker (*Picus viridis*).
M Cuckoo (*Cuculus canorus*).
M Barn-Owl (*Tyto alba*).
— Short-eared Owl (*Asio flammeus*).
M Little Owl (*Athene noctua*).
M Common Buzzard (*B. buteo*).
M Kestrel (*Falco tinnunculus*).
M Pheasant (*Phasianus colchicus*).

(3) Of doubtful value, which varies with circumstances, (see under separate species):

*B Jackdaw (*Colœus monedula*).
*B Magpie (*P. pica*).
*B Jay (*Garrulus glandarius*).
B Greenfinch (*C. chloris*).
M House-Sparrow (*Passer domestucus*).
M Tree-Sparrow (*P. montanus*).
M Treecreeper (*Certhia familiaris*).
B Wryneck (*Jynx torquilla*).

(4) Distinctly injurious, calling for repressive measures if abundant:

*M Hooded Crow (*Corvus cornix*).
*M Carrion-Crow (*Corvus corone*).
C Crossbill (*Loxia curvirostra*).
— House-Martin (*Delichon urbica*).
— Sand-Martin (*R. riparia*).
— Swallow (*Hirundo rustica*).
— Swift (*A. apus*).
M Ring-Dove (*Columba palumbus*).
M Stock-Dove (*C. œnas*).
B Turtle-Dove (*Streptopelia turtur*).

(5) To be exterminated at all times:

*M Sparrowhawk (*Accipiter nisus*).
C Capercaillie (*Tetrao urogallus*).
M Black Game (*Lyrurus tetrix*).

Local authorities (County Councils) protect most birds during the breeding season, and some throughout the year; those birds never protected include the sparrowhawk, sparrows, hooded and Carrion crows; and rarely, if ever, protected are the rook, jackdaw, and jay, and the seed-eating finches.

Under the Game Laws, pheasants are protected from February 1st to September 30th inclusive, and black game from December 10th to August 20th, except in Devon and Somerset, when the close season is extended to August 31st.

By the "Hares Preservation Act, 1892," the close time for these animals is from March 1st to July 31st, inclusive.

For taking action for damage under the "Rabbits and Rooks Act, 1925," see under the rabbit and rook.

Compensation for damage by deer, pheasants, grouse and black game is obtainable under the "Agricultural Holdings Act, 1923." (*Note.*—Grouse properly includes Capercaillie. It is to be noticed that there are, as yet, no measures against Hares).

APPENDIX IV

COSTS

(1) COST OF PROTECTION FROM RABBITS AND HARES

For prices of netting and stakes, and cost of erection, the writer is indebted to Mr. A. P. Long, of the Forestry Commission, and these figures apply to a typical 500 acre square block in the Breckland, which it is assumed averages 4 rabbits to the acre, and is completely cleared in 12 weeks. The warreners are first paid by piece-work until the stock is so reduced that they are unable to earn the minimum weekly wage of 35/-. The fence is 3′ 6″ high (3′ 0″ for rabbits only), which is the minimum for flat ground (see Diagram).

Assets: sale of 2,000 rabbits at 1/6 a couple, £75 0s. 0d.

Expenditure: £75 0s. 0d.

		£	s.	d.
Cost of first 1,300 rabbits, at 8d. a couple		21	13	4
2 warreners, at 35/- a week each, for 8 weeks		28	0	0
Traps, wire, nets, implements [variable]	about	1	0	0
		50	13	4
Balance [Revenue]	about	25	0	0

This balance helps to defray the cost of netting the area (1,555 yards square) for which the maximum cost is given :

		£	s.	d.	£	s.	d.
6,220 yards of 1½ inch mesh netting 3′ 6″ wide, at 20/10 per 50 yard roll [125 rolls]		130	4	2			
Stakes, 8 to the chain, total 2,262 Stakes, at 4d. each		37	14	0			
Carting above, about 2d. a chain		2	7	0			
Erection of netting and posts, 1d. per yard run.		25	18	4			
					196	3	6
Plus 6,220 yards barbed wire for hanging netting, and 6″ straining posts every 80 yards, makes total cost approximately £200.	about				£200	0	0
Less Revenue from rabbits	about				£25	0	0
Actual Cost	about				£175	0	0

Or 7/- per acre with revenue from rabbits ;
Or 8d. per yard run for netting alone.

