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Kime, R. D.

A STUDY OF TWO BIRD FLEAS, CERATOPHYLLUS GALLINAE (SCHRANK) AND DASYPSYLLUS GALLINULAE (DALE), IN THE NESTS OF HOLE - NESTING BIRDS

By R.D.Kime

(University College)

Being a thesis presented for the Degree of Master of Science.

A STUDY OF TWO BIRD FLEAS, CERATOPHYLLUS GALLINAE (SCHRANK) AND DASYPSYLLUS GALLINULAE (DALE), IN THE NESTS OF HOLE-NESTING BIRDS.

Birds' nests were taken from nest-boxes in Hamsterley State Forest, Co. Durham, to discover what species of fleas occurred in them and if possible to determine the factors responsible for the relative numbers of each species found. 133 nests were collected at intervals after the 1954, 1955 and 1960 breeding seasons and these contained 23,171 fleas, 15,373 _Ceratophyllus gallinae_ and 7798 _Dasypsyllus gallinulae_.

Both flea species were found in some of the nests of redstarts, pied flycatchers, tree-creepers, great tits, blue tits and coal tits; usually both were present.

C. gallinae was rare or absent from the nests of redstarts in 1954 and 1955, and rare in all nests during the winter of early 1955. No redstart's nest contained over 100 _C. gallinae_, which is not as well suited to redstarts' nests as _D. gallinulae_.

There was evidence to show that many _C. gallinae_ dispersed from the nests in the winter, the means fell dramatically.

D. gallinulae was well established in the study area and survived in the presence of _C. gallinae_ over a period of seven years, it cannot be regarded as of casual occurrence in nest-boxes.

The fleas fared best where the bird hosts bred successfully themselves.

Populations were affected by the weather and by the seasonal behaviour of _C. gallinae_, and perhaps by different behaviour of the sexes. The latter was not conspicuous in the annual emigration of _C. gallinae_.

There were significantly more females than males, the ratio fluctuating. Humidity may be the most important factor producing this fluctuation, at present it cannot be precisely explained.

The evidence did not show that the aspect of the nest was important in determining the flea population.

INTRODUCTION.

Bird flea studies.

A considerable proportion of the work done on bird fleas has been done in Great Britain. In the early part of this century much was done by the Hon. N.C.Rothschild,culminating in " A synopsis of the British Siphonaptera " in 1915,whilst Waterston was working in Scotland. Following this,Jordan worked in a number of countries and discovered additional species. Some of the important papers written by these gentlemen are included in the bibliography,as are the later classifications of fleas by Wagner (1939),Hopkins and Rothschild,M. (1952) and Smit (1954) that they helped to make possible.

Ecological studies on fleas began with rat fleas because of their medical importance; Bacot produced an important paper in 1914 and further publications included those of Buxton (1932-8), Ioff (1941) and Cole (1945). Ecological studies have been extended to bird fleas,largely in Scotland and England,and these are detailed in the work of this thesis.

There are relatively few species of bird fleas,only 15 having so far been recorded in Great Britain out of 55 reported in the world. It is believed that the supposed change from mammalian to avian hosts involves difficult changes of environment; perhaps the most serious of these is the lower humidity of birds' nests, except in some hole-nesting birds or those using wet material in their nests. Colonization of a new host may also demand a new behaviour pattern,particularly if the flea can breed only at the time that its host is nesting.

There is geographical and anatomical evidence of the descent of bird fleas from mammal fleas,and bird fleas may be host or habitat specific. Ceratophyllus styx Rothschild has only been recorded on the sand martin, *Riparia riparia* (L.). The martin fleas are regarded as host specific, though some straggling does occur. Other fleas demonstrate what is known as host preference, being found more frequently in association with certain bird families, for instance *Ceratophyllus garei* Rothschild is associated with ducks and geese but is also found in other wet nests on the ground. Therefore the association between flea and host may well be one of habitat, "host preference" being an accident of the bird's habitat coinciding with that of the flea. On the other hand only some birds may provide a suitable nest for the flea. The species of bird may be less important as a source of food than as a biotic factor in the environment. The fleas showing no apparent host preference, such as *Ceratophyllus gallinae* and *Dasypsyllus gallinulae*, are surely limited in distribution by ecological factors, the precise nature of which remains to be discovered.

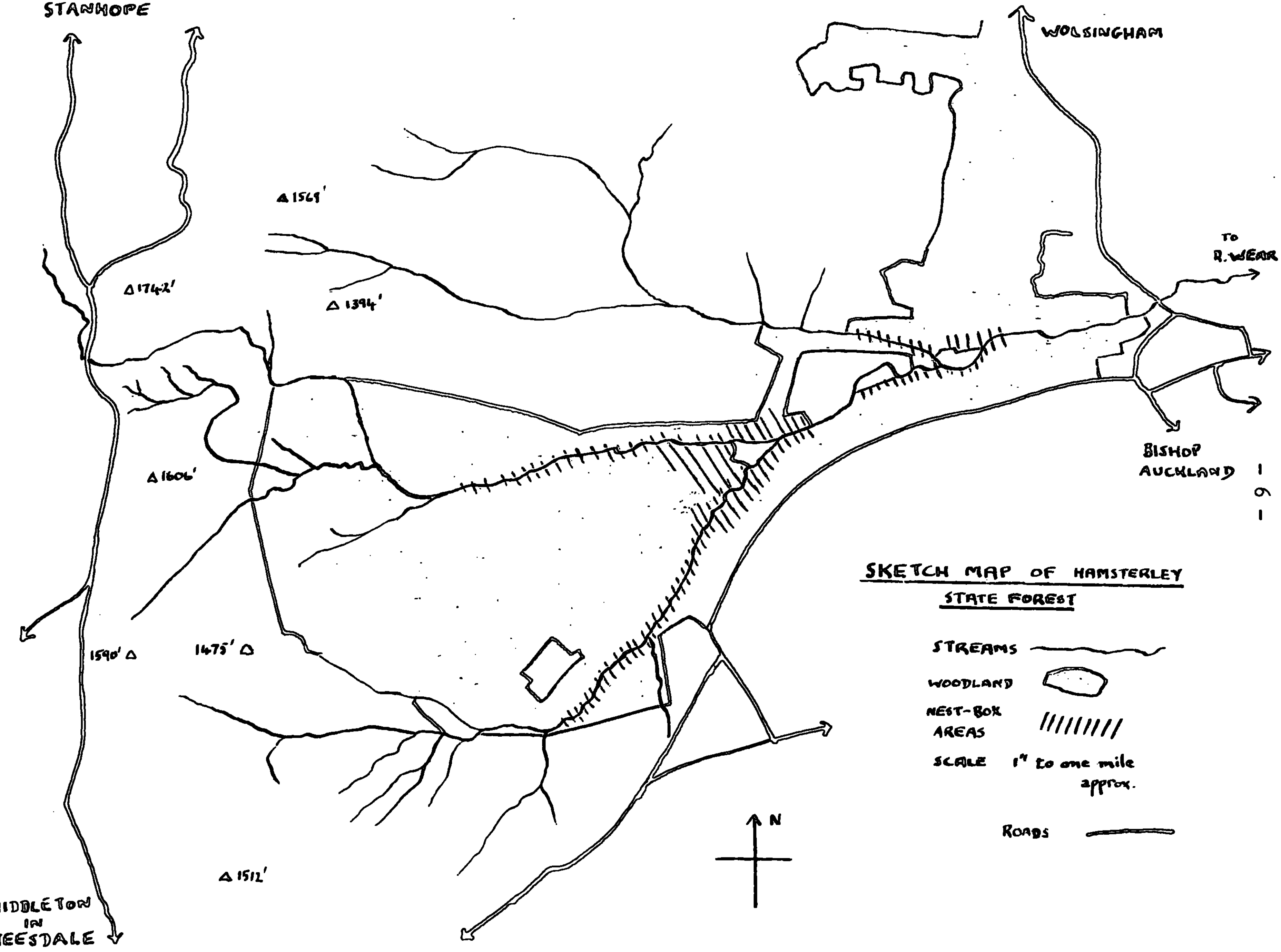
Introduction to the work contained in this thesis.

Two flea species, Ceratophyllus gallinae (Schrank) and Dasypsyllus gallinulae (Dale), occur commonly in the nests of hole-nesting birds. Rothschild and Clay (1952) point out that neither species is markedly host specific, but that this indifference may be more apparent than real. They cite the fact that C.gallinae has not been recorded from the Anseriformes or the Charadriiformes, and also that while both fleas have been found in nests of the pheasant (Phasianus colchicus, L.) neither has been recorded from nests of the partridge (Perdix perdix (L.)). Nevertheless C.gallinae has been recorded from 65 bird hosts and D.gallinulae from 59 bird hosts. While it is not known what makes some birds or their nests unattractive to fleas - at least not in exact terms - attempts have been made to account for their distribution by studies on their habitat preferences. Smit (1952) has suggested that the nature of the nest site, and especially the humidity requirements of the larvae may restrict the distribution of Orneacus waterstoni (Jordan) and Frontopsylla laetus What. (Smit (1957) names these fleas Callopsylla (Orneacus) waterstoni (Jordan) and Frontopsylla (Orfrontia) laeta (Jordan and Rothschild)). Subsequently, Dunnet and Allan (1955) have shown that these two species are found in nests of house martins (Delichon urbica (L.)) in coastal cliff sites in Scotland but do not colonize inland nests of the same host. This important work prompted an investigation of nests likely to contain Ceratophyllus gallinae and Dasypsyllus gallinulae to discover what possible factors might lead to their success or failure, and to discover how far their habitats overlapped and which was the more successful if so. It was also intended to discover whether the fleas harmed their hosts to any important degree, or indeed whether the fleas relied on the birds for the right microhabitat and only prospered when the young birds were in the nest long enough to fledge successfully.

Nests from nest-boxes were examined for fleas, and the study relates to nests collected after the 1954, 1955 and 1960 breeding seasons. Nests of six species of birds, the redstart (*Phoenicurus phoenicurus* (L.)), pied flycatcher (*Muscicapa hypoleuca* (Pall.)), tree-creeper (*Certhia familiaris* L.), great tit (*Parus major* L.), blue tit (*Parus caeruleus* L.) and the coal tit (Parus ater L.), were examined for fleas to establish whether there was any difference in the species composition according to the host species. Data were also collected on the numerical fluctuations of the two flea species, both annually and seasonally; this was considered important because the behaviour of a bird flea must have an annual pattern to coincide with the breeding cycle of the host. Facts about the nests were also recorded so that as many factors as possible could be examined independently in an endeavour to account for any significant variations in the flea faunas of the nests, and as many nests as possible were collected in order that these possible variations could be statistically valid. It was decided to record the numbers of male and female fleas of each species in order to work out statistics on sex-ratio because Rothschild and Clay (1952) had indicated a predominance of females in nests, and Cole (1945) had shown fluctuations associated with temperature in the sex-ratio of fleas found on rats. Finally, it was deemed necessary to record the nature of the woodland surrounding each nest-box, as well as its site.

SITE OF WORK.

The work described in this thesis was carried out in Hamsterley State Forest,Co.Durham,which lies west of Bishop Auckland on the slopes of the Pennines,its focal point,the Grove (O.S.map ref. 40675299 - Teesdale sheet),being nine miles away. The forest extends five miles from east to west and three miles from north to south,although it is very irregular in shape (see map,p.6,overleaf). The nest-boxes are placed on trees close to,or within a few hundred yards of the principal streams of the area; the areas they occupy are shown on the map. They are mostly situated in patches of deciduous woodland remaining from the days before the coniferous plantations were set,extending from just below 500' to just over 800' above sea level. The patches of deciduous woodland are,however, extremely narrow and confined to the bottoms of the narrow valleys occupied by the streams. Thus the area worked consisted of deciduous, mixed or coniferous woodland,in any case surrounded by coniferous plantations,and in turn surrounded by moorland (mostly) or upland pasture.



STANHOPE
WOLSINGHAM
TO R. WEAR
BISHOP AUCKLAND
MIDDLETON IN TEESDALE
Δ 1569'
Δ 1742'
Δ 1394'
Δ 1606'
1590' Δ
1475' Δ
Δ 1512'
N
SKETCH MAP OF HAMSTERLEY STATE FOREST
STREAMS
WOODLAND
NEST-BOX AREAS
SCALE 1" to one mile approx.
ROADS

NEST COLLECTION

Since the flea faunas of the nests were to be compared at different seasons of the year it was necessary to plan the nest collection so that on each visit nests were taken from each kind of woodland,from each kind of bird and from different parts of the forest. The number of known nests of each bird species was relatively few,so it was decided to largely rely on collecting alternate nests throughout the forest at two main seasons,late summer (or early autumn) and winter. This would give two comparable sets of figures, sufficiently large to have meaning. As it was,the figures obtained in 1954 and 1955 had to be supported by two further large collections which were made in 1960 and 1961. It was not of course possible to have directly comparable figures since the number of nests of each bird species varied from place to place and from year to year,and only very approximately could half the nests be removed in autumn and half in winter. When as a result of the 1954 and 1955 figures it became probable that C.gallinae was both rare in redstart nests always and rare in all nests in winter it became necessary to collect all the 1960 redstart nests in late summer to establish the former.

As each nest was removed not only were the habitat,bird species and site recorded,but also the height of the nest above the ground and its condition (i.e. whether particularly wet,dry or decomposed,and additional notes of,for instance,deserted eggs.) After George's paper was published in 1959 the direction that the nest-hole faced was recorded too,in order to repeat his experiment with far more nests. Unfortunately it was not possible to include the results of previous years in this respect as several nest-boxes are removed for repairs or blown down in the winter and are not always replaced in exactly the same position. Normally old nests were removed from the boxes at the time of the winter check and discarded nearby so that few,if any,of the flea pupae remained in the boxes.

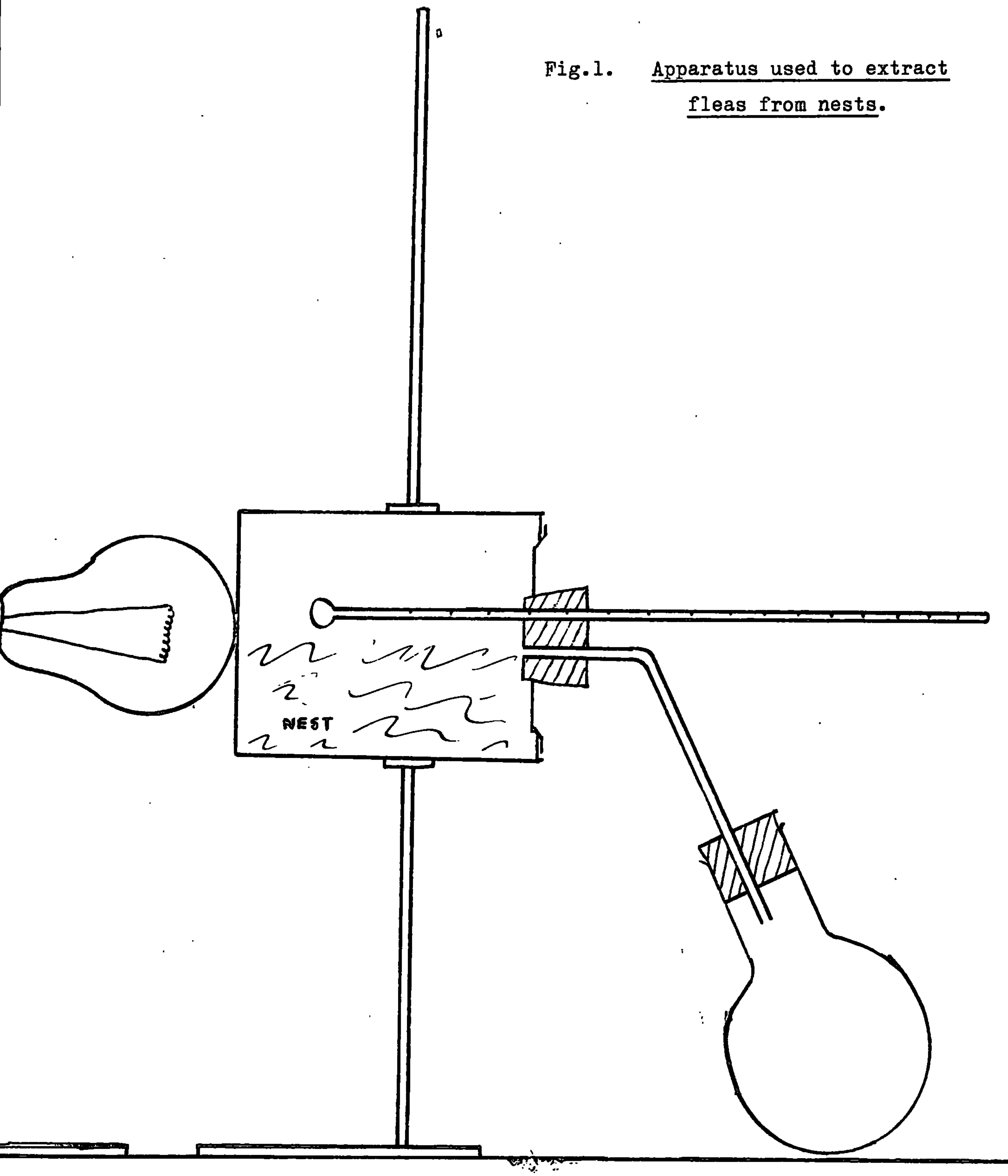
TRANSPORT AND SORTING OF NESTS.

The first nests to be collected were placed in tins and some of the fleas escaped despite sealing with sellotape. Thereafter the nests recorded for 1954 and 1955 were collected in treacle tins with very close-fitting lids and no escapes occurred. In 1960 and 1961 polythene bags closed with elastic bands wound round many times proved less bulky and equally efficient,although they were quickly placed in honey jars after the expedition in case any animal should eat its way out.

As each nest was placed in its container a piece of card or stiff paper was included with the code number of the nest-box written on it in biro ink which was sufficiently permanent to last until the nest was sorted. This code number corresponded to that in the book of records made at the same time,and previously referred to.

At first the tins were opened in a flea-proof box,white inside,with a sloping glass roof and back,and fitted with sleeves, and the fleas were hand sorted with forceps. Later 1955 nests were allowed to stand in the tins,which were fitted with new lids so that a glass tube and thermometer led out (see fig.1,overleaf). The tins were placed on their sides with the glass tube leading sharply downhill into a closed glass flask. When the tins were heated to about 40°C with light bulbs the fleas came off rapidly into the flasks. On being subsequently hand sorted very few of the nests so treated were found to contain fleas,the few that were found were added to the appropriate collection. The tins were agitated before being left - it was noticed during hand sorting how many fully metamorphosed fleas emerged from disturbed pupae,in which they are known to lie quiescent (Rothschild and Clay,1952).