This is higher than the usual figure, because only a small area has been enclosed (2,000 acres costs only twice as much as 500 acres), and the wire, the chief item, is new, whereas in practice a block is gradually extended, and the old wire used several times. The posts, also, are 3′ 6″ high, instead of 3′ 0″, because they are required for hare-wire. Hare-wire (No. 12, B.W.G.) at 2d. a chain, and 4d. a chain for erection, adds 4% to the cost of rabbit-netting (combined fencing at 8½d. a running yard).

It therefore appears that combined protection against hares and rabbits over 1,000 acres should not cost more than 5/- an acre *where rabbits are*

numerous, and if it is netted in one block, whether the whole area is bare or some part of it already wooded.

The cost of extermination will be much less if, *before felling*, the area is netted, for it is the growth of grass and weeds which attract these rodents; on the other hand, the cost of netting the area in such cases is much greater, for there is no revenue from the sale of rabbits; then it may easily amount to one-third of the total cost of regeneration (54, 1925).

(2) DEER FENCING

Unfortunately the writer is unable to ascertain this cost, which is very variable, for no reliable figures are given anywhere. The cheapest wire fence effective against all deer, with galvanized wire and creosoted larch thinnings, 5′ 6″ high, is given, as adapted from Nisbet ("Elements of British Forestry, 1911," page 168). This would appear to work out about 1/- per running yard, more where the timber has to be bought.

The top wire of smaller gauge is specially recommended, as it is found in practice that deer, particularly roe, try to leap over the thick wire, but failing to see the thin strand jump too low, with the result that they are either caught by their forelegs between the two top wires, or receive so severe a shock that they never again attempt the jump.

(3) NESTING-BOXES

It has already been stated (Chapter II) that it is almost useless to induce woodpeckers to nest in

boxes, because they are turned out by starlings, and also because the boxes need to be specially made and are too expensive to buy. However, since woodpeckers excavate their own breeding places they can be encouraged by other means.

The following remarks, then, apply only to the nuthatch, starling, redstart, robin, and those tits which nest in holes. Now these birds, in the natural state, will breed in almost any hole or crevice in a wall or tree, or even a drainpipe, etc., etc., provided that it is big enough. In spite of this, Baron von Berlepsch claims that the boxes which he has invented, because they are exact replicas of woodpecker borings, must and do attract birds better than any other type. In fact, Hiesemann (43) goes so far as to state that any other form of box is 'practically useless' and a 'worthless imitation'.

It is such gross misrepresentation of fact which prejudices the forester against the whole scheme of bird encouragement, for he very naturally prefers to dispense with nesting-boxes rather than pay the 4/6 to 7/6 (plus cost of carriage) demanded for every 'perfect product'—a most prohibitive price.

After a careful study of many nesting-boxes which are annually used by various birds, the writer has satisfied himself—even were it not for the plain evidence afforded by the selection of natural sites—that, with ordinary care in construction and placing in position, excellent results can be obtained with ordinary boxes, for approximately one-fifth of the cost. Where the labour is available, as in the case of a gamekeeper at odd times during the winter, and there is an estate sawmill, the only cost is that of the screws and nails.

A certain amount of care must be observed in the construction of the box, for it is false economy

to go to the other extreme, and knock a few odd pieces of wood together so badly that they fall apart in one or two years. It must be remembered also that they are almost as useful for shelter in winter as for breeding purposes in summer. Birds are sometimes found frozen to death inside thin-walled and badly made boxes.

Therefore, the following general rules must be followed in the construction of a nesting-box:

(*a*) It must be made of wood, preferably unbarked, for bark is the natural insulation against cold. If made of boards they should be at least ¾" thick, and made of a durable wood, alder being the best for the purpose.

(*b*) The hole must be made the exact size recommended, and can be bored sloping upwards, though this is not important if the box is tilted forwards. For the same reason (to keep out the wet) the lid should be larger than the top of the box.

(*c*) The parts of the box should be screwed together, and the outside only roughly creosoted with a brush, some time before placing out in the woods.

(*d*) Since it is only possible to use nails or screws to secure the boxes to the trees, the less valuable species should be chosen, or those which would come out as thinnings.