Fig.1. Apparatus used to extract fleas from nests.



The nests collected in 1960 and 1961 were sorted at home where it was not practicable to use large quantities of apparatus; for this reason they were hand sorted in a polythene bowl which was deep enough to prevent the fleas jumping out,any crawling up the sides being the more easily picked up with forceps.

Forceps wetted with alcohol were found to be the most useful tool for picking up fleas. Normally the fleas adhered to the wetted forceps and it was not necessary to squeeze them at all. At the same time some fleas could be much more easily extricated from nest debris and corners by holding them lightly with the forceps, and,provided that sufficient care was taken,the fleas picked up in this manner were not damaged,certainly not enough to render identification difficult.

The fleas from any one nest were all placed in a glass tube of 70% alcohol for storage,with the nest code number inside written in pencil on a piece of paper and outside written in ink on the cork.

IDENTIFICATION OF FLEAS.

The fleas were cleared for identification one tube at a time by boiling them for several minutes in 10% potassium hydroxide solution or by leaving them in a similar solution overnight. They were then filtered and returned to their tubes in 70% alcohol.

Each tube of fleas was placed in turn on the left hand side of a microscope,and some of the fleas were taken out with forceps and placed on a microscope slide. They were then arranged in a row and looked at one at a time by pushing the slide from left to right. Each flea was checked for species and sex and marked in the appropriate column. This was repeated until the nest was finished. Each batch was recorded separately and the total checked with the number of fleas on the slide. When each batch was finished it was placed in a second glass tube on the right hand side of the microscope.

The fleas were identified from Danmarks Fauna,Lopper, by Smit (1954).

NUMBERS OF FLEAS IN THE NESTS OF SIX BIRD SPECIES.

The numbers of the two flea species in the nests are grouped in Table 1 according to the season in which they were found and under the bird host concerned. These figures were analysed for possible host specificity and marked seasonal or annual variation. Nests of the 1960 breeding season were taken because the evidence from 1954 and 1955 was insufficient, and because it was necessary to distinguish between results that might be attributable to host preference on the one hand and to seasonal effects on the other. Thus, when evidence of host preference was established or not disproved, the affected or possibly affected nests were not used in analyses of other factors.

In order that the evidence could be assessed arithmetic and geometric means were worked out for each group of nests. The arithmetic mean, ($\bar{x}$), was not entirely satisfactory because a few nests contained very high numbers of fleas and gave rise to means much higher than the number of fleas in the "average" nest. The geometric mean was therefore worked out; whilst it did not allow the vast numbers of fleas in some nests to unduly weight the mean it had its limitations with these data because many nests contained no fleas. It was therefore necessary to add one to the number of fleas n/ in each nest to avoid multiplying by nothing. Where ~~x~~ = number of fleas per nest the geometric mean for a group of x nests was worked out as follows:

The logarithms of n + 1 were written down (for each of the x nests) and added together. The total was divided by x and the anti-logarithm found. This was taken as the geometric mean (G).

The geometric mean, like the arithmetic mean, gives poor results with small groups of nests and, using this formula, gives a mean of unity where the nests have no fleas. This inaccuracy with low numbers becomes insignificant with high numbers. Making allowances for these weaknesses, the means were very valuable in assessing the flea distribution (a) according to the host species, and, (b) seasonally and annually.

Table 1 Numbers of fleas found in the nests of six bird species at Hamsterley, Co. Durham.

Date collected	Number of nests	*Ceratophyllus gallinae*			*Dasypsyllus gallinulae*			Percentage *C. gallinae*
		Total	Means		Total	Means		
			$\bar{x}$	G		$\bar{x}$	G	
REDSTART								
Oct., 1954.	8	2	0	1	518	65	7	0.4
Feb./Mar., 1955.	3	26	9	3	246	82	6	9.6
Aug., 1955.	5	0	0	1	91	18	2	0.0
Sept., 1960.	8	299	37	13	474	59	29	38.7
PIED FLYCATCHER								
Oct., 1954.	5	371	74	18	669	134	23	35.7
Feb./Mar., 1955	5	11	2	2	584	117	12	1.8
April, 1955.	3	45	15	4	81	27	4	35.7
Aug., 1955.	3	400	133	58	62	21	20	86.6
Sept., 1960.	14	1560	111	45	475	34	8	76.7
Jan., 1961.	9	733	81	20	207	23	11	78.0
TREE-CREEPER								
Oct., 1954.	1	397	-	-	57	-	-	87.4
Feb., 1955.	2	0	0	1	41	21	6	0.0
Sept., 1960.	2	12	6	5	0	0	1	100.0

continued..........

Table 1, continued

Date collected	Number of nests	*Ceratophyllus gallinae* Total	Means $\bar{x}$	Means G	*Dasypsyllus gallinulae* Total	Means $\bar{x}$	Means G	Percentage *C. gallinae*
GREAT TIT								
Oct.,1954.	4	693	173	39	172	43	12	80.1
Feb./Mar.,1955.	8	59	7	3	1017	127	15	5.5
April,1955.	2	120	60	11	40	20	6	75.0
Aug.,1955.	6	180	30	6	5	1	2	97.3
Sept.,1960.	8	2487	311	66	143	18	7	94.6
Jan.,1961.	4	190	48	24	95	24	10	66.7
BLUE TIT								
Oct.,1954.	3	653	218	35	84	28	11	88.6
Feb./Mar.,1955.	8	25	3	2	784	98	6	3.1
Sept.,1960.	5	1302	260	98	224	45	20	85.3
Jan.,1961.	2	720	360	27	226	113	15	76.1
COAL TIT								
Oct.,1954.	1	48	-	-	5	-	-	90.6
Feb./Mar.,1955.	2	3	2	2	911	456	457	0.3
Aug.,1955.	3	0	0	1	292	97	22	0.0
Sept.,1960.	8	5027	628	66	239	30	11	95.5
Jan.,1961.	1	10	-	-	56	-	-	15.2

Differences in flea distribution in the nests of the host species.

There is a striking difference in the composition of the flea populations in the nests of the redstart as compared with the other five bird species. This is evident in Table 1,and revealed clearly in table 2,below,which summarizes Table 1.

Table 2 Total and mean numbers of fleas per nest of each bird host,regardless of year or season.

	Number of nests	Ceratophyllus gallinae Total	Means $\bar{x}$	Means G	Dasypsyllus gallinulae Total	Means $\bar{x}$	Means G	% C. gallinae	Means: fleas /nest $\bar{x}$	G
Redstart	24	327	14	11	1329	55	23	20	69	34
Pied flycatcher	39	3120	80	50	2078	53	40	60	133	90
Tree-creeper	5	409	82	4	98	20	3	81	101	7
Great tit	32	3729	117	37	1472	46	28	72	163	65
Blue tit	18	2700	150	19	1318	73	19	67	223	37
Coal tit	15	5088	339	18	1503	100	20	77	439	38
Totals and overall means	133	15373	116	11	7798	59	10	66	174	21

Only 20 per cent of the fleas in the nests of the redstart were C.gallinae while between 60 and 81 per cent of the fleas in the nests of the three tits,the pied flycatcher and the tree-creeper were of this species. At the same time the populations of D.gallinulae in redstarts' nests are revealed as being much the same as in the nests of the other birds.

Table 3 shows that there were six redstart nests which contained only _Dasypsyllus gallinulae_ but none of the nests contained only _Ceratophyllus gallinae_; this is in marked contrast to the other bird species, all of which had at least one nest containing _C.gallinae_ only and fewer nests containing no fleas than the redstart.

Table 3 Distribution of fleas in the nests of six bird species.

	No. of nests containing both fleas	No. of nests containing _C.gallinae_ only	No. of nests containing _D.gallinulae_ only	No. of nests containing no fleas
Redstart	8	0	6	10
Pied flycatcher	27	2	2	8
Tree-creeper	1	2	1	1
Great tit	18	5	1	8
Blue tit	8	1	3	6
Coal tit	9	1	5	0

Annual and seasonal fluctuations in flea populations.

The maximum numbers of fleas of each species found in the nests of each bird host are shown in Table 4,below,together with the year in which this maximum occurred. This indicates that 1954 was a relatively favourable year for *Dasypsyllus gallinulae*,whereas the 1960 breeding season favoured *Ceratophyllus gallinae*. A similar conclusion can be reached from the more extensive data in Table 5, overleaf. Yet,despite this marked domination by *C.gallinae* in 1960 no redstart nest contained over a hundred specimens of this flea.

It is difficult to decide whether 1954 and 1960 were importantly different from the climatic point of view. 1955 and especially 1959 were dry years. As far as can be judged,the fleas did not have a particularly prosperous year in 1955,and if 1953 and 1959 had an effect on the populations of the following years,it might be that 1959 had an adverse effect on *Dasypsyllus gallinulae*.

Table 4 Maximum number of each flea species found in a nest of each host,with the year in which this number was found (winter results being referred to the previous year).

	Maximum number of *C.gallinae* found.	Maximum number of *D.gallinulae* found.
Redstart	94 (1960)	323 (1954)
Pied flycatcher	385 (1960)	398 (1954)
Tree-creeper	397 (1954)	57 (1954)
Great tit	674 (1960)	408 (1954)
Blue tit	720 (1960)	425 (1954)
Coal tit	2945 (1960)	474 (1954)

Table 5 Numbers of fleas collected in different seasons and years from the nests of pied flycatchers, great tits, blue tits and coal tits, where there is no apparent host preference. (The redstart results favour *D. gallinulae* and the inconclusive results from the tree-creeper might favour *C. gallinae*.)

Season of nest collection and the year in which the nest was built.	*Ceratophyllus gallinae*			*Dasypsyllus gallinulae*			% *C. gallinae*
	Total	Means $\bar{x}$	G	Total	Means $\bar{x}$	G	
Oct.,1954. (1954)	1765	136	29	930	72	15	66
Feb./Mar.,1955. (1954)	98	4	2	2898	126	14	3
April,1955. (1954)	165	33	6	121	24	5	58
Aug.,1955. (1955)	580	48	7	359	30	6	62
Sept.,1960. (1960)	8069	231	60	943	27	10	90
Jan.,1961. (1960)	1653	103	21	584	36	13	74

Table 5 shows that there were pronounced annual variations in the numbers of fleas in the nests. In the summer of 1954 there were averages of 136 C.gallinae and 72 D.gallinulae per nest,but in the summer of 1955 the respective numbers had dropped to 48 and 30 per nest,a decrease of 65% in the case of C.gallinae and 58% for D.gallinulae. In 1960,the average number of C.gallinae per nest had increased by more than four times on the 1955 number,whereas the average number of D.gallinulae was almost the same. Although the geometric means were naturally lower than these arithmetic averages the percentage fluctuations were yet greater. There was some evidence from the geometric means to show that Dasypsyllus gallinulae may have been more common in 1960 than in 1955. Otherwise the geometric means entirely supported the arithmetic results.

It should be remembered that the summer of 1955 was a dry one (there were record sunshine figures in June at Durham) and the humidity characteristics of the nests were quite possibly different in that year. It seems possible that the marked decrease which occurred in the numbers of fleas present in the nests in 1955 was related to the relatively dry condition of the nests. 1959 was also very dry,and for a longer period,and if the numbers of fleas were low in that year this was certainly not reflected in the 1960 numbers of C.gallinae.

It was most noticeable in 1955 that the fleas were mostly well below average size. Measurements were taken of batches of fleas and compared with those taken from batches of 1954 fleas. These results were discarded as mathematical evidence however on the grounds that they were open to too much criticism,since the fleas had been in alcohol or boiled in potassium hydroxide solution for varying lengths of time. Nevertheless the possibility must remain that there is a connection between the small size of fleas and low relative humidity. The larvae require adequately high humidities

(Smit,1952) and perhaps the low humidity results in an abbreviated larval life resulting in undersized adults.

There were far fewer C.gallinae in the nests during the winter of 1954-55 than at any other time; about three per cent of the number present in the previous October. Further nests were collected during 1960 and 1961 to see whether this decrease was a normal occurrence. Between September,1960,and January,1961,the numbers of C.gallinae dropped from an average of 231 to 103 per nest. The winter sample in 1955 was taken in February and March, and it is possible that a larger decrease would have been found in 1961 had the winter sample been taken later. As it was there was a decrease of 55% in the arithmetic mean and 65% in the geometric mean of the C.gallinae populations between September,1960,and January,1961. It would appear that there is a considerable reduction in the numbers of C.gallinae remaining in nests over the winter. No such reduction occurred in D.gallinulae numbers (if anything,the means tended to increase) and it seems unlikely that the decrease in C.gallinae can be accounted for by differential predation. It is more likely that C.gallinae emigrates,the adults leaving the pupal case and becoming active sometime between the autumn and the early spring. Fleas were noticed walking on the inside and outside of undisturbed nest-boxes in January,1961,even though it was snowing at the time.

THE DISTRIBUTION OF FLEAS IN THE STUDY AREA.

Both Ceratophyllus gallinae and Dasypsyllus gallinulae were found throughout the study area and it was not possible to make any micro-geographical or vegetational boundaries that coincided with a change in the flea population. Flea abundance did not vary according to site or tree species in any obvious way. However, in Hamsterley Forest no nest-box was more than a few hundred yards from mixed woodland and it would be unwise to assume that the result would be the same in really large stands of single-species woodland without pursuing the matter further.

THE EFFECT OF THE HEIGHT OF THE NEST ABOVE THE GROUND.

It seemed unlikely that the height of the nest above the ground would be a significant factor in determining the flea distribution within the range of heights found in Hamsterley Forest nest-boxes; most of the nests were between six and nine feet from the ground. Just in case this was a significant factor a table was drawn up ignoring all other factors; in the first instance this comprised the results from 1954 and 1955 (Table 6, below).

Table 6 Numbers of *Ceratophyllus gallinae* and *Dasypsyllus gallinulae* found at different heights above the ground between September, 1954, and August, 1955.

Height of nest	Number of nests	*Ceratophyllus gallinae*		*Dasypsyllus gallinulae*	
		Total	Mean	Total	Mean
4'6"–5'6"	1	96	96	112	112
5'6"–6'6"	6	1082	180	645	108
6'6"–7'6"	18	1194	66	3179	177
7'6"–8'6"	5	11	2	1070	214
8'6"–9'6"	1	2	2	138	138
9'6"–10'6"	3	71	24	155	52
11'6"–12'6"	1	0	0	18	18

The results in Table 6 might have been of some significance and were subjected to the Chi-square test. On the Null Hypothesis the number of C.gallinae found below a height of 7'6" exceeds expectation,whilst at heights above 7'6" the number falls below that expected. However,the standard error of the means is so great as to invalidate the test. Later in this thesis this point is discussed at length (p.29ff). As it is,another table,Table 7,was drawn up from the results of 1960 and 1961; this demonstrates that high populations of C.gallinae can certainly be found above 7'6".

Table 7 Numbers of fleas found at different heights above the ground in 1960 and 1961.

Height of nest	Number of nests	Ceratophyllus gallinae		Dasypsyllus gallinulae	
		Total	Mean	Total	Mean
5'6"-6'6"	5	1147	229	198	40
6'6"-7'6"	20	2133	107	687	34
7'6"-8'6"	29	7605	262	870	30
8'6"-9'6"	6	1440	240	361	60

The results in Table 7 indicated no significant difference attributable to the limited range of the heights of the nests above the ground,and precluded the possibility that the different flea populations of redstarts' nests might be merely an accident of the height they happened to be above the ground.

Table 8 shows the data from the most redstart nests to be collected at any one time,in September,1960.

Table 8 Fleas found in redstarts' nests in September,1960.

height of nest	Number of nests	*Ceratophyllus gallinae*		*Dasypsyllus gallinulae*	
		Total	Mean	Total	Mean
5'6"-6'6"	1	15	15	21	21
6'6"-7'6"	4	61	15	80	20
7'6"-8'6"	2	129	65	132	66
8'6"-9'6"	1	94	94	241	241

Unfortunately the results were too few to be significant as means obtained from one or two nests are totally unreliable. It was not possible to obtain any useful results by dividing Table 7 up into separate host species.

Since Table 7 was drawn up to obtain an unprejudiced view of the effect of height,allowing for the possibility that the low numbers of Ceratophyllus gallinae in redstarts' nests might be attributable to this factor rather than to host specificity,and since host specificity was not disproved,it became necessary to redraw Table 7 omitting the redstart results. This produced Table 9, which is still inconclusive. The only figures worth testing statistically are those of nests between 6'6"-7'6" and 7'6"-8'6". The dividing line is arbitrary and the range of heights too narrow here to avoid experimental error; the floor of the forest is often steeply sloping and uneven. Consequently no calculations were made. The tendency of Dasypsyllus gallinulae to decrease as the nest becomes higher is not supported by the data in Table 6 showing the results from 1954 and 1955. The conclusion is that height cannot be proved important in this particular study.

Table 9 As Table7,but omitting the redstart results.

Height of nest	Number of nests	Ceratophyllus gallinae		Dasypsyllus gallinulae	
		Total	Mean	Total	Mean
5'6"-6'6"	4	1132	283	177	44
6'6"-7'6"	16	2072	130	607	38
7'6"-8'6"	27	7476	277	738	27
8'6"-9'6"	5	1346	269	120	24

THE HUMIDITY OF THE NESTS.

Unfortunately it was not possible to make a detailed investigation of the humidity of the nests at the most important period of the breeding season. As the birds were being encouraged and protected by the Forestry Commission it was out of the question to interfere with enough nests to give a satisfactory result. When each nest was collected it was classified as wet,damp or dry. Most of the nests were damp,only those dry enough to produce dust or wet enough to squeeze water from were classified as dry or wet respectively. In the appendix at the end of this thesis there is a complete list of all the nests collected,grouped under bird hosts, showing their condition at the time of collection. In the summer of 1955 all the nests were dry and this has already been associated with low numbers of fleas under seasonal and annual variation of populations. Apart from this nothing significant can be ascertained.

FLEA NUMBERS AND THE BREEDING SUCCESS OF THE HOST.

Almost all of the nests collected had been used successfully by their bird occupants,fledged young having left them. In a number of cases eggs were not laid or were deserted,or dead fledglings remained. To avoid disturbing the birds too much,complete records were again forfeited,but where it is known that not all the young were fledged this information is given in Table 10,below. This information is also given in the appendix,in the full list of nests.

Table 10 Numbers of fleas in nests where breeding was known to be in part or wholly unsuccessful.