APPENDIX V

TYPE A

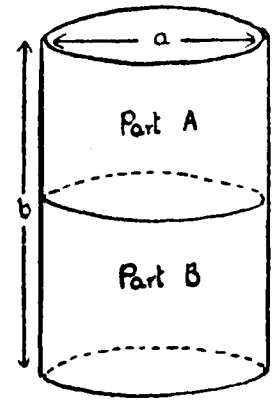


Figure 1.

The log, covered with bark ¼" thick, is first sawn in half.

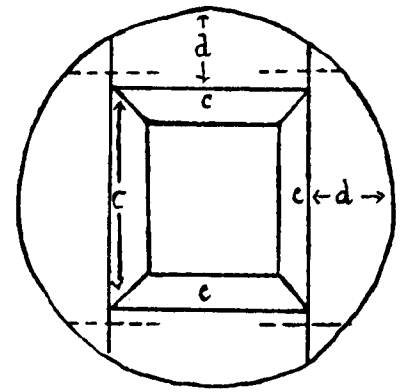


Figure 2.

Part *A*, from above, showing method of cutting out centre, and joining together the four parts with 1½" wire nails, or screws.

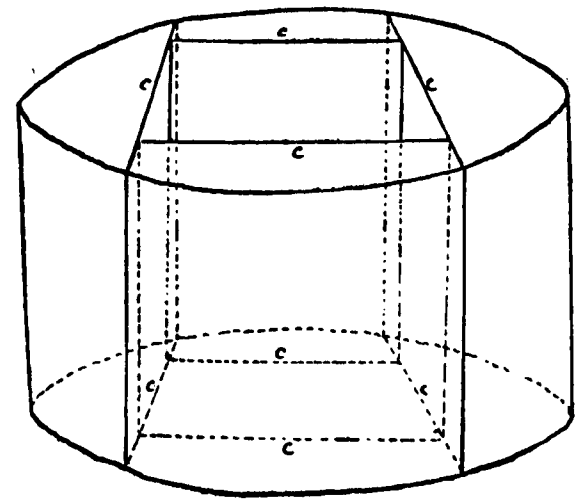


Figure 3.

(*diagrammatic*)

Part *A*. From this it is seen that Part *A* is divided by four straight cuts, and the centre (shaded) is square.

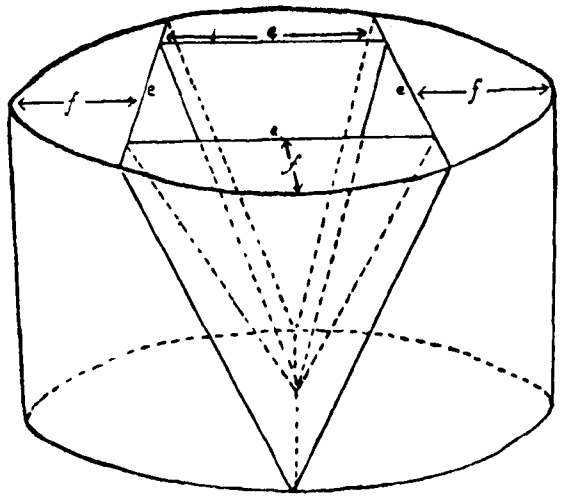
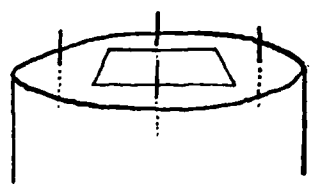


Figure 4.

Part *B* is made by four straight cuts at an angle towards the centre of the box, the resulting cavity being in the form of an inverted pyramid.

Figure 5.

Method of fastening *A* and *B* together with wire nails



The completed box is as near an approach to the Berlepsch type as it is possible to make with straight cuts. It is seen to be very simple in construction.

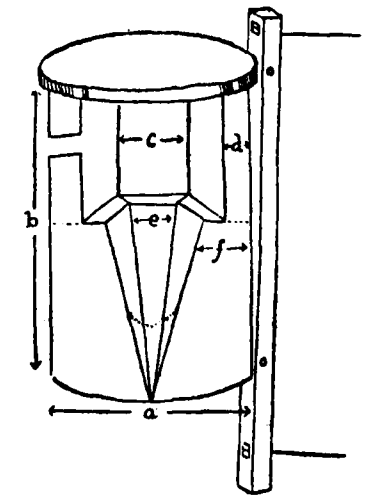


Figure 6.