Bird sp.	Year nest constructed	Breeding details	Number of C.gallinae	Number of D.gallinulae
Redstart	1955	Deserted	0	0
Redstart	1955	Deserted	0	0
Pied flyr.	1960	1 egg deserted	0	0
Pied flyr.	1960	3 eggs deserted	0	0
Pied flyr.	1960	4 eggs deserted?	93	0
Pied flyr.	1960 '	1 egg deserted?	6	3
Pied flyr.	1960 '	4 eggs deserted	0	1
Great tit	1955	2 dead young	2	0
Great tit	1955	5 eggs left	0	0
Great tit	1960 '	Eggs destroyed	10	0
Blue tit	1954	3 eggs remained	584	20
Blue tit	1960	1 dead young	2	0
Coal tit	1955	1 egg deserted?	0	1
Coal tit	1960	Eggs and dead young left	4	1

' signifies nest collected in winter.

With two exceptions Table 10 indicates that where the birds fared badly so did the fleas. The only evidence indicating that the fleas might have seriously harmed the birds came from these two nests,and there were many nests containing more fleas where the birds bred successfully,as the appendix shows. In nearly all cases where there were large flea populations the birds had bred successfully.

THE NUMBERS OF FLEAS IN RELATION TO THE ASPECT OF NEST-BOXES.

George (1959) claimed to have shown that the direction in which the nest-hole faces is an important factor in determining the flea population. His data,however,were not sufficient to warrant such a conclusion,the examination of a much larger number of nests would be necessary before such a claim could be substantiated. George considered 19 nests collected in 1955 and 1956 in the Forest of Dean. He took an arbitrary line running from NW to SE and divided his nests into two groups,one where the nest-holes faced north and east of this line and the other where the nest-holes faced south and west of this line. The two groups are set out below:

Nests facing N and E

Number of fleas

C.gallinae	D.gallinulae
7	0
2	0
45	0
88	3
42	1
88	1
272	5

Mean fleas per nest : 46

Ratio C.gal.: D.gal. 54.4 : 1

Nests facing S and W

Number of fleas

C.gallinae	D.gallinulae
789	19
132	114
103	7
48	0
97	36
153	1
634	7
58	0
262	2
469	10
0	0
202	56
128	0
3075	252

Mean fleas per nest : 255

Ratio C.gal.:D.gal. 12.16 : 1

When George's figures are analysed they can be attributed to random sampling. Calculations proceed as follows:

Taking batches which are all alike,

1. Six individual nests facing N & E,

Number of *C.gallinae*	Deviation from mean	Square of deviation
7	-38	1444
2	-43	1849
45	0	0
88	43	1849
42	-3	9
88	43	1849
Total 272		Total 7000

Number of samples 6

Mean 45

Sample variance = $\frac{7000}{6}$ = 1167

Standard deviation = $\sqrt{1167}$ = 34.16 (s = 34.16)

One expects most of the samples to lie within the range $\bar{x} \pm 2s$

$= 45 \pm 68.3$ ie. 0 to 113.3

These samples all fall within the expected range of normal distribution.

2. Thirteen individual nests facing S & W

(for these calculations see overleaf).....

Number of C.gallinae	Deviation from mean	Square of deviation
789	552	304704
132	-105	11025
103	-134	17956
48	-189	35721
97	-140	19600
153	-84	7056
634	397	157609
58	-179	32041
262	25	625
469	232	53824
0	-237	56169
202	-35	1225
128	-109	11881
Total 3075		Total 704436

Number of samples 13

Mean 237

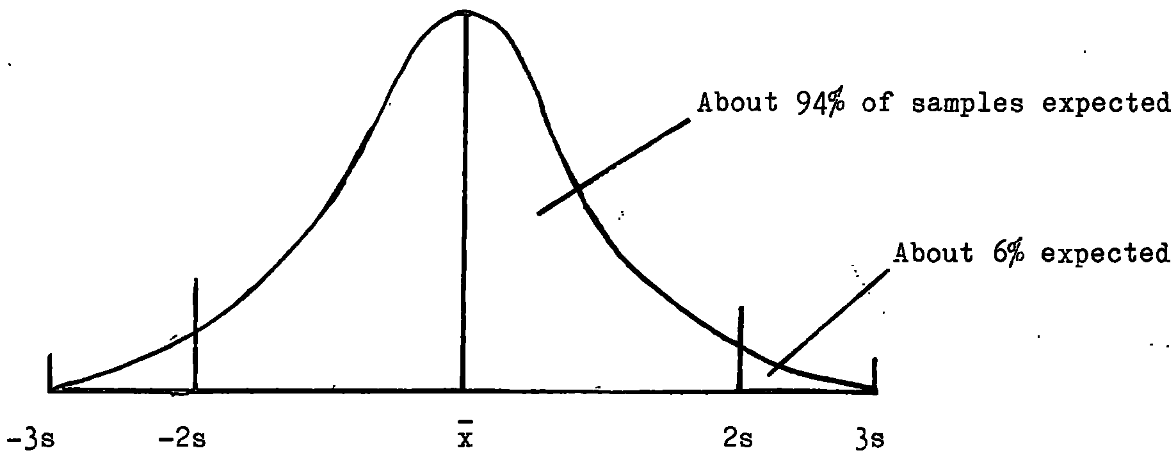
$$\text{Sample variance} = \frac{704436}{13} = 54187$$

$$\text{Standard deviation} = \sqrt{54187} = 232.8$$

$\bar{x} \pm 2s = 237 \pm 465.6$, ie. 0 to 702.6

All the samples fall within this range, except the first which falls within the range $\bar{x} + 3s$. Again this is a normal distribution. Fig.2, overleaf, shows a normal distribution curve with the number of samples expected in the range $\bar{x} \pm 2s$ and the range $\bar{x} \pm 3s$.

Fig.2. Normal distribution curve.



It is obvious that the expected range of numbers of fleas in the group of nests facing south and west is such that it embraces all the numbers of fleas in the nests facing north and east. Since there are only six nests in the group facing north and east, although each of them contains a number of fleas lower than the mean of the whole nineteen nests, there are no justifiable grounds for making a division. If the nineteen nests are regarded as belonging to a like batch and the division is not made, all the nests collected do in fact fall within one random sample. This is worked out overleaf....

Number of C.gallinae	Deviation from mean	Square of deviation
789	613	375769
132	-44	1936
103	-73	5329
48	-128	16384
97	-79	6241
153	-23	529
634	458	209764
58	-118	13924
262	86	7396
469	293	79549
0	-176	30976
202	26	676
128	-48	2304
7	-169	28561
2	-174	30276
45	-131	17161
88	-88	7744
42	-134	17956
88	-88	7744
Total 3347		Total 860219

Number of samples 19

Mean 176

Sample variance $= \frac{860219}{19} = 45275$

Standard deviation $= \sqrt{45275} = 213$

$\bar{x} \pm 2s = 176 \pm 426$, ie. 0 to 602 All but two nests in this range.

$\bar{x} \pm 3s = 176 \pm 639$, ie. 0 to 815 Includes the other two nests.

The direction of the nest-box hole was noted for 45 nests collected at Hamsterley Forest in September,1960,and the results are given in Table 11,overleaf. It is clear that George's claim that there are fewer fleas in nests with the entrance hole facing north and east cannot be substantiated since in these nests $\bar{x} = 276$ whereas in nests with the entrance hole facing south and west $\bar{x} = 267$. On the other hand the geometric mean is higher for the group facing south and west. It was decided to make further calculations.

The numbers of Ceratophyllus gallinae in the nests varied from 0 to 2945 and the numbers of Dasypsyllus gallinulae varied from 0 to 241. Calculations such as those made on George's figures once more revealed random distributions,although one nest had an exceptionally high population of C.gallinae,2945,which was more than $\bar{x} + 3s$. Very large standard deviations were obtained; standard errors of the means calculated by dividing the standard deviation by the square root of the number of samples in the batch concerned also proved very large. These figures are shown in Table 11. In all cases the standard deviations were higher than the means themselves; this was because some nests had very large populations which gave a very high figure for their deviation squared,and,at the same time, several nests had no fleas in them and deviated by as much as the mean. With such margins of error it is very difficult to calculate an "expected" population of fleas in a nest-box and for this reason the Chi-square test cannot be confidently applied. It is worth noting that whilst these results concerning the aspect of the nest-boxes can be explained by random sampling and fall within the range of a normal distribution a normal distribution curve cannot be obtained; many nests have no fleas and $\bar{x} - 2s$ is always less than nothing. There are therefore more nests at zero than anywhere else. It is obviously quite impossible to have minus numbers in this study, zero is the measure of total lack of success. Bearing all these points in mind, neither George's results nor those presented here reach a level of significance sufficient to warrant any firm conclusion.

Again, George has claimed that there are proportionally fewer D.gallinulae than C.gallinae in nest-boxes whose entrance holes face north and east. The data collected at Hamsterley support this conclusion (Table 11), there being about half as many D.gallinulae in the nests with entrances facing north and east. But graphical diagrams on a circular compass plan do not reveal any coherent distribution round an optimum compass direction. These diagrams are shown for both C.gallinae (page 36) and D.gallinulae (page 37). Once again the evidence is not good, and it cannot be established that a southerly aspect favours D.gallinulae.

Table 11 The numbers of fleas in nests according to the direction of the nest-box hole, September, 1960.

	Nest-hole facing north and east. Between NNW and SE						Nest-hole facing south and west. Between SSE and NW					
	No. of nests	No. of fleas	Means $\bar{x}$	Means G	s	$\frac{s}{\sqrt{n}}$	No. of nests	No. of fleas	Means $\bar{x}$	Means G	s	$\frac{s}{\sqrt{n}}$
C.gallinae	26	6554	252	38	569	112	19	4132	217	44	332	76
D.gallinulae	26	612	24	8	31	6	19	952	50	15	63	14

ratio D.gallinulae : C.gallinae 1 : 10.7 between NNW and SE
1 : 4.3 between SSE and NW

DIAGRAM TO SHOW THE NUMBERS OF CERATOPHYLLUS GALLINAE IN NESTS FACING IN DIFFERENT DIRECTIONS, SEPTEMBER, 1960.

THE LENGTH OF THE LINES INDICATES THE MEAN NUMBER OF FLEAS FACING IN THAT DIRECTION. 1" = 100 FLEAS.

THE WIDTH OF THE BLOCKS SHOWS THE NUMBER OF NESTS. 1" = 10 NESTS.

THE AREA OF THE BLOCKS IS THEREFORE PROPORTIONAL TO THE TOTAL NUMBER OF FLEAS.

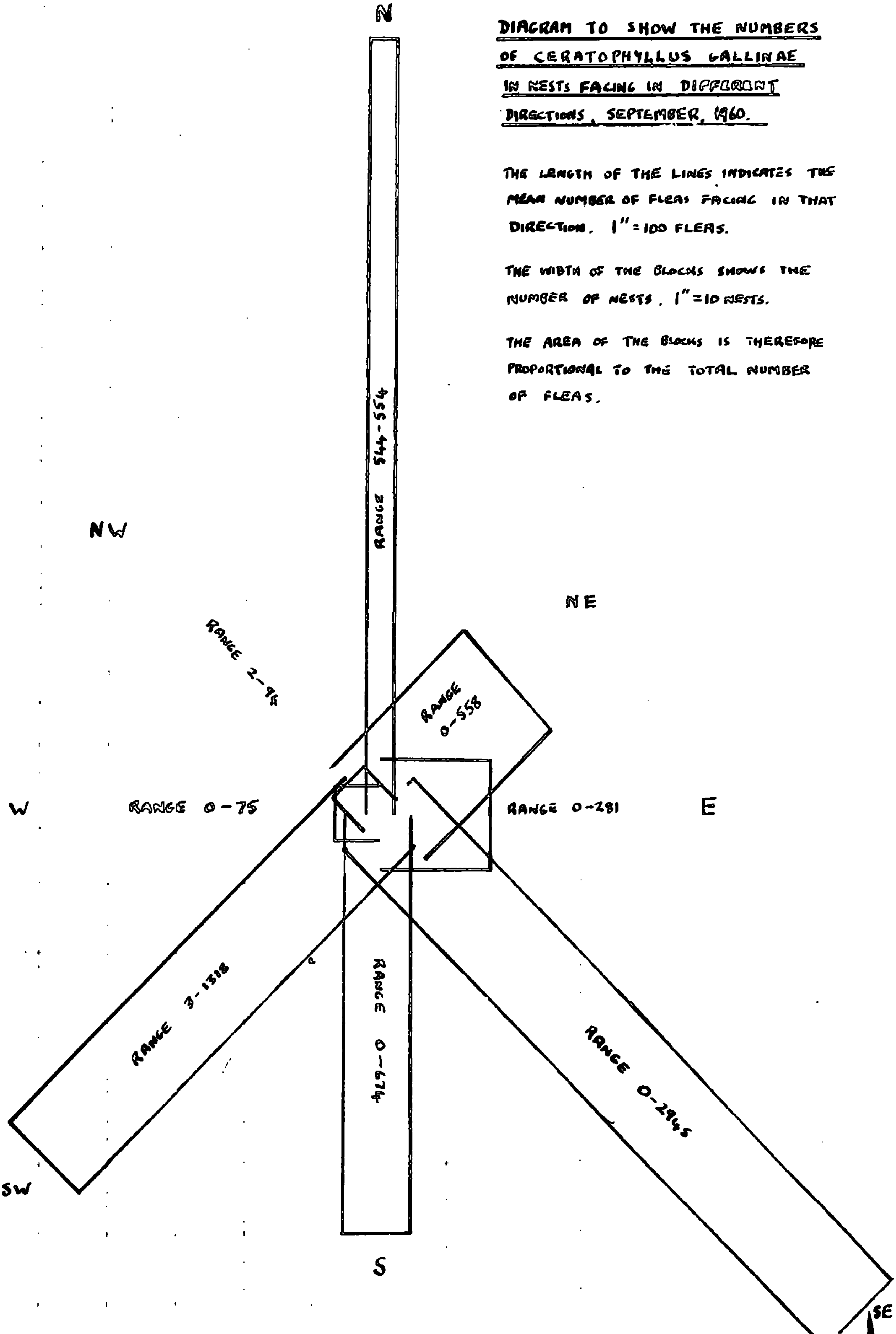
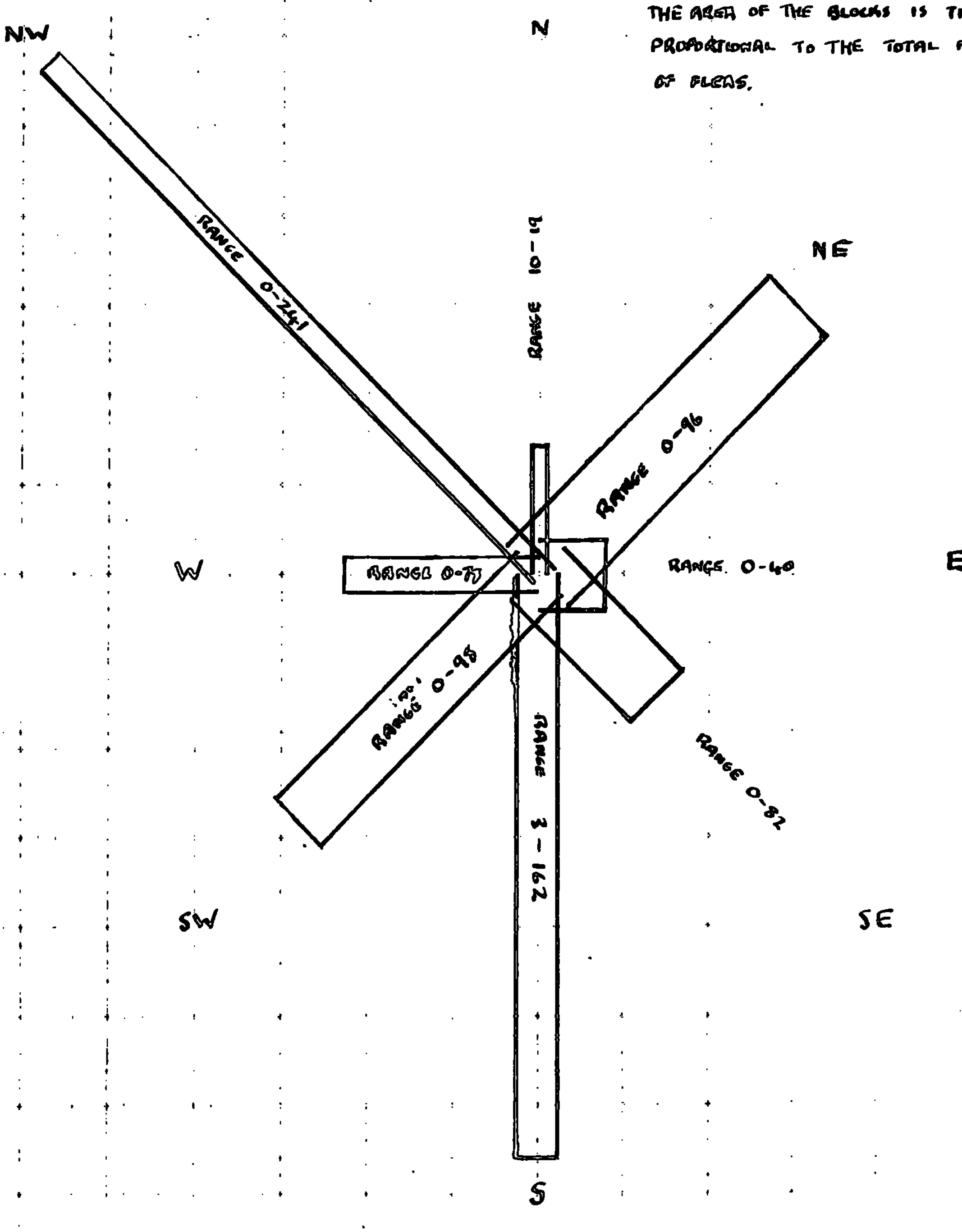


DIAGRAM TO SHOW THE NUMBERS OF DASYPSYLLUS GALLINULAE IN NESTS FACING IN DIFFERENT DIRECTIONS, SEPTEMBER, 1960.

THE LENGTH OF THE BLOCKS INDICATES THE MEAN NUMBER OF FLEAS FACING IN THAT DIRECTION. 1" = 20 FLEAS.

THE WIDTH OF THE BLOCKS SHOWS THE NUMBER OF NESTS. 1" = 20 NESTS.

THE AREA OF THE BLOCKS IS THEREFORE PROPORTIONAL TO THE TOTAL NUMBER OF FLEAS.



SEX-RATIO AND ITS SEASONAL CHANGES IN THE NEST-BOX FLEA POPULATIONS.