(Diagrammatic).

The ledge halfway down will be noticed as an important feature, also the fact that this type is virtually made of only five instead of six parts. The lid, ¾" thick projecting by ½", is also calculated to tilt the box forwards at the correct angle. Two to three inches of sawdust, or better still, small wood-chips, must be placed in the bottom.

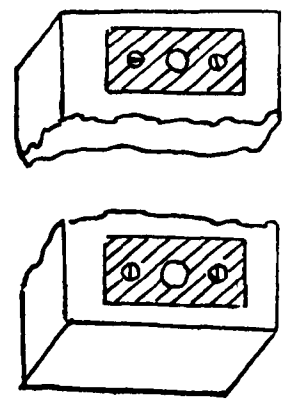


Figure 7.

Showing method of fixing box in position. The slat is 1" broad by ½" deep, and two small iron plates, with holes for large-headed 2½"-3" nails, are screwed to the slat to prevent the nails from being occluded by the annual growth of the tree.

The following sizes must be observed:

Size 1. Diameter of opening $1^1/_{16}$", for all tits, except great tit. The opening is too small for sparrows.

Size 2. Diameter of opening $1\frac{1}{4}$", for great tit, starling, redstart and nuthatch, the latter plastering up the hole to suit itself.

	a	*b*	*c*	*d*	*e*	*f*
Size 1.	$6\frac{1}{2}$"	9"	$3\frac{1}{2}$"	$1\frac{1}{2}$"	3"	$1\frac{3}{4}$"
Size 2.	$7\frac{1}{2}$"	12"	$4\frac{1}{2}$"	$1\frac{1}{2}$"	4"	$1\frac{3}{4}$"

TYPE B

A simpler, and, therefore, a cheaper box, which will appeal to the practical man, is made by four straight cuts out of a log of wood.

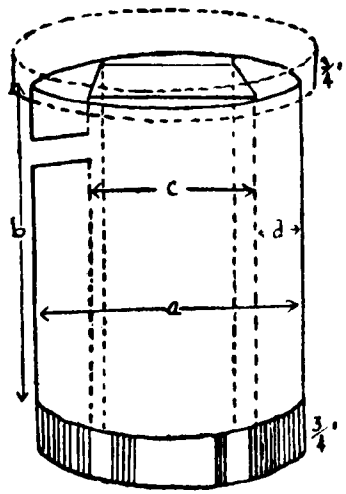


Figure 8.

This needs a second round of wood for the bottom. The sizes for this type are smaller, though the diameter of the opening is, of course, the same:

	a	*b*	*c*	*d*
Size 1.	6"	8"	3"	$1\frac{1}{2}$"
Size 2.	$7\frac{1}{2}$"	10"	4"	$1\frac{1}{2}$"

A simple cheap and effective nesting-box for redstarts, robins and some tits, but which does not exclude sparrows, is made from $\frac{3}{4}$" boards as follows:

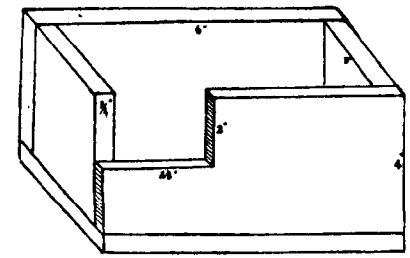
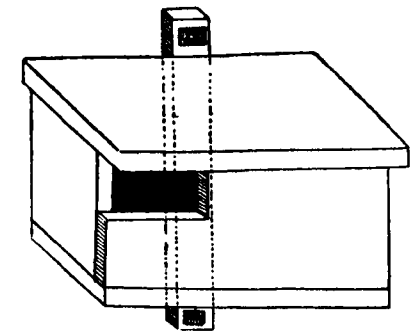


Figure 9.

Figure 10.