Table 12,below,shows that there was an excess of females in the total number of fleas collected in both species. However,the proportion of females did not remain constant throughout the study. It is interesting to note that the sex-ratio of both species appeared to alter in the same manner,both showing the highest proportion of females during the warm dry summer of 1955 when the population was low. This suggests that the environmental conditions may influence the sex-ratio of the fleas remaining in the nest-boxes.

Table 13,overleaf,shows that the sex-ratio of C.gallinae was very similar in the nests of five host species in September,1960, when the numbers were high enough to be significant. The standard errors of the percentages are given in order that their validity can be assessed.

Table 12 Numbers of male and female fleas collected.

When collected	Ceratophyllus gallinae			Dasypsyllus gallinulae		
	Males	Females	% males and standard error	Males	Females	% males & st. error
Oct.,1954.	1093	1071	50.5 ± 1.1	715	790	47.5 ± 1.3
Feb.,1955.	62	62	50.0 ± 4.5	1659	1924	46.3 ± 0.8
April,1955.	74	91	44.8 ± 3.9	31	90	25.6 ± 4.0
Aug.,1955.	199	381	34.3 ± 2.0	177	273	39.3 ± 2.4
Sept.,1960.	4377	6314	40.9 ± 0.5	640	911	41.3 ± 1.2
Jan.,1961.	745	908	45.1 ± 1.2	283	301	48.5 ± 2.1
Total	6550	8827	42.6 ± 0.4	3505	4289	45.0 ± 0.6

Table 13 Percentages of male <u>Ceratophyllus gallinae</u> found in the nests of five host species in September,1960.

Host species	Percentage males and standard error
Redstart	42.1 ± 2.9
Pied flycatcher	39.7 ± 1.2
Great tit	38.8 ± 0.9
Blue tit	38.4 ± 1.3
Coal tit	43.0 ± 0.7

The standard error of the percentage was calculated thus:

Say you have 40% males,then the probability of any one flea being male is .4 and of being female is .6 since the total probability must = 1.

Standard error of probability $= \sqrt{\frac{.6 \times .4}{n}}$

The standard error of the percentage must be 100 times this figure.

DISCUSSION.

There is evidence to show that Dasypsyllus gallinulae remained in the nests throughout the year,at least until the spring, when under normal conditions they might await the arrival of a bird at the old nest or conceivably emigrate to seek new hosts elsewhere. At the same time the figures clearly indicate large annual variations in the numbers of both species as well as seasonal variation attributable to winter emigration of Ceratophyllus gallinae. No other factor has been found which is of comparable importance in causing seasonal variation in the numbers of fleas. Nests were taken from the same parts of the forest in winter as in summer,and the nests were as representative of the host species as possible. An exception was made in the case of the redstart nests for 1960 for,as already stated,if the nests had been left until the winter of 1960-61 it would not have been certain whether low numbers of Ceratophyllus gallinae were indicative of host preference or winter emigration, and consequently they would have had little value. The two flea species were reasonably evenly distributed throughout the forest; there were fewer nests in pure stands of conifers but their flea populations were typical. Similarly there was no significant difference in the flea populations of nests at different heights from the ground - from 5' to 12'. In view of these facts it seems that the relative scarcity of C.gallinae in redstarts' nests is significant,and indicative of some unsuitability of the redstart as a host or of its nest as a habitat.

Rothschild (1952) has suggested that the three commonest bird fleas in Britain can be zoned as follows,admitting an overlap:
Ceratophyllus gallinae - dry aerial nests at high elevations,
Dasypsyllus gallinulae - damp nests in low situations,
Ceratophyllus garei Roths. - wet nests on the ground.

Thus there is complete agreement over Ceratophyllus garei, which was totally absent from the boxes in this study. With regard to the other two fleas the position is by no means clear,and it is difficult to decide how far a nest-box resembles a dry aerial nest or a low damp nest. Leleup (1947) found nine types of nest,classified by ecological considerations,those in holes above the ground being given as hygrophile to different degrees with a characteristic rich fauna. If the success of the flea depends upon larval humidity requirements as Rothschild (1952) and Smit (1952) suggest,then the nest itself,and particularly the seasonal weather are of paramount importance. The loosely knit nests of the pied flycatcher,redstart and tree-creeper averaged fewer fleas than the more closely knit tit nests which might retain moisture more easily. Ceratophyllus gallinae certainly occurs in wet nests and Dasypsyllus gallinulae occurs in dry nests,though in the latter case it is possible that the nest was wetter during the breeding season. Many of the nests collected were beginning to decompose and smelt earthy or of excrement,and if an aerial situation is normally considered as dry (except during rainy weather) the protection of a box hinders the drying out of a nest which does happen to become wet. No doubt both these fleas require a certain amount of dampness to breed successfully, and it is clear that a lot of data must be collected from nests during the breeding season before the problem can be elucidated.

According to Rothschild and Clay (1952) egg production in Ceratophyllus gallinae is thought to fall off in dry years. Table 5 (page 18) either confirms this or indicates a high larval mortality in 1955,which was very dry.

There is no evidence to show that Dasypsyllus gallinulae is a casual in the nests. When George (1959) found an average of 20 D.gallinulae per nest in the Forest of Dean in 1955 the average was 30 at Hamsterley. This was a low mean and the summer was very dry. The nine nests George lists gave a mean of 146 C.gallinae however, as compared with a mean of 48 from 17 nests at Hamsterley. George considered it surprising that D.gallinulae should be found in dry nests in nest-boxes. In 1956 he found an average of 204 C.gallinae and 8 D.gallinulae in ten pied flycatcher nests and arrived at his conclusion that D.gallinulae is marginal (i.e. casual) in occurrence. Unfortunately there are no data from Hamsterley in 1956, but the Hamsterley figures in general indicate fluctuations in which D.gallinulae may be successful in the nest-box habitats. It may be "dominant" in redstarts' nests as it is quoted to be in blackbirds' (Turdus merula, L.) nests by Rothschild (1952). Also George collected only a few nests and experience at Hamsterley indicates that the number of fleas per nest is very variable. Consequently two groups of ten nests can give totally different results even when collected on the same day. Statistically significant results can only be obtained from large numbers of nests. Even though there were fewer D.gallinulae than C.gallinae in nests facing north and east at Hamsterley in 1960 (this is true in both total and proportional numbers) the result is not mathematically significant when allowing for the errors in estimating distribution with too few samples. The graphical diagrams on pages 36 and 37 revealed the insufficiency of the results. Since nests facing, say, east could be in boxes nailed by side struts either on the north side or the south side of the tree trunk and are placed in shaded situations anyway, a significant difference would be surprising.

It is interesting to record that the fleas follow the pattern of parasitic insects in having more females than males recorded (Rothschild and Clay, 1952). It cannot be certain from this study whether there is a differential birth rate or whether the difference is attributable to differing sexual behaviour patterns. Since the numbers fluctuate,the migratory behaviour of fleas is important. Cole (1945) stated that the sex-ratio of Xenopsylla cheopis (Roths.) on the bodies of rats varied according to climatic conditions,males predominating on hot days and females on cold days.

A final conclusion is that the habitat is of extreme importance in that under different environmental conditions different flea populations are produced. It is possible that the low numbers of Ceratophyllus gallinae in redstarts' nests can be related to the nests' influence as a habitat,though on the face of it there is little difference between these and pied flycatchers' nests. But there is no evidence and once again further investigation is necessary. What is certain is that there are no more Dasypsyllus gallinulae in the redstarts' nests than in the others,or,in other words,they are no more successful in redstarts' nests in the absence of C.gallinae than they are in the other nests with C.gallinae present. There are two possible explanations of this; one is that competition between the two species is not acute (at least unless there are enormous numbers of them),the other is that D.gallinulae cannot itself become abundant in the nests of redstarts under the conditions found at Hamsterley. The highest number found in a redstart's nest was 323; there were several tits' nests with populations of over 400,the maximum being 474. Ceratophyllus gallinae frequently achieves populations of well over 500 though not of course in redstarts' nests where the maximum was 94. Finally,the successful breeding of the bird host improves the habitat for the fleas; in nearly all the nests where there were high flea populations fledging was successful,there were twelve certain and some suspected instances where breeding failed and flea populations were minute or absent. The continuous presence of birds during the incubating and fledging periods must inevitably maintain environmental conditions which would not be found in similar less frequented nests. Apart from considerations of food, continuously inhabited nests might well be warmer and more humid than nests where breeding is interrupted.

SUMMARY.

1. The 23,171 fleas found in 133 nests taken from nest-boxes at Hamsterley State Forest, Co. Durham, were of two species, *Ceratophyllus gallinae* and *Dasypsyllus gallinulae*.

2. Both flea species were found in at least some of the nests of redstarts, pied flycatchers, tree-creepers, great tits, blue tits and coal tits; usually both were present.

3. *C.gallinae* was rare or absent from the nests of redstarts in 1954 and 1955, and rare in all nests during the winter of early 1955. No redstart's nest contained over 100 *C.gallinae*, which is not as well suited to redstarts' nests as *D.gallinulae*.

4. There was evidence to show that many *C.gallinae* dispersed from the nests in the winter, the means fell dramatically.

5. *D.gallinulae* is well established in the study area and survived in the presence of *C.gallinae* over a period of seven years, it cannot be regarded as of casual occurrence in nest-boxes.

6. The fleas fared best where the bird hosts bred successfully themselves.

7. Populations were affected by the weather and by the seasonal behaviour of *C.gallinae*, and perhaps by different behaviour of the sexes. The latter was not conspicuous in the annual emigration of *C.gallinae*.