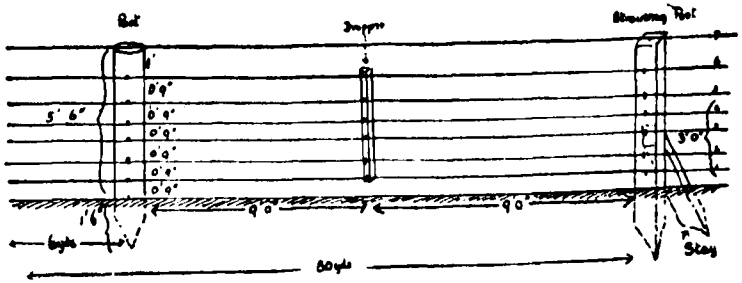


This is nailed in position as follows; with a lid overlapping the front of the box by $\frac{1}{2}$".

DEER FENCING

Posts or stobs, 7′ 0″ long (1′ 6″ buried) by 5″ diameter, the ends charred or creosoted, and pointed, every 6 yards.

Sawn droppers, 4′ 0″ long x 2″ x 1″ between each stob.



Straining posts, 7′ 0″ long by 6″ diameter, or creosoted larch posts 5″ square, every 80 yards with stays or struts.

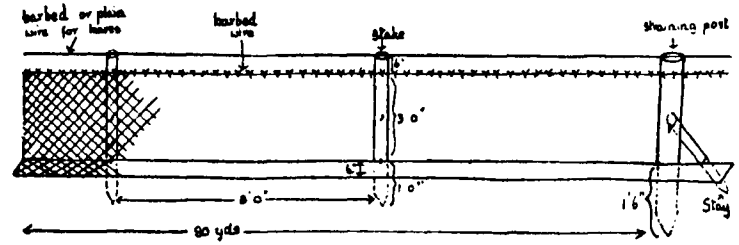
Strands 1-6 are No. 8, 9 or 10 B.W.G.; the top strand is No. 14 B.W.G.

When combined with rabbit netting strand 4 will be of barbed instead of plain galvanized wire, and numbers 1 and 3 will not be required. This type of fence will exclude horses, cattle and sheep.

COMBINED RABBIT AND HARE FENCING

Stakes (4′ 6″ x 3″ thinnings) with pointed and charred or creosoted ends every 8 feet.

Straining posts (5′ 0″ x 5″ thinnings, or sawn *and creosoted* posts 4″ square) every 80 yards, with stays or struts on the *inside* of the fence.



6″ of netting turned down along the ground, and kept in position with sods of turf at every yard.

It is now generally considered unnecessary and inhumane to have barbed wire for the top strand, as a protection against hares, though it should be used to suspend the netting.

Small staples are used to fix the wire to the stakes and posts. In practice the extra expense does not justify the use of 4′ 0″ width of netting, so that by turning the top 6″ over at an angle of 45° towards the outside, the rodents are prevented from climbing over the top (see under rabbits) except around nurseries. Hedgehogs easily climb up wire-netting, and stoats and weasels are small enough to get through the mesh.

Unfortunately space does not permit mention being made of the various ways of trapping and snaring hares, rabbits, squirrels, crows, sparrow-hawks, and other 'vermin.' The best methods and the cost of the most efficient and up-to-date traps are given in an excellent little book, entitled "Traps and Trapping" (second edition) obtainable from Messrs. Henry Lane Limited, Eagle Works, Wednesfield, Wolverhampton.

A mass of information is also given in works by Abbey (1) and Carnegie (9). For the most effective means of destroying squirrels see under (2); to which may be added the fact that fungi, especially the white agarics (*Boletus borinus*, *Amanita rubescens*, *Russula heterophylla*) are the best baits for traps.

Useful nursery traps for mice and voles are given under (1), and it will be found that powdered aniseed exerts a great attraction for these rodents.

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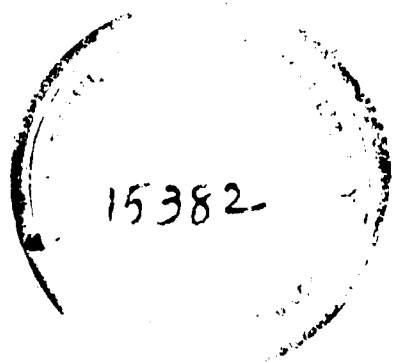

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