8. There were significantly more females than males, the ratio fluctuating. Humidity may be the most important factor producing this fluctuation, at present it cannot be precisely explained.

9. The evidence did not show that the aspect of the nest was important in determining the flea population.

ACKNOWLEDGEMENTS.

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Kime, R.D., 1962, A study of two bird fleas, *Ceratophyllus gallinae* (Schrank) and *Dasypsyllus gallinulae* (Dale), in the nests of hole-nesting birds, *Ent. mon. Mag.*, 98:54-9.

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APPENDIX.

This appendix gives data concerning individual nests. The nests are grouped according to host species in order of collection. The numbers of male and female fleas are shown for both flea species. After the column giving the condition of the nest when collected the two final columns give the direction that the nest-hole faced - where this is known - and nests where the birds' breeding was known to be unsuccessful. Where breeding was unsuccessful the column contains a cross, thus: X. Where breeding was fairly certainly unsuccessful the column contains a question mark. It is possible that in some cases breeding was not completed and this escaped observation. In most cases breeding was successful, however.

REDSTART NESTS.

Nest	Date collected	C.gallinae Males	C.gallinae Females	D.gallinulae Males	D.gallinulae Females	Condition of nest		
1.	Oct.,1954.	0	0	26	30	Damp		
2.	"	0	0	0	0	Dry		
3.	"	0	0	0	1	Dry		
4.	"	0	0	0	0	Dry		
5.	"	1	1	54	84	Dry		
6.	"	0	0	0	0	Damp		
7.	"	0	0	0	0	Damp		
8.	"	0	0	145	178	Dry		
9.	Feb./Mar.,1955.	0	0	0	0	Damp		
10.	"	18	8	111	135	Dry		
11.	"	0	0	0	0	Damp		
12.	Aug.,1955.	0	0	0	0	Dry		X
13.	"	0	0	62	29	Dry		
14.	"	0	0	0	0	Dry		X
15.	"	0	0	0	0	Dry		

REDSTART NESTS (continued)

Nest	Date collected	C.gallinae Males	C.gallinae Females	D.gallinulae Males	D.gallinulae Females	Condition of nest	
16.	Aug.,1955.	0	0	0	0	Dry	
17.	Sept.,1960.	9	6	6	15	Dry	NE
18.	"	0	1	0	2	Damp	SE
19.	"	42	52	94	147	Damp	NW
20.	"	32	42	35	58	Damp	NE
21.	"	0	0	24	24	Damp	S
22.	"	21	34	13	26	Damp	SW
23.	"	22	38	10	15	Damp	SE
24.	"	0	0	0	5	Damp	NE

PIED FLYCATCHER NESTS.

Nest	Date collected	C.gallinae Males	C.gallinae Females	D.gallinulae Males	D.gallinulae Females	Condition of nest		
1.	Oct.,1954.	76	92	80	83	Dry		
2.	"	0	0	0	0	Damp		
3.	"	58	38	53	59	Damp		
4.	"	49	58	204	190	Dry		
5.	"	0	0	0	0	Dry		
6.	Feb./Mar.,1955.	7	1	3	0	Wet		
7.	"	0	0	191	207	Damp		
8.	"	0	0	0	0	Dry		
9.	"	2	1	87	96	Damp		
10.	"	0	0	0	0	Damp		
11.	April,1955.	0	0	0	0	Damp		
12.	"	20	25	24	57	Damp		
13.	"	0	0	0	0	Damp		
14.	Aug.,1955.	8	9	13	16	Dry		
15.	"	7	22	4	8	Dry		
16.	"	113	241	10	11	Dry		
17.	Sept.,1960.	15	17	0	0	Damp	E	
18.	"	68	111	37	59	Damp	NE	
19.	"	0	0	0	0	Damp	SE	X
20.	"	27	48	30	48	Damp	W	
21.	"	41	73	3	2	Damp	E	
22.	"	139	142	20	20	Damp	E	
23.	"	29	45	2	1	Damp	S	
24.	"	0	0	0	0	Wet	NE	X
25.	"	29	46	0	1	Damp	SE	

PIED FLYCATCHER NESTS (continued)

Nest	Date collected	C.gallinae Males	C.gallinae Females	D.gallinulae Males	D.gallinulae Females	Condition of nest		
26.	Sept.,1960.	21	64	2	4	Damp	E	
27.	"	23	70	0	0	Dry	SW	X
28.	"	158	227	73	89	Damp	S	
29.	"	68	97	1	1	Damp	NE	
30.	"	2	0	28	54	Damp	NE	
31.	Jan.,1961.	28	25	17	28	Damp	E	
32.	"	2	0	3	6	Wet	N	
33.	"	5	16	22	28	Wet	N	
34.	"	121	134	1	0	Damp	SE	
35.	"	148	221	27	32	Damp	W	
36.	"	2	4	0	3	Wet	SE	X
37.	"	0	0	0	1	Damp	SE	X
38.	"	5	3	1	1	Wet	SE	
39.	"	8	11	17	20	Wet	E	

TREE-CREEPER NESTS.

Nest	Date collected	*C.gallinae* Males	Females	*D.gallinulae* Males	Females	Condition of nest	
1.	Oct.,1954.	148	249	26	31	Dry	
2.	Feb.,1955.	0	0	21	20	Dry	
3.	"	0	0	0	0	Damp	
4.	Sept.,1960.	3	8	0	0	Dry	SE
5.	"	1	0	0	0	Damp	W

GREAT TIT NESTS.

Nest	Date collected	C.gallinae Males	C.gallinae Females	D.gallinulae Males	D.gallinulae Females	Condition of nest		
1.	Oct.,1954.	13	9	1	1	Damp		
2.	"	96	106	49	47	Wet		
3.	"	0	0	0	0	Damp		?
4.	"	248	221	37	37	Wet		
5.	Feb./Mar.,1955.	7	7	214	194	Damp		
6.	"	0	0	0	2	Damp		
7.	"	4	4	191	217	Damp		
8.	"	1	1	12	20	Damp		
9.	"	19	16	83	84	Damp		
10.	"	0	0	0	0	Damp		?
11.	"	0	0	0	0	Damp		?
12.	"	0	0	0	0	Damp		
13.	April,1955.	54	66	7	33	Damp		
14.	"	0	0	0	0	Damp		
15.	Aug.,1955.	0	2	0	0	Dry		X
16.	"	5	6	0	0	Dry		
17.	"	0	0	0	0	Dry		X
18.	"	64	95	1	2	Dry		
19.	"	2	6	0	2	Dry		
20.	"	0	0	0	0	Dry		
21.	Sept.,1960.	2	5	0	0	Damp	E	
22.	"	103	120	13	16	Damp	NE	
23.	"	223	321	3	7	Wet	N	
24.	"	204	280	12	16	Damp	SE	
25.	"	0	1	0	0	Damp	E	?

GREAT TIT NESTS (continued)

Nest	Date collected	C.gallinae Males	C.gallinae Females	D.gallinulae Males	D.gallinulae Females	Condition of nest		
26.	Sept.,1960.	230	444	25	32	Damp	S	
27.	"	0	0	0	0	Wet	E	
28.	"	203	351	5	14	Damp	N	
29.	Jan.,1961.	68	68	38	34	Wet	SE	
30.	"	10	29	5	7	Wet	N	
31.	"	3	2	6	5	Wet	S	
32.	"	3	7	0	0	Wet	E	X

BLUE TIT NESTS.

Nest	Date collected	C.gallinae. Males	C.gallinae. Females	D.gallinulae. Males	D.gallinulae. Females	Condition of nest.		
1.	Oct.,1954.	340	244	8	12	Dry		X
2.	"	38	31	30	34	Wet		
3.	"	0	0	0	0	Damp		
4.	Feb./Mar.,1955.	1	24	0	9	Damp		
5.	"	0	0	172	177	Damp		
6.	"	0	0	0	0	Damp		?
7.	"	0	0	0	0	Dry		
8.	"	0	0	125	300	Damp		
9.	"	0	0	0	0	Damp		
10.	"	0	0	0	1	Damp		
11.	"	0	0	0	0	Damp		?
12.	Sept.,1960.	273	384	46	52	Damp	SW	
13.	"	138	220	23	35	Damp	S	
14.	"	79	155	27	32	Damp	SW	
15.	"	10	41	2	7	Damp	W	
16.	"	0	2	0	0	Damp	NW	X
17.	Jan.,1961.	336	384	118	108	Damp	W	
18.	"	0	0	0	0	Wet	SE	

COAL TIT NESTS.

Nest	Date collected	C.gallinae Males	C.gallinae Females	D.gallinulae Males	D.gallinulae Females	Condition of nest		
1.	Oct.,1954.	26	22	2	3	Damp		
2.	Feb./Mar.,1955.	3	0	228	246	Damp		
3.	"	0	0	221	216	Damp		
4.	Aug.,1955.	0	0	9	9	Dry		
5.	"	0	0	1	0	Dry		X
6.	"	0	0	77	196	Dry		
7.	Sept.,1960.	2	2	0	1	Damp	NW	X
8.	"	575	743	30	59	Damp	SW	
9.	"	12	40	0	0	Damp	SW	
10.	"	1276	1669	49	33	Damp	SE	
11.	"	68	111	37	59	Damp	E	
12.	"	0	3	0	2	Damp	SW	
13.	"	0	0	2	3	Damp	W	
14.	"	236	322	24	26	Damp	NE	
15.	Jan.,1961.	6	4	28	28	Wet	NE